THE

VOYAGE OF H.M.S. CHALLENGER.

NARRATIVE—VOL. I.

FIRST PART.

REPORT

ON THE

SCIENTIFIC RESULTS

OF THE

VOYAGE OF H.M.S. CHALLENGER

DURING THE YEARS 1873-76

UNDER THE COMMAND OF

CAPTAIN GEORGE S. NARES, R.N., F.R.S.

AND THE LATE

CAPTAIN FRANK TOURLE THOMSON, R.N.

PREPARED UNDER THE SUPERINTENDENCE OF

THE LATE

Sir C. WYVILLE THOMSON, Knt., F.R.S., &c.

REGIUS PROFESSOR OF NATURAL HISTORY IN THE UNIVERSITY OF EDINBURGH

DIRECTOR OF THE CIVILIAN SCIENTIFIC STAFF ON BOARD

AND NOW OF

JOHN MURRAY

ONE OF THE NATURALISTS OF THE EXPEDITION

NARRATIVE—VOL. I.

FIRST PART.

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EDITORIAL NOTES.

The Hydrographic Part of the Narrative of the Cruise of H.M.S. Challenger would have been written by Captain Sir George S. Nares, K.C.B., had he remained in command of the ship during the whole of the voyage.

When the Expedition reached Hong Kong in December 1874, Captain Nares was recalled to take command of the last British Arctic Expedition, and he then placed his Journals in the hands of his successor in the Challenger,—the late Captain Frank Tourle Thomson.

Captain Thomson was, however, of opinion that the description of the Hydrographic Work of the Expedition should be undertaken by an officer who had been with the Challenger from the beginning, and consequently Captain Nares' Journals were, with the concurrence of the late Sir C. Wyville Thomson, handed over to Staff-Commander T. H. Tizard, the Senior Surveying Officer of the Expedition.

On the return of the Expedition to England, Staff-Commander T. H. Tizard was, on the recommendation of the Hydrographer to the Admiralty,[1] temporarily employed in the Hydrographic Office, for the purpose of preparing for publication the Charts, Diagrams, and Hydrographic Notes for the Narrative of the Cruise, and Commander J. L. P. Maclear and Lieutenant A. C. B. Bromley were also employed for a short time in preparing for publication the Magnetical Observations. The Journals of Captain G. S. Nares were freely used by the Challenger Officers, and they had throughout the assistance of the permanent Officers of the Hydrographic Department of the Admiralty. This work was commenced in 1876 and completed in 1879,

[1] Then Captain F. J. Evans, R.N., C.B., in succession (in 1874) to Rear-Admiral G. H. Richards, C.B., under whose auspices the Expedition was originally fitted out.

when the whole of the Manuscript was placed in the hands of the late Sir C. Wyville Thomson.

On the death of Sir C. Wyville Thomson in March 1882 I was entrusted by the Government with the direction of the whole of the work connected with the publication of the Official Reports on the Scientific Results of the Expedition, and as the Meteorological and Magnetical Observations had been for several years in type, these were at once issued as Volume II. of the Narrative, along with two Appendices: one on the Pressure Errors of the Challenger Thermometers, by Professor P. G. Tait, and the other on the Petrology of St. Paul's Rocks, by the Abbé A. Renard.

In his Provisional Preface to the first volume of Zoological Reports, published in 1880, Sir Wyville says:—"The first volume will contain a short narrative of the voyage, with all necessary hydrographical details; an account of the appliances and methods of observation; a running outline of the results of the different observations; and a chapter epitomising the general results of the voyage. This volume will be illustrated by a general physical chart; a series of charts of the ship's course; a series of diagrams of the vertical distribution of temperature; and some photographs of scenery. It will probably be in two parts, and is being prepared by Staff-Commander Tizard, R.N., and myself."

Although the form and scope of the present volume was thus sketched out, yet, owing to ill health and his many professional occupations, Sir Wyville was never able to make any progress with the preparation of the Manuscript for the press; he had, however, selected and caused to be printed the thirty-seven photographic plates which now accompany the text.

Under these circumstances I consulted with my former colleagues in the Challenger, Staff-Commander T. H. Tizard, Professor H. N. Moseley, and Mr. J. Y. Buchanan, as to the best course to adopt, and it was finally arranged that the first volume of the Narrative of the Cruise should be undertaken by us jointly, and should embrace as far as possible a general account of the Scientific Results of the Expedition—an arrangement which has now been carried out.

The various Abstracts indicating the nature and extent of the investigations and discoveries made by the specialists who have been engaged in the preparation of the Official Reports will be found to constitute a prominent feature of the volume; these have been prepared by the authors of the several special Reports, or have been revised by them. Great care has been taken to ensure that all statements of fact are correct, but when deductions are drawn or opinions expressed in any of the paragraphs within inverted commas, my colleagues or myself do not necessarily endorse these, the author whose name is attached to the paragraphs being responsible.

I have to acknowledge, without exception, my indebtedness to the contributors to the Official Scientific Reports, whose names appear in Appendix VII. to this volume. It would have been impossible to have compiled a general account of the Scientific Results without their cordial assistance and co-operation, at all times freely given, though often at considerable inconvenience to the authors.

As in the previously published volumes of Reports the Fahrenheit Scale of temperature has been used when not otherwise expressly stated.

The Abbé A. Renard, F.G.S., has named the rock specimens collected at the various Oceanic Islands, and he has in most instances revised the determinations of the minerals or crystalline particles found in the deposits.

Nearly all the woodcuts of scenery, and many of those of animals, are from the sketches and drawings of Dr. J. J. Wild, who accompanied the Expedition as Artist and Private Secretary to the Director of the Civilian Scientific Staff; in 1884 Dr. Wild forwarded from Australia a large number of sketches taken during the cruise, from which a selection was made.

I have had in my possession for reference the Official Journals of Dr. Wild and the late Dr. Rudolf von Willemoes-Suhm. Captain Pelham Aldrich, Lieutenant Herbert Swire, Lieutenant Arthur Channer, Fleet-Surgeon George Maclean, and Mr. R. R. A. Richards placed journals or sketch-books in my hands for reference; a few of the sketches have been reproduced in this volume as woodcuts, and two of the coloured plates of natives are from the sketches of Lieutenant Swire. I take this opportunity of acknowledging the friendly assistance which has been extended to me by all the Naval Officers of the Expedition whenever information was desired in connection with the Editorial Work. A similar acknowledgment must be extended to Captain Sir Frederick J. Evans, K.C.B., till lately the Hydrographer, and the Officers of the Hydrographic Department of the Admiralty, to Sir Joseph D. Hooker, K.C.S.I., and the Botanists at the Royal Herbarium, Kew, and to Professor Archibald Geikie, the Director-General of the Geological Survey, as also to T. Digby Pigott, Esq., the Controller, and Gentlemen in the various departments of Her Majesty's Stationery Office.

To Dr. A. Günther and the Naturalists in the British Museum I return my thanks for the trouble they have at all times taken in determining or assisting in the determination of specimens, and in furnishing me with short Reports on the Incidental Terrestrial Collections from the Oceanic Islands. To the Rev. O. P. Cambridge and many other Naturalists and Scientific Men at home and abroad I am also indebted for like information and services.

In the Editorial Work connected with the passing of the Official Reports through the press, I have for more than two years had the able assistance of Mr. W. E. Hoyle, M.A., M.R.C.S., and for a shorter period of Mr. Frank E. Beddard, M.A. In the general scientific and other work of this Office valuable assistance has also been rendered by Mr. James Chumley, Mr. Frederick Pearcey, and Mr. James Monteith. In various ways while engaged in the preparation of the Narrative of the Cruise I have been assisted by Mr. Hugh Robert Mill, B.Sc., Mr. J. Rattray, M.A., B.Sc., Mr. J. T. Cunningham, B.A., and Mr. H. Roscoe Dumville, B.A.

To the Artists, Engravers, Lithographers, and Printers who have been engaged in the work my thanks are also due.

John Murray.

Challenger Office, 32 Queen Street,
Edinburgh, *6th March* 1885.

NARRATIVE

OF THE

CRUISE OF H.M.S. CHALLENGER

WITH A

GENERAL ACCOUNT OF THE SCIENTIFIC RESULTS OF THE EXPEDITION

BY

STAFF-COMMANDER T. H. TIZARD, R.N.; PROFESSOR H. N. MOSELEY, F.R.S.;
MR. J. Y. BUCHANAN, M.A.; AND MR. JOHN MURRAY, PH.D.;
MEMBERS OF THE EXPEDITION.

Partly Illustrated by Dr. J. J. WILD, Artist to the Expedition.

PREFACE.

HAD the responsibility of the production of the Narrative of the Cruise rested with the same members of the Expedition from the commencement, a somewhat different method would probably have been followed in the preparation of this volume. The arrangement of the matter and the style have been largely determined by the circumstances arising out of the change of Captains during the Cruise, the unexpected death of Sir C. Wyville Thomson in 1882, and the necessity for publication before the completion of many of the special Reports.

It is hoped, however, that the volume will be found to contain a faithful record of the Work of the Expedition, and as complete an account of the scientific results as is possible in the present state of the investigations.

A considerable part of Professor Moseley's contribution to the Narrative is in the form of revised and modified extracts from his Journal, published in 1877.[1]

With respect to the depths assigned to the Zoological specimens, it may be well to state that the Naturalists of the Expedition have simply recorded the greatest depth to which the dredge or trawl was believed to have descended at each Station. It will be evident that the instrument may have been occasionally dragged into slightly deeper or shallower water than was recorded by the sounding line, and what is of greater consequence, the trawl or dredge may have caught animals while sinking through the water or being hauled up again. In the great majority of cases there is little

[1] Notes by a Naturalist on the Challenger, London, 1877.

difficulty in deciding which animals were dredged from the bottom and which were caught by the instruments in the surface or subsurface waters. With some Fish, Crustaceans, Medusæ, and other groups, however, there is considerable difficulty; in these cases the organisation is often a guide, and the specialist who has made a careful study of the group to which the species belongs, is best able to form an opinion as to the depth at which the specimens were probably captured. These circumstances should therefore always be borne in mind when the depths at which animals have lived are being discussed, and only after careful consideration should it be inferred that they were procured at the depths ascribed to them in the lists.

We desire on our own behalf, and on that of the members of the Expedition generally, to offer most grateful thanks for the liberal hospitality and ready assistance we received in all parts of the world, not only in the British Colonies but also in Foreign Countries. It has not been possible to refer in every instance to those who extended a friendly welcome to members of the Expedition and added so much to the pleasure of the Cruise, but the remembrances of many incidents and friendly acts appear, to the members of the Naval and Civilian Staffs who survive, to grow brighter rather than more dim with the lapse of time.

CONTENTS.

FIRST PART.

CHAPTER V.

CHAPTER VI.

CHAPTER VII.

CHAPTER VIII.

CHAPTER IX.

CHAPTER X.

CHAPTER XI.

CHAPTER XII.

SECOND PART.

CHAPTER XIII.

CHAPTER XIV.

CHAPTER XV.

CHAPTER XVI.

CHAPTER XVII.

CHAPTER XVIII.

CHAPTER XIX.

CHAPTER XX.

CHAPTER XXI.

CHAPTER XXII.

APPENDICES.

LIST OF ILLUSTRATIONS.

I. CHROMO-LITHOGRAPHIC PLATES.

First Part.

Second Part.

II. PHOTOGRAPHIC PLATES.

First Part.

SECOND PART.

III. PLANS OF H.M.S. CHALLENGER

AS FITTED FOR A VOYAGE OF DEEP-SEA EXPLORATION.

IV. CHARTS SHOWING THE DREDGING AND SOUNDING STATIONS.

First Part.

Second Part.

V. DIAGRAMS SHOWING THE VERTICAL DISTRIBUTION OF TEMPERATURE IN THE OCEAN.

First Part.

Second Part.

VI. WOODCUTS.

First Part.

SECOND PART.

TAIL-PIECES.

First Part.

Second Part.

ERRATA.

Page 199, in explanation of woodcut (fig. 83), for "*wyvilii*" read "*wyvillii.*"
Page 436, line 7, for "*Chætoceras*" read "*Chætoceros.*"
Pages 470 and 471, brackets round *Taonius* instead of *Procalistes* in the explanation of woodcuts.
Page 487, line 9 from bottom, *for* "fig. 141" *read* "fig. 176."
Page 496, line 15 from bottom, *for* "Vitu" *read* "Viti.'
Page 521, line 15, for "*Aphynonus*" read "*Aphyonus.*"
Page 541, line 7, for "*strata*" read "*strota.*"

INTRODUCTION.

Knowledge possessed by the Ancients concerning the Ocean, its Saltness and its Inhabitants—Researches during the Middle Ages, the Fifteenth, Sixteenth, and Seventeenth Centuries—The Expeditions of the Eighteenth Century, and the Arctic and Antarctic Expeditions of the early part of the Nineteenth Century—The "Lightning" and "Porcupine" Expeditions—Correspondence between the Royal Society and the Admiralty with reference to the investigation of the Great Ocean Basins.

A brief review of the efforts made to acquire a knowledge of the Ocean, and a general account of the opinions held prior to the year 1872 as to the physical and biological conditions of the great ocean basins, may form an appropriate Introduction to the Narrative of the Voyage of H.M.S. Challenger. The objects which the promoters had in view when they urged Her Majesty's Government to fit out and despatch an Expedition on a special scientific investigation of the depths of the sea will thus be indicated.

The sea and the life in its waters were little studied by the learned men of the ancient civilisations, which were clustered round the nearly tideless Mediterranean. Their sea-lore consisted in great part of wildly exaggerated descriptions of the more striking marine phenomena woven into a vague mythology. The sea was an object of terror, for navigation was uncertain in the extreme; what lay beyond the Pillars of Hercules was veiled in mystery, and what lay beneath the surface of the waters crossed by the ancient navies was equally unknown.

The sea was not, so far as is known, made the subject of close attention until Aristotle (384–322 B.C.) brought his mind to bear on it in common with the other departments of natural history. Aristotle studied the physical conditions of the sea as far as a man without apparatus could study them. He thought that in the ocean the water was warmer and salter at the surface than at the bottom; he considered that as the sun's heat was always evaporating the water the sea would ultimately be dried up.[1] Aristotle's opinions regarding ocean physics must be viewed as mere speculations, but his researches on marine animals were of distinct scientific value. He named and described more or less minutely one hundred and sixteen species of fishes, about twenty-four species of Crustaceans and Annelids, and some forty Molluscs and Radiates,[2] making a total of one hundred and eighty species inhabiting the Ægean Sea; and the student is still reminded of his study of the anatomy of *Echinus* by the significant name "Aristotle's Lantern" applied to its masticatory apparatus.

After Aristotle no original inquirer into these matters appeared for many centuries.

Pliny the elder (23–79 A.D.), in his gossipy "Natural History," presents Aristotle's discoveries modified by much subsequent superstition and tradition. He concisely catalogues marine animals into one hundred and seventy-six species, being four less than the number recorded by Aristotle in the Ægean Sea alone. Pleased with this enumeration, he then exclaims:—"Surely then everyone must allow that it is quite impossible to comprise every species of terrestrial animal in one general view for the information of mankind. And yet, by Hercules! in the sea and in the Ocean, vast as it is, there exists nothing that is unknown to us, and, a truly marvellous fact, it is with those things which Nature has concealed in the deep that we are the best acquainted!"

Pliny had to confess himself unable to give a detailed account of the depth of the ocean, some parts he stated to be 15 stadia (over 1500 fathoms) deep, others "immensely deep, no bottom having been found;"[3] but he makes up for this in a way by explaining very clearly "why the sea is salt." He says:—"Hence it is that the widely diffused sea is impregnated with the flavour of salt, in consequence of what is sweet and mild being evaporated from it, which the force of fire easily accomplishes; while all the more acrid and thick matter is left behind, on which account the water of the sea is less salt at some depth than at the surface."[4]

In this explanation Pliny followed Aristotle, and helped to open up a magnificent arena for the hair-splitting scholastics of the Middle Ages to dispute in. Bishop Watson[5] says:—"There are few questions respecting the natural history of the globe which have been discussed with more attention, or decided with less satisfaction, than that concerning the primary cause of the saltness of the sea. The solution of it had perplexed the philosophers before the time of Aristotle; it surpassed his own great genius, and those of his followers who have attempted to support his arguments have been betrayed into very ill grounded conclusions concerning it. Father Kircher,[6] after having consulted three and thirty authors upon the subject, could not help remarking, that the fluctuations of the ocean itself were scarcely more various than the opinions of

[1] Meteorolog., lib. ii. cap. iii.

[2] De Animal. Hist., lib. iv. cap. i.–vii.; Eng. transl. by Ogle, pp. 97–115, London, 1882.

[3] Hist. Nat., lib. ii. cap. cii.

[4] *Ibid.*, lib. ii. cap. c.

[5] Chemical Essays, vol. ii. pp. 93, 94, 2nd ed., 1782.

[6] Mundus Subterraneus, Liber iii. chap. iii.

men concerning the origin of its saline impregnation." It was not until the time of Boyle that the theory at present held regarding the origin of salt in the sea was propounded.

The rage for geographical exploration which set in after the discovery of America naturally brought the phenomena of the sea into greater prominence. Sir John Hawkins' story, as told by Boyle, while almost poetical enough to suggest Coleridge's well-known lines,[1] has yet a flavour of scientific observation about it:—

"Were it not for the Moving of the Sea, by the Force of Winds, Tides and Currents, it would corrupt all the World. The Experience of which I saw *Anno* 1590, lying with a Fleet about the Islands of *Azores*, almost Six Months, the greatest Part of the time we were becalmed, with which all the Sea became so replenished with several sorts of Gellies and Forms of Serpents, Adders and Snakes, as seem'd Wonderful; some green, some black, some yellow, some white, some of divers Colours, and many of them had Life, and some there were a Yard and a half, and some two Yards long; which had I not seen, I could hardly have believed; and hereof are Witnesses all the Company of the Ships, which were then present, so that hardly a Man could draw a Bucket of Water clear of some Corruption."[2]

The Science of the Sea may be said to date from the seventeenth century. The methods used were crude, but they sometimes contained the germs of great ideas; the results arrived at were often erroneous, but they were steps in the right direction; and the researches were animated by the true scientific spirit, the spirit of observation and experiment.

In his paper, Of the Saltness of the Sea,[3] Boyle detailed a great number of experiments. He personally made a series of observations on the water of the English Channel, collecting it from various depths, and observing its specific gravity. The samples from beneath the surface were probably procured by means of Hooke's water-bottle, an extremely ingenious valved box, which is fully described and figured in one of the early numbers of the Philosophical Transactions.[4] Boyle investigated the saltness of the water by a number of processes: he tried the estimation of total solids by direct evaporation and ignition, but not being satisfied with the result he ultimately took the density as an index of the saltness, and determined this either by means of a glass hydrometer, by weighing in a phial which was afterwards weighed when full of distilled water, or by weighing a piece of sulphur in distilled water and sea water consecutively.

"As for the different degrees of the saltness of the sea," says Boyle, "I shall deliver what I have been informed of as briefly as I can. And first, it hath been observed, by one

[1] "The very deep did rot: O Christ!
That ever this should be!
Yea, slimy things did crawl with legs
Upon the slimy sea."

[2] Boyle's Works, epitomized by Boulton, vol. i. p. 281, London, 1699. [3] *Ibid.*, p. 274.

[4] *Phil. Trans.*, vol. ii. p. 442, 1667. (The figure is reproduced in the tailpiece to this Introduction.)

to whom I gave a glass conveniently shaped to try the specific gravity of the water, that it grew heavier and heavier as he came nearer the line, till within about 30° latitude; from whence to Jamaica he observed no alteration in the specific gravity in the least. And in confirmation of this I am likewise informed, by one, who for his own satisfaction weighed the water, both under the Aequinoctial and at Cape of Good Hope, and found that the weight of both was the same. To which may be added that it is commonly observed at Mozambique, one of the hottest places in the world, that the sea is so salt there, that it bears up the ships a considerable height out of the water, more than in other places; and that the water may be much salter in one place than another, by having more salt dissolved in it, does not only appear from what hath been said, but also from what is frequently observed in the different strengths of brine-pits."[1]

About this time Hooke invented a machine for ascertaining the depth of the sea without a line.[2] It consisted of a sphere of light wood carefully pitched and varnished, which was sunk by means of a leaden sphere attached to it by a spring hook. When it reached the bottom the catch was released by the impact, the lead ball remained, and the float rose to the surface. The depth was calculated, by means of a certain formula, from the time which elapsed between letting it go and again seeing the float; and the machine answered well in shallow and still water. Hooke himself pointed out that in a current it would not show the true depth, but that the arrangement would be extremely valuable as a means of detecting under currents, and measuring their direction and velocity. The idea of self-detaching weights was not revived for two hundred years, when Brooke's sounding machine was invented.

The early volumes of the Philosophical Transactions abound in records of work done on subjects connected with the sea. In 1680 a "Person of Honour who was becalmed off of Pantalara near Sicily" amused himself by calculating the pressure at great depths by sinking a bottle "stopp'd with an excellent, good, tender cork" fixed in by various devices; he obtained some interesting results.[3]

These researches are now only of interest as showing how active a part was taken in marine physics in the early days of the Royal Society.

The phosphorescence of the sea attracted much attention about the beginning of the eighteenth century. The beautiful display seen on moving an oar through the water on a calm dark autumn night, the milky way of powdery light starred here and there with globes of soft brilliance, and the grand effect of a swell breaking on a rocky beach in showers of luminous spray, were examined by several investigators, and reasons the most various were assigned for the appearance. Newton suggested that the light was produced by the continual agitation of the water,[4] some observers thought it a phosphorescence of

[1] Boulton's Boyle, vol. i. p. 282.
[2] Lowthorp's Abridgment, *Phil. Trans.*, vol. ii. p. 257. (Figured in tailpiece to this Introduction.)
[3] *Phil. Trans.*, vol. i. p. 504.
[4] Optics, Bk. iii. p. 314, 1730.

decomposition like that of rotten wood, others held it to be a bituminous substance endowed with a self-shining power,[1] and others considered that it was produced in some unknown manner by living creatures.

The specialization of research in the modern sense was unknown to the philosophers of the seventeenth century, and when in the eighteenth the observational and experimental sciences began to separate out and develop, each in its own direction, marine research was, for a time, practically neglected. The chemist was busy investigating the riches of the earth and fighting over theories; the natural philosopher was studying light, heat, sound, electricity, and motion; the geologist was at work on the rocks and in the mines; the naturalist studied the terrestrial animals and plants of his own and distant countries, those living in the sea or on the seashore receiving less attention. The attention of navigators was fully taken up with the perfecting of their science, the development of nautical astronomy, the study of the forces which control the magnetic needle, the discovery of the longitude, the search for new lands and new routes.

Deep soundings in several parts of the ocean were recorded about the middle of the eighteenth century, but considerable caution must be used in discussing these, as the methods in use at that time were not such as to make any depth exceeding a few hundred fathoms a matter of certainty. In 1749 Ellis sounded in 891 fathoms off the northwest coast of Africa, and observed the temperature at that depth. Before the invention of the self-registering thermometer, the temperature below the surface was ascertained by taking a sample of water from the required depth in a bottle or valved box made of as imperfect heat-conductors as possible, and noting the temperature when brought on deck; this, at the best, was unsatisfactory.

In 1558 appeared the fourth book of Gesner's work on the History of Animals,[2] which is devoted to the nature of fishes and marine animals, and John Jonston,[3] who studied at St. Andrews in 1619, published in 1649 a treatise on aquatic animals, while other authors of less note contributed to the slowly increasing knowledge of littoral and pelagic animals and plants during the fifteenth, sixteenth, and seventeenth centuries.

The honour of first employing the dredge as a means of scientific investigation is claimed for two Italian naturalists—Marsili and Donati—who about 1750 used an ordinary oyster dredge for obtaining specimens in shallow water. In 1779 Otho F. Müller, a Danish zoologist, invented a special naturalists' dredge, a net attached to a square iron frame, and with this arrangement he studied the marine fauna of the coast of Denmark to a depth of 30 fathoms. The rich variety of form and colour, the enormous abundance of living creatures of all kinds, seemed like the revelation of a new world. It may be imagined how those old explorers felt who first caught sight of the wonders hidden by

[1] Encyclopédie Méthodique, art. Mer, t. ii. p. 744, 1786.
[2] Historiæ Animalium, Liber iv., Tiguri, 1558.
[3] Historiæ naturalis de Piscibus et Cetis Libri V.; de Exanguibus aquaticis Libri IV., Francf., 1649, Amst., 1657.

the waves on reading Edward Forbes' enthusiastic description of his first deep-water dredging:—

"Beneath the waves there are many dominions yet to be visited and kingdoms to be discovered, and he who venturously brings up from the abyss enough of their inhabitants to display the physiognomy of the country, will taste that cup of delight, the sweetness of whose draught those only who have made a discovery know. Well do I remember the first day when I saw the dredge hauled up after it had been dragging along the sea bottom, at a depth of more than 100 fathoms. Fishing lines had now and then entangled creatures at as great, and greater depths, but these were few and far between, and only served to whet our curiosity, without affording the information we thirsted for. They were like the few stray bodies of strange red men which tradition reports to have been washed on the shores of the Old World, before the discovery of the New, and which served to indicate the existence of unexplored realms inhabited by unknown races, but not to supply information about their character, habits, and extent. But when a whole dredgeful of living creatures from the unexplored depth appeared, it was as if we had lighted upon a city of the unknown people, and were able, through the numbers and varieties taken, to understand what manner of beings they were. Well do I remember anxiously separating every trace of organic life from the enveloping mud, and gazing with delighted eye on creatures hitherto unknown, or on groups of living shapes, the true habitats of which had never been ascertained before, nor had their aspect, when in the full vigour and beauty of life, ever before delighted the eye of a naturalist. And when, at close of day, our active labours over, we counted the bodies of the slain, or curiously watched the proceedings of those whom we had selected as prisoners, and confined in crystal vases, filled with a limited allowance of their native element, our feelings of exultation were as vivid, and surely as pardonable, as the triumphant satisfaction of some old Spanish 'Conquisatador,' musing over his siege of a wondrous Astlan[1] city, and reckoning the number of painted Indians he had brought to the ground by the prowess of his stalwart arm."[2]

Dredging in shallow water was found to be so easy, and its results so interesting, and often so unexpected, that it soon became popular among naturalists, and assisted in turning their attention more particularly to marine life.

The increased interest in the biological conditions was accompanied by a more careful study of the physical and chemical problems presented by sea water. A great many analyses were made towards the end of last century, but the methods then employed were too imperfect to yield results of much scientific value, and the principle on which they were conducted was erroneous. It was assumed that a proximate analysis of the salts in sea water could be made by weighing the amount of each particular salt that could

[1] Astlan was the country from which, according to native tradition, the Aztecs came.
[2] Natural History of European Seas, p. 11, 1859.

be separated from the water, and thus these analyses gave long and very conflicting lists, all claiming to present the precise quantity of sulphate and muriate of soda, of sulphate and muriate of magnesia, and of sulphate and muriate of lime, in the water. It was not until 1818 that the different proportions in which these salts were procured were conclusively shown to be due, not, necessarily, to any difference in the sea water, but to differences in the methods of analysing it. In that year Dr. John Murray of Edinburgh published an extremely valuable research on the water of the Firth of Forth;[1] he showed that by treating portions of the same sample of water in different ways, widely different quantities of the various salts might be obtained, and that the only satisfactory method of proceeding was to determine each base and each acid separately. The attempt to discover whether the composition of sea water differed at different places was frequently made, but the conditions of observation were unsatisfactory. The samples could not be relied upon as properly collected or preserved, and much uncertainty remained on the subject.

Péron, a French naturalist who went round the world in the year XII. of the Republic (1805), made a number of observations on the temperature of the ocean at different depths. He was strongly impressed by the importance of oceanic research, and wrote :—" Of all the experiments in Natural Philosophy there are few the results of which are more interesting or more curious than those which form the subject of this memoir. The meteorologist must derive from them valuable data in regard to atmospheric observations in the middle of the ocean ; they may furnish to the naturalist knowledge indispensably necessary in regard to the habitation of the different tribes of marine animals ; and the geologue and philosopher will find in them the most certain facts in regard to the propagation of heat in the middle of the seas, and of the physical state of the interior parts of the globe, the deepest excavations of which can scarcely go beyond the surface. In a word, there is no science which may not derive benefit from the results of experiments of this kind. How much then ought we to be surprised that they have hitherto excited so little attention ! "[2]

Péron's results were very erroneous ; he imagined that the bed of the ocean was covered with eternal ice, and that, as a consequence, life was impossible there. From the state of deep-sea research at the time this theory was quite plausible and required to be refuted before it was rejected. Sir John Ross's great Arctic voyage in 1818 furnished complete and most satisfactory evidence that Péron's deductions were wrong. Apart from the exploring work and the very valuable magnetic observations of Ross's expedition, it stands out in history as the first in which satisfactory soundings were made and samples of the bottom obtained. Ross had invented an arrangement, which he called the " Deep-sea Clamm," for gripping a portion of the bottom and

[1] *Trans. Roy. Soc. Edin.*, vol. xiii. p. 205, 1818.

[2] *Journal de Physique*, t. lix. p. 361, an. xiii. ; *Phil. Mag.*, ser. 1, vol. xxi. p. 129, 1805.

bringing it up safely.[1] He attached this to the line on a number of occasions, and succeeded in bringing up as much as 6 lbs. of mud from the great depth of 1050 fathoms in Baffin Bay; and on September 1st, 1819, in Possession Bay, "soundings were obtained correctly in 1000 fathoms, consisting of soft mud, in which there were worms, and entangled on the sounding-line, at the depth of 800 fathoms, a beautiful *Caput-Medusæ*,"[2] thus proving that there was animal life on the bed of the ocean notwithstanding the darkness, stillness, silence, and enormous pressure produced by more than a mile of superincumbent water. Starfishes were frequently found attached to the line at depths of over 800 fathoms from the surface, but these discoveries were strangely lost sight of for many years. The zoological collections made on this voyage must have been of great scientific value, and it is much to be regretted that, on their arrival in this country, a large number of the specimens were in a state unfit for identification. The scientific work of the cruise had been entrusted to Sir Edward Sabine, who, while anxious to do justice to the whole circle of the sciences, naturally devoted himself most to his own department of physical and magnetic observations. Sir John Ross keenly felt the want of a naturalist. He writes :—

"An endless variety of the class Acalephæ were brought home, and sent to the Museum, but in a state so much contracted by the spirit as to render it impossible for Dr. Leach to make out their genera. Observations on these animals whilst living accompanied by accurate drawings, are quite necessary to render the preserved specimens of any degree of use; and it is to be regretted that no Naturalist capable of performing these indispensable parts of his duties accompanied the Expedition."[3]

Considerable attention was also paid to meteorology and ocean physics, and the record of the voyage includes a number of tables of continuous meteorological observations. the density of the surface water was observed daily, and occasionally that at a depth of 80 fathoms.[4] Deep-sea temperatures were taken at short intervals of time and of depth by means of a self-registering thermometer with a protected bulb, resembling that devised by Sir William Thomson[5] and Professor W. A. Miller half a century later.[6]

In his second Arctic voyage, from 1829 to 1833, Sir John Ross continued his scientific observations, and frequently dredged in shallow water, his limit of depth being 70 fathoms.[7] The large zoological collections were unfortunately lost to science, as they had to be abandoned with the "Victory," and since there was no naturalist on the expedition the loss was complete.

The researches of Mr. Darwin during the voyage of H.M.S. "Beagle" (1831–36), remarkable in so many respects, are to be noted in this connection chiefly for his obser-

[1] Voyage of Discovery in His Majesty's Ships "Isabella" and "Alexander," Appendix, p. cxxxv, London, 1819.
[2] *Ibid.*, p. 178.
[3] *Ibid.*, Appendix, pp. lxiii, lxiv.
[4] *Ibid.*, Appendix, three large plates.
[5] Depths of the Sea, p. 293, 1874; *Proc. Roy. Soc. Edin.*, vol. ii. pp. 267–271, 1851.
[6] Depths of the Sea, p. 290.
[7] Narrative of a Second Voyage in Search of a Northwest Passage, Appendix, p. lxxxi, London, 1835.

vations on the bathymetrical limit of reef-forming corals, and on the structure and origin of coral reefs and islands.

About this time appeared Sir John Dalyell's interesting investigations on Scottish zoophytes and the first microscopic researches of Ehrenberg upon living and fossil marine organisms. The microgeologic studies of the latter, pointing out the relation between modern marine deposits and geological formations, added a new interest to the investigation of marine life. In 1837 Mr Alan Stevenson applied the method still in use for ascertaining the direction and velocity of marine under-currents.[1]

The next great advance in marine zoology was the invention of Ball's dredge in 1838. The special features of this dredge were such as to give it at once the first place as a naturalist's appliance, and after the lapse of nearly half a century it remains practically unexcelled.

The great importance of dredging as a means of zoological research was recognised in 1839 by the British Association, which appointed a committee "for researches with the dredge, with a view to the investigation of the marine zoology of Great Britain, the illustration of the geographical distribution of marine animals, and the more accurate determination of the fossils of the Pliocene period under the superintendence of Mr. Gray, Mr. Forbes, Mr. Goodsir, Mr. Patterson, Mr. Thompson of Belfast, Mr. Ball of Dublin, Dr. George Johnston, Mr. Smith of Jordan Hill, and Mr. A. Strickland."[2]

From the number of eminent men on this committee valuable reports were looked for, and not in vain. One alone, Professor Edward Forbes, did more than any of his contemporaries to advance marine zoology. He conducted long and patient investigations into the bathymetrical distribution of life in various seas; and by the fascination of his literary style he invested his reports with an interest that carried the knowledge of his work far beyond the limits usually set to the labours of specialists. Forbes' ideas on many points are no longer entertained; had he lived longer he himself would doubtless have been the first to discover and proclaim the falsity of many of them. "To Forbes is due the credit of having been the first to treat these questions in a broad philosophical sense, and to point out that the only means of acquiring a true knowledge of the *rationale* of the distribution of our present fauna, is to make ourselves acquainted with its history, to connect the present with the past. This is the direction which must be taken by future inquiry. Forbes, as a pioneer in this line of research, was scarcely in a position to appreciate the full value of his work. Every year adds enormously to our stock of data, and every new fact indicates more clearly the brilliant results which are to be obtained by following his methods, and by emulating his enthusiasm and his indefatigable industry."[3]

[1] The Principles and Practice of Canal and River Engineering, by David Stevenson, F.R.S.E., p. 116, 2nd ed. Edinburgh, 1872.

[2] *Brit. Assoc. Report*, p. 127, 1839; Memoir of Edward Forbes, F.R.S., by Wilson and Geikie, p. 246, 1861.

[3] Depths of the Sea, p. 6, 1874.

Forbes believed with all the intensity of the old school of naturalists in the immutability of species, and in specific centres of distribution; he based his beliefs on facts of his own observation, and if these now appear insufficient and unsatisfactory, it must be remembered that he worked before Darwin's Origin of Species gave to naturalists the modern ideas of natural selection and evolution.

Forbes' name is inseparably associated with the bathymetrical distribution of marine life, and his clearly defined zones—the Littoral, Laminarian, Coralline, and the Region of the Deep-sea Corals—enormously facilitated the work of descriptive naturalists. The region of deep-sea corals extended from 50 fathoms to an unknown depth, and Forbes points out that vegetable life is entirely absent from it, and "as we descend deeper and deeper in this region, the inhabitants become more and more modified, and fewer and fewer, indicating our approach towards an abyss where life is either extinguished, or exhibits but a few sparks to mark its lingering presence. Its confines are yet undetermined, and it is in the exploration of this vast deep-sea region that the finest field for submarine discovery yet remains."[1] In another place he indicates the plateau between Shetland and the Færöe Islands, on which the depth nowhere exceeds 700 fathoms, as the place on which dredging is most likely to settle the question of the existence of a zero of life, and he points out that while the life-zero is probably about the 300 fathom line in the Mediterranean, the researches of Arctic voyagers have shown it to be much deeper in Polar regions. The disciples of all great men tend to assert dogmatically what their master suggested hypothetically, and it was so with the followers of Edward Forbes. They viewed the life-zero, not as a probability, but as a certainty, building their belief more on the *à priori* absurdity of creatures being able to live in the absence of light and air, and under the great pressure which must prevail in the depths of the sea, than on any direct evidence.

The United States Government sent out their first purely scientific expedition in 1838 under the command of Captain Wilkes. This expedition returned in 1842; its work was chiefly geographical and astronomical, but during the first year a few dredgings were made in shallow water, and a number of deep soundings were obtained at intervals during the voyage. The sounding line employed was a copper wire, a great improve menton previous methods. The great American naturalist Dana, who accompanied this expedition, added much to the knowledge of several groups of shallow water and pelagic animals.

A British Antarctic Expedition under Sir James Clark Ross sailed in the "Erebus" and "Terror" in 1839, and returned safely in 1843. Like Sir John Ross in the Arctic voyages, his nephew was determined to make the most of his opportunities in all directions, and was seconded in his efforts by the able co-operation of Sir Joseph Dalton Hooker, who accompanied the expedition as assistant surgeon. Without neglecting

[1] Natural History of European Seas, p. 26, 1859. This classification was given as early as 1839. See Memoir of Edward Forbes, p. 255.

his main purpose—the exploration of the ice-bound coasts of the southern hemisphere and the search for the South Magnetic Pole—Ross carried on astronomical, physical, and zoological work, and achieved results so important and hitherto so overlooked as to justify a somewhat detailed notice.

Sir Joseph Hooker first made known some of the results of Ross's deep-sea dredgings and investigations in 1845,[1] and fuller details were given by Ross himself in the account of the voyage published in 1847.

A number of unsuccessful attempts were made to ascertain the depth of the water in mid-ocean, the failure being due to the want of a proper line. Sir James Ross accordingly had one made on board, 3600 fathoms long, fitted here and there with swivels to prevent it unlaying in its descent, and made strong enough to support a weight of 76 lbs.

On the 3rd January 1840, when in lat. 27° 26′ S. and long. 17° 29′ W., the first abysmal sounding was satisfactorily made with the new line, the depth marked being 2425 fathoms.[2] Such great depths could only be attempted in dead calm weather, and the line was allowed to run out from an enormous reel in one of the ship's boats, the time each 100 fathom mark left the reel being noted in the usual way.

On the 3rd March 1840, a sounding of 2677 fathoms was made in lat. 33° 21′ S. and long. 9° E., 450 miles west of the Cape of Good Hope. Water of equal depth was frequently sounded during the cruise, and on two occasions at least no bottom could be found with over 4000 fathoms of line.

The temperature of the water was observed very frequently at all depths down to 2000 fathoms, and its density at the surface and at various depths was determined almost daily. These observations were very valuable at the time, as giving the first real clue to the distribution of temperature at the bottom of the sea; but both in this expedition and in those of Wilkes and D'Urville, the thermometers were not properly protected against pressure, and consequently it came to be generally believed that in all open seas the water below a certain depth maintained a uniform temperature of 39° F. right down to the bottom.

Ross lays special emphasis on the fact mentioned by earlier observers that the surface temperature of the water falls rapidly as the depth of the sea diminishes; he cites one instance when in a single day the temperature at the surface fell from 70° F. where the depth was 400 fathoms, to 51°·5 where it was only 48 fathoms,[3] a fact now known to be of local but not of universal occurrence.

The dredgings, which were taken occasionally, turned out to be one of the most valuable parts of the scientific work of the expedition. On the 21st April 1840, a haul of the dredge was taken in 95 fathoms of water, and it came up full of coral. On the 18th January 1841, when in lat. 72° 57′ S. and long. 176° 6′ E., a Pycnogonid

[1] *Ann. and Mag. Nat. Hist.*, ser. 1, vol. xvi. p. 238, 1845.
[2] Antarctic Voyage, vol. i. p. 26, 1847.
[3] *Ibid.*, vol. i. p. 34.

(*Nymphon gracile*) was found attached to the lead, after a sounding in 230 fathoms. Next day, when the depth was 270 fathoms, a dredge was put over, and when hauled up was found to be nearly full; it contained a block of granite, a number of small stones, some beautiful specimens of living corals, and, to quote Captain Ross's own words:—

"Corallines,[1] Flustræ, and a variety of marine invertebrate animals, also came up in the net, showing an abundance and great variety of animal life. Amongst them I detected two species of *Pycnogonum*, *Idotea baffini*, hitherto considered peculiar to the Arctic Seas, a Chiton, seven or eight bivalves and univalves, an unknown species of *Gammarus*, and two kinds of *Serpula* adhering to the pebbles and shells."[2]

On January 20th, 1841, the deep-sea clamm brought up stiff green mud containing corals and fragments of Starfish from a depth of 320 fathoms. Two days later the dredge was put over and allowed to trail along the bottom for two or three hours in 300 fathoms, and its contents included "many animals, some Corallines, and a quantity of sand, mud, and small stones."[3]

Ross's deepest dredging was made at 10 A.M. on the 11th August 1841, in lat. 33° 32′ S., long. 167° 40′ E., when the dredge was let go in 400 fathoms; after being dragged along the ground for half an hour, it was hauled on deck, and found to contain "some beautiful specimens of Coral, Corallines, Flustræ, and a few Crustaceous animals." The reflections of the accomplished leader of the expedition are extremely significant. So completely had Ross's researches faded from memory, that twenty years after they were made, the fact of living creatures being found under 400 fathoms of water was hailed as a great discovery. Yet Ross, referring to his dredgings in 1841, says:—

"It was interesting amongst these creatures to recognise several that I had been in the habit of taking in equally high northern latitudes; and although contrary to the general belief of naturalists, I have no doubt that from however great a depth we may be able to bring up the mud and stones of the bed of the ocean, we shall find them teeming with animal life; the extreme pressure at the greatest depth does not appear to affect these creatures; hitherto we have not been able to determine this point beyond a thousand fathoms, but from that depth several shellfish have been brought up with the mud."[4]

From the fact that the same species were to be found at both poles, and that these animals are very sensitive to a change of temperature, he suggested that it would be possible for them to pass from one frigid zone to another, provided the temperature of the intervening sea bottom had a range not exceeding 5° F. Ross's observations confirmed his idea that the temperature at the bottom of the open sea was uniform in all latitudes, and subsequent investigations prove it, generally speaking, to be correct.

Sir James Ross was an indefatigable zoological collector, but it is to be regretted that his large collections of deep-sea animals, which he retained in his own possession

[1] Most probably Polyzoa are here referred to.—J.M.
[2] Antarctic Voyage, vol. i. p. 202.
[3] *Ibid.*, p. 207.
[4] *Ibid.*, pp. 202, 203.

after the return of the expedition, were found to be totally destroyed at the time of his death. Had these been carefully described during the cruise or on the return of the expedition to England, the gain to science would have been immense, for not only would many new species and genera have been discovered, but the facts would have been recorded in the journals usually consulted by zoologists, instead of being lost sight of as was the case. A large number of zoological drawings made by Sir Joseph Hooker during the Antarctic cruise were recently handed to the various naturalists engaged in working up the Challenger collections, and these show that some of the Challenger discoveries had been anticipated by Ross. Sir Joseph Hooker, whose botanical researches are so well known, recorded the existence of immense numbers of Diatoms on the surface of the Antarctic Ocean, and pointed out that the mud at the bottom, as obtained in Ross's dredgings, consisted of their dead remains.[1]

When Sir John Franklin's ill-fated Polar expedition set out in 1845, Mr. Harry Goodsir, a young zoologist of great promise, sailed on board the "Erebus" as assistant surgeon and naturalist. The expedition never returned, and only fragmentary records are preserved of the valuable work which Goodsir had already accomplished. "On the 28th June a dredge was sunk to the enormous depth of 300 fathoms, and produced many highly interesting species of Mollusca, Crustacea, Asteriadæ, Spatangi, and Corallines; such as *Fusus*, *Turritella*, *Venus*, *Dentalium*, &c., and also some large forms of Isopoda. As bearing upon the geographical distribution of species, Mr. Goodsir considers the occurrence of *Brissus lyrifer* (Forbes) and *Alauna rostrata* (Goodsir) as of the greatest interest, both of them being natives of the Scottish seas. The remarkable depth also appears to us to give peculiar interest to these researches, as we believe that the deepest dredgings ever previously obtained were those of Professor E. Forbes in the Levant, the deepest of which was 230 fathoms, itself far beyond any made by other naturalists."[2]

Up to this time all the deep dredgings had been made during Polar expeditions, though not necessarily in Polar regions; the reason being that the time and trouble of working a dredge in deep water were too great to make it feasible except on scientific expeditions, and the only scientific expeditions of those days were despatched toward the poles. In 1846, however, Captain Spratt, R.N., dredged in 310 fathoms, 40 miles to the east of Malta, and found abundance of animal life, including eight distinct species of Mollusca.[3]

During this period of rapid advance in marine zoology, the problems of ocean physics and meteorology were not lost sight of. Rennel had been collecting particulars of the currents, prevailing winds, and general meteorology of the ocean from 1810 to 1830, and his Investigation of Currents, &c., is still a valuable book of reference. Maury also collected facts of all kinds bearing on these matters between the years 1848 and

[1] Flora Antarctica, vol. ii. p. 503, London, 1847.

[2] *Ann. and Mag. Nat. Hist.*, ser. 1, vol. xvi. p. 163, 1845.

[3] Spratt, On the Influence of Temperature upon the Distribution of the Fauna in the Ægean Sea, *Brit. Assoc. Report*, Communications, p. 81, 1848.

1858, and published his famous Sailing Directions embodying these statistics. One important result of Maury's exertions was the maritime conference held in Brussels in 1853, which resulted in international observations being taken on many naval and mercantile ships, thus obtaining several of the advantages of scientific expeditions at very little expense.

Before 1850 the attention of the Norwegian naturalist, Michael Sars, had been directed to the bathymetrical distribution of life on his native coasts, and he published in the following year a list of thirteen species which lived at a depth of about 300 fathoms.[1] His son, G. O. Sars, afterwards assisted him in the work of deep-water dredging, and the result was, in 1864, a list of ninety-two species, which lived between the depths of 200 and 300 fathoms.[2] A few years later these untiring investigators found abundance of life at the bottom under 450 fathoms of water.[3]

A great impulse was given to deep-sea soundings when Brooke, an officer in the United States Navy, invented his sounding machine in 1854. Its principle was that described by Hooke two centuries before; the sinker was detached when the weight struck the bottom, but it differed in that the sounding tube could be drawn up by the line, bringing with it a small sample of the deposit on which it struck. Bailey's description of the micro-organisms found in these deposits, as well as others obtained by the U.S. Coast Survey, excited great interest among scientific men.[4] A few years later the instrument was modified and improved by Commander Dayman, who employed it for his soundings across the Atlantic, when investigating the depths through which the Atlantic telegraph cable would require to pass.[5] The necessity for ascertaining the form and conditions of the sea bed for telegraph purposes was the occasion of considerable increase in the scientific knowledge of great depths.

The samples of "Atlantic ooze" procured from the greatest depths of that ocean by the sounding rods of the telegraph ships were eagerly examined by the leading European and American naturalists. The ooze was found to consist largely, in some cases almost wholly, of the shells of Foraminifera and the siliceous skeletons of Radiolarians and Diatoms. The question soon came to be whether all the Foraminifera naturally lived on the bottom, or whether it was only their dead shells that collected there, the animals living and dying on the surface, or at some intermediate depth. This question was exceedingly difficult to settle from the data possessed by the disputants prior to the Challenger and other exploring expeditions.

[1] Beretning om en i Sommeren 1849 foretagen zoologisk Reise i Lofoten og Finmarken, *Nyt Mag. f. Naturvid.*, Bd. vi. p. 133, 1851.

[2] Bemærkninger over det dyriske Livs Udbredning i Havets Dybder, *Forhandl. Vidensk. Selsk.*, Christiania, p. 54 (1864), 1865.

[3] *Forhandl. Vidensk. Selsk.*, Christiania, p. 248 (1868), 1869 ; translation, *Ann. and Mag. Nat. Hist.*, ser. 4, vol. iii. p. 425, 1869.

[4] *Amer. Journ. Sci. and Arts*, vol. lxxi., 1856.

[5] Depths of the Sea, p. 214.

In the preserved samples of the ooze it was believed that there was evidence of the existence of sheets of living protoplasm—a shell-less Rhizopod named *Bathybius*[1]—covering the bottom of the ocean everywhere. The Naturalists of the Challenger failed to detect *Bathybius* in freshly procured samples of the ooze, and have shown that the protoplasmic appearance arose from the great excess of alcohol used in the preservation of the samples of the ooze, producing a gelatinous-like precipitate of calcium sulphate.

The voyage of the "Bulldog" in 1860, under Sir Leopold M'Clintock, is especially noteworthy amongst the cruises of surveying ships. The "Bulldog," which was sent to examine a proposed northern cable route, took soundings from Færöe to Iceland and thence to Greenland and Labrador. Though bad weather prevailed for a great part of the cruise, a large number of soundings and many samples of mud were taken; as the expedition had the good fortune to be accompanied by Dr. G. C. Wallich as naturalist, these were carefully examined as they were brought up. The invention of the "Bulldog" sounding machine—a combination of Ross's deep-sea clamm with Brooke's detaching weight—made it possible to obtain larger samples of the bottom than had been usual before.

On one occasion a depth of 1260 fathoms was indicated. "That single sounding," says Dr. Wallich, "I may be permitted to say compensated for every disappointment that weather and accident may have previously engendered. At the eleventh hour, and under circumstances the most unfavourable for searching out its secrets, the deep has sent forth the long-coveted message."[2] That message was conveyed by thirteen Starfishes which had attached themselves to a portion of the sounding line that had been allowed to lie on the bottom for some time. This haul raised a storm of controversy. Dr. Wallich was firmly convinced that it was proof beyond question of the existence of highly organised animal life at great depths, but many eminent zoologists argued that it was quite probable that the Starfishes had "convulsively embraced" the line somewhere on its way up. The idea of a life-zero was far too firmly fixed in the zoological mind of that period to be readily displaced.

In the same year, 1860, a telegraph cable which was being raised for repair in the Mediterranean under the direction of Mr. Fleeming Jenkin, now Professor of Engineering in the University of Edinburgh, was the means of definitely deciding the fact of highly organised creatures living at great depths.[3] Parts of the cable which had been lying under 1200 fathoms of water for many years were found covered with animals that had fixed themselves at a very early stage of development and had grown to maturity there. Some of these were examined and described by Professor Allman of Edinburgh, others by M. Milne-Edwards of Paris.

[1] Huxley, *Quart. Journ. Micr. Sci.*, N.S., vol. viii. p. 210, 1868; Haeckel, Studien über Moneren und andere Protisten, p. 86, Leipzig, 1870.

[2] North-Atlantic Sea-bed, p. 68, London, 1862.

[3] Depths of the Sea, p. 26, 1874.

During Otto Torell's expedition to Spitzbergen in 1864, a great number of creatures were taken at a depth of 1000 to 1400 fathoms in the "Maclean nets." They included Rhizopoda, Bryozoa, Sponges, Annelids, Crustacea, and other forms. In subsequent expeditions to Spitzbergen, creatures were frequently secured from a similar depth.[1]

In 1865 a paper by Professor Forchhammer of Copenhagen on the Composition of Sea-Water in different parts of the Ocean was published in the Philosophical Transactions,[2] recording the result of twenty years of patient work, and its publication made an era in the history of ocean chemistry. Forchhammer worked under great disadvantages; his samples of water were brought home by seafaring men from different parts of the world in corked bottles, and they were necessarily all taken from the surface or immediately beneath it. Forchhammer did not attempt to determine quantitatively all the elements that occur in sea water, but confined himself to the very accurate estimation of the principal components, viz., chlorine, sulphuric acid, magnesia, lime, potash, and (by difference) soda. Although his methods have since been improved on, all the analyses were models of care and accuracy, and all his results have been confirmed and extended by Professor Dittmar's elaborate research, carried on under conditions so immensely more favourable on the water samples carefully collected on board the Challenger. Forchhammer's grand conclusion is that although the salinity of sea water may and does vary within certain limits, yet if samples be taken in all parts of the open sea, avoiding the vicinity of land and the mouths of large rivers, the proportion of each constituent to the total salts will be found to be the same everywhere. The differences in surface sea water then are merely differences due to dilution and concentration.

In 1867 Count L. F. de Pourtalès commenced, in connection with the United States Coast Survey, a series of deep dredgings on the margin of the Gulf Stream. Working in the U.S. Coast Survey steamer "Corwin," he dredged down to a depth of 350 fathoms; and in the following year he resumed the work in the same place in the U.S. Coast Survey steamer "Bibb," and dredged successfully in 510 fathoms, finding animal life exceedingly abundant. Although a great part of the collections made by Pourtalès were lost in the great fire of Chicago, many new species have been described and brought under the notice of zoologists, and the wide bearing of the new facts obtained were comprehensively discussed by Professor Louis Agassiz, who took part in these explorations with Pourtalès.[3]

It has always been supposed that costly appliances and a large crew are absolutely necessary for successful dredging in water of any great depth. G. O. Sars indeed had worked down to 300 fathoms in a small boat manned by three men, off the Lofoten

[1] *Zeitschr. f. wiss. Zool.*, Bd. xx. p. 457, 1870.
[2] *Phil. Trans.*, vol. clv. pp. 203–262, 1865.
[3] *Bull. Mus. Comp. Zoöl.*, Cambridge, U.S.A., 1868 and 1869.

Islands, but his example was not much followed. In 1868 Professor Perceval Wright[1] proceeded to Setubal in Portugal, in order to investigate the occurrence of *Hyalonema*, which was reported to be frequently taken on the lines of the shark-fishers who had long pursued their calling, at the great depth of 500 fathoms. He succeeded in getting abundance of specimens of *Hyalonema*, although six men were required to work the dredge, and the depth of the water was 480 fathoms. "This dredging," says Professor Wyville Thomson, "is of special interest, for it shows that although difficult and laborious, and attended with a certain amount of risk, it is not impossible in an open boat, and with a crew of alien fishermen, to test the nature of the bottom, and the character of the fauna, even to the great depth of 500 fathoms."[2] But although possible, such dredging is too laborious and dangerous to be frequently resorted to, and for any systematic study of the depths of the sea more elaborate arrangements must be made.

The subject of deep-sea dredging was not being neglected in Great Britain. In the spring of 1868 Professor Wyville Thomson, in a letter to Dr. W. B. Carpenter, urged the employment of a Government vessel in a dredging expedition off the coast of Scotland, and in consequence of this the Royal Society laid before the Admiralty a statement of the advantages to science likely to result from a short dredging cruise in the North Atlantic. The Admiralty responded by placing the surveying ship "Lightning," Captain May, at the disposal of Drs. Thomson and Carpenter in the autumn of the same year. The conditions of work in the "Lightning" were very unfortunate both as regards the vessel and the weather which prevailed during the six weeks that the cruise lasted. In spite of all the difficulties in the way, dredging was carried on to a depth of 650 fathoms, and temperature observations of the greatest interest were obtained, which ultimately led to the discovery of the Wyville Thomson Ridge in the Færöe Channel in 1880.[3] Professor Wyville Thomson thus sums up the results of the "Lightning" expedition :—

"It had been shown beyond question that animal life is varied and abundant, represented by all the invertebrate groups, at depths in the ocean down to 650 fathoms at least, notwithstanding the extraordinary conditions to which animals are there exposed.

"It had been determined that, instead of the water in the sea beyond a certain depth varying according to latitude having a uniform temperature of 4° C., an indraught of Arctic water may have at any depth beyond the influence of the direct rays of the sun a temperature so low as $-2°$ C.; or on the other hand, a warm current may have at any moderate depth a temperature of 6°·5 C., and it had been shown that great masses of

[1] See Notes on Deep-Sea Dredging, *Ann. and Mag. Nat. Hist.*, ser. 4, vol. ii, pp. 423–427, 1868.

[2] Depths of the Sea, p. 277, 1874.

[3] Exploration of the Færöe Channel, *Proc. Roy. Soc. Edin.*, vol. xi. pp. 638–717, 1882.

water at different temperatures are moving about, each in its particular course; maintaining a remarkable system of oceanic circulation, and yet keeping so distinct from one another that an hour's sail may be sufficient to pass from the extreme of heat to the extreme of cold.

"Finally, it had been shown that a large proportion of the forms living at great depths in the sea belong to species hitherto unknown, and that thus a new field of boundless extent and great interest is open to the naturalist. It had been further shown that many of these deep-sea animals are specifically identical with tertiary fossils hitherto believed to be extinct, while others associate themselves with and illustrate extinct groups of the fauna of more remote periods; as, for example, the vitreous sponges illustrate and unriddle the ventriculites of the chalk."[1]

In consideration of the value and novelty of these results, the Royal Society urged the Admiralty to provide means of extending the observations. In 1869 the surveying ship "Porcupine," Captain Calver, was appointed to this service. In addition to the temperature observations, which had turned out so interesting in the "Lightning," it was decided to make a number of chemical observations on the water. For this purpose the chartroom was fitted up as a laboratory, and a chemist was invited to join the biologists on the cruise. A number of arrangements were also made for facilitating dredging and the subsequent observations. The "Porcupine" was a first-rate vessel for the purpose, and between May and September 1869 she made three distinct trips. The first of these was under the scientific direction of the late Mr. Gwyn Jeffreys, and it was chiefly devoted to dredging off the west coast of Ireland and in the channel between Scotland and Rockall. The deepest dredging made was in 1470 fathoms, and no lack of life was found at that depth. It was accordingly resolved that, during the second trip, under the direction of Professor Wyville Thomson, an attempt should be made to dredge in the deepest water within reach, so that a definite answer to the general question of the existence of life at great depths could be arrived at. The "Porcupine" was steered for the Bay of Biscay, and at a point about 250 miles west of Ushant two highly successful hauls of the dredge were taken in water over 2000 fathoms deep, and in both animal forms from the Protozoa to the Mollusca were abundant.[2] It was on this cruise that Captain Calver suggested the employment of hempen tangles attached to the dredge frame, an idea which Professor Thomson says inaugurated a new era in dredging.[3]

The third cruise of 1869, during which Dr. Carpenter was the naturalist in charge, was intended to be a repetition of that of the "Lightning" in the previous autumn. The observations of the earlier expedition were confirmed and extended in various directions.

In 1870 Mr. Gwyn Jeffreys and Dr. Carpenter continued the work in the

[1] Depths of the Sea, pp. 79, 80, 1874. [2] *Ibid.*, pp. 96, 97. [3] *Ibid.*, p. 256.

"Porcupine" by a highly interesting series of soundings and dredgings in the Mediterranean and current observations in the Strait of Gibraltar. Dr. Carpenter resumed the study of this region in the following year in the "Shearwater," commanded by Captain G. S. Nares, afterwards Captain of the Challenger, and this expedition was no less interesting or important than those that went before.

The chemical and physical work of the "Porcupine" expeditions was not so satisfactory as might have been expected. Marine chemistry was so entirely new, that a great deal of preliminary work had to be done in order to gain the experience necessary for further more accurate experiments; and it was in the way of suggesting improvements for future use that the chemical work of the "Porcupine" was most valuable.

In December 1871 and early in 1872 the U.S. Coast Survey steamer "Hassler," under the scientific direction of Professor Louis Agassiz, dredged in considerable depths off the coast of South America.

About this period appeared an important work by Delesse on the lithology and distribution of marine deposits,[1] in which the littoral formations of the coast of France are described in detail, and our knowledge of the deeper deposits of the North Atlantic are reviewed.

This introductory chapter is not intended as a history of marine scientific research; its purpose is merely to trace the gradual growth of knowledge of the physical and biological conditions of the ocean up to 1872, and to recall some of the more important of the earlier researches which have been allowed to fade from the attention of the scientific public. More emphasis is laid on the beginning of the various enterprises than on their subsequent development, and prominence has been given throughout to the work carried on by British investigators. It is not on account of any notion that the expeditions despatched by other countries were less important at the time, or productive of less permanent results, that the older cruises of the "Astrolabe," of the "Venus," and the "Bonite," and the more modern ones of the "Eugenie," the "Novara," the "Magenta," and other vessels have not been dwelt upon. It is because the line of researches which had a direct bearing on the despatch of the Challenger could be indicated sufficiently clearly without entering into greater detail.

The cruises of the "Porcupine" proved that there was life at vast depths in the sea, and that, with a little care, this life could be investigated by ordinary and well known means. The results, taken in conjunction with the conclusions of the contemporary German North Sea Expedition, also showed the great importance of a careful study of the physical, and especially the chemical, as well as the biological, conditions of the sea.

[1] A. Delesse, Lithologie du Fond des Mers, Paris, 1871.

The vast ocean lay scientifically unexplored. All the efforts of the previous decade had been directed to the strips of water round the coast and to enclosed or partially enclosed seas; great things had certainly been done there, but as certainly far greater things remained to be done beyond. This consideration led to the conception of the idea of a great exploring expedition which should circumnavigate the globe, find out the most profound abysses of the ocean, and extract from them some sign of what went on at the greatest depths.

The following correspondence extracted from the Minutes of Council of the Royal Society giving expression to this idea, and tracing the progress of its realisation, will best show how all the difficulties in the way of inaugurating an undertaking of such magnitude and novelty were successfully surmounted; and their perusal will be a fitting introduction to the chapters containing the Narrative of the Cruise, the study of which cannot fail to convince the reader that, high as were the hopes entertained by the promoters of the Expedition, the performance was even greater than had been anticipated.

"*June 29th*, 1871.

"Read the following Letter from Dr. Carpenter:—

"'University of London, Burlington Gardens, W.
"'*June* 15, 1871.

"'Dear Prof. Stokes,—The information we have lately received as to the activity with which other nations are now entering upon the Physical and Biological Exploration of the Deep Sea, makes it appear to my colleagues and myself that the time is now come for bringing before our own Government the importance of initiating a more complete and systematic course of research than we have yet had the means of prosecuting.

"'The accompanying slip from last week's 'Nature' will make known to the Council what is going on elsewhere, and the feeling entertained on the subjects alike in the scientific world and (as I have good reason to believe) by the public generally.[1]

"'For adequately carrying out any extensive plan of research, it would be requisite that special provision should be made; and as the Estimates for next year will have to be framed before the end of the present year, no time ought now to be lost, if the matter is to be taken up at all.

"'In order that the various departments of Science to which these researches are related should be adequately represented,—so that any Application made to Government should be on the broadest basis possible, —I should suggest that the Council of the Royal Society, as the promoters of all that has been already done in the matter, should take the initiative; and should appoint a Committee to consider a Scheme, in conjunction with the President of the British Association, and the Presidents of the Chemical, Geographical, Geological, Linnean, and Zoological Societies. Such a Committee might meet before the Recess, and decide upon some general plan; and this would be then considered as to its details by the Members representing different departments

[1] *Nature*, vol. iv. p. 107, 1871. The paragraph states that the Governments of Germany, Sweden, and the United States were preparing to despatch ships to various parts of the ocean expressly fitted for deep-sea exploration.

of Scientific Enquiry, so that they might be able to report to the Council, and enable it to lay that Scheme (if approved) before the Government by the end of November.

"'Believe me, dear Prof. Stokes,

"'Yours faithfully,

"'William B. Carpenter.'

"'*Prof. Stokes.*'

"Resolved,—That the subject of Dr. Carpenter's Letter be taken into consideration at an early Meeting of the Council after the Recess.

"*October* 26*th*, 1871.

"In reference to the subject of Dr. Carpenter's Letter of the 15th June, read at the last Meeting of Council, the Secretary stated that he had received a subsequent Letter from him, dated Malta, 29th Sept., which was now read. In this Letter Dr. Carpenter urges the expediency of making arrangements for the proposed circumnavigating Expedition without delay, and communicates a correspondence with the First Lord of the Admiralty, from which it appears that H.M. Government will be prepared to give the requisite aid in furtherance of such an Expedition on receipt of a formal Application from the Royal Society; and in consequence of this information, Dr. Carpenter now suggests a modification in the composition of the Committee to which, in his former Letter, he had proposed that the matter should be referred.

"Resolved,—That a Committee be appointed to consider the plan of operations it would be advisable to follow in the proposed Expedition, the staff of scientific superintendents and assistants to be employed, and the different provisions and arrangements to be made, with an estimate of the probable expense, and to submit to the Council for approval a scheme which might be laid before H.M. Government, if the Council see fit, at as early a period as may be convenient. The Committee to consist of the President and Officers of the Royal Society, Dr. Carpenter, Dr. Frankland, Dr. Hooker, Professor Huxley, the Hydrographer of the Admiralty, Mr. Gwyn Jeffreys, Mr. Siemens, Sir William Thomson, Dr. Wyville Thomson, and Dr. Williamson, with power to add to their number.

"*November* 30*th*, 1871.

"The following Report of the Committee on the proposed voyage of circumnavigation was read:—

"'*Report of the Committee appointed at the Meeting of the Council held October* 26*th, to consider the Scheme of a Circumnavigation Expedition.*

"'The Committee having before them the correspondence which has already taken place between the First Lord of the Admiralty and Dr. Carpenter, are of opinion that it is advisable that the Council should make immediate Application to Her Majesty's Government for the means of carrying out the objects therein referred to; but that it would not be expedient that such Application should include more than a *general specification* of those objects,—which may be stated as follows:—

"'1. To investigate the *Physical Conditions* of the *Deep Sea*, in the great Ocean-basins,—the North and South Atlantic, the North and South Pacific, and the Southern Ocean (as far as the neighbourhood of the great ice-barrier); in regard to Depth, Temperature, Circulation, Specific Gravity, and Penetration of Light; the observations and experiments upon all these points being made at various ranges of depth from the surface to the bottom.

"'2. To determine the *Chemical Composition* of *Sea Water*, not merely at the surface and bottom, but at various intermediate depths; such determinations to include the Saline Constituents, the Gases, and the Organic Matter in *solution*, and the nature of any particles found in *suspension*.

"'3. To acertain the *Physical* and *Chemical* characters of the *Deposits* everywhere in progress on the Sea-bottom; and to trace, so far as may be possible, the sources of those deposits.

"'4. To examine the Distribution of *Organic Life* throughout the areas traversed, especially in the *deep* Ocean-bottoms and at different depths; with especial reference to the Physical and Chemical conditions already referred to, and to the connection of the present with the past condition of the Globe.

"'It is suggested that the Expedition should leave this country in the latter half of the year 1872; and as its perfect organization will require much time and labour, it is desirable that suitable preparations should be commenced forthwith.

"'For effectively carrying out the objects just specified, there will be required:—

"'1. A Ship of sufficient size to furnish ample accommodation and storage-room for sea-voyages of considerable length and for a probable absence of four years.

"'2. A Staff of Scientific Men, qualified to take charge of the several branches of investigation above enumerated.

"'3. An ample supply of all that will be required for the Collection of the objects of research; for the prosecution of Physical and Chemical investigations; and for the study and preservation of the various forms of Organic Life which will be obtained.

"'The Committee would propose that in making this Application to the Admiralty, the President and Council should offer their services in suggesting the Route which may appear to be most desirable for the Expedition to pursue; and also in framing Instructions for the Officers charged with the several branches of Scientific Research; with a view to facilitate the preparation by their Lordships of their general Instructions for the conduct of the Voyage to the Naval Officers commanding.

"'With this object they would propose that a Committee should be appointed by the Council, which should include persons thoroughly versed in the various branches of Science to be represented in the Expedition, who should give their advice and assistance previous to and during the progress of the Expedition.

"'The President and Council should also express their readiness to select and recommend to their Lordships persons qualified to be entrusted with the various branches of Scientific investigation to be represented, naming the Salaries which may appear to them commensurate with the duties to be fulfilled.

"'The President and Council should also, in the opinion of this Committee, recommend that in accordance with former precedents in regard to Expeditions of a similar character undertaken by this and other Governments, a full and complete publication of the results of the Voyage with adequate illustrations should form a part of the general plan; and that the work should be brought out as soon after the return of the Expedition as may be convenient.

"'It may be well to point out to the Admiralty, that the operations of the Expedition now proposed should not dispense with such researches of a less laborious character as their Lordships might be disposed to make from time to time from either the home or the foreign stations of the British Navy.'

"Resolved,—That this Report be received, and be taken into consideration at the next Meeting of Council.

"*December 7th*, 1871.

"The Report of the Committee on the subject of a Scientific Circumnavigation Voyage, received at the last Meeting, having been taken into consideration, it was

"Resolved,—That application be made to Her Majesty's Government, as recommended by the Committee, and that the following Draft of a Letter to be addressed by the Secretary to the Secretary of the Admiralty be approved:—

"'*To the Secretary of the Admiralty.*

"'THE ROYAL SOCIETY, BURLINGTON HOUSE,
"'*December 8th*, 1871.

"'SIR,—I am directed by the President and Council of the Royal Society to request that you will represent to the Lords Commissioners of the Admiralty that the experience of the recent scientific investigations of the deep sea, carried on in European waters by the Admiralty at the instance of the Royal Society (Reports of which will be found in their 'Proceedings' herewith enclosed), has led them to the conviction that advantages of great importance to Science and to Navigation would accrue from the extension of such investigations to the great oceanic regions of the Globe. The President and Council therefore venture to submit to their Lordships' favourable consideration a proposal for fitting out an Expedition commensurate to the objects in view; which objects are briefly as follows:—

"'(1) The Physical conditions of the deep sea throughout all the great Ocean-basins.

"'(2) The chemical constitution of the water at various depths from the surface to the bottom.

"'(3) The physical and chemical characters of the deposits.

"'(4) The distribution of organic life throughout the areas explored.

"'For effectively carrying out these researches there would, in the opinion of the President and Council, be required—

"'(1) A ship of sufficient size to afford accommodation and storage-room for sea-voyages of considerable length and for a probable absence of four years.

"'(2) A staff of scientific men qualified to take charge of the several branches of investigation.

"'(3) A supply of everything necessary for the collection of the objects of research, for the prosecution of the physical and chemical investigations, and for the study and preservation of the specimens of organic life.

"'The President and Council hope that, in the event of their recommendation being adopted, it may be possible for the Expedition to leave England some time in the year 1872; and they would suggest that as its organization will require much time and labour, no time should be lost in the commencement of preparations.

"'The President and Council desire to take this opportunity of expressing their readiness to render every assistance in their power to such an undertaking; to advise upon (1) the route which might be followed by the Expedition, (2) the scientific equipment, (3) the composition of the scientific staff; (4) the instructions for that staff; as well as upon any matter connected with the Expedition upon which their Lordships might desire their opinion.

"'The President and Council have abstained from any allusion to geographical discovery or hydrographical investigations, for which the proposed Expedition will doubtless afford abundant opportunity, because their Lordships will doubtless be better judges of what may be conveniently undertaken in these respects, without departing materially from the primary objects of the voyage; and they would only add their hope that in accordance with the precedents followed by this and other countries under somewhat similar circumstances, a full account of the voyage and its scientific results may be published under the auspices of the Government as soon after its return as convenient, the necessary expense being defrayed by a grant from the Treasury.

"'The President and Council desire, in conclusion, to express their willingness to assist in the preparation for such publication of the scientific results.

"'I remain, &c.'"[1]

It is unnecessary to describe the cruises of the United States ship "Tuscarora," of the German ship "Gazelle," or the yearly expeditions of the Norwegian Government in the North Atlantic, for these belong to the same period as that of the Challenger. Nor is it necessary to do more than refer to the still more recent cruises of the "Knight

[1] For continuation of this correspondence, see Appendix A. to Chapter I.

Errant" and "Triton," to the explorations of Alexander Agassiz in the U.S. Coast Survey steamer "Blake," to the work of the Italians in the ship "Washington," to the French expeditions in the "Travailleur" and "Talisman," or to the systematic researches of the United States Fish Commission.

The work done by all of these was of the same general character; they were in many respects supplementary, and, as a result, the science of abysmal research has been founded and carried on to a prosperous state of development. This science cannot, from its nature, advance slowly and gradually; it must proceed by strides, which will probably be as far apart in point of time as they are important with respect to discovery.

H.M.S. Challenger.

CHAPTER I.

Selection of H.M.S. Challenger—Her Fittings—Description of the Decks, Workrooms, and Laboratories—List of Officers—Departure from Sheerness—Arrival at Portsmouth—Appendices.

THE deep-sea investigations conducted on board H.M. Ships "Lightning," "Porcupine," and "Shearwater," in the years 1868, 1869, 1870 and 1871, and the subsequent correspondence between the Lords Commissioners of the Admiralty, the Council of the Royal Society, and Dr. W. B. Carpenter, C.B., F.R.S., have been referred to in the preceding introductory chapter.

The practical outcome of these preliminary expeditions and negotiations was the decision by the Government and the Lords Commissioners of the Admiralty to equip an Expedition for the examination of the physical and biological conditions of the deep sea throughout the great ocean basins. The proposal to defray the expense of such an Expedition out of the public funds received the cordial assent of the House of Commons in April 1872.

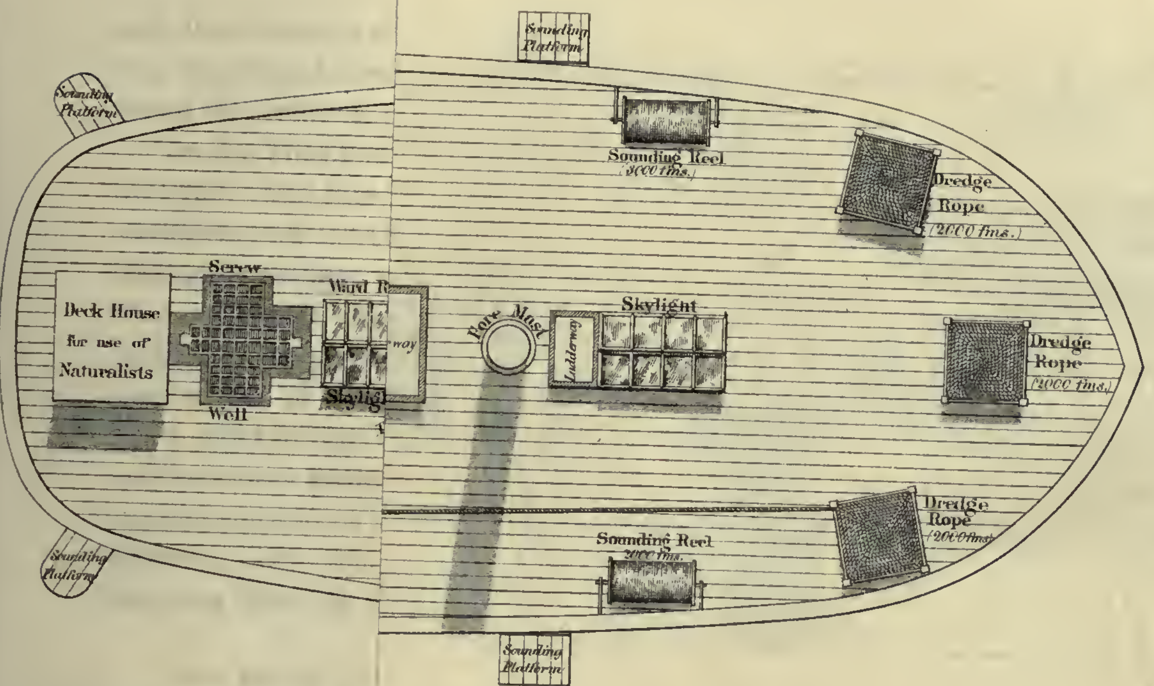
The work connected with the despatch of the Expedition from England was at once vigorously taken up by Admiral G. H. Richards, at that time Hydrographer to the Admiralty. H.M.S. Challenger, a steam corvette, with a spar upper deck, of 2306 tons displacement, and an indicated power of 1234 horses, was chosen for this service. Captain George Strong Nares, an experienced surveying officer, was selected by the Lords Commissioners of the Admiralty to take command of the Expedition. Captain Nares received his appointment to the Challenger in May 1872, and all the arrangements and fittings which were necessary in order to make the ship suitable for the peculiar duties in which she was to be employed, were carried out under his general superintendence. All the guns were removed with the exception of two, and the space which they and the stores and ammunition in connection with them had occupied, was devoted to the necessary accommodation for laboratories, workrooms, dredging and sounding rope, storage of specimens, spirits of wine, boxes, trawls, and nets.

The following description of the arrangements finally adopted on board the ship, will be readily understood by reference to the accompanying plans.

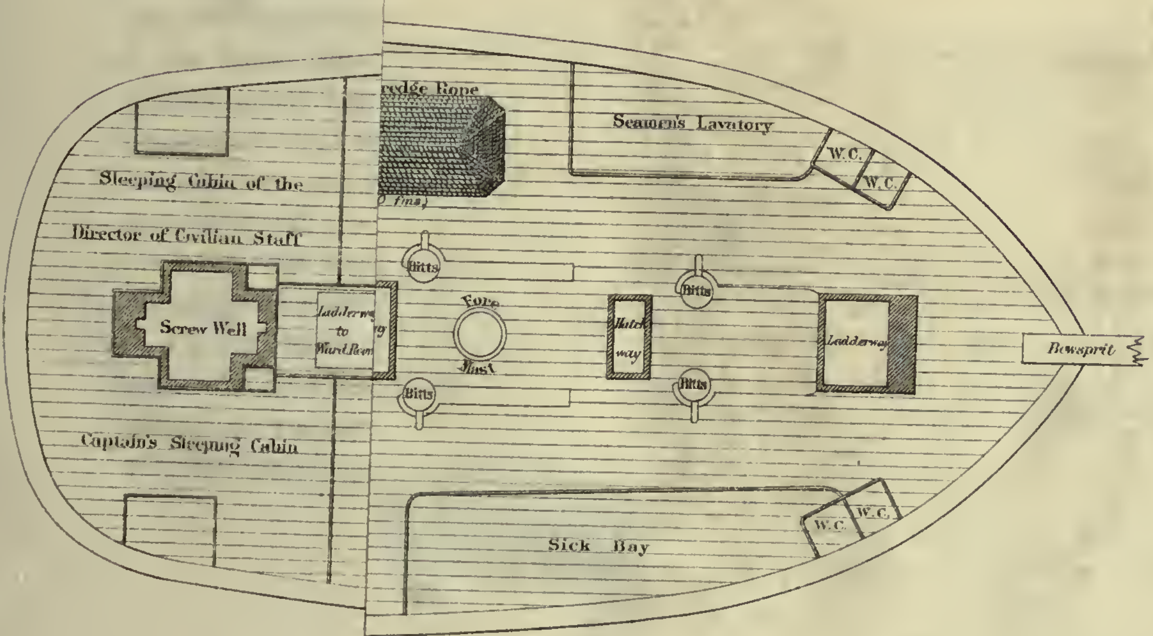
Upper Deck.

On the forecastle three cordage racks, each 5 feet square and 3½ feet high, were placed, and in them the dredging rope in use was coiled, each rack holding about 2000 fathoms. Attached to each side of the ship, just before the foremast, was a reel of sounding line suspended on spurs extending from the bulwarks, so that it could revolve freely; one reel held the line used to ascertain the depth, and the other that set apart for temperature observations. Projecting outwards from each side abreast the foremast, were two small platforms level with the upper deck, placed exactly under the foreyard, so that the deep-sea sinkers could be lowered into the water without the necessity of hoisting them over the bulwarks. These platforms also rendered it possible to work lines simultaneously from the fore and main yards, so that in fine weather specimens of water could be obtained from various depths forward, whilst temperature observations were being carried on from the dredging platform. In the central part of the ship, before the mainmast, a dredging platform was built level with the hammock nettings, from which the operations of dredging and trawling could be pursued, and upon which the contents of the dredge might be emptied, so that the naturalists, while engaged in sifting the mud and preserving the specimens, might not be interrupted by the seamen working the ropes; and also in order that the refuse from the dredge might be thrown overboard without dirtying the decks, for which purpose two large shafts were fitted from the platform to the water's edge. The sieves and tubs used in sifting the mud and ooze brought up in the dredgings were kept on the port side of this bridge. Here also were permanently situated two large oblong boxes, with strong zinc cases inside, for holding spirit, in which large fish, reptiles, and mammals were kept for about ten days, before being finally packed in tins for transmission to England.

Under the after part of the dredging platform a small engine was placed, of eighteen horse-power, which worked a series of drums attached to each end of a shaft extending across the ship, so that two lines could be worked simultaneously, one on each side; another advantage was also gained by having drums on each end of the shaft, for, when the strain on the dredging rope was so great that the friction of the drum revolving was not sufficient to make it bite (even with ten or twelve men holding on behind,



Sounding Platform
Sounding Platform
Sounding Reel
(3000 fms.)
Dredge Rope
(2000 fms.)
Deck House for use of Naturalists
Screw Well
Ward R
way
Skylig
Fore Mast
Ladderway
Skylight
Dredge Rope
(2000 fms.)
Dredge Rope
(2000 fms.)
Sounding Reel
2000 fms.
Sounding Platform
Sounding Platform



redge Rope
0 fms.)
Seamen's Lavatory
W.C.
W.C.
Sleeping Cabin of the
Director of Civilian Staff
Screw Well
Ladderway to Ward Room
Bitts
Fore Mast
Hatch way
Bitts
Ladderway
Bitts
Bitts
Bowsprit
Captain's Sleeping Cabin
Sick Bay
W.C.
W.C.


MAIN DECK.

and three turns of the rope round the drum), it was possible by leading it abaft through two blocks, and then forward again as shown in the plan, to take three additional turns round the drum on the other side of the ship, and thus prevent it slipping.

On the after part of the upper deck, just before the mizenmast, four small circular skylights were fitted, two on each side, to give the necessary light to the naturalists' workroom and the chartroom, on the main deck. Before the mizenmast, level with the hammock nettings, was the usual pilotage bridge, on which stood the standard compass, from which all observations for variation taken on board were made, and under this bridge, on the port side, a screen was built for the thermometers used in ascertaining the temperature of the air. A few feet abaft the mizenmast, in the centre of the ship, was a stand for the Fox dipping needle, from which all observations for inclination taken on board were made. Projecting outwards on each side over the quarter were two small sounding platforms for the ordinary sounding work of a surveying vessel, and over these platforms were small davits, with snatch blocks, to facilitate hauling in the ordinary sounding lines, log lines, &c.

Deck House for use of Naturalists.—Abaft the screw well was situated a deck house, 7 feet fore and aft, by 8 feet athwart ships, built after the departure of the ship from England, in order to give increased accommodation to the naturalists. The work connected with the preservation of birds, mammals, fish, deep-sea deposits, and the examination of tow-net gatherings, was usually conducted in this house.

A door opened on the port side, and sash-windows extended the whole width of the house at a height of four feet from the deck. A dresser, 2 feet wide, ran across the house abaft, at the height of the lower part of the sash-windows, and was furnished all round with racks for small bottles. A Hartnack microscope was always at hand on this dresser, and in rough weather was fixed to it by a clamp. Three large holes were cut in the dresser for holding glass globes, into which the contents of the surface nets were usually emptied, and as the tow-nets were hauled in abaft, just at the door of the house, this arrangement was very convenient. Underneath this dresser was another, about two feet above the deck, fitted completely with racks for large bottles. Underneath this again were several boxes with zinc cases, in which fish and other animals were stored; here also was a locker, in which all the apparatus and materials connected with the skinning and preservation of birds were kept. In the fore part of the house was a table, which could be raised or lowered at will, and on which the bird-skinning and other operations were conducted.

On the starboard side of the house was a small table, one foot square, with one stout leg firmly fixed into the deck of the ship so as to render it steady. On this a binocular microscope was permanently clamped, which was found to be very convenient for working with low magnifying powers, and for ascertaining the general character of the surface gatherings. There was excellent light in this house, and the microscope could be used satisfactorily in all kinds of weather. Several strong hooks fixed into the roof were most serviceable as holdfasts in the operation of skinning birds. A netting, in which bird-skins were kept till dry, was suspended from the roof. The tow-nets, a gun, a rifle, a water glass, and scoops for surface work were kept in this house ready for use whenever a boat was lowered from the ship to collect surface animals or shoot birds. A deck house such as this, where all the rougher work of the naturalists can be carried on, should be provided in every vessel expressly fitted for researches similar to those carried on in the Challenger.

Boat Equipment.—The boat equipment consisted of a steam pinnace 39 feet in length, a barge 29 feet in length, two cutters, three whalers, a life gig, and a dingey. Of

Fig. 1.—The Steam Pinnace in Sydney Harbour.

these boats the pinnace, barge, and two whalers were carried inboard, the cutters were hoisted to davits abreast the mizenmast, the life gig to davits over the stern, and one whaler and the dingey to wooden davits in the main chains. In bad weather the two latter boats were topped into the rigging. The pinnace (see fig. 1) was specially adapted for dredging in harbours and in shallow water. A small engine was fitted on the top of the boiler, and was used for hauling in dredging and sounding lines, and a small derrick could be erected forwards, whilst in the bow there was a dredging platform; the dredge rope being coiled away on the bottom in the after part.

Main Deck.

On the main or gun deck special cabins and workrooms were built; the after part was, as is usual in all ships, appropriated for the use of the Captain, who in this case shared his accommodation with the Director of the Civilian Staff. Outside the foremost bulkhead of the captain's cabin two large workrooms were built, one on each side of the ship, 18 feet in length by 12 in breadth, the room on the port side being appropriated to the use of the naturalists, whilst that on the starboard side was used by the surveying officers as a chartroom. On the foremost bulkhead of the captain's cabin the barometer was hung.

Zoological Laboratory.—The zoological laboratory (see fig. 2) was lighted by two skylights and a port fitted with a pair of windows, whilst the bulkhead separating it from the main deck was provided with ground glass sash windows, so as to afford further light. Two dressers reaching the whole breadth of the room were fixed, one at each end, and beneath these were constructed a series of drawers, four large cupboards, and a pair of knee-hole spaces to afford places for seats. The drawers were fitted with a series of sockets for bottles of various sizes, and with compartments to contain instruments of all kinds, which were thus secured from injury by the motion of the vessel. It was found very convenient to have several of the cupboards fitted inside with air-tight zinc linings, or rather complete zinc boxes, each having an opening in its front, about a foot square. The edges of the opening were framed with wood with a projecting ledge, against which fitted a wooden lid, which closed the opening, and was held in position by a couple of buttons. With the edges of the lids greased, the zinc cupboards became air-tight and damp proof, and plants and other objects, when once thoroughly dried by artificial heat and packed into them, were perfectly secure from the effects of the saturation of the air with moisture, which in many regions is one of the greatest obstacles to contend with when preparing specimens on board ship. The ordinary cupboard door of mahogany protected the face of the zinc lining from injury. All round the dresser next to the bulkhead was fitted a rack to hold large wide-mouthed bottles, and other racks, perforated to hold tubes or smaller bottles, were fixed to the ship's side or the bulkheads wherever space was available. These racks proved of the greatest service. In weather at all rough it is most important that plenty of such racks should be ready to hand, so that bottles containing specimens may be secured from injury at a moment's notice. The racks for large bottles should be carefully made, and should be rather deeper in proportion than shown in the woodcut of the laboratory. The bottles should fit into two circular apertures in wood, one at the bottom of the bottles, the other at about half their height. With such an arrangement it is unnecessary to wedge them in position in heavy weather, and there is no fear of specimens being lost owing to a sudden lurch of the ship.

Fig. 2.—Zoological Laboratory on the Main Deck.

A long table was fixed across the laboratory, with its end close up to the port. It was found that only at either side of the table, close to the port, could a really satisfactory light for the use of the microscope be obtained. It should therefore be a matter of care, that in future the ports of any similar laboratory should be fitted with windows constructed with as little opaque material as possible. Those of the Challenger laboratory might certainly have been improved in this respect had the matter received attention when they were constructed. Plate glass windows in iron frames would probably be best. In harbour or during very calm weather, the light from the skylights could be used for the microscope with advantage, but whenever the ship was in motion, the tables so constantly shifted their angle of inclination to the light, that it was impossible to keep the field illuminated for many seconds together. At the two seats close to the window this effect was not felt, because the reflectors could be exposed directly to a wide range of illuminated sky, and did not cease to gather light from some part of it, unless the motion were very extreme indeed. The oblong table had its feet securely screwed to the deck, and the simple oval-topped wooden stools occupied by the microscopists were also screwed to the deck on each side of the window. They were so placed, and of such a height, that the sitter, by jamming his knees against the frame of the securely fixed table, could hold himself firm and motionless. The microscopes were secured to the table at will in any position by means of small brass holdfasts. With all these arrangements for steadiness it was found possible during a gale of wind, provided that the port had not to be closed altogether, to work comfortably, even with very high powers. A No. 10 immersion of Hartnack was used successfully under such circumstances with a drawn-out tube.

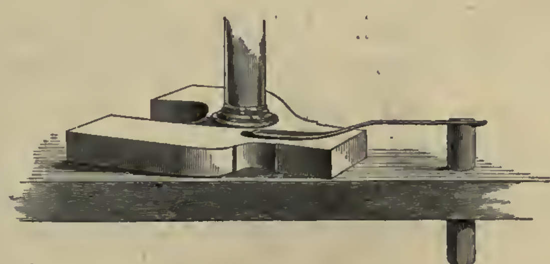


FIG. 3.—The Holdfast.

The holdfast is a simple instrument (fig. 3), well known to artificers of all kinds, but it was found so useful as a means of clamping microscopes on board ship, that it is as well to give some description of it here. It consisted of a piece of stout brass rod, about 4 inches long and $\frac{1}{3}$ of an inch in diameter, to which was fixed at right angles by one of its ends a stout flat strip of brass, about $\frac{1}{2}$ an inch broad. This strip is slightly bent downwards and again upwards a little at its free tip, as seen in the woodcut. A neat vertical hole, large enough to receive the rod freely, is bored in the table where the microscope is to be used. When the free end of the horizontal arm is placed upon any part of the foot of the microscope, a slight pressure on the rod downwards into the hole clamps it firmly in any position in which it may stand. A slight pull on the rod frees it instantly, and the microscope can thus be secured in any position round the hole with the greatest ease. There is no other method by which this can be effected so readily, and in working at sea, unless the instrument be thus fixed, it is often liable to be upset or thrown altogether off the table at any moment. Microscope lamps with ring feet may be conveniently secured to the table in the same manner.

The spirit in constant use for the preservation of specimens was stowed in one of the ship's powder magazines, specially retained for the purpose. From this store a tank placed in the hammock netting on the upper deck was filled as required, and the spirit was drawn off from the tank by means of a pipe with a tap placed in the laboratory, and secured under lock and key. The key was placed under special charge, especially at night, as a precaution against danger from fire.

In the case of any similar expedition in the future, it would be a great gain to have a drying chamber of some kind provided. In damp weather in the tropics, and also in the Southern Ocean and elsewhere, it was found extremely difficult to dry plants and other objects satisfactorily. The plants had usually to be dried in the ship's oven when vacant and cooling at night, or by being placed in the funnel casings, or in the stokehold. It would have been easy to have partitioned off, by means of perforated sheet-iron, a small drying chamber in the stokehold or elsewhere, where the hot air from the fires passing through would have produced the required effect. It would, however, be better if such a chamber could be provided with a separate source of heat of its own, to be used when the boiler fires were not lighted. A drying apparatus thus arranged would be of the greatest service for drying deposits, corals, sponges, and many animal specimens as well as plants. The specimens put to dry, for lack of a better place, in the ovens, or in the stokehold, were often, of necessity, inadvertently destroyed.

A press with weights intended for use in drying plants was taken on board the ship, but not used. It was found far better to use wire frames between the drying papers as ventilators, and to employ straps or ropes placed round the bundles to produce the requisite pressure. If plants be placed between single sheets of botanical drying paper, and packed in bundles with a ventilator between each two sheets, they may be successfully dried by means of artificial heat, without any change of the papers.

A list of the instruments and apparatus taken on board the ship for natural history purposes, which experience proved to be serviceable, is given in Appendix C to this chapter. It may be well here to point out some of those items which were found especially useful, and also to give a few words of warning as to those found useless.

By far the most economical wide-mouthed bottles, and the most convenient and handy in every way for use on a large scale, are known in the trade as "rock bottles," manufactured for holding sweetmeats. They are made in three sizes, and sold packed in wooden cases, with handles at each end and compartments for each bottle, padded with cork. The bottles are all about the same height, 9 inches, made of pale green, but very transparent, glass, and closed by glass stoppers with cork rims. The diameters of the three sizes of bottles are 6, $4\frac{1}{2}$, and $3\frac{3}{4}$ inches, with mouths $3\frac{3}{4}$, $2\frac{3}{4}$, and $2\frac{3}{4}$ inches respectively. They are very cheap; 200 cases complete, containing 2300 jars, were supplied to the Expedition by Messrs. E. Breffit & Co., Upper Thames Street, London, at a cost of £70.

Worth mentioning also, as especially useful and cheap, were roughly made bottles of white glass, with ground glass stoppers, measuring $3\frac{1}{2}$ inches in height, 2 inches in diameter, and with mouths of about $1\frac{3}{4}$ inches. The bottles are manufactured by machinery as pomatum bottles, and are sold very cheaply by the gross. They are very strong, survive much hard usage, and were in constant use throughout the voyage. They were found, on account of their strength, especially useful for collecting expeditions on land. Rectangular leather cases, with leather lids secured by a strap and buckle, and divided inside into compartments for six of these bottles placed upright, and with long straps for suspending them from the shoulders, are most useful appliances for the collector on shore, and it is especially convenient that such cases should be made to contain a kind of bottle the supply of which is practically unlimited. The pomatum bottles were obtained from Messrs. James Powell & Sons of Whitefriars.

A large store of sheet zinc and solder was found indispensable, as the majority of the larger animals were preserved in zinc cases made on board.

Common fish globes are especially useful on board ship for containing living animals in water, washing the contents of surface nets into, and all similar purposes. Their shape is better adapted than any other to prevent the splashing over of the contents. They should be of various sizes, and racks should be provided for them to fit into.

A slate and plate-glass aquarium, closed by slate above, and so arranged that, in order to prevent constant splashing and motion of the contents, it should always be completely full and yet permit of a frequent change in the water being effected, was set up on the main deck, but proved a complete failure. The reason of the failure was, that owing both to its own weight and that of the contained water, it was found impossible to keep its joints water-tight. The motion of the ship, and the working of the deck to which it was secured, caused the slate and glass to play against one another at the joints, and no application of bolts and screws seemed able to prevent this action.

In the hope that Cetacea might be secured during the voyage, a stock of harpoons and a harpoon gun and its gear formed part of the equipment, but not a single Porpoise or Whale was obtained. Porpoises and Dolphins frequently accompanied the ship in various parts of the world, and it was most disappointing that not a single specimen could be secured. The harpoon gun was a large one, fit for use only for full-sized Whales, from a specially built whale boat by a trained crew, but as the Challenger did not carry such a whale boat nor a crew acquainted with whaling operations, and as there was no one on board specially expert in the use of the harpoon from the bows of the vessel, nothing was obtained by its use. It is most important that the smaller Cetacea met with during scientific voyages should be secured, whenever practicable. What is required is a gun to be fired from the shoulder, and to carry a small harpoon suitable for catching the smaller Dolphins or Porpoises, which might be used from the ship's bows. Such a weapon is now used with success by the U.S. Fish Commission.

Of the fishing-nets used by the Expedition, exclusive of those employed for dredging work, the trammels were by far the most useful. They are the best appliances for collecting shore fish for scientific purposes, since they secure all sorts and sizes which may be swimming in the waters where they are put down. As they are very liable to be torn and injured, there should be a good supply. These nets, as well as the trawls, were supplied by Mr. Jonathan Hearder, Plymouth. Lobster pots, drum nets, and shrimp nets were very little used during the Expedition, but mainly because the stay at the places visited was usually short. They would probably be found very useful on any scientific voyage not so exclusively devoted to deep-sea research as that of the Challenger. It is most important that on any future scientific expedition it should be arranged, if possible, that some of the seamen composing the crew should have been trained as fishermen. It might be expected that plenty of fishermen would be met with in any ship's company, but such is not the case; the men in the navy are mostly such as have been trained for special naval duties.

Chartroom.—The chartroom was fitted with two drawing tables, each 6 feet by 5, with nests of drawers underneath, in which the smaller instruments and stationery were stowed. At the after end cupboards were built for a complete set of charts of the world, and were so arranged that any particular chart could be got at without difficulty. In these cupboards also the larger instruments such as theodolites, declinometers, &c., were stowed. At the foremost end a bookcase was placed, which contained the sailing directions and such of the narratives of former circumnavigators as might prove useful on the voyage.

Before the zoological laboratory and chartroom on each side were cabins for the use of the commander and navigating officer. Farther forward, again, were two reels containing spare sounding and temperature lines, and here also was a hydraulic press (fig. 4). The pump A is of the ordinary construction, but with a very narrow cylinder, the diameter of the cylinder and piston being $\frac{1}{4}$ inch. The water is pumped into the reservoir B, a cast-iron tube of 3 inches internal, and 9 inches external, diameter, closed above by the plug C, which is held in its place by the bolt D. The instruments to be tested are placed in B; the plug C is inserted and made fast by the bolt, and water is pumped in until the desired pressure has been obtained. This is indicated by water issuing from the safety-valve E, which is of the ordinary construction. The machine, which was made by Messrs. James Milne & Sons, Edinburgh, works up to a pressure of 4 tons on the square inch. (See p. 100.)

In the central part of the main deck, abreast the mainmast, other cabins were built for a chemical laboratory and photographic room, each of which was specially fitted for the purpose for which it was intended, under the immediate superintendence of those members of the Civilian Staff who were to use them. Between the funnel and the foremast two large tiers were built, one on each side, in which a portion of the spare dredging rope was coiled, 6000 fathoms in each tier.

Chemical Laboratory.—The engraving of the laboratory (see fig. 5), which is from a careful and accurate drawing by Mr. Wild, gives a very faithful idea of the arrangements and fittings in all their details. The artist is supposed to be sitting on the locker seat, and immediately in front of him to the right is seen the blowpipe table, a square deal table, with a cylindrical double-action bellows 8 inches in diameter. It is shown with the leaf up, which was necessary to give support to the arm while working. The air was delivered in a horizontal jet by a nozzle with a ball and socket joint for adjustment. For use with the bellows a glass-blower's lamp with double wick, burning tallow, was supplied. This form of lamp was not found satisfactory, being dirty and cumbersome,

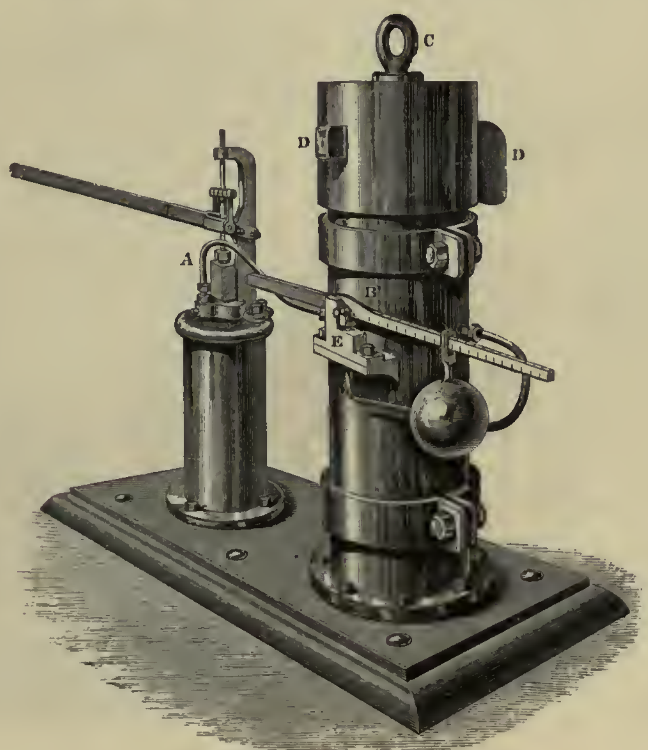


FIG. 4.—Hydraulic Compression Apparatus.

besides causing waste of time, as the tallow had to be melted before being used. After a very few weeks, therefore, it was rejected, and its place supplied by an ordinary glass spirit lamp, when only a small flame was required. For glass-blowing purposes, however, where more heat was necessary a four-ounce wide-mouthed bottle was used, to which was fitted a wick socket made of sheet copper, and of such a size as to accommodate the greatest possible amount of wick. This lamp was fed with spirit, and it would have been impossible to have had a better flame for glass-blowing purposes, especially for working lead glass. There is also the great advantage in using spirit as compared with gas or oil, that it burns with a non-luminous flame at all times, and saves the eyes the fatigue of alternating glare and gloom, according as the bellows are worked or not. The lamp was fixed between two cords stretched across the table, and was thus kept from shifting with the rolling of the ship. After a very little practice, there was no difficulty in doing any glass-blowing which could have been done by the same means on land, as long as the weather was not so boisterous as to necessitate the barring in of the port.

To the left of the blowpipe table was a small mahogany table, 30 in. long by 21 in.

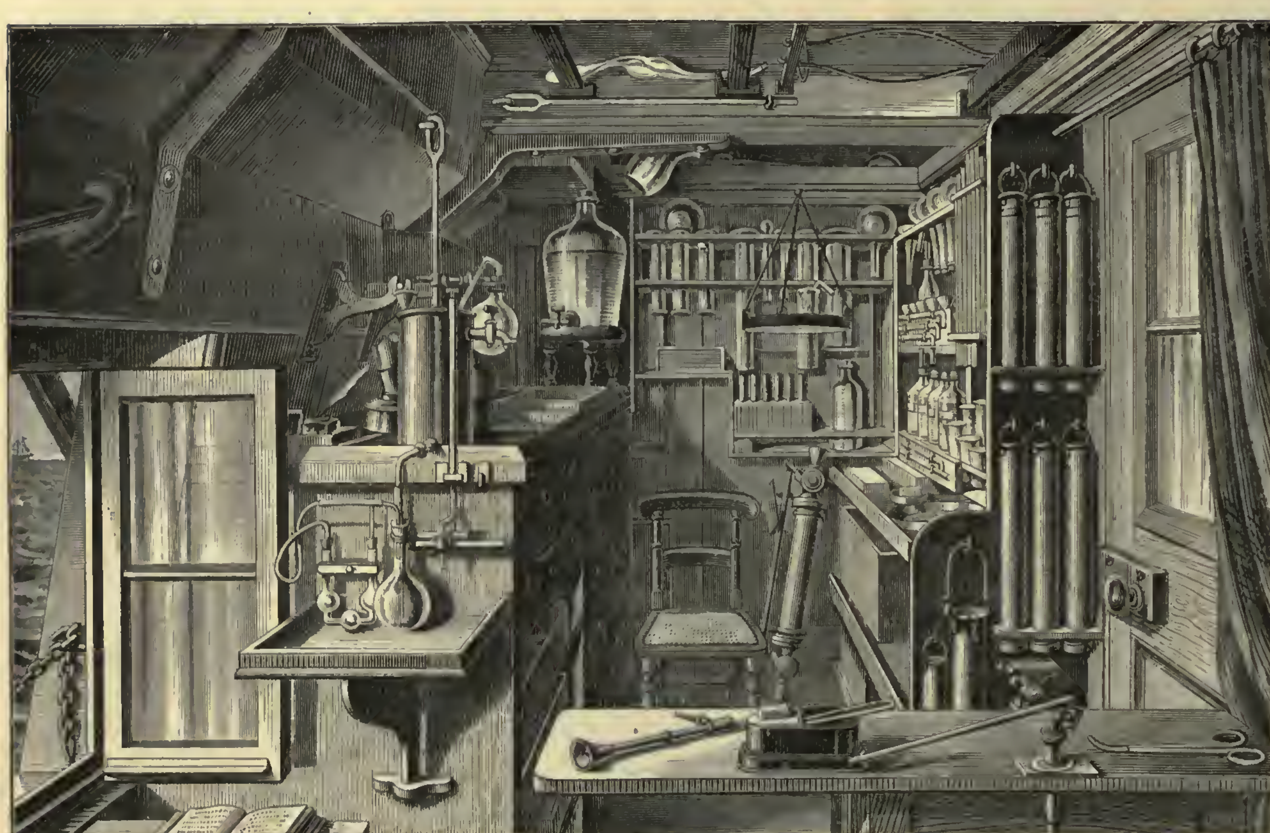


Fig. 5.—Chemical Laboratory.

broad, fixed to the window, and against the foremost sash of it. When not required it could be removed and put out of the way. The working bench occupied the space against the ship's side, between the port and the after bulkhead. It was 4 ft. long, 2 ft. wide, by 3 ft. 10 in. high, and was built of teak, the top in two slabs $1\frac{1}{2}$ in. thick, below which were arranged a number of drawers and some shelves for the reagents and apparatus in constant use. The reagents were contained in bottles of four sizes, large and small for liquids, and large and small for solids, with flat stoppers. The large ones held about 350 cubic centimetres and the small ones about 50. The large bottles occupied three drawers, divided into eighteen compartments each, and the small, two drawers, each with sixty compartments. For the sake of handiness these drawers were divided into two, so that each recess instead of having one drawer 2 ft. long, had two drawers, each 1 ft. long, stowed one behind the other. A number of drawers were fitted to receive articles in every-day use—filtering paper, blowpipe apparatus, corks, india-rubber, &c.; and one was specially set apart for nails, screws, and hooks, things not without their uses in a laboratory on shore, and absolutely indispensable at sea, where every article, even the smallest, must not only have its place, but must be secured in it.

The top of the bench was fitted with shifting battens to keep things from falling off, and at one corner a leaden sink was let into it, communicating with the sea by a pipe passing through a scupper. At the aftermost end of the bench, and on a low three-legged stool, was a large tubulated glass bottle for holding distilled water. The whole of the ship's supply of water was condensed from sea water, with rare exceptions during prolonged sojourns in harbour, and it was always of excellent quality. For the laboratory it was generally obtained fresh and hot from the condenser, and before it could take up carbonate of lime from the white-wash with which the tanks were coated. The glass bottle was broken in the first rough weather met with on the passage from Bahia to the Cape of Good Hope. During nearly a year's cruising in the comparatively calm waters of the tropics, the precaution of lashing the bottle in its place had been neglected, with the result above mentioned. It was replaced at the Cape by an earthenware filter.

In place of retort-stands, to support apparatus, iron stanchions were used, let into eyebolts in the beams, and fitting into holes in the top of the bench, or capable of being folded up against the beams above when not in use. There were two of these, and one is shown in the figure stowed away above out of use, and the other is supporting a part of the carbonic acid apparatus, which will be described further on. To accommodate another part of this apparatus, a small folding table, supported by a bracket, was fitted to the foremost part of the bench.

Against the after bulkhead were shelves for accommodating flasks, cylinders, and other pieces of apparatus, also blocks of wood pierced for test-tubes. Against the inner bulkhead were shelves for bottles containing standard solutions, flasks, beakers, and other apparatus. The burettes were supported against the front of the shelves. They were of the ordinary type of Mohr's burettes, except that at the top they were contracted to the same diameter as at the lower end. When not in use they were closed by a piece of india-rubber tube carrying a glass stopper. When one was to be filled, a glass tube, long enough to reach to the bottom of the bottle holding the standard solution, was attached to the nozzle below the pinchcock, and a sucking tube inserted above in place of the glass stopper. By opening the pinchcock and sucking above, the burette could be easily and economically filled with any reagent. For carbonic acid determination, baryta-water was in constant use, and by filling the burettes in this way a litre of the solution could be used from beginning to end without any sensible alteration of strength.

Below these narrower shelves were two broader ones, which were occupied as required. Against the foremost support of the shelves a variety of copper cases were hung. They contained pressure gauges or piezometers, so constructed as to register the combined effect of temperature and pressure on a mass of water at any depth. (See p. 102.)

Against the ship's side, and above the working bench, was a small iron frame (fig. 6) holding a cast-iron plate, or sand-bath, or other support for vessels to be heated, and having a gimbal motion. The size of the frame was arranged so as to hold one of Bunsen's thermostats in ordinary use in laboratories. The rods D D, on which the weight E slipped, were of the same diameter as the retort-stand rods above referred to, and could

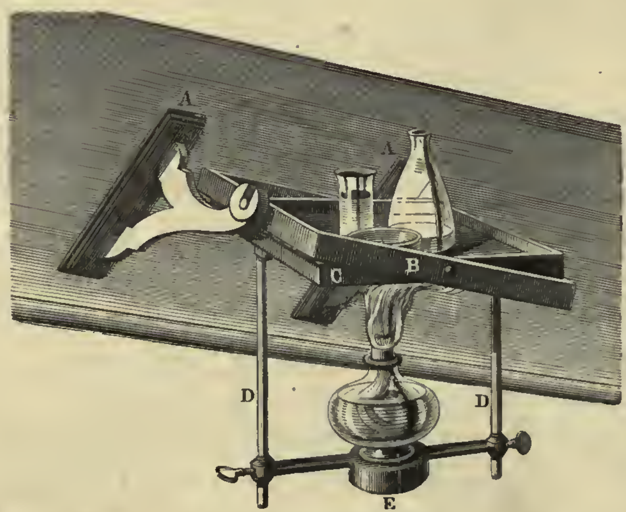


Fig. 6.—Sea-going Sand-Bath.

therefore carry the large laboratory spirit-lamps; but it was always found more convenient to use the ordinary glass spirit-lamp shown in the figure. The whole apparatus suited itself so easily to the motion of the ship, that even in very rough weather the lamp was perfectly safe as shown, and there was no danger of spilling the contents of even the flattest evaporating dish.

The arrangement of the apparatus for extracting and collecting the carbonic acid in sea water is shown in fig. 7. The flask *a* has a capacity of about 500 c.c., and receives the sample of sea water, amounting in volume to from 200 to 250 c.c., in which the carbonic acid is to be determined. It is closed by an india-rubber cork, through which pass two tubes. Of these, one, reaching to the bottom, communicates with the atmosphere by means of the soda-lime tube *f*, and flexible tube supported by hooks and rings as shown, the other, opening a little below the cork, communicates with the condenser *b*, a cylindrical copper vessel $5\frac{1}{2}$ inches in diameter, with a block-tin worm. The lower end of the worm is attached to the receiver *c* by a bent glass tube with a flexible joint *k*, from which a glass tube leads to the bottom of the receiver. The flexibility thus obtained is of much use, and enables fresh surfaces of baryta-water to be constantly exposed to the passing gases by shaking the receiver. After passing through the baryta-water in the receiver, the gases leave it by a tube filled with broken glass moistened with baryta-water, not shown in the figure, and thence through the bulbed U-tubes *d*, *d*, containing baryta-water, and soda-lime tube *x* to the aspirator *e*, which delivers into a bottle outside the port.

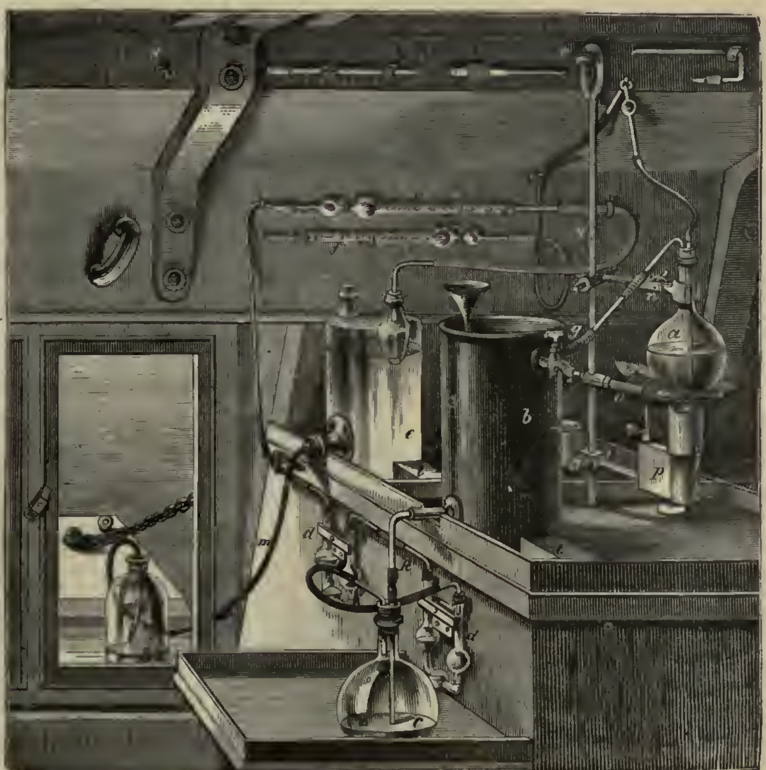


Fig. 7.—Carbonic Acid Apparatus.

The flask *a* is supported on the ring *o* by the clamp *n*. Both of these, along with the lamp *p*, are pinched to the iron rod *q* in the usual way. This rod is attached to the projecting beam of the ship's side by the eye-bolt *r*, in which it has a play of rather more than an inch, to enable it to be withdrawn from the hole in the working bench into which it fits. The usual amount of water used for the carbonic acid determination was 225 c.c., and the condenser *b* held sufficient water to condense this amount without requiring renewal.

The woodcut shows well how apparatus of the kind can be fixed and used on board ship. The aspirator and the condenser were kept steady by blocks bearing against the table battens. It shows also a convenient way of keeping bent tubes and other light articles, which are held up by a piece of india-rubber tube, slit lengthwise, and attached to the beam by a tack. An india-rubber clamp is thus formed sufficiently strong to retain any small article of suitable shape. Long tubes may be supported by more than one clamp.

For a particular description of the method of determining the carbonic acid by this apparatus, the reader is referred to the special memoir on the subject.[1] In this place it will be sufficient if the nature of the method is briefly indicated. The sample of sea water freshly drawn was brought into the flask *a*, and mixed with a saturated solution of chloride of barium in sufficient quantity to precipitate the sulphates. Heat was then applied, and the contents of the flask distilled off to very near dryness in a current of air freed from carbonic acid. The carbonic acid liberated from the water was retained by the baryta-water in the receiver *c*, and U-tubes *d*, *d*. Its amount was determined by measuring the baryta remaining in solution.

An ingenious modification of Bunsen's apparatus, by Jacobsen, was used for boiling the atmospheric gases out of the water (see fig. 8). It consists of three principal parts—the flask, the bulbed tube, and the receiver for the gases. The flask is spherical, with a strong welted lip, and holds about 900 c.c. The peculiarity of the apparatus consists in the form of the bulbed tube, and in its connection with the flask. The bulb *a*, in which the water is boiled to expel the air from the apparatus, is of the pear shape represented in the figure, in order to have the exit tube as nearly as possible at its highest point, so as to prevent the accumulation of any air in its upper part. Its capacity is about 60 c.c. The lower end of the tube is closed, but about half an inch from the end it has a very small hole *c* in the side. The perforated india-rubber cork *d* fits the neck of the flask accurately, and through the perforation the tube passes air-tight and with some friction. The receiver *b* holds from 50 to 60 c.c., and has the entry and exit tubes contracted as shown in the figure. It is joined to the bulbed tube by an air-tight india-rubber connection, and carries at its exit another piece of tubing, for a purpose to be mentioned presently. The upper part of the apparatus is supported by the clamp *m*, and by the bent rod *f*, which is clamped firmly on the lower part of the bulbed tube. The flask is supported in the water-bath *g* by the clamp *h* attached to the retort-stand *k*, which in its turn is lashed to the blowpipe table.

When the apparatus is to be used, a sufficient quantity of boiled distilled water is introduced into the bulb, and the cork *d* pushed over the opening *c*. The sea water to be examined is run directly into the flask from the deep-sea water bottle, through a tube with a narrow opening reaching to the bottom of the flask, the tube being gradually withdrawn

[1] Dittmar, Phys. Chem. Chall. Exp., part. i. p. 103, 1884; see also *Journ. Chem. Soc.*, p. 464, 1878.

until the flask is overflowing. The opening *c* in the tube is then brought just below the lower surface of the cork, which is pressed tightly into the neck of the flask. A certain amount of water is displaced by the cork, rises into the bulb, and the tube is carefully

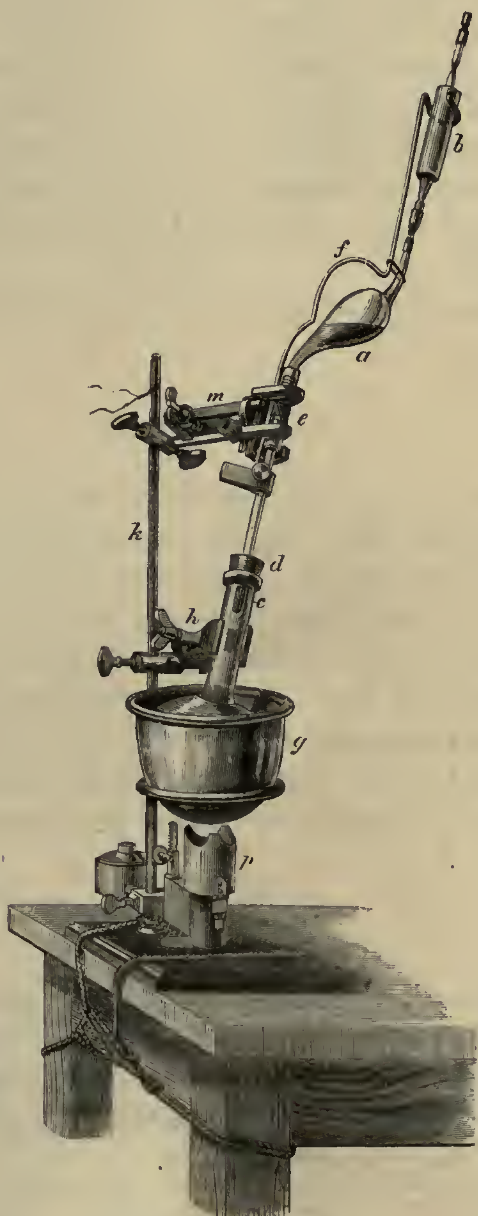


FIG. 8.—Apparatus for collecting the Atmospheric Gases from Sea-Water.

drawn upwards till the opening is well within the cork and therefore closed. A certain suction or diminution of pressure is produced, causing the immediate appearance of air-bells in the water. The receiver *b* is now attached, and the water in the bulb brought to the boiling point by a hand spirit-lamp, and kept so until the whole of the air has been expelled, which takes from six to eight minutes. In practice the boiling was kept up briskly for ten minutes, and sometimes longer. While the water is still boiling, the india-rubber tube or the exit tube of the receiver is closed with a glass stopper, so tapered that the point slips easily into the tube, and being pressed in closes it tightly. The receiver is now hermetically sealed at the upper contraction, and connection made between the bulb and the flask, by pushing down the tube until the hole *c* is below the cork. A lively disengagement of gas commences, which is kept up by heating the water-bath slowly until the water boils, at which temperature it is kept for some time. When it is judged that the gas has been wholly expelled, the receiver is sealed up at the lower contraction, and the operation is ended.

For chemicals and chemical apparatus supplied to the Expedition, see Appendix C to this chapter.

Lower Deck.

The fittings on the lower deck differed but little from the ordinary fittings of a man-of-war. The wardroom was extended in length to accommodate the additional members of the mess, since—there being no midshipmen or subordinate officers—the sub-lieutenants, as well as the members of the Civilian Staff, messed in the wardroom. The old gunroom was converted into cabins, and the gunroom steward's berth into a chronometer room, and these additional cabins, with those of the gunner, marine officer, and chaplain, were sufficient to provide accommodation for the members of the Civilian Staff.

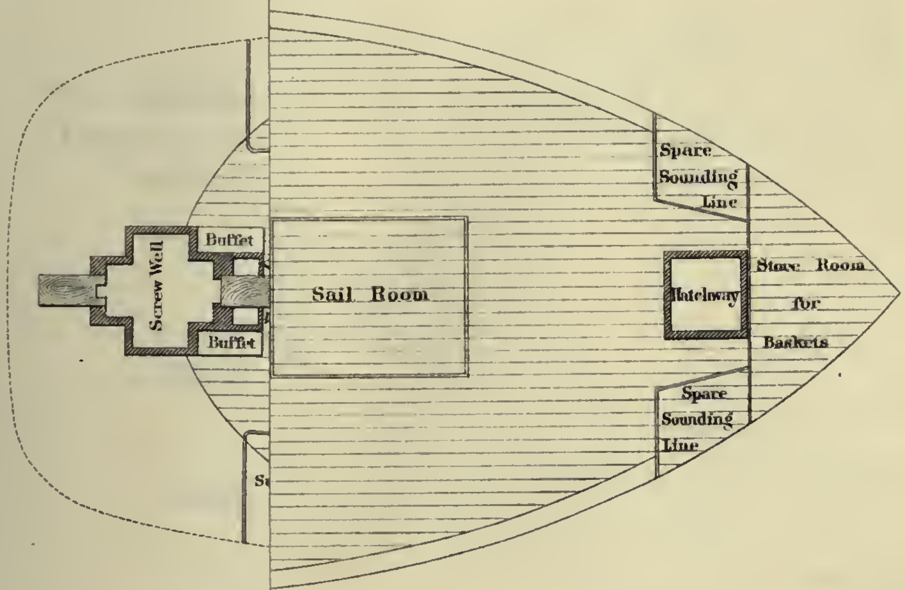
In the extreme forepart of the lower deck, a small storeroom was built for lobster pots and other basket-work, and two small tiers for spare sounding line.

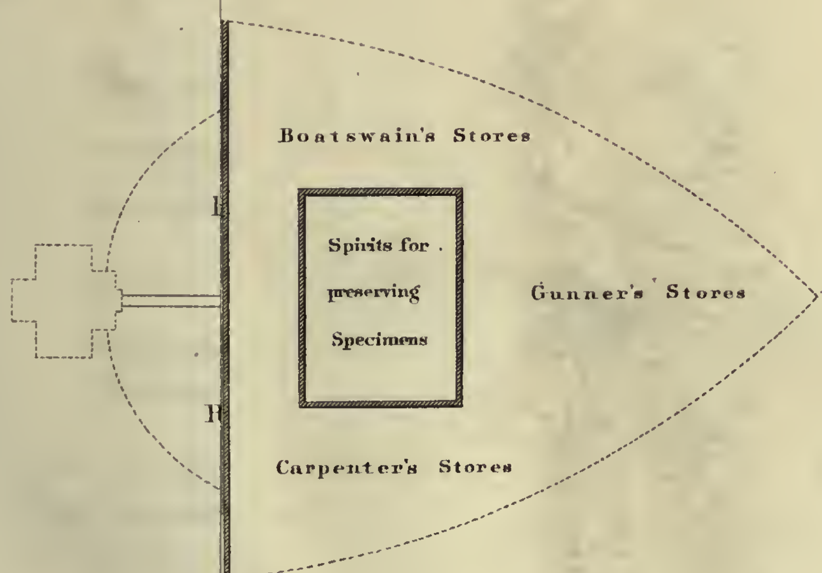
The Hold.

The hold of the ship remained unaltered, except in one particular, for the magazines, being no longer required for powder, were converted, the foremost one into a storeroom for spirits of wine, and the after one into a storeroom for dredging rope. The space formerly devoted to shell being amply sufficient, with the reduced number of guns, to provide accommodation both for powder and shell.

The fitting out of the Challenger was commenced in June 1872, and the ship was commissioned at Sheerness on the 15th November of the same year.

When the provisions and most of the stores had been received on board, the ship was carefully swung, to ascertain the errors of the magnetic instruments in use on board, and on the 7th December she sailed for Portsmouth, from which port it had been arranged that


Screw Well
Buffet
Buffet
Sail Room
Spare Sounding Line
Hatchway
Store Room for Baskets
Spare Sounding Line


Boatswain's Stores
Spirits for preserving Specimens
Gunner's Stores
Carpenter's Stores

the Expedition should finally depart. The ship arrived at Portsmouth on the 11th December, after a very stormy passage, one of the quarter boats being lost during a gale.

The following is a list of the officers and Civilian Staff engaged in the Expedition:—

Naval and Scientific Staff of the Expedition.

Captain,	G. S. Nares.
Director of Civilian Staff,	Professor C. Wyville Thomson.
Members of the Civilian Staff,	J. Y. Buchanan, Chemist. H. N. Moseley, Naturalist. John Murray, Naturalist. R. von Willemoes Suhm, Naturalist. J. J. Wild, Secretary and Artist.
Commander,	J. L. P. Maclear.
Lieutenants,	Pelham Aldrich. A. C. B. Bromley. G. R. Bethell.
Navigating Lieutenant,	T. H. Tizard.
Paymaster,	R. R. A. Richards.
Staff-Surgeon,	Alexander Crosbie.
Surgeon,	George Maclean.
Chief Engineer,	James Ferguson.
Sub-Lieutenants,	Lord G. G. Campbell. H. C. Sloggett. A. F. Balfour. Arthur Channer.
Navigating Sub-Lieutenants,	Arthur Havergal. Herbert Swire.
Assistant Paymaster,	John Hynes.
Engineers,	W. J. J. Spry. A. J. Allen.
Assistant Engineers,	W. A. Howlett. W. J. Abbott.
Boatswain,	Richard Cox.
Carpenter,	F. W. Westford.

The following changes took place during the commission:—

Sub-Lieutenant Sloggett left at Halifax, N.S., and was succeeded by Sub-Lieutenant H. C. Harston.

At Hongkong, in December 1874, Captain Nares and Lieutenant Aldrich left to proceed on the Polar Expedition, and were succeeded by Captain F. T. Thomson and Lieutenant A. Carpenter. Mr. Westford the carpenter left and was succeeded by Mr. Higham.

On the voyage to Tahiti, Dr. R. von Willemoes Suhm died after a short illness from erysipelas, and at Valparaiso Sub-Lieutenants Lord G. G. Campbell and A. F. Balfour left the ship on promotion.

APPENDICES TO CHAPTER I.

APPENDIX A.

Official Correspondence with reference to the Challenger Expedition. Extracted from the Minutes of Council of the Royal Society.

March 21*st*, 1872.

Read the following communication from the Admiralty :—

"ADMIRALTY, 2*nd March* 1872.

"SIR,—In reply to your Letter of the 8th of December 1871 conveying a representation from the President and Council of the Royal Society that advantages of great importance to Science and Navigation would result from equipping an Expedition for the Examination of the Physicial Conditions of the Deep Sea throughout all the Great Oceanic Basins, and for other special objects therein named,—

"2. I am commanded by my Lords Commissioners of the Admiralty to acquaint you, for the information of the President and Council, that they have had the subject under their consideration, and have decided to fit out one of Her Majesty's ships to leave England on a Voyage of Circumnavigation towards the close of the present year, in prosecution of the objects specified in your letter.

"3. I am further desired to inform you that their Lordships will be prepared to receive from the President and Council of the Royal Society any suggestions that they may desire to make on the Scientific Equipment of the Vessel, the Composition of the Civilian Scientific Staff, or any other Scientific matter connected with the Expedition upon which that body may desire to offer their opinion.

"I am, Sir,

"Your obedient Servant,

"THOS. WOLLEY."

"*The Secretary to the Royal Society.*"

Resolved,—That the Letter from the Admiralty be referred for consideration and for report to the Council, to a Committee consisting of the President and Officers, Dr. Carpenter, Dr. Frankland, Dr. Hooker, Professor Huxley, the Hydrographer of the Admiralty, Mr. Gwyn Jeffreys, Mr. Siemens, Sir William Thomson, Dr. Wyville Thomson, Dr. Williamson, and Mr. Alfred R. Wallace, with power to add to their number.

June 20*th*, 1872.

In reference to the arrangements to be made for the Circumnavigatory Expedition, for which H.M.S. Challenger has now been put in commission, the Committee presented the following Report to the Council, viz. :—

"The Committee suggest that the President and Council should direct a Letter to be written to the Secretary of the Admiralty to the following effect :—'That it appears desirable that the Scientific gentlemen who are to accompany the Challenger Expedition should be selected at an early date and their salaries decided on, in order that they may be enabled to make the necessary arrangements for an extended absence from England.

"'The President and Council of the Royal Society therefore recommend as a fit and proper person, to superintend and be at the head of the Civilian Scientific Staff of the Expedition, Wyville Thomson, LL.D., F.R.S., &c., Regius Professor of Natural History in the University of Edinburgh; and that, as Professor Thomson will have to give up his position, with its emoluments, at Edinburgh for the time he is absent, the President and Council are of opinion that a less sum than £1000 per annum cannot properly be offered to him.

"'They propose that the other members of the Staff and their Salaries should be as follows:—

Mr. John James Wild, as Secretary to the Director and Artist,	£400
Mr. John Young Buchanan, M.A. (Glas.), Principal Laboratory Assistant in the University of Edinburgh, as Chemist and Physicist,	200
Mr. Henry Nottidge Moseley, B.A. (Oxon.), Radcliffe Travelling Fellow of Oxford University, as Naturalist,	200
Mr. William Stirling, D.Sc. (Edin.), M.B., Falconer Fellow of the University of Edinburgh, as Naturalist,[1]	200
Mr. John Murray, as Naturalist,	200'

"The Committee further report that Professor Wyville Thomson informed them that he had gone with Admiral Richards to Sheerness to examine the Challenger, and that the arrangements appeared to be satisfactory in every respect."

Resolved,—That the Report of the Circumnavigation Committee be adopted, and that a communication be made to the Admiralty in terms of their recommendation.

November 14th, 1872.

The Council proceeded to consider the Report of the Circumnavigation Committee.

The following is the Letter from the Admiralty to which the Report refers:—

"Admiralty, *August 22nd*, 1872.

"Sir,—With reference to my letter of the 6th instant, and to previous correspondence on the subject of the intended deep-sea exploratory Expedition, I am commanded by My Lords Commissioners of the Admiralty to acquaint you that H.M.S. Challenger will probably be ready to leave this country about the end of November; and their Lordships will be glad to learn what are the precise objects of research which the President and Council of the Royal Society have in view, and in what particular portions of the Ocean such investigations may, in their opinion, be carried out with the greatest advantage to science and the best probability of success.

"2. The object of their Lordships is to frame their instructions to the Officer in command of the Challenger, so far as may be possible, to meet the recommendations of the President and Council of the Royal Society.

"I am, Sir,

"Your obedient Servant,

"Vernon Lushington."

"*W. Sharpey, Esq., M.D., &c.*

"*Secretary of the Royal Society, Burlington House.*"

The Report having been considered, was adopted as follows:—

The Circumnavigation Committee have had before them the Letter from the Admiralty to the Royal Society, dated August 22, 1872, and as the Council were not in Session and the matter was pressing, they have thought it best to treat the letter as having been referred to them by the Council. They beg leave to recommend to the Council that an answer be returned to the Admiralty to the following effect:—

[1] Dr. Stirling resigned his appointment before the departure of the Expedition (see p. 33).

The principal object of the proposed Expedition is understood to be to investigate the physical and biological conditions of the great Ocean basins ; and it is recommended for that purpose to pass down the coast of Portugal and Spain, to cross the Atlantic from Madeira to the West-Indian Islands, to go to Bermuda, thence to the Azores, the Cape Verde Islands, the Coast of South America, and across the South Atlantic to the Cape of Good Hope. Thence by the Marion Islands, the Crozets, and Kerguelen Land, to Australia and New Zealand, going southwards *en route*, opposite the centre of the Indian Ocean, as near as may be with convenience and safety to the southern Ice-barrier. From New Zealand through the Coral Sea and Torres Straits, westward between Lombok and Bali, and thence through the Celebes and Sulu Seas to Manila, then eastward into the Pacific, visiting New Guinea, New Britain, the Solomon Islands ; and afterwards to Japan, where some considerable time might be profitably spent. From Japan the course should be directed across the Pacific to Vancouver Island, then southerly through the eastern trough of the Pacific, and homewards round Cape Horn. This route will give an opportunity of examining many of the principal ocean phenomena, including the Gulf-stream and Equatorial currents; some of the biological conditions of the sea of the Antilles; the fauna of the deep water of the South Atlantic, which is as yet unknown, and the specially interesting fauna of the borders of the Antarctic Sea. Special attention should be paid to the botany and zoology of the Marion Islands, the Crozets, Kerguelen Land, and any new groups of islands which may possibly be met with in the region to the south-east of the Cape of Good Hope. Probably investigations in these latitudes may be difficult; it must be remembered, however, that the marine fauna of these regions is nearly unknown, that it must bear a most interesting relation to the fauna of high northern latitudes, that the region is inaccessible except under such circumstances as the present, and that every addition to our knowledge of it will be of value. For the same reasons the Expedition should, if possible, touch at the Auckland, Campbell, and especially the Macquarie Islands. Particular attention should be paid to the zoology of the sea between New Zealand, Sydney, New Caledonia, and the Fiji and Friendly Islands, as it is probable that the Antarctic fauna may be found there at accessible depths. New Britain and New Ireland are almost unknown, and from their geographical position a special interest attaches to their Zoology, Botany, and Ethnology. The route through this part of the Pacific will give an opportunity of checking and repeating previous observations on the structure of coral-reefs and the growth of coral, and of collecting series of volcanic rocks. The Japan current will also be studied, and the current along the coast of California. The course from Japan to Vancouver Island and thence to Valparaiso will afford an opportunity of determining the physical geography and the distribution of life in these regions, of which at present nothing is known.

I. Physical Observations.

In crossing the great Ocean-basins, observations should be made at stations the positions of which are carefully determined, chosen so far as possible at equal distances, the length of the intervals being of course dependent on circumstances. At each station should be noted the time of the different observations, the state of the weather, the temperature of the surface of the sea, the depth, the bottom temperature determined by the mean of two Miller-Casella thermometers, the specific gravity of the surface and bottom water. The nature of the bottom should be determined by the use of a sounding instrument constructed to bring up samples of the bottom, and also, if possible, by a haul of the dredge. When practicable, the amount and nature of the gases contained in the water, and the amount and nature of the salts and organic matter, should be ascertained. As frequently as possible, especially in the path of currents, serial temperature soundings ought to be taken either with the instrument of Mr. Siemens or with the Miller-Casella thermometer, and in the latter case at intervals of 10, 50, or 100 fathoms, to determine the depth and volume of masses of moving water derived from different sources.

The simple determination of the depth of the ocean at tolerably regular distances throughout the entire voyage is an object of such primary importance that it should be carried out whenever possible, even when circumstances may not admit of dredging, or of anything beyond sounding. The investigation of various problems relating to the past history of the globe, its geography at different geological epochs, and the existing distribution of animals and plants, as well as the nature and causes of oceanic circulation, will be greatly aided by a more accurate knowledge of the contour of the ocean-bed.

Surface-Temperature.—The surface-temperature of the sea, as also the temperature of the air as determined by the dry- and wet-bulb thermometers, should be regularly recorded every two hours during the day and night throughout the voyage.

These records should be reduced to curves, for the purpose of ready comparison: and the following points should be carefully attended to:—

1. In case of a general correspondence between the temperature of the sea and that of the air, it should be noted whether in the diurnal variation of both the sea appears to *follow* the air, or the air the sea.

2. In case of a marked discordance, the condition or conditions of that discordance should be sought in (*a*) the direction and force of the wind, (*b*) the direction and rate of movement of the ocean surface-water, (*c*) the hygrometric state of the atmosphere. When the air is very dry, there is reason to believe that the temperature of the surface of the sea is reduced by excessive evaporation, and that it may be below that of the subsurface stratum a few fathoms deep. It will be desirable, therefore, that every opportunity should be taken of comparing the temperature at the surface with the temperature of the subsurface stratum,—say at every 5 fathoms down to 20 fathoms.

Temperature Soundings.—The determination of the temperature, not merely of the bottom of the ocean, over a wide geographical range, but of its various intermediate strata, is one of the most important objects of the Expedition; and should, therefore, be systematically prosecuted on a method which should secure comparable results. The following suggestions, based on the experience already obtained in the North Atlantic, are made for the sake of indicating the manner in which time and labour may be economised in making serial soundings, in case of the employment of the Miller-Casella thermometer. They will be specially applicable to the area in which the work of the Expedition will commence; but the thermal conditions of other areas may prove so different, that the method may need considerable modification.

The following strata appear to be definitely distinguishable in the North Atlantic:—(*a*) a "superficial stratum," of which the temperature varies with that of the atmosphere, and with the amount of insolation it receives. The thickness of the stratum does not seem to be generally much above 100 fathoms; and the greatest amount of heating shows itself in the uppermost 50 fathoms. (*b*) Beneath this is an "upper stratum," the temperature of which slowly diminishes as the depth increases down to several hundred fathoms; the temperature of this stratum in high latitudes is considerably *above* the normal of the latitude; but in the intertropical region it seems to be considerably *below* the normal. (*c*) Below this is a stratum in which the rate of diminution of temperature with increasing depth is rapid, often amounting to 10° or more in 200 fathoms. (*d*) The whole of the deeper part of the North Atlantic, below 1000 fathoms, is believed to be occupied by water not many degrees above 32°. With regard to this "glacial stratum," it is exceedingly important that its depth and temperature should be carefully determined.

It will probably be found sufficient in the first instance to take, with each deep *bottom* sounding, *serial* soundings at every 250 fathoms, down to 1250 fathoms; and then to fill up the intervals in as much detail as may seem desirable. Thus, where the fall is very small between one 250 and the next, or between any one and the bottom, no intermediate observation will be needed: but where an abrupt difference of several degrees shows itself, it should be ascertained by intermediate observations whether this difference is sudden or gradual.

The instrument devised by Mr. Siemens for the determination of submarine temperatures is peculiarly adapted for serial measurements, as it does not require to be hauled up for each reading. It should, however, be used in conjunction with the Miller-Casella thermometer, so as to ascertain how far the two instruments are comparable: and this point having been settled, Mr. Siemens' instrument should be used in all serial soundings; and frequent readings should be taken with it, both in descending and ascending.

A question raised by the observations of the U.S. Coast Surveyors in the Florida Channel, and by those of our own surveyors in the China Sea, is the extent to which the colder and therefore heavier water may run *up* *hill* on the sides of declivities. The position of the Azores will probably be found very suitable for observations of this kind. Temperature soundings should be taken at various depths, especially on their north and south slopes, and in the channels between the islands; and the temperatures at various depths should be compared with those of corresponding depths in the open ocean.

It is in the Southern Oceans that the study of ocean temperatures at different depths is expected to afford the most important results; and it should there be systematically prosecuted. The great Ice-barrier should be approached as nearly as may be deemed suitable, in a meridian nearly corresponding to the centre of one of the three great Southern Oceans,—say to the south of Kerguelen's Land; and a line of soundings should be carried north and south as nearly as may be.

In connection with the limitation of the area and depth of the reef-building corals, it will be very important to ascertain the rate of reduction of temperature from the surface downwards in the region of their greatest activity; as it has been suggested that the limitation of living reef-builders to 20 fathoms may be a thermal one.

Wherever any anomaly of temperature presents itself, the condition of such anomaly should, if possible, be ascertained. Thus there is reason to believe that the cause of the temperature of the surface water being below that of the subsurface stratum, in the neighbourhood of melting ice, is that the water cooled by the ice, by admixture with the water derived from its liquefaction, is also rendered less salt, and therefore floats upon the warmer and salter water beneath. Here the determination of specific gravities will afford the clue. In other instances a warm *current* may be found beneath a colder stratum; and the use of the "current drag" might show its direction and rate. In other cases, again, it may happen that a warm submarine spring is discharging itself,—as is known to occur near the island of Ascension. In such a case it would be desirable to trace it as nearly as may be to its source, and to ascertain its composition.

Movements of the Ocean.—The determination of *Surface* Currents will, of course, be a part of the regular routine, but it is particularly desirable that accurate observations should be made along the line of sounding in the Southern Ocean, as to the existence of what has been described as a general "Southerly set" of oceanic water, the rate of which is probably very slow. It is also very important that endeavours should be made to test by the "current drag," whether any *underflow* can be shown to exist from either Polar basin towards the Equatorial region. A suitable locality for such experiments in the North Atlantic would probably be the neighbourhood of the Azores, which are in the line of the glacial flow from the North Polar Channel. The guide to the depth at which the current drag should be suspended will be furnished by the thermometer, especially where there is any abrupt transition between one stratum and another. It would be desirable that not only the rate and direction of surface drift, but those of the subsurface stratum at (say) 200 fathoms' depth, should be determined at the same time with those of the deep stratum.

Tidal Observations.—No opportunity of making tidal observations should be lost. Careful observations made by aid of a properly placed tide-pole in any part of the world will be valuable. Accurate measurements of the sea level once every hour (best every *lunar* hour, *i.e.*, at intervals of $1^h\ 2^m$ of solar time) for a lunar fortnight (the time of course being kept) would be very valuable information.

Bench Marks.—In reference to the interesting question of the elevation or subsidence of land, it will be very desirable, when sufficient tidal observations can be obtained to settle the mean level of the sea, that permanent bench marks should be established, recording the date and height above such mean level. Even recording the height to which the tide rose on a certain day and time would render a comparison possible in future years.

A good determination of the mean sea level by the simple operation of taking means may be made, in less than two days, with even a moderate number of observations *properly distributed so as to subdivide both solar and lunar days into not less than three equal parts.* Suppose, for example, we choose 8-hour intervals, both solar and lunar. Take a lunar day at $24^h\ 48^m$ solar time, which is near enough, and is convenient for division, and choosing any convenient hour for commencement, let the height of the water be observed at the following times, reckoned from the commencement:—

h.	m.	h.	m.	h.	m.
0	0	8	0	16	0
8	16	16	16	24	16
16	32	24	32	32	32

The observations may be regarded as forming three groups of three each, the members of each group being separated by 8 hours solar or lunar, while one group is separated from the next by 8 hours lunar or solar. In the mean of the nine results the lunar and solar semi-diurnal and diurnal inequalities are all four eliminated.

Nine is the smallest number of observations which can form a complete series. If the solar day be divided into m and the lunar into n equal parts, where m and n must both be greater than 2, there will be mn observations in the series; and if either m or n be a multiple of 3, or of a larger number, the whole series may be divided into two or more series having no observation in common, and each complete in itself. The accuracy of the method can thus be tested, by comparing the means obtained from the separate sub-series of which the whole is made up.

Should the ship's stay not permit of the employment of the above method a very fair determination may be made in less than a day, by taking the mean of n observations taken at intervals of the nth part of a lunar day, n being greater than 2. Thus if $n=3$, these observations require a total interval of time amounting to only $16^h\,32^m$. The theoretical error of this method is very small, and the result thus obtained is decidedly to be preferred to the mere mean of the heights at high and low water.

The mean level thus determined is subject to meteorological influences, and it would be desirable, should there be an opportunity, to redetermine it at the same place at a different time of year. Should a regular series of observations for a fortnight be instituted, it would be superfluous to make an independent determination of the mean sea level by either of the above methods at the same time.

Besides taking observations on the ordinary waves of the sea when at all remarkable, the Scientific Staff should carefully note the circumstances of any waves attributable to earthquakes.

Specific Gravity.—The specific gravity of the surface and bottom water should be carefully compared, whenever soundings are taken; and whenever serial soundings are taken, the specific gravity at intermediate depths should be ascertained. Every determination of specific gravity should be made with careful attention to temperature; and the requisite correction should be applied from the best Table for its reduction to the uniform standard of 60°. It would be well to check the most important results by the balance; samples being preserved for examination in harbour. Wherever the temperature of the surface is high,—especially, of course, in the Intertropical region,—samples should be collected at every 10 fathoms, for the purpose of ascertaining whether any effect is produced upon the specific gravity of the upper stratum by evaporation, and how far down this effect extends.

Transparency of the Water.—Observations for transparency should be taken at various depths and under different conditions by means of Mr. Siemens' photographic apparatus. As, however, the action of this depends upon the more refrangible rays, and the absorption of these and of the more luminous rays might be different, and that in a manner varying with circumstances, such as the presence or absence of suspended matter, &c.; the transparency of the sea should also be tested by lowering a white plate or large white tile to various measured depths, and noting the change of intensity and colour as it descends, and the depth at which it ceases to be visible. The state of the sky at the time should be mentioned, and the altitude of the sun, if shining, roughly measured, or if not shining, deduced from the time of day.

Relation of Barometric Pressure to Latitude.—In Poggendorff's Annalen, vol. xxvi., 1832, p. 395, is a remarkable paper by Professor G. F. Schouw on the relation between the height of the barometer at the level of the sea, and the latitude of the place of observation. At page 434 is a rough statement of the results of his researches, the heights being given in Paris lines.

Lat.	Barometer mercury at 0° C.
0°	337·0
10	337·5
20	338·5
30	339·0
40	338·0
50	337·0
60	335·5
65	333·0
70	334·0
75	335·5

The Expedition might contribute to the examination of this law, not only by giving especial attention to the barometer observations at about the critical latitudes 0°, 30°, 65°, 70°, but also by comparing any barometers with which long series of observations have been made at any port they may touch at, with the ship's standard barometer.

It appears probable from Schouw's paper, that certain meridians are meridians of high pressure and others of low pressure.

For comparison of barometer and measures of heights, it appears that the aneroid barometer constructed by Goldschmid of Zürich would be very useful.

It is very desirable that the state of the barometer and thermometer should be read at least every two hours.

II. Chemical Observations.

1. Samples of sea water should be collected for chemical analysis at the surface and at various depths, and in various conditions. Each sample should be placed in a Winchester quart glass-stoppered bottle, the stopper being tied down with tape and sealed in such a manner that the contents cannot be tampered with.

2. Portions of the same samples should be, immediately after their collection, boiled *in vacuo*, the gases collected, their volume determined as accurately as may be, and a portion, not less than one cubic inch, hermetically sealed in a glass tube, to be sent home at any time for complete analysis.

3. Frequent samples of sea water taken at the surface, and others taken beneath as opportunity offers, should have determinations of chlorine made upon them at once, or as soon as convenient.

This operation could easily be carried on in any but very heavy weather. On the other hand, it is not thought that any trustworthy analyses of gases could be made on board ship, unless in harbour or in the calmest weather.

4. Such samples of the sea bottom as are brought up should be carefully dried and preserved for examination and analysis.

5. The gas contained in the swimming-bladders of fishes caught near the surface and at different depths should be preserved for analysis. In each case the species, sex, and size, and especially the depth at which the fish was caught, should be stated.

III. Botanical Observations.

The duties of a botanist in travelling are twofold, and in the case of the voyage of circumnavigation about to be undertaken by H.M.S. Challenger they are of equal importance.

Of these, the one refers to forming complete collections of the plants of all interesting localities, and especially of the individual islands of oceanic groups.

The other, to making observations upon life, history, and structure in the case of plants where special knowledge is concerned.

In the first of these the botanist must necessarily be largely helped by the assistance to be obtained on board ship from the officers and crew, working under his guidance and close supervision. When time and opportunity are wanting for making complete collections, preference should be given to the phanerogamic vegetation.

In the second he will have to depend upon his own resources, and will therefore require that the mere process of collection does not make too great demands upon his time, although in itself exceedingly important, and by no means to be neglected.

The general directions for travellers, printed in the Admiralty Manual of Scientific Inquiry, will of course be kept in view.

Especial stress must, however, be laid upon the necessity of obtaining information about the vegetation of oceanic islands. These are, in many cases, the last positions held by floras of great antiquity; and, as in the case of St. Helena, they are liable to speedily become exterminated, and therefore to pass into irremediable oblivion when the islands become occupied.

Of many that lie not far from the usual tracks of ships, absolutely nothing is known, whilst of the flora of a vast majority we possess most imperfect materials. The following are especially worth exploring; and to the list is added an indication of the least explored coast lines of the great continents. As far as possible complete dried collections should be made, not only of each group, but of each islet of the group; for it is usually the case that the floras of contiguous oceanic islets are wonderfully different. Of those in italics the vegetation is absolutely unknown, or all but so.

1. Atlantic Ocean. Cape Verde Islands, Tristan da Cunha, *Fernando Noronha*, *Trinidad*, and *Martin Vaz* (off the Brazil coast), *Diego Ramirez*, S. Georgia. The African coast between Morocco and Senegal, the Gaboon, and Damara Land offer the most novel fields. On the American coast, Cayenne, Bahia to Cape Frio, Patagonia.

2. West Indies. The Bahamas and St. Domingo and the Antilles have been very imperfectly explored, except Dominica, Trinidad, and Martinique. On the mainland, Honduras, Nicaragua, and the coast region of Mexico, the Mosquito shores and Guatemala offer rich fields for botanical research.

3. Indian Ocean. The Seychelles, *Amirantes*, Madagascar, Bourbon, *Socotra*, St. Paul's, and Amsterdam Islands, *Prince Edward* and *Marion* and *Crozet* groups. Of the E. African coast to the north of Natal no part is well explored, and the greater part is utterly unknown botanically.

4. Pacific Ocean. 1. N. Temperate. Collections are wanted from N. Japan and the Kuriles and Aleutian Islands. 2. Tropical. Considerable collections have been made only in the Sandwich Islands, Fiji Islands, Tahiti, and New Caledonia; from all of which more are much wanted. The Marquesas, New Hebrides, *Marshall's*, Solomon's, and *Caroline's*, together with all the smaller groups, are still less known. Of the American Continent, the Californian Peninsula, Mexico, and the whole coast from Lima to Valparaiso, are but imperfectly known. Of the small islands off the coast, Juan Fernandez and the Galapagos alone have been partially botanized. 3. S. Temperate. Juan Fernandez, *Masafuera*, St. Felix, and St. Ambrose, *Pitcairn*, *Bounty*, *Antipodes*, *Emerald*, *Macquarie* Islands.

5. Indian Archipelago. Java alone is explored, and the Philippines very partially; collections are especially wanted from all the islands east of Java to the Louisiade and Solomon Archipelagos, especially Lombok and New Guinea. Siam, Cochin China, and the whole Chinese sea-board want exploration.

6. Australia. All the tropical coasts are very partially explored.

Photographs or careful drawings of tropical vegetation often convey interesting information, and should contain some reference to a scale of dimensions.

An inquiry of much importance, for which the present Expedition affords a favourable opportunity, is that into the vitality of seeds exposed to the action of sea water.

Observations should especially be made on the fruits and seeds of those plants which have become widely distributed throughout the tropical regions of the world, apparently without the intervention of man; but further observations on other plants of different natural orders may be of great value with reference to questions of geographical distribution.

The following instructions have been drawn up for the botanical collectors as to objects of special attention at particular places :—

Porto Rico.—In collecting, distinguish the plants of the Savannahs from those of the mountains, which, if possible, should be ascended. The palms and tree-ferns are quite unknown; marine algæ also are wanted.

Cape Verde Islands.—Make for the highest peaks, where the vegetation is peculiar and analogous to that of Madeira and the Canaries.

Fernando Noronha.—Land if possible. Very remarkable plants are said to occur, different from those of Brazil.

Trinidad.—A complete collection is required. A tree-fern exists, but the species is unknown.

Prince Edward's Island and Crozets.—Two spots more interesting for the exploration of their vegetation do not exist upon the face of the globe. Every effort should be made to make a complete collection.

Kerguelen Island.—A thorough exploration should be made, and the cryptogamic plants and algæ diligently collected. The Antarctic Expedition was only there in midwinter; flowering specimens of *Pringlea* are wanted.

Auckland and Campbell Islands.—The floras should be well explored.

South Pacific and Indian Oceans.—Attend to general instructions, more especially as regards palms and large monocotyledons generally. Marine algæ are said to be scarce, and should be looked for all the more diligently. In the North Pacific, south temperate algæ are said to prevail.

Aleutian Islands.—Collections are particularly wanted.

Every effort should be made to land on islands *between Lat.* 30° N. *and* 30° S. along the marked track (between Vancouver Island and Valparaiso), so as to connect the vegetation of the American continent with the traces of it that exist in the Sandwich Islands.

Straits of Magellan.—Cryptogams are abundant, but very partially explored.

The following additional notes have been drawn up for the more especial guidance of the botanists of the circumnavigation :—

Phanerogams.—1. Fleshy parasitic plants (*Balanophora*, *Rafflesia*, &c.) are little suitable for dissection and examination unless preserved in spirit; and the same remark applies to fleshy flowers and inflorescences generally. Dried specimens, however, are not without their value, and should always be obtained as well.

2. The stems of scandent and climbing plants are often very anomalous in their structure. Short portions of such stems should be collected when the cross section is in any way remarkable, with the foliage, flowers, and fruit when possible. A few leaves and flowers should also be tied up between two pieces of card, and attached at once to the specimens of the stem, so as to ensure future identification.

3. Attention should be given to the esculent and medicinal substances used in various places. Specimens should be obtained, and whenever possible they should be accompanied by complete specimens of the plants from which such substances are obtained.

4. The common weeds and ruderal plants growing about ports or landing-places should not be overlooked, and, as far as practicable, trustworthy information should be recorded as to the date and circumstances of the introduction of foreign species.

5. The distribution of marine phanerogamic plants (*Zostera*, *Cymodocea*, &c.) should also be noted, and specimens preserved with their latitude and longitude. Their buds and parts of fructification should be put into spirit.

6. The flowers of *Loranthaceæ* and *Santalaceæ* should be preserved in spirit, and also dried to exhibit general habit.

7. The inflorescence of Aroids should be dissected when fresh, or put into spirit. Note the placentation and position of the ovules.

8. Devote especial attention to the study of Screw-Pines and Palms when opportunity arises, even if necessary to the neglect of other things. The general habit of the plants should be sketched; the male and female infloresence should be preserved, and also the fruit; the foliage should be dried and folded, and packed in boxes. Many fleshy vegetable objects may be "killed" by a longer or shorter immersion in spirit. They then dry up without decaying, and form useful specimens.

9. With respect to palms, further note the height, position of the spadix, and preponderance of the sexes in both monœcious and diœcious species, also form and dimensions of leaves.

10. Surface driftings should be examined, and any seeds or fragments of land plants carefully noted when determinable, with direction of currents and latitude and longitude.

11. Facts are also required as to the part played by icebergs in plant distribution. If any opportunity occurs for their examination, it would be desirable to preserve and note any vegetable material which might be found upon their surface; also to examine any rock fragments for lichens.

12. *Ferns.*—Ferns should always, when possible, be obtained with fructification. In the case of tree-ferns, our knowledge of which, from the imperfection of material for description, is very defective, a portion of the stem sufficient to illustrate its structure should be obtained, with notes of its height; a fragment of a frond (between pieces of card) and the base of a stipes should be tied to the specimen of the stem; also a note as to whether the adventitious roots were living or dead.

The number of fronds should be counted, their dimensions taken, and the basal scales carefully preserved.

Note if tree-ferns are ever attacked by insects or fungi, and whether they form the food of any class of animals.

13. *Mosses, &c.*—Many mosses are aquatic. In the case of diœcious species of mosses, plants of both sexes should be, when possible, secured.

14. Aquatic species of *Ricciaceæ* should be looked for. Minute *Jungermanniaceæ* are found on the foliage of other plants.

15. *Podostemaceæ* are found in rocky running streams in hot countries. They have a remarkable superficial resemblance to Hepaticæ. Except at the flowering season they are altogether submerged. Specimens should be preserved in spirit as well as dried.

16. *Fungi.*—Take notes of all fleshy fungi, especially as regards colour; the spores should be allowed to fall on paper, and the colour of these noted also. The fleshy species may sometimes be advantageously immersed in spirit before preparing for the herbarium.

17. Examine the fungi which grow on ants' nests, taking care to get perfect as well as imperfect states, and to secure, if possible, specimens which have not burst their volva.

18. Look out for luminous species, and ascertain whether they are luminous in themselves, or whether the luminosity depends on decomposition.

19. Secure specimens of all esculent or medicinal fungi which are sold in bazaars, noting, if possible, the vernacular name.

20. Note any species of fleshy fungi which arise like the *Pietra Fungaja* from a mass of earth impregnated with mycelium, or from a globose resting-mass.

21. Attend especially to any fungi which attack crops, whether cereal or otherwise; and particularly gather specimens of vine mildew and potato mildew, should they be met with. Even common wheat mildew, smut, &c., should be preserved.

22. In every case note date of collection, soil, and other circumstances relative to particular specimens.

23. Look after those fungi which attack the larvæ of insects.

24. In the case of the *Myxogastres*, sketches should be made on the spot of their general form, with details of microscopic appearance. It would be worth while attempting to preserve specimens for future microscopic examination by means of osmic acid.

25. *Algæ.*—Marine algæ may be found between tide-marks attached to rocks and stones, or rooting in sand, &c.; those in deeper water are got by dredging, and many are cast up after storms; small kinds grow on the larger, and some being like fleshy crusts on stones, shells, &c., must be pared off by means of a knife.

The more delicate kinds, after gentle washing, may be floated in a vessel of fresh water, upon thick and smooth writing or drawing paper; then gently lift out paper and plant together, allow some time to drip; then place on the sea-weed clean linen or cotton cloth, and on it a sheet of absorbent paper, and submit to moderate pressure—many adhere to paper but not to cloth; then change the cloth and absorbent paper till the specimens are dry. Large coarser kinds may be dried in the same way as land plants; or are to be spread out in the *shade*, taking care to prevent contact of rain or fresh water of any kind; when sufficiently dry, tie them loosely in any kind of wrapping paper; those preserved in this rough way may be expanded and floated out in water at any time afterwards. A few specimens of each of the more delicate algæ ought to be dried on mica or glass. A note of date and locality ought to be attached to every species.

Delicate slimy algæ are best prepared by floating out on smooth-surfaced paper (known as "sketching paper"), then allowed to drip and dry by simple exposure to currents of air, without pressure.

26. Very little information exists regarding the range of depth of marine plants. It will be very desirable that observations should be made upon this subject, as opportunity from time to time presents itself.

Professor Dickie remarks, and the caution should be borne in mind:—"When the dredge ceases to scrape the bottom, it becomes in its progress to the surface much the same as a towing-net, capturing bodies which are being carried along by currents, and therefore great caution is necessary in reference to any marine plants found in it. Sea-weeds are among the most common of all bodies carried by currents near the surface or at various depths below, and from their nature are very likely to be entangled and brought up."

27. Carefully note and preserve algæ brought up in dredge in moderate depth, under 100 fathoms or deeper. Preserve specimens *attached* to shells, corals, &c., which would indicate their being actually *in situ*, and not caught by dredge as it comes up.

28. Examine mud brought up by dredge from different depths for living diatoms; examine also for the same purpose the stomachs of *Salpæ* and other marine animals.

29. Note algæ on ships, &c., with the submerged parts in a foul condition; also preserve scrapings of coloured crusts or slimy matter, green, brown, &c.

30. Observe algæ, *floating*, collect specimens, noting latitude and longitude, currents, &c.

31. Examine loose floating objects, drift-wood, &c., for algæ. If no prominent species presents itself, preserve scrapings of any coloured crusts. Note as above.

32. It might be useful to have a few moderate-sized pieces of wood, oak, &c., quite clean at first, attached to some part of the vessel under water to be examined, say, monthly. The larger or shorter prominent algæ should be kept and noted, and crusts on such examined and preserved, with notes of the vessel's course.

33. Various instances have been mentioned by travellers of the coloration of the sea by minute algæ, as in the Straits of Malacca by Harvey; any case of this kind would be worth especial attention.

34. The calcareous algæ (*Melobesia*, &c.) are comparatively little known, and are apt to be overlooked.

35. Freshwater algæ should be collected as occasion presents. Professor Dickie states that they may be either dried like the marine kinds, or preserved in a fluid composed of 3 parts alcohol, 2 parts water, 1 part glycerine, well mixed.

36. Cases are recorded of the presence of algæ in hot springs. If such are met with, the temperature should be noted and specimens preserved.

IV. Zoological Observations.

As the Scientific Director of the Expedition is an accomplished zoologist, and has already had much experience in marine exploration, it will suffice to offer a few suggestions under this head.

The quadrant-like zone of the Pacific, which separates the northern and eastern boundaries of the Polynesian Archipelago (using "Polynesia" in its broadest sense as inclusive of "Micronesia") from the coasts of N. Asia and America, is as little explored from the point of view of the physical geographer as from that of the biologist. It would be a matter of great importance to examine the depth, and the nature of the deep-sea fauna, of this zone by taking a line of soundings and dredgings in its northern half (say between Japan and Vancouver) and in its eastern half (say between Vancouver and Valparaiso). If practicable, it would further be very desirable to explore the littoral fauna of Waihou or Easter Island, and Sala-y-Gomez, with the view of comparing it critically with that of the west coast of South America.

If H.M.S. Challenger passes through Torres Straits, it will be very desirable to examine the littoral fauna of the Papuan shore of the straits in order to compare it with that of the Australian shore. The late Professor Jukes, in his Voyage of the Fly many years ago, directed attention to this point and to its theoretical bearings.

The Hydrographic examination of "Wallace's line" in the Malay Archipelago, and of the littoral faunas on the opposite sides of that line, is of great importance, considering the significance of that line as a boundary between two Distributional provinces. And additional interest has been given to the exploration of this region by Captain Chimmo's recently obtained sounding of 2800 fathoms in the Celebes Sea, the mud brought up being almost devoid of calcareous organisms, but containing abundant spicula of sponges and *Radiolaria.*

The light from any self-luminous objects met with should be examined with a prism as to its composition. The colours of animals captured should also be examined with a prism, or by aid of the microscopic spectroscope.

V. Concluding Observations.

Attention should be paid to the Geology of districts which have not hitherto been examined, and collections of minerals, rocks and fossils should be made. Detailed suggestions as to the duties of the geologist accompanying the Expedition are unnecessary; but it seems desirable that, at all shores visited, evidence of recent elevation or subsidence of land should be sought for, and the exact nature of these evidences carefully recorded.

Every opportunity should be taken of obtaining photographs of native races to one scale; and of making such observations as are practicable with regard to their physical characteristics, language, habits, implements, and antiquities. It would be advisable that specimens of hair of unmixed races should in all cases be obtained.

Each station should have a special number associated with it in the regular journal of the day's proceedings, and that number should be noted prominently on everything connected with that station; so that in case of labels being lost or becoming indistinct, or other references failing, the conditions of the dredging or other observations may at once be forthcoming on reference to the number in the journal. All specimens procured should be carefully preserved in spirit or otherwise, and packed in cases with the contents noted; to be dealt with in the way which seems most likely to conduce to the rapid and accurate development of the scientific results of the Expedition.

A diary, noticing the general proceedings and results of each day, should be kept by the Scientific Director, with the assistance of his Secretary; and each of the members of the Scientific Staff should be provided with a note-book in which to enter from day to day his observations and proceedings; and he should submit this diary at certain intervals to the Scientific Director, who should then abstract the results, and incorporate them, along with such additional data as may be supplied by the officers of the ship, in general scientific reports to be sent home to the Hydrographer at every available opportunity.

The Scientific Staff should be provided with an adequate set of books of reference, especially those bearing on perishable objects.

Resolved,—That the Report of the Circumnavigation Committee, now adopted by the Council, be transmitted by the Secretary to the Secretary of the Admiralty, with the following Letter:—

In reply to your Letter of the 22nd of August, referring to the Exploratory Voyage of H.M.S. Challenger, and desiring to learn, for the information of the Lords Commissioners of the Admiralty, what are the precise objects of research which the Royal Society have in view, and in what particular portions of the Ocean such investigations may, in their opinion, be carried out with the greatest advantage to science and the best probability of success, I am directed to acquaint you that the matter was carefully considered by a Committee, consisting of the President and Officers, with Dr. Allman, Dr. Carpenter, Dr. Frankland, Dr. Hooker, Professor Huxley, the Hydrographer of the Admiralty, Mr. Gwyn Jeffreys, Mr. Siemens, Sir William Thomson, Dr. Wyville Thomson, Mr. Wallace, and Dr. Williamson. That Committee has presented a Report which has been approved by the President and Council, by whose direction I herewith transmit it to you, to be communicated to the Lords Commissioners of the Admiralty in answer to their Lordships' inquiry.

November 30th, 1872.

Read the following Letter:—

"ADMIRALTY, *27th November* 1872.

"SIR,—I am commanded by the Lords Commissioners of the Admiralty to thank you for your communication of the 22nd instant, in regard to the objects of research which the Royal Society have in view with reference to the intended voyage of H.M.S. Challenger, and to acquaint you that they are desirous of affording to the President and Council of the Royal Society, as well as the Members of the Circumnavigation Committee, an opportunity of inspecting the ship, and the arrangements made with a view to her equipment for the service she is intended to perform.

"2. My Lords therefore invite those gentlemen to proceed to Sheerness on the 6th proximo for the purpose of visiting the Challenger; and a saloon carriage will be ordered to be in readiness to convey them to that port by the 10.30 A.M. train from Victoria Station.

"3. The visitors will be able to return by the 5.10 P.M. train from Sheerness, and free railway passes will be provided for them both ways. They will also be met by their Lordships' Hydrographer on the occasion.

"4. I am to request you will inform me, as soon as may be convenient, of the number of the gentlemen who will avail themselves of their Lordships' invitation, in order that the proper number of tickets may be procured.

"I am, Sir,

"Your obedient Servant,

"ROBERT HALL."

"*The Secretary of the Royal Society.*"

Before the Expedition left England, Dr. William Stirling resigned his appointment as Naturalist; and Dr. Rudolph von Willemoes Suhm, Privat-Docent in Zoology in the University of Munich, was appointed by the Admiralty in his place, on the recommendation of the Council of the Royal Society.

APPENDIX B.

Hydrographic Instructions to Captain G. S. Nares, H.M.S. Challenger.

The Lords Commissioners of the Admiralty having caused H.M.S. Challenger to be specially equipped for a voyage of scientific research, and having appointed you to the command, it becomes my duty, under their Lordship's direction, to furnish you with the following hydrographical instructions for your guidance in the conduct of the expedition.

You are aware that this voyage has been undertaken principally upon the recommendation of the President and Council of the Royal Society, and that the main objects of it, and the general principles on which they should be carried out, have been set forth in a memorandum prepared by a committee of that body at the request of the Admiralty.

On the recommendation of the President and Council of the Royal Society, a staff of scientific gentlemen, presided over by Professor Wyville Thomson, F.R.S., of the University of Edinburgh, has been attached to the expedition, and it is their Lordship's wish and desire that throughout the voyage, in all matters connected with its scientific conduct, you will consider Professor Thomson as your colleague; that in all these matters you will observe such consideration in respect to his wishes and suggestions as may be consistent with a due regard to the orders under which you are acting, and to the comfort, health, discipline, and efficiency of your crew; and, moreover, that those friendly relations and unreserved communications may be maintained between you which will tend so materially to the success of an expedition from which so many important results are looked for.

The objects of the expedition are manifold; some of them will come under the entire supervision of Professor Thomson and his staff, others will depend for their success on the joint co-operation of the naval and civil elements, while many will demand the undivided attention of yourself and your officers; it is not, however, too much to say that upon the harmonious working and hearty co-operation of all must depend the result of the expedition as a whole.

In as far as the memorandum of the Royal Society deals with questions hydrographical, or of a kindred nature, you will consider it as supplied for your guidance, but manifestly in a voyage of this extent and character there are many questions practical and technical which require to be dealt with in greater detail.

The main object of the voyage is to investigate the physical conditions of the deep sea throughout the three great ocean basins, that is, to ascertain their depth, temperature, circulation, &c., to examine the physical and chemical characters of their deposits, and to determine the distribution of organic life throughout the areas traversed, at the surface, at intermediate depths, and especially at the deep ocean bottoms.

As secondary, but by no means unimportant objects, are the hydrographical examination of all the unknown or partially explored regions which you may visit, a diligent search for all doubtful dangers which may be in or near your track, with a view to expunging them from the charts or definitely determining their positions, a careful series of magnetical and meteorological data, and the observation and record generally of all those oceanic and atmospherical phenomena which, when faithfully recorded, afford the means of compiling practical information of the greatest importance to seamen. Your own experience as the commander of a surveying ship, and the general rules which have been issued from time to time by the Hydrographical Department for the guidance of Admiralty Surveyors,—copies of which are supplied to you,—obviate the necessity of entering into any detailed instructions on this head, and I will only observe that on all the coasts along which you may pass, and at all the ports which you may visit, I shall hope to receive from you such surveys and such complete hydrographical information as circumstances and the time at your disposal may enable you to accomplish.

If any one of the various objects of the expedition is more important than another, it may be said to be the accurate determination of the depth of the ocean, for on this must depend many other problems of deep scientific interest.

If the bottom is reached by the sounding line, late experience has shown that it can be examined by the dredge even at very great depths; thus the existence and distribution of organic life is ascertained, as well as the temperature, specific gravity, and chemical condition of the sea from the surface to the bottom. With this view you have been abundantly supplied with all the instruments and apparatus which modern science and practical experience have been able to suggest and devise, and, with the exception of a few beaten tracks in the Atlantic and other isolated lines through the Indian Ocean, you have a wide field and virgin ground before you.

Independently of the great scientific interest which attaches to these experiments, it is to be remembered that the rapidly progressing establishment of electric communication between all parts of the earth renders it most important that the accurate depths of the ocean and the character and temperature of its bed should be known. You are therefore furnished with a series of charts on which are shown the spots where soundings are most required, and which, wherever they lie within or near to your course, you will endeavour to obtain. On these charts are also shown the existing lines of submarine cables, in order that you may be able to avoid them in your dredging operations, and as their positions are not determined with critical accuracy, a wide margin should be allowed while working in their locality.

In regard to magnetical observations, you are supplied with a complete suite of instruments both for observations on shore and at sea, and the most clear and minute instructions have been drawn up by Captain Evans, the chief of the Magnetical Department, for their use. Several of your officers have likewise undergone a course of instruction at the Hydrographical Department and at Kew Observatory, and I will say no more than urge upon you the great importance of a complete and careful record of such observations throughout the whole voyage, for rarely if ever has so favourable an opportunity presented itself as the present.

Your attention is also drawn to the subject of the measurement of waves, which no doubt you will have many opportunities of observing, especially in passing from the Cape of Good Hope to the southward, and printed instructions prepared by Mr. Froude on this subject are forwarded to you, and they have been supplemented by a paper of Professor Stokes. These documents, together with the magnetical instructions, which I have also caused to be printed should be distributed among your officers.

The phenomena of the tides will no doubt receive your special attention, and I would desire particularly to refer you to that part of the Royal Society's memorandum which treats on the question of permanent bench marks, to denote any changes which may be going on in the elevation or subsidence of the land, and especially on the eastern coast of Australia, which is generally believed to be rising. Full particulars should be noted, so that these bench marks, which should be cut deep into the rock, and metal plates affixed, may be identified in future years.

The general route which it is proposed the ship should follow is shown on a chart of the world which you are provided with, and although it is possible that it may be found necessary to deviate in some degree from the course there laid down, and that you may not be able to adhere strictly to the dates assigned in these instructions, yet they are to be observed as far as circumstances will admit, and there must be no departure from the general programme without the special sanction of their Lordships.

Leaving England at this season of the year, you should endeavour to get south of Cape Finisterre with as little delay as possible. You will then carry a line of soundings from the Cape, between the depths of 140 and 1000 fathoms, to Lisbon, and especially between the parallels of 40° and 38°, where, according to the present chart, there is a submarine valley running in towards the Burlings Rocks between two projecting and comparatively shallow banks.

From Lisbon, should you deem it necessary to call there, you will proceed on to Gibraltar, making a short stay, and, if opportunity offers, without much delay you may be able to add to the current observations southward of the ground already examined by yourself in the "Shearwater." Stretching then across to Madeira, circumstances may enable you to make an examination of Josephine Bank, unless it should be more convenient to do so after leaving Lisbon, and perhaps to get a haul of the dredge upon it. It will also be desirable to obtain a few deep soundings in as direct a line as convenient between Cape St. Vincent and Madeira. During your stay at Madeira it would be an object to make a larger and better plan than exists of the anchorage on the south side of Porto Santo, which is a far better rendezvous for a fleet than Funchal Roads, but in this you must be governed by time and circumstances, bearing in mind that at this season of the year strong southerly winds may be looked for at times.

From Madeira you would pass between Tenerife and Gran Canaria, getting a deep-sea sounding or two in the channel if the north-east wind, which generally blows with great force between these islands, will permit, and thence cross the Atlantic to the island of St. Thomas, one of the Virgin Islands, where you would probably arrive about the middle of March.

From St. Thomas you would go to Bermuda, and in this neighbourhood perhaps a fortnight might be devoted to deep-sea researches. A bank of 11 fathoms has recently been discovered by the "Ariadne," nearly four miles east of the Kitchen Shoals, which should be further examined.

Having completed what supplies you require, a line of soundings should be carried to the edges of the bank, in about 600 fathoms, which extends off the American coast in the neighbourhood of Long Island. You would then recross the Atlantic to the Azores, and having completed your researches in the neighbourhood of these islands, you will send to England from Fayal a tracing of the soundings you have obtained since your departure.

The time of your leaving the Azores for the south will probably be about the 1st July, and if it is convenient to stand to the eastward in the direction of Madeira as far as the 20th meridian, and to ascertain the depth and nature of the bottom there, it will be desirable. Thence a course should be steered for the Cape Verde Islands, where, at St. Vincent, you will be able to replenish fuel, if nothing else, and, should time permit, it would be well to make a new survey of that part of Porto Grande which is used as an anchorage, for the present plan is imperfect and the soundings are not very exact. Leaving the Cape Verde Islands, you will carry a line of soundings between St. Vincent and St. Antonio, and proceed to the southward, endeavouring to reach the equator between the meridians of 10° and 15° west longitude, working out that region thoroughly from east to west as far as St. Paul's Rocks, or about 30° W.; here you will be in the focus of the great westerly current, and with the calm weather which may be looked for, you will probably be able to set at rest many points of special interest. There is reason to believe that the depth of the Atlantic equatorial region does not exceed 2000 fathoms, which is easily within the reach both of the sounding lead and the dredge, and it is hoped that by means of anchoring a boat or beacon you will be able to ascertain to what depth the surface current extends, and what are the conditions of the circulation in the lower strata of the ocean. Any reasonable amount of time devoted to this inquiry will be most profitably spent. From St. Paul's Rocks you will proceed to Fernando Noronha, where the ship should be anchored. This is one of the spots especially recommended by Dr. Hooker as a field for the botanist, and the survey of the anchorage may be improved with advantage.

Bahia should be the next place of call, where you would probably arrive about the middle of September, and, if you are able to obtain the necessary supplies there, it will be well not to call at Rio de Janeiro on your outward voyage, but, after refreshing your crew, to proceed on to the Cape of Good Hope.

You will probably be able on your way to ascertain the depth of the bank which unites the coast of Brazil and the Abrolhos Shoals with Trinidad and Martin Vas, and to examine the submarine base of Tristan da Cunha, as well as to ascertain its correct elevation, bearing in mind while on this ground that none of the soundings shown on the chart of the South Atlantic, with the exception of those obtained by Captain Shortland in the "Hydra," can be considered reliable.

You will probably reach the Cape about the 1st November, and here you should remain a month to refit the ship and for the rest and refreshment of your crew prior to proceeding on the second stage of your voyage into the high latitudes of the Southern Ocean.

Leaving the Cape, Marion and Crozet Islands should be next visited, and subsequently Kerguelen's Land, and it is unnecessary, I am sure, for me to impress upon you the extreme caution and vigilance which will be necessary in navigating this boisterous and little known region with a single ship, even in the middle of the summer season.

Kerguelen's Land will be a fertile field of exploration in every department of science, and acquires additional interest as one of the stations selected for the observations of the transit of Venus in December 1874. What is known of it will be found in the published account of the voyage of Ross, who visited it with the "Erebus" and "Terror" in 1840. A memorandum from the Astronomer-Royal will furnish you with the nature of the information required for the guidance of the transit party, which will probably proceed there towards the close of 1874, and as it is possible you may not be able to transmit this information to England in time for them before they leave, I should wish you to forward a copy of it to the astronomer at the Cape observatory from the first point you touch at in Australia, for the information of the officer in charge, who will certainly take his final departure from that place. It is desirable that the longitude of the transit station at

Kerguelen's Land should be ascertained with the greatest possible accuracy, and although your interval from the Cape will be large for chronometrical measurement, yet you should bring the whole force of your chronometers to bear on the question of connecting the station with the Cape observatory, and also with the observatory at Melbourne.

Much importance is attached to the examination of the region in the neighbourhood of the great Ice-barrier, and after leaving Kerguelen's Land and looking at Heard's or M'Donald's Island, where, I have been informed by Captain M'Donald, who discovered it, that he observed the appearance of a probable harbour, you will strike southerly in the neighbourhood of 90° of east longitude and approach the edge of the ice as near as may be with safety. Captain Moore reached to the parallel of 65° in this meridian in 1845, and observed the appearance of land to the westward. It is not desirable, however, that you should pursue any extended hydrographical explorations in this region with a single unfortified ship, but after having made the necessary investigations of the depths, temperature, and fauna of the ocean, you will again turn north for Melbourne in Australia, where I calculate you may arrive in March 1874. While navigating in these southern latitudes, I strongly commend to your study and that of your officers the Ice Chart of the Antarctic Regions published by the Admiralty.

Having remained a short time at Melbourne, you will proceed to Sydney, which will be the second stage for a complete refit and a rest from your labours, and from Australia a report of your proceedings will be looked for in England with great interest.

It is probable you will leave Sydney about the middle of May 1874, and carrying a line of deep-sea soundings direct to the north cape of New Zealand, proceed on to Auckland. Some importance is attached to the examination of the region of those small islands which lie to the southward and westward of New Zealand, viz., the Auckland, Macquarie, and Campbell Islands, but the adoption or rejection of this portion of the programme must be left to your own judgment when this stage of the voyage shall have been reached; the time at your disposal, and the health and condition of your crew, must necessarily be the principal elements of consideration in coming to a decision. Under any circumstances it is desirable that you should finally quit New Zealand not later than the first week in August of 1874.

From New Zealand your course will be through the Coral Sea towards Torres Straits. At the French settlement at Noumea Bay, on the south-west side of New Caledonia, you will be able to replenish your fuel; passing thence to the northward, you would carry out your investigations along the Lousiade Archipelago and southern shores of New Guinea, and enter Torres Strait by the Bligh Passage and the great north-eastern channel, passing out by Prince of Wales or one of the neighbouring channels, thence through the Arafura Sea to Koepang in the island of Timor, where you will be able to obtain refreshments and probably fuel.

Koepang is a very well determined station for longitude by measurements between the observatories of both Sydney and Batavia.

From Timor you would proceed either north or south of Sumba as convenient, and enter the Java Sea by the Strait of Allas or Lombok, taking care to secure your westing before the westerly monsoon has set in. You will then have before you the investigation of a most interesting and little known region. At Macassar you will procure all that you may need in regard to supplies of fresh provisions and fuel, and passing between Celebes and Borneo, you will enter the Celebes and Sulu Seas, and as it is not desirable you should reach Manila until the close of the hurricane season in November, you will probably find leisure to prosecute hydrographical in addition to other researches by determining accurately the positions of any prominent points or islands which may be in your route or in any other direction which circumstances may permit. Commander Chimmo in the "Nassau" has lately added something to our knowledge of this region, and the results when received here shall be duly communicated for your information.

As you will have been able thoroughly to refit the ship and machinery at Sydney, and if necessary to dock her, it is not contemplated there will be any necessity to visit Hong-Kong, but you will have to consider in good time whether it may be necessary to apply to the senior officer there to forward stores or provisions to you at Manila, which latter will be a good port for refit and refreshment before proceeding into the Pacific.

You would leave Manila about December 1874, and as there will be no subsequent opportunity of visiting the western or Polynesian region of the Pacific, it will be necessary to make a stretch as far eastward and southward as the seasons and other circumstances will admit before proceeding to Japan. It will be most convenient for you to enter the Pacific either by the Balintang Channel or closer round the north end of Luzon Island.

You are supplied with a set of Admiralty charts of the Pacific on which I have had clearly marked all the doubtful positions which require to be rectified; their name is legion, and I cannot hope under the most favourable circumstances that you will be able to accomplish much in this direction during the three months at your disposal. The weather, moreover, will be against you, for during January and February you must expect much rain at New Ireland, New Britain, and the Solomon Islands. Under these circumstances, it must be left to your own judgment and experience on the spot how far you will penetrate to the eastward, or what precise direction you will take—all is new ground.

If circumstances permit, I should wish you to visit the Pelew Islands, in the neighbourhood of which there are several doubtful dangers; thence you might endeavour to push eastward and make a short visit to New Britain and New Ireland. Our knowledge of these remarkable islands is very limited, but you are supplied with all the works of D'Entrecasteaux and D'Urville both on these and on the north coast of New Guinea, which, though imperfect, cannot fail to be of great assistance to you. Belcher also visited New Ireland in July 1840, when the rain was incessant, but some partial surveys were made, especially of Port Carteret and the anchorages in its neighbourhood; these will be of assistance to you. If you visit the Solomon Islands, it will be desirable if possible to settle the position of the small isles and reefs which lie about one hundred miles to the southward of this group. Bellona and Rennel Islands, and especially Pandora and Indispensable Reefs, which are well known to exist, although their positions and extent are very inaccurately defined. Also Neptune Reef, which was erased from the chart by Captain Denham, but on which a vessel has since been wrecked. Many partial surveys of the Solomon Isles by the missionary vessels and from other sources are supplied to you, but they must be regarded as mere sketches, which may assist you, but in which no great confidence can be placed. Whether you get farther eastward into the Pacific must depend on circumstances, but it will be desirable that you should reach Japan by the middle of March 1875.

You will have previously communicated with the admiral commanding on the China station in order to ensure that, if necessary, provisions and stores should be sent to Nagasaki or Yokohama, whichever may be most convenient, and after refreshing your crew you may profitably pass two months in the investigation of the neighbouring seas, and, especially, in regard to the great Japan current.

No hydrographical operations will be necessary on the coast of Japan. For some years, as you are aware, the survey of these coasts has been systematically pursued by the Admiralty, and although the surveying vessel has for the present been withdrawn, this work will doubtless be resumed at an early period. Moreover, your stay should obviously be directed to the main objects of the expedition.

On leaving Japan you should carry a line of deep soundings across that section of the ocean between it and the coast of America, although the strong winds which may be looked for in these latitudes will probably necessitate considerable intervals between your observations, and you should reach Vancouver's Island, if possible, during the months of June or July. Esquimalt will be your port for refit and obtaining supplies before setting out on the last stage of your voyage, which will be the long sea passage to Valparaiso previous to your return to England.

The depth of this eastern section of the Pacific will probably be found very considerable, but physically it is a region of great interest, and every effort should be made for a full investigation of it. You would probably sight no land until you reached Easter Island and Sala-y-Gomez, which should both be examined. You would then proceed on to Valparaiso, which port you would leave about November, and return to the Atlantic by the Straits of Magellan. Should you pass through the channels by the Gulf of Penas, you will observe by the notes on the charts that there are certain portions of those channels which are out of adjustment, and a few days devoted to their rectification would be well spent.

You would be at liberty to call at the Falkland Islands, Rio de Janeiro, and Ascension, and to complete any work in the Atlantic which circumstances may have prevented on your outward voyage, and your return to England might be looked for in the spring of 1876.

During your absence you will communicate to this department from time to time all hydrographical and other information which you may obtain, and you will make timely demands for all surveying stores, and extra provisions, &c., which must be sent from this country, specifying the place to which they shall be sent, and the dates.

All specimens which you may have to send, or which Professor Thomson may desire to send, are to be carefully packed and sent by safe opportunities addressed to the Secretary of the Admiralty, and marked, Natural History Collection for Hydrographical Department.

The Commanders in chief on the different stations through which you may pass will be instructed to afford you any assistance that you may require, and not to divert you from the special service on which you are employed. It will be your duty, therefore, to communicate with each of these officers as you may arrive within the limits of their respective commands.

Their Lordships have provided that in the event of any unforeseen circumstances depriving the expedition of the services of Professor Wyville Thomson, the Scientific Staff are to conduct their researches under your own immediate direction, and it only remains for me now to express the entire confidence which I feel in your judgment and ability to carry out this great and important work which has been entrusted conjointly to yourself and Professor Thomson, and thus to add to the favourable reputation which you have already earned for yourself as an able and intelligent naval surveyor.

George Henry Richards, *Hydrographer.*

Admiralty Instructions to Professor C. Wyville Thomson.

Admiralty, *3rd December* 1872.

Sir,—With reference to my letter of the 1st October, acquainting you that the Lords Commissioners of the Admiralty had appointed you Director of the Scientific Civilian Staff, in the Expedition about to leave England in H.M.S. "Challenger," on a voyage of scientific research, and that further instructions would be furnished to you prior to your departure; I am now directed to inform you that at their Lordships' request a memorandum, of which a copy is enclosed, has been prepared by the President and Council of the Royal Society, setting forth the principal scientific objects of the Expedition, and recommending the order and conditions under which they should be carried out; and it is their Lordships' desire, that so far as circumstances will admit, the suggestions contained in this memorandum, should be followed during the course of the voyage.

2. The General Instructions for the conduct of the Expedition are furnished by their Lordships to Captain Nares, the officer in command, as well as detailed Hydrographical Memoranda, prepared by the Hydrographer, under their Lordships' instructions; and Captain Nares has been directed to communicate freely with you on all matters connected with the scientific objects of the Expedition, and as far as possible to meet your views and wishes in connection with them; and their Lordships feel assured that you will co-operate and act in concert with him, with the view, as far as possible, to secure the success of an enterprise which it is hoped will be attended with important results in the various branches of science which it is intended to investigate.

3. It is to be understood that all natural history or other collections, and all scientific journals or other data, are to be considered as primarily the property of the Government, the former to be ultimately deposited in the National Museum, or as may be otherwise decided on,—the latter for publication in a connected form should the Government on the return of the Expedition so determine; but as it may be desirable during the progress of the voyage, that any new discoveries should be at once made known in the interests of science, their Lordships will leave to your judgment, the time and method of accomplishing this object, and of communicating such scientific information as you may judge fitting, to the Royal Society, or to other learned Societies of the United Kingdom;—it being understood that such communications are to be made through their Lordships.

4. The Natural History specimens which you may consider it desirable to send to England from time to time, will, at your request, be forwarded in the usual way by the officer in command, as safe opportunities occur, addressed to the Secretary of the Admiralty, and accompanied by a recommendation from yourself as to their temporary disposal.

5. In the event of any unforeseen circumstance, rendering it necessary for you to leave the Expedition, and return to England before its final conclusion, it is their Lordship's desire that you should place Captain Nares in full possession of your views and opinions in regard to the further prosecution of the scientific objects of the voyage, and that the Scientific Staff should in such an event continue their investigations under his directions.

I am, Sir,
Your obedient Servant,
ROBERT HALL.

Professor Thomson, F.R.S.,
Regius Professor of Natural History
at the University of Edinburgh.

Professor Thomson's Appointment.

ADMIRALTY, 1*st October* 1872.

SIR,—I am commanded by my Lords Commissioners of the Admiralty to acquaint you that, having decided to despatch H.M.S. "Challenger" on a Circumnavigating Voyage of Scientific Research and Exploration, and hearing from the President and Council of the Royal Society that you are willing to afford your services on such a voyage: They have been pleased to appoint you Director of the Scientific Civilian Staff of the Expedition, giving you the control and superintendence in all matters relating to the scientific duties of the gentlemen who have been appointed to assist you.

2. Your own salary while employed on this service will be £1000 per annum, and the names and salaries of the gentlemen associated with you who have been approved by yourself and recommended by the President and Council of the Royal Society are as follows, viz.:—

Mr. J. J. Wild, Artist and Secretary,	£400
Mr. Henry Nottidge Moseley, B.A., Naturalist,	200
Mr. John Murray, Naturalist,	200
Mr. John Young Buchanan, M.A., Chemist and Physicist,	200

Before the ship's final departure from England, their Lordships will cause you to be furnished with such memoranda and instructions as they may deem necessary for your guidance while employed on this service.

It is requested that the receipt of this letter be acknowledged.

I am, Sir,
Your obedient Servant,
ROBERT HALL.

Professor Wyville Thomson, F.R.S.,
&c., &c., &c.

Appointment of other Members of the Scientific Civilian Staff.

ADMIRALTY, 1*st October* 1872.

SIR,—I am commanded by my Lords Commissioners of the Admiralty to inform you that they have been pleased to appoint you Chemist and Physicist in the Expedition about to proceed on a voyage of scientific research in H.M.S. "Challenger."

While employed on this service, it is expected that you will perform your duties under the superintendence of Professor Wyville Thomson, F.R.S., who has been appointed Director of the Scientific Civilian Staff, and that you will conform to the usages and customs observed on board Her Majesty's ships.

Your salary while so employed will be (£200) two hundred pounds per annum.

I am, Sir,
Your obedient Servant,
ROBERT HALL.

John Young Buchanan, Esq.

Dr. R. von W. Suhm, Mr. Moseley and Mr. Murray, received appointments as Naturalists similar to the above, with the same salary; and Mr. Wild an appointment as Secretary to the Director, and Artist, with a salary of £400 per annum.

APPENDIX C.

STORES AND APPARATUS SUPPLIED FOR THE USE OF THE EXPEDITION.

Apparatus for Deep-Sea Soundings, taking Temperatures, and procuring Specimens of the Water.

Name of Article.	Quantity originally supplied.	Additional quantity received in the course of the voyage.	Total quantity expended.	Remarks.
Sounding rods, Hydra,	18	...	10	
„ Baillie,	...	12	2	
Sinkers, 1 cwt.,	240	...	228	
„ ½ cwt.,	...	1,479	1,281	
Valve leads, 1½ and 1 cwt.,	...	30	2	
Cup leads, 1 cwt.,	40	...	4	
Sounding line, No. 1, (fathoms)	20,000	20,000	26,000	
„ No. 2, „	64,000	...	34,000	
Iron gin-blocks, patent sheaves, 9 inch,	3	...	...	
Worsted for marking lines, (lbs.)	50	60	70	
Accumulators,	50	...	50	
For suspending sinkers, Wire, (fathoms)	2,240	...	1,000	
„ „ Washers,	730	...	430	
For deep-sea sounding. Wire, (fathoms)	10,000	...	...	
For deep-sea sounding. Drums,	2	...	...	
For deep-sea sounding. Clock-work,	2	...	...	
Thermometers (protected),	35	69	48	
Slip water-bottles,	6	12	12	
Stop-cock water-bottles,	6	6	6	
Apparatus for trying Submarine Currents.				
Current line, (fathoms)	60,000	...	23,000	
Current buoys,	25	...	7	
Current drags,	2	...	2	
Apparatus for Dredging and Trawling.				
Dredges,	34	...	11	
Dredge-nets,	20	...	11	
Trawls,	22	...	16	
Rope, 3 inch, (fathoms)	10,000	...	4,200	
„ 2½ inch, „	10,000	21,000	27,100	
„ 2 inch, „	5,000	10,000	10,860	
Accumulators,	100	160	260	
Iron gin-blocks, patent sheaves, 12 inch,	6	...	...	
„ „ 9 inch,	3	...	...	
Copper sieves, (sets)	6	...	3	
Copper wire ladles,	7	...	4	
Swivels,	100	...	40	
Galvanized iron chain, ¼ inch, (fathoms)	280	...	120	

Ordinary Sounding Gear Supplied.

Article.	Quantity.	Article.	Quantity.	Article.	Quantity.
Deep-sea leads,	50	Twine,	600 lbs.	Tents,	5
Hand leads,	100	Beeswax,	24 lbs.	Boats' cooking stoves,	5
Cup leads, ½ cwt.,	30	Boats' compasses,	6	American axes,	12
Patent logs,	24	Boats' sounding davits,	9	Hand saws,	12
Burts' nippers, and bags,	12				

Surveying Instruments Supplied.

Article.	Quantity.	Article.	Quantity.
Chronometers,	12	Measuring tapes, 100 feet,	2
,, (pocket),	5	,, ,, 50 ,,	2
Altitude and azimuth, 8 inch,	1	Station pointers,	6
Theodolites, 6½ inch, 5 inch, and 4 inch,	5	Protractors, circular,	2
Level,	1	,, semi-circular,	1
Levelling staves,	2	,, rectangular,	11
Sextants, observing,	2	Parallel rulers, rolling,	4
,, sounding,	6	Brass scales, 4 ft., 3 ft., 2 ft.,	4
,, pocket,	4	Steel straight edges, 6 ft. and 4 ft.,	2
Repeating circle,	1	Beam compasses, 4 ft., 3 ft., and 2 ft.,	3
Artificial horizons,	2	Drawing instruments, (sets)	4
Compasses, azimuth, prismatic,	5	Sector,	1
,, ,, Kater's,	1	Ivory scales, (set)	1
,, ,, pocket,	12	Curves, (set)	1
Dipping needle, Barrow,	1	Colour boxes,	2
Declinometer,	1	Proportional compasses,	2
Inclinometer Fox circle,	2	Hair spring dividers,	9
Vibrating needle,	1	Ruling pens,	6
Gimbal table for Fox circle,	1	Mercury, (bottle)	1
Compass bowl and card for Fox circle,	1	Box of tools,	1
Telescopes,	4	Sounding clock,	1
Binoculars,	2	Tide watches,	2
Micrometer Telescopes,	2	Piezometers,	2
Measuring chains, 100 feet,	2	Heliostat,	1

Meteorological Instruments Supplied.

Marine barometers,	3	Rain gauges,	2
Mountain barometers (syphon),	2	Thermometers (dry- and wet-bulb),	24
Aneroids,	2	Pocket thermometers,[1]	12
,, pocket,	3	Maximum and minimum thermometers,	24
Anemometers,	2	Hydrometers,	12

[1] Some of these should be constructed to register up to the boiling point, for use in testing thermal springs.

Apparatus, &c., Supplied for use in Naturalists' Workroom.

Glass Ware, &c.

1000 Glass tubes, corked, 6 inches × $\frac{3}{4}$ inch.
1000 „ „ 5 „ × $\frac{5}{8}$ „
1000 „ „ 4 „ × $\frac{3}{4}$ „
1000 „ „ $3\frac{1}{2}$ „ × $\frac{5}{8}$ „
1000 „ „ 3 „ × $\frac{1}{2}$ „
24 Large tubes, 36 in. × 2 in. for Pennatulids, but zinc cylinders are better for the purpose.
144 Wide-mouthed stoppered bottles, 6 in. × 3 in., in boxes containing 12.
288 Wide-mouthed stoppered bottles, $2\frac{3}{4}$ in. × $2\frac{1}{8}$ in., in boxes containing 24.
1728 Rough-made wide-mouthed stoppered bottles, (pomatum bottles), $3\frac{1}{2}$ in. × 2 in., mouths $1\frac{1}{5}$ in., cost 36s. per gross.
Glass fish globes, of various sizes.
400 Rock bottles, 9 in. × 6 in., with mouths $3\frac{3}{4}$ in., in boxes containing 8, cost 65s. per gross.
400 Rock bottles, 9 in. × $4\frac{1}{2}$ in., with mouths $2\frac{3}{4}$ in., in boxes containing 8, cost 55s. per gross.
400 Rock bottles, 9 in. × $3\frac{3}{4}$ in., with mouths $2\frac{3}{4}$ in., in boxes containing 15, cost 40s. per gross.
432 Pill bottles, 2 in. × 1 in. and $1\frac{5}{8}$ in. × $\frac{3}{4}$ in., with corks with turned wooden tops.
500 Flattened glass tubes, 2 in. × $\frac{1}{4}$ in.
Small stoppered bottles, 1 in. × 1 in.
Corks, a large store.
A large store of zinc and tin for cases for larger animals preserved in spirit, and for lining cases of dried objects, botanical specimens, &c.

Boxes, &c.

7200 Cardboard boxes, $2\frac{3}{4}$ in. × $1\frac{3}{4}$ in.
288 Pill boxes, $1\frac{1}{2}$ in. × 1 in.
144 „ 1 in. × $\frac{3}{4}$ in.
1152 „ nested, four sizes, largest $1\frac{1}{2}$ × 1 in.
144 Cigar boxes.
144 Seidlitz powder boxes, 3 × $4\frac{1}{4}$ × $1\frac{1}{2}$ in.
144 „ „ $3\frac{1}{2}$ × $2\frac{1}{4}$ × $1\frac{1}{8}$ in.
144 Oval boxes, $3\frac{1}{4}$ × 2 × 1 in.
Forceps, scissors, knives, scalpels, saws, &c., in cases, screw drivers and other tools, and vice.
50 Common shoemakers' knives, and whetstones for them (very useful).
6 Measuring tapes, common.
1 Measuring tape, 50 feet.
1000 Zinc labels (very useful).
Supply of glass dissecting troughs with covers.
Cases containing glass microscope slips.
Cases containing mounted microscope cells.
Store of thin covering glasses.
1 Case for 12 large and 6 small bottles for special microscopic reagents.
Supply of horsehair for packing specimens in spirits.
Supply of tow and cotton wool, needles and thread, &c., for preserving birds.
12 Leather sling cases and slings for collection on shore, containing each 6 pomatum bottles.
Japanned tin vascula with straps of various sizes (some of these should be fitted with compartments, to contain birds shot for skinning).
6 Spades.
6 Steel hawk traps.
1 Fox trap.
6 Steel rabbit traps.
3 Galvanised rat traps.
3 Mouse traps.
Birdlime.
15 Butterfly nets.
2 Sweeping nets.
4 Insect forceps.
12 Pupa diggers.
2 Lanterns.
2 Sugaring tins.
6 Pocket collecting boxes.
6 Quires white paper for butterflies, cut in squares.
Supply of tin pocket boxes to contain these.
12 oz. Insect pins.
72 Pieces of thin cork, 8 in. × 3 in.
1 Deal case fitted with 6 store boxes corked, and setting boards.
4 Harpoons.
1 Grain.
12 Shark hooks.
Other fish hooks, a large box full.
36 Spinning baits.
2 Trammel nets, 50 fathoms.

Apparatus, &c., Supplied for use in Naturalists' Workroom—*continued.*

3 Shrimp nets, mouth 4 ft. wide. (These yield good results, if worked at night at low tide.)
3 Circular prawn nets, 3 ft. in diameter.
3 Drum net traps, 5 ft. × $2\frac{1}{2}$ ft.
24 Lobster pots.
2 Fishing rods.
Store of lines, swivels, &c.
50 Wire ventilating screens 22 in. × 12, for drying plants. (A large supply is recommended if the collection of plants on any great scale is intended.)
4 Reams botanical paper.
2 ,, filtering paper.
4 ,, ordinary brown paper.
2 ,, fine white paper for algæ.
Supply of calico for covering algæ when drying.
Supply of microscopic reagents, picric acid, osmic acid, chromic acid, chromate of potassium, cyanide of potassium for preserving specimens, corrosive sublimate, arsenical soap, &c.

Chemical Apparatus Supplied.

Reagents.—Large supplies of all chemicals which could possibly be of use were taken. As was expected, many substances were never used at all, but, on the other hand, there was nothing wanted which was not to be had. Experience showed that it is necessary to have a complete set of the ordinary laboratory reagents such as are included in the lists in Fresenius' Qualitative and Quantitative Analysis. These need not take up much room, for, the great majority of them are wanted so seldom that very small quantities suffice. The liquid reagents should be made up in 2 oz. stoppered bottles, and the solid substances required for replenishing them or for use in the dry way should be kept in 2 oz. wide-mouthed stoppered bottles, and for most reagents this supply is sufficient. There are, however, certain chemicals, which are always in more frequent use, and others which, from the special nature of the work, will be required in greater quantity, and of these larger supplies must naturally be provided. Of the ordinary reagents so required, there are the acids, sulphuric, hydrochloric, and nitric, the alkalies, potash and ammonia, and salts, such as chloride of barium and nitrate of silver. The acids should be both dilute and concentrated, and it is well to have the dilute acids handy in larger quantity than would be contained in a 2 oz. bottle. Caustic potash should be kept in the solid state. The special reagents required in larger quantity are determined by the nature of the work contemplated, and as the principal purely chemical work carried on regularly was the determination of carbonic acid, considerable supplies of hydrate of baryta as well as of chloride of barium were required. Spirits of wine is necessarily carried in large quantity on account of its use as fuel and for preserving specimens. A solvent such as ether, sulphide of carbon, or chloroform, is often wanted, the last of these should be preferred.

In fitting out the laboratory with chemicals, an *abundant* supply of those required for the regular every day work which it is proposed to carry out should be taken, but room should not be wasted in accommodating reserve supplies of substances which are likely to be wanted only occasionally. As apothecaries and photographers are to be found all over the world, there is no difficulty in replenishing the store of any chemical which may be exhausted. Strong acids should not be kept on board in large quantities, as they also can be replenished.

General Laboratory Apparatus.

The following is a list of apparatus supplied or purchased, aud found useful during the cruise :—

Metal Apparatus.

1 Copper air-bath.
4 ,, water-baths.
8 Iron sand-baths.
2 Retort stands.
6 Tinned iron spirit lamps.
18 Brass clips.
2 Crucible tongs.
3 Spatulas.
5 Steel pincettes.
2 ,, ,, with platinum points.

General Laboratory Apparatus—*continued.*

2 Sets cork borers.
1 Vice.
48 Files.
6 Rasps.
2 Scissors.
2 Gimlets.
1 Awl.
2 Turnscrews.
1 Chisel.
1 Gouge.
1 Metal shears.
Copper wire.
Sheet copper.
Sheet zinc.
1 Hammer.
Nails, screws, corks, &c.
India-rubber tubing of all sizes.
" " corks "
" " sheet (stout)
" " " (thin)

Porcelain Apparatus.

24 Evaporating dishes.
2 Mortars.
74 Crucibles.
1 Mercury trough.
6 Boats.

Glass Apparatus.

88 Flasks chiefly of the sizes required for CO_2 determination and for the gas apparatus.
5 Sets beakers.
8 Retorts.
18 Cylinders of sizes from 1 litre to ¼ litre, some graduated.
24 Funnels.
180 Stoppered bottles, chiefly for reagents.
72 Small sample bottles (1 oz.),
2 Large (2 gallon) water-bottles with tubulure for stop-cock.
4 Woulff's bottles.
296 Test-tubes.
48 Watch glasses.
7 Spirit lamps.
40 lbs. Tubing.
10 lbs. Rod.
6 Pipettes.
6 Burettes.
1 Litre bottle.
4 Half-litre bottles.
1 Quarter-litre bottle.
3 Hydrometers, ordinary,
4 " special for sea water.
4 Thermometers (Geissler's).
3 " ordinary.
20 Chloride of calcium tubes.
500 Tubes for collecting gases.
144 Corbyn quart bottles for samples of sea water.

Miscellaneous Apparatus.

1 Chemical balance (Oertling).
1 Small hand scales.
2 Sets weights.
3 Platinum crucibles.
3 " dishes.
1 " spatula.
4 " small spoons.
" foil and wire.
1 Plattner's case of blowpipe apparatus.
6½ gross of corks.
1 Microscope.
1 Micro-spectroscope.
1 Pocket spectroscope.

Library.

The Library consisted of several hundred volumes, including Voyages, Travels, standard works on Zoology, Botany, Chemistry, Transactions and Proceedings of Societies, &c. These were either supplied by the Admiralty, or were the property of the Scientific Staff. It does not appear that any useful purpose would be served by giving a list of these books.

CHAPTER II.

Departure from Portsmouth—Sounding and Dredging—Arrival at Lisbon—Soundings and Dredgings off the Tagus—Gibraltar—Soundings and Dredgings between Gibraltar and Madeira—The Pennatulida—Tenerife—Soundings and Dredgings in the vicinity of the Canary Islands—Departure from Tenerife for the West Indies—Description of Method of Sounding, Dredging, and of making other Observations at Sea.

PORTSMOUTH TO GIBRALTAR.

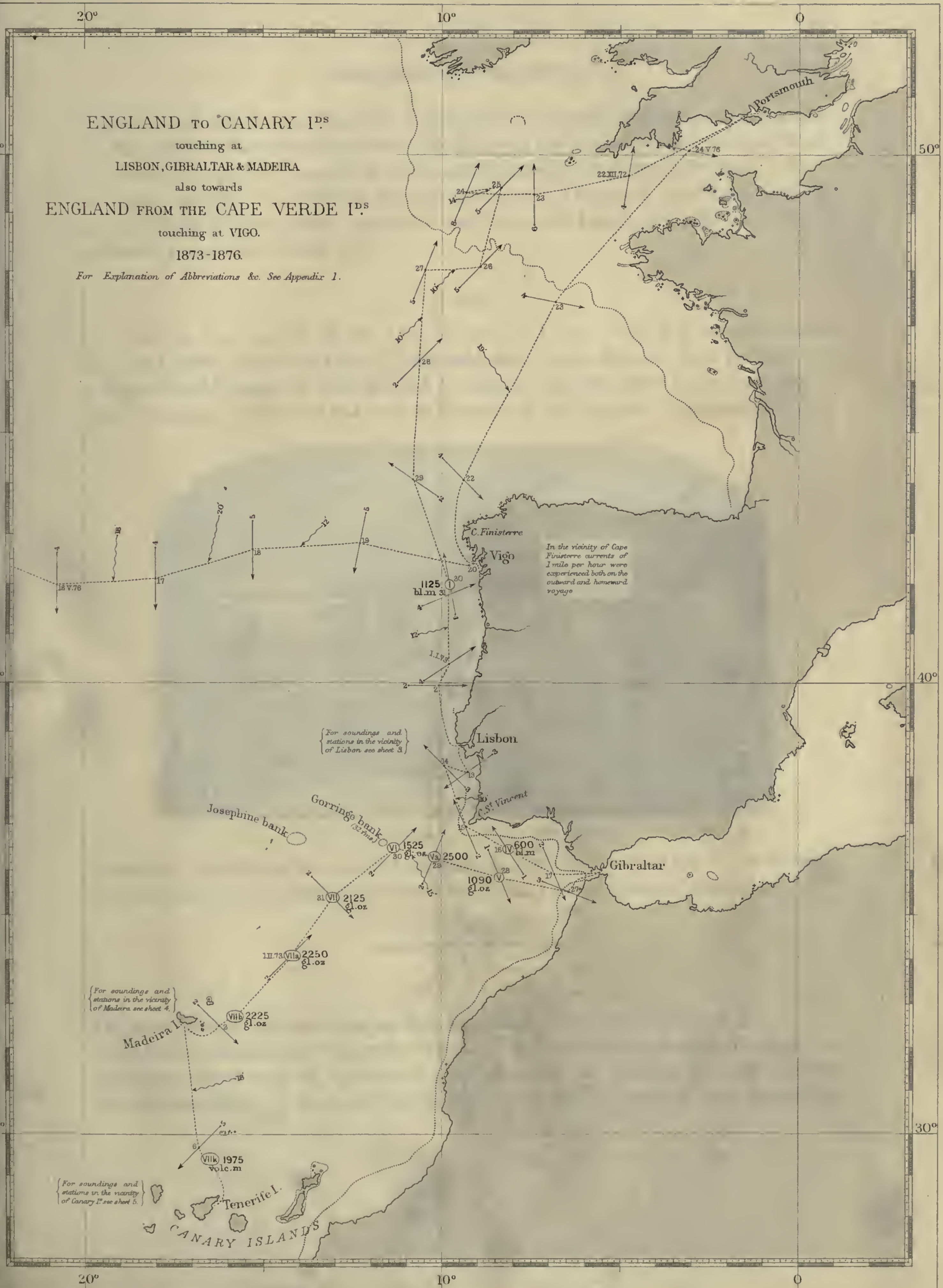
THE Challenger left England on the 21st December 1872, and experienced heavy southwesterly gales until the 30th, when the parallel of Cape Finisterre was reached. From this position to Lisbon, which port was reached on the 3rd January 1873, the weather was variable, but on the whole fine, so that it was possible to test the sounding and dredging gear, and instruct the ship's company in duties new to nearly all of them. Five soundings and three hauls of the dredge were obtained in depths varying from 325 to 1975 fathoms (see Sheets 2 and 3). These first operations were not very successful, as the sounding line parted on three occasions, the dredge rope once, and the dredge on one occasion came up foul. These accidents were due partly to inexperience, and partly—as was found out afterwards—to the defective condition of the medium-sized sounding line which was at first used instead of the No. 1 line, its breaking strain being 7 cwt. instead of 10 cwt. The dredge rope was lost owing to the dredge fouling something at the bottom, from which it could not be cleared, and at the time it parted the tension was certainly equal to, if not greater than, the warranted breaking strain, viz., 2½ tons. It has been suggested that the dredge may have fouled the telegraph cable which passes along this coast.

The ship was detained at Lisbon till the afternoon of the 12th January by a heavy gale from the southwest and by cloudy weather, which prevented the observations necessary for rating the chronometers being obtained.

On leaving Lisbon light easterly and northerly winds were experienced, and several soundings and some successful hauls with both the dredge and trawl were taken, in depths varying from 84 to 1800 fathoms (see Sheet 3). The incline off the river Tagus was found to slope gently down to 1475 fathoms, 31 miles from the shore.

The deposit at 560 fathoms, off the mouth of the Tagus, was a green mud, consisting of Foraminifera, Coccoliths, fragments of Echinoderms, Molluscs, and Polyzoa; angular fragments of quartz, felspar, mica, magnetite, and many glauconitic particles. The calcareous organisms made up 32 per cent. of the deposit, and, after treatment with weak hydrochloric acid, many dark and pale green, perfectly formed, glauconitic casts were observed. The percentage of carbonate of lime in the deeper deposits remained about the same, but the glauconitic particles were not nearly so abundant. The mineral constituents of this

SHEET 2.



Engraved by Malby & Sons

deposit are chiefly derived from the disintegration of continental land, and are similar in all respects to those found later on to prevail along the borders of the great continents.

Between Cape St. Vincent and the Straits of Gibraltar, it occurred to Captain Nares to use an ordinary beam trawl in place of the dredge. This was a very happy idea, for the trawl was found to answer admirably, and, as is well known, has since been almost exclusively used for deep-sea work.

Gibraltar.

Gibraltar was reached on the 18th January at 8 A.M. The ship remained seven days, and during that time a plan of the anchorage inside the new mole was made on a large scale, by means of lines, marked at every 25 feet, stretched across from side to side of the space enclosed by the mole, at distances of 50 feet apart. The soundings were

Fig. 9.—H.M.S. Challenger at the New Mole, Gibraltar.

reduced to 5 feet below the level of the mole in Rosia Bay, or to 6 feet below the level of a line cut in the masonry of the camber at the head of the dockyard mole, thus—

"CHALLENGER."

H. W. 2 feet.

The mean level of high-water spring tides was found to be 2 feet below that line.

H.M. surveying sloop "Shearwater" being at Malta during the stay at Gibraltar, the surveying officers took the opportunity of determining the meridian distance between Gibraltar and Malta, by means of the telegraph cable kindly placed at their disposal for this purpose by the superintending electricians at those places. The observing station at Malta was Spencer's Monument, and at Gibraltar the head of the mole in Rosia Bay, and the following were the results :—

	h.	m.	s.
Meridian distance, by signals transmitted from Gibraltar to Malta,	1	19	29·75
Do. do. Malta to Gibraltar,	1	19	28·54
Mean meridian distance, ...	1	19	29·15

From which it appears that it took 0·60 s. to transmit the signal between the two places, a distance of 1000 miles.

The magnetic observing station at Gibraltar was in the middle of the garden of the Main Guard, on the Neutral Ground. The observing station for rating chronometers was the head of the mole in Rosia Bay, which is a much more convenient place for this purpose than almost any other in Gibraltar, as, besides its seclusion, the sun is seen there earlier in the morning than at the Ragged Staff, or the dockyard mole, a matter of some moment when the easterly winds, so frequent in summer, keep the summit of the rock constantly capped with cloud, for when this occurs, the town, the Ragged Staff, and the dockyard are in the shade during the greater part of the forenoon, whilst the sun is shining brilliantly on Europa Point, and nearly always as far north as Rosia Bay.

On the 26th January, at 9 A.M., the vessel proceeded to the eastward of the Rock to be swung for the errors of the compass and dipping needle. For the deviation of the compass the ship was swung on the line of transit of Frayle Tower with Europa Lighthouse, the true bearing of which had been previously ascertained. The error of the dipping needle was ascertained by keeping the ship steaming slowly and steadily on a given point of the compass, while observations were made for inclination, and these observations were repeated on a sufficient number of points, to allow a curve to be drawn from which the error could be ascertained for any part of the circle. The force of the ship was ascertained by vibrating a needle on the four cardinal points, and comparing its results with those obtained by the same needle on shore. These operations having been satisfactorily completed, the ship returned to port to land letters, &c., and finally left at 6 P.M. for Madeira.

Gibraltar to Madeira.

Between Gibraltar and Madeira six soundings and three hauls of the trawl were obtained, in depths varying from 1090 to 2600 fathoms (see Sheets 3 and 4). The deposit at each of these Stations was a Globigerina ooze. The percentage of carbonate of lime ranged from 53 to 75, and consisted almost entirely of pelagic Foraminifera, Coccoliths, and Rhabdoliths. The residue, insoluble in weak acid, consisted of a few Radiolarians, minute particles of quartz, felspar, augite, glassy volcanic fragments, and clayey matter.

ET 3

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The trawl again worked admirably, and brought up many specimens of fish, Echinids, Asterids, Molluscs, Pennatulids, and other animals. The trawl after this was used throughout the voyage for deep-sea work almost to the exclusion of the dredge. It produces on the whole better results, and naturalists are much indebted to Captain Nares for having had the courage to attempt the use in deep water of an instrument which must fall on its proper side in order to work successfully.[1] On the other hand, it must be remembered that the results appear to show that the trawl is not so favourable as the dredge[2] for catching certain forms, such as Corals and Molluscs.

The Pennatulida.—On the 31st January, at a depth of 2125 fathoms, a fine representative specimen of the remarkable Alcyonarian genus *Umbellula* was taken. *Umbellula* belongs to the suborder of the Alcyonarians, called by Professor v. Kölliker the Pennatulida. It is a colonial organism, consisting of a bunch of polyps borne on the one extremity of a long stem, provided with a flexible horny axis, the opposite end being implanted firmly in the deep-sea mud. In the present specimen, which proved to be a new species, named by Professor v. Kölliker *Umbellula thomsoni*, the stem measured 36 inches in length. It is shown in fig. 10 (cut short). Many of the Pennatulida are known to be phosphorescent, and in this specimen of *Umbellula*, when taken from the trawl, the polyps and the membrane covering the axis of the stem exhibited a most brilliant phosphorescence. A like phenomenon was observed in the case of many other Alcyonarians obtained from the deep sea,—a matter of peculiar interest in connection with the presence of eyes in certain deep-sea animals, which inhabit a region totally devoid of any other source of light.

Umbellula was long one of the rarest of zoological curiosities. The first specimens ever described were obtained on the coast of Greenland, early in the last century, by Captain Adriaanz, commander of the "Britannia," while on a whale-fishing expedition; on this occasion two specimens were found adhering to the sounding line at a depth of 236 fathoms. These were described by M. Christlob Mylius, and one of them was again described in the Philosophical Transactions for 1754, in a letter from Mr. John Ellis to Mr. Peter Collinson, "Concerning a cluster-polyp found in the sea near the coast of Greenland." Mr. Ellis compared it to the "*Encrinos* or *Lilium lapideum* of the curious in fossils," and indeed the resemblance to a Crinoid is not a little striking. For more than a century the animal was not seen again, and it is only a few years since two specimens were dredged in deep water during the cruise of the Swedish ships "Ingegerd" and "Gladan," in the Arctic Ocean. These were described in 1874 by J. Lindahl as two new species,—*Umbellula miniacea* and *Umbellula pallida*.[3]

[1] Since this page was in type, Mr. Rathbun (*Science*, vol. iv. p. 56, 1884) states that the trawl was systematically used in scientific research by the U. S. Fish Commission in 1872, but he does not say whether they employed it for deep-sea work prior to Captain Nares' suggestion.

[2] A comparison of the results obtained by means of the trawl and dredge will be given in the concluding Report of the Challenger series.

[3] Lindahl, J., Om Pennatulid-slägtet Umbellula, *K. Svensk. Vetensk.-Akad. Handl.*, Bd. xiii., No. 3, 1874.

The Report on the Challenger collection of Pennatulida,[1] by Professor Albert v. Kölliker, adds much to our knowledge of this suborder—especially with regard to the geographical distribution of the species. All the previously known species, with a few exceptions, are from shallow water, but the number of deep-sea forms dredged during the voyage of the Challenger is so considerable as to nearly equal the total number of known shallow-water forms. A species of *Umbellula*—*Umbellula leptocaulis*—dredged S.E. of New Guinea in 2440 fathoms, lives at a greater depth than any

FIG. 10.—Two views of *Umbellula thomsoni* with the stem cut short to show the bunch of large polyps by which it is surmounted.

of the other known species of Pennatulida, and of the eight new species of *Umbellula* described in the Report, no less than six are, so far as is known at present, confined to depths greater than 1000 fathoms, while the remaining two were dredged in 565 fathoms, off the coast of Japan.

The Umbellulidæ belong to the simpler and more archaic of the Pennatulida,

[1] Zool. Chall. Exp., part ii., 1880.

in which the polyps are directly sessile upon the stem, instead of being borne on lateral pinnules, as they are in the more complex forms. One of the most important conclusions to which Professor v. Kölliker has been led by the study of the Challenger collection, is that the simpler forms of Pennatulida more especially abound in great depths. There are altogether eight families in this lower group, of which seven are—with the exception of one or two species—invariably found in deep water. Of these the Umbellulidæ and Protoptilidæ are the most important, and have furnished the greatest number of new species, many of which have also a wide horizontal distribution. The eighth family, that of the Veretillidæ, seems, however, to be confined to shallow water. On the other hand, the members of the higher group, comprising the families Pteroeididæ, Pennatulidæ, Virgularidæ, and Renillidæ are nearly always found in depths less than 100 fathoms.

With regard to horizontal distribution, the general conclusion arrived at is :—Of the various families the Umbellulidæ are the most widely distributed; they occur in the North Polar Sea, in the Atlantic Ocean, in the South Polar Sea, in the Southern Ocean west of Kerguelen Island, and in the North and South Pacific. The Stachyptilidæ, Protocaulidæ, and Protoptilidæ have two centres, one in the Pacific Ocean on the coasts of New Zealand, New Guinea, and Japan, and the other in the North Atlantic and North Sea. In the Pacific, Atlantic, and Southern Oceans, far removed from land, the representatives of this order are exceedingly rare, but are more abundant as land and shallower water are approached. The Anthoptilidæ are only found on the east coast of America, but range from Halifax as far southward as Buenos Ayres and Tristan da Cunha. The Kophobelemnonidæ and Veretillidæ, on the other hand, appear to have a limited distribution, but very little has been added by the investigations of the Challenger to our knowledge of the distribution of these two families.

Among the more complex forms, the Virgularidæ and Pennatulidæ are the most widely distributed; the latter are found on the coasts of Europe, China, Japan, Australia, New Guinea, on the west coast of North America, and on the east coast of Africa. The Pteroeididæ have a well-defined centre in the southeast coasts of Asia, extending as far northward as Japan, and as far westward as the Red Sea and the west coast of Africa; one species indeed, *Pteroeides griseum*, inhabits the Mediterranean. There are altogether seven new genera and twenty-seven new species in the Challenger collection, and Professor v. Kölliker has, in consequence, found it necessary to form a new systematic arrangement of the suborder.

Madeira.

On the 2nd February the Madeira group was sighted, and the ship proceeded towards the south end of the Dezertas to obtain soundings for the Lisbon-Madeira submarine cable (see Sheet 4). At 8 P.M., when between the Dezertas and Madeira, the trawl was put over, it being too dark to continue sounding during the night; but at 2.30 A.M. on the 3rd, the trawl fouled something at the bottom, and the rope parted at 6 A.M., after four hours tedious labour in endeavouring to recover it. The ground being evidently unfit for trawling at this place, sounding operations were resumed towards Madeira, and were completed by 11 A.M., at which hour the anchor was let go in Funchal Bay. The deposits about the Dezertas and Madeira were volcanic sand and mud, with usually 30 to 40 per cent. of carbonate of lime. The mineral particles in the deposits were fragments of felspar, magnetite, lapilli, basaltic scoriæ, and glassy fragments.

At Madeira magnetic observations were taken at three places: (1) on the highest part of the rocky cliff forming the first point west of Pontinha Fort, after crossing the bridge over the valley, on some waste ground close on the seaward side of, and rising a little above, the main road, immediately opposite a garden gateway, in a wall on the opposite side of the road; (2) in Fort Pontinha; and (3) on the small almeida on the eastern side of the above mentioned bridge.

Tenerife.

On the 5th the ship left Madeira for Tenerife, arriving at that island on the 7th, one sounding having been obtained on the passage (see Sheet 2). On the way from Madeira to Tenerife a very strong N.E. trade wind was experienced, which prevented dredging or any other deep-sea work at or near the Salvage Islands. Immediately after the ship anchored at Santa Cruz, a salute of 20 guns was fired from the shore, and on inquiry it was found to be in honour of a son born to King Amadeo, who by that date had abdicated the throne and left Spain.

The anchorage off the town of Santa Cruz being imperfectly known, the permission of the Governor of Tenerife was obtained to resurvey it, and that work was commenced at once. The usual magnetic observations were taken on a circular enlargement of the main road to Laguna outside the town south of the first bridge. The observations for rating chronometers were taken in Fort San Pedro, and during the operations it was noticed that the mercury in the artificial horizon occasionally vibrated considerably for a few seconds, without there being any apparent reason for its doing so. Whether this arose from seismic action or not is uncertain; it clearly did not arise from the movements of carts, or men in the vicinity, especially as it occurred in the afternoon, when every one on shore was enjoying the usual siesta.

On the 10th the ship left the anchorage at Santa Cruz for a sounding and dredging excursion round the island, obtaining twelve soundings and two dredgings (see Sheet 5). The weather was remarkably fine, and the Peak of Tenerife, capped with snow, distinctly visible.

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Excursion up the Peak of Tenerife.—As a means of testing the appliances of the Scientific Staff, and affording its members an opportunity of making a preliminary trial of their capabilities as collectors and observers, and accustoming themselves to exploring work generally, an excursion up the Peak was organised, and a party, consisting of Sub-Lieut. Lord George Campbell, Mr. Buchanan, Mr. Moseley, Mr. Murray, with a marine and a blue jacket, ascended the Peak as far as was found practicable during the absence of the vessel from the harbour. The island was crossed to the town of Orotava, on the opposite shore to Santa Cruz, and from thence the ascent was made

FIG. 11.—Santa Cruz, Tenerife.

by the usual route. From an elevated point on the road between the two towns the first view of the Peak (Pico de Teyde), which is not visible from Santa Cruz, was obtained. The middle part of the mountain was concealed by a dense bank of white clouds, the condensed vapour of the trade wind. Beneath, a broad valley stretching down to the bright blue sea with its snow-white edging of surf, was thrown partly into deep shadow by the cloud-bank, partly lit up by the bright hot sun, which shone brilliantly upon the snowy peak of the mountain, high up in the sky above the clouds. The town of Orotava was seen lying on the shore below.

Mr. Murray started for Orotava by stage-coach early on the 10th, and was followed later on the same day by the rest of the party. With the kind assistance of the British

Vice-Consul, all the arrangements were made for an ascent of the Peak on the following morning. The route lay up a long sloping ridge, which leads to the base of the actual cone of the Peak. This ridge is bounded by a precipice on the side facing Orotava. When a height of about 2000 feet had been attained, the villagers tried to dissuade the party from going farther, saying that all would be frozen to death.

The well-known zones of vegetation of the Peak of Tenerife are not very well defined on the ordinary route which was the one adopted. The limit of cultivation was reached at about 3000 feet, at which height corn of some kind was just springing up, and above this a zone was entered covered with a tree-like Heath (*Erica arborea*), which continued for about 2000 feet, and then ceased abruptly. A little higher up, the mountain side was somewhat sparsely covered by large bluish-green bushes of the species of Broom (*Spartocytisus nubigenus*), called by the natives "Retama," and well known from the accounts of numerous travellers; amongst these shrubs a tent was pitched, at an elevation of 6500 feet. Above the retama, a small Violet (*Viola teydea*) is said to extend up to 10,000 feet, and beyond this all is barren. The Pine (*Pinus canariensis*) which grows on some parts of the mountain is not seen on the usual track of ascent. A halt was made amongst the heath for lunch, and plenty of water cresses were found growing in a spring. Water had to be carried up from this spring, since there is none to be obtained above, except by melting snow, as the porous volcanic ashes soak up all the water yielded by the natural melting of the snow, and there is no place where any can collect. At about 4000 feet elevation a dense bank of cloud, formed by the trade wind, was passed through, a similar one to that which had been seen from below on the day before, and had hidden the middle of the mountain from view, but not the same, for in the early morning there had not been a cloud in the sky; the bank formed about mid-day. At the camp, far above this cloud-bank, the sun shone brightly, until about six o'clock in the evening, when it began to disappear, and the air, which had been almost too hot, became suddenly cold, the temperature going down almost to freezing point.

A very extraordinary sunset effect was observed. The upper surface of the cloud-bank stretched below in every direction, like a snow-white billowy sea hiding the actual sea from sight entirely, but just allowing a glimpse to be caught of the far-off island of Palma, which appeared as a purple streak at the edge of the cloud horizon. As the sun went down, the clear sky beyond the white motionless cloud-bank became tinged of a brilliant orange colour, and over it there shot out from the descending sun a fan of pale crimson streamers deeply tinted at their base, and gradually fading off into the dark blue sky above but visible nearly to the zenith. Beyond the great cloud-bank more distant streaky clouds, lit up of a brilliant violet, formed a sort of background to the scene. Some of these little distant clouds from time to time assumed fantastic shapes, and once it seemed almost certain that it was the sea in the distance that was seen below with

SHEET 5

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two very far-off ships upon it, but it was merely an illusion. The actual sea was entirely shut out from view, except once for a few seconds, when a small rift in the cloud-bank occurred and gave a momentary glimpse of the rippling surface far below, a sort of vista dimmed by the misty frame through which it was seen. All the while the snowy Peak itself was perfectly cloudless, and stood out clear and sharp against a deep blue arctic looking sky. Soon the sunlight faded, and the moon shone out brightly, and the Peak glistened in its light, which was strong enough to read by easily. The view of the tent and camp fire amongst the dark broom bushes, with the moonlit snowy Peak in the background, fronted by some dark ridges of lava, was most picturesque. Some of the large dry retama bushes were set fire to, and a glaring blaze was soon raised, the flames shooting high up into the air, so that they were seen at Orotava, and even as far as Santa Cruz. The ground was frozen on the surface around the tent during the night, the thermometer standing at 30° F. just before sunrise.

From the camp the party walked to the Cañadas—a remarkable plain covered with scoriæ, and shut in on nearly all sides by a perpendicular wall of basaltic cliff. From this plain of vast extent the present terminal cone of the mountain rises. The Cañadas represents an ancient and much larger crater, in the centre of the remnant of which the more modern smaller peak has been thrown up. The bottom of the Cañadas is dotted over with the retama bushes, but the ground is devoid of any other vegetation. Rabbits were found to be tolerably abundant, but were so wary that none were shot. They feed on the retama and make no holes, but live in any chance crack or hole in the rocks. The radiant heat of the sun was extremely powerful on the arid plain of the Cañadas. Both guides and mule drivers had deserted the party, refusing to accompany it at this season of the year to the top of the Peak. The ascent therefore was only accomplished to a height of about 9000 feet, the last 200 of which was climbed over snow. From this height were watched the often described struggles of the opposing winds, the trades and anti-trades, as shown by the eddying and twisting of the wreaths of cloud. In the neighbourhood of the camp, at 6500 feet, winter was evidently still in force as far as the animals were concerned. All the spiders and beetles found there were under stones, apparently hibernating.[1]

[1] The Rev. O. P. Cambridge writes—"The collection of spiders from Tenerife contains twenty-one species, of which twelve have been previously described, these are:—

Dysdera wollastoni, Bl.	*Argyrodes epeiræ*, Sim.
Zoropsis ochreata, C. L. Koch (immature).	*Tetragnatha extensa*, Linn.
Tegenaria derhamii, Scop.	*Epeira perplicata*, Cambr.
Scytodes thoracica, Latr.	*Cyrtophora opuntiæ*, Duf.
Pholcus phalangioides, Fuessl.	*Uloborus zosis*, Walck.
Steatoda versuta, Bl.	*Ocyale mirabilis*, Clk.

"The remaining species await further consideration; one or two seem to be new to science, the others may probably be referred to the following genera—*Segestria*, *Tegenaria*, *Theridion* (*Theridion pulchellum*, Bl. ?), *Linyphia*, *Xysticus*, *Lycosa*, The camp was moved, after remaining two nights at 6500 feet, to the spring at about 3500 feet altitude, called Fuente Pedro, amongst the arboreal heath, on the verge of the precipice bounding the ridge where lay the route of ascent. Here it was much warmer at night, and at daybreak the temperature was 45° F. But the descent had brought the party within the cloud-bank, and there was constant heavy rain. The steep side of the ridge overlooking Orotava is covered with a luxuriant vegetation of laurels, heaths, and ferns, and is very different in this respect from the comparatively barren surface of the slope above.

The rocks collected during this excursion were basaltic scoriæ, tephrite, trachyte, augite-andesite, phonolite, felspathic basalt, obsidian, and pumice.

The vessel returned to Santa Cruz on the 13th, and was rejoined by the party from the Peak, and, after the soundings off the town had been completed and rates for the chronometers obtained, left for St. Thomas Island, West Indies, at 7.30 P.M. on the 14th.

Methods of Observation at Sea.

From the date of departure from Tenerife the full routine course of scientific investigation systematically pursued during the remainder of the voyage was commenced. Hitherto soundings, temperatures, and dredgings had been taken more with a view of exercising the ship's company, and testing the apparatus supplied, than for scientific purposes; however, the labour was by no means thrown away, the results having been in some cases extremely valuable. Before, however, commencing the account of the work accomplished during the trip, it will be necessary to give a detailed description of the methods employed to obtain accurate soundings, temperatures, &c., &c., and in doing so the whole subject will be treated as viewed from the experience gained throughout the voyage, instead of describing the modifications introduced with a view of increasing the accuracy of the results, or decreasing the labour expended in obtaining the observations.

and *Menemerus*. *Argyrodes epeiræ* was doubtless found in the mazy snares of *Cyrtophora opuntiæ*, of which several examples are in the collection. The thoroughly European character of the above list is very strongly marked."

Mr. Edgar A. Smith gives the following list of Helicidæ collected at Tenerife:—

1. *Vitrina lamarckii*, Fér.	8. *Helix lenticula*, Fér.
2. *Zonites cellaria*, Müll.	9. „ *fortunata*, Shuttl.
3. *Helix malleata*, Fér.	10. „ *pavida*, Mouss.
4. „ *adansoni*, Webb and Berth.	11. „ *phalerata*, Webb and Berth.
5. „ *lactea*, Müll.	12. „ *lancerottensis*, Webb and Berth.
6 „ *apicina*, Lamk.	13. „ *lineata*, Olivi.
7. „ *circumsessa*, Shuttl.	14. *Bulimus tarnerianus* (juv. ?), Grasset.

Of these Nos. 2, 5, 6, 8, 12, 13 are not restricted to the Canaries, but range either to North Africa or Europe (see Wollaston's Testacea Atlantica). Two small specimens of *Limax canariensis*, d'Orb., were also collected at this locality, apparently only half grown (*Proc. Zool. Soc. Lond.*, p. 276, 1884).

Three species of Lizards were brought from Tenerife, *Tarentola delalandii*, *Lacerta galloti*, and *Lacerta muralis*.

Sounding.—The apparatus used to obtain soundings consisted of—(1) a deep-sea sounding line; (2) a reel on which this line was kept; (3) a number of sinkers; (4) an apparatus for detaching the sinkers when they reached the bottom, technically termed a sounding rod; (5) some iron wire and discs to attach the sinkers to the disengaging

FIG. 12.—Dredging and Sounding arrangements on board the Challenger.

apparatus during their descent; (6) a number of india-rubber bands, technically termed accumulators; and (7) some iron gin-blocks with patent sheaves for the line to reeve through.

Sounding Lines.—Two kinds of sounding line were supplied, the first being 1 inch in circumference, with a breaking strain of 14 cwt. (called No. 1 line), and the second being $\frac{3}{4}$ inch in circumference, with a breaking strain of 10 cwt. (called No. 2 line). These lines were made of the best Italian hemp, well hackled and rubbed down, to prevent any ragged parts projecting outside and increasing the friction of the cordage during its descent through the water; they were made in lengths of about 120 fathoms each, a number of which were spliced together so as to form a connected line of 3000 fathoms, which was marked at every 25 fathoms, the 25 and 75 fathom marks being white, the 50 fathom marks red, and the 100 fathom marks blue. The material used for marking was worsted, and the number of 100 fathoms was indicated by tucking this worsted under and over the strands of the rope, one tuck for every 100 fathoms up to 1000 fathoms, and then again commencing at 1100 fathoms with one tuck. The whole length of 3000 fathoms was kept on one reel, so that it might run out uninterruptedly, the first 25 fathoms being doubled, as they had to bear the strain of lifting the sinkers over the side. The object of marking the line with worsted "tucked in" was to prevent any projections rendering it liable to foul, either in the blocks or on the drum when heaving in.

Great care was necessary in splicing the lengths of the sounding line together, as if too short a "long splice" were made it was very apt to draw, in consequence of the line being laid up slackly to increase its strength and pliability.

Owing to some defect in its construction, the No. 2 line was found unequal to the strain it was intended to bear, so that it parted in "heaving in," and therefore, after a few trials, it was entirely discarded for deep-sea soundings, the No. 1 line, which was of excellent quality, being exclusively used. The cost of this line was £10, 5s. 6d. per 1000 fathoms, and its weight per 100 fathoms was 18 lbs. 9 oz. in air and 8 lbs. in water.

Sounding Reels.—The reel on which the 3000 fathoms of sounding line was kept, was 5 feet in length, and, with the line on it, $2\frac{1}{2}$ feet in diameter. The heart of the reel was 5 inches in diameter, and through its centre was driven an iron rod, which projected at each end so as to form an axle. Extending out from, and firmly fixed to, the ship's side, on the forecastle, were iron cranks on which these axles rested and revolved, so that the reel could be turned easily and smoothly. To prevent the sounding line becoming entangled in the axle or cranks, a wooden disc, $2\frac{1}{2}$ feet in diameter, was fitted at each end of the reel, and one of these discs was grooved, so that by passing a gasket over it, one end of which was attached to the ship's side, and the other end held in a man's hand, the revolutions of the reel could be retarded when the impetus given by the pitching or rolling of the ship would otherwise have caused it to revolve too quickly.

The Sinkers.—Each sinker was of cast-iron, 56 lbs. in weight, cylindrical in form, with a hole through its centre, and a groove on each side; on its upper surface were fitted two studs, and on its lower were two holes, so that when one sinker was placed upon another the studs on the upper surface of the one fitted into the holes on the under surface of the other, and the holes through their centres, as well as the grooves at their sides, coincided. (See Baillie sounding machine, fig. 14 B.)

Sounding Machines.—Two kinds of apparatus for detaching the sinkers were supplied; one the Hydra rod, before leaving England, and the other, the Baillie rod, at the Cape Verde Islands.

The Hydra rod (so called from its having been made by the blacksmith of H.M.S. "Hydra," as an improvement on Brooke's rod, the American invention) is a cylinder of brass tubing $1\frac{1}{3}$ inches in diameter and $3\frac{1}{2}$ feet in length (see fig. 13), having at its bottom B a butterfly valve, and at its top a sliding iron rod C $2\frac{1}{2}$ feet in length. On the upper part of this iron rod is a small stud D, with a spring that reaches out to the head of the stud when there is no pressure on it. The sinkers were attached to the rod, and on reaching the bottom they were disengaged. To attach the sinkers, an iron disc or washer E with a hole through it (of a slightly larger diameter than the cylinder of the sounding-rod) was placed over one of the holes in a grating; a piece of wire (No. 9 gauge), two fathoms in length, was fastened at each end to this disc, and the bight of the wire was left standing up; on the top of the iron disc a sinker was placed so that the hole through its centre corresponded precisely with that in the disc and grating; other sinkers F were now added until the weight was sufficient for the supposed depth of water, two sinkers, or 1 cwt., being generally allowed for each thousand fathoms. When the requisite number had been placed in position, one on another, the rod was passed through the hole in their centres, and through the iron disc at the bottom, and the bight of the wire attached to the disc was placed over the stud D on the upper part of the rod (the spring being fastened back with a piece of twine to facilitate this operation), and the rod A on being lifted raised with it, by means of the wire on the stud, the sinkers which were kept in their places by the rod passing through their centres, and by the wire fitting into the grooves at their sides. When the full weight of the sinkers was on the stud, the twine which confined the spring was cut so that it was then only kept back by the weight of the sinkers on the wire. On reaching the bottom the weight of the sinkers no longer rested on the wire, so that the spring pushed it off the stud, and the sounding rod was thus relieved from the weights; the disc, wire, and sinkers being left at the bottom.

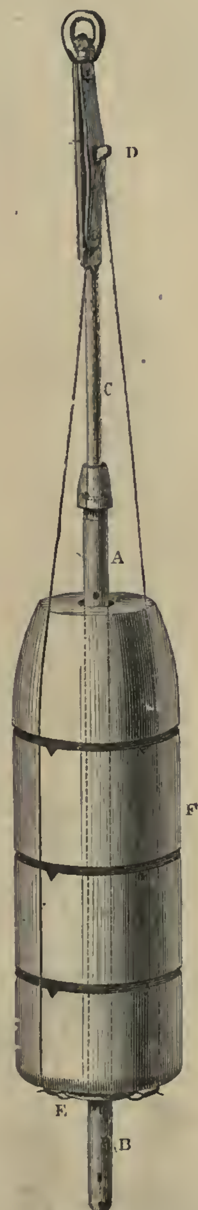


Fig. 13.—Hydra Sounding Machine.

It will be evident from this description that the whole secret of the successful disengaging of the weights at the bottom rests on the spring of the rod being nicely adjusted as to strength—that is, it must not be so strong as to push the wire off the stud directly a portion of the weight of the sinkers is removed by letting go the line, and it must be strong enough to spring sharply back into its place directly the whole weight is removed. The system adopted was to ease the sinkers down without jerks for about 400 or 500 fathoms, so that when the line was eventually let go the friction of the 500 fathoms of cordage passing through the water above the rod was sufficient to keep the requisite strain on the spring. By letting go the line suddenly when the sinkers were near the surface, they were found frequently to disengage at once.

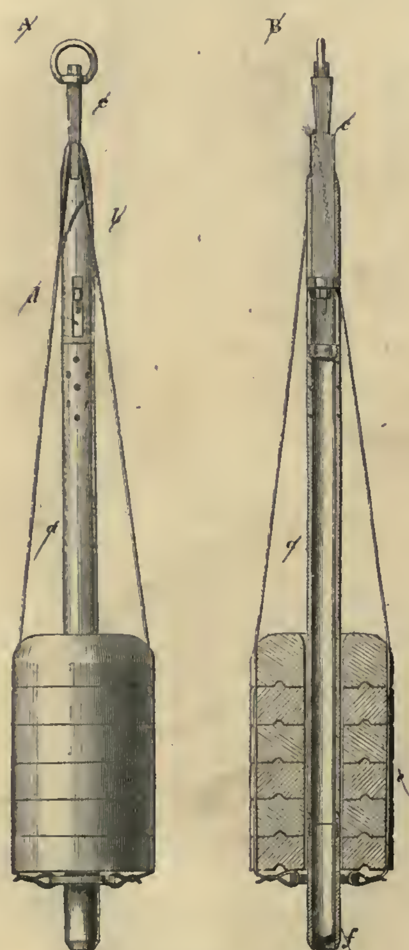


Fig. 14.—Baillie Sounding Machine.

The Baillie rod (which is an invention of Navigating Lieutenant Baillie, R.N.) is a much better apparatus than the Hydra rod, as the arrangement for disengaging the sinkers is entirely independent of springs. It consists of an iron cylinder with a butterfly valve at the bottom *f* and a brass tube *b* on the top, which screws on to the cylinder (see fig. 14). The brass tube is bevelled at its upper end, and in it is a cylindrical iron weight *c* which slides backwards and forwards, the length of movement being regulated by a slit *d* cut in the side of the brass tube *b*, through which a stud, fastened on to the weight, projects. Attached to the upper part of the weight is a flat bar of iron, which protrudes through another slit, cut in the pointed top of the brass tube, and this bar moves in or out as the weight is moved backwards or forwards. The upper part of the flat bar is narrowed abruptly so as to form two shoulders, and the distance of these shoulders from the weight is so regulated that when the stud fastened to it is at the upper end of the slit these shoulders are above the brass tubing, but when the weight falls down, and the stud rests on the lower end of the slit, they are concealed by the tubing, which thus forms a sort of sheath for the shoulders. The upper part of the bar is furnished with a ring to facilitate the attachment of the lead line. When the sounding rod is lifted by this ring the weight inside the brass tubing is pulled up until the stud fastened to it is at the upper end of the slit at the side of the tubing, and consequently the shoulders on the iron bar are above the head of their conical sheath, and so long as the rod is suspended by the ring they remain in that position; directly, however, the rod is placed upright on the ground, and the power which suspended it is relaxed, the weight inside the tube falls down until the stud fastened to it is at the bottom of the slit, and the shoulders on the flat bar are concealed in their sheath.

The method of using this apparatus was to pass the iron cylinder through the hole in the centre of the sinkers, in a similar way to that in which the Hydra rod was rove, to suspend the rod by the ring, and then place the bight of the wire attached to the disc under the sinkers, over one of the shoulders of the flat iron bar. The apparatus was then ready for lifting over the side, the sinkers being suspended from the shoulders of the iron bar, which remained outside its sheath as long as the whole apparatus was hung by the ring. When the rod reached the bottom, the lower end of the cylinder touching the ground, and the sounding line above being relaxed, the weight in the brass tube fell down and the shoulder disappeared in its sheath, so that the wire which suspended the sinkers was pushed off and the rod thus became freed from the weights. The shoulder over which the suspending wire was placed was slightly hollowed to prevent the wire being knocked off as the apparatus was hoisted over the side. Care was requisite in making this hollow, for, if too deep, the wire was apt to jam between the outer part of the shoulder and the brass tubing. The Baillie rod, which weighed 35 lbs., only failed once in the Challenger, and then not from any fault of construction, but from the wire being caught by the spout of the slip water bottle which descended on the rod. To facilitate collecting the mud brought up by the tubes their lower ends were made to unscrew. The tube of the Baillie rod was $2\frac{1}{2}$ inches in diameter, and was usually made to project 15 inches beneath the weights. A substantial valve of some sort is necessary to prevent the bottom samples falling out when the tube is being brought on board. When, however, the bottom is a tenacious clay, no valve is required, as the rod, without a valve, frequently brought up a section of the bottom 2 feet in depth. A valve is always a great impediment to the entrance of the mud into the tube.

It would be a great improvement so to arrange the Baillie tube that the weight should be more effectually utilised in pushing it into the ground, as it is of importance to procure samples of the deposits below the superficial layer (see page 118).

The Accumulators.—The accumulators are india-rubber bands $\frac{3}{4}$ of an inch in diameter and 3 feet in length, having at each end a thimble "seized in" (fig. 15 A). They are used to prevent any sudden jerks arising from the pitching or rolling of the ship, bringing an undue strain on the sounding line. They are capable of stretching 17 feet, when they each exert a force of 70 lbs.; beyond this they should not be stretched, as they are then liable to "carry away." When stretched 13 feet they each exert a force of 56 lbs.

Forty of these accumulators were found sufficient for sounding purposes in the Challenger, as they were strong enough to withstand the strain of the sinkers on the

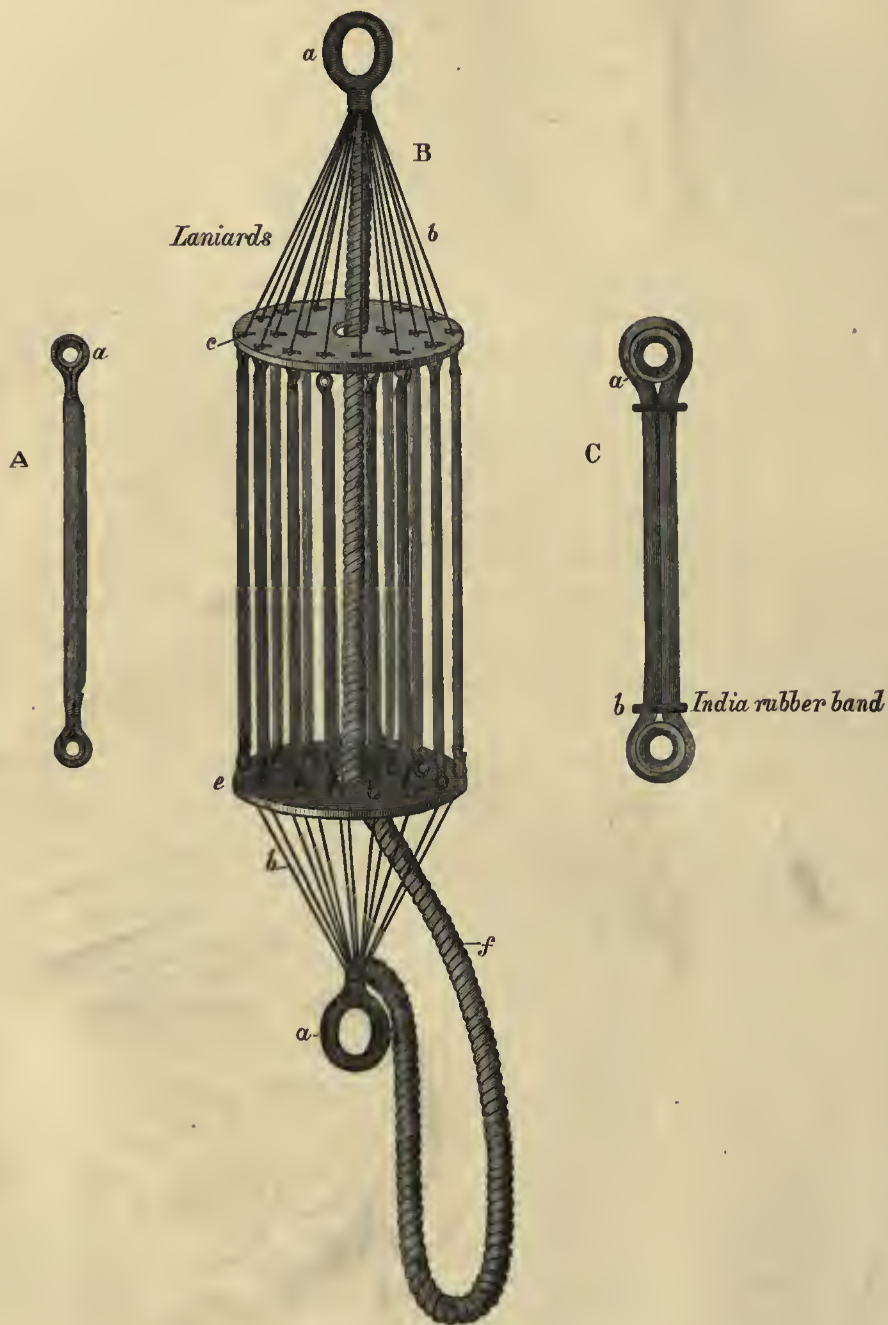


FIG. 15.—The Accumulator.

lead line without being too strong to give readily with the motion of the ship. In order to combine these forty accumulators so that they should exert a force proportionate to their number, they were attached to two discs of wood by laniards spliced into the thimbles at each end. These laniards were passed through corresponding holes in the upper and lower wooden disc, and were then collected together and formed into an eye at top and bottom, so that a rope could be "bent on," or a block "hooked on," to these eyes. To keep the discs at right angles to the line of accumulators the eyes of the splices which fastened the laniards to the thimbles were made sufficiently long to come through the disc, so that a small toggle driven in through these eyes, on the upper part of the disc, wedged it in its place (see fig. 15 B). To prevent the accumulators being by any accident stretched to such a length as would render them liable to break, a short piece of 4-inch rope was rové through a large hole in the centre of the wooden discs and spliced into the eyes formed at each end by the accumulated laniards, and the length of this rope was regulated so as to allow the accumulators to stretch 15 feet, after which any additional strain, which would otherwise have been borne by them, was borne by this preventor rope.

It was found by experience that, owing to the compression of the india-rubber by the seizings used to secure the copper thimbles at each end, the accumulators occasionally broke just below the compressed part. In order to remedy this defect Captain Nares suggested to the maker that he should construct the accumulators in the form of a ring, and put a wooden thimble in each bight, securing it there with a small india-rubber band, as shown in fig. 15 C. Some accumulators made in this manner were forwarded for trial, and were found to answer exceedingly well; being doubled only half the number were required, and this reduced the number of laniards securing them together, which was a great advantage. It was also found that nothing damaged the accumulators so much as smoke from the funnel; during the first eighteen months of the commission, when Welsh coal was in use, they suffered little or no damage, but when Australian coal was burnt the smoke dried up and ruined them very quickly.

The Gin-Blocks.—The blocks used for sounding purposes were 9-inch gin-blocks with patent sheaves. The sheaves were made to fit close to the shell of the block, so as to prevent the sounding line getting between the sheave and block.

Method of Sounding.—When a sounding was required steam was got up and all sail shortened and furled except the spanker. This proceeding was indispensable, as no trustworthy soundings could be obtained from the ship under sail, even in the calmest weather, the heave of the sea, or the surface current, being sufficient to drift her in a very short time a considerable distance from the place where the lead was originally let go, and thus prevent the line from running out perpendicularly. Sail being shortened and steam up, the ship was brought head to wind and the sounding gear got ready, as shown in fig. 16. A block A was secured to the foreyard a little outside the boom-iron, and a whip rove through it to trice up the set of accumulators B. At the bottom of the accumulators a 9-inch gin-block C was hooked with the sounding line rove through it and secured to the sounding rod and sinkers D. To the line immediately above the sounding apparatus was attached a water bottle E, and above the water bottle two, or sometimes three, thermometers (these instruments will be described subsequently), and a pressure gauge F. The whole apparatus ready for sounding is shown in the figure, but it

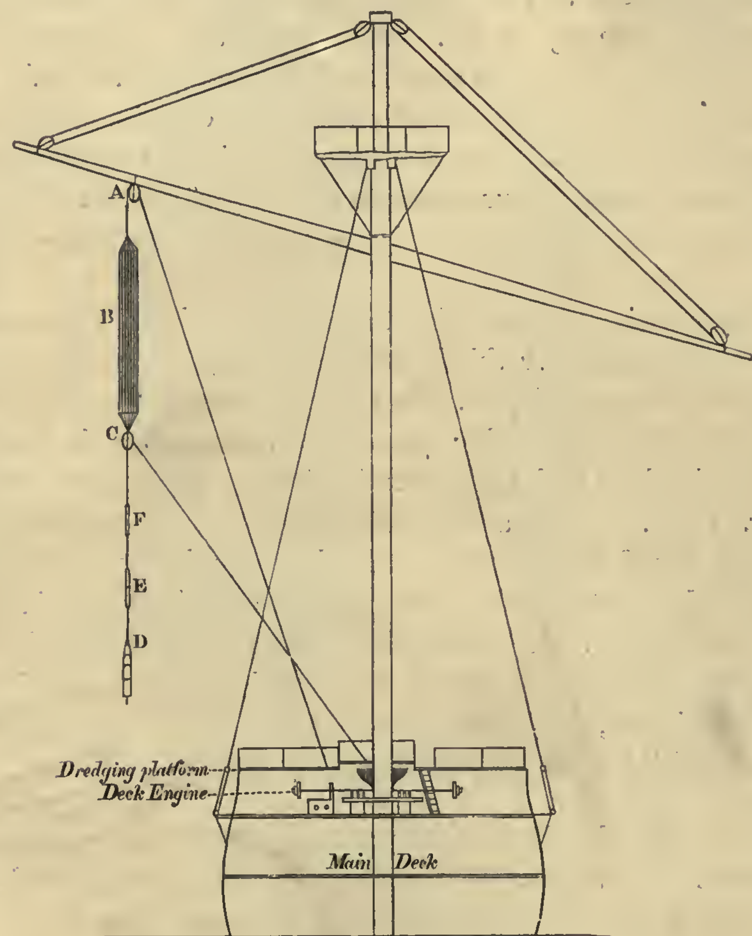


FIG. 16.—Diagram to illustrate the method of Sounding.

must be explained that, owing to the constant motion of the ship, the sounding rod and sinkers were lowered into the water directly they were lifted over the side to prevent their swaying backwards and forwards with the risk of doing considerable damage, and the water bottle and other instruments were attached after the sinkers were in the water. Before the sounding line was bent on to the rod it was rove through a thimble at the end of a lizard, so that the bight of the line could at any time be hauled in close to the dredging platform.

When all the instruments had been attached to the line it was eased down 400 or 500 fathoms by being passed round the drum of the donkey-engine, which was fitted with a break for this purpose. When that amount of line had been eased out it was allowed to descend freely, the ship being kept exactly over the spot where the sinkers entered the water. As the line ran out the exact time each 100 fathom mark entered the water was registered and entered in its appropriate column in a book provided for that purpose, and the interval between these times was calculated and entered in another column. These intervals gradually increase in length as the depth increases, the sinkers being retarded in their descent by the friction of the line as it passes through the water, which increases with the amount of line paid out; they will, however, be found to increase in regular proportion as long as the sinkers are descending, but directly they reach the bottom there will be a sudden lengthening of these intervals, as then only

TABLE *showing the Mean Rate of Descent of Sounding Lines with Weights of 3 and 4 cwt. attached.*

No. 1 line with 3 cwt. attached.			No. 1 line with 4 cwt. attached.	
Interval.	Time each 100 fathom mark entered water.	Depth in fathoms.	Time each 100 fathom mark entered water.	Interval.
m. s.	h. m. s.		h. m. s.	m. s.
...	9 0 0	500	9 0 0	...
1 8	1 8	600	0 59	0 59
1 13	2 21	700	2 1	1 2
1 18	3 39	800	3 7	1 6
1 23	5 2	900	4 17	1 10
1 28	6 30	1000	5 31	1 14
1 33	8 3	1100	6 49	1 18
1 37	9 40	1200	8 11	1 22
1 41	11 21	1300	9 37	1 26
1 44	13 5	1400	11 7	1 30
1 47	14 52	1500	12 40	1 33
1 50	16 42	1600	14 16	1 36
1 52	18 34	1700	15 55	1 39
1 54	20 28	1800	17 37	1 42
1 56	22 24	1900	19 22	1 45
1 58	24 22	2000	21 10	1 48
2 1	26 23	2100	23 1	1 51
2 3	28 26	2200	24 54	1 53
2 5	30 31	2300	26 49	1 55
2 7	32 38	2400	28 46	1 57
2 10	34 48	2500	30 45	1 59
2 12	37 0	2600	32 46	2 1
2 14	39 14	2700	34 49	2 3
2 16	41 30	2800	36 54	2 5
2 18	43 48	2900	39 1	2 7
2 20	46 8	3000	41 10	2 9

the weight of the sounding line plus the impetus given it by the descending sinkers will be dragging the line off the reels. Directly, therefore, a sudden lengthening of the intervals was observed it was known that the sinkers were at the bottom, and the heaving in of the line was commenced by bringing it to the drum of the donkey-engine. Care was taken not to heave up too quickly at first, and also to keep the ship carefully in position over the line, for if allowed to fall off, the wind drifting her to leeward, brought an unnecessary strain on the sounding line. When hove up, the water bottle and thermometers were taken off, and the lower part of the cylinder of the sounding rod unscrewed and its contents carefully preserved.

The preceding table shows the rate of descent of the sounding lead from 500 to 3000 fathoms, and being the mean of a great number of observations, will probably be useful to surveyors taking deep-sea soundings with apparatus similar to that used on board the Challenger, as any great difference from the numbers therein given would show either that the weights were at the bottom, that the line was incorrectly marked, or that a current was affecting it.

The time-intervals observed in seven of the exceptionally deep casts obtained by the Challenger are given in the following tables, from 1000 fathoms to the depth obtained; five of them with 4 cwt., and two with 3 cwt., of sinkers attached.

It may be as well to remark here that although only the time each 100 fathom mark entered the water, and the intervals between these times are given in these tables, in actual practice the time each 50 fathom mark entered the water was registered when 2000 fathoms of line had been paid out, and the time each 25 fathom mark entered the water when 3000 fathoms had run out, so that it was possible to detect at once when the sinkers reached the bottom.

[Table of Challenger Soundings.

TABLE *of Challenger Soundings at Depths exceeding* 3000 *Fathoms with* 3 *cwt. of Sinkers.*

Depth in Fathoms.	Wednesday, 26th March 1873. Wind, E^bN. Force, 4. Weather, bc. Sea, moderate. Line, No. 1. Machine, Hydra. Lat. 19° 41′ N., long. 65° 7′ W.			Tuesday, 23rd March 1875. Wind, E^bN. Force, 4. Weather, bcp. Sea, swell from ENE. Line, No. 1. Machine, Baillie. Lat. 11° 24′ N., long. 143° 16 E.			REMARKS.
	Time each 100 fathom mark entered water.	Interval.	Average interval, see p. 65.	Time each 100 fathom mark entered water.	Interval.	Average interval, see p. 65.	
	h. m. s.	m. s.	m. s.	h. m. s.	m. s.	m. s.	
1000	6 42 48	1 36	1 28	6 1 30	...	1 28	
1100	44 25	1 37	1 33	3 0	1 30	1 33	
1200	46 3	1 38	1 37	5 0	*2 0	1 37	* Line checked slightly.
1300	47 45	1 42	1 41	7 12	*2 12	1 41	
1400	49 32	1 47	1 44	8 43	1 31	1 44	
1500	51 20	1 48	1 47	10 22	1 39	1 47	
1600	53 12	1 52	1 50	12 4	1 42	1 50	
1700	55 7	1 55	1 52	13 52	1 48	1 52	
1800	57 5	1 58	1 54	15 43	1 51	1 54	
1900	59 2	1 57	1 56	17 41	1 58	1 56	For explanation of the letters used to denote the state of the weather, see Narr. Chall. Exp., vol. ii. p. 301, 1882.
2000	7 1 6	2 4	1 58	19 47	2 6	1 58	
2100	3 8	2 2	2 1	21 54	2 7	2 1	
2200	5 13	2 5	2 3	24 15	2 21	2 3	
2300	7 24	2 11	2 5	26 28	2 13	2 5	
2400	9 38	2 14	2 7	28 32	2 4	2 7	
2500	11 53	2 15	2 10	30 40	2 8	2 10	
2600	14 11	2 18	2 12	33 4	2 24	2 12	
2700	16 26	2 15	2 14	35 25	2 21	2 14	
2800	18 37	2 11	2 16	37 56	2 31	2 16	
2900	20 59	2 22	2 18	40 13	2 17	2 18	
3000	23 26	2 27	2 20	checked	...	2 20	
3100	25 45	2 19	...	52 53	...	...	
3200	28 11	2 26	...	55 1	2 8	...	
3300	30 38	2 27	...	57 10	2 9	...	
3400	33 5	2 27	...	59 30	2 20	...	
3500	41 40	checked	...	7 1 48	2 18	...	
3600	44 20	2 40	...	4 3	2 15	...	
3700	47 12	2 52	...	6 26	2 23	...	
3800	57 22	checked	...	8 52	2 26	...	
3900	8 0 19	2 57	...	11 25	2 33	...	
4000	4 39	4 20	...	13 57	2 32	...	
4100	...	...	...	16 36	2 39	...	
4200	...	...	...	19 1	2 25	...	
4300	...	...	...	21 25	2 24	...	
4400	...	...	...	23 51	2 26	...	
4500	...	...	...	26 20	2 29	...	
4600	...	...	...	...	...	...	
4700	...	...	...	...	...	...	
4800	...	...	...	...	...	...	
4900	...	...	...	...	...	...	
5000	...	...	...	...	...	...	

TABLE *of Challenger Soundings at Depths exceeding* 3000 *Fathoms with* 4 *cwt. of Sinkers.*

Depth in Fathoms.	Wednesday, 26th February 1873. Wind, E. Force, 6. Weather, bc. Sea, moderate. Line No. 1. Machine, Hydra. Lat. 23° 23′ N., long. 35° 11′ W.			Tuesday, 11th March 1873. Wind, E. Force, 4·5. Weather, bc. Sea, smooth. Line No. 1. Machine, Hydra. Lat. 19° 15′ N., long. 57° 47′ W.			Thursday, 13th March 1873, Wind, EbS. Force, 4·5. Weather, bc. Sea, smooth Line No. 1, Machine, Hydra. Lat. 18° 54′ N., long. 61° 28′ W.			Tuesday, 23rd March 1875. Wind, EbN. Force, 4. Weather, bcp. Sea, swell from ENE. Line No. 1. Machine, Baillie. Lat. 11° 24′ N., long. 143° 16′ E.			Friday, 18th June 1875. Wind, SSW. Force, 5·6. Weather, ocdf. Sea, swell from SW. Line No. 1. Machine, Baillie. Lat. 35° 18′ N., long. 144° 8′ E.			REMARKS.
	Time each 100 fathom mark entered water.	Interval.	Average interval, see p. 65.	Time each 100 fathom mark entered water.	Interval.	Average interval, see p. 65.	Time each 100 fathom mark entered water.	Interval.	Average interval, see p. 65.	Time each 100 fathom mark entered water.	Interval.	Average interval, see p. 65.	Time each 100 fathom mark entered water.	Interval.	Average interval, see p. 65.	
	h. m. s.	m. s.	m. s.	h. m. s.	m. s.	m. s.	h. m. s.	m. s.	m. s.	h. m. s.	m. s.	m. s.	h. m. s.	m. s.	m. s.	
1000	11 45 0	1 24	1 14	1 45 55	1 22	1 14	2 33 19	1 20	1 14	10 54 21	...	1 14	...	...	1 14	For explanation of the letters used to denote the state of the weather, see Narr. Chall. Exp., vol. ii. p. 301.
1100	46 25	1 25	1 18	47 17	1 22	1 18	34 42	1 23	1 18	55 36	1 15	1 18	...	...	1 18	
1200	47 50	1 25	1 22	48 40	1 23	1 22	36 5	1 23	1 22	56 57	1 21	1 22	11 39 17	...	1 22	
1300	49 12	1 22	1 26	50 8	1 28	1 26	37 31	1 26	1 26	58 24	1 27	1 26	41 2	1 45	1 26	
1400	50 37	1 25	1 30	51 36	1 28	1 30	38 59	1 28	1 30	11 0 1	1 37	1 30	42 43	1 41	1 30	
1500	52 5	1 28	1 33	53 11	1 35	1 33	40 33	1 34	1 33	1 41	1 40	1 33	44 26	1 43	1 33	
1600	53 45	1 40	1 36	54 48	1 37	1 36	42 11	1 38	1 36	3 23	1 42	1 36	46 6	1 40	1 36	
1700	55 21	1 36	1 39	56 30	1 42	1 39	43 50	1 39	1 39	5 5	1 42	1 39	49 46	checked	1 39	
1800	57 2	1 41	1 42	58 12	1 42	1 42	45 33	1 43	1 42	6 44	1 39	1 42	51 27	1 41	1 42	
1900	58 41	1 39	1 45	59 59	1 47	1 45	47 18	1 45	1 45	8 24	1 40	1 45	53 23	1 56	1 45	
2000	12 0 25	1 44	1 48	2 1 45	1 46	1 48	49 1	1 43	1 48	10 11	1 47	1 48	55 24	2 1	1 48	
2100	2 12	1 47	1 51	3 33	1 48	1 51	50 46	1 45	1 51	12 2	1 51	1 51	57 23	1 59	1 51	
2200	3 53	1 41	1 53	5 26	1 53	1 53	52 42	1 56	1 53	14 0	1 58	1 53	59 22	1 59	1 53	
2300	5 55	2 2	1 55	7 20	1 54	1 55	54 36	1 54	1 55	15 55	1 55	1 55	12 1 22	2 0	1 55	
2400	7 50	1 55	1 57	9 12	1 52	1 57	56 39	2 3	1 57	17 55	2 0	1 57	3 24	2 2	1 57	
2500	9 50	2 0	1 59	11 9	1 57	1 59	58 38	1 59	1 59	20 0	2 5	1 59	5 20	1 56	1 59	
2600	11 40	1 50	2 1	13 11	2 2	2 1	3 0 38	2 0	2 1	22 14	2 14	2 1	7 16	1 56	2 1	
2700	13 40	2 0	2 3	15 12	2 1	2 3	2 41	2 3	2 3	24 21	2 7	2 3	checked	...	2 3	
2800	15 43	2 3	2 5	17 22	2 10	2 5	4 48	2 7	2 5	26 15	1 54	2 5	12 3	...	2 5	
2900	17 45	2 2	2 7	19 32	2 10	2 7	6 56	2 8	2 7	28 14	1 59	2 7	13 54	1 51	2 7	
3000	19 50	2 5	2 9	21 45	2 13	2 9	9 7	2 11	2 9	30 37	2 23	2 9	17 53	checked	2 9	
3100	21 53	2 3	...	24 59	3 14	...	12 6	2 59	...	36 15	checked	...	19 36	2 3	...	
3200	24 45	2 52	...	...	...	...	...	...	...	38 14	1 59	...	21 35	1 59	...	
3300	...	...	...	...	...	...	...	...	...	40 23	2 9	...	23 24	1 49	...	
3400	...	...	...	...	...	...	...	...	...	42 36	2 13	...	26 40	3 26	checked	
3500	...	...	...	...	...	...	...	...	...	48 38	checked	...	28 24	1 44	...	
3600	...	...	...	...	...	...	...	...	...	50 43	2 5	...	30 12	1 48	...	
3700	...	...	...	...	...	...	...	...	...	52 57	2 14	...	31 58	1 46	...	
3800	...	...	...	...	...	...	...	...	...	55 15	2 18	...	33 48	1 50	...	
3900	...	...	...	...	...	...	...	...	...	12 0 10	checked	...	35 50	2 2	...	
4000	...	...	...	...	...	...	...	...	...	2 20	2 10	...	38 32	2 42	...	
4100	...	...	...	...	...	...	...	...	...	12 4	checked	...	...	...	...	
4200	...	...	...	...	...	...	...	...	...	14 34	2 30	...	...	...	...	
4300	...	...	...	...	...	...	...	...	...	16 58	2 24	...	...	...	...	
4400	...	...	...	...	...	...	...	...	...	19 20	2 22	...	...	...	...	
4500	...	...	...	...	...	...	...	...	...	22 3	2 43	...	...	...	...	
4600	...	...	...	...	...	...	...	...	...	25 51	3 48	...	...	...	...	
4700	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
4800	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
4900	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
5000	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	

The sounding machine and disengaging sinkers were only used when there was reason to expect a depth of over 1000 fathoms; for lesser depths either a valve or cup lead of 56 lbs., 112 lbs., or 168 lbs. was used, and the apparatus was recovered.

The Cup Lead (see fig. 17) is an ordinary deep-sea lead A, having at its lower end an iron spike C driven in; at the bottom of this spike is an inverted hollow iron cone B,

FIG. 17.—The Cup Lead.

FIG. 18.—The Valve Sounding Lead.

and above the cone is a sliding iron disc D movable up and down the spike between the lead and the top of the cone, and just large enough to cover the opening of the cone when resting on it. During the descent of the lead the disc is raised off the cone by the friction of the water, so that when the bottom is reached the cone penetrates and is filled with the mud or other material it encounters, and as the lead is raised to the surface the friction of the water forces down the sliding disc D on to the top of the cone B and prevents any of its contents being washed out.

The Valve Lead (see fig. 18) is an ordinary deep-sea lead, fitted at its base so that an iron cylinder A with a butterfly valve B at the bottom can be screwed on to it. It was found to be by far the best form of lead for ordinary sounding work, and the cylinder unscrewing enabled the contents to be collected expeditiously and without loss.

Wire Rope.—At the time when the Challenger was fitted out, Sir William Thomson had revived the subject of sounding in deep water with wire in place of hemp, and before the ship left England an apparatus of his was put on board. During the absence of the Challenger on her voyage, this method was energetically and successfully developed by Sir William Thomson, and being adopted by the American surveyors in the "Tuscarora" under Captain Belknap, and later by Captain Sigsbee, it is now universally used for rapid sounding in deep water. The great extension of oceanic telegraphy rendering detailed surveys of the various routes necessary, materially assisted in this development, and for this purpose the method is admirably adapted. The advantage which the wire possesses over the hemp is the rapidity with which the operation can be conducted, owing to the very slight friction of the wire against the water. In telegraph ships this is taken advantage of to its utmost limits, and as nothing is risked but a sinker and a length of wire, but little heed is paid to the parting of a wire. The work of the Challenger, however, was very different. It is true that at every station the depth had to be ascertained, but this was only a small part of the work, and a saving of half an hour in the operation, even if it could have been effected without risk, would have been unimportant. On the same line with which the depth was ascertained were attached deep-sea thermometers and piezometers, also one, and sometimes two, water bottles, together making up a heavy and valuable load, the loss of which, though only occasionally, would not have been compensated by any saving of time. In view, therefore, of the special character of the work assigned to the Challenger, and of the great value of the instruments used, and also of the fact that the captain and officers of the ship were thoroughly acquainted with the use of hemp for sounding and other investigations at great depths, while the programme of the voyage did not admit of time being spent in the development of a method adapted for a different style of work, hemp line was invariably used throughout the cruise, and with unvarying success. After the rejection of the No. 2 sounding line, there were few accidents, and during the last two years of the voyage neither a fathom of line nor an instrument was lost in deep sounding. The great disadvantage of wire arises from its liability to break, owing to circumstances independent of the strain to which it is exposed. A hemp line may be bent and twisted in any way without its strength being at all affected. With wire it is otherwise; it must never suffer a sharp bend, twist, or kink; if it do its strength is gone, and if the damaged part be not cut out an accident is sure to occur. Where steam power is not available for heaving up, the wire possesses a very great advantage, for it can be easily worked, even at very great depths, by hand.

Captain Belknap of the U.S.S. "Tuscarora," who in 1874 sounded out the route from San Francisco to Japan, and in so doing surveyed the deepest water in the world, did all his sounding by hand. His successor Captain Sigsbee, the author of the admirable volume on deep-sea sounding and dredging,[1] devised and constructed an elaborate wire-sounding apparatus with steam power, especially adapted for scientific work. More recently, Captain Magnaghi, Hydrographer to the Italian Navy, has fitted his ship the "Washington" throughout with wire, not only for deep-sea work, but for ordinary harbour surveying, all the boats used in this work being fitted with small stages for the wire sounding reel.

It is evident, then, that in the twelve years which have elapsed since the Challenger cruise began, the use of wire for sounding purposes has received enormous development. For purposes of deep-sea investigation, however, which includes actual sounding only as one of its items, good hemp sounding line is still indispensable. It is of course necessary to have steam power for working the line. With it in depths up to 500 or 600 fathoms hemp is better for all purposes than wire, and is equally expeditious, for a sinker can be used to make it descend nearly as quickly as wire, and with instruments attached it can be hove in with safety more rapidly from such depths than wire. Deep-sea thermometers which have been carefully compared with a standard, and which have been used in many soundings, are instruments of very great value, and if lost, are not replaced by the purchase of new ones. Further, it is important at every station to observe the temperature at as many different depths as possible. Where wire, with its liability to break, is used, it is very imprudent to use more than one or two valuable thermometers at a time, while with hemp, which is almost absolutely free from risk of rupture, eight or ten thermometers may be sent down at once. Therefore to obtain, with safety, the same number of observations with the wire, would require the operations of sinking and heaving in to be repeated a greater number of times than with the hemp; and as a thermometer must be allowed a certain time to take the temperature of the water, it is evident that for such work the wire is in the end not more expeditious than the hemp.

With regard to *dredging*, which formed so important a part of the Challenger's work, there can be no doubt of the great superiority of wire over hemp rope. The advantage in point of rapidity of work and of saving in stowage is much greater than in the case of sounding. Here we are indebted for a scientific instrument to the enterprise of those engaged in the manufacture of telegraph cables, for it is owing to the development of this industry that there is now a regular manufacture of the beautifully flexible steel-wire hawsers which are now to be found on board almost every well-appointed ship.

[1] Sigsbee, Deep-Sea Sounding and Dredging, Washington, 1880.

Steel-wire rope was first used for deep-sea dredging by Alexander Agassiz, in the winter of 1877–78, and since then he has continued to use it with great success. His rope[1] "was one and one-eighth inches in circumference, and was composed of six strands laid around a tarred hemp heart. Each of the six strands was composed of seven galvanized steel wires of No. 19 American gauge (No. 20 Birmingham gauge). The ultimate strength of the rope was 8750 pounds, weight per fathom 1·14 pounds in air, and approximately one pound in sea water; price, eight cents per foot." Captain Sigsbee sets down the following as safe work when dredging with wire rope—"Time per one hundred fathoms paying out and hauling back, three to five minutes, according to circumstances; time for dragging, ten to thirty minutes, according to depth and the character of the bottom. The rate of dragging may be from one and a half to three miles per hour, according to the character of the bottom and the state of the sea."[2] In the summer of 1878,[3] Mr Buchanan fitted the steam yacht "Mallard" with a steel-wire rope for work in depths up to 200 fathoms. It consisted of five strands arranged round a centre of cotton, and each strand consisted of seven steel wires (No. 24 B.W.G.) 0·023 inch in diameter. The diameter of the rope was only 0·19 inch, its weight per fathom 0·33 lb., and its breaking strain 30 cwt. This rope was unfortunately not galvanized, and in the course of four seasons gradually perished with rust. It was replaced by a slightly stouter rope made of *phosphor-bronze*, which seems to have many advantages; especially it does not rust, nor does it fly into kinks whenever it gets loose on the deck, while its tensile strength is very little inferior to that of steel, and when worn out it has a value as old metal. In the "Mallard" the dredge rope was laid through a block suspended by a stout iron davit in the bow, and in-board it passed through a dynamometer. This arrangement was also adopted by Captain Magnaghi in the "Washington."

For dredging in very deep water it might be of importance to have a *tapered* wire rope. For, taking Agassiz's rope, with a breaking strain of 8750 lbs., and weighing in water 1 lb. per fathom, it would be working at half its breaking strain in 4000 fathoms of water, even without any dredge or dragging. This points to a definite limit of depth, beyond which dredging with wire rope becomes practically impossible. A similar limit to the use of hemp line exists also, but owing to its great buoyancy this is unlikely to be approached in any existing sea. It is conceivable that a sea might be so deep that it would be impossible to reach its bottom with a line of any known material.

Dredging and Trawling.—For dredging and trawling purposes the Challenger was supplied with three different sizes of rope—2, $2\frac{1}{2}$, and 3 inches in circumference. This cordage was made of the best Italian hemp, tarred, well hackled and rubbed down, and laid up softly. The 2-inch rope weighed 95 lbs. per 100 fathoms, and

[1] Sigsbee, Deep-sea Sounding and Dredging, Washington, 1880, p. 155.
[2] *Loc. cit.*, p. 146.
[3] *Journ. Soc. Arts*, vol. xxix. p. 326, 1881, London.

its breaking-strain was 1 ton 12 cwt.; the $2\frac{1}{2}$-inch rope weighed 158 lbs. per 100 fathoms, and its breaking-strain was 2 tons 6 cwt. ; and the 3-inch rope weighed 220 lbs. per 100 fathoms, and its breaking-strain was 2 tons 11 cwt. In proportion to its weight, therefore, the 2-inch was the strongest rope, and this or the $2\frac{1}{2}$-inch was used for deep trawlings or dredgings, the 3-inch rope being reserved for comparatively shallow water. The rope was spliced together so as to form one uninterrupted length of 4000 fathoms, and was kept coiled away in racks on the forecastle, each size of rope by itself. Sheep pens were used as racks for coiling the rope away, and were found very convenient for that purpose. When rope was first used in such great lengths, swivels were spliced in at each 500 fathoms to take the turns out, but it was found by experience that these swivels were of little use for this purpose, and that they frequently got jammed in the blocks, so they were discarded. The rope was marked at each 100 fathoms, in the same manner as the sounding lines.

The Dredge consisted of two parts, the iron framework which skimmed the surface of the bottom, and the bag or sack which caught and retained the skimmings. A third part was added by Captain Calver in H.M.S. "Porcupine," viz., the swabs at the bottom, but the dredge itself was complete without this appendage. The iron framework was oblong in shape (see fig. 19), having attached to each of its short sides an arm A, A. These arms were connected together with iron screw bolts B, B, B, and between them was an iron tongue C, with a swivel-ring D at its upper end, to which the dredge-chain was fastened. When not in use the arms were disconnected and fell down on the framework, so that the dredge could be stowed away in a small space, a great advantage on board ship. On each of the long sides of the iron framework was a broad knife-edged piece of iron E, E, E, at an angle of about 10° from the perpendicular, intended to skim the surface off the bottom and throw it into the sack. The sack F was made of network of soft line (something like marline) in very small meshes, the size of the sack depending, of course, on the size of the framework. It was lined inside with cotton cloth or "bread-bag stuff" so as to prevent minute animals being washed out whilst heaving in, and it was secured to the framework by a lacing, eyelet holes being made at regular intervals in the framework for this purpose.

Under the sack an iron bar G, G was secured to the bights of two pieces of rope H, H the ends of which were spliced on to the framework on either side. On the bar G, G flat headed swabs K, K, K, K were hung, so that, trailing along the ground, they might entangle any animals missed by the dredge after it had become choked with mud. To prevent the rope chafing, five or six fathoms of chain were, in the first place, attached to the dredge and the rope secured to this, the ends of this chain were hitched to one of the short sides of the frame and the bight seized to the ring D, so that if the dredge caught a rock, the seizing carrying away would give a better chance of its recovery.

The iron framework of the largest dredge was 5 feet in length, 1 foot 3 inches in breadth, its weight being 137 lbs.; the next size, which was made much stronger, was 4 feet in length, 9 inches in breadth, and weighed 259 lbs.; and the smallest was 3 feet

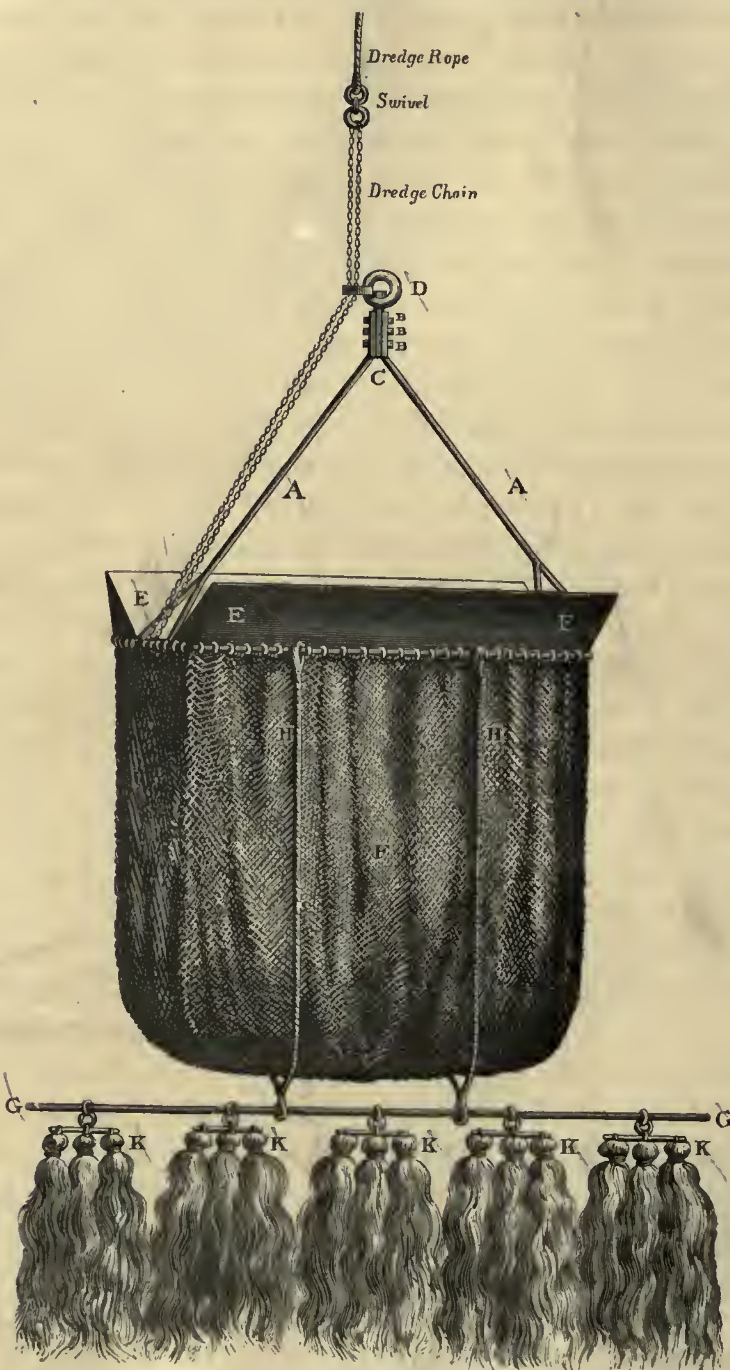


FIG. 19.—The Dredge.

in length, 1 foot in breadth, and weighed 85 lbs. The smallest was generally used in great depths; and with it a successful haul was obtained in 3875 fathoms.

The Trawl (see fig. 20) was of the ordinary pattern, consisting of a beam of wood with an iron at each end, to which a large V-shaped net was attached, so that its mouth was kept spread open by the trawl irons and beam. The size of the net depended on the length of the trawl-beams, which were 17, 13, and 10 feet in length; the smallest being used for very deep water and the others for lesser depths. On the trawl-irons and bag of the net were hung 28 lb. leads, so as to keep the net down to the bottom when trailing along. At first, beams made of fir were used for trawling in deep water, but were replaced by oak or teak beams, as the fir spars came up broken, and so much compressed from the pressure of the water that the knots in the wood stood out three quarters of an inch above the surface of the spar. The bottom of the netting was, as in the case of the dredge, usually lined with bread-bag stuff, to prevent the smaller animals being washed out whilst being hove up through the water. It is, however, preferable in place of this bread-bag stuff, to use a small strip of fine linen or cotton for the netting of both the trawl and dredge, and to change it at each haul. Improvements, both in the form and the method of using the dredge and trawl, have recently been suggested by Captain Sigsbee,[1] by the naturalists of the Norwegian North Atlantic Expedition,[2] and others.

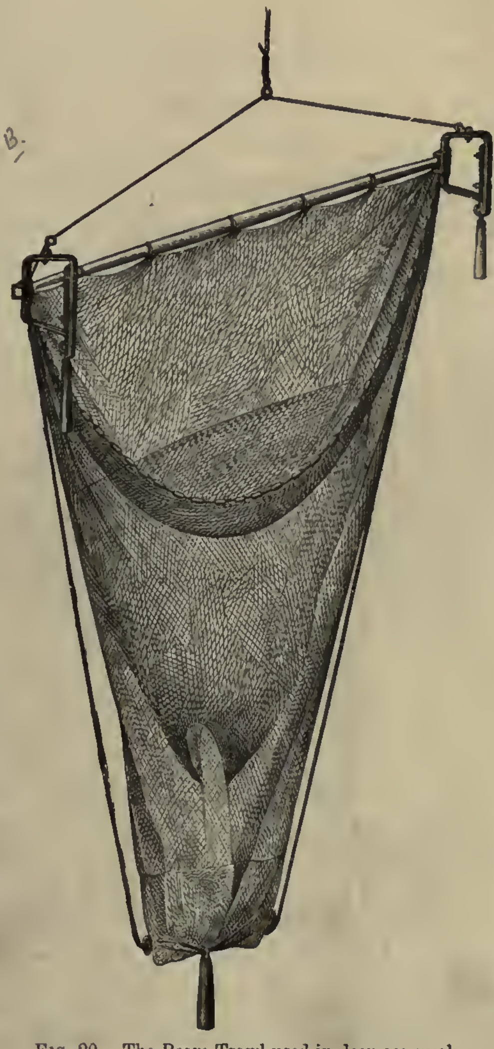


Fig. 20.—The Beam Trawl used in deep-sea work.

The Sieves.—Close to the place where the dredge was emptied there were always one or two tubs, about two or three feet in diameter and twenty inches deep, each of which was provided with a set of sieves, so arranged that the lowest sieve fitted loosely within the bottom of the tub, and the three succeeding sieves within one another (see fig. 21). Each sieve was provided with a pair of iron handles, through which the hand could pass easily, and those of the largest sieve were made long, so that the whole nest could be lifted without stooping and putting the arms into the water. The upper smallest sieve was usually deeper than the others; it was made of a strong open net of

[1] Sigsbee, Deep-Sea Sounding and Dredging, Washington, 1880.

[2] C. Wille, Norwegian North Atlantic Expedition, 1876–1878, part iv., The Apparatus and How Used.

brass wire, the meshes half an inch to a side. The second sieve was much finer, the meshes a quarter of an inch to a side. The third was finer still, and the fourth so close as only to allow the passage of mud or fine sand. The sieves were put into the tub, which was then filled up to the middle of the top sieve with sea water. The top sieve was then half filled with the contents of the dredge, and the set of sieves gently moved up and down in the water. It is of great importance not to give any rotary motion to the sieves in this part of the process, for this is very ruinous to fragile organisms; the sieves should be gently churned up and down, whether singly or together. The result of the process was that the rougher stones and gravel, and the larger organisms, were washed and retained in the upper sieve, the fine mud or sand passing through the whole of the sieves and subsiding into the bottom of the tub, while the three remaining sieves contained, in graduated series, the objects of intermediate size. The sieves were examined carefully in succession, and the organisms which they contained gently removed with a pair of brass or bone forceps into jars of sea water, or placed at once in bottles with spirits of wine. The manner in which the sieves are used will, of course, vary according to circumstances and the nature of the deposit.

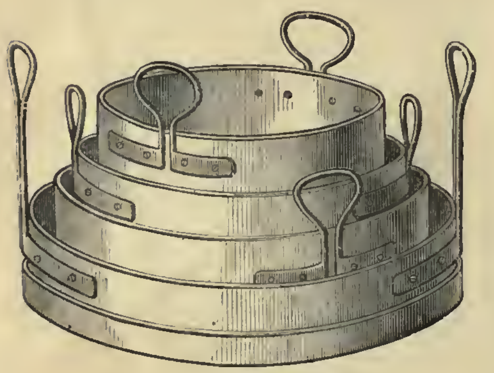


Fig. 21.—The Sieves.

The operations of trawling or dredging were carried on from the mainyard, the dredge rope being rove through an iron gin-block with a patent sheave, which was attached to the accumulators in the manner previously described. For dredging purposes, however, no less than eighty accumulators were used, and in order to stretch them 17 feet, a force of $2\frac{1}{2}$ tons had to be exerted—that is a force equal to the breaking strain of the rope. The accumulators, instead of being triced up to a block on the yard, as they were for sounding purposes, were secured to a pendant hooked on to the cap, the pendant being hauled out, or eased in, by a burton on the end of the yard, as the dredge was required to plumb the sea or the dredging platform (see fig. 12). Before being fastened to the chain of the dredge, the dredge rope was passed through two thimbles. One was used for a special purpose, described hereafter; to the other a small tackle was hooked, to haul the rope close to the ship's side when required. The dredge or trawl being ready to go over, the ship was put before the wind, and the jib hoisted, the wind being kept a little on the quarter of that side of the ship it was intended to work from, in order to drift the dredge clear of the propeller. The dredge was now triced up to the block below the accumulators, and the burton on the mainyard hauled out until the dredge plumbed the sea; it was then lowered down a fathom or two below the surface, and the rope checked, so that from the platform the swabs might be seen to trail clear of the sack.

This having been satisfactorily ascertained, the rope was let go and allowed to run out freely, the ship forging slowly through the water, leaving the dredge to sink astern, and thus prevent all chance of fouling. The rope was checked occasionally to ensure its being taut from the dredge.

When from 300 to 500 fathoms had been paid out a toggle was lashed to the rope, which was then let run until a sufficient quantity had been paid out to allow the toggle

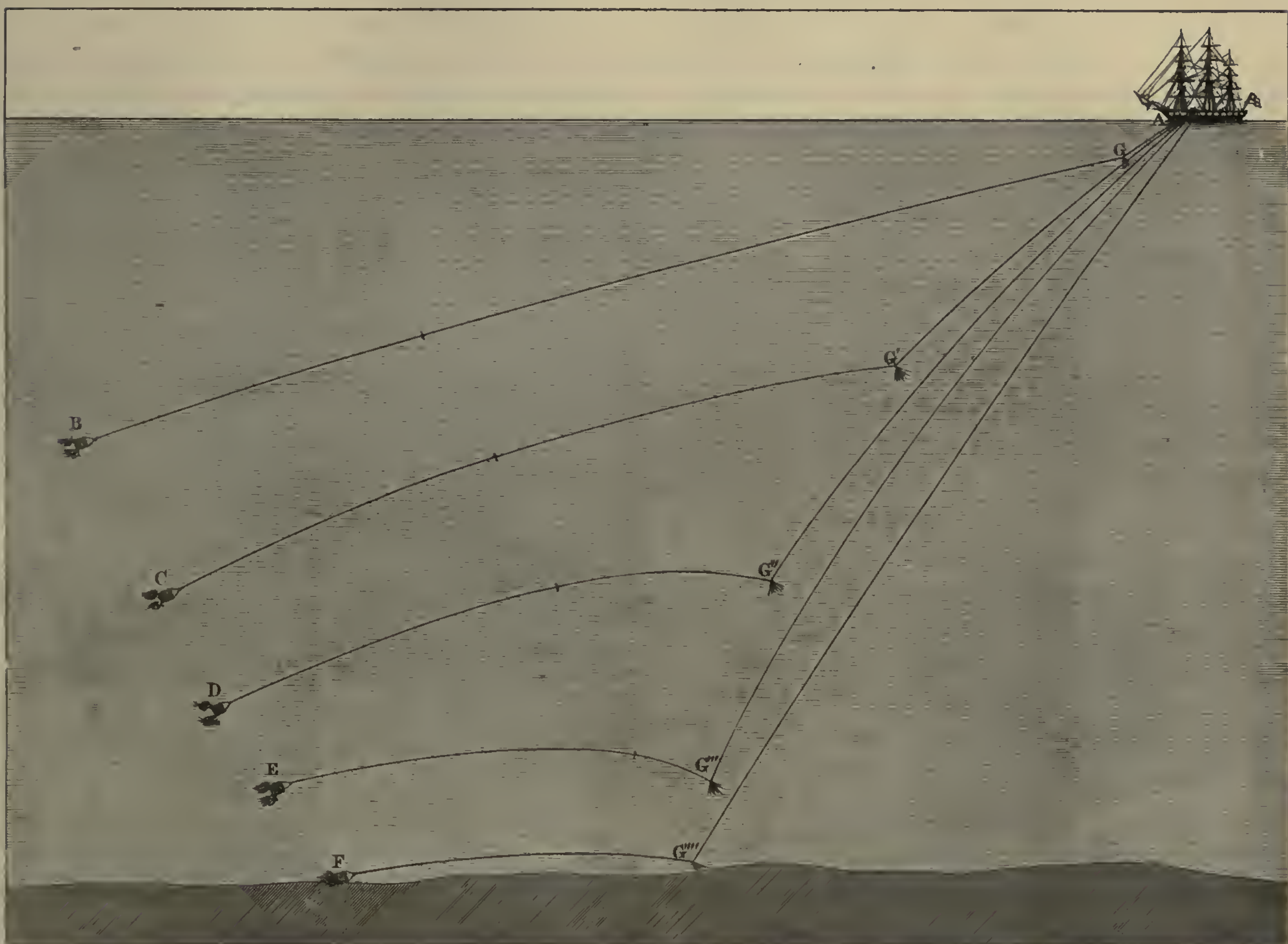


Fig. 22.—Diagram illustrating the supposed action of the Deep-Sea Dredge.

to reach the bottom were the line perpendicular. The dredge and rope then occupied the position A B, shown in fig. 22, and the ship was brought to the wind and kept stationary, or, if there were much wind, steamed slowly towards the dredge, taking care not to overrun it. A weight of $1\frac{1}{2}$ cwt. was now attached to the thimble through which the rope had been rove previously to its being secured to the dredge chain, and the weight and thimble being let go they travelled down the curve of the rope until they were brought up at the toggle G. The dredge and rope by means of this additional weight now successively assumed the positions A C, A D, and A E, until finally the dredge reached the bottom at F, the weights being in the positions G′, G″, G‴, G⁗.

It must be evident that, provided there were no surface or under current, the dredge would reach the bottom with the swabs trailing fairly behind it, if sufficient time were allowed for it to sink. The surface current could always be ascertained and allowed for; when the dredge, therefore, came up foul, as it occasionally did, this could only be ascribed to the influence of some under-current, which need not necessarily have been at the bottom, or to the rope when new twisting the dredge round and round with the weights on the toggle. It was found by experience that about three hours were required to sink the dredge in this manner when the depth was about 2500 fathoms. When it was once down the ship was allowed to drift broadside to the wind for a certain time, and the accumulators pointed out, by their expansion and contraction, that the dredge was being dragged slowly over the ground. When it fouled anything the strain of the ship immediately stretched the accumulators to their utmost, and the line was at once let go to prevent its carrying away, the ship being brought head to wind and kept stationary, while the rope was hove in easily. Did the dredge still continue foul, the ship was steamed ahead of and all round the supposed position of the dredge to endeavour to clear it (in the same manner as a boat's anchor is cleared when jammed on a coral reef or amongst rocks), until the dredge was freed by the stop (see fig. 19 D) breaking, or the line carrying away. Supposing no accident occurred, when the dredge had been on the bottom a sufficient time—from half an hour to an hour—the rope was brought to the donkey-engine, and the dredge hove up. It was found that the strain on the line was so great that the men could not hold on to it while it was being hove in, when turns were passed round only one drum of the engine. Fortunately, the engine was fitted with drums of the same diameter on each side of the deck, so that by taking a number of turns with the rope round the drum on one side, and then leading it abaft through two blocks across the deck, it was possible to take a number of additional turns round the drum of the engine at the other side, so that the men were enabled to hold on to it easily, and a great support was given to the bearings of the engine.

On one or two occasions, when, owing to the depth (over 3000 fathoms), sufficient time could not be spared to allow the dredge or trawl to sink in this manner, a sounding rod was fastened to the bottom of the dredge or trawl and 4 cwt. put on the rod. The dredge was then let go perpendicularly, the ship being kept stationary, until sufficient line had been paid out to allow the rod to reach the bottom and disengage the weights, when the ship was allowed to drift a little way, and then the weights were attached to the thimble and allowed to slide down the rope to the toggle. This is a very successful way of dredging or trawling quickly in deep water.

Tow-Nets.—These nets were continually in use during the cruise, and a stock of over a dozen was always kept ready to hand. The hoops were 10, 12, 14, and 16 inches in diameter, and the bags were made of fine muslin and buntin or strong cotton.

During the daytime they were usually towed from the ship about 50 fathoms beneath the surface with a 6 lb. lead, and sometimes to 200, 400 and 800 fathoms with a 14 lb. lead. The weights were placed about 10 fathoms in front of them, as represented in the woodcut (see fig. 23). The finest muslin ones were generally used when a boat was lowered from the ship for the purpose of tow-netting, and could be pulled very slowly through the water. During the last years of the voyage these nets were attached to the dredge line just below the weights, and also to the sides of the dredge and beams of the trawl.

On a good many occasions they were tied alongside a rope, as represented in the woodcut (see fig. 24), and sent down two miles with a lead and then hauled up again. In this operation, they, of course, only worked while being hauled up. The object of using them in this manner was to ascertain whether or not organisms lived in the deeper layers of water.

Fig. 23.—Ordinary method of using the Tow-Net.

Fig. 24.—A method of using the Tow-Net in deep water.

Current Observations.

Current Drags.—Current observations were occasionally attempted on board the Challenger. The surface current could, of course, be roughly ascertained by the difference between the ship's position, as found by observation and by dead reckoning; but the accuracy of this estimate, depending as it does entirely on the correct steerage of the ship, and the proper allowance being made for speed through the water, cannot be implicitly relied on.

When circumstances were favourable, therefore, a boat was anchored by the dredge rope, and the speed and direction of the surface current ascertained by heaving a log from the anchored boat; and in order to ascertain by actual observation whether currents existed below the surface, an apparatus was lowered to such a depth as was thought advisable. As the movements of the apparatus could only be ascertained by attaching to it a float on the surface, it is evident that *exact* observation of the motions of the apparatus could not be ascertained, as these motions were liable to be retarded or accelerated by the friction of the surface water on the float, as well as by the friction of the water on the line connecting the float and apparatus. A fair approximation, however, of the movement of the sunken apparatus may be made if that apparatus be constructed in such a manner as to expose as large an area as possible to the influence of such forces as may be at work where it happens to be, while the float be constructed to present as small an area as possible to the surface current. The lower apparatus must be of sufficient weight to sink readily, and to keep the line between it and the float as nearly perpendicular as possible, otherwise there would be no certainty as to the depth at which it was; and the float must be of sufficient size to support the weight of the sunken apparatus and the connecting line together with the strain caused by the difference between the lower and surface currents.

Fig. 25. –The Current Drag.

It will thus be seen that the current apparatus consisted of three parts, one called the "current drag," which was lowered down to such depths as were deemed requisite, another the "watch buoy," which pointed out on the surface the movements of the current drag, and a third the "current line," which connected the drag with the buoy. The current drag (see fig. 25) was made of two cross-pieces of iron at the top and bottom A A, A A, with canvas spread between them; the iron cross-pieces were each 4 feet in length, and were joined together by a bolt in the centre, so that they might be folded up when not required; they were kept at right angles when in use by a laniard fastened to their extremities. The canvas between the cross-pieces was 4 feet in depth. On the lower part of the drag was a ½ cwt. lead B to sink it readily, and the current line was fastened to the upper part; this was the ordinary service cod line. The current drag was lowered to the required depth, and the line was then fastened to the watch buoy C, which was like a large anchor buoy, being 5 feet in length and

1 foot in diameter at the centre, tapering towards the ends, and was capable of supporting in the water a weight of 70 lbs. If necessary, two or more buoys were used.

A boat was generally used to obtain the current observations. The first operation was to find out the direction and rate of the surface current by attaching the boat to the dredge rope and letting it go from the ship; the boat thus became anchored by the dredge. The surface current log was now hove and allowed to run out for from six to twelve minutes. The current log ship was made of a triangular piece of wood, with a weight at its apex, and it was kept close to the surface by an oar lashed across its base; the current log-line was marked to fathoms. When the log-line had been running a certain time it was checked, and the bearing of the log ship taken, which gave the direction of the current; the number of fathoms run out, divided by the time it was running (expressed as a fraction of an hour), gave the velocity per hour.

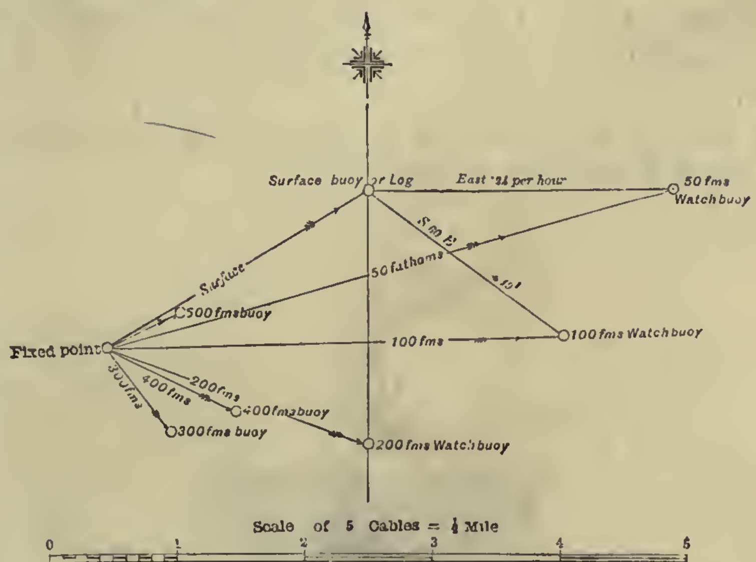


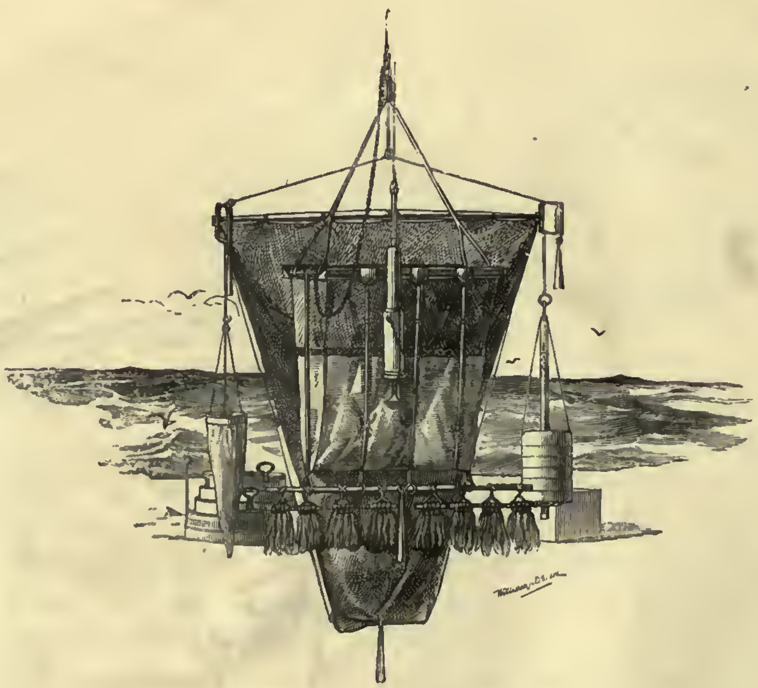
FIG. 26.—Diagram to illustrate the action of the Current Drag.

The current drag was next lowered to a depth of 50 fathoms, and the watch buoy attached. The boat now followed the buoy, keeping close to it, but taking care not to touch it in any way. The surface current log was next put over the boat's side, with a line attached, and the time when it was put over noted. This log was now perfectly stationary with reference to the surface water, moving exactly as the surface water moved, whilst the watch buoy of the drag was affected by the movement of the water at 50 fathoms. The boat continued to follow the watch buoy for from six to twelve minutes after the surface log had been put over, paying out line to the surface log. After a given interval the line to the surface log was checked, its bearings taken, and the number of fathoms run out, with the time it took to run out registered; this gave both the direction and rate of the movement of the watch buoy of the drag through the *surface water;* but during this time the surface water itself may have been moving, the actual movement of the watch buoy, with reference to a fixed point, was therefore represented by the resultant of the movement of the surface water and the movement of the watch buoy through the surface water.

Figure 26 shows the result of the observations made on the currents on the 24th April 1873. The surface current was found to be nearly N. 60° E. 0·24 mile per hour; the watch buoy of the drag at 50 fathoms was found to move E. 0·24 mile per hour from the surface current log; the movement of the watch buoy from a fixed point was therefore N. 75° E. 0·46 mile per hour. In the same manner the current was ascertained at 100 fathoms, 200 fathoms, &c.

These results were assumed as giving the rate and direction of the current at different depths with sufficient accuracy to ascertain any marked movements, but it is evident that they are not strictly accurate, as no allowance was made for the retarding or accelerating influence of the surface water on the watch buoy, or of the intermediate water on the line.

To facilitate lowering and hauling in the current drag, a small derrick was made to ship in the boat where the foremast stepped.



CHAPTER III.

Oceanic Temperatures—Modes of Determination—Self-Registering Thermometers of Six, Aimé, Negretti & Zambra, and others—Electrical Thermometer—Sources of Error—Professor Tait's Experiments—Piezometers—Compressibility of Water—Specific Gravity Determinations—Collection of Samples of Water—Slip Water-Bottle—Buchanan's Water-Bottle—Combined Water-Bottle and Sounding Rod—Method of taking Temperatures.

One of the chief objects of the Expedition was to collect information as to the distribution of temperature in the waters of the ocean. It was therefore important to observe the temperature, not only at the surface, but at the bottom, and at intermediate depths. The determination of the temperature of surface water is simple. It suffices to collect a sample in a bucket, taking care that it is not contaminated with water, either from the scuppers, or from the discharge pipes of the engine, to plunge a good thermometer into it, and observe it carefully. The thermometers[1] supplied for this purpose were very sensitive, and divided into single degrees of Fahrenheit's scale.

For the purpose of observing the temperature of the waters below the surface in lakes and seas, three classes of thermometers have been used—namely, ordinary thermometers, self-registering thermometers, and electrical thermometers.

Ordinary Thermometers.—The earliest observations were made with the ordinary thermometer, and it was used in one of two ways—either it was sunk itself to the desired depth, and was so enveloped and protected by badly conducting material, that in bringing it up again through the layers of water of different temperature it had not time to alter its own temperature, or a quantity of the water at the desired depth was enclosed in a bucket of suitable construction and brought to the surface, and then immediately tested with the thermometer. Many very excellent and trustworthy observations exist which were made in one or other of these ways. Our first knowledge of the temperature of the deep water of freshwater lakes was obtained from the observations of Saussure on the lakes of Switzerland, made with a thermometer so padded and protected that it could be drawn up through 1000 feet of water of any temperature likely to be found in nature without sensibly altering its temperature.

At an earlier date, observations had been made at sea on the temperature of the water below the surface. Captain Ellis[2] was the first to attempt this line of investigation. In 1749, in lat. 25° 13′ N., he fetched samples of water from 3900 and 5346 feet in an apparatus devised by Dr. Hales,[3] and took their temperature when brought to the surface. The method of bringing a sample of the water to the surface, and then testing its

[1] For list of Thermometers, see Appendix C to Chapter I., p. 42.
[2] *Phil. Trans.*, vol. xlvii. p. 214, 1752. [3] *Ibid.*, p. 213.

temperature, instead of sending a thermometer to the required depth, was that followed by all navigators up to the beginning of this century, and many valuable observations were made by its means, more especially in the colder waters of the Arctic seas. Various forms of special apparatus were designed and made for the purpose of securing the sample of water, and bringing it to the surface with as little change of temperature as possible, but they all consisted essentially of a vessel, as large as could conveniently be made, furnished at top and bottom with valves opening upwards. While descending these valves were kept open by the rush of water through the apparatus, and while ascending, they were kept shut by the resistance of the water. In many cases where no special apparatus was at hand, one was improvised out of a cask, and its use for this purpose demonstrated to many of these experimenters the enormous effect of the pressure of the water, especially on structured substances like wood. There being very little difference in the temperature of the water at different depths in the Arctic Seas, the results thus obtained were very accurate and valuable.

Whether the water is brought from the required depth and then tested according to the original method of Ellis and Hales, or the thermometer suitably protected is sent down to the water, then brought up and observed according to the method of Saussure, the accuracy of the results depends largely on the skill of the observers and on the approach to uniformity of temperature in the columns of water traversed. In the case of Saussure's observations on the temperatures of lakes in Switzerland and of Fischer and Brunner's on the Lake of Thun, there can be no doubt as to the trustworthiness of the results, as the experiments were made with very great care and attention to every particular; but the method besides occupying much time could not be recommended to any but skilled and careful observers. The same applies, but in a much less degree, to the use of the "sea gauge."

A method of determining the temperature at the bottom, analogous to the use of the sea gauge, consists in bringing up in a dredge or other apparatus as large a sample of the bottom as possible and plunging a thermometer into it. As a mass of mud conducts heat very slowly and is not affected by convection currents, the temperature of its interior is but very slowly affected by variations in that of the surrounding medium.

Self-Registering Thermometers.—By far the greatest number of observations has been made with self-registering thermometers of one form or another.

The first self-registering thermometer was made by Cavendish.[1] He constructed both a maximum and a minimum thermometer, and they were of the kind called by the French *à deversement, out-flow* thermometers. In fact, his maximum thermometer is in every particular identical with that known in France as Walferdin's; his minimum is on the same principle, but has a U-formed stem instead of a straight one. There are two

[1] *Phil. Trans.*, vol. l. p. 300, 1758.

disadvantages in this form, namely, the indications are not continuous, but by jerks, depending on the size of the mercury drops, and they require to be constantly set, the maximum at a higher and the minimum at a lower temperature than the one to be observed; and they also require constant comparison with a standard. They are, therefore, not suitable for use where many observations have to be made expeditiously.

In the year 1782, Six[1] published a description of the combined maximum and minimum thermometer which bears his name, and which has since continued to assert its place among meteorological instruments as, perhaps, the best self-registering thermometer for sea temperature observations. The instrument is too well known to require particular description. It may, however, be noted that Six himself did not use a hair for a spring to keep his indices from falling down, but a fine glass thread soldered to the top of the index, and sticking up in a direction very slightly inclined to that of the length of the index, so that it pressed gently against the sides of the tube. The advantage of the glass over the hair is that it does not lose its elasticity; but, on the other hand, the index takes up more room, and requires a thermometer with a longer stem.

Maximum and minimum thermometers such as Cavendish's and Six's, when used for deep-sea exploration, show only the maximum and minimum temperatures to which they have been exposed in any one excursion, and a single observation with such a thermometer does not give with certainty the temperature of the water at the depth to which it has been sunk. Hence, if it were possible for the temperature of a sea or lake to vary in any conceivable way with the depth, these instruments would be valueless. There is, however, no justification for this assumption; it is known, on the contrary, that in all seas where the surface is not exposed to a freezing temperature, the temperature of the water, as a rule, diminishes as the depth increases; and therefore that the minimum temperature, as shown by the self-registering thermometer, is, in fact, the temperature at the greatest depth attained by the instrument. Hence, in such cases, this instrument is to be relied on, and more especially when *series* of temperatures are taken—that is, when the temperatures at different depths in the same locality are taken, so that the evidence of the decrease of temperature with increase of depth is rendered as strong as possible. In order to render an account of the state of the sea as regards temperature, it is absolutely necessary to have such serial observations; hence, for such investigations, the maximum and minimum thermometer is not only perfectly trustworthy, but a most valuable and, indeed, indispensable instrument, for it has the great advantage that, as it is in the strictest sense *self*-registering, any number can be attached to the same line, and so at one haul the temperature can be observed at a number of different depths.

The instrument used for almost all the observations made on board the Challenger, was Six's thermometer with a double bulb, of the pattern made by Mr. Casella for deep-sea

[1] *Phil. Trans.*, vol. lxxii. p. 72, 1782.

work, and generally known as the Miller-Casella thermometer. It is represented in fig. 27, and the copper case in which it is enclosed when sent down is shown, on a smaller scale, in fig. 28. The instrument is of small size (9 inches in length), to reduce, as far as possible, the friction in passing through the water. The tube is mounted in ebonite, and the scale (Fahrenheit's) is engraved on slips of glass which are fixed to the ebonite alongside the capillary tube of the instrument. The primary bulb of the thermometer is enclosed in a secondary one, and the space between them partially filled with spirit. The thermometer is filled with a solution of creosote in spirit. The capillary portion is bent in the form of a U, and the bend is filled with mercury; the limb furthest from the bulb ends in a cylindrical reservoir, partially filled with the thermometric liquid, but with a large space empty, or rather containing the vapour of the liquid and slightly compressed air. A small piece of steel wire enclosed in a very thin glass tube forms the index; it retains its place in any part of the tube by the spring of a hair tied on one end of it. Each limb carries an index of this kind. When the thermometer is to be used, the indices are drawn down in each limb of the tube by a strong magnet till they rest on the surface of the mercury on each side. When the thermometer is brought up, the height at which the lower end of the index stands in each tube indicates the limit to which the index has been driven by the mercury, the extreme of heat or cold to which the instrument has been exposed.

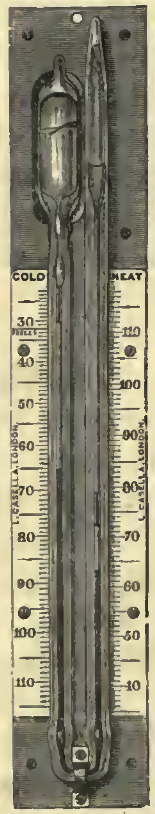


FIG. 27.—Six's Deep-Sea Thermometer.

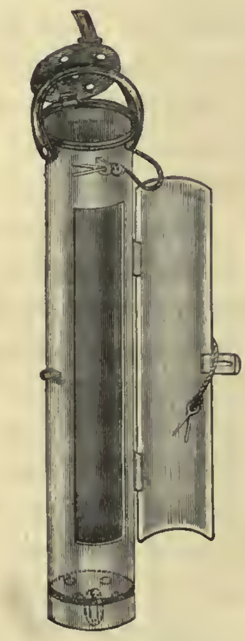


FIG. 28.—Case for enclosing Six's (Miller-Casella) Thermometer.

During the course of the voyage, it became evident that the thermometers as supplied were wanting both in delicacy and in accuracy. It is true that the great source of error had been removed by the application of the secondary bulb, so that the indications were practically unaffected by pressure, but when it had been found that the great bulk of the ocean water is at a low and nearly uniform temperature at great depths, it became of importance to be able to distinguish accurately fractions of a degree. With the thermometers supplied this was impossible, because they were so short for the range of temperature they had to show, that the length occupied by one degree could not easily have been subdivided beyond a quarter, even if the scale had been engraved on the stem, and it was impossible to attain even that degree of accuracy with certainty when the scale was on a slip of glass at the side of the stem, and about a quarter of an inch away from the index, the position of which had to be determined in reference to it. In order to remedy this defect, Professor Wyville Thomson ordered two thermometers to be sent out specially constructed to show low temperatures with accuracy. They were of the ordinary type but longer, and the upper portion of the minimum limb was contracted to a small diameter, so that the degrees between 30° and 40° F. occupied 0·3 inch each, instead of 0·05 inch as in the ordinary ones. Unfortunately these thermometers only reached the ship near the end of the cruise, and in both of them there was a defect about the fitting of the indices in consequence of which they stuck in the tube and allowed the mercury to pass them.

Since the termination of the cruise, Mr. Buchanan has had constructed, and has largely used, an improved form of thermometer of the protected Six type. The size of the instrument is increased so that the degrees are wider apart, a degree Fahrenheit on the minimum leg occupying about three millimetres of its length. Besides the scale of degrees which is attached on enamelled slips to the vulcanite at the sides of the stem, there is an arbitrary (millimetre) scale etched on the stem itself. The values of the divisions of this scale are ascertained by a careful comparison with a standard thermometer. It is thus possible to read with certainty to a quarter of a millimetre or a twelfth of a degree Fahrenheit. The errors due to the scale not being rigidly attached to the thermometer, and to the difficulty of determining the height of the index by reference to a scale at the side of, instead of over, it, are thus eliminated. Finally, by having the ordinary scale at the sides, the instrument can be used independently of the stem-scale, and even where the scale is principally relied on, the scale of degrees at the sides enables the observer to know very approximately the true temperature at the moment of observation without reference to tables; and further, by noting on every occasion the reading on *both* scales, the chance of errors from misreading is greatly reduced.

The maximum leg, which is only rarely used, is of larger bore than the minimum; the degrees, therefore, are closer, and the temperature of the instrument may rise as high as 100° F. without the index entering the terminal bulb. This is a detail of considerable practical importance, for it is impossible always to protect the thermometers when on deck from the direct rays of the sun, which would speedily disable the maximum side of the thermometer if its range were as limited as that of the minimum.

For isolated observations the Six thermometers just described are not so satisfactory, and a very great amount of ingenuity has been displayed in the invention of instruments for registering the actual temperature of the water at any depth independently of that of the water above it. None of the instruments devised for this purpose have been strictly *self*-registering; they have all required some assistance from the observer, who, by various forms of mechanical appliance, brings about a change in the condition of the instrument. It is obvious that any control which an observer may have over an instrument separated from him by, it may be, three or four miles of line, is very limited. By a simple mechanical contrivance vertical motion may be made to produce one of rotation, and, in fact, the assistance thus afforded by the observer to the thermometer to enable it to register its own temperature consists in his turning it either upside down or through a whole circle when it has reached the desired depth. The first observer who made use of such a device was Aimé. By allowing a weight to slip down the line the upper attachment of his thermometer was set free and it fell over. The change thus produced was the means of registering the temperature at the depth.[1] His *thermomètre à bascule*, along with a number of ingenious modifications of existing forms, is described in the same journal.[2] It was unfortunately only after he was obliged to leave the Mediterranean, which had been the scene of his labours, that he invented the very elegant combination of thermometers by which he was enabled to ascertain the temperature at any depth, no matter what the intervening distribution might be. It is described in the memoir just cited. It consists of two outflow thermometers, so constructed that one of them registers the sum of the rises of temperature, and the other the sum of the falls of temperature, to which it is exposed in any excursion. When they have reached the required depth they are inverted, and on their way back to the surface they register, as above described, the rises and falls of temperature to which they are exposed. If r be the sum of the rises of temperature, f the sum of the falls, and s the temperature of the surface, then the temperature at the depth where they were inverted will be $d=s+r-f$. If they are allowed to register on the way down, and then inverted at the greatest depth, so as not to register on the way up, the effect will be precisely the same, though the functions of the thermometers will be reversed. Beautiful and ingenious as Aimé's thermometers are, they have the disadvantages common to all outflow thermometers; they are neither simple enough nor handy enough for work involving many observations.

During the course of the voyage Messrs. Negretti & Zambra patented an instrument which promised to fulfil the conditions required of a thermometer for isolated observations. Staff-Commander Tizard made an extensive series of experiments with it under various conditions, of which he gives the following account:—

"Messrs. Negretti & Zambra's instrument for ascertaining temperatures is a mercurial thermometer (see fig. 29 C), the tube of which is contracted at the point D, so that when the instrument is held upside down the mercurial column separates at that point and falls to the bottom in the enlarged part of the tube E. If a complete revolution of the thermometer be slowly made, the portion of mercury separated falls over into the tube F, which is graduated so as to register the exact amount separated when the instrument is reversed. By attaching this thermometer to machinery which reverses it at a certain time, or at a certain depth, the temperature at that time or depth is registered. To readjust the instrument all that is required

[1] *Ann. d. Chim.*, sér. 3, t. vii. p. 497, 1843. [2] *Ibid.*, t. xv. p. 5, 1845.

is to again turn it over slowly, when the mercury in the tube F will fall into the enlarged part E, and from thence into the other tube, rejoining the portion in the bulb, after which it rises or falls in the tube as the temperature increases or decreases. The bulb of the thermometer is protected from pressure by an outer bulb partially filled with mercury.

"From this description it will be seen that the instrument consists of two parts—the thermometer for recording the temperature, and the machine for rotating the thermometer at any required depth. The contrivance for turning the thermometer over may be described as a vertical propeller to which the instrument is pivoted. So long as the instrument is descending the propeller is lifted out of gear and revolves freely; but as soon as the ascent commences the action of the propeller is reversed, and it falls into gear with a pinion connected with the thermometer, and by these means the thermometer is turned over. After one revolution it becomes locked, and remains immovable. The woodcut (fig. 29 A) shows the general arrangement—T being the thermometer, S a metal screw connected with the frame of the thermometer by a wheel and pinion movement at W; S+ is the stop for arresting the movement of the thermometer when it has made one revolution. It was found in practice that the propeller being arrested, after it had turned over the thermometer, brought such a strain on the cogwheel W as to twist it off the spindle and cause its loss.

"This defect was remedied by Mr. Ferguson, the Chief Engineer of the Challenger, who applied an ingenious apparatus by which, when the thermometer has made one complete revolution, the pinion is lifted clear of the cogwheel, and thus the propeller is allowed to revolve as freely in its ascent to the surface as it did in its descent. Fig. 29 B shows Mr. Ferguson's improvement. The pinion Z is lengthened considerably, and is connected to the rod L which turns the thermometer by a key on the rod and a slot in the pinion, allowing it to move up and down the rod. M is a brass nut attached to the rod L, and movable up and down that portion of it which has a screw; from this nut two arms descend, and are attached to a collar round the upper part of the pinion Z. The nut M is kept from revolving by being lengthened sufficiently to clasp one of the supports of the apparatus. As the instrument descends, the wheel W is lifted clear of the pinion as before; directly it is reversed it falls into gear, but, as the pinion and rod revolve, the nut M is raised on the screw part of the rod lifting with it the pinion, and as long as the rod revolves the pinion is rising; the length of the pinion is so arranged that when the thermometer has made a complete revolution the lower part of the pinion is just lifted clear of the upper part of the cogwheel, consequently the screw S and cogwheel W can then revolve freely. The apparatus, as thus improved, has been found to answer admirably.

"Several thermometers for use in the apparatus were forwarded from time to time. A great number were found broken when they reached the ship, owing either to imperfect packing or negligence in the transport, but a sufficient number arrived in safety to admit of their having a fair trial.

"The first time they were used was in the Sulu Sea, where the minimum temperature is reached at a depth of 400 fathoms, and it was thought a good opportunity to try whether the water at greater depths exceeded this temperature. The apparatus was consequently

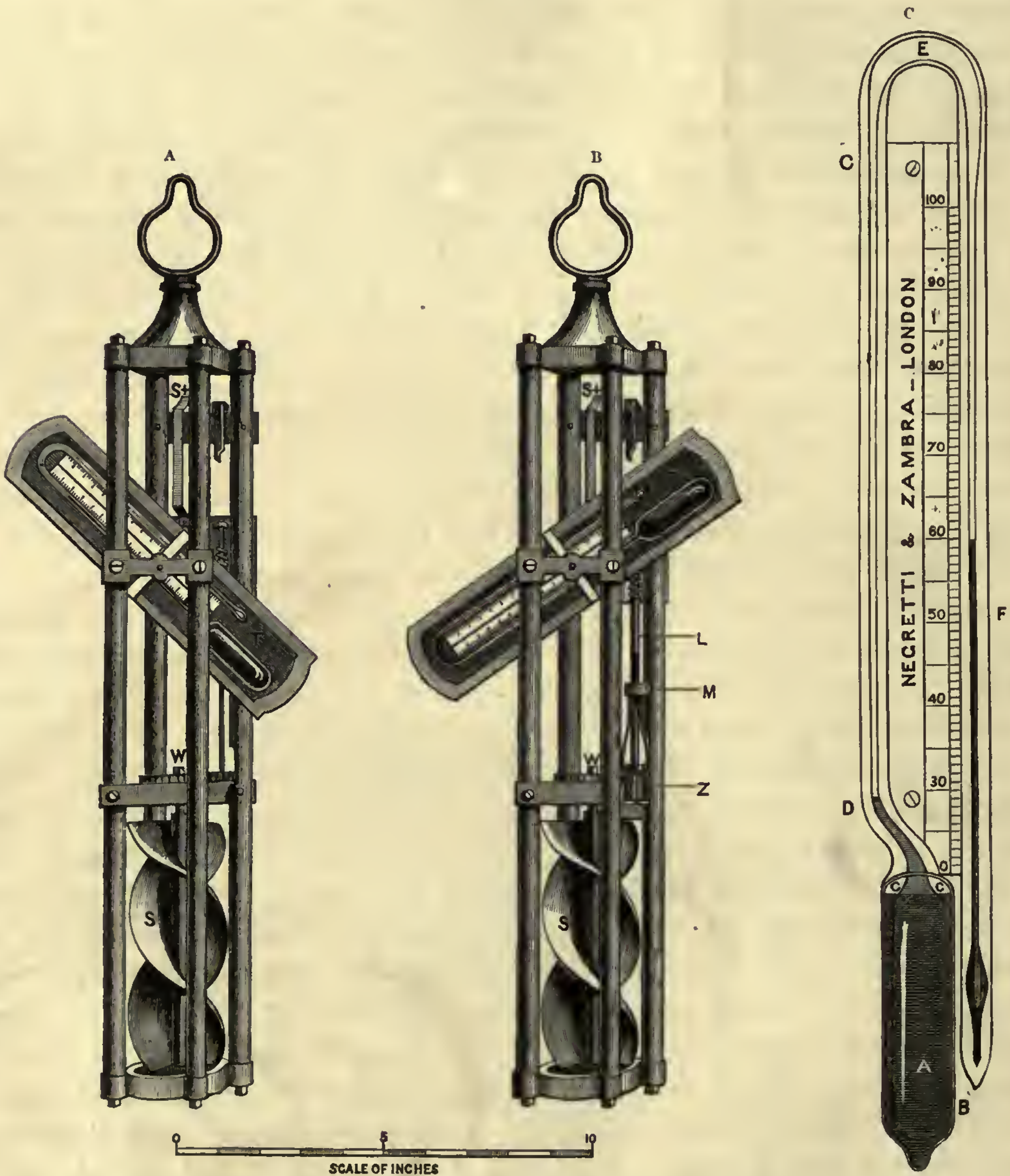


FIG. 29.—A, C, Negretti & Zambra's Deep-Sea Thermometer; B, Ferguson's modification.

sent to the bottom, the depth being 2225 fathoms, and the thermometer (No. 18) registered 54°, whereas the minimum temperature at 400 fathoms was 50°·5; the temperature of 54° being at the depth of 190 fathoms by the Miller-Casella thermometer. The same thermometer (No. 18) was next sent to 400 fathoms, the depth of minimum temperature, to test its accuracy, for had it given the same result as the Miller-Casella, it would have been a conclusive proof that the water was warmer below the depth of minimum temperature, instead of, as was supposed, remaining at that temperature. This time, however, when hove to the surface, the cogwheel attached to the propeller was missing, and the thermometer was in the same position as it was when sent down, consequently it did not register. On February 12, 1875, the machine being again in working order, the observations were proceeded with. The apparatus was first sent to the bottom in 2550 fathoms, No. 18 thermometer being again used, and it was afterwards sent to less depths with the following results:—

Depth in Fathoms.	Temp. by Miller-Casella.	Temp. by Negretti & Zambra, No. 18.	Depth at which temp. given by Neg. & Zam. was found by Miller-Casella.	Remarks.
50	74°·5	71°·0	80 fathoms	
100	68·0	70·0	85 „	
200	54·0	46·5	290 „	
2550	35·4	43·0	400 „	

"From this date the experiments with this instrument were continued as opportunity offered; the results are embodied in the table on the next page.

"It will be seen from the above and following tables that four thermometers have been under trial on board, Nos. 18, 30, 77, and 152, and that observations with each instrument have been taken at various depths, the results being briefly as follows:—With No. 18 five observations were made, four of which gave a higher reading than the protected Six thermometer, and one a lower reading; with No. 30 twelve observations were taken, ten of the results being higher than those obtained by the protected Six, and two lower; with No. 77 six observations were obtained, all the results being higher than those obtained by the protected Six; and with No. 152 twenty-five observations were obtained, ten of which were higher than the protected Six, fifteen of them agreeing within 1° with the results given by that instrument, and none being lower. Of the fifteen results given by No. 152, which agree so closely with the protected Six observations, it will be noticed that ten of them were taken at depths less than 400 fathoms, whilst the ten results that disagree were, with one exception, taken at depths exceeding 400 fathoms. It will thus be seen that, of forty-eight observations taken with these thermometers thirty were higher, three were lower, and fifteen similar to the observations taken with the protected Six instruments at the same depth.

"That the Negretti & Zambra instrument might occasionally show a lower temperature than the protected Six can easily be understood; for, supposing them both to stand at the same temperature at a given depth, if, in the process of turning, the mercury, instead of separating at the point D as it is intended to do, separates at a point

Date on which experiments were made.	No. of Thermometer used.	Depth to which Therm. was immersed in fathoms.	Temp. by Deep-Sea Therm.	Temp. by Negretti & Zambra's instrument.	Difference.
June 30, 1875	77	175	52°·0	61°·0	9°·0
,,	,,	2775	34·9	55·5	20·6
July 2, 1875	77	200	52·6	56·0	3·4
,,	,,	700	37·3	39·8	2·5
July 3, 1875	77	150	53·4	58·8	5·4
,,	,,	2530	35·2	60·0	24·8
July 5, 1875	30	40	55·5	58 0	2·5
,,	,,	700	36·4	41·0	4·6
July 12, 1875	30	125	50·5	54·2	3·7
,,	,,	500	40·0	34·8	5·2
,,	,,	1500	35·1	53·5	18·4
July 14, 1875	30	800	36·4	52·0	15·6
,,	,,	1500	35·1	54·8	19·7
July 17, 1875	30	225	46·1	29·0	17·1
,,	,,	1500	35·5	49·0	13·5
July 19, 1875	30	700	37·0	45·0	8·0
,,	,,	1500	35·2	56·0	20·8
July 21, 1875	30	1500	35·1	64·0	28·9
Dec. 14, 1875	152	100	49·0	49·0	0·0
,,	,,	300	41·7	42·2	0·5
,,	18	1500	35·2	40·0	4·8
Dec. 17, 1875	152	175	45·5	45·5	0·0
,,	,,	500	39·6	41·0	1·4
,,	,,	1200	35·9	46·0	10·1
Dec. 28, 1875	152	200	42°·5	43°·0	0°·5
,,	,,	600	37·5	40·2	2·7
,,	,,	1000	36·3	38·8	2·5
Dec. 30, 1875	152	1325	36·0	36·8	0·8
Feb. 12, 1876	152	2425	32·7	42·0	9·3
March 2, 1876	152	1000	37·1	38·2	1·1
March 3, 1876	152	1000	36·6	37·7	1·1
March 4, 1876	152	125	62·0	61·8	0·2
,,	,,	400	40·4	41·0	0·6
,,	,,	500	39·2	39·8	0·6
March 8, 1876	152	150	55·4	55·4	0·0
,,	,,	300	44·8	44·6	0·2
,,	,,	700	37·2	55·2	18·0
March 9, 1876	152	50	57·9	57·9	0·0
,,	,,	500	37·5	38·8	1·3
,,	,,	700	37·0	37·7	0·7
March 21, 1876	152	300	42·9	59·8	16·9
,,	,,	800	38·2	45·8	7·6
March 23, 1876	152	100	59·2	59·8	0·6
,,	,,	1000	37·8	40·0	2·2

somewhat higher, the amount of mercury which will be deposited in the recording column will be less than it should be, and consequently the instrument will show a lower temperature than really exists, and the three occasions on which the Negretti & Zambra gave a lower reading than the protected Six may be readily accounted for in this manner. That the instrument in the majority of cases gives a higher reading than the protected Six thermometer must be due to one of two causes; either the pressure of the water outside the tube as the thermometer descends is sufficient to close entirely the contracted point at D, or the outer protecting bulb being filled with mercury instead of spirit does not succeed in preserving the inner bulb from pressure, or both these causes may be combined. That the outer mercurial bulb does not protect the instrument in all cases from pressure appears to be almost certain, as a reference to the table shows that the results given by No. 77 at depths of 2775 and 2530 fathoms are higher than at 700 fathoms, and No. 30 gives higher readings at 1500 fathoms than at less depths. These results could only be obtained if the thermometer bulb were influenced by pressure. Nos. 18 and 152 appear to be affected both from pressure on the bulb and from pressure closing the contracted part of the tube, as at depths less than 400 fathoms they agree fairly well with the protected Six instrument, but at depths over 400 fathoms their indications are very erratic."

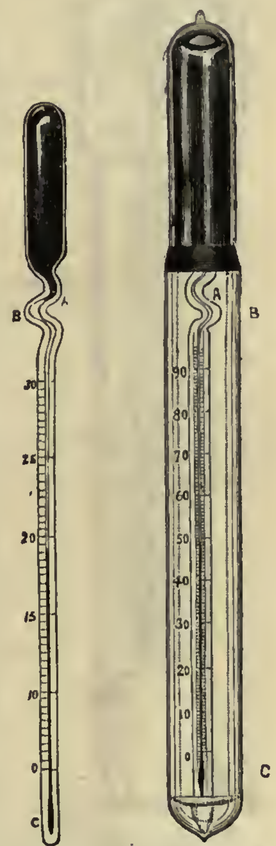


Fig. 30.—Negretti & Zambra's Improved Standard Deep-Sea Thermometer.

Since the return of the Challenger, Messrs. Negretti & Zambra have made an important modification in the form of this thermometer. The new instrument is not double-limbed, and instead of requiring to describe a complete revolution in order to register the temperature, it requires only to describe half a turn. The construction of the thermometer will be understood by reference to fig. 30. The bulb is cylindrical, and mercury is the thermometric fluid. The neck of the bulb is contracted at A, and upon the shape and fineness of this contraction the success of the instrument depends. Beyond A the tube is bent, and a small reservoir is formed at B. At the end of the tube a small receptacle C is provided. When the bulb is downward it contains sufficient mercury to fill the tube, and a part of the reservoir C, if the temperature be high, leaving sufficient space for the expansion of the mercury. In this position no scale would be possible, as the apparent movement of the mercury would be confined to the space C. When the thermometer is held bulb upward, the mercury breaks off at A, and by its own weight flows down the tube, filling C and a portion of the tube above. The scale accordingly is made to read upwards from C. To set the thermometer for observation it is only necessary to place it bulb downward, then the mercury registers the temperature like an ordinary thermometer. Whenever the existing temperature is required, all that has to be done is to turn the thermometer bulb upward, and keep it in this position until read off. The reading may be taken any time after.

The reversing apparatus at first used with this thermometer was somewhat clumsy and unsatisfactory. It has been replaced by a very elegant instrument, designed by Captain

Magnaghi, Hydrographer to the Royal Italian Navy, by means of which the thermometer may be attached to any part of the line during the descent; and after the first regular haul in of from 10 to 80 feet, according to adjustment, any number of stoppages or any amount of line may be afterwards run out without altering the temperature obtained at the commencement of hauling up.

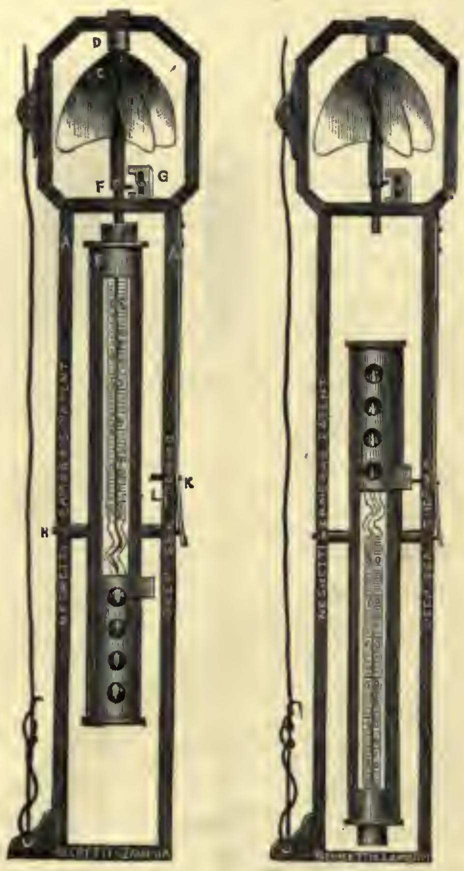


Fig. 31.—Magnaghi's reversing apparatus for Negretti & Zambra's Thermometer.

The apparatus will be best understood by reference to fig. 31. A is a metallic frame in which the case B, containing the thermometer, is pivoted upon an axis H, but not balanced upon it. C is a screw-fan attached to a spindle, one end of which works in a socket D, and on the other end is formed the thread of a screw E, about half an inch long, and just above it is a small pin or stop F on the spindle. G is a sliding stop-piece against which the pin F impinges when the thermometer is adjusted for use. The screw E works into the end of the case B, the length of play being adjusted as necessary. The number of turns of the screw into the case is regulated by means of the pin and stop-piece. The thermometer in its case is held in position by the screw E, and descends into the sea in the position shown in the left hand figure, the fan C not acting during the descent because it is checked by the stop F. When ascent commences the fan revolves, raises the screw E, and releases the thermometer, which then turns over and registers the temperature at that spot, owing to the axis H being below the centre of gravity of the case B as adjusted for the descent. Each revolution of the fan represents about 10 feet of movement through the water upwards, so that the whole play of the screw requires 70 or 80 feet of ascent; therefore the space through which the thermometer should pass before turning over must be regulated at starting. If the instrument ascends a few feet by reason of a stoppage of the line while attaching other thermometers, or through the heave of the sea, or any cause whatever, the subsequent descent will cause the fan to carry back the stop to its initial position, and such stoppages may occur any number of times provided the line is not made to ascend through the space necessary to cause the fan to release the thermometer. When the hauling-in has caused the thermometer to turn over, the lateral spring K forces the pin L into a slot in the case B and clamps it (as seen in the right hand figure) until it is received on board, so that no change of position can occur in the rest of the ascent from any cause. The case B is cut open to expose the scale of the thermometer, and is also perforated to allow the free entry of the water.

The new form of Negretti & Zambra thermometer is completely enclosed in a glass tube, and is therefore not exposed to errors due to pressure. Experiments made with it on board H.M.S "Triton" during the summer of 1882, and by Mr. Buchanan on board the steam yacht "Mallard," showed that, as supplied by the makers at that time, it could not be depended on to turn the moment it was released, but would remain in its original position while being hauled through 10 or 15 fathoms. This defect, however, was very easily rectified by attaching an india-rubber band, so as to press lightly against the upper part of the thermometer when being sent down. As soon as it was released, the india-rubber spring pushed the thermometer out of the vertical, and it at once turned over. With this small but most important addition, the instrument acts satisfactorily, provided that there be no lateral motion of the water relatively to the thermometer. This may occur in one of two ways,—either by the motion of the ship or by currents. In either case the water moving past the instrument turns the screw fan, and sets the thermometer free before it is intended. In the Strait of Gibraltar, for instance, it is impossible to get satisfactory results with these thermometers, except at the periods of slack water.

Quite recently the method, adopted by Aimé, of allowing a weight to slide down the line so as to effect the registration of the thermometer, has been developed by Captain Rung of the Danish Meteorological Institute, by the U.S. Fish Commission, and also at the Scottish Marine Station at Edinburgh. The Danish instrument[1] consists of two pieces, one containing the thermometer which is pivoted to the other and turns over when the weight falls upon a catch, which retains it in position. The "messenger" is very ingeniously made in two pieces, so that it can be put upon the rope at any point. The Scottish instrument[2] is a modification of Captain Magnaghi's: the fan is removed and a pin fits into the slot in the upper part of the thermometer case, this is connected with a horizontal lever, one end of which embraces the sounding line, so that when the weight falls upon it, it lifts the pin out of the slot and the thermometer is released.

Electrical Thermometer.—The Challenger carried a deep-sea electrical thermometer, designed by the late Sir C. W. Siemens, F.R.S.,[3] on the principle of the variation of the electrical resistance of a conductor with its temperature.

The apparatus consists essentially of a coil of wire T, which is lowered by means of a cable to the required depth, and is coupled by connecting wires to form one arm of a Wheatstone's bridge. The connections of the bridge are shown in fig. 32. The arm

[1] Rung, *Den tekniske Forenings Tidsskrift*, 1883.
[2] Mill, *Proc. Roy. Soc. Edin.*, vol. xii. p. 927, 1884.
[3] *Proc. Roy. Soc. Lond.*, vol. xxxiv. pp. 89–95, 1883.

CD is the comparison coil S, made of the same wire as the resistance coil T, and equal to it in resistance when the temperatures of both are the same. This coil is immersed in a copper vessel with double sides, filled with water, and the temperature of the water is adjusted by adding iced or hot water until the bridge is balanced. The temperature of the water in the vessel is then read by a mercurial thermometer; and this will also be the temperature of the resistance coil T. To avoid the error which would be otherwise introduced by the leads to the resistance coil T, the cable was constructed of a double core of insulated copper wire, protected by twisted galvanised steel wire. One of the copper

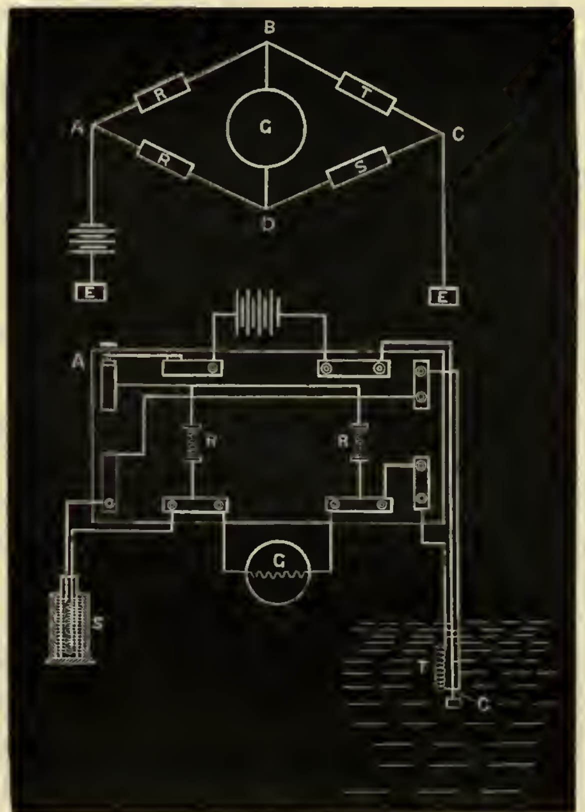


Fig. 32.—Siemens' Electrical Thermometer.

cores was connected to the arm BC of the bridge, and the other to the arm DC, and the steel wire served as the return (earth) connection for both. The resistance coil and comparison coil were made of silk-covered iron wire 0·15 mm. diameter, and each about 432 ohms resistance at a temperature of 66° F. To allow the resistance coil to be readily affected by changes in the temperature of the water, it was coiled on a brass tube with both ends open, allowing a free passage to the water. Sir William Thomson's marine galvanometer, with a mirror and scale, was employed to determine the balance of the bridge.

Several more or less successful observations were made with this instrument during the cruise, which agreed fairly well with those made by the protected thermometers. No permanent place was fitted for the galvanometer or apparatus, and in consequence continuous and careful observations were not made.

Dr. Siemens gives, in the paper above cited, an account of some valuable and accurate observations made by one of the instruments on board the U.S.S. "Blake" in 1881. When accurate temperature observations are required from intermediate depths, this instrument is especially valuable, and it will in all probability be extensively used in future deep-sea investigations.

Sources of Error.—In Six's instruments there is a possible error from looseness of the indices, in consequence of which they are apt to be shaken out of their places by the jarring of the line. Errors from this source may be avoided to a great extent by attaching the thermometer to the line by means of an elastic or india-rubber "stop." Where the only scale is on a slip attached to the backing of the instrument, and is not engraved on the stem, there is a great liability to error through shifting of the thermometer relatively to the attached scale. Errors from this source are very liable to occur, and are due solely to defective instrument-making. No instrument of this kind should be sent out of the workshop, to be used on such important work as deep-sea investigation, which has not a scale etched on the stem.

The most serious source of error in the results of observations of the temperature of deep water by means of self-registering thermometers, has been the effect produced on them by the hydraulic pressure to which they are subjected at the moment of recording. This was early recognised.

Cavendish, who invented the self-registering thermometer, foresaw also the most important of the uses to which it could be applied. Thus he suggests that the higher regions of the atmosphere might be investigated by attaching it to a kite—balloons not having been then invented. With regard to deep-sea explorations, he says: "If instruments of the nature above described were to be used for finding the temper of the sea at great depths, some alteration would be necessary in the construction of them, principally on account of the great pressure of the water, the ill effect of which can, I believe, be prevented no other way than by leaving the tube open."[1] This was written in 1757, and it was not till 1762 that Canton proved that liquids are compressible. Cavendish therefore hoped that as the pressure would not produce distortion of the glass when the tube was open, it would have no visible effect on the apparent volume of the liquid. The device of leaving the thermometer open at the end was adopted by Aimé in some of his experiments, the effect of pressure on the apparent volume of the liquid being determined independently, and a correction applied accordingly.

Many attempts were made to use Six's and Walferdin's thermometers at great

[1] *Phil. Trans.*, vol. l. p. 308, 1758.

depths, protecting them from pressure by enclosing them in strong metal tubes with a top firmly screwed on. This method was extremely uncertain and generally failed. The tube generally came up quite full of water, indicating that it had afforded no protection to the instrument inside it. In some instances Walferdin's thermometer, which is a straight-tubed instrument, and not curved like Six's, was used entirely enclosed in a glass tube hermetically sealed. In this way, of course, complete protection was afforded so long as the glass tube did not collapse.

The method of protection used in the case of the thermometers supplied to the Challenger has been described above. It consists in encasing the true thermometer bulb in another bulb partially filled with liquid to facilitate transmission of heat. The remainder of the space is filled with the vapour of the liquid. Any compression therefore which might be suffered by the outer bulb would produce no rise of pressure in the space between the two bulbs, and would therefore not be transmitted to the inner bulb.

The effect of pressure on a glass vessel is to produce compression and diminution of internal volume while it lasts. When the bulb of a thermometer is compressed and its capacity diminished, the liquid contained in it is squeezed up into the stem, and the top of the column stands higher than it did before, so that the compression of the bulb produces the same effect as a slight rise of temperature.

If now the thermometer be a self-registering one, and it be sunk to a certain depth in a sea of uniform temperature identical with that of the thermometer, the index or recording mechanism will indicate the rise of the thermometric column in the tube due to the compression of the instrument. If the same thermometer, at the same temperature to begin with, be carefully warmed, exactly the same apparent effect will be produced, namely, the thermometric column will rise, and when the temperature has risen to a certain height, it will place the index in exactly the same position as was the case when it was sunk in the sea of uniform temperature. If in the latter case the effect of pressure be neglected, we shall ascribe to the water at the particular depth a temperature higher than the true temperature by the thermometric equivalent of the shift of the index produced by the pressure of the column of water.

It does not require demonstration to show that the apparent effect of pressure on a thermometer will be almost wholly due to its effect on the bulb. The stem suffers compression also, but the apparent effect so produced is negligible compared with that due to the compression of the bulb. Hence when Six's thermometers had to be protected from pressure, it was held sufficient to protect the bulb. There seems to be considerable uncertainty as to who first proposed and carried out the preparation of thermometers with a double bulb, but they were certainly used on board H.M.S. "Cyclops" by Captain Pullen[1] in 1858, and there seems to be good reason for believing that the thermometers used by Sir John Ross in 1818 were protected by the same or some similar device.

[1] *Phil. Trans.*, vol. clxv. pp. 608, 609, 1875.

Notwithstanding previous experience, when H.M.S. "Lightning" was employed in sounding and dredging in the Færöe Channel in 1868, she was supplied with unprotected thermometers. On her return a number of interesting experiments were made by Professor W. A. Miller and Mr. Casella, to find the "pressure correction" for the instruments used.[1] The corrections so found, though good for the thermometers actually experimented on, are of no use for correcting other instruments, even though they may be of the same pattern. This is due to the fact that the bulbs of even the most carefully made thermometers are never uniform in thickness of glass, and consequently yield differently to pressure. It has been mentioned above that the stem of the thermometer suffers compression though the effect so produced on the reading of the thermometer is insignificant. If the stem be uniform, the effect will be proportional to the length utilised. In the case of the thermometers supplied to the Challenger, the bore of the stem was not uniform. Close to the bulb there was a swelling, and at the bend there were other swellings. As it was the minimum limb that was almost exclusively used, the effect of pressure on the reading was limited to that produced on about 2 inches of tube with a slight swelling near the neck of the bulb. Along with each instrument was supplied, as "pressure correction," the amount to be deducted from the reading according to the depth to which the instrument had been sent. During the first part of the cruise this correction was applied without question, and the results embodied in reports with sections sent home to the Admiralty. As, however, observations multiplied, and side by side with the thermometric observations experiments were made on the effects of pressure on various substances contained in *piezometers*, the readings of which required to be "cleared for temperature" the question of the validity of the "pressure correction" came to be seriously considered, and the conclusion was come to that it had been improperly applied. It was obvious that the correction referred to could have been obtained only in one way, namely, by submitting the thermometer to pressure in a hydraulic machine, and noting the rise of the maximum index. This rise would be caused by the compression of the stem forcing the liquid up the tube, and by the actual rise of temperature produced by the compression of the water of the hydraulic receivers. It was at once evident that the part due to actual rise of temperature caused by compression must be rejected altogether, because in use the thermometer takes the temperature of the water in which it is immersed. Of the residual amount due to actual compression of the stem, only so much ought to be taken as is applicable to the portion of stem between the bulb and the mercury on the minimum leg. This would as a rule be about one-sixth of the length of stem from the bulb to the mercury meniscus in the maximum leg, without adding anything for the swellings at the bend. The errors for a pressure of 3 tons per square inch varied from 1° to $1\frac{1}{2}$° F., and even if nothing be rejected for heat effect, the sixth part would be considerably less than the probable error of observation. The temperature

[1] Depths of the Sea, p. 295, 1873.

sections sent home in the preliminary reports continued, however, to be constructed with temperatures "corrected for pressure," in order that they might be comparable with those that had gone before, although thus far it had become evident that the thermometers, in so far as they were used as minimum instruments, were sufficiently protected by the outside bulb against the effects of pressure, and that in consequence their readings at great depths were not affected by any sensible error due to this cause.

With a view of finding out the true effect of pressure on the readings of the protected thermometers, Sir Wyville Thomson, on the return of the Expedition, requested Professor Tait to investigate the whole question, and handed over to him about thirty of the thermometers, which had been used during the cruise, and also the hydraulic pressure apparatus constructed in 1872, which had been on board during the voyage. The results of the investigation have been published *in extenso* in Appendix A to Vol. II. of this Narrative.[1]

Professor Tait commenced by remarking that a correction so large as that given by Captain J. E. Davis for the maximum index, if it were to be applied at all, must be applied with but little diminution to the minimum index also. So that the question is a serious one. He then tested the pressure apparatus, but found it to be in many respects unsuitable for the work he contemplated.

1. It was capable of holding only two thermometers at once; and, when two were inserted, there was no room for other necessary apparatus, such as pressure gauges, &c.

2. The Bourdon-gauge attached to it was graduated only to four tons weight per square inch, while it was desirable to carry the pressure to six tons at least.

3. When compared with an air-manometer inserted in the pressure cylinder, this gauge proved to be very inaccurate.

4. Even with the moderate pressures which had been applied to it, the cylinder was not deemed perfectly safe, and had in consequence been strengthened (?) by massive rings of Swedish iron clamped round it.

Professor Tait therefore informed Sir Wyville Thomson, that if the experiments were to be conducted in the Edinburgh University Buildings, it was essential that a stronger and much more capacious pressure cylinder should be procured; and suggested that it should be constructed on the principle of the Fraser gun.

In the spring of 1879 the new instrument[2] (weighing nearly three tons) arrived in Edinburgh from the Royal Gun Factory at Woolwich, and was erected on a mass of concrete embedded in the ground below the floor of one of the basement rooms in the College. As the gas-engine belonging to the Physical Laboratory happened to be fixed in a neighbouring cellar, the requisite shafting was put up to connect it with the pump;

[1] The Pressure Errors of the Challenger Thermometers, by Professor P. G. Tait, Narr. Chall. Exp., vol. ii., Appendix A.

[2] Described and figured in the above mentioned paper, where will be found a full description of the experiments and their results, also an account of the various new forms of gauges employed for the accurate measurement of pressure.

and, by a simple but effective mechanism, the engine was made after each stroke to open automatically the suction valve of the pump, which was continually liable to become jammed when very high pressures were reached. The only defect of this arrangement was that some minutes elapsed (even when there was no air in the pressure cylinder) before a pressure of three or four tons was reached. Professor Tait therefore procured for his laboratory an additional but very much smaller apparatus, in which a couple of strokes of the pump sufficed to produce the full required pressure. The comparison of the effects produced on the same thermometers, by the same pressure, in these very different instruments was of great value in verifying some of the more important results of the inquiry.

Professor Tait had satisfied himself by calculation from the best data available, that the utmost *direct* effect of pressure on the protected thermometers could be only a small fraction of that assigned by Captain Davis,[1] and he verified this conclusion directly by trials with tubes of varied dimensions.

It only remained to ascertain why the large results of Captain Davis's experiments on the Challenger thermometers, which were closely reproduced by Professor Tait in the new apparatus, were so different from the theoretical amount; and it was found, after several trials with tallow and other plastic materials placed so as to surround the bulbs of the thermometers, that the slabs of vulcanite, on which the thermometers are mounted become heated by compression to an extent hitherto unsuspected, and fully competent to account for the discrepancy. Thus the greater part of the effect obtained by Captain Davis was shown to be due to heating produced by pressure, not to pressure directly.

But when the thermometers are let down into the sea, the circumstances are very different from those in the pressure cylinder, for the constant current of sea water which passes round the bulb of the instrument keeps it and its mounting steadily at the temperature of the sea:—the heat due to compression being (in consequence of the slow rate of increase of pressure) developed much more slowly than in the laboratory experiment, and being besides carried away by convection as fast as it is developed.

He concluded from these experiments, as well as from the experimental verification of his theoretical calculations, that had the tubes of the Challenger thermometers been free from "aneurisms" the utmost pressure correction required in deep-sea observations would have been for the minimum index (which is the important one) about 0°·05 F. only for each mile of depth. The aneurisms above spoken of are small distended parts of the tube. The only serious one, whose object is to prevent the recording index from being drawn into the main bulb if the instrument be exposed to too low a temperature, is close to the protected bulb, and ought itself to have been protected. The pressure effects due to this aneurism are usually greater than those due to the tube of the thermometer. Professor Tait has calculated, for each of the instruments he

[1] Davis, J. E., On Deep-Sea Thermometers, *Proc. Meteorol. Soc.*, vol. v. pp. 305–342, 1871.

examined, the effect of this aneurism, and his Report concludes with a table of the results. From these it appears that, even with the aneurisms, there is none of the instruments examined in which the requisite correction for pressure amounts to more than 0°·14 F. per mile of depth in the sea, while the average value is considerably lower.

Under the circumstances in which the thermometers are usually hauled on board, and considering also the difficulty of reading to small fractions of a degree, it is clear that it is scarcely necessary to apply any correction for pressure, though it would certainly have been much more satisfactory to have had the aneurisms protected as well as the main bulb.

Professor Tait's experiments with the new apparatus have led to several curious results which, though not directly bearing on the pressure errors of the thermometers, may be found of importance in other departments of the Challenger work. He has, for instance, investigated the compressibility of fresh and salt water at different temperatures under great pressures, and has shown that the maximum density point of fresh water is lowered by pressure. Various additional questions of this kind, directly connected with the great problem of ocean circulation, are now being investigated by means of the new pressure apparatus—and a verification of the unit of his gauge was obtained in the autumn of 1882, by sinking a number of his gauges, whose behaviour in the pressure apparatus had been previously ascertained, to depths of 800 and 1300 fathoms from H.M.S. "Triton," which made a special cruise for this and other connected purposes.

Piezometers.—In the Mediterranean, the Red Sea, and many of the seas of the Eastern Archipelago, besides, possibly, large tracts both of the Atlantic and Pacific Oceans, the temperature decreases regularly down to a certain depth, which varies in different seas, and at all greater depths the protected Six thermometer gives identical readings, indicating that the water is either at the same temperature or some higher one. In the neighbourhood of ice, layers of water are frequently met with at various depths whose temperature, being higher than that of the surface, is indicated by the maximum index of the protected Six thermometer. Besides these layers there may be, and there probably are, others whose temperature is higher than that of the water immediately above them without reaching that of the surface, and their temperature would remain unrecorded.

This fact was brought prominently under the notice of the members of the Expedition during the cruise in Antarctic waters, where a large stratum of water was found at depths exceeding 300 and 500 fathoms from the surface, the temperature of which could not be ascertained by any instrument on board, and had to be reported as uncertain.

In order to prevent the recurrence of such an experience, the matter was carefully investigated by the chemist of the Expedition, who devised and constructed an instrument suitable for determining the temperature of water arranged as it was in the Antarctic Ocean. Before leaving home he had had constructed several piezometers filled with water or saline solutions, with a view of determining the compressibility of these liquids when sunk to different depths (or conversely of determining the depth by the amount of compression). These piezometers are really nothing more than Six's thermometers open at the end. If such an instrument be sunk to any depth in the sea it will register the combined effect of temperature and pressure on its contents and the glass envelope. If the temperature be known the contraction due to pressure can be computed, and conversely, if the depth and so the pressure be known, the temperature to which it has been exposed can be computed. It occurred to Mr. Buchanan at the time to use the piezometers for this purpose, but as they were all filled with either water, sea water, or salt solution, liquids which at such low temperatures show hardly any thermal dilatability, it was felt that no assistance could be got from them. It was not until much later that the idea occurred to open the end of an unprotected Six's thermometer, or to open the end and the secondary bulb of a protected one, and so obtain a record of the combined effect of pressure and temperature on the thermometric liquid usually employed, which could be cleared for effect of pressure by subsequent experiment. Several trials were made with an opened unprotected thermometer in the South Atlantic on the voyage between Sandy Point and Monte Video, and it was found to work well.

As the working of the Negretti & Zambra thermometers which were sent out was not considered satisfactory, a piezometer filled with mercury was constructed. It resembled an inverted Six's thermometer, the bulb filled with mercury and the bend of the tube filled with water, in which the magnetic index had free play. The bulb A (see fig. 33), of about 19 c.c. capacity, held about 250 grammes of mercury. The stem, through a considerable portion of its length BC, was filled with water, in which the index moved. The space between the end of the water column and the end of the stem was filled with mercury, and the end dipped into the bulb D filled with mercury, which communicated with the water or air outside. The instrument was fixed to a backing of vulcanite, principally by wire lashing across the bulb; the small brass clamps on the stem were there solely for steadying and bore no weight. It was fortunate that the possibility of having to do work of this kind was foreseen, and that the laboratory stores included several pieces of ebonite suitable for the purpose, and some graduated capillary tubes of the size used for the piezometers that were taken out. One or two spare indices were also taken, but the supply both of them and of capillary tubes was augmented by preserving the fragments of any thermometers that were broken. In this way an instrument can be constructed filled with a very large quantity of mercury and a very small quantity of water, after whose immersion the position of the index shows the apparent volume assumed by this mixture under the combined influence of temperature and pressure. As far as the effects of temperature are concerned, the amount of water in the instrument is almost wholly negligible; but when the effect of pressure is considered, the apparent compressibility of mercury is so small, being little more than one-fiftieth of that of water, that the presence of even so small a quantity of water as can be contained in the graduated tube increases very materially the amount of contraction produced by pressure. The instrument which was chiefly used contained 256·61 grammes of mercury in the bulb and stem immediately above it; the volume of the part of the stem filled with water was 0·1935 c.c. The apparent contraction of this mass of mercury and water was 0·000581 c.c. per 100 fathoms, and 0·0025 c.c. per degree (C.) respectively. A fall therefore of one degree (C.) in temperature produced the same effect as an increase of pressure equal to 430 fathoms of sea water. Hence (and this forms the important peculiarity of the instrument) as long as the temperature of the sea does not increase with the depth at a greater rate than 1° C. per 430 fathoms, the instrument will record the temperature correctly. The ratio subsisting between the rise or fall of temperature and the column of water, which produced the same effect on the apparent volume, is a constant for each instrument; in this it is $\frac{1}{430}$. By altering only very slightly the amount of water, the sensibility to pressure is greatly increased or diminished, while that to temperature remains practically unchanged. As the instrument described was intended principally for bottom waters, the above ratio ($\frac{1}{430}$) was considered sufficient, and it proved practically useful. It must be remembered that the greater the value of this ratio is made, the greater is the error introduced into the determination of the temperature by any inaccuracy in the measurement of the depth.

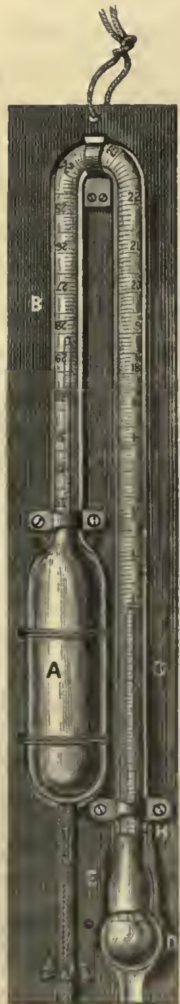


FIG. 33.—Mercury Piezometer.

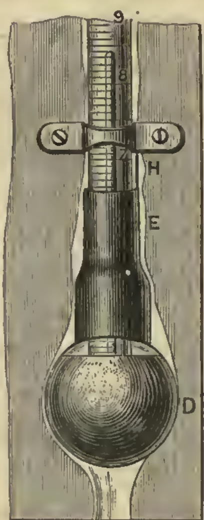


FIG. 34.—Enlarged view, showing attachment of bulb to end of Piezometer.

This instrument was constructed entirely at sea, and though the chemical laboratory was specially lucky in its freedom from breakage, there seemed to be an exception in the case of the mercury piezometer. Four of them had to be made before one stood. The first was broken by accident, the second by a foul on the sounding line, the third in the receiver of the hydraulic apparatus by the collapse of a protected thermometer, which was being exposed to pressure along with it, and the fourth stood, being used as often as possible on the sounding line along with other instruments until the ship returned home, when it was broken in its turn by an over-curious instrument-maker who was employed to copy it. The filling of the instrument with so large a quantity of mercury was effected by means of an improvised

Sprengel pump, which acted quite satisfactorily, even when the ship was rolling steadily through 20° to 30°.

The apparent compressibility of the mixture of mercury and water in glass represented by this instrument was determined in a number of satisfactory soundings between Tahiti and Valparaiso, the temperature being determined by one or more protected thermometers attached to the line close to the piezometer. Of course no "pressure correction" was applied to the readings of these thermometers. The result was, that the apparent compressibility of mercury for 100 fathoms was 0·0000271, being per atmosphere 0·0000015. After the return of the Expedition, the absolute compressibility of glass was directly measured by Mr. Buchanan[1] in a specially designed apparatus, and found to be 0·00000292 per atmosphere up to 240 atmospheres, at a temperature of 12° to 13° C. The absolute compressibility of mercury would therefore be 0·00000442 per atmosphere.

Fig. 35.—Water Piezometer.

The water piezometer has already been referred to. It is shown in fig. 35. It consists essentially of a thermometer-shaped instrument open at the end. A cylindrical bulb A contained, in the one that was chiefly used, about 9 c.c. The stem, which was rather more than a foot long, had a diameter of almost exactly one millimetre The end of the stem dips into the bulb D, which was filled so far with mercury, and the instrument was set by heating it to such a temperature, that when it cooled down to the atmospheric temperature the mercury would rise to a convenient height so as to be visible and able to be read at any moment at a given temperature by plunging it into water. The arrangement for protecting the open end of the instrument is somewhat peculiar. It is necessary to allow the water on the outside to have access to the mercury in the bulb in order that the pressure may exert itself in the interior of the instrument, in the same way as air must have access to the mercury in the reservoir of the barometer. At the same time it is of importance that the mercury should not be able to come out of the bulb. For this purpose care was taken to have a bulb D blown, into the neck of which the stem of the instrument fitted with some accuracy. This was connected with the stem by means of a piece of india-rubber, which was prevented from fastening hermetically on the stem by having a small piece of glass rod H pushed in between the india-rubber and the stem. In this way communication was constantly kept open between the outer water and the mercury in the bulb.

[1] *Trans. Roy. Soc. Edin.*, vol. xxix. p. 589, 1880.

The stem of the instrument was divided into millimetres, and carefully calibrated, the weight of the water filling the instrument, and also the coefficient of expansion of the glass, being at the same time determined.

If the position of the water-mercury meniscus in the stem be noted under observed conditions of temperature and pressure, and the instrument be then observed under different conditions of temperature and pressure, the apparent volume occupied by the water, and therefore the position of the meniscus, will depend on the difference of the combined effects of temperature and pressure on the water and on the glass. This resultant effect is measured by the position of a magnetic index similar to, and in fact exactly the same as, that used in Six's thermometer. The deep-sea thermometer used was after Six's pattern, with a protected bulb. When the instrument is subjected to increased pressure or diminished temperature, or both together, the index is pushed up by the mercury, which enters owing to the decrease of temperature and the increase of pressure, and its position thus gives the sum of the effects of change of pressure and of temperature on the apparent volume of the water.

If now, along with this instrument a sufficiently protected thermometer has been attached to the line, and its readings be taken at the same time, we have a measure of the temperature to which the instrument has been subjected. Knowing the dimensions of the instrument in every particular, and its behaviour under varying conditions of temperature, we can subtract from the whole reading of the instrument that which is due to temperature, and the remainder is that due to pressure. If the coefficient of apparent compressibility of the liquid be known, the depth is given at once.

Attention was principally directed to determining the apparent compressibility of distilled water and some other liquids by means of the sounding line, that is to say, using the sounding line as the gauge of pressure, and taking particular care to observe that these experiments were made when the sounding was not vitiated by perturbing causes. When currents are present, they are always very evident from the behaviour of the sounding line. If the sounding line remain vertical during the whole of the sounding, then it is perfectly certain that there is no disturbance from currents either at the the surface or below. If there be a current of any appreciable force, the sounding line begins to wander about, and has to be followed by the ship. This is an operation of considerable delicacy, even in good weather, and in bad weather, when the winds and currents cross and complicate each other, it is one which calls for the highest skill on the part of the officer in charge. There was, however, no difficulty in determining whether a sounding had been good, and only such soundings, free from vitiation by any of the above-mentioned perturbing causes, were used for this purpose.

In fig. 35 the stem of the water piezometer is represented as being swelled into a small bulb at F. The purpose of this bulb is to enable the instrument to be used at depths so great that with a uniform stem the contraction produced would be equal to the whole volume of the stem. The capacity of F is equal to the contractions due to the fall of temperature and the increase of pressure produced by the first 1000 or 1500 fathoms of depth, so that the instrument would only register depths greater than 1000 or 1500 fathoms, but it would do so with almost as much precision as can be obtained at less depths.

The observations which have been taken as a basis for determinations of depth were made in the latter part of the year 1875, in the South Pacific Ocean. They were twenty in number, and were made at depths varying from 500 to 2300 fathoms, and at temperatures varying from 1°·4 to 4°·03 C. The mean compressibility of water determined from these observations was 0·0008986 per 100 fathoms of sea water, the extreme values being 0·000915 and 0·000882. Observations made at greater depths in the North Pacific, gave as a mean of six observations at depths varying from 2740 to 3125 fathoms the value 0·000878, indicating a slight diminution in the coefficient of compression at very high pressures.

The change of volume of water with change of temperature at the low temperatures found in the deep sea is very slight. The change of volume of mercury, however, for all ordinary temperatures is very considerable. On the other hand, the compressibility of water, or its sensibility to change of volume with change of pressure is very great, whereas that of mercury is very small. Consequently, by sending a pair of these instruments down on the sounding line, and reading them when they come up, two independent values of the sum of the effects of change of temperature and of pressure are obtained. Taking as the first approximation to the depth the length of the sounding line, applying it to the reading of the mercury instrument, and so correcting it for pressure, we have a first approximation to the temperature; applying this temperature to the reading of the water piezometer, we obtain a second approximation to the depth, indeed, practically the true depth. The reading of the mercury piezometer now being corrected for pressure by this value of the true depth, we have a second approximation to the temperature. In fact we have now practically the true depth and the true temperature.

Fig. 36*a* refers to the water piezometer, and fig. 36*b* to the mercury piezometer; the thick lines represent the apparent changes of volume for changes of pressure, and the dotted lines the apparent changes of volume for changes of temperature. Distances measured along the horizontal line of abscissæ represent depths on the scale of 0·01 inch to a fathom, and temperatures on the scale of 0·1 inch to a degree centigrade. Distances measured along the line of ordinates represent scale divisions (millimetres) on the scale of 0·1 inch to a division. For 100 fathoms of depth the apparent contraction of the mercury instrument was 0·7 millimetre on the stem; in the water instrument the apparent contraction for 100 fathoms was somewhat over 7·8 millimetres. Considering that the effect of a change of temperature of 1° C. causes an apparent change of volume in the mercury piezometer represented by about 2·5 millimetres, while in the water piezometer at the low temperature always found in the deep sea the temperature may be anything between 0° and 10° C. without altering the apparent volume of the water by more than 2 millimetres on the stem, we see that an error in determination of the depth of 100 fathoms would only make a difference in the reading of the mercury instrument of about 0·6 millimetre, equivalent to a difference of temperature of about 0°·25 C. Therefore, applying the possibly erroneous depth given by the sounding line to "clear" the reading of the mercury piezometer for effect of pressure, we obtain a first approximation to the temperature which would almost always be within half a degree of the truth, but which might occasionally differ more than a degree from it. Using the temperature thus found to clear the reading of the water piezometer for the effect of temperature, we obtain a second approximation to the depth which cannot differ appreciably from the true depth. Applying the depth so found to clear the reading of the mercury instrument for effect of pressure, we

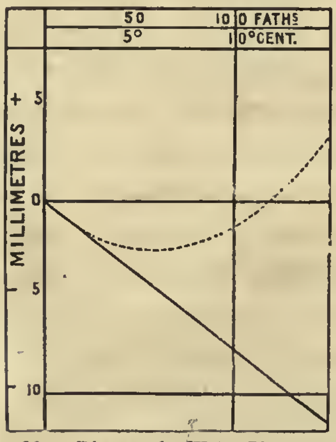


FIG. 36a.—Diagram for Water Piezometer.

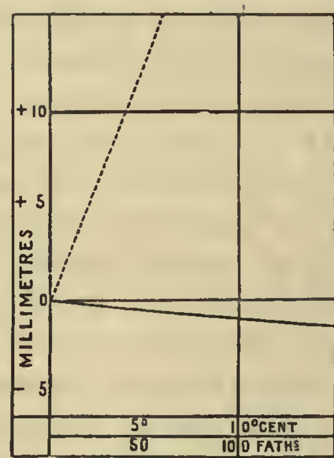


FIG. 36b.—Diagram for Mercury Piezometer.

obtain a second approximation to the temperature which cannot differ appreciably from the truth. This process of gradual approximation may of course be carried as much farther as we please, but the results obtained in the second approximation may under all circumstances be taken as representing the truth.

The use of water for filling piezometers to be used in the determination of great depths is not to be recommended, as its elasticity varies greatly with the temperature, so that a small error in the determination of the temperature has a serious effect on the depth as given by the piezometer.

The piezometer, when filled with sea water, shows directly, when corrected for the contraction of the glass, the density of the water at the depth where it registers. A certain number of observations in this direction was made during the cruise.

Specific Gravity of Ocean Water.—It has been shown above that the density of the water, in so far as it depends on temperature and pressure, can be directly observed with the piezometer. When the salinity of the water varies, and it is required to observe its variations, it is necessary, by one method or another, to measure and weigh a mass of the liquid. This was effected satisfactorily by the use of a hydrometer (fig. 37), specially designed by Mr. Buchanan for the purpose.[1]

The following is a description of the instrument used for the whole of the work done during the cruise. The stem, which carries a millimetre scale 10 centimetres long, has an outside diameter of about 3 millimetres, the external volume of the divided portion being 0·8650 cubic centimetre; the mean volume of the body is 160·277 c.c., and the weight of the glass instrument is 160·2128 grammes. With this volume and weight, it floats in distilled water of 16° C. at about the lowest division (100) of the scale. In order to make it serviceable for denser waters, a small brass table is made to rest on the top of the stem, of such a weight that it depresses the instrument in distilled water of 16° C. to about the topmost division (0) of the scale. By means of a series of six weights, multiples by 1, 2, 3, 4, 5, and 6, of the weight of the table, specific gravities between 1·00000 and 1·03400 can be observed. It is not necessary that these weights should be accurate multiples of the weight of the table; it is sufficient if they approach it within a few milligrammes, and their actual weight be known with accuracy. The weights of the table and of the weights in actual use were :—

Fig. 37.—Hydrometer.

Weight of table, ...	0·8360 grammes.
,, of weight No. I. . . .	0·8560 ,,
,, ,, II. . . .	1·6010 ,,
,, ,, III. . . .	2·4225 ,,
,, ,, IV. . . .	3·2145 ,,
,, ,, V. . . .	4·0710 ,,
,, ,, VI. . . .	4·8245 ,,

For oceanic waters, the hydrometer is always used with the table, and either No. IV. or No. V. weight.

For using this instrument at sea, about 900 c.c. of sea water are taken, and the containing cylinder placed on a swinging table, in a position as near the centre of the ship as possible (fig. 38). The observation with the hydrometer, loaded with the necessary table and weight, is then effected in the ordinary way, the accuracy of the readings being but little affected by rolling; pitching, however, is found to have a distinctly disturbing effect, and when it is in any way violent, it is advisable to store the specimen of water till the weather improves.

The temperature of the water at the time of observation is determined by one of

[1] Phys. Chem. Chall. Exp., part ii., 1884.

Geissler's "normal" or standard thermometers, graduated into tenths of a degree centigrade; and it is essential for the accuracy of the results that the water, during the observations of the hydrometer, should be sensibly at the same temperature as the

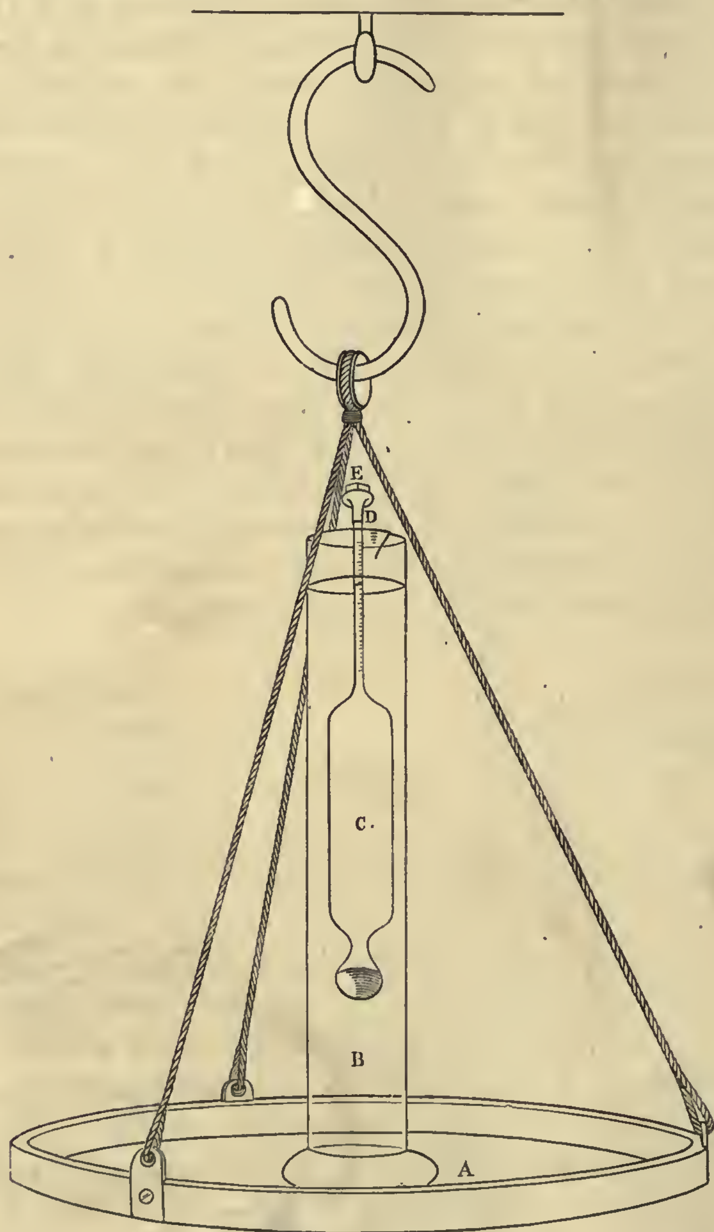


Fig. 38.—Method of using the Hydrometer.

atmosphere, otherwise the changing temperature of the water makes the readings of both the hydrometer and the thermometer uncertain.

Collection of Samples of Ocean Water.—Water from the *surface* was collected in the ordinary way in a bucket. Water from the *bottom* was collected in an instrument specially constructed for the purpose.

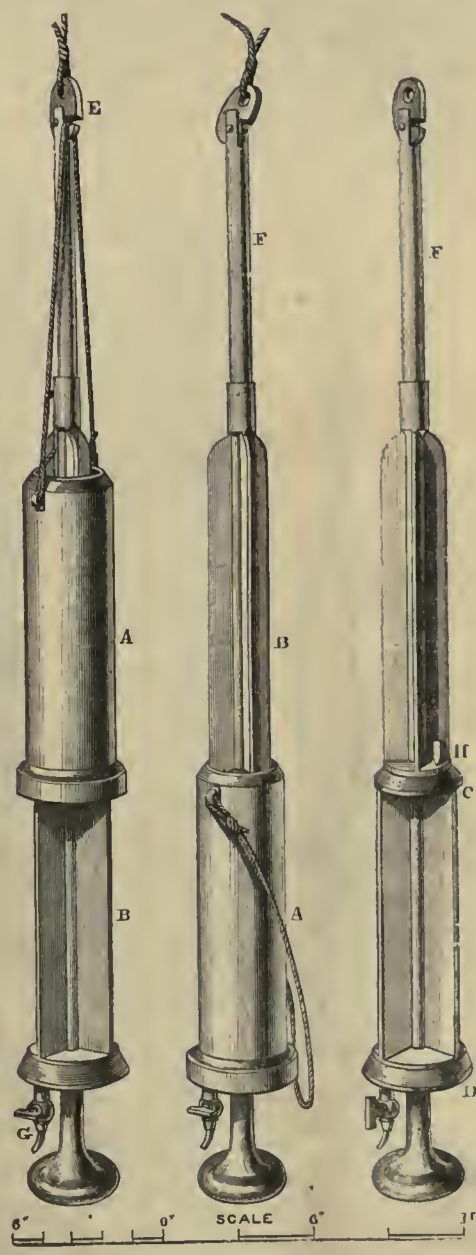


FIG. 39.—The Slip Water-Bottle.

The Slip Water-Bottle consists essentially of a brass cylinder A (fig. 39), which slides up and down a metal shank B, of at least twice its length. When the water-bottle is sent down, the cylinder is fixed in the upper part of the shank; and when it arrives at the bottom it is released and falls down to the lower part, where it rests on the lower of two accurately ground valves C and D, which fit into two conical surfaces on the inside of its upper and under edges. Thus the water which surrounds the shank at the moment of slipping is securely enclosed. The proper working of the instrument is dependent on the shank remaining straight; any bend in it would cause the valves to leak. In the instrument used in the German North Sea Expedition[1] this was provided for by the two valves being connected by a short iron rod, and the upper valve with the slipping arrangement by means of four slighter ones. But for deep soundings, where it is attached to a line along with a weight of three and often four hundredweight, greater strength is necessary to enable it to withstand the knocks to which, even with the utmost care, it is exposed, in being hoisted over the ship's side in a sea-way. Mr. Milne of Edinburgh, into whose hands the construction of the instrument was put, secured this end in a way which adds equally to the elegance and to the strength of the instrument. The shank and valves are one solid brass casting of the shape shown in the figure, the cylinder is another, and the slipping arrangement E, fixed to the end of a rod F of suitable length and great stoutness, is screwed into the top of the shank, the screw being secured by a rivet. The water enclosed is removed by means of a tap G, passing through the lower

[1] Die Expedition zur physicalisch-chemischen und biologischen Untersuchung der Nordsee im Sommer 1872, Berlin, 1875.

valve, air being at the same time admitted at the top by the removal of a plug H, from a hole in the upper valve. The lower valve and stop-cock are protected from damage when striking against the ground by the casting extending about six inches below the valve. The arrangement and dimensions of the parts are sufficiently apparent from the wood-cut to make further description unnecessary. The slipping arrangement is in principle the same as that used on Brooke's sounding rod.

In order to adapt this water-bottle to collecting water at intermediate depths, it is fitted with a slipping plate (see fig. 40), furnished with a metal flap Q, which depresses it when the motion of the instrument is reversed. It is inserted into a slot S, immediately below the usual slipping plate to which the sounding line is attached, and differs from the latter in having a deeper notch R, and having a slot instead of a hole for the reception of the pin T, round which it turns. The object of this slot is, that after the string has been cast free, the flap may fall down close alongside the rod and afford as little resistance as possible in pulling up. In using the instrument, it must be let go before the flap enters the water, and not checked until the depth desired has been reached. On board the Challenger the slip water-bottle was only used to obtain specimens from the bottom.

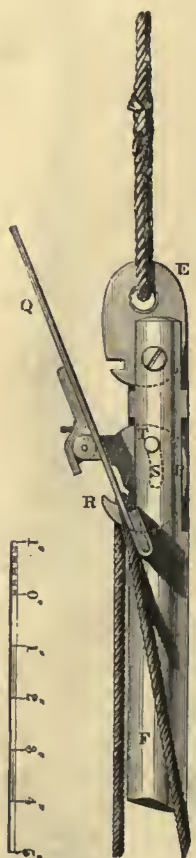


Fig. 40.—Instrument for slipping the Cylinder at intermediate depths.

The Stop-cock Water-Bottle.—Water from *intermediate* depths is obtained in an instrument represented in fig. 41. It is made entirely of brass, which, however, might advantageously be nickel-plated. It consists of a cylinder A, terminated at both ends by similar stop-cocks B, B, which are connected by the rod C. This rod carries, near its upper extremity, a piece of stout sheet brass E, 10 centimetres long by 15 broad, soldered to the casting F, which is movable about an axis. The function of this part of the apparatus will be more easily explained by describing the manipulations necessary when collecting water.

When intermediate water is to be obtained, the water-bottle is firmly attached to the sounding line, which carries at its end usually a 56 lb. or a 1 cwt. lead; the stop-cocks are then opened, giving them, with the rod C, the position represented in the left hand figure. The line is then lowered carefully by hand, until the water-bottle is close to the surface, when it is let go, and the line allowed to run out without a check. During its passage downwards, the water courses freely through it, being considerably assisted by the conical end pieces M, M. When the requisite depth has been reached, the line is checked, hauled in a few fathoms, then let go, checked again at the same mark, and finally hauled in altogether by the donkey-engine. When the line is hauled in at first, the flap E falls down into a horizontal position, when it is caught by the movable piece of brass F, and is supported on the side opposite to E, by the rod G, which rests on the spiral spring H. The water rushing past E when thus in a horizontal position, exercises a sufficient pressure upon the rod to close the stop-

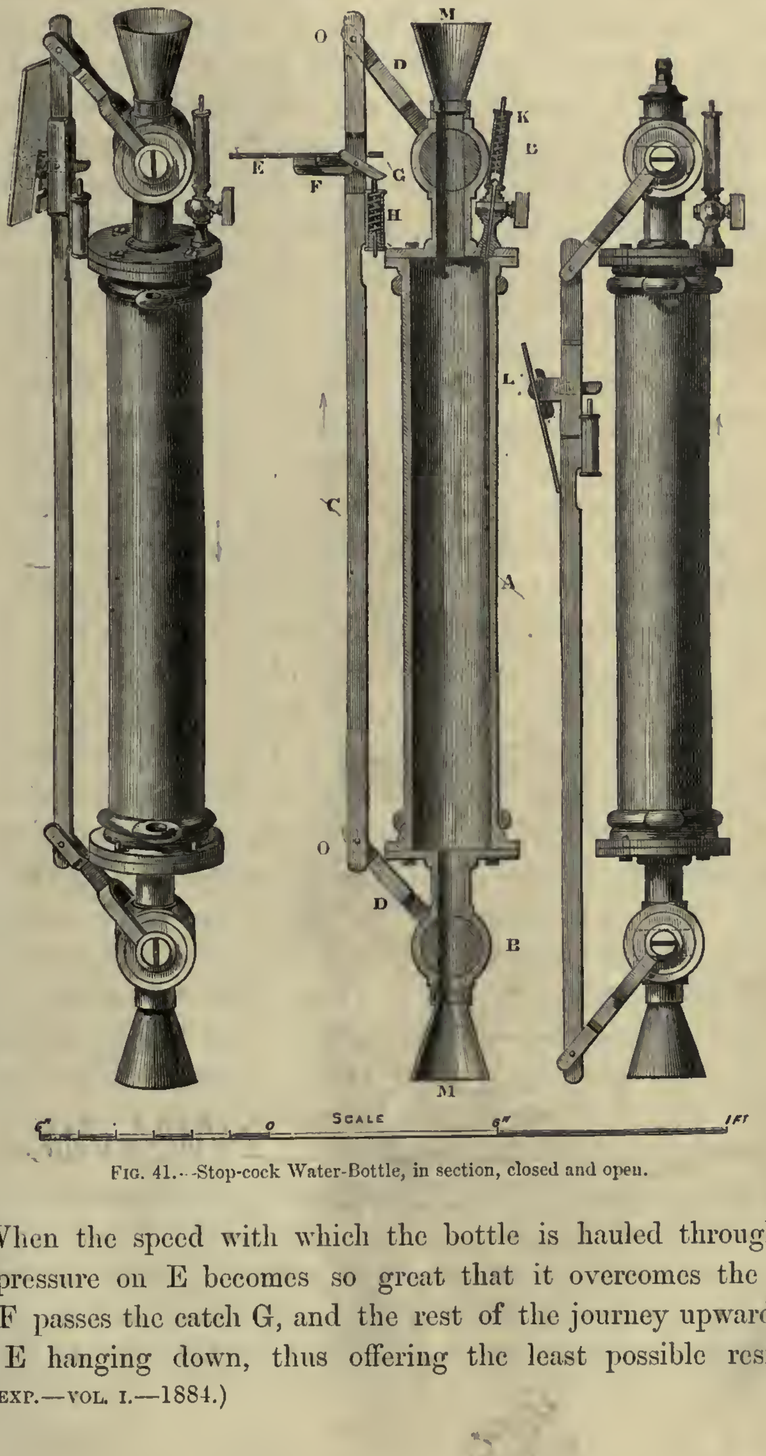


FIG. 41.—Stop-cock Water-Bottle, in section, closed and open.

cocks B, B. When the speed with which the bottle is hauled through the water is increased, the pressure on E becomes so great that it overcomes the tension of the spring H, and F passes the catch G, and the rest of the journey upwards is performed with the flap E hanging down, thus offering the least possible resistance to the water. The object of at first hauling in only a couple of fathoms or so, and letting the line go again, is to ensure the cocks being closed; for, supposing after the first hauling in they were not quite closed, by letting the instrument descend through the water, the flap E sets itself again, and, on heaving in, it shuts down the stop-cocks, which were before but partially closed; or, if they were closed before, it shuts them the tighter. When the water-bottle has been brought up, it is only necessary to substitute for the lowermost brass funnel a small nozzle, when the water may be tapped into any vessel destined to receive it. This done, the bottle may be at once lowered to any other required depth, much time being saved by not having to detach it each time. At the upper end of the bottle a small spring safety-valve K is introduced, in order that the considerably denser water from below may be able to make room for itself as the surface is approached. In order that the instrument may do its work properly, it is evident that, firstly, the stop-cocks should be so stiff that the weight attached to their levers be not sufficient to close them, and secondly, the spring H should be so strong as to ensure the shutting of the cocks before it gives way itself. These conditions are secured by the following means of adjustment. The stop-cocks can be made stiffer in the usual way, by tightening the screws which secure the "plugs" in the "barrels"; the tension of the spring H can be increased or diminished by means of a screw at the lower end of the tube containing it; and the mobility of the stop-cocks can be further regulated by means of the screws O, O. Although from this description the operation of adjustment may appear complicated, it is in fact, practically, very simple. After being once used, it is rare that any further adjustment is required than a turn of the screws O, O.

The diameter of the apertures at either end is necessarily smaller than that of the cylinder; it is therefore impossible for the water in it to be entirely changed while it descends through a distance equal to its own length. It became a question, therefore, for experiment to decide what actually was the rate of change of water. To this end, a few experiments were made in a freshwater lake. The bottle being filled with water containing some yellow prussiate of potash, was sunk in the lake, until the surface of the water was on a level with the upper stop-cock, when the stop-cocks were opened and the line let go. On being brought up again, the contents were tested with solution of perchloride of iron. It was found that when the bottle had been sunk to a depth of a fathom and a half the water had been entirely changed, the iron solution being wholly without action on it. It is certain, then, that the water obtained by this means is an average of the last two fathoms through which the bottle has passed.

The weight used as a sinker should be chosen so as to impart sufficient velocity not to lose time unnecessarily over the operation, and at the same time not to give an excessive velocity at the depth where the water is to be collected, because the rate of change of water depends on the friction of the water inside the bottle, and so on the velocity of descent. In practice, for depths over 100 fathoms a weight of 112 lbs. was used, and for depths from 25 to 100 fathoms a weight of 56 lbs. was used, whilst for depths less than 25 fathoms the weight of the bottle itself was sufficient. The velocity of descent at the depth where the water is to be collected should not exceed 12 feet per second. The mean velocity of descent for the interval between 75 and 100 fathoms from the surface was, with 56 lbs. 9 feet, and with 112 lbs. $11\frac{1}{2}$ feet per second.

When once let go, it is essential that the line should run out to the required depth without a check; then, however, it is immaterial, as far as the water-bottle is concerned, what interruptions occur in heaving in. The fulfilment of the condition of running out without a check never presented any difficulty on board the Challenger, depending as it does on the care of those who tend the line. When, however, by accident a check does occur, the line is stopped, and the water-bottle brought up, reset and sent down again. In order to utilise any such accidents, it is usual to take the water from the greatest depth first, then if a check should occur, it may do so at one of the desired intermediate depths, and so no time would be lost.

Buchanan's Improved Stop-cock Water-Bottle with Depth Gauge.—During the whole of the cruise, when it was in daily use, Mr. Buchanan felt that the mechanism for relieving the pressure in the instrument as it came towards the surface ought to be made to register the depth at which it closed. It was at once obvious that if the volume of the instrument could be allowed to increase, and its increase could be measured, while no water was allowed to escape, a method would be found. If instead of the safety valve K, a calibrated plunger penetrated through a water-tight joint into the body of the instrument, then after closing at a certain depth, the plunger would be thrust out as the instrument rose. At the first glance this seems a simple and effective method, but when the actual dimensions, which the plunger must have, come to be considered, it is evident that the method is impracticable when dealing with water from any considerable depth. This will be seen from the following considerations. The absolute compressibility of sea water may be taken at 0·00085 per 100 fathoms, which means that one litre contracts by 0·85 c.c. for every hundred fathoms of depth; consequently, every litre of water collected below, expands by about 0·85 c.c. per hundred fathoms of ascent. In a water-bottle of two litres capacity, and to be used at no greater depth than 1000 fathoms, the plunger would have a play involving a volume of 16 c.c. As from the nature of the instrument it is important to have the ratio of the diameter of the stop-cocks to that of the cylinder as large as possible, there is no room for a wide plunger in the cover of the instrument, and if it is made narrow, its length puts it out of the question. Since the close of the cruise, experiments made by Mr. Buchanan on board the "Mallard," have resulted in a fairly satisfactory practical solution of the problem. The water-bottle as altered is shown in fig. 42. In it the spring safety valve is replaced by a nozzle K, screwed water-tight into the top. To this nozzle inside the bottle is attached an elastic vessel capable of collapsing under slight pressure, and returning to its original volume when the pressure is relieved. For most purposes a piece of india-rubber tube, closed at the end as represented in the cut, suffices. Before sending the bottle down, the inside of the india-rubber tube and nozzle is filled up with water. When it reaches the required depth the

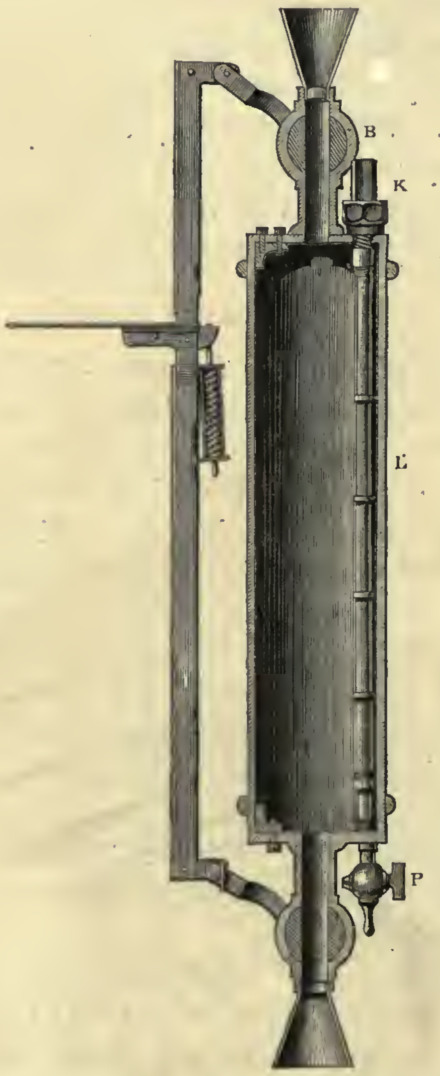


FIG. 42.—Buchanan's Improved Stop-cock Water-Bottle in section.

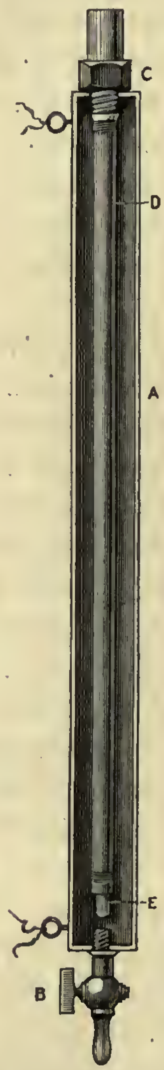


FIG. 43.—Depth Gauge.

bottle closes on its own volume of water. As it rises the water expands, and the collapsible vessel easily makes room for the increased volume. After having arrived at the surface, the small pet-cock P is opened, and the water escaping is caught in a graduated vessel. Water runs out of this cock until the internal india-rubber tube has dilated to its original volume, being kept itself full of water. From the volume of the overflow as compared with that of the bottle the depth at which it closed can be readily calculated.

The same principle has also been applied in the construction of a sounding machine for ascertaining the depth. A straight brass tube A (fig. 43) is closed at the lower end by a stop-cock B, and at the upper end by a nozzle C, to which the india-rubber tube D is attached inside the tube A. D is closed by a valve E, opening downwards. As this instrument sinks, water enters through C, D, and E into the brass tube A. When it begins to ascend, the water cannot get back through the valve E, and in expanding it crushes the tube D. On arrival at the surface, the excess of water is tapped off through B, and the depth calculated, regard being had to the temperature.

A water-bottle of peculiar and ingenious construction, used by Jacobsen in the German North Sea Expedition in the "Pommerania" in 1872,[1] was supplied to the Challenger, but was unfortunately mislaid at the fitting out, and notwithstanding repeated searches was not found till the ship returned. It is described by Dr. Jacobsen in the report of the above voyage, and also in Liebig's Annalen for May 1873.

Buchanan's Combined Sounding Tube and Water-Bottle.—Figs. 44, 45, 46, 47, represent a sounding tube with detaching weight, suitable for ordinary sounding with wire. With it good samples of the mud and of the bottom water are obtained without trouble. The instrument consists of the "water bottle" A, a tube about 18 inches long and 2¼ inches in diameter, of about one litre capacity. It has at each end a valve H, K, made of india-rubber, on a metal seating, opening upwards. Above the upper valve H, the shank C is screwed into the tube A, and below the lower one K, the mud tube B, which is 12 inches long and 1 inch in diameter, is screwed to A. Into the lower end of the mud tube B can be inserted the valve L, which consists of a piece of thin sheet brass, cut out like a comb, and bent round into a cylindrical shape. It is soldered to a stouter piece of brass tube, which fits into the end of B and is retained by a bayonet-joint. At the upper end of the shank C the tumbler D supports the weight E by the sling F, and is in its turn supported by the sounding line M.

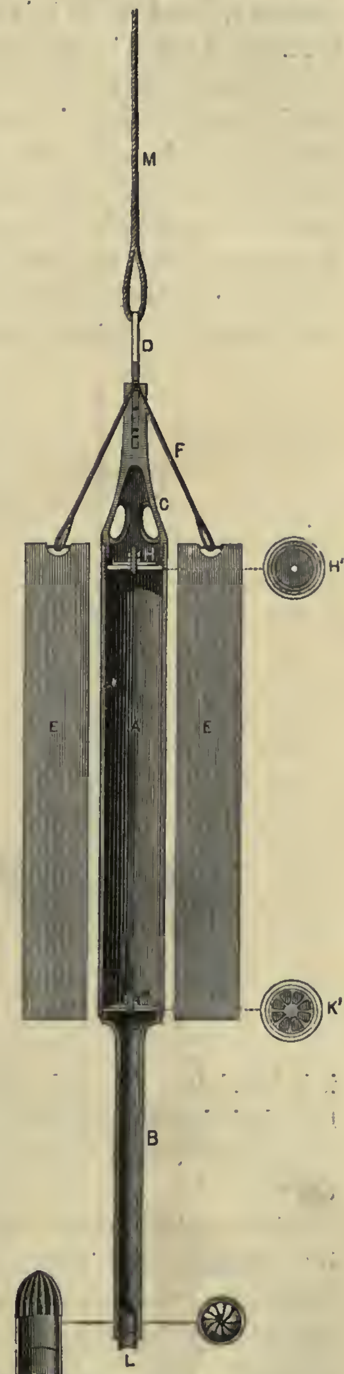


Fig. 44.—Buchanan's Combined Sounding Tube and Water-Bottle.

The details of the tumbler are shown in figs. 45, 46, 47. It will be seen that at its upper end it

[1] Die Expedition zur physicalisch-chemischen und biologischen Untersuchung der Nordsee im Sommer 1872, Berlin, 1875.

has the hole *a*, into which the eye of the sounding line is spliced. At the lower end it has three notches, *b*, *c*, and *d*. If it is not wished to detach the weight, the sling supporting it is hooked into the notch *d*, which is considerably below the suspending axis. Consequently, when the tube reaches the bottom and the sounding line above slackens, the tumbler still preserves its upright attitude, and on heaving up, the sinker is recovered along with the tube. If the sinker is not to be recovered, the sling is hooked in the notch *b*, which is above the axis. When the tube reaches the bottom and the sounding line slackens, the pressure of the sling upsets the tumbler, which falls over into the position fig. 46. In getting into this position the weight drags the sling out of the notch *b*, and it falls into the notch *c*. Here it remains as long as the tube is at the bottom, exerting all its weight in pushing it into the ground. On heaving in, the tumbler is drawn into an upright position, when the sling slips free and the tube is brought up without the sinker. When it has been brought to the surface,

Fig. 45.

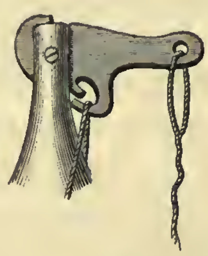


Fig. 46.

Fig. 47.

Disengaging Apparatus for Buchanan's Water Bottle.

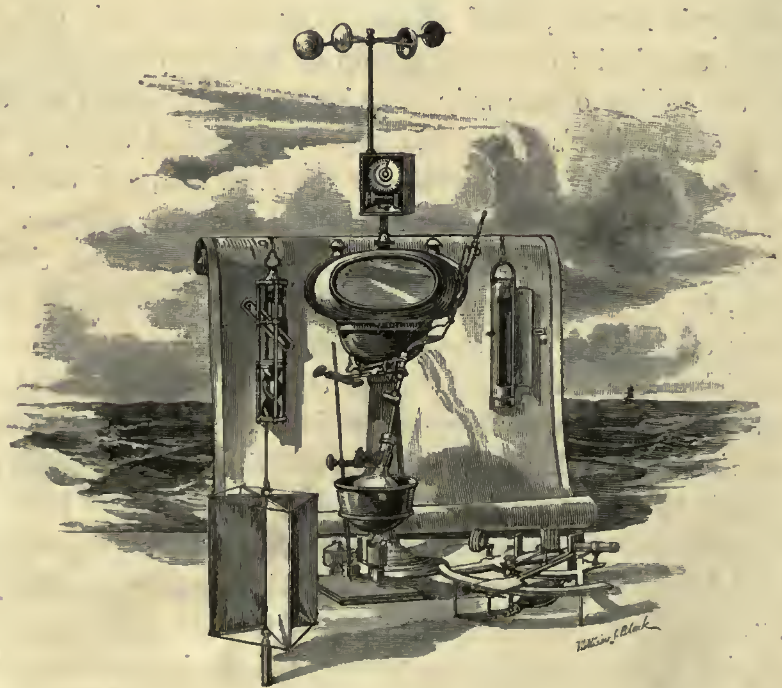
it is found that the mud tube B is filled with a compact cylinder of mud, which by its weight has kept the india-rubber valves closed by drawing them tight down on their seats, and has therefore insured that the water enclosed at the bottom has not been contaminated by admixture with other water on the way up.

The localities, even in mid ocean, where the bottom is "hard ground" are by no means rare, and if the tube just described be dropped on it with a 50 lb. sinker, the mud tube will be much disfigured; but if there be any loose material at all, such as gravel or coral, a little of it will be nearly sure to get entangled behind the comb valve. In the absence, however, of a mud plug, the bottom water will be valueless. As a rule, the bottom of the sea, whether deep or shallow, consists of mud sufficiently soft and tenacious to fill the mud tube throughout the greater part of its length with a compact plug, and if the tube B be screwed water-tight into the lower part of the tube A, it is retained in it just as a liquid is retained in a pipette. In soft mud, clay, Globigerina ooze, and the like, it is better to discard altogether the comb valve L, because it always offers some resistance to the entrance of the mud, and is not wanted to keep it in. In fact it not only offers resistance to the entrance of the mud, but as its diameter is necessarily somewhat smaller than that of the tube B, the mud cylinder is also of less diameter than B, and rests on the valve L, leaving a passage between the mud and B. This interferes with the action of the instrument as a mud-pipette, on which its efficiency as a water-bottle depends. The instruments are fitted with mud tubes of two sizes, namely, the smaller of 1 inch diameter, and the larger of $1\frac{3}{4}$ inches diameter. In the ordinary routine work of running a line of soundings the smaller size should be used and without the comb valve. It is screwed into A on the top of a thin leather washer to make the joint tight. At each sounding a sample of the mud and of the bottom water will be obtained. When the tube is brought on board the mud tube is unscrewed, any water that may be on the top of the mud cylinder is poured off, and the mud cylinder itself pushed out by a metal plunger which just fits the tube. The water is simply poured out of the bottle into any convenient vessel. If the gases dissolved in the water are to be examined, then it must be drawn off by a siphon passed through the upper valve and down to the bottom of the tube.

This sounding tube has been very successfully used on board the ships "Dacia" and "International," belonging to the India-rubber, Gutta-percha and Telegraph Works Company, while surveying the route for the cable from Cadiz to the Canary Islands. It has the advantage that on board such ships, where rapidity of work is of the greatest importance, good samples of mud and of bottom water are obtained in the course of the ordinary routine work, and without having to use any extra instruments. The weight of the sinkers used was 60 lbs., but 50 lbs. is quite heavy enough. When the sinker is to be recovered its weight should not exceed 30 lbs.

Method of Taking Temperatures.—The actual method adopted on board the Challenger for obtaining the temperature below the surface was as follows :—A temperature line, of No. 1 sounding rope, 1500 fathoms in length, was kept on a separate reel, and a set of accumulators, twenty in number, fitted with a patent block at their end for the line to reeve through, was attached to either the fore or main yardarm, generally the main, so as to prevent the rolling of the ship bringing an undue strain on the line, and to keep it well clear of the ship's side. The rope was marked at every 10 fathoms for the first 200 fathoms, at every 25 fathoms for the next 100, and at every 50 fathoms to 700 fathoms, after which it was only marked at the 100 fathoms. Fifty fathoms were allowed for stray line at the beginning. It was first rove through a leading block on the deck, for the convenience of bringing it to the drum of the engine, then through the block attached to the accumulators, and then through the thimble of a "lizard," after which a cup lead was attached to it, of from $\frac{1}{2}$ to $1\frac{1}{2}$ cwt. according to circumstances. The weight was then lowered into the water 50 fathoms, or until the first mark on the line was level with the hammock rail, when the bight of the line was hauled in to the rail by means of the lizard, and a thermometer "bent on"; the bight of the line was then carefully eased out by the lizard until it hung perpendicularly from the yardarm, when 100 fathoms were veered and another thermometer attached, and so on until eight had been "stopped on." Only that number of thermometers was used at a time, as there is always a risk of the sounding line parting and the instruments being lost. As a rule it was not deemed necessary to obtain temperatures at every 100 fathoms below 1500 fathoms, as the difference of temperature between that depth and the bottom is very small. The observations were generally first made between 800 and 1500 fathoms. When 1500 fathoms of line had been "paid out," and the mark on the line carefully brought level with the surface of the water, the line was secured and kept quite perpendicular for five minutes, each thermometer then registered the temperature of the water at the depth to which it had been lowered. The line was then hove in, and as each thermometer reached the level of the sounding platform, or hammock rail, it was hauled in by the lizard, unbent, carefully read off, and registered. The temperatures were then taken from the surface to 700 fathoms in the same manner, or when they varied much they were taken at intervals of 25 or even 10 fathoms between the thermometers.

The results of these temperature observations were then corrected for errors of zero point, after which they were plotted on a paper of equal squares, specially provided for that purpose, and a curve of temperatures drawn, so that the temperature at any depth could be ascertained. The curve shows directly whether any of the results disagree with the temperatures shown by the main body of the thermometers, and if such were the case, the temperatures at those depths were taken again. When the temperature observations between any two places had been completed, a section was constructed from the temperature curves showing the relative positions of the isotherms from the surface to the bottom. The observations and curves used in the production of the Diagrams of Temperature given in this volume are published as Part III. of the Physics and Chemistry of the Expedition.



CHAPTER IV.

Tenerife to St. Thomas—St. Thomas—St. Thomas to Bermuda—The Brachiopoda—Gulf Weed Fauna—Description of Bermuda—Bermuda to Halifax—The Gulf Stream—Halifax to Bermuda—The Tunicata.

Tenerife to St. Thomas Island, West Indies.

The Challenger left Santa Cruz, Tenerife, on the evening of the 14th February. The weather was bright and pleasant, with a light breeze from the northeast. A southwesterly course was pursued for a few days, until well within the northern limit of the trade wind, after which the route followed was, as nearly as practicable, in a straight line

Fig. 48.—Peak of Tenerife from the N.W., 40 miles.

to Sombrero Island, the outlying sentinel at the northeast extremity of the Lesser Antilles. On the 14th March the island of St. Martin was sighted, and the last sounding on the Tenerife–Sombrero section obtained, after which a course was shaped to pass between Sombrero and Dog Island, and on the 15th three soundings and three dredgings were obtained in from 450 to 590 fathoms southwest of Sombrero. On the 16th, at 1.30 p.m., the ship arrived at St. Thomas Island, and anchored in the Gregerie Channel, so as to enjoy the full benefit of the sea breeze during the stay in the port.

On this section twenty-four soundings, fifteen dredgings, two trawlings and thirteen serial temperature soundings were taken (see Diagram 1 and Sheet 6). The sounding line parted on one occasion, owing to the spring of the Hydra rod failing to disengage the sinkers; and on another occasion the rod when it reached the surface had nearly 100 fathoms of sounding line entangled around it, owing, in all probability, to the perfect stillness of the water for some considerable distance over the bed of the sea, so that the quantity of line allowed to run out in excess of the depth (necessary to obtain by the time intervals a proof that the bottom had been reached) descended exactly on the sounding rod, and remained entangled by the last coil hitching itself round the other parts before "heaving in."

Of the fifteen dredgings five were unproductive, the dredge having come up empty twice and foul thrice. One of the most successful dredgings in this section, so far as procuring a large sample of the deposit from the bottom was concerned, was obtained by sinking the apparatus with 3 cwt. of sinkers attached to a Hydra rod at the bottom of the dredge net, the depth being 3150 fathoms. The bag came up with a large quantity of mud in it. The temperature of the mud was found to be the same as the bottom temperature given by the deep-sea thermometers, and some champagne was cooled by placing the bottles in it. The first trawling in 1950 fathoms, the deepest up to that time attempted, was unsuccessful, as the beam of the trawl, which was of fir, was broken at the bottom, whilst the pressure of the water was sufficient at that depth to crush the softer parts of the wood to such an extent that, when the beam was brought to the surface, the knots were standing out nearly three quarters of an inch beyond the general surface of the wood.

This section (see Diagram 1) shows a remarkable rise in the bed of the Atlantic from 2000 to 1525 fathoms, at a point about 160 miles S.W. of Ferro Island (see Sheet 6). This elevation, which appears to be of small extent, is probably of volcanic origin. Westward of it the bed of the ocean sinks until a depth of 3150 fathoms is reached 1100 miles from Tenerife, after which it gradually rises to 1900 fathoms 1650 miles from Tenerife, and again sinks to 3000 fathoms (which depth it retains for 200 miles, until within 100 miles of Sombrero Island). In short, the soundings clearly indicate the existence of depressions on each side of the section, separated from each other by a gradual submarine elevation of over 1000 fathoms (6000 feet). As the United States surveying vessel "Dolphin" had obtained some soundings on this elevation in 1851, it was named the "Dolphin Ridge."

The temperature of the water at the bottom was, at all depths exceeding 1800 fathoms, exceedingly uniform, varying only 1°·5, or from 35°·5 to 37°·0; but although this range is small, it is sufficient to indicate a decided difference between the bottom temperatures on the eastern and western sides of this section. For instance, the twelve temperatures on and to the eastward of the Dolphin Ridge only vary half a degree, from 36°·5 to 37°·0, the mean being 36°·8; whilst the mean of the seven temperatures west of

the ridge is 36°·0, or 0°·8 below those on the east side ; their range being 1°·0, or from 35°·5 to 36°·5 ; so that the highest bottom temperature registered in this section west of the ridge was the same as the lowest obtained on the eastern side.

The thirteen serial temperature soundings obtained showed that the water gradually cooled from the surface to 40°·0 at an average depth of 900 fathoms ; and as the mean depth of the ocean between the Canary and Virgin Islands was found to be 2400 fathoms, it follows that for an average height of 1500 fathoms (9000 feet) from the bottom, or two-thirds of the whole depth, the water is below the temperature of 40°·0 (see Diagram 1). The range in the depth occupied by the isotherm of 40° was considerable, being as much as 300 fathoms, but although the greatest depth it attained was near the eastern extremity of the section, and the least near the western, the change was by no means gradual, for it was found to occupy a mean depth of 1000 fathoms for 1000 miles west of Tenerife, whilst for 1700 miles east of Sombrero Island its mean depth was only 800 fathoms, the change occurring in the intermediate 300 miles. At the depth of 380 fathoms the temperature of 49°·0 was found constant the whole way ; from the surface to that depth the water became gradually warmer towards the West Indies, the alteration being due principally to a change of 10° in latitude, viz., from 28½ at Tenerife to 18½ at Sombrero Island.

The specific gravity of the surface water rose rapidly on leaving Tenerife from 1·0272 to 1·0277 in mid ocean, and diminished again to 1·0269 as the West Indies were approached. The ship had thus passed through the saltest water found anywhere in the open ocean. The specific gravity of the bottom water varied from 1·0260 to 1·0275. Serial determinations of specific gravity showed that in mid ocean the saltest water was at the surface, but nearer the West Indies, where the surface water instead of 1·0277 showed a specific gravity of only 1·0269, the specific gravity of the water was 1·02712 at 50 fathoms, 1·02740 at 100 fathoms, and 1·02752 at 150 fathoms, falling off to 1·02682 at 200 fathoms and 1·02613 at 500 fathoms.[1]

The current drag was tried occasionally on the passage to St. Thomas. On the 17th February, at Station 2, it was lowered to 200 fathoms, and the watch buoy attached ; and as no movement of the water past the buoy was perceptible, it was concluded that either there was no current, or that the whole body of water, to the depth of 200 fathoms, was moving in the same direction and with the same velocity. On the 18th February, at Station 3, the drag was lowered to 100 fathoms with the same result. On the 26th February, at Station 9, the drag was lowered to 200 fathoms, and the surface water was found running past the watch buoy to the S.S.W. (true) at the rate of 0·3 mile per hour. On the 3rd March, when lowered to 250 fathoms, at Station 12, the surface water ran past the watch buoy in a W. by S. (true) direction at the rate of 0·3

[1] The specific gravities quoted in this volume are reduced to their value at 60° F. (15°·56 C.) and referred to that of distilled water at 39°·2 F. (4° C.) as unity ; see Phys. Chem. Chall. Exp., part ii., 1884.

mile per hour, and on the 13th March, at Station 21, the drag was lowered to 100 fathoms, when no movement of the water could be detected.

Anemometer observations were obtained whenever circumstances were favourable, that is, when the ship was stationary whilst sounding, and the instrument was not masked by an awning, a sail, or any part of the rigging. When first used it was placed on the top of the small deck charthouse on the pilotage bridge; but as it was in that position so frequently masked by the awnings or rigging, it was shifted to the top of the foremost davit of the weather quarter boat, where it was quite clear of such obstructions. On the 17th February, at Station 2, the force of the wind being registered as 2 in the Meteorological Register, the velocity by the anemometer was 10 miles per hour. On the 21st, at Station 5, the force of the wind being registered as 3, the velocity by the anemometer was 16 miles per hour from noon on that day to 8.40 A.M. on the 22nd. On the 23rd, at Station 6, from 4 to 6 P.M., the velocity was 30 miles per hour, and the force was registered as 5 to 6. On the 24th February, at Station 7, from 3 to 6 P.M., the force of the wind 4 to 5, the velocity was 17 miles per hour. On the 25th February, at Station 8, the force of the wind being 4 to 5, the velocity was 19 miles per hour; and on the 26th February, at Station 9, the force of the wind being registered as 5, its velocity was 23 miles per hour.

The observations with respect to the position of the ship, wind, currents, temperature, and depth, are represented graphically on Sheets 6 and 7, and Diagram 1. With respect to the Diagrams accompanying this Narrative, they are designed with a view of showing the distribution of temperature in the part of the ocean traversed, and the horizontal and vertical scales have been chosen accordingly. Horizontal lengths or distances from Station to Station are on a scale of 200 miles to the inch, which gives the diagram a convenient length; and depths are on a scale of 500 fathoms to the inch, which separates the isothermal lines to a convenient distance from each other. Hence, depths or heights, as compared with horizontal distances are exaggerated in a proportion of 400 to 1. In looking, therefore, at the plan as one of the bed of the area, it must be remembered that the inclines as observed were 400 times less steep than they are represented. The diagram shows the isotherms for every five degrees. The positions of the isotherms for each whole degree as represented were found by plotting the observations and drawing the curve as referred to in the preceding chapter[1] (see page 120).

The dredgings and trawlings in the deeper water of the Mid Atlantic did not yield a large number of animals. An Annelid (*Myriochele*) was obtained from 2975 fathoms, several Polyzoa and two small Lamellibranchs from 2740 fathoms, and Sponges, Brachiopods, Polyzoa, small Lamellibranchs, and Gasteropods, and several Crustaceans from 1900 and 1950 fathoms. In 450 fathoms, however, close to Sombrero Island, a large number of animals—Alcyonarians, Echinoderms, Annelids, Molluscs, Crustaceans, and Fishes—were obtained.

[1] See Phys. Chem. Chall. Exp., part iii., 1884.

On the 18th February a dredging was taken in 1525 fathoms, about 160 miles S.W. of Ferro Island (see Sheet 6, Station 3), which has proved to be one of the most curious during the whole cruise. Two soundings were taken at the same spot, giving 1520 and 1525 fathoms. The Hydra tube in both cases came up empty, but was marked on the outside with black streaks. The dredge was lowered at 10 A.M., with 2200 fathoms of line, and 2 cwt. of sinkers 300 fathoms from the dredge, and at 5.30 P.M. it was hauled up, and contained some large branches of an Alcyonarian Coral allied to *Corallium*.[1] Some of the larger branches were nearly an inch in diameter. The central portion of the axis was very compact and of a pure white colour, while the surface was glossy black. The bases of the Coral were attached to large fragments of what turned out to be portions of manganese-iron concretions, which appeared to have been torn away from still larger masses. The whole of the Coral was dead, and appeared to have been so for a long time, as its surface was everywhere covered by a deposit of peroxide of manganese. It is not improbable, however, that the Coral lived at the depth at which it was dredged, at the time the deposit of the manganese was going on, inasmuch as the flattened bases of the Coral were seen between the concentric layers of manganese nodules to which they were attached.

Attached to the branches of the Coral there was a magnificent specimen of a Hexactinellid sponge, allied to *Hyalonema*, which has been described by Professor C. Wyville Thomson under the name of *Poliopogon amadou*[2] (see p. 439). The basal portions of the sponge had some patches of Globigerina ooze attached to them, made up of pelagic Foraminifera, Pteropods, Heteropods, Coccoliths, Rhabdoliths, otoliths of Fish, fragments of Echinoderms, and a good many particles of volcanic minerals. An Ophiurid, portions of a *Brisinga*, several Annelids, several Polyzoa, and one or two Corals came up in the same dredge.

With the exception of a few stormy Petrels and an occasional Puffin, no birds approached the ship while making this passage of the Atlantic. This was in striking contrast with experiences in more northern and southern latitudes, where large numbers of sea birds usually followed in the wake of the ship. The tow-net was frequently used, but not so constantly or systematically as in the latter part of the cruise; and while the vessel was engaged in sounding and dredging operations, boats were frequently lowered to enable the Naturalists to pick up the animals on the surface of the sea, but life was not found so abundant in this trade wind region as during the voyage from Gibraltar to Madeira. Towards the western portion of the Atlantic, large masses of Gulf Weed were passed, and frequent excursions made to these patches in boats in order to examine the animals living upon them (see p. 136). Dead shells of *Spirula* were frequently

[1] Mr. S. O. Ridley of the British Museum, who has examined specimens of this Coral, believes that they belong to a species of *Pleurocorallium*, Gray, probably the white or cream-coloured species *Pleurocorallium johnsoni*, Gray, which occurs at Madeira.

[2] Voyage of the Challenger, The Atlantic, vol. i. p. 175, London, 1877.

found on the surface, and were generally covered with small Cirripeds, whilst in some instances they were completely enveloped by species of *Acineta* and *Podophrya*.

The character of the deposits in this section presented considerable variety. With the exception of the hard ground already referred to, composed of manganese and coral, all the deposits in depths less than 2500 fathoms contained more than 50 per cent. of carbonate of lime. For these the names Globigerina and Pteropod oozes have been adopted, the latter being confined to two deposits from the depths of 1420 and 450 fathoms on the western side of the section, in which occurred very many Pteropod and Heteropod shells, in addition to pelagic and other Foraminifera, and in which the proportion of carbonate of lime was the greatest, being 80 to 84 per cent. Only a few fragments of Pteropods were found in the Globigerina ooze, from depths ranging between 1890 and 2500 fathoms, the carbonate of lime being made up chiefly of the dead shells of pelagic Foraminifera. In depths greater than 2500 fathoms, the quantity of lime decreased as the depth increased, and below 3000 fathoms there were only traces of carbonate of lime in the deposit.

Siliceous organisms, such as spicules of Sponges, Radiolarians, and Diatoms, were not abundant; generally they did not appear to make up more than 1 or 2 per cent. of the whole deposit, with the exception of the two deposits at 1420 and 450 fathoms, above referred to, where the proportion rises to about 6 per cent.

The mineral particles, which were mostly of volcanic origin, seldom exceeded 0·15 mm. in diameter, and consisted of felspars, hornblende, augite, magnetite, glassy fragments, and palagonite. In the deposits from the eastern portion of the section there were numerous small rounded particles of quartz covered with ologist, which would appear to be mostly wind-borne particles, carried by the Harmattan and other winds from the coast of Africa.[1] The Red Clays from the greater depths were almost entirely composed of argillaceous matter and fine mineral particles not exceeding 0·05 mm. in diameter. In the dredging on the 7th March in 2435 fathoms, there were several round compact manganese nodules, pieces of pumice several millimetres in diameter, and three or four Sharks' teeth coated with peroxide of manganese.

St. Thomas, Virgin Islands.

As the ship steamed towards the harbour at St. Thomas, Frigate Birds soared high overhead, with their long tail feathers stretched widely out. A number of brown Pelicans (*Pelecanus fuscus*) were flying at a moderate height near the shore, and every now and then dashing down with closed wings into the water on their prey like their close allies the Gannets. Often several of the birds dashed down together at the same instant.

The island of St. Thomas itself, as well as the outlying islets, is covered with a wild bush

[1] See Darwin, Journal of Researches during the Voyage of H.M.S. "Beagle," p. 5, ed. 1879.

growth, which at first sight might perhaps be taken for indigenous vegetation, but is composed of plants that have overrun deserted sugar plantations. It is only in a few remote parts of the island, and in small streaks of broken ground bordering the water-courses, that any original forest exists. The whole of the available land in the island itself, and in all the adjoining islands, was planted with sugar cane until the emancipation of the slaves in 1833; since that time the ground has been allowed to run wild. There was only one estate partly under cultivation at the time of the ship's visit, and the owner of it, Mr. Wyman, said that he made no sugar, but found sufficient sale for his canes in the raw state to be cut up and resold for chewing. The consumption of cane for this purpose must be considerable, for chewing cane appears to be the constant occupation of the negroes of both sexes and all ages. Mr. Wyman was nearly ruined by the emancipation, and said that the planters received only 50 dollars per head compensation for the loss of their slaves, and that after the lapse of three years.

The shore is covered with corals bleached white by the sun, and amongst these occur quantities of Calcareous Seaweeds (*Halimeda opuntia* and *Halimeda tridens*), branching masses composed of leaf-shaped joints of hard calcareous matter articulated together. These are all quite dry and bleached white, and hard and stiff, like corals. Seaweeds belonging to two very different groups of algæ thus secrete a calcareous skeleton, *Halimeda* and its allies, belonging to the Siphonaceæ—green coloured algæ; and *Lithothamnion* and allied genera belonging to the Corallinaceæ, which are red coloured algæ. These lime-secreting algæ are of great importance from a geological point of view, as supplying a large part of the material of which calcareous reefs and sand rocks are built up. At St. Thomas the Siphonaceæ are especially abundant, whereas at other places, as at St. Vincent, Cape Verde Islands, the Corallinaceæ appear to supply most of the calcareous matter separated from the sea water by plants.

There is only one kind of Humming Bird at St. Thomas, but it is very common, and is constantly to be seen poised in the air in front of a blossom or darting across the roads. It is remarkable how closely Humming Birds resemble in their flight Sphinx Moths, such as our common Humming Bird Sphinx, so named from this resemblance. They make in their flight exactly the same rapid darts, sudden pauses, quick turns, and the same prolonged hovering over flowers. The most conspicuous land bird in the island is commonly called the "Black-witch" (*Crotophaga ani*). These birds are usually to be seen in flocks of three or four, in constant motion amongst the bushes, and screaming harshly when they apprehend danger. They behave very much like Magpies, but are somewhat smaller than the English Magpie and black all over. They belong structurally to the family of the Cuckoos (Cuculidæ).

Two Snakes, one a species of *Typhlops* and the other apparently referable to the genus *Coronella*, were obtained, as also specimens of Lizards belonging to the genera *Anolis* and *Ameiva*.

A large ground Spider (*Lycosa*) is very abundant in the island, inhabiting a hole in the ground about six inches in depth, and from half an inch to an inch in diameter, with a right-angled turn at the bottom to form a resting chamber. Negro boys take a delight in digging the Spiders out; they believe their bite to be poisonous, and that they feed on Lizards, leaving their holes at night to search for them. They are great, heavy, venomous-looking brutes, about three inches across. Their holes were so common, that on one tolerably clear patch of about an acre in extent, they were dotted over the entire area at only about one or two feet distance from one another, and were quite conspicuous.[1]

A species of White Ant (*Termes*) is very common. It makes large globular nests of a hard brown comb, as much as two feet in diameter, perched high up in the fork of a tree. From the bottom of the tree covered galleries about half an inch in breadth lead up on the surface of the bark to the nest, looking like long, narrow, brown streaks upon the tree trunk. The galleries usually follow a somewhat irregular course up the trunk to the nest, reminding one of the curious deviations which are always to be seen in footpaths, traced by people walking across fields, in their endeavours to go straight from one point to another. The galleries, or rather tubular ways, for they have bottoms to them, are made of the same tough brown substance as the nests, and are cemented firmly to the bark. Though they are so broad as to allow numerous Ants to pass and repass, they are only high enough for the Ants to walk under. When one of these galleries is broken, a number of soldier Termites come out and begin biting the marauder's hands, and though hardly making themselves felt, they are as brave as if they had a sting. A considerable length of the gallery has to be broken before any of the working Termites' beds are reached, as they retire from the scene of danger. A new species of Wasp (*Polistes madoci*, Kirby) was found.[2]

An Agouti, a species of Rodent (*Dasyprocta*), occurs in the island, and Mr. Wyman said that it was common in the gullies near his sugar plantation.

A shooting excursion to the opposite side of the island was organised in pursuit of wild goats, pigs, guinea fowl, and the domestic fowl which breed in the wild condition in various parts of the island, having sprung, in most instances, from stock which has escaped

[1] The Lepidoptera collected on this island included the following species (Butler, *Ann. and Mag. Nat. Hist.*, ser. 5, vol. xiii. pp. 183–187, 1884).

Anosia leucogyne, Butler.
Dione vanillæ (Linn.).
Junonia cœnia, Hübner.
Heliconius charithonia (Linn.).
Tmolus columella (Fabr.).
Appias poeyi (?), Butler.
Ganoris cleomes (Boisd. and Lec.).
Callidryas sennæ (Linn.).
Terias euterpe (Ménét.).
Papilio polydamas, Linn
Goniuris proteus (Linn.).
Goniuris dorantes (Stoll).
Proteides amyntas (Fabr.).
Pamphila pustula (Hübner).
Pyrgus syrichtus (Fabr.).
Composia sybaris (Cramer).
Deiopeia ornatrix (Linn.).
Margaronia flegia (Cramer).
Botys (?) *onophasalis*, Walker.

[2] *Ann. and Mag. Nat. Hist.*, ser. 5, vol. xiii. p. 411, 1884.

and been scattered during the hurricanes. The feral fowls are very wary, like their progenitors, the Indian Jungle-fowl, and are not at all easy to shoot. The entire bag consisted of only one wild fowl. Flights of the brown Pelicans were met with passing over-head, flying one after another along the shore almost always exactly over the same spot on their way from one feeding ground to another.

The late Dr. R. von Willemoes Suhm states in his diary, that the doctor of the garrison assured him that of the human internal parasites, only *Ascaris* and *Oxyuris* were common; *Tænia* was very rare, and found, not among the natives, but usually among foreign sailors. *Phthirius pubis* and *Pediculus capitis* were both known but also very rare; when upon negroes they have a dark colour, a curious fact already known with regard to these parasites on several dark human races, which recalls the correspondence between the colour of the species of Anoplura, and that of the feathers of the birds they infest.

One day a party landed on one of the small outliers of St. Thomas, Little Saba Island, about a mile and a half distant from the main island. A Puffin (*Puffinus* sp.) was nesting in holes amongst the grass, laying a single large white egg; the birds allowed themselves to be caught in the nest with the hand. In the beach of the island there was being formed a reddish conglomerate sandstone rock, composed of the débris of the rock of which the higher parts of the island consist, cemented together by calcareous matter derived from the corals, and calcareous sand. This rock, which was hard and compact, contained embedded in it plenty of the various corals from the beach and large *Turbo* shells (*Turbo pica*), with their nacre quite fresh in lustre, and their bright greenish colour unimpaired. In St. Thomas large examples of these *Turbo* shells, as much as two inches in diameter at the base, are carried up far inland by terrestrial Hermit-crabs. A large number of them were seen amongst the bush at an elevation of 1000 feet, some of them containing crabs, many empty. These large heavy sea shells occurring in abundance at great heights, puzzled geologists, until it was found that they were carried up by the crabs. On the shore at Little Saba Island grew a number of plants of *Guilandina bonduc*. This plant bears a pod covered with prickles, containing nearly spherical beans of about the size of a hazel nut, which have a perfectly smooth, as it were, enamelled surface, and are flinty hard. These seeds float, and are carried by ocean currents to distant shores, and in Tristan da Cunha and Bermuda are known as "Sea-beans," and supposed to grow at the bottom of the sea; they are also found occasionally washed up at the Azores.

The stay at St. Thomas extended to eight days, which time was fully occupied, as far as the naval staff was concerned, in refitting and coaling the ship, in obtaining magnetic and other observations on shore, and in correcting the charts. The evidences of the destruction caused at St. Thomas by the hurricanes and occasional earthquake waves, more especially by that of 1867, were everywhere conspicuously apparent. Numbers of small houses were constructed partially with the bulkheads of wrecked ships; and even in 1873, six years after the last hurricane, there were a few wrecks still on the shore.

It having been reported during the stay that a distressed British ship had anchored in the sound between the islands of St. Thomas and St. John, the ship proceeded to her assistance and towed her into harbour. She proved to be the "Varuna," an iron ship of 1300 tons, abandoned by the crew two months previously, about 350 miles N.N.E. of Bermuda; she was taken charge of by the mate and nine of the crew of the ship "Roundtree," and navigated to St. Thomas, having only her foremast and foretopmast

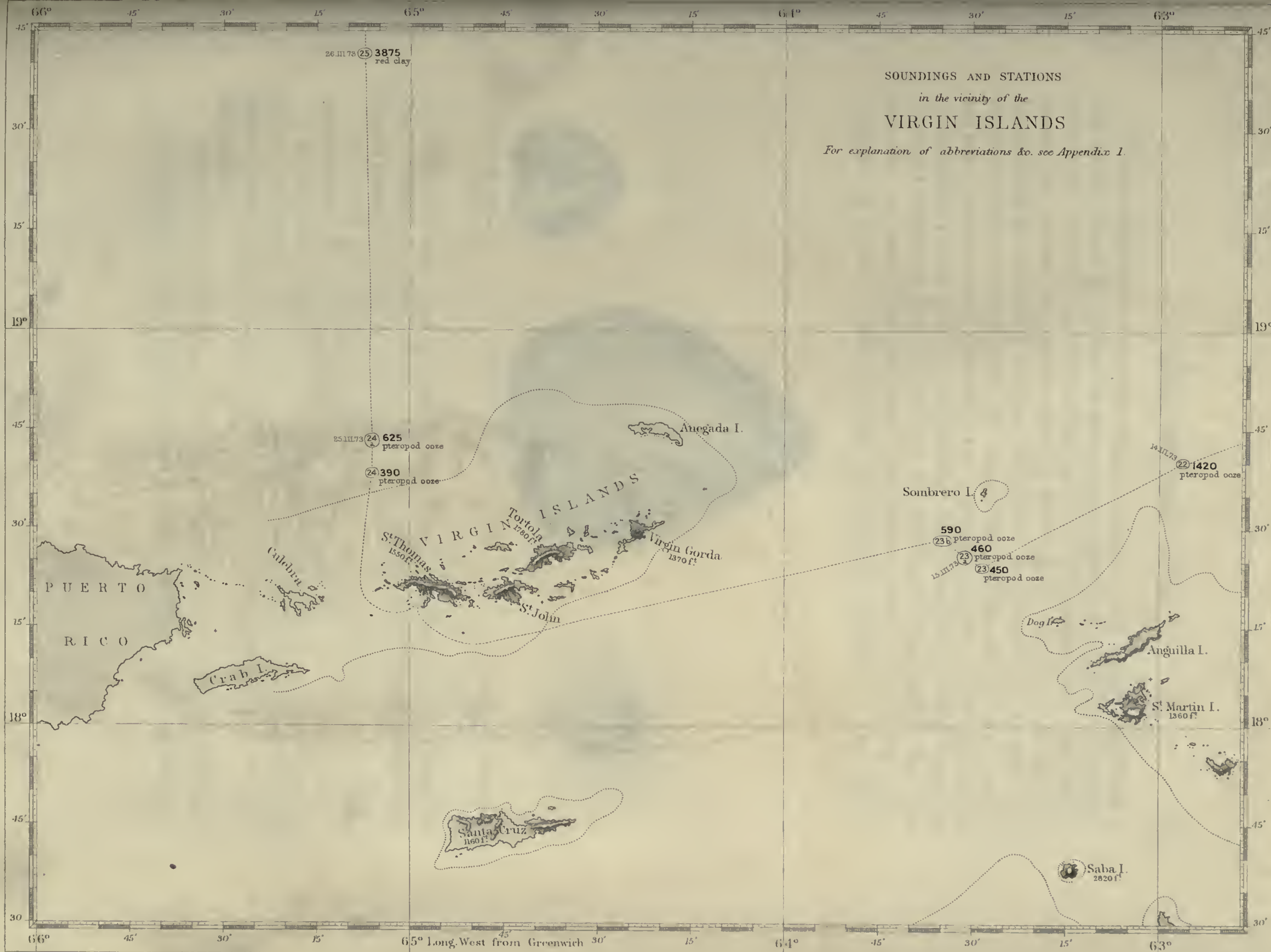
Fig. 49.—Boarding the wreck of the "Varuna," off Cabrite Point, St. Thomas.

standing. These men deserve great credit for bringing the "Varuna" to port, and it is to be hoped that they got a handsome amount of salvage, although they distrusted the motives of the Challenger in coming to their assistance, thinking they were to be deprived of some of their hardly-earned recompense, and had to be reassured on that point before the vessel was taken in tow.

St. Thomas to Bermuda.

On the 24th March the Challenger sailed for Bermuda; the 25th was spent in dredging off the northern edge of the Virgin Island bank, in 390 and 625 fathoms (see Sheet 7), and a large number of animals were obtained, resembling, in most respects, those taken in 450 fathoms off Sombrero. In addition to these there were three species of Brachiopoda, which are referred to in the following résumé, by Thomas Davidson, Esq., F.R.S., of his Report on the Brachiopoda collected during the Expedition:[1]—

[1] Zool. Chall. Exp., part i., 1880.


SOUNDINGS AND STATIONS
in the vicinity of the
VIRGIN ISLANDS
For explanation of abbreviations &c. see Appendix 1.
26.III.73 (25) 3875
red clay
25.III.73 (24) 625
pteropod ooze
(24) 390
pteropod ooze
Anegada I.
VIRGIN ISLANDS
Tortola
1780 ft.
St. Thomas
1550 ft.
St. John
Virgin Gorda
1370 ft.
Culebra
PUERTO RICO
Crab I.
Santa Cruz
1160 ft.
Sombrero I.
590
(23b) pteropod ooze
460
(23) pteropod ooze
15.III.73
(23) 450
pteropod ooze
14.III.73
(22) 1420
pteropod ooze
Dog I.
Anguilla I.
St. Martin I.
1360 ft.
Saba I.
2820 ft.
66°
65°
64°
63°
19°
18°
65° Long. West from Greenwich
Engraved by Malby & Sons

"*The Brachiopoda* are a most interesting and important class among the Invertebrata, from the fact that they represent the earliest known forms of life, and have continued to exist under a variety of more or less allied species up to the present time. They appear, however, to be much localised, for although the dredge or trawl had been put down by the Challenger Expedition at about 250 stations, Brachiopoda were brought up 38 or 39 times only.[1] Out of about 120 known recent species, 34 only were obtained, and out of this number 27 were dredged at depths varying from 2 to 600 fathoms, and the remaining 7 from 1035 to 2900 fathoms. The investigations carried out by the Challenger Expedition tend to prove that abyssal forms are less localised than those that occur in seas of moderate depth; but deep-sea species, as far as our present experience goes, are of small size, and specifically few in number. Their shell is

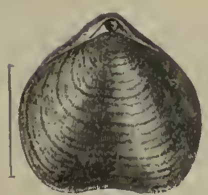


FIG. 50.—*Terebratula wyvillii*, Dav., enlarged.

FIG. 51.—*Terebratulina wyvillii*, Dav., natural size.

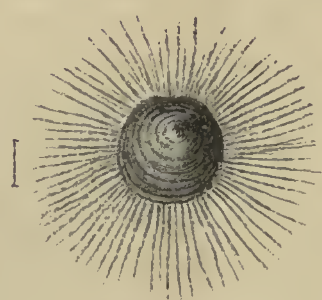


FIG. 52.—*Discina atlantica*, King, enlarged.

extremely thin, glassy, and semi-transparent, as in *Terebratula wyvillii*, *Terebratula dalli*, *Waldheimia wyvillii*, *Waldheimia tenera*, *Terebratella frielii*, *Atretia gnomon*, *Discina atlantica*, and one or two others.

"The three most interesting species brought home by the Expedition were *Terebratula wyvillii*, *Terebratulina wyvillii*, and *Discina atlantica*.

"*Terebratulina wyvillii*, Dav., is the largest species of the genus, either recent or fossil, hitherto discovered. One specimen only was dredged, on the 25th March 1873, off Culebra Island, to the northwest of St. Thomas in the West Indies, Station 24, depth 390 fathoms.

"*Terebratula wyvillii*, Dav., is one of the most remarkable of the series of small abyssal

[1] In the opinion of the Naturalists of the Expedition this may, to some extent, be due to the nature of the instrument used, whether dredge or trawl.—J. M.

forms brought back by the Expedition. It was obtained at six different Stations, and appears to abound over a wide geographical area, occurring at depths varying from 1035 to 2900 fathoms,—the greatest depth whence any living Brachiopod has been brought up. None of the specimens procured exceeded 7 lines in length by 9 in breadth; its shell is extremely thin and brittle, almost transparent, smooth and glassy. It bears much resemblance in shape to more than one Tertiary, Cretaceous, and Jurassic species.

"*Discina atlantica*, King, is another of the widely spread abyssal forms, and was brought up by the Challenger at six or seven different Stations. Its shell is small, very thin, and semi-transparent. The cirri proceeding from the edges of the mantle are of great comparative length, equalling the diameter of the shell.

"Only a small number of the species brought home by the Challenger Expedition are positively known to occur in the upper Tertiaries. Those that are both recent and fossil are *Terebratulina caput-serpentis*, *Terebratula vitrea*, var. *minor*, *Terebratella dorsata*, *Megerlia truncata*, *Platydia anomioïdes*, and *Argiope decollata*. None of the abyssal forms have yet been found in the fossil condition; but if we take into consideration the 120 known species of recent Brachiopoda, 26 of these occur both recent and fossil. The chief object of the Challenger Expedition being to dredge in open seas in various longitudes and latitudes, much time could not be devoted to searching coral reefs and shallow rocky bottoms, where the larger number of species are to be found, and where they often congregate in great number and variety. Thus, for example, about 30 species have been obtained from Japanese and Korean Seas; a large number also are to be found in New Zealand waters, near the Cape of Good Hope, &c. In deep seas with muddy bottoms it is rare to find more than one, two, or three species living at the same spot, and this was amply confirmed by the Challenger Expedition."

An unfortunate accident occurred on board on the morning of the 25th. Owing to the rugged nature of the ground over which the dredge was dragging, the strain on the dredge rope increased on one occasion so suddenly, that before it could be relieved the hook of one of the spans, to which the leading blocks were secured, broke, and the block striking W. Stokes, a boy, fractured his leg, and otherwise injured him so severely that he died in the afternoon.

On the 26th March when barely 100 miles from land, the depth was found to be 3875 fathoms. Such a rapid increase in the depth not having been expected, only 3 cwt. of sinkers had been attached. After 3000 fathoms had run out, there was some uncertainty as to the time that should be occupied by the weights in descending, as hitherto the deepest cast had not much exceeded that depth. Twice, the intervals appearing longer than they should be, the line was checked; but the strain on it, as indicated by the stretching of the accumulators, showed in a most satisfactory manner that the bottom had not been reached. Finally, when the sinkers did strike the ground, the intervals occupied by the line in running out increased so considerably, that no doubt was felt as to the accuracy of the result. The time each 50 fathom mark entered the water was registered from 3000 fathoms to the bottom; and the following intervals obtained just before and after the sinkers touched the ground, may prove interesting, as they show how quickly the speed of descent of the line slackens when the weight of the sinkers is no longer felt:—

Depth.	Time.	Interval.	Rate per 100 Fathoms.
	h. m. s.	m. s.	m. s.
3800 fathoms	7 57 22	1 15	2 30
3850 "	58 40	1 18	2 36
3900 "	8 0 19	1 39	3 18
3925 "	1 18	0 59	3 56
3950 "	2 23	1 5	4 20

The time the line occupied in descending the first 3800 fathoms will be found on page 67.

Two thermometers and a slip water-bottle were sent to the bottom. The thermometers were broken, and the mode in which the fracture occurred is in itself curious, and has an important bearing upon the use of these instruments at extreme depths. A valuable instrument which had been used for some time, whenever for any reason great accuracy was required, was shattered to pieces (fig. 53 A). The other instrument was externally complete, with the exception of a crack in the small unprotected bulb on the right limb of the U-tube, whilst the inner shell of the protected bulb was broken to pieces (fig. 53 B). In both of these cases there seems little doubt that the damage occurred through the giving way of the unprotected bulb.

In the first case its upper part was reduced to a powder like table salt, and the fragments packed into the lower part of the bulb and the top of the tube. The large bulb and its covering shell were also broken, but into larger pieces, disposed as if the injury had been produced by some force acting from within. The thermometer tube was broken through in three places; at one of these, close to the bend, it was shattered into very small fragments. The creosote, the mercury, and bubbles of air were irregularly scattered through the tube, and it is singular that each of the steel indices had one of the discs broken off. The whole took place no doubt instantaneously by the collapse of the small bulb, which at the same time burst the large bulb and shattered the tube.

In the other a crack only occurred in the small bulb, either through some pre-existing imperfection in the glass or from the pressure. When the pressure became extreme the crack yielded a little and the sea water was gradually forced in, driving the contents of the thermometer before it, and, taking it at a disadvantage from within, breaking the shell of the large bulb, which was unsupported on account of the belt of rarefied vapour between it and its outer shell. The pressure was now equalised within and without the instrument, and the injury went no farther. Alcohol, creosote, mercury, and sea water were mixed up in the outer case of the large bulb with the débris of the inner bulb, and one of the steel indices lay uninjured across its centre.

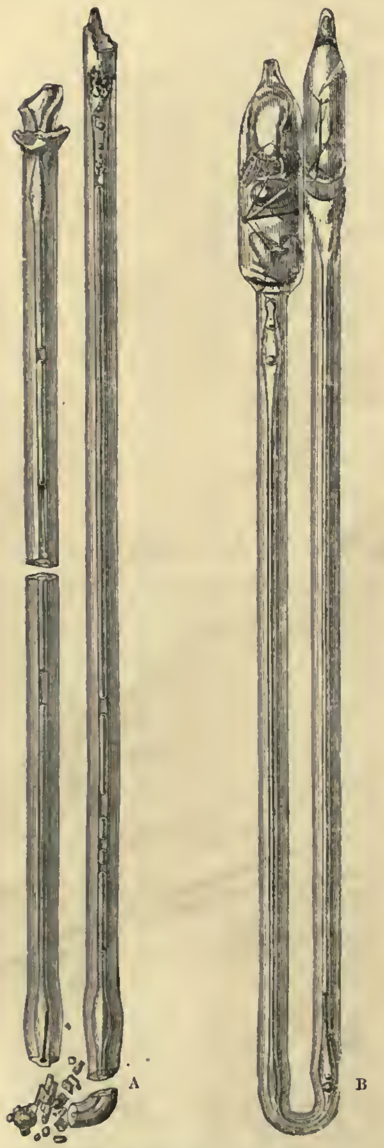


Fig. 53.—Thermometer tubes broken by pressure at a depth of 3875 fathoms (Station 25).

As this was the deepest sounding yet taken, it was desirable to try whether the dredge would still prove serviceable. The small dredge was accordingly lowered at 10.30 A.M., with the usual bar and tangles, and from the centre of the bar a Hydra sounding tube, weighted with 4 cwt., was suspended about 2 fathoms below the dredge. A 2-inch rope was veered to 4400 fathoms; a toggle was stopped on the rope 500 fathoms from the dredge, and when the dredge was well down, two weights of 1 cwt. each were slipped down the rope to the toggle. Heaving in was commenced about 1.30 P.M., and the dredge came up at 5 P.M., with a considerable quantity of reddish-grey ooze. The mud was carefully examined, but no animals were detected, except a few small calcareous Foraminifera, and some, considerably larger, of the arenaceous type.

The officers of the United States Coast Survey have recently obtained depths of 4561 and 4223 fathoms about 50 miles to the west of this sounding of 3875 fathoms; so that this, the deepest part of the Atlantic, is probably a depression of considerable extent, with its longest diameter running east and west. On the 27th, 100 miles north of the 3875 fathoms sounding, the depth had decreased to 2800 fathoms.

On this St. Thomas–Bermuda section, twelve soundings, five dredgings, and five serial temperature soundings were obtained (see Sheet 6).

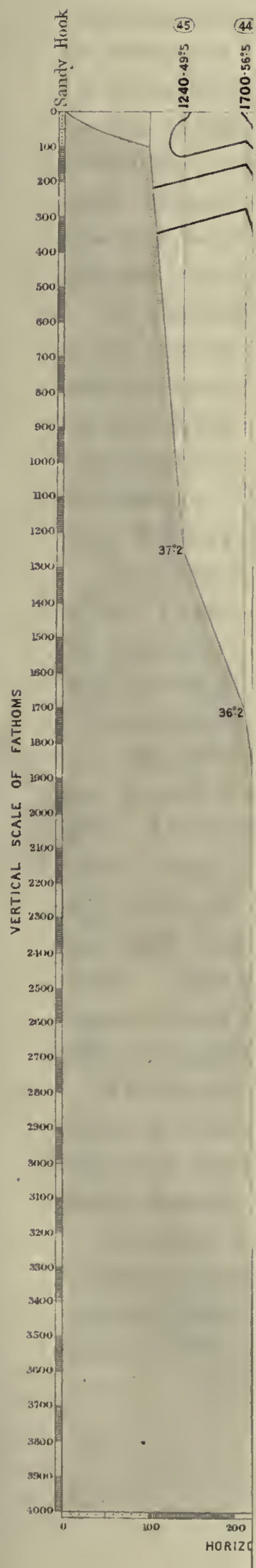
The ocean bed rises gradually from the deep depression just referred to towards Bermuda, the depth being 2475 fathoms at a distance of 50 miles from that island (see Diagram 2).

The temperature at the bottom ranged from 36°·2 to 36°·7, the mean being 36°·4.

DIAGRAM 2

Diagona

Bermud



The isotherm of 40° was found to occupy a mean depth of 750 fathoms (ranging from 700 to 800 fathoms), or nearly the same depth as in the western portion of the Tenerife–Sombrero section. The isotherm of 60° descended steadily from 200 fathoms at St. Thomas to 310 fathoms at Bermuda, although the surface temperature decreased from 76° at the former to 68° at the latter place.

The specific gravity of the surface water rose from 1·02712 off St. Thomas to 1·02732 off Bermuda, that of the bottom water being about 1·0260. The serial determinations on the 31st March showed a similar distribution to that observed before reaching St. Thomas; the surface being 1·02739, the water at 100 fathoms 1·02782.

On the 28th March, at Station 27, a boat, anchored by the lead line with the sinkers on the bottom, found the surface current running N.W. half a mile per hour, agreeing in direction though not in rate with the current determined by the ship's reckoning. On the 2nd April, at Station 30A, the current drag showed that the water, to the depth of 100 fathoms, was moving in the same direction and with the same velocity as that at the surface. From 100 to 300 fathoms the velocity decreased, until at the latter depth there was no perceptible current.

The deposits at the depths of 625 and 390 fathoms on the plateau to the north of the Virgin Islands were Pteropod oozes, with 69 and 73 per cent. of carbonate of lime, containing a few small mineral particles and some argillaceous matter. The deposits from depths greater than 2700 fathoms contained only 4 or 5 per cent. of carbonate of lime, which consisted of a few broken shells of pelagic Foraminifera, and was mostly confined to the surface layers. A few inches beneath the surface the deposit showed only a very slight sign of effervescence when treated with weak acid. At 2700 fathoms there was 22 per cent. of carbonate of lime, at 2600 fathoms 29 per cent., and at 2475 fathoms 54 per cent. The deposits immediately surrounding the island of Bermuda in some instances contained as much as 93 per cent. of carbonate of lime, the percentage being greater the nearer the reef and the less the depth. The mineral particles in all the deposits in this section were exceedingly minute, rarely exceeding 0·07 mm. in diameter, and consisting of fragments of pumice, felspars, magnetite, and augite.

The dredgings in depths less than 500 fathoms, north of St. Thomas and around the island of Bermuda, yielded a large number of interesting animals; but the deep water dredgings were singularly unproductive, only a few Foraminifera and a few shrimps being obtained.

Floating masses of Gulf Weed were frequently met with, and were usually visited in boats while the ship was engaged in sounding and dredging. Besides the ordinary *Sargassum bacciferum*, isolated specimens of another weed, *Fucus vesiculosus*, were occasionally picked up. The following is a complete list of the animals that have been collected on the Gulf Weed, compiled chiefly from the Challenger collections :—

Plumularia obliqua, *Aglaophenia latecarinata*,[1] *Desmoscyphus pumilus*.[1]

Stylochus mertensi, *Stylochus pellucidus*. *Spirorbis* sp.

Pontia atlantica. *Lepas anserifera*, *Lepas pectinata*, *Lepas anatifera*, *Conchoderma virgatum*. *Amphithoë pelagica*, *Vibilia pelagica*, an Amphipod of the family Hyperidæ. *Idotea metallica*, *Idotea whymperi*, *Bopyrus squillarum*, *Bopyroides latreuticola*. *Siriella* sp. *Sergestes oculatus*, *Tozeuma stimpsoni*, *Palæmon pelasgicus*, *Palæmon fucorum*, *Leander tenuicornis*, *Hippolyte tenuirostris*, *Hippolyte ensiferus*, *Virbius acuminatus*, *Alpheus* sp., *Caridina sargopæ*. *Lupea* sp., *Nautilograpsus minutus*, *Neptunus sayi*.

Patina tella, *Patina pellucida*, *Lepeta cæca*, *Ianthina rotundata*, *Litiopa melanostoma*. *Phylliroë atlantica*, *Scyllæa pelagica*, *Scyllæa pelagica*, var. *marginata*, *Æolidella occidentalis*, *Spurilla sargassicola*, *Fiona marina*, *Cuthona pumilio*, *Glaucus atlanticus*, *Doto pygmæa*. *Creseis spinifera*. *Onychia caribæa*.

Membranipora tuberculata, *Flustra membranacea*, *Flustra tuberculata*, *Flustra peregrina*.

Antennarius marmoratus, *Dactylopteris volitans*, *Syngnathus pelagicus*.

The nest of *Antennarius*, an ally of the common Angler of British seas, though very unlike it in its habits, was frequently procured; it is composed of bunches of the Gulf Weed bound together by means of long sticky gelatinous strings formed by the fish for this purpose, and is filled with eggs.

The Gulf Weed fauna, as is well known to naturalists, is a peculiar one, and presents many remarkable instances of protective resemblance. The Crustacea, Molluscs, and Fish are all bright yellow or orange in colour with white spots, thus imitating very perfectly the Gulf Weed with the white patches of *Membranipora* and Cirripeds. A similar fauna, comprising species of some of the same genera (*e.g. Antennarius*), inhabits the floating weed in the Pacific Ocean. Oscillatoriæ were very abundant on the surface throughout this trip, and at times were sufficient to discolour the water for several miles.

On the 3rd April the Bermudas were sighted at 2 P.M., and that day and the greater part of the 4th were occupied in obtaining soundings and dredgings off the group. In the afternoon of the 4th, the ship proceeded to the anchorage in Grassy Bay.

Bermuda.

At, and in the neighbourhood of, this interesting group of islands, the Challenger remained from the 4th to the 23rd April, and from the 28th May to the 13th June.

The group, with its outlying reefs, is in the form of an ellipse, the major axis of which

[1] Professor Allman says that these two species are destitute of gonosomes, a fact probably connected with the floating habit of the plant, which is itself never provided with reproductive organs in the Sargasso Sea.

lies in a N.E and S.W. direction, and it is described generally as a coral atoll; but any one who has visited coral atolls in the China Sea, Pacific, or Indian Oceans, will be at once struck with some remarkable differences between these and Bermuda. The typical atoll consists of a low, more or less circular, strip of land enclosing a lagoon, into which there is usually a well-defined opening on the leeward side. In Bermuda the land is 260 feet in height at one point, and is massed to the southeast side of the atoll, with the exception of a small outlier known as the "North Rock" (see Sheet 8), which is composed of the same "Æolian" rocks as the mass of land to the southeast, and this

FIG. 54—Stratified "Æolian" Rocks, Bermuda.

indicates an extension of the land surface of the atoll in this direction at a former period. Although the outer reef is almost continuous, there is no well-defined lagoon as in a typical atoll. The whole of the northwest portion of the banks is crowded with coral flats and heads, with intervening lanes and spaces of coral sand, with a depth of usually 4 or 5 fathoms and nowhere more than 10 fathoms. The basins, known as Great Sound, Little Sound, and Castle Harbour, are almost completely enclosed by the Æolian rocks, and have evidently been formed by the solvent action of the sea water on these rocks. Navigators have remarked upon the light blue colour of the water when compared with the deep blue of southern atolls. This arises most probably from the particles of calcareous matter suspended in the water whenever there is the slightest motion. Owing to the shallowness of the lagoon channels, the water becomes quite turbid when there is much wind, thus rendering the navigation of the narrows very difficult. The Æolian rocks are found below the level of low water at many points of the islands.

A satisfactory proof of at least a local subsidence was given a few years ago. In preparing a bed for the great floating dock it was necessary to make an excavation in the Camber, extending to a depth of 50 feet below low water. First there came in the cutting, at a depth of 25 feet below the surface, a bed of calcareous mud, 5 feet thick, forming the floor of the basin; next, loose beds, 20 feet thick, of what has been called "coral crust"—coral sand mixed with detached masses of *Diploria* and isolated examples of smaller corals and of many shells,—passing into "freestone,"—the coral sand cemented together but somewhat loosely coherent. Beneath this, at a depth of about 45 feet, there was a bed of a kind of peat, and vegetable soil containing stumps of cedar in a vertical position, and the remnants of other land vegetation, with the remains of *Helix bermudensis*, and of several birds; the bed of peat was ascertained by boring to lie upon the ordinary hard "base-rock."

A microscopical examination of the deeper rocks of this section showed that a deposition of crystals of calcite had taken place between the calcareous fragments forming the rock. There are no freshwater lakes or ponds on the island, indeed, the wells contain brackish water, except on the surface immediately after rain. The whole atoll is filled with sea water like a sponge; large quantities of carbonate of lime are dissolved and precipitated again in crystals of calcite. It is not improbable that this action may be a cause of subsidence of the land without any subsidence of the primary atoll or sea floor having taken place.

The fine chalky mud which fills the lagoon channels and basins consists of 90 to 95 per cent. of carbonate of lime, which is made up of the comminuted fragments of Corals, calcareous Algæ, Foraminifera, Echinoderms, *Serpulæ*, and Molluscs. The residue, after the removal of the lime, consists of organic matter, Diatoms, and siliceous spicules, and some very fine mineral particles. This coral mud is called a "clay" by navigators, and is so tenacious that ships seldom, if ever, drag their anchors, even in exposed positions, such as Murray's Anchorage, where it is said one vessel, the sloop "Driver," rode out a gale although she carried away her bowsprit by pitching it under her cable.

Large parts of the Bermuda reefs are formed of *Serpula*-tubes, and along the south coast there are numerous miniature atolls, from 2 to 20 feet in diameter, entirely formed by *Serpulæ*. The outer rim is the highest part of these atolls, and at low tide one can see that it is composed of living *Serpulæ*, whereas in the inner part, dead tubes only are found. The lagoons are filled with water at low tide, and in the larger ones the depth is 2 or 3 feet. The bottom is covered with a fine calcareous sand, and in some parts of the lagoons living Actiniaria, Hydroids, &c., are found growing. These little atolls were evidently formed without subsidence, and at once suggested the possibility that the larger atolls of the Pacific and Indian Oceans might have been formed by a somewhat similar mode of growth.

Attention was directed during the stay to defining, as far as practicable, the edges and slope of the bank or atoll, carrying the soundings down to 1500 or 2000 fathoms, in fact, to oceanic depths. No information on these points had as yet been ascertained, but it was believed—from the fact of H.M.S. "Ariadne" having obtained a cast of $11\frac{1}{2}$ fathoms 4 miles from the breakers or rocks awash, and from the statement that banks existed in a S.W. direction from the island,[1] which had been surveyed by H.M.S. "Columbine" in 1829—that the bank on which the islands and reefs are situated was really of much larger extent than was generally supposed. By the kindness of Captain Aplin, then in charge of the dockyard, who placed one of the yard tugs at the disposal of the Expedition, and gave assistance in other ways, it was possible to commence this work at once. It was found that on the southeast edge of the bank the 100 fathom line of soundings was at an average distance of $1\frac{1}{4}$ miles from the rocks awash, and that the depth increased rapidly from 30 to 350 or 400 fathoms, the slope being at an angle of about 20° from the horizontal, but from that depth to 1000 fathoms the slope varied from 7° to 15° from the horizontal. On the northeast edge of the bank the 100 fathom line of soundings was at an average distance of 3 miles from the rocks awash, and the slope was much more gradual. On the southwest side of the bank the 100 fathom line of soundings appears to extend at one point nearly 5 miles from the rocks awash.

About 4 miles southwest of the southwest extremity of the 100 fathom edge of the Bermuda Bank the Challenger sounded and anchored on the "inner bank" of the "Columbine," in 30 fathoms, with Gibb's Hill lighthouse, N. 54° 14′ E. (true), distant 13 miles. The boats were employed one day in obtaining soundings on this bank, but owing to the rough weather rendering the men sick,[2] and to the barometer falling, the officers were unable to define its limits or to look for the "outer shoal," out of sight of land, on which the "Columbine" anchored in 1820, and on which soundings were also taken by the "Larne" in 1836. From the depths obtained, the inner or Challenger Bank appears to be of some extent, certainly not less than 10 miles in circumference, the shallowest water found being 24 fathoms, and it is quite possible that it joins the outer or "Columbine" Bank, or that at any rate the depths between the two do not much exceed 100 fathoms.

In the depression, $3\frac{1}{2}$ miles wide, between the Challenger Bank and the southwest extremity of the Bermuda Bank, the soundings, in all probability, do not exceed 1000

[1] Dana, Corals and Coral Islands, London, 1872; Findlay, North Atlantic Memoir, London, 1856.

[2] Seamen unused to the work of surveying ships are very often sea-sick in boats.

fathoms, as a cast of 1075 fathoms was obtained just east of the northwest part of the depression and another of 1250 fathoms just west of it.[1]

Circumstances did not permit of the definition of the edge of the 100 fathom bank on the northwest side of the Bermudas, but a cast of 1370 fathoms was obtained at a distance of 6 miles from the rocks awash, and one of 2100 fathoms at a distance of 10 miles. The deepest sounding obtained close to the atoll was one of 1950 fathoms, $5\frac{1}{2}$ miles west of the extreme west point of the rocks awash (see Sheet 8).

Another important point to which attention was directed was the magnetic condition of the islands. Observations made by the Governor, General Lefroy, at his official residence, differed considerably from the Admiralty charts, and, consequently, instructions were received from the Hydrographer to ascertain whether those charts were in error or not. The observations made by the Expedition showed that the variation differed in various parts of the island as much as 6°, ranging from 4° W. to 10° W., the smallest amount being found at a small islet just under the lighthouse on Gibb's Hill, and the greatest at the point on the west side of Clarence Cove. The correct variation was found by swinging the ship on all points of the compass, and ascertaining its errors by azimuths of the sun, and the result so obtained agreed precisely with the Admiralty chart. It does not appear that before the visit of the Expedition this peculiarity of the Bermuda group was known, as the islands were said to consist entirely of calcareous rocks, derived from comminuted shells and corals, although Lieutenant Nelson, R.E., noticed on the island small pieces of oxide of iron of very questionable origin. It is, however, evident from these observations[2] that some disturbing cause exists in the neighbourhood of the islands which vitiates magnetic observations taken on shore.

At a depth of 200 fathoms, about 2 miles from the reefs, the deposit was composed of large fragments of Coral, Foraminifera, Echinoderms, Polyzoa, Molluscs, Algæ, and concretionary lumps, some of which were 2 or 3 centimetres in diameter. At 380 fathoms, 3 miles from the reefs, the fragments were smaller, and, in addition to the above, there were many Pteropod and Heteropod shells. At 950 fathoms, 4 miles from the reefs, the particles were still smaller, and there was a considerable admixture of pelagic Foraminifera. At 1950 fathoms, 5 miles from the reefs, the deposit was a nearly pure Globigerina ooze, made up chiefly of pelagic Foraminifera, with only a small proportion of species living on the bottom, and fragments from the reefs. All these deposits contained from 85 to 91 per cent. of carbonate of lime. The residue, after treatment with weak acid, consisted of a few siliceous spicules, fragments of felspar, augite, magnetite, and glassy rocks; none of the mineral particles exceeded 0·07 mm. in diameter. At 2600 fathoms, 30 miles from the reef, the deposit was a Globigerina ooze, containing only about 50 per cent. of carbonate of lime.

[1] Since this was written the outer bank, over which the least depth is 10 fathoms, has Been surveyed by H.M.S. "Argus," and named after that vessel, the depth between it and the Challenger Bank being about 500 fathoms.

[2] Narr. Chall. Exp., vol. ii. p. 25, 1882.


SOUNDINGS AND STATIONS
in the vicinity of
BERMUDA
For explanation of abbreviations &c. see Appendix 1.
North Rock
Wreck Hill
Gibbs Hill (256 ft)
Lt. Ho.
Challenger Bank (24 fms.)
Columbine Bk. (28 fms.)
2450 globigerina ooze
1370 coral mud
640 coral mud
175 coral sand
2100 globigerina ooze
1950 globigerina ooze
2650 globigerina ooze
1775 globigerina ooze
1500 globigerina ooze
435 coral mud
265 hard ground
125 hard ground
120 coral mud
380 coral mud
780 coral mud
690
1575 coral mud
1250 coral mud
30 coral
506
1075 coral mud
950 coral mud
1325 coral mud
1820 globigerina ooze
2250 globigerina ooze
65° Long. West from Greenwich
Engraved by Malby & Sons.

Bermuda and its outlying banks are thus situated on the summit of a large cone with a wide base, rising from the submerged plateau of the Atlantic, which is, in this region, three miles (2600 fathoms) beneath the surface of the sea. It is very probably an ancient volcano, now completely covered with a white shroud, composed of the skeletons and shells of organisms.

The late Sir C. Wyville Thomson was of opinion that the "red earth" which largely forms the soil of Bermuda had an organic origin, as well as the "red clay" which the Challenger discovered in all the greater depths of the ocean basins. He regarded the red earth and red clay as an ash left behind after the gradual removal of the lime by water charged with carbonic acid. This ash he regarded as a constituent part of the

Fig. 55.—"Æolian" Limestone Beds in process of formation, showing stratification, and the remains of a grove of Cedars which has been overwhelmed. Elbow Bay, Bermuda. (*From a Photograph.*)

shells of Foraminifera, skeletons of Corals, and Molluscs.[1] This theory does not seem to be in any way tenable. Analysis of carefully selected shells of Foraminifera, Heteropods, and Pteropods, did not show the slightest trace of alumina, and none has as yet been discovered in coral skeletons. It is most probable that a large part of the clayey matter found in red clay and the red earth of Bermuda is derived from the disintegration of pumice, which is continually found floating on the surface of the sea.[2] The Naturalists of the Challenger found it among the floating masses of Gulf Weed, and it is frequently picked up on the reefs of Bermuda and other Coral islands. The red earth contains a good many

[1] Voyage of the Challenger, Atlantic, vol. i. p. 316.

[2] Murray, On the Distribution of Volcanic Débris over the Floor of the Ocean, *Proc. Roy. Soc. Edin.*, vol. ix. pp. 247–261, 1876–77.

fragments of magnetite, augite, felspar, and glassy fragments, and when a large quantity of the rock of Bermuda is dissolved away with acid, a small number of fragments are also met with. These mineral particles most probably came originally from the pumice which had been cast up on the island for long ages (for it is known that these minerals are present in pumice), although possibly some of them may have come from the volcanic rock, which is believed to form the nucleus of the island.

The land surface of the islands is almost entirely composed of blown calcareous sand, more or less consolidated into hard rock. In several places, and especially at Tuckerstown and Elbow Bay, there exist considerable tracts covered with modern sand dunes, some of

Fig. 56.—"Sand-Glacier" overwhelming a garden. Elbow Bay, Bermuda. (*From a Photograph.*)

which are encroaching inland upon cultivated ground (see fig. 56), and have overwhelmed at Elbow Bay a cottage, the chimney of which only is now to be seen above the sand (see fig. 57). The constant encroachment of the dunes is prevented by the growth upon them of several binding plants, amongst which a hard prickly grass (*Cenchrus*), with long, deeply penetrating root-fibres, is the most efficient. When these binding plants are artificially removed, the sand at once begins to shift.

The scenery of Bermuda is in some respects not unlike that of certain northern lake districts, for the numerous small islands which are dotted over the sounds and land-locked sheets of water are covered with vegetation down to the water's edge. The dark colour of the Juniper (*Juniperus bermudiana*, a species peculiar to these islands and the West Indies), called in the island "Cedar," the prevailing foliage, not unlike that of Pines in appearance, gives the landscape a northern aspect, and on cloudy days, the island, as viewed from the sea, looks cold and bleak. The extreme lowness of all the land, however, is characteristic and distinctive. Most conspicuous, next to the Juniper as a general feature in the vegetation, is probably the Oleander (*Nerium oleander*), which, having been introduced, flourishes everywhere. A large portion of the uncultivated land is covered with a dense growth of another introduced plant, *Lantana camera*, a most troublesome weed.

The most refreshing and beautiful vegetation in Bermuda is that growing in the marshes and caves. The marshes or peat bogs lie in the inland hollows between two ranges of hills, and are covered with a tall luxuriant growth of ferns, especially two species of *Osmunda* (*Osmunda cinnamomea* and *Osmunda regalis*). Some ferns are restricted to particular marshes; one salt marsh fern (*Acrostichum aureum*) grows

FIG. 57.—Chimney of a Cottage which has been buried by a sand-glacier. Elbow Bay. (*From a Photograph.*)

densely to a height of 4 or 5 feet. Together with the ferns grows the Juniper, which thrives in the marshes, and a species of Palm (*Sabal blackburniana*), thus giving a pleasing variety to the foliage.

A very careful collection of the plants of the islands was made during the stay, and this, together with a most valuable series of specimens collected by General Lefroy after prolonged exertions extending over the whole period of his residence in the group, forms the basis of the treatise on the flora of the islands which forms one of the Botanical Reports of the Expedition.[1] It is there shown that the group possesses far more vegetable forms peculiar to itself than had hitherto been suspected. It is probable that the occurrence of North American plants in the islands is connected with the fact that

[1] Bot. Chall. Exp., part i., 1884.

the islands are visited from time to time by immense numbers of migratory birds from that continent, especially during their great southern migration. Of these the American Golden Plover (*Charadrius marmoratus*) seems to visit Bermuda in the greatest numbers, but various other birds frequenting marshes—gallinules, rails, and snipes—arrive in no small quantities every year. These birds have possibly brought a good many plants to Bermuda, as seeds attached to their feet or feathers, or in their crops. Some of the most conspicuous of the present land birds of Bermuda, such as the "Red Bird," or Cardinal, have been introduced for ornamental effect.

The birds most interesting to the naturalist encountering them for the first time,

Fig. 58.—Natural Swamp-Vegetation, Bermuda. (*From a Photograph.*)

are the "Boatswain-birds" (*Phaëthon flavirostris*). They are white, a little smaller than the commonest English Gull, and shaped more like a Sea-swallow or Tern, though allied to the Gannets and Cormorants; in the tail are two long narrow feathers of a reddish tint, which, as the bird flies, are kept extended behind, and give it a curious appearance. The birds breed, more or less gregariously, in holes in the rock formed by the weathering out of softer layers; it is easy to secure them in the hole by clapping a cap over its mouth, when both male and female can often be caught together. It is, however, quite a different matter to get hold of them for skinning: their bills are very sharp and strong, and they fight furiously, screaming all the while. Only one egg is laid, and it is of a dark red colour like that of the kestrel.

The corals of Bermuda may be seen growing to great advantage by the use of a water glass. The species are, as will be seen by the list below, as far as is yet known, 25 in number, of which 23 are Anthozoan and 2 Hydrozoan; the latter (species of *Millepora*) are very abundant, and contribute largely to the reef formation. While some species, such as the great Brain Coral (*Diploria cerebriformis*), which is conspicuous

FIG. 59.—Group of Palms on the croquet-lawn, Mount Langton.

at the bottom as a bright yellow mass, appear to prefer to grow where the water is lighted up by the sunshine, other species, such as *Millepora ramosa* and *Isophyllia dipsacea*, seem to thrive best in the shade. One species, *Agaricia fragilis*, occurs growing in colonies in great abundance in water from a foot to a fathom in depth, inside small caverns, and forms very thin and fragile plate-like laminæ, which when bleached are almost the loveliest of corals.[1]

[1] *Reef Corals of Bermuda*.—Mr. J. J. Quelch, B.Sc., of the British Museum, who is engaged in the preparation of a Report on the Challenger collection of Reef Corals, contributes the following note:—"The structure and position of the Bermudas give a special interest to the reef-corals which are found there, the more so as those hitherto obtained have been confined to a few species. A list of these has been given by Dana (Corals and Coral Islands, p. 114) and includes the following:—Of the Astræa tribe, *Isophyllia dipsacea*, *Isophyllia rigida*, *Diploria cerebriformis*; of the Oculina tribe, *Oculina diffusa*, *Oculina pallens*, *Oculina varicosa*, *Oculina valenciennesi*; of the Fungia tribe, *Siderastræa radians*, *Mycedium fragile*; of the Madrepora tribe, *Porites clavaria*; also the Hydroid coral *Millepora alcicornis*.

The following notes are from the late Dr. R. v. Willemoes Suhm's Journal, June 1873:—

"On looking at the Blue and Red Birds of the island (*Sialia wilsoni* and *Pitylus cardinalis*), one would imagine them to be in the most suitable and natural habitat, and that their existence here was not due to artificial introduction; yet we are told that the red bird was introduced only some thirty years ago. When we remember the swarms of

"To these should have been added the *Oculina bermudensis* of Duchassaing and Michelotti. With the exception of *Oculina valenciennesi*, these were all obtained by the Challenger; and, in addition, *eleven* other species of true corals, and one Hydroid coral; thus doubling the number formerly known.

"*Astræa* proper (*Favia*) and *Mæandrina* are *with certainty* recorded for the *first* time from this locality, there being two species of the former and three of the latter genus. To the species of *Isophyllia*, four others have been added, one of which, according to Milne-Edwards and Haime, occurs both in the Atlantic and Pacific. Three other species of *Oculina* were obtained, one of these being a new one.

"The complete list of the reef-corals with revised synonymy includes the following:—

Isophyllia dipsacea, Dana.
" *strigosa*, Duch. and Mich. (=*Isophyllia rigida*, Verrill).
" *australis*, M.-Edw. and H.
" *knoxi*, Duch. and Mich.
" *marginata*, Duch. and Mich.
" *cylindrica*? Duch. and Mich.
Mæandrina strigosa, Dana.
" *sinuosissima*, M.-Edw. and H.
" *labyrinthiformis*, (Linn.) Ell. and Sol.
Diploria cerebriformis, Lamk.
Astræa ananas, Ell. and Sol.
" *coarctata*, Duch. and Mich.
Agaricia fragilis, Dana.
Siderastræa galaxea, Ell. and Sol.
Porites clavaria, Lamk.
Oculina diffusa, Lamk.
" *pallens*, (Ehrb.) Dana.
" *varicosa*, (Les.) Dana.
" *speciosa*, M.-Edw. and H.
" *coronalis*, n. sp.
" *bermudensis*, Duch. and Mich.

"To these must be added *Pentalophora decactis*, Lyman, and the *Oculina valenciennesi*, mentioned by Dana, making a total of twenty-three species which are now known from the Bermuda Reefs; besides the two Hydroid Corals—

Millepora alcicornis, Linn.
" *ramosa*, Pall.

"It will be seen that the species not previously found are *Isophyllia marginata, Isophyllia australis, Isophyllia knoxi, Isophyllia cylindrica; Mæandrina strigosa, Mæandrina sinuosissima, Mæandrina labyrinthiformis; Astræa ananas, Astræa coarctata; Oculina speciosa, Oculina coronalis*, and *Millepora ramosa*.

"*Mæandrina labyrinthiformis* was recorded from this locality by Dana in the "Zoophytes," but it has been omitted in his later work; and although General Nelson, in his paper read before the Geological Society in 1834, on the structure of the Bermudas, speaks of large, massive, and perfect *Mæandrina* as being found in the chalk conglomerate, yet there is no certainty as to whether *Diploria*, *Mæandrina* proper, or even *Manicina* was intended, since the *Mæandrina* of Lamarck included the three; while his obtaining the *Mæandrina areolata* from a large block of reef in the solid rock, 15 or 20 feet from the surface, indicates that *Manicina* has flourished in this locality, although no representative of the genus has been found living on the Reefs.

"Taking into consideration the large increase in the number of species of reef-corals occurring at Bermuda which has resulted from the Challenger Expedition, it cannot be doubted that a lengthened stay in this interesting group would yield still greater results."

lizards which inhabit the walls and rocks of Italy, it is astonishing that here, where there are plenty of insects, only one little Scincoid, a species of *Mabouya*, is now and then to be met with under a stone. In some brackish water there was a little Mugiloid. The Mugilidæ are known to live in all kinds of water, from fresh to salt; they are found in the Lagoon of Venice, in brackish, salt, and fresh water. Cyprinoids, true freshwater forms, have

FIG. 60.—Papaw-trees (*Carica papaya*), in the Governor's garden at Clarence Hill. (*From a Photograph.*)

not been introduced here, with the exception of the gold-fish; and the *Anguilla*, which in other islands, as the Azores, Færöes, and Tahiti, ascends into the lakes, does not seem to inhabit the coasts of these islands, the whole fish fauna of which, as well as the invertebrate fauna generally, has a decidedly West Indian character.

"Since our last stay here many insects have come out which we did not see before, spiders, beetles and butterflies, the latter, however, being very scarce.[1] The scarcity of Hemiptera is astonishing, for besides the Green-bug (*Rhaphigaster*) only a few small Cicadas, found on the cedar trees, were observed. Under the stones I always found a few land shells,[2] several species of *Blatta*, and very often a *Gryllus*. Flying beetles are rare. When returning at night from our excursions, we observed no insects filling the air as they do in Europe, with the exception of some Sphingidæ, and no Bats were observed. It is true that bats have been found here, but they all belong to American species, which have either been brought over in ships transporting wood, or have been driven over by storms.

"I visited Hungry Bay specially with the intention of watching and obtaining specimens of a Crab, which is well known to the Bermudians, from its habit of ascending the Mangrove trees. This is the *Grapsus cruentatus*, Latr., known from Brazil and the Antilles. It inhabits the holes seen everywhere in the soft and moist brown earth near the Mangrove trees. The larger of these holes have a diameter of three to four inches, and they go down to a depth of three or four feet, as deep down, indeed, as the moist earth itself. Wet mud was found at the bottom of each hole, so that when the Crabs are sitting in these, there is plenty of moisture for their gills, and when on the Mangrove trees, they are noticed from time to time retiring into the pools which are met with under each tree. This explains the astonishing, and, as far as I am aware, unknown fact, that a member of the Grapsoidea has been able to take up the habits of a Gecarcinoid, without having the anatomical apparatus, which from Milne-Edwards' dissections is well known in the latter. The gills of this *Grapsus cruentatus* do not differ, as I ascertained by dissection, from those of the Brachyura of marine habits. *Grapsus* has, however, not assumed all the habits and manners of land crabs, for though it is seen walking on the land and climbing up the trees, it spends most of its time in the water, or in moist media, and does not seem to be nocturnal, like *Gecarcinus*. On walking over the place where these crabs have their holes, one disturbs hundreds of the younger ones, and the larger ones may be noticed watching attentively from the entrances to the holes, and retiring in the greatest hurry when approached. Many full-grown specimens were caught, and among these a female carrying its eggs. Animals which have assumed

[1] The Lepidoptera collected on the islands include the following species (Butler, *Ann. and Mag. Nat. Hist.*, ser. 5, vol. xiii. pp. 184–188, 1884):—

Junonia cœnia, Hübner.	*Plusia ou*, Guénée.
Chœrocampa tersa (Drury).	*Remigia marcida*, Guénée.
Leucania antica, Walker.	*Thermesia monstratura*, Walker.
Laphygma macra, Guénée.	*Margaronia jairusalis*, Walker.
Perigea subaurea, Guénée.	*Stenopteryx hybridalis* (Hübner).

[2] The following terrestrial Mollusca were collected at the Bermudas (E. A. Smith, *Proc. Zool. Soc. Lond.*, p. 277, 1884):—

Helix bermudensis, Pfeiffer.	*Bulimus ventrosus*, Fér.
„ *circumfirmata*, Redfield.	*Succinea bermudensis*, Pfeiffer.
„ *microdonta*, Desh.	*Helicina convexa*, Pfeiffer.
„ *vortex*, Pfeiffer.	*Melampus gundlachi*, Pfeiffer.

The common European *Limax gagates*, Drap., was also found, and has not been previously recorded from this locality.

altered habits from those of their congeners, and live in different media, usually have an accelerated embryological development, because the medium necessary for the early stages of the larvæ has been relinquished by the parent. Crabs are known to live in three media,—in the sea, in fresh water, and on the shore. The mode of propagation of the sea crabs, passing through a zoea stage, must be considered their normal way of development. In *Telphusa*—as I discovered after carefully investigating these freshwater crabs in the mountains of Italy—the newly hatched young ones remain attached to the abdomen of their mother. They have no metamorphosis, and as their mode of life

FIG. 61.—Cedar Avenue, Hamilton, Bermuda. (*From a Photograph.*)

has many resemblances to that of the *Grapsus* found here, one may fairly conjecture that in this Crab also no metamorphosis occurs.

"The Mangrove swamp is a hot and damp place, especially favourable for tropical animal life. Large Dragon-flies (*Libellula* and *Agrion*) fly about, and a little *Cicindela* is perpetually flitting from one place to another, and many other insects can be captured. Under stones two specimens of another land crab were procured, which evidently belongs to the Telphusidæ, the freshwater crabs, and comes nearest to the genus *Boscia*, found in Brazil and South America, from which it differs, however, in some slight respects. There was no fresh water near the place where I found the specimens. With regard to its habits, it is far from having the agility of the *Grapsus*, is easily caught, and seems to live in holes under stones. Some specimens of *Ocypoda rhombea* and *Gecarcinus* *lateralis*, as well as two very large specimens of *Cardiosoma guanhumi* (known as the "crabe blau" in the Antilles), were procured by the other naturalists. These latter crabs had been caught by torch-light in the sand hills of the interior, as they leave their holes only at night. We also procured large specimens of what is known as the Soldier-crab (*Grapsus pictus*), and which can be seen living and fighting in great numbers on the rocky shores of the south coast of Bermuda, where in April we saw many of their cast-off skins.

FIG. 62.—Land Nemertine, *Tetrastemma agricola*, Suhm (young male). Pt 1–4, Successive portions of the proboscis; 1, entrance; 2, papillary portion; 3, pouch of stylets; 4, glandular portion; *ca*, muscular entrance of glandular portion; *o*, mouth; *i*, intestine; *g*, ganglion; *n*, lateral nerves.

"In the moist brown earth, near the edges of the Mangrove swamp, I found besides a *Lumbricus*, a white slimy worm, shooting out a proboscis when touched, which showed clearly that it was a Land Nemertine (fig. 62). It belonged to the genus *Tetrastemma*. It differs little from the *Tetrastemma obscurum* described by Max Schultze from the Baltic; I have named it *Tetrastemma agricola*. Only two other terrestrial Nemertines are as yet known, one discovered by Semper in the Philippine Islands, and a second found in hot-houses in Europe, evidently imported from some unknown tropical region.[1] When irritated the worm darts out its armed proboscis as an aid in progression, fixing its tip to a distant point and then drawing the body up to the point by contracting the protruded organ. The animal is ciliated all over, and has two pairs of eyes. The earth in which it lives contains a good deal of salt. It is very probable that these Nemerteans live in the tropics in the same regions as do the land Planarians, but, owing to their being less conspicuous, they have hitherto been overlooked. A good many, both old and young, were caught, and kept alive for some time in glasses, in some of the earth in which I found them.[2]

"I made an excursion to Harrington Sound, with the view of looking for specimens of the *Nebalia* (*Paranebalia*, Claus)[3] which Murray had found there in April, and was fortunate enough to find, under stones and on the under surface of *Agaricia fragilis*, many females and some males of this interesting Crustacean, which are likely to throw some

[1] Others have been discovered, since the above was written, in the Mascarene Islands and elsewhere.

[2] On a Land Nemertean found at the Bermudas, *Ann. and Mag. Nat. Hist.*, ser. 4, vol. xiii. pp. 409–411, pl. xvii., 1874.

[3] This species has since been erected into a new genus, under the name *Paranebalia longipes*, by Claus, Grundzüge der Zoologie, 4th ed., 1880, p. 576.

light on the morphological value of different parts of the animal. The male is only known in one species (*Nebalia geoffroyi*), in which it is but little more slender than the female, and has the first pair of antennæ only slightly larger and the second pair much longer than

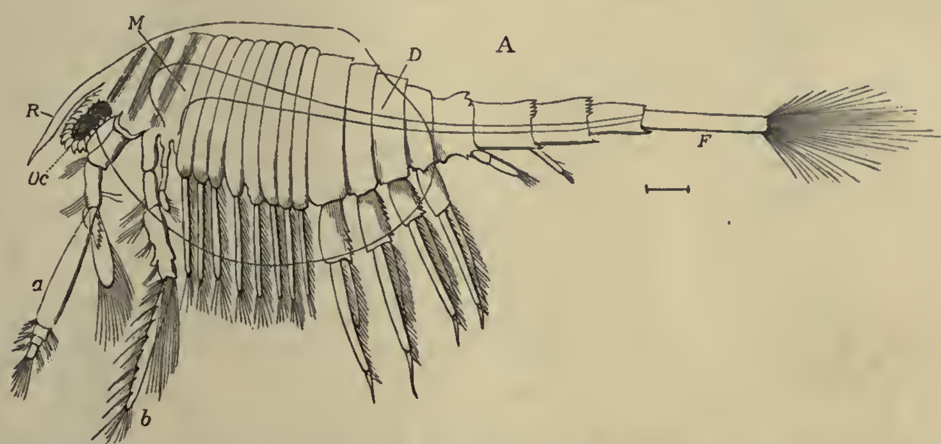


FIG. 63, A.—Female of *Nebalia* (*Paranebalia*) *longipes*, Suhm, magnified about 20 diameters, from a drawing by von Suhm. *a*, first antenna; *b*, second antenna; *Oc*, eye; *R*, rostrum; *M*, stomach; *D*, intestine; *F*, furcal process.

is the case in the female. In this Bermudian *Nebalia* (*Paranebalia*), which differs in many ways from any *Nebalia* hitherto known, the male is only half the size of the female, and has the first pair of antennæ changed into strong prehensile organs, whilst the second pair

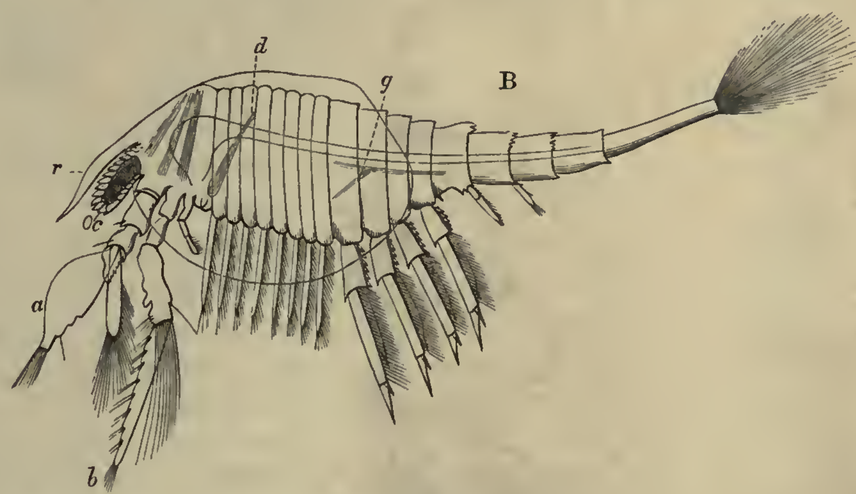


FIG. 63, B.—Male of the same, magnified about 35 diameters. Letters as in A. *d*, palp of the first maxilla ("Putzfuss," Claus); *g*, ductus ejaculatorius.

does not differ from that of the female. In both cases the genital opening is at the base of the eighth pair of pectoral limbs. These differences in the males of the two species are so considerable that, according to the principles adopted for the classification of other groups, for example the Copepods, it would be necessary to make another genus of this new form; but in *Nebalia*, I think, this would not be advisable, as our knowledge of this singular little group is only beginning, and many discoveries of new forms are to be expected which will better fix its systematic position. The pectoral feet of this species are of great interest, as confirming the opinions of Claus[1] and Mecznikoff that the genus *Nebalia* should be associated with the Schizopods rather than the Phyllopods. The pectoral limb of *Nebalia geoffroyi* (fig. 63, C) shows very clearly the two leaf-like appendages KA and NA, which led earlier observers to place it in the latter group; in the corresponding member of *Nebalia* (*Paranebalia*) *longipes* (fig. 63, D) one of these KA is represented only by a small rudiment, and the other has lost its flattened form and become a rounded limb comparable with one branch of the typical Schizopod appendage, such as that of *Lophogaster typicus* (fig. 63, E).[2] Had this been the first form of *Nebalia* made known, the group would probably never have been classed with Phyllopods. From a Darwinian point of view this form, which I propose to call *Nebalia longipes*, represents a more advanced stage of these strange creatures, which are the connecting links between Phyllopods and the higher Malacostraca (Schizopods)."

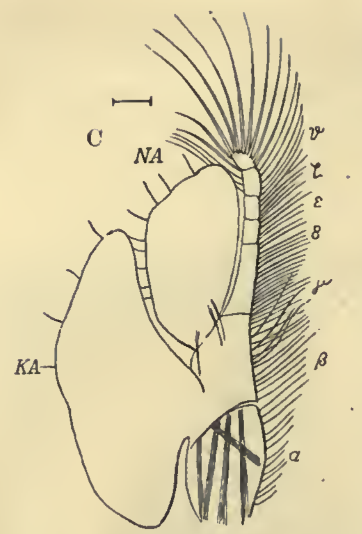


Fig. 63, C.—Phyllopod-like thoracic limb of *Nebalia geoffroyi*, from Suhm, after Claus. α, basal joint with branchial appendage (*KA*); β, second joint with lateral appendage (*NA*); γ, main branch; δ–θ, successive joints of the same.

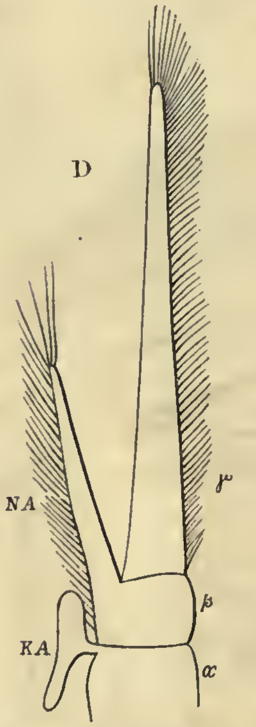


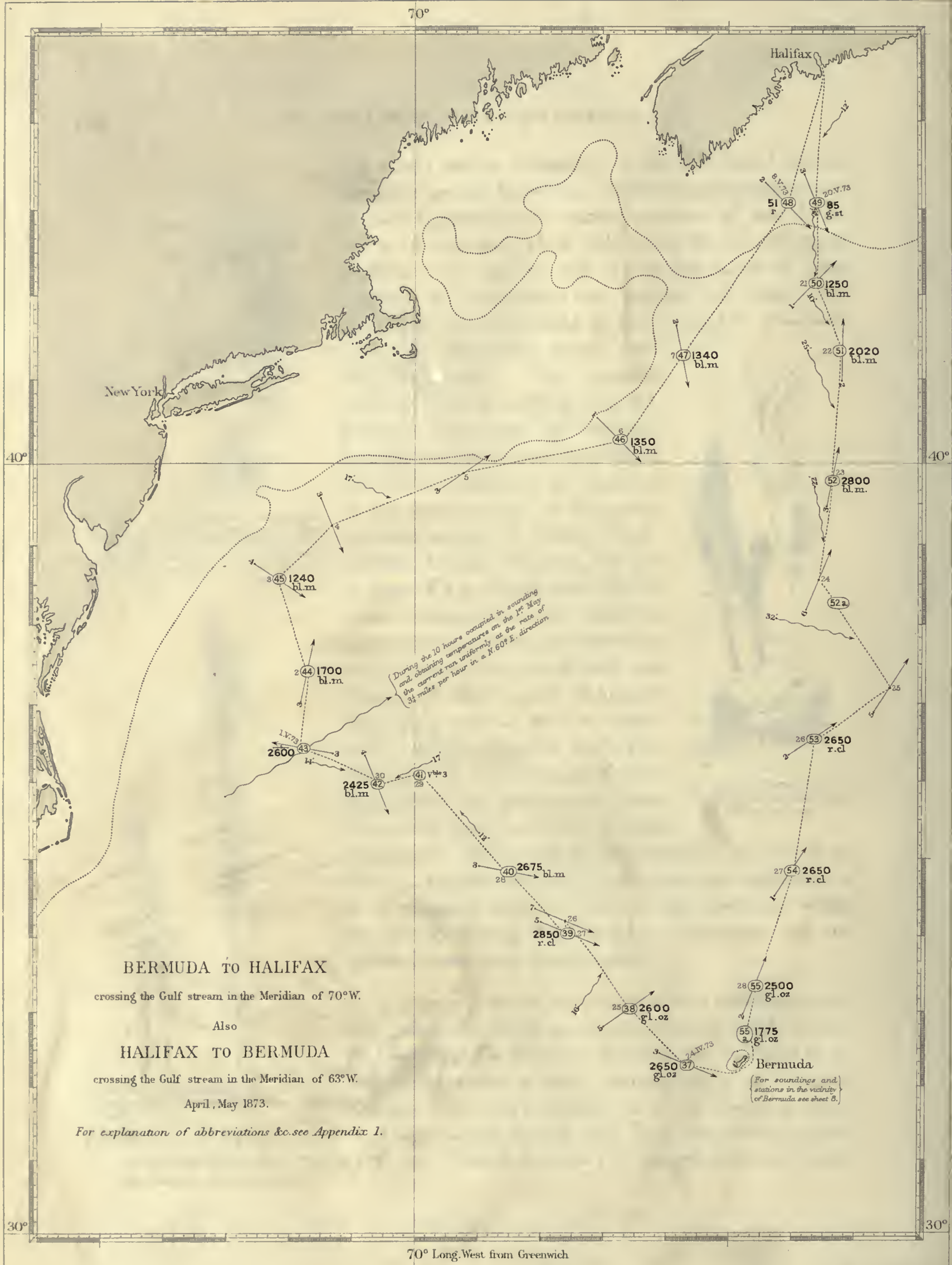
Fig. 63, D.—Corresponding limb of *Nebalia* (*Paranebalia*) *longipes*, from Suhm. Letters as in C.

Fig. 63, E.—Thoracic limb of *Lophogaster typicus*, from Sars, for comparison.

A large number of invertebrates were collected on the reefs and on the sandy patches between the coral clumps. Professor Wyville Thomson[3] found, in the collection of an amateur naturalist, a small worn cup of the rare Crinoid *Holopus*. He looked carefully in all the dredgings about Bermuda for living specimens of this genus, but in vain. Dr. P. H. Carpenter gives the

[1] Claus, *Zeitschr. f. wiss. Zool.*, Bd. xxii. p. 323, 1872. [2] Sars, M., Beskrivelse over Lophogaster typicus, tab. ii. fig. 35.
[3] The Atlantic, vol. i. p. 321, 1877.

SHEET 9



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following note about *Holopus*,[1] which, unfortunately, was not obtained in any of the Challenger dredgings:—

"*Holopus* is one of the most curious of the recent Crinoids, and appears to be sessile throughout life. The basals and radials enclose a tubular chamber, in which the viscera are contained; and this is attached directly to the rock on which it rests by a spreading calcareous expansion, instead of being borne on a stem, as most other Crinoids are, for the whole or part of their life. The central mouth is protected by five triangular oral plates, as in *Hyocrinus* and *Thaumatocrinus*, and surrounded by five massive arms, which are articulated in pairs to five axillary plates that rest on the edge of the cup. Only half a dozen specimens are known, most of which have been brought up by fishermen's lines in the neighbourhood of Barbados. One very young individual was obtained by the U.S. Coast Survey steamer 'Blake,' in 100 fathoms, off Bahia Honda, and a fragment of a larger one in 110 fathoms off Montserrat. The genus is not known to occur out of the Caribbean Sea, and was not dredged by the Challenger. It is closely allied to a remarkable fossil known as *Cyathidium*, which occurs in the upper Chalk of Faxöe in Zeeland, and also to some singular sessile Crinoids characteristic of the Middle Lias in central and western Europe. Certain Palæocrinoids and Cystideans also seem to have been sessile like *Holopus*, and not stalked like most of the Pelmatozoa."

Bermuda to Halifax, Nova Scotia.

The vessel left the neighbourhood of Bermuda on the 21st April, and at first a course was shaped towards New York. After crossing the Gulf Stream and obtaining soundings and temperatures to the edge of the 100 fathom bank off the American coast (see Sheet 9), the ship was steered to the northeastward for Halifax, Nova Scotia, arriving there on the 9th May. The usual dirty weather was experienced on the passage towards New York: occasional strong winds, amounting sometimes to a gale, with light breezes intervening, and after crossing the Gulf Stream thick fogs, with rain, until close in to the land.

On the 28th April the sounding line parted as it was being hove in, but later on the dredge brought up a specimen of the bottom. On the 29th the sea was so short and heavy that in keeping the ship head to wind, in order that a sounding might be obtained, the rudder took charge and carried away the wheel ropes, so that the attempt had to be abandoned for that day.

On the 30th April at 2 P.M. the temperature of the surface water, which, since leaving Bermuda, had varied between 65°·0 and 70°·0, rose to 71°·5, and continued at a temperature of from 71°·0 to 73°·0 until 6 A.M. on the 1st May, when it rose to 75°·0. At that hour

[1] See Zool. Chall. Exp., part xxxii., 1884.

the ship was stopped to sound and obtain temperatures, and a good set of observations of the sun were taken at 6.40 A.M., and as its bearing was E. 6° N. (true), a considerable error in the latitude was of but little consequence to the resulting longitude. From these observations it appeared that from noon on the 30th April to 6 A.M. on the 1st May, when the sudden increase of surface temperature took place, little if any current had been experienced, the longitude from Dead Reckoning being 72° 8′ W., and that by observation 72° 4′ W. This result was also confirmed by an observation at 4.40 P.M. on the 30th April, the longitude by chronometer at that time agreeing with the D.R. longitude.

At 6 A.M. on the 1st May the wind was from the N.E., force 3 to 4, with a considerable swell, and owing to the rise of surface temperature to 75°·0, the opinion was formed that the vessel was in the Gulf Stream. In sounding the sinkers were lowered over the side of the ship without, as usual, keeping head to wind. When 250 fathoms of line were out, it trended rapidly to the W.S.W., and made it necessary to put the ship before the wind to keep exactly over the descending weights; in fact, the vessel had to steam W.S.W. (S. 60° W., true), at the rate of 3 miles per hour, to keep the line perpendicular, and even then could only do so by constantly checking, as when it was allowed to run out freely the surface drift of 3 miles per hour carried the bight rapidly astern. It will, therefore, be readily understood that the speed of the line as it ran out over the ship's side was the speed of descent of the sinker plus the rate at which it was being carried away by the current, and that, therefore, the time intervals were of little value in determining the moment at which the weights struck the bottom. When 2600 fathoms were out, the line was checked and was apparently perpendicular; but as the accumulators showed what was believed to be a decrease in the strain, and the line did not readily come up and down, it was concluded the bottom had been reached. This was a mistake, for on being hove up, it was found that the sinkers had not disengaged, nor was there any sign of mud on the rod.

A serial temperature observation obtained at this position showed that the warm water was quite superficial; at 60 fathoms the temperature was 71°, at 80 fathoms 68°, at 100 fathoms 65°, and at 125 fathoms 57°. To obtain these results a weight of 2 cwt. had to be attached to the bottom of the line to keep it perpendicular; with a less weight the bight of the line was carried away, forming a bow.

With the current drag lowered to a depth of 100 fathoms a very slight motion of the surface water past the watch buoy was apparent, but when lowered to a depth of 250 fathoms the surface water ran past the watch buoy at the rate of 1¾ miles per hour. It is therefore probable that at that depth, even if not at a less, the current drag was in still water, as the force of the 3-knot stream on the watch buoy and the upper portion of the current line was, probably, sufficient to move the drag through the water at about the rate of a mile per hour.

In investigating the strength and direction of ocean currents, such as the Gulf

Stream, when out of sight of land or unable to anchor a boat, observations of the heavenly bodies are the only resource, and when the weather is clear, so that these observations can be obtained at short intervals, and especially when stars have been taken at sunrise and sunset, with a well-defined horizon, so that both latitude and longitude are determined at the same instant *twice* during the day, a very accurate estimate can be formed, by astronomical observations alone, of the rapidity of the stream. If star observations cannot be obtained, the operation is by no means so simple; and is sometimes impossible, as then the latitude cannot be determined at the same instant as the longitude,[1] double altitudes of the sun not being available owing to the want of knowledge of the alteration in the position of the ship between the times of observation; the latitude, therefore, can only be got at noon by meridian altitude of the sun.

Unfortunately, nearly all the great ocean streams, the phenomena of which it is most desirable to investigate, have in their neighbourhood cloudy, thick weather, with short, sharp gales, rendering their exploration at all times difficult. The officers were so far fortunate in the weather in the Challenger, whilst taking temperatures, soundings, &c., in the Gulf Stream from 6 A.M. to 5 P.M. on the 1st May, as to be able to obtain frequent observations of the sun, although the sky was too cloudy to permit the determination of the position by star observations at sunrise or sunset. It was therefore only possible to obtain one latitude at noon by meridian altitude of the sun. The positions of the ship at various times during the day were determined in the following manner:—A set of observations for longitude was taken at 6.40 A.M., when the bearing of the sun was E. 6° N., or nearly on the prime vertical, and another at 4.27 P.M., when its bearing was W. 1° S., or almost exactly on the prime vertical. Any error, therefore, of the latitude used in working these observations would have but a slight effect on the longitude. Now, the resulting longitude at 6.40 A.M. was 72° 4′ W., and at 4.27 P.M. 71° 31′ 30″ W., it is, therefore, evident that between those hours the drift in longitude experienced by the ship was 32½ minutes. But in keeping the sounding line perpendicular it was found necessary to steam W.S.W. (S. 60° W. true) at the rate of 3 miles per hour, from which it is evident that the direction in which the stream was running was N. 60° E. Having then the direction in which the current was going, and the alteration of longitude due to it in a given time, it was possible to calculate the speed at which it was running, which amounted to 3¼ miles per hour, or very nearly the same rate at which it was necessary to steam in a W.S.W. direction whilst sounding.

If this conclusion as to the direction and rate of the current be correct, it is evident that by applying the amount due to a given interval of time, the longitude of the ship at that time, as determined by this method, should agree with the longitude obtained by actual observation. By taking a proportion of the whole alteration in the longitude between 6.40 A.M. and 4.30 P.M., it was found that the longitude at noon was 71° 45′ 54″ W.,

[1] Unless the moon is visible, or Venus or Jupiter passes the meridian during the day.

the observed latitude being 36° 23′ 30″ N. At 10.20 A.M. a set of sights was obtained, and as the bearing of the sun at that time made it a matter of importance to know exactly the latitude (an error of one mile of latitude causing an error of one mile in longitude), the result given by the observations then taken furnishes a very good test of the accuracy of the deductions. The interval from noon being 1·7 hour, it follows that the position of the ship at the moment, calculated by the known rate of the current from the noon results, will be lat. 36° 20′ 48″ N., long. 71° 51′ 44″ W., and the longitude, calculated from the observations, was 71° 53′ 45″ W. Again, at 8.40 A.M. the position calculated from the noon observation was lat. 36° 18′ 15″ N., long. 71° 57′ 6″ W., and longitude calculated from the observations at the time was 71° 57′ 30″ W. Such an accordance between the calculated positions and those obtained by observation will, in all probability, be deemed a sufficient proof, together with the fact of the rate at which it was necessary to steam to keep the sounding line perpendicular, that this estimate of the strength and direction of the Gulf Stream whilst the vessel was in it is a very close approximation to the truth.

At 5 P.M., these observations being completed, the ship proceeded N.N.W. (N. 30° W. true) at right angles to the direction of the stream. At 9.30 P.M. the surface temperature had fallen from 75°·0 to 69°·0, and the patent log showed that the vessel had gone 10 miles through the water. At 11 P.M. the surface temperature was 67°·5, but at midnight it had fallen to 56°·5, and continued nearly the same the whole of the next day.

On the 2nd and 3rd May the weather was so thick with rain and fog that no observations of any of the heavenly bodies could be obtained. On the 4th May the clouds cleared off, and it was possible to ascertain the position of the ship at 6 A.M., which proved to be lat. 39° 5′ N., long. 71° 55′ W., the position by D.R. at this time being 38° 57′ N., 71° 57′ W., that is allowing for a current of $3\frac{1}{4}$ miles per hour up to 9.30 P.M. on the 1st, at which time the temperature decreased 6°. It will, therefore, be seen that the position by D.R. was 8 miles south of that by observation—a difference due, in all probability, to an error in the leeway allowed from 2 P.M. on the 3rd to 6 A.M. on the 4th, during which time the ship was close hauled ; previously the course had been off the wind.

Recapitulating, then, it appears that on May 1st, at 6 A.M., the temperature of the surface water rose to 75°·0, and that at 6.40 A.M., when soundings, &c., were taken, and when the ship had run 5 miles to N.N.W. from 6 A.M., her position by D.R. and observation showed a difference of but 4 miles in longitude ; that by astronomical observation the ship drifted between 6.40 A.M and 4.30 P.M. $3\frac{1}{4}$ miles per hour in a N. 60° E. direction (true), the temperature of the surface water remaining at 75° ; that from 5 P.M. to 9.30 P.M. the ship proceeded in a N. 30° W. direction (true) for 10 miles, the surface temperature still remaining at 75°·0, but that immediately afterwards it fell to 69°·0, and was at midnight 56°·5 ; and that allowing a current of $3\frac{1}{4}$ miles per hour N. 60° E. (true) during the time the surface temperature remained at 75°·0, the longitude by D.R. agrees with that obtained by observation at 6 A.M. on May 4th, the first time the position of the ship could be ascertained by those means after the temperature of the water fell below 75°·0.

Observations taken below the surface showed that the water retained a temperature of over 70° to 60 fathoms, and that it then decreased rapidly to 57° at 125 fathoms, and then slowly to the bottom.

It therefore appears that the Gulf Stream on the 1st May 1873, in lat. 36° 23′ N., long. 71° 46′ W., was 15 miles in breadth and about 100 fathoms in depth, that its speed was $3\frac{1}{4}$ miles per hour in a N. 60° E. direction, and that it was, at that time, discharging 4·87 cubic miles of water per hour into the North Atlantic basin, equal to 116·88 cubic miles per day, or 42,661 cubic miles per year. Taking into consideration the high specific heat of water some idea may be formed of the vast amount of heat annually carried from the tropics into the North Atlantic.

In the section from Bermuda towards New York eight soundings, seven temperature soundings, and four dredgings were obtained, and from the New York end of the section to Halifax three soundings and three dredgings (see Sheet 9).

The bottom temperature, at depths exceeding 1800 fathoms, was again remarkably uniform, from 36°·5 to 36°·8, the mean being 36°·6, nor was it affected in any way by the cold surface water on the northwest side of the Gulf Stream (see Diagram 2).

The isotherm of 40° was found at a uniform depth of 810 fathoms for 350 miles N.W. of Bermuda, but after crossing the Gulf Stream it rose to 280 fathoms. The other isotherms maintained a position parallel to that of 40°.

On the 24th April, at Station 37, the weather being fine and the sea smooth, a boat was anchored by the dredge to try the current, with the following results :—

On the surface the current was setting		N. 60° E.	0·24	mile per hour.
At a depth of 50 fathoms	„	N. 75° E.	0·46	„
„ 100 „	„	N. 87° E.	0·36	„
„ 200 „	„	S. 70° E.	0·22	„

Below 200 fathoms there was no perceptible set.

On the 28th April, at Station 40, a boat was again anchored by the dredge and the current tried, with the following results :—

On the surface the current was setting		N. by W.	0·75	mile per hour.
At a depth of 50 fathoms	„	N. by W.	0·75	„
„ 100 „	„	N.N.W.	0·6	„
„ 200 „	„	N.W.	0·6	„

On the 6th May, at Station 46, the surface current found by anchoring a boat by the dredge was E.S.E., a little over a mile per hour.

The anemometer on the 26th April, when the ship was kept laying-to under double reefed topsails (waiting for finer weather), showed the velocity of the wind to be 38 miles per hour, the force registered being 7 to 9, 39 miles per hour when the force registered was 8, and 30 miles per hour when the force was registered as being 6 to 7. On the 27th April the anemometer showed the velocity of the wind to be 21 miles per hour, the force of the wind being registered as 5.

On the 8th May the ship dredged in 51 fathoms on the Le Havre Bank off the coast of Nova Scotia, and a large number of Cod-fish were caught by hand lines. At 5.10 A.M. on the 9th the land about Sambro Island was sighted, and the Challenger steamed in for Halifax Harbour. The weather was quite calm, and the mirage so great that it was difficult to distinguish the land, so much was it distorted. It was noticed that the new lighthouse at Chebucto was placed on the summit of the hill over the coast—a questionable advantage in a port so subject to fogs as Halifax. At noon the vessel was lashed alongside the dockyard wharf in the harbour.

Halifax, Nova Scotia.

The ship remained at Halifax from the 9th to the 19th May. On the 15th, at 11 P.M., the sky was brilliantly illuminated by an aurora borealis, stretching from north to east, which shot up rays of light to an altitude of 30°. Numerous excursions were made by the naturalists and officers into the surrounding country.

Sir C. Wyville Thomson thus describes the glaciated rocks near Halifax :—" We went with the photographer to 'The Point,' a little way out of the town, where there is a very astonishing exhibition of the action of ice. There is a round tower at the top of 'The Point,' mounting a few cannon, with a guard of soldiers, and this tower stands in the middle of an area of one or two acres, where the rock, a highly altered Silurian schist, is perfectly bare and polished. The undulations and contortions in the foliations of the schist are seen in section on the polished surface ; and traversing these sinuous markings there is a wonderful system of parallel ruling in grooves of greater or less depth, cut into the stone by boulders and fragments of rock borne by the ice-cap in its slow progress over it " (see Pl. I.).

Halifax to Bermuda.

On the 19th May, at 5 P.M., the Expedition left Halifax for Bermuda, and fine weather was experienced on the passage, the wind on one occasion only exceeding a force of 5, viz., on the 24th and 25th, on which days a moderate gale was experienced from the S.W., lasting 26 hours.

The phenomenon most noticeable in the section from Halifax to Bermuda was the marked variation in the temperature of the surface water. On leaving Halifax the surface temperature was 39°, and it rose gradually as the ship proceeded to the south-

Plate I.

HORSBURGH, EDINBURGH. PERMANENT PHOTOTYPE.

ROCK WITH GLACIAL MARKINCS,
NOVA SCOTIA.

ward, until it reached 41° on the 21st May in lat. 42° 10′ N., long. 63° 39′ W. From this position the change was more rapid, as at 7 A.M. on the 22nd, in lat. 41° 19′ N., long. 63° 11′ W., the temperature at the surface was 57°·5. It is remarkable that although the ship remained stationary the whole of that day, sounding and dredging, and although no current whatever could be detected whilst so employed, yet the temperature at the surface increased from 57°·5 at 7 A.M. to 62°·5 at 4 P.M. It is true that the sky was clear, and that the power of the sun was therefore great, still it will be seen, by referring to the meteorological register, that the maximum temperature of the air was 61°·0, or 1°·5 below that of the water, although the wind was from the southward.

At 6 P.M. on that day, having completed the observations, the vessel proceeded towards Bermuda, the surface water retaining its temperature of 62°·5 until 8 P.M., after which it fell to 58°·0, and at midnight to 54°·0, but at 1 A.M. on the 23rd May it rose again to 64°·8, and at 1.30 A.M. to 68°. At 4 A.M. the surface water attained a temperature of 70°·5, which it retained until 9 A.M., when a line of ripple on the water was passed, and the temperature fell to 66°·5. At 10.15 A.M. on the 23rd the ship stopped to sound, remaining stationary until 5 P.M.; during this time the surface water, which was ascertained, by astronomical observation, to be running to the southward (confirmed by having to steam to the northward to keep the line perpendicular), varied in temperature from 67°·2 to 68°·0. The position at this time was lat. 39° 44′ N., long. 63° 22′ W., and the serial temperature sounding placed the isotherms of 60°, 50°, and 40° at precisely the depths that they occupied at Bermuda, then distant 450 miles, and these depths they steadily retained for the remainder of the section (see Diagram 2).

At 5 P.M. on the 23rd the course was continued towards Bermuda, and the surface temperature was found to vary from 67°·0 to 71°·2 until 8 A.M. on the 24th, when it rose to 73°·5, and remained steady until 6 P.M. A serial temperature, taken at 4 P.M. in lat. 38° 16′ N., long. 63° 17′ W., showed that the temperature of 73° continued to a depth of 50 fathoms, but that between 50 and 75 fathoms a decrease of 5°·5 took place. The current, as ascertained by difference between the position calculated from D.R. and observation between 9.30 A.M. and 4 P.M. was easterly, its rate being 1½ miles per hour. Unfortunately, the weather on the 24th was unfavourable either for sounding or dredging, so that it was impossible to test the current by mooring a boat.

After 6 P.M. on the 24th the surface temperature again became variable, falling to 64°·5 by 8 A.M. on the 25th, and varying between 64°·5 and 69°·5 until 4 A.M. on the 26th, when it again rose to 70°·5 and at 2 P.M to 73°·5, but the serial temperatures on that day (at Station 53) showed that the warm water was quite superficial, as at 25 fathoms the temperature was 69°, and at 50 fathoms 66°, whereas on the 24th the temperature of 73° was observed at the latter depth.

At 1 P.M. on the 26th, after completing the temperature sounding, the course was resumed, and Bermuda was reached without encountering any other considerable changes in the condition of the surface water, the mean temperature of which for the remainder of the passage was 71°·7, the extremes being 73°·5 and 69°·0.

In the Halifax–Bermuda section eight soundings, five dredgings and two trawlings in deep water, and eight serial temperature soundings were obtained.

On the 22nd May, at Station 51, the dredge rope parted as it was being hauled in, apparently without cause, as the dredge was off the bottom, and the accumulators did not indicate any undue strain. The rope had probably got stranded previously by meeting some obstruction on the bottom.

On the 26th May, at Station 53, the line used in obtaining submarine temperatures became jammed between the rudder and the stern-post, and defeated all attempts to recover it, eventually parting, by which accident seven thermometers were lost. This was the only occasion on which any serious mishap occurred in taking temperature observations throughout the voyage.

The temperature of the water at the bottom in the Halifax–Bermuda section was, as in the previous sections, remarkably uniform when the depth exceeded 1800 fathoms, the mean being 36°·2 and the extremes 36°·0 and 36°·3. One bottom temperature of 35° was obtained in 85 fathoms on the 20th May at Station 49, in the centre of the Labrador Current.

The serial temperature observations indicate in a remarkable manner the influence of the cold water of the Labrador Current on the temperatures below the surface, for it will be seen by referring to the section (Diagram 2) that although that current, judging from the surface temperatures obtained, does not extend more than 100 miles from the land, and is consequently confined in this locality to a depth not exceeding 100 fathoms, yet its lowest stratum apparently flows over the edge of the 100 fathom bank off Nova Scotia, and gradually descends to the bottom of the North Atlantic basin, as evidenced by the parallelism of the isotherms to the contour of the bottom in the immediate vicinity of that bank. The influence of the Labrador Current upon the adjacent water was traced for 150 miles to the southward of its edge, for it will be noticed that the isotherm of 40°, which for 450 miles north of Bermuda occupied the same or nearly the same depth at which it had hitherto been found over nearly the whole of the western part of the North Atlantic, rises almost vertically to the surface 600 miles north of Bermuda.

On the 27th May, at Station 54, the surface current was found to be N.E. $\frac{1}{4}$ mile per hour.

On the 28th May, at Station 55A, the surface current was found to be N. 60° E., $\frac{1}{2}$ mile per hour, and the current drag at 200 and 500 fathoms indicated no movement at those depths, as the surface water ran past the watch buoy at the same rate and in the same direction as when it was anchored, by the lead line, to the bottom.

On the 28th May, at 8 P.M., Bermuda was sighted, and the 29th, 30th, and part of the 31st were spent in sounding and dredging on the south and southeastern sides, proceeding into harbour on the afternoon of the 31st.

The deposits between Bermuda and the coast of North America showed, irrespective of depth, a regular decrease in the quantity of carbonate of lime as the American shores were approached. While over 50 per cent. occurred at 2600 fathoms about 100 miles from Bermuda, only 15 and 16 per cent. was found in 1240 and 1250 fathoms near the American shores. The large pelagic Foraminifera made up the principal part of the carbonate of lime in the deposits around Bermuda, but they disappeared almost completely from the bottom when within the influence of the Labrador Current. Rhabdoliths likewise disappeared from the bottom along with the larger tropical pelagic Foraminifera, while Coccospheres were found in the deposits under the Labrador Current.

The mineral particles increased in size and number as the American continent was approached, where they consisted of fragments of quartz, monoclinic and triclinic felspars, hornblende, augite, magnetite, mica, and glauconite. On the 7th May a large block of syenite weighing 490 lbs., which had become jammed between the arms of the dredge, was brought up from 1340 fathoms. In this and the other dredgings within the influence of the Labrador Current, over 100 miles from the shore, many stones were dredged, most of these being rounded pebbles or large grains with rounded angles; nearly two-thirds of the smaller fragments were milky quartz, whilst the larger fragments were quartzite, compact limestone, dolomite, mica-schist, and serpentine rocks, some of them with glacial striations. The deposits along the American coast were blue muds with a reddish surface layer, in which quartz and fragments of ancient rocks were abundant, making up over 60 per cent. of the deposits in 1240 and 1350 fathoms, while these minerals were not detected in the deposits around Bermuda.

The dredgings and trawlings in very deep water around Bermuda were not very productive: in 2650 fathoms six *Ophioglypha bullata*, one *Amphiura verrilli*, two *Calymne relicta*, some empty worm tubes and a few Shrimps were obtained; in 1075 fathoms there were *Bathyactis symmetrica*, *Deltocyathus italicus*, *Ophiacantha segesta*, *Amphiura duplicata*, several species of *Trochus* and other Molluscs, a Pagurid, Galatheids, several Shrimps and siliceous Sponges; in 435 fathoms *Caryophyllia cylindracea*, *Axohelia dumetosa*, *Cladocora arbuscula*, *Ophiomusium cancellatum*, *Ophiopyren longispinus*, *Ophiacantha troscheli*, *Ophiomitra chelys*, *Astroschema brachiatum*, a species of *Crania*, several Molluscs, Alcyonarians, Crustaceans, and Sponges. In depths of less than 50 fathoms a large number of genera and species were obtained.

The dredgings and trawlings in 1700, 1240, 1350, 1250 fathoms and lesser depths along the coast of North America yielded a very large number of genera and species, the fauna having a decidedly Arctic character, many of the species being identical with those dredged on the northern coasts of Europe. The relative abundance of genera and species in these dredgings, compared with those at similar depths around Bermuda, was remarked, and will be referred to again when comparing the dredgings along continental shores with those at similar depths around oceanic islands. A *Boltenia*-like Ascidian, belonging to the new genus *Culeolus*, was taken for the first time in the dredging in 1700 fathoms, and is referred to in the following notes by Professor W. A. Herdman of University College, Liverpool, on the Tunicata collected by the Expedition :—

The Tunicata.—" The large collection of Tunicata made during the Expedition has added greatly to our knowledge of this interesting group, especially as regards its distribution. The pelagic Tunicates (the Salpidæ, the Doliolidæ, and the Pyrosomidæ), which form such an important constituent of the surface fauna of the ocean, have, on account of their abundance and the comparative ease with which they may be obtained, been much studied in many parts of the world. Hence the Challenger collection of these forms contains few novelties, but is of great value, since, from the constancy and care with which tow-net observations were conducted, and their results preserved, it affords much additional information as to the distribution of these pelagic Tunicates horizontally, and to a less degree vertically.[1]

" The remarkable new genus *Octacnemus* described by Mr. Moseley[2] (see fig. 64), of which two species are known, seems to be an abyssal and considerably modified ally of the pelagic Salpidæ.

" The collection is rich in Compound Ascidians, but although many of them are new species, the great majority belong to common and well-known genera. This can be accounted for by the fact clearly brought out by the Challenger Expedition, that the Ascidiæ Compositæ form essentially a shallow water group, the bulk of the collection having been obtained close to land, or at localities, such as Kerguelen Island and Port Jackson, where the shore fauna was investigated. A few Compound Ascidians were, however, obtained from great depths, such as 1600, 2050, and 2900 fathoms; but they show no notable morphological peculiarities.

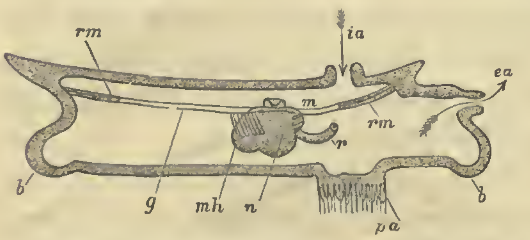


FIG. 64.—*Octacnemus bythius*, Moseley. Schematic, vertical, and longitudinal section, through the animal, along the middle line. *ia*, Mouth ; *m*, opening of the œsophagus ; *r*, rectum and anus ; *ea*, cloacal aperture ; *rm*, *rm*, radiating muscles ; *n*, nucleus ; *mh*, muscles of the nucleus ; *g*, respiratory membrane ; *b*, thickened margin of the base ; *pa*, pedicle of the attachment. (After Moseley.)

" The horizontal distribution of the group is very wide, representatives being found in all the great oceans and in almost all latitudes.

[1] For details, see the forthcoming Report on the Tunicata, Part II.

[2] Moseley, *Trans. Linn. Soc. Lond.* (Zool.), ser. 2, vol. i. p. 287, 1877 ; see also Report on the Tunicata, Part I., Zool. Chall. Exp., part xvii., 1882.

"Among the Ascidiæ Simplices, the most important new forms constitute a small group of pedunculated Cynthiidæ, apparently confined to deep water, and characterised by several striking peculiarities. They are more nearly allied to *Boltenia* than to any other previously known genus, and have been placed in two closely related new genera—*Culeolus* (see fig. 65) and *Fungulus*, the former containing six species and the latter one. Their most important morphological feature is the very remarkable condition of the branchial sac, which is simplified, apparently, by the total absence of the system of fine interstigmatic vessels; the result being that the large meshes are not divided into

FIG. 65.—*Culeolus wyville-thomsoni*, Herdman. Seen from the left side ; natural size.

stigmata, as they are in a typical Simple Ascidian (see fig. 66). In *Culeolus* the branchial sac is strengthened by the development in the walls of the vessels of a system of rather gracefully branched and curved calcareous spicules, marked internally by a series of 'contour' lines.[1] These are quite different in appearance from the fusiform echinated spicules found in *Cynthia pallida*, Heller, and in the two new species, *Cynthia complanata* and *Cynthia papietensis*. Another noteworthy feature in the anatomy of the genus *Culeolus* is the condition of the blood-vessels of the test in

[1] Zool. Chall. Exp., part xvii. p. 95, 1882.

some of the species. In *Culeolus murrayi* the terminal twigs of the vessels open into large vesicles placed just below the surface of the test, and only separated from the external medium by a very delicate membrane. In several of the species there are

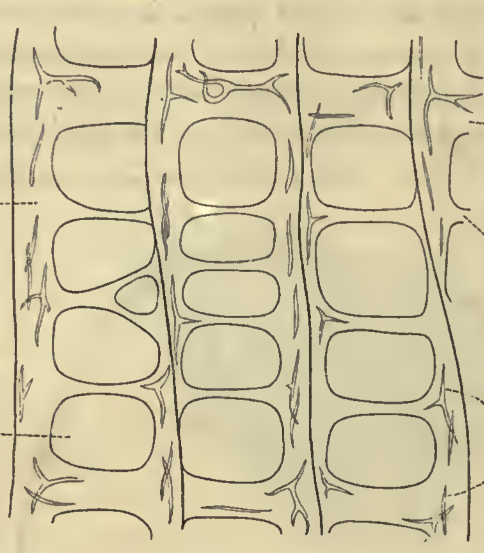


FIG. 66.—The Branchial Sac of *Culeolus wyville-thomsoni*, Herdman, from the inside; magnified about 50 diameters. *tr.*, large transverse vessel; *tr'.*, smallest size of transverse vessel; *i.l.*, internal longitudinal bar; *mh.*, mesh; *sp.*, spicules.

thin-walled hollow papillæ or projections from the surface of the test, and these are in free communication with either the large vesiscle or the ends of the vessels. This is obviously an accessory respiratory apparatus, permitting the blood circulating in the test (which when the heart contracts dorso-ventrally is impure) to be brought into such close relation with the external water as to ensure a certain amount of oxidation.[1]

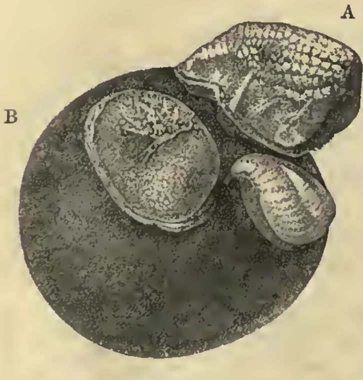


FIG. 67.—A, *Styela squamosa*, Herdman, and B, *Styela bythia*, Herdman (natural size), attached to a manganese nodule, from 2600 fathoms.

"A large number of other new species of Cynthiidæ were obtained, but the only other one which cannot be referred to a known genus is *Bathyoncus mirabilis*, a form which agrees with the typical Stycelinæ in having simple tentacles, but differs from them in having a branchial sac of the skeleton type found in *Culeolus* and *Fungulus*. The large and well-marked genus *Styela* is remarkable on account of its very extended bathymetrical range. Most of the species are found in shallow water, some few between tide marks; while six species in the collection are from between 100 and 600 fathoms, and two, *Styela bythia* and *Styela squamosa* (see fig. 67), both fairly typical members of the genus, were obtained at a depth of 2600 fathoms.

[1] For further details the reader is referred to the Report on the Tunicata, Zool. Chall. Exp., part xvii. pp. 93, 276.

"In the Family Molgulidæ, beyond the two gigantic pedunculated forms, destitute both of hair-like processes from the test and incrusting sand, which have been placed in the new genus *Ascopera*, no very striking novelties were discovered. In the Ascidiidæ, however, there are three noteworthy new genera—*Corynascidia*, *Abyssascidia*, and *Hypobythius*, all from deep water. Of the last, one species, *Hypobythius calycodes*, was described by Mr. Moseley,[1] and a second, *Hypobythius moseleyi*, agreeing with the first in the simple structure of the branchial sac, but differing in the body form and some other details, was afterwards found in the collection. *Corynascidia suhmi* (see fig. 68) is, like so many other of the abyssal forms, supported upon a peduncle. The position and course of the intestine are peculiar,[2] and the branchial sac is one of the most beautiful and delicate known. The third genus, *Abyssascidia*, is a connecting link between the well-known genera *Ascidia* and *Corella*. It resembles the latter genus in the position and especially in the course of the intestine, while in the structure of the branchial sac it differs greatly from *Corella*, and exhibits the simpler arrangement found in *Ascidia*, from which again it differs in the condition of the dorsal lamina, and in the large number of lobes surrounding the branchial and atrial apertures.

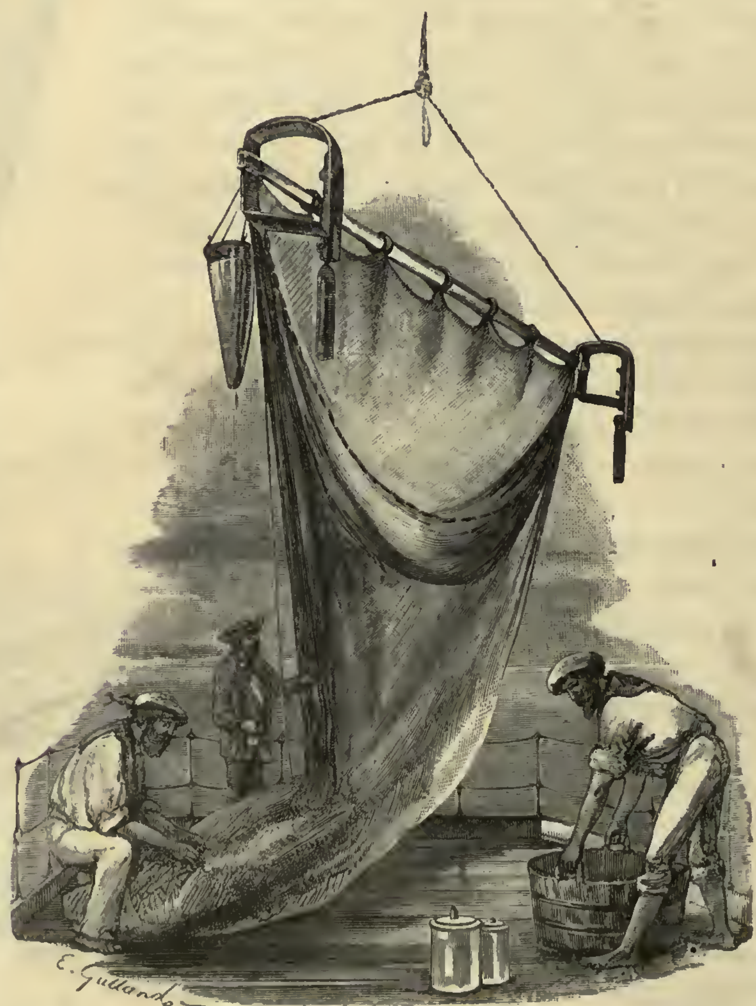
FIG. 68.—*Corynascidia suhmi*, Herdman. Seen from the right side, natural size.

"A little group of three species, for which the new genus *Ecteinascidia* has been founded, forms a connecting link between the previously known Clavelinidæ and the Ascidiidæ, and shows that the group of Social Ascidians, established in 1828 by Milne-Edwards, must now be merged in the Ascidiæ Simplices.

"The geographical distribution of the Simple Ascidians is very wide, but it appears from the Challenger investigations that they are not abundant in the northern hemisphere, and are comparatively scarce in tropical latitudes, while they attain their greatest numerical development in southern temperate regions. The bathymetrical range is also wide, extending from the littoral zone down to 2900 fathoms. Out of 82 species, 47 were found between the shore and 50 fathoms, and only 7 at depths over 2000 fathoms. The tables given in the

[1] Moseley, *Trans. Linn. Soc. Lond.* (Zool.), ser. 2, vol. i. p. 287, 1877.
[2] See Report on the Tunicata, Part I., Zool. Chall. Exp., part xvii. p. 283.

Report (see especially p. 273) show that although the Ascidiæ Simplices extend into very deep water, and are fairly well represented in the abyssal zone, still they are mainly a shallow water group, and are found in greatest abundance immediately around the coasts in a few fathoms of water."



CHAPTER V.

Bermuda to the Azores—The Ophiuroidea—The Azores—The Azores to Madeira—Madeira to the Cape Verde Islands—Saint Vincent and San Iago.

Bermuda to the Azores.

The second visit of the Challenger to Bermuda lasted from the 31st May till the 13th June, and during this time as well as during the visit in April, the Members of the Expedition were hospitably received by the Governor, Sir Henry Lefroy, the naval and military officers stationed on the island, and the inhabitants; every one being interested in the objects of the Expedition, and anxious to render assistance.

The ship left Bermuda for the Azores at 6 a.m. on the 13th June, obtaining the usual observations on the passage across, and maintaining as nearly as practicable the great circle route. On the 1st July at daylight the summit of Pico Island was seen, and at 9 a.m. Fayal. At 4.45 p.m. the ship anchored in Horta Bay.

On this section sixteen soundings, twelve serial temperature soundings, two dredgings, and seven trawlings were obtained (see Sheet 6).

The wind during the passage was from the southward nearly the whole time, with moderately smooth water, and on no occasion did it exceed a force of 7. The weather was on the whole fine, with occasional passing showers; but the atmosphere was very damp and oppressive, the mean daily relative humidity being seldom under 95.

No accident occurred either in taking soundings or temperatures, nor was any dredging rope lost, but the trawl came up fouled twice. On the 16th June, at Station 60, the trawl had evidently not reached the bottom, as it had no mud in the cod or on the leaden weights attached to the trawl irons; and on the 27th, at Station 71, the trawl-net and 25 fathoms of rope were twisted round the beam when it arrived at the surface.

The soundings in this section show that all indications of the existence of the Bermuda peak cease in a northeasterly direction at a distance of 90 miles from its summit; that the Azores stand on a bank which rises gradually, though not uniformly, from the bed of the ocean, at a distance of 500 miles from Fayal; and that between the bases of the Bermuda and Azores elevations the bottom is fairly level, the mean depth being 2700 fathoms (see Diagram 3).

The temperature of the water at the bottom was again remarkably uniform, when the depth exceeded 1800 fathoms, the mean result being 36°·3 and the extremes 36°·5 and 36°·2, or a range of merely 0°·3.

The mean temperature of the surface water was 74° at Bermuda, decreasing gradually to 69° at the Azores.

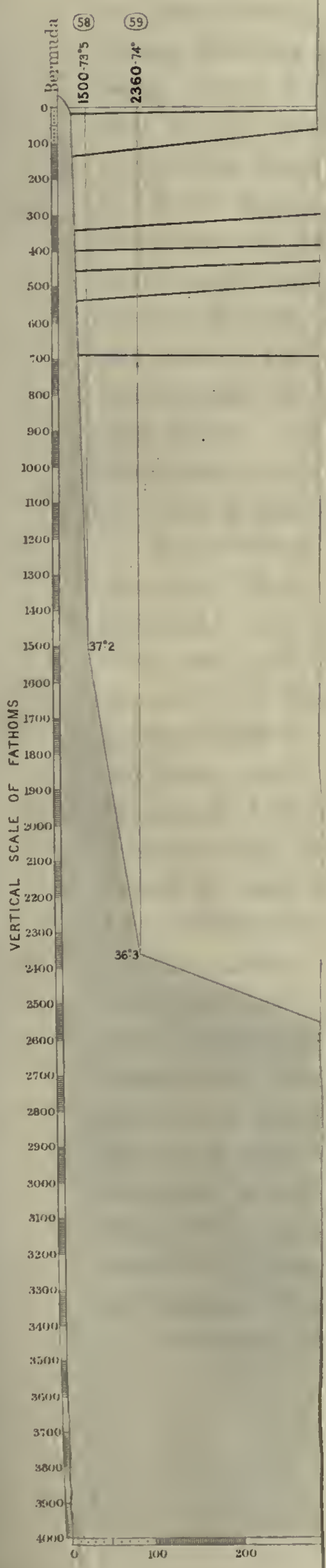
The serial temperature soundings showed that the isotherm of 40° was at a uniform depth of 700 fathoms for 600 miles from Bermuda, when it gradually descended to 900 fathoms at 900 miles from Bermuda, and again rose to 700 fathoms 1200 miles from Bermuda, remaining at or about that depth until within 300 miles of Fayal, after which it again descended to 900 fathoms, thus the mean depth occupied by the isotherm of 40° in this section was 750 fathoms, and the range 210 fathoms, viz., from 690 to 900 fathoms from the surface. The isotherm of 60° occupied an average depth of 300 fathoms for 1200 miles east of Bermuda, or to within 600 miles of Fayal, ranging 70 fathoms, or from 260 to 330 fathoms; it then rose gradually to a depth of 50 fathoms 300 miles west of Fayal, and continued at or near that depth for the remaining portion of the section. The temperature of the space enclosed between the isotherms of 40° and 60° calls for no special remark, as the alteration was gradual between those isotherms. The isotherm of 65° was at a depth of 100 fathoms at Bermuda where the surface temperature was 74°, and gradually rose to 20 fathoms at the Azores where the surface temperature was 69°; its position, therefore, may be assumed to depend immediately on the surface temperature (see Diagram 3).

On the 19th, at Station 63, the surface current was tried by attaching a buoy to the sounding line before heaving in, but no appreciable movement of the water could be detected. On the 26th, at Station 70, a buoy was anchored with a valve lead of 168 lbs., and here again no appreciable movement of the surface water could be detected. Subsequently the current drag was lowered successively to depths of 50, 100, 200, and 300 fathoms; no movement of the water was apparent at any of these depths. On the 27th, at Station 71, a buoy was again anchored by a weight at the bottom, and the surface current was found running to the southwards at a rate of 0·7 mile per hour. The current drag at 50 fathoms indicated a set S. 59° E. at the rate of 0·4 mile per hour, and at 100 fathoms N. 82° E. at the rate of 0·25 mile per hour. These results were obtained between 9 and 10 A.M. Subsequently, for convenience in obtaining temperatures and other purposes, a boat was anchored by the trawl, and it was noticed that at 6 P.M., when the ship took the trawl rope from the boat, that there was no perceptible surface current. This would seem to indicate that the result obtained between 9 and 10 A.M. was due to tidal movement. On the 28th, at Station 72, the surface current appeared to be going to the southward whilst sounding was in progress, but no direct observations were made.

On the 18th, at Station 62, the anemometer showed the velocity of the wind to be 18 miles per hour between 3 and 6 P.M., the force registered being 4 to 5. On the 22nd, at Station 66, the velocity was 20 miles per hour from 4.30 P.M. to 6.30 P.M., and the force was registered as 6.

With the exception of the deposit from 2700 fathoms on the 23rd, which contained 54 per cent. of carbonate of lime, all the deposits in this section from depths greater

IAGRAM 3



Bermuda
58
59
1500·73°5
2360·74°
37°2
36°3
VERTICAL SCALE OF FATHOMS
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900
3000
3100
3200
3300
3400
3500
3600
3700
3800
3900
4000
0
100
200

than 2400 fathoms contained less, and those from depths less than 2400 fathoms contained more, than 50 per cent. of carbonate of lime, the highest percentage being 88·30 in 1675 fathoms. In the greatest depths, 2850 and 2875 fathoms, there were only 8 and 10 per cent. In the greater depths the lime consisted chiefly of fragments of pelagic Foraminifera and Coccoliths; in depths less than 1600 fathoms, the shells of pelagic Molluscs and fragments of Echinoderms were more or less abundant, and along with pelagic and other Foraminifera made up the principal part of the carbonate of lime in the deposits. Radiolarians and Sponge spicules sometimes made up 3 or 4 per cent. of the deposit.

In the deep water, immediately to the south of the banks of Newfoundland, there were fragments of quartz, monoclinic and triclinic felspars, and fragments of mica-schist and other ancient continental rocks. These were believed to be ice-borne fragments, although apparently south of the southern limit of the ice region in the North Atlantic as shown on the charts. On approaching the Azores these fragments disappeared completely from the bottom, and the mineral fragments then consisted almost entirely of volcanic minerals and pumice. Except the pumice, the mineral particles seldom exceeded 0·25 mm. in diameter, and generally they were much smaller. A few fragments of tufa coated with peroxide of manganese were dredged.

Boats were several times lowered for the use of the Naturalists. On the 26th a small Hawksbill Turtle (*Eretmochelys imbricata*) covered with barnacles and small crabs, was captured; its stomach was filled with Vellelas. A large box was observed, a few days later, and on being hoisted on board, was found to contain decaying salt meat. It was covered with Barnacles (*Lepas anatifera*) and surrounded by fish, the attempts to capture which were unsuccessful. Very little Gulf Weed was met with during the passage but some pieces of *Fucus vesiculosus* were picked up, to which were attached several specimens of *Scyllæa pelagica*. *Nautilograpsus minutus* was observed resting on every floating thing; many were found on *Ianthina* shells, and it was curious to observe that several of them had a distinctly blue tinge in imitation of the colour of these shells. Dr. v. Willemoes Suhm writes in his journal:—"*Nautilograpsus minutus*, the small crab found in all the oceans clinging to gulf weed, logs, or animals larger than itself, was obtained to-day (21st) resting on *Ianthina*. Closer examination showed that it was covered with small brown spots, which proved to be little parasitic Nemertines. This is the first known example of a Nemertine living as a parasite. The worm, a small ordinary Tremacephalid, presents no modification induced by parasitism; it appears to be a new species, and from its colour may be called *Tetrastemma fuscum*. In accordance with the character of the genus, it has two large eyes, and two very small ones, one on each side of the proboscis. The ganglia are especially large and conspicuous, and send out two nervous branches running along the sides of the body. The proboscis is very short, and distinguished from all other species I know of by having the stylet-sac placed close behind the ganglia and just above the mouth, which, semicircular as usual, leads into a folded intestine terminated by an anus. Length 0·75 mm., breadth 0·25 mm."

On the 25th a very large colony of a new species of *Pyrosoma* was captured in the trawl; the cylinder was 4 feet 2 inches in length, and 10 inches in diameter, closed at one end, and, as in the smaller forms, the colony was spotted with red, the red spots being the visceral nuclei of the several animals. The specimen was kept in a tub of water till after dark, when it gave off brilliant phosphorescent light on being disturbed. The

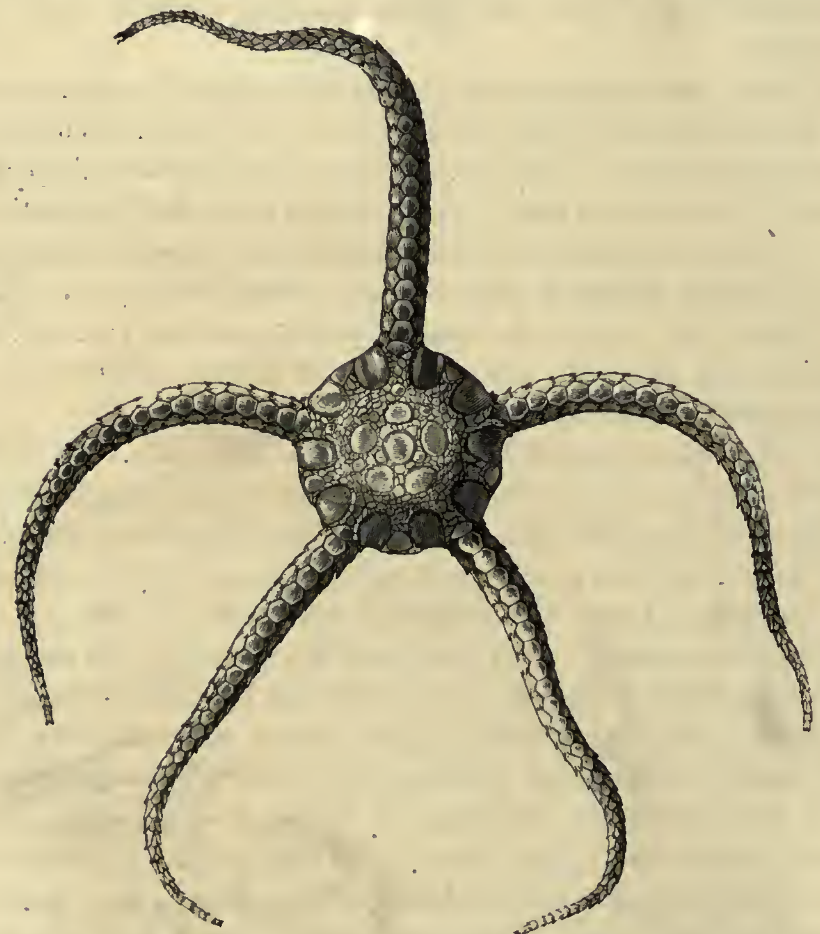


FIG. 69.—*Ophioglypha bullata*, Wyv. Thoms. Dorsal aspect; three times the natural size.

officers amused themselves by writing their names along this living cylinder with one finger, the track of which remained as a bright line of light for some seconds. *Salpæ* were the commonest animals in the surface waters; there were several kinds, and many long bands of them in the chain form were taken in the surface nets. Brilliant phosphorescence was observed at night during calm weather, and the following are some of the animals taken near the surface on these occasions:—Foraminifera, Radiolarians, *Gleba*, *Diphyes* and other Siphonophora, Medusæ, *Sagitta*, *Alciope*, Cypris-larvæ of

Cirripeds, *Hyperia, Phronima, Oxycephalus, Rhabdosoma, Mysis, Leucifer, Diacria, Styliola, Cleodora, Ianthina, Atlanta, Salpa.* Although pelagic Molluscs were very abundant in the surface water on that part of the section where the greatest depths were found, not a trace of their shells was found in the deposits at the bottom.

A Stormy Petrel was frequently seen following the ship, but no other sea birds were noticed till the Azores were neared.

The trawl brought up from 2850 fathoms several specimens of *Ophioglypha bullata*, two very small siliceous Sponges, two large reddish Holothurians, six specimens of *Scalpellum regium*, a few worm tubes, and a fragment of a crab. A trawl and a dredge

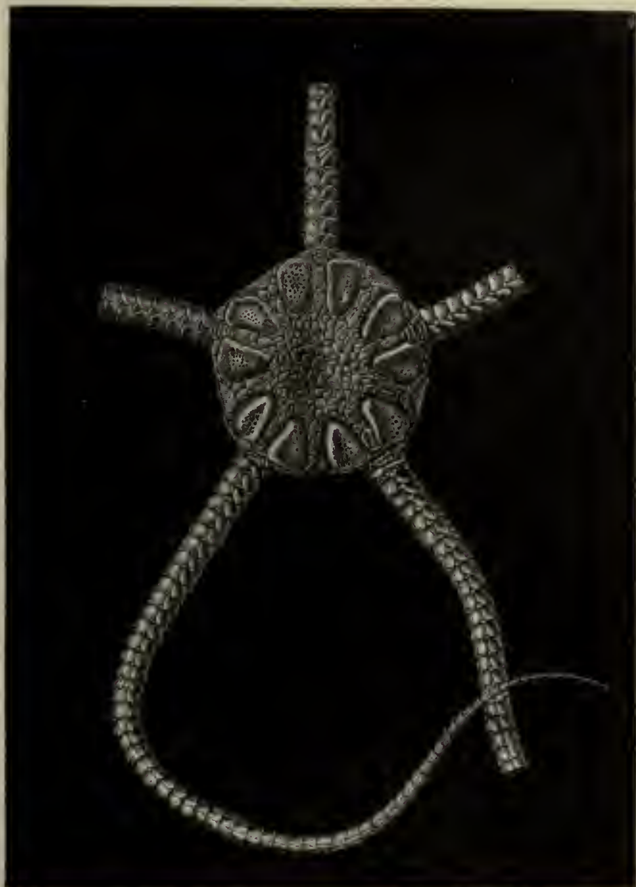


FIG. 70.—*Ophiomusium lymani*, Wyv. Thoms. Dorsal surface; natural size.

procured from 2750 fathoms, one specimen of a new genus of deep-sea fishes, *Bathyophis ferox*, Gün., and a new species, *Halosaurus rostratus*, Gün., three specimens of *Scalpellum regium*, three Annelids, one or two Annelid tubes, three Actiniaria belonging to two species, *Ophioglypha bullata*, small pieces of a Hydro-Medusoid stock on the *Scalpellum*, a Polyzoon (*Farciminaria delicatissima*, Busk), and a Priapulid. There were small Nematodes in the body wall of one of the Actiniaria. It is of course impossible to say from what depth the fishes came. In the shallower dredgings, from 2175 to 1000 fathoms, on the edge of the Azores plateau, a larger number of species and individuals were found than in the deeper water, nearly all groups being represented.

The Ophiuroidea.—The Challenger collection of Ophiurans has been carefully examined and described by Mr. Theodore Lyman, who furnishes the following résumé of his Report:[1]—" In no group, perhaps, was our knowledge more extended by the explorations of the Challenger than in that of the Ophiuroidea. The number of known living species was increased from 380 to about 550, or nearly by one half, while the corresponding increase of novel groups is indicated by the addition of twenty genera. By far the

FIG. 71.—*Ophiomusium pulchellum*, Wyv. Thoms. Oral aspect of the disk; seven times the natural size.

greater number of new species are of the deep-sea fauna; that is to say, they occur below the 100 fathom line, so that this Expedition has furnished the first opportunity of comparing the littoral and the deep faunæ over a wide extent of the oceans of the world. The result is that these Echinoderms are found to be animals which live very much in defiance of temperature, light, and water pressure. Something other than environment has determined their growth; or rather, their growth is not affected by an important part of their environment. To be sure there are some genera which are confined to the profound region of cold, darkness, and crushing weight; such are *Ophiotrochus*, *Ophioplinthus*, and *Ophiernus*; but there are others, for example *Amphiura* and *Ophiacantha*, which are

[1] Zool. Chall. Exp., part xiv., 1882.

found from the littoral zone down to the lowest points reached by the dredge. In the different zones these genera may present modifications; for instance, the *Amphiuræ*, below 1000 fathoms, often have more numerous mouth papillæ, and the corresponding *Ophioglyphæ* usually have swollen arm-plates and a microscopically tuberculous surface. Such structural features, however, plainly have no connection with the conditions of life, nor have they any relation to the survival of specially favoured forms. From a depth of over 1500 fathoms are found the strongly armoured *Ophiomusium pulchellum* (see fig. 71), the delicate *Amphilepis*, and the *Ophiomitra chelys* (see fig. 72), with its thorny spines and soft disk. At that great depth the peculiar conditions, apparently so unfavourable to a rich and varied growth, have not checked the development of widely differing forms.

"While, however, the Ophiuroidea yield little to the dictation of light, heat, or water pressure, they show well-marked laws of growth. Certain genera take the lead, like the larger clans of a barbarous nation. The collections of the Challenger, when combined with those of the "Blake," show that the four genera *Ophioglypha*, *Amphiura*, *Ophiacantha*, and *Ophiothrix* contain more than two-fifths of the known species. There is a tendency also to elaboration and variety in structure. The naked and embryonic genera, like *Ophiomyxa* and *Ophiogeron*, have few representatives; while the finely constructed *Ophioglypha* has many species, and even the highest group, composed of the closely allied *Ophiura*, *Pectinura*, and *Ophiopeza*, is pretty strong in numbers.

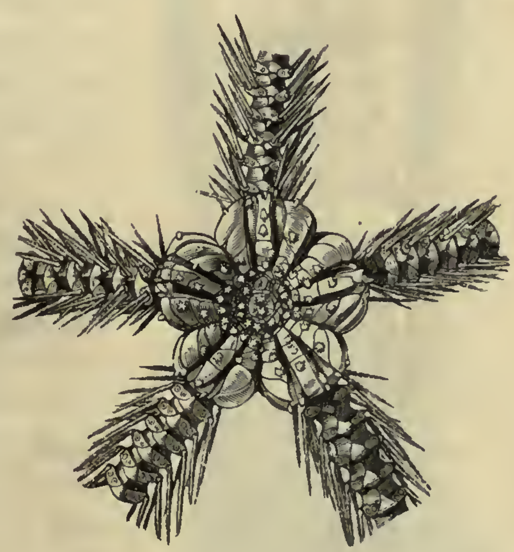


FIG. 72.—*Ophiomitra chelys* (Wyv. Thoms.). Dorsal aspect of the disk; four times the natural size.

"The dredgings of the Challenger have further taught us that we must not look exclusively in the abysses for surprising shapes, or for those that connect us closely with geological times. If the singular *Ophiotholia* (see fig. 73) must be sought in 1800 fathoms, its relative *Ophiohelus* may be found in less than 100 fathoms; and if *Ophiomastus* from the deep sea brings to mind the extinct *Aspidura*, *Pectinura* of the littoral zone recalls the so-called *Ophiura* of the Oolite. Nor must we forget that the extraordinary *Astrophiura*[1], apparently intermediate between the Brittle-stars and the Starfishes, lives in shallow water."

The "singular *Ophiotholia*," above referred to, was discovered by Mr. Murray in the

[1] Sladen, On the structure of Astrophiura, a new and aberrant genus of Echinodermata, *Ann. and Mag. Nat. Hist.*, ser. 5, vol. iv. pp. 401–415, 1879.

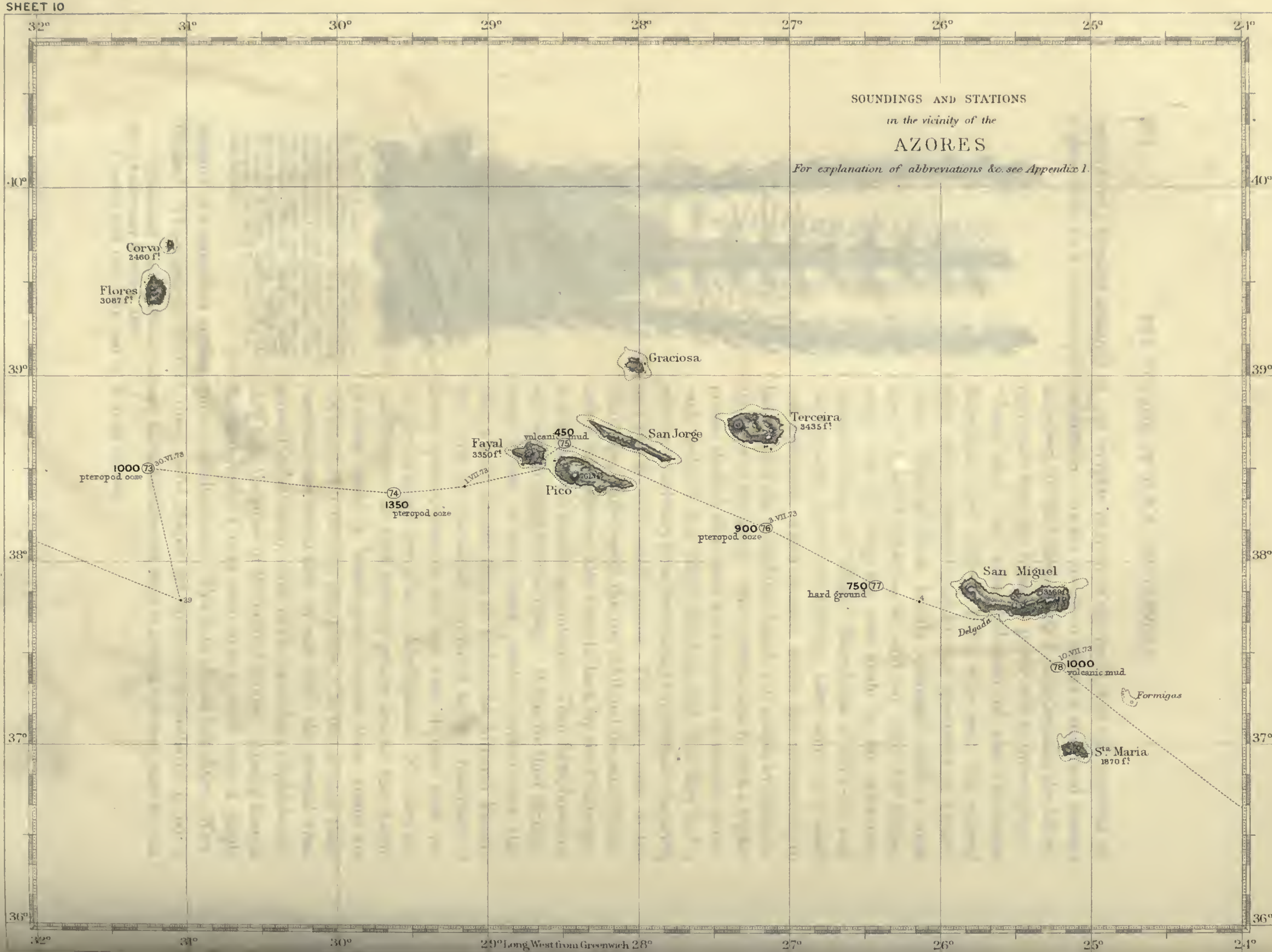
contents of a tow-net attached at the weights in front of the trawl, and was mounted on a glass slide as a microscopic preparation. As the specimen shows a structural feature unknown till that time among Echinodermata, the following details from Mr. Lyman's paper[1] will be interesting:—"Long after the main collection of the Challenger Expedition had arrived, there were sent me several glass slides containing additional specimens of Ophiuridæ. One of these, hastily examined with a weak lens, I labelled *Ophiomyces*, and set aside for further study. In the very last cast made by Mr. Alexander Agassiz, during the "Blake" Expedition of 1878–79, near the Barbados, and in 82 fathoms, there came up a small soft Ophiuran, which seemed, under the microscope, to have little tufts resembling bunches of simple hydroids on the sides of the arms. More careful search, with a higher power, showed that these were bunches of minute spines, each enclosed in a thick skin-bag, and that they had a most extraordinary form, resembling long-stemmed agarics, or parasols with small shades. On going back to the Challenger *Ophiomyces*, this too exhibited the same spines, and a third species, also brought back by the Challenger, was found with similar appendages. Their form, however, was not the most curious thing. It was by their arrangement in two, or even three, parallel vertical rows, that they wholly differed from all Ophiuridæ hitherto known. For, with all the variety exhibited by the hundreds of living species, there is not one that departs from the unvarying single row of articulated spines. Not even the double rows of hook-bearing grains among the Astrophytidæ would be homologous, because these grains are not attached to the side arm-plates. In one species, these parasol-spines stood side by side with the normal arm-spines (*Ophiotholia*), while in the two others (*Ophiohelus*), they took the place of the normal spines. Among known Echinodermata I have been able to find only a single instance of a somewhat similar spine, or pedicellaria. This is in *Aceste bellidifera*, Wyv. Thoms.[2] The question whether these novel shapes are spines or pedicellariæ is not a

FIG. 73.—*Ophiotholia supplicans*, Lym. The entire animal, ten times the natural size, seen in profile, with its arms and disk stretched upward, and its mouth angles turned downward and outward, and armed with their mouth papillæ like those of *Ophiomyces*. On the outer arm joints are the small parasol spines. Station 296, November 9, 1875, southwest of Juan Fernandez, lat. 38° 6′ S., long. 88° 2′ W.; 1825 fathoms.

[1] A Structural Feature, hitherto unknown among Echinodermata, found in Deep-sea Ophiurans, *Boston Soc. Nat. Hist.* (Anniversary Memoirs), 1880.

[2] Agassiz, Zool. Chall. Exp., part ix., pl. xl. fig. 66, 1881.

SHEET 10


SOUNDINGS AND STATIONS
in the vicinity of the
AZORES
For explanation of abbreviations &c. see Appendix I.
Corvo
2460 f!
Flores
3087 f!
Graciosa
Terceira
3435 f!
San Jorge
Fayal
3350 f!
Pico
450
volcanic mud
75
1000
73
30.VI.73
pteropod ooze
74
1350
pteropod ooze
1.VII.73
900
76
3.VII.73
pteropod ooze
750
77
hard ground
San Miguel
Delgada
1000
78
10.VII.73
volcanic mud
Formigas
Sta Maria
1870 f!
29° Long. West from Greenwich 28°

very important one, since a pedicellaria is only a spine peculiarly modified. But it may be said that their supplementary character and abnormal shape give these parasol spines the position of what used to be carefully distinguished as pedicellariæ.

"*Ophiotholia* is indeed an *Ophiomyces* with this peculiar character, while *Ophiohelus* is an allied but distinct form. Both may be considered low genera, with elaborate appendages. The want of radial shields and imperfect calcification suggest their position, which is confirmed by the embryonic character of their arm-bones, which are longitudinally divided into the two halves they theoretically should have. These bones are so large and independent, even close to the tip of the arm, that it is not easy to understand how they can be spurs of the small side arm-plates, as they should be according to one theory. Unfortunately I could nowhere find a terminal joint, which would have shown how the arm-bones take their rise.

"These soft little creatures illustrate how small an influence certain kinds of the notorious 'environment' have in determining structure. Of the two species of this abnormal *Ophiohelus*, one comes from 82 fathoms, near the Barbados, and the other from 1350 fathoms, near the Fiji Islands. When we consider the differences of locality, light, pressure, and temperature (differences which are supposed to create varieties, or species so called), between these two Stations, we may well be a little sceptical as to the potency of such environment.

"These genera stand quite apart from others of the family, and call for diligent renewal of the endless search after those constantly increasing missing links."

The Azores.

The ship only remained at the anchorage in Horta Bay, Fayal, from 4.45 P.M. on the 1st July till 11 A.M. on the 2nd, as, in consequence of small-pox being prevalent in the port, it was deemed advisable not to prolong the visit.

The Naturalists made short visits to the shore in the evening of the 1st and morning of the 2nd July. Horta is beautifully situated in a nook surrounded by volcanic hills, some of which are wooded to the top; one crater close to the shore is very conspicuous, and is cut into by the waves. The town is thoroughly Portuguese, and is built along the shore of a wide bay.

The afternoon of the 2nd July was spent in dredging in 50, 90, and 450 fathoms, in the straits between Pico and Fayal; a large number of animals were procured, very many of which have turned out to be new species (see Sheet 10).

The deposit was a volcanic mud, containing pumice, fragments of volcanic rock, plagioclase, sanidine, augite, magnetite, hornblende, biotite, and pelagic and other Foraminifera, Pteropods and other Molluscs, Coccoliths, Polyzoa, *Serpula*-tubes, and a few

Radiolarians and siliceous Sponge spicules. In some instances the pumice stones were completely coated with *Serpula, Polytrema,* and calcareous Algæ.

The ship passed between Pico and San Jorge, and on the 3rd obtained a dredging in 900 fathoms between Pico and San Miguel. The bottom was a Pteropod ooze, containing 52 per cent. of carbonate of lime, which consisted of Pteropods, Heteropods, Foraminifera, Coccoliths, Rhabdoliths, and fragments of Molluscs and Echinoderms. The mineral particles were all of volcanic origin. The dredge contained a few Echinoderms, Annelids, Polyzoa, Hydrozoa, and Crustaceans.

It was noticed, during the time the ship was kept stationary, that the surface water ran to the westward in the forenoon and to the eastward in the afternoon. Now, on the 3rd it was high water at Fayal at 5.30 P.M., and consequently low water at 11.30 A.M., from which it would appear that the flood tide sets to the eastward and the ebb to the westward in the vicinity of the Azores.

On the 4th, at 6.40 P.M., the Challenger arrived at Ponta Delgada, the chief town of the island of San Miguel, and, there being no epidemic, remained there five days.

During the stay at San Miguel excursions were made to many parts of the island, but more especially to the Caldeira des Sette Cidades, or Cauldron of the Seven Cities, situated at the western, and the picturesque valley of the Furnas at the eastern, end of the island. The former is a marvellous hollow of enormous size, with two lakes at its bottom and a number of villages in it. One slowly climbs the mountains from the sea and suddenly looks down from the edge upon the lakes, 1500 feet below. On the flat bottom of the main crater, which is covered with verdure and cultivated fields, are several small secondary cones, the whole reminding one of the representation of a lunar volcano. One of the small craters has been so cut up by deep water-courses, that between them only a series of sharp radiating ridges is left standing, and it thus presents a very fantastic appearance.

The Furnas valley is a similar deep, nearly circular crater, in which there is a large lake, numerous boiling springs, and the Furnas village,—the fashionable watering place of San Miguel. Sir Wyville Thomson writes:—"The principal boiling springs are about half a mile from the village. Round them, over an area of perhaps a quarter of a mile square, there are scorched-looking heaps like those which one sees about an iron-work, only whitish usually, and often yellow from an incrustation of sulphur. Over the ground, among one's feet, little pools of water collect everywhere, and these are all boiling briskly. This boiling is due, however, chiefly to the escape of carbonic acid, and of vapour formed below, for the temperature, even of the hottest springs, does not seem to rise above 90° C. The largest of the springs is a well about twelve feet in diameter, enclosed within a circular wall. The water hisses up in a wide column nearly at the boiling point, bubbling in the centre to a height of a couple of feet, and sending up columns of steam with a slight sulphurous smell. A little further on there is a smaller spring in even more violent ebullition, tossing up a column five or six feet high; and beyond this a vent opening into a kind of cavern, not inaptly called 'Bocco do Inferno,' which sends out water, loaded with grey mud, with a loud rumbling noise. The mud comes splashing out for a time almost uniformly, and with little commotion, and then, as if it had been gathering force, a jet is driven out with a kind of explosion to a distance of several yards. This spring, like all the others, is surrounded by mounds of siliceous sinter, and of lime and alumina and sulphur efflorescence. The mud is deposited from the water on the surface of the rock around in a smooth paste, which has a high character as a cure for all skin complaints. At first I could not account for the grooves running in stripes all over the face of the rocks; but I afterwards found that they were the marks of fingers collecting the mud, and I was told that such marks were more numerous on Sunday, when the country people came into the village to mass, than on any other day.

"At a short distance from the 'Caldeiros' a spring gushes out from a crack in the rock of a cool chalybeate water, charged with carbonic acid, and with a slight dash of sulphuretted hydrogen. There is a hot spring close beside it. The flavour of the aërated water is rather peculiar at first, but in the hot steamy sulphurous air one soon comes to like its coolness and freshness, and it seems to taste all the better from the green cup, extemporised out of the beautiful leaf of the *Caladium*. The warm water from all the springs finds its way by various channels to join the river Quente, which escapes out of the 'Valley of the Caves,' at its northeastern end, and, brawling down through a pretty wooded gorge, joins the sea on the north coast about six miles from Villa Franca."

FIG. 74.—*Araucaria cookii*, in the garden of Don José do Canto, San Miguel. (*From a Photograph.*)

San Miguel is well cultivated. The orange groves (see fig. 77) are surrounded by high walls or close set hedges, to protect the trees from the strong winds which prevail all the winter. The fields of maize and corn are shielded from the wind by tall hedges of Reeds (*Arundo donax*), and the appearance of the cornfields is peculiar, because a kind of

Lupine is planted in geometrical patterns amongst the corn, to be ploughed in as manure after the crop is reaped.

There are many fine flower gardens containing a large variety of Australian, New Zealand, and South American plants. On the road to Furnas numerous hills, small volcanic cones, were passed, planted with firs and various timber trees with great care. The appearance of the island has been remarkably modified by careful plantation, most of the work having been done by Mr. Brown, a gardener from Kew, who was brought to the island by Don José do Canto to superintend the laying out of his garden. Most

Fig. 75.—*Cryptomeria japonica*, in the garden of Don José do Canto, San Miguel. (*From a Photograph.*)

Fig. 76.—*Araucaria excelsa*, in the garden of Don José do Canto, San Miguel. (*From a Photograph.*)

curious is the markedly Australian feature which the general aspect of the vegetation has assumed in many places. Clumps of blue Gum Trees (*Eucalyptus*) abound, and the gardens by the roadside are full of Banksias and Melaleucas; but when once the higher plateaus of the island are reached, the foreign element disappears, and the moorland is covered with Bog Myrtle (*Myrica faya*), Heath (*Erica azorica*), and the splendid Fern *Dicksonia culcita*, which almost forms a tree. The beautiful golden brown silky substance covering its shoots is gathered, as elsewhere from tree ferns, for stuffing cushions. The moor looks very much like a Scotch moor, and stretches far and wide over the flat hill tops. In the narrow glens of the Furnas valley, in the warm streams of mineral water flowing from the hot springs, the edible Arum (*Caladium esculentum*), the staple food ("taro") of the Polynesians, thrives exceedingly well, and is cultivated all over the Azores. In the excessively hot water of the hot springs, close to their points of issue, bright green lowly organised Algæ (*Botryococcus*) grow, and in places form a thick crust upon the rock surface on the sides of the fissures from which the hot water escapes. Similar growths of lowly organised plants, thus growing in the water of hot springs, have been observed in various parts of the world.[1]

FIG. 77.—Orange Groves near Ponta Delgada. (*From a Photograph.*)

A fine breakwater was in course of construction at Ponta Delgada, which, when completed, would form a well-sheltered port—a great desideratum, as the southwest gales send in a very heavy sea. This breakwater was partially washed away in 1867, during a violent storm, in consequence of its outer slope not having a sufficient angle; this defect, however, was remedied, and it was believed no other accident would occur. Some idea of the violence of the sea in the Atlantic may be gathered from the fact that the swell, dashing against the breakwater, has been known to wash up a block of stone, 6½ tons in weight, from the water's edge to the top of the breakwater, a distance of over 30 feet.

The Azores to Madeira.

The ship left San Miguel on the 9th July for Madeira, and anchored in Funchal Bay on the 16th at 7 A.M., fine weather being experienced on the passage.

[1] For further account of the vegetable growths in the hot springs of Furnas, see H. N. Moseley, *Journ. Linn. Soc. Lond.* (Botany), vol. xiv. p. 321, 1875. Also papers on the same subject by Mr. W. T. Thiselton Dyer and Mr. W Archer, *Ibid.*, pp. 326, 328.

Six soundings, three dredgings, and four serial temperature soundings were obtained during the passage (see Sheet 6).

No accident occurred whilst the observations were being obtained, except that on the 11th July the thermometer sent to the bottom came up with the quicksilver separated, so that the result, which was considerably lower than usual, was rejected.

A sounding of 1000 fathoms was obtained midway between San Miguel and Santa Maria, another of the Azores. Between the Azores and Madeira there is a gradual descent to 2700 fathoms, and then as gradual a rise to Madeira, so that the summit of that island really stands 22,000 feet above the valley which separates it from the plateau of the Azores.

The mean temperature of the bottom water, at depths exceeding 1800 fathoms, was 36°·7, ranging from 36°·6 to 37°. It will be noticed that this bottom temperature is 0°·4 higher than the mean result obtained between Bermuda and the Azores, and that the lowest temperature obtained was higher than the highest registered between those two places. This is precisely the same result as that obtained on the east side of the Dolphin Ridge in the Tenerife–Sombrero section, whilst the mean temperature at the bottom in the Bermuda–Azores section, viz., 36°·3, is 0°·3 higher than that obtained west of the Dolphin Ridge in the Tenerife–Sombrero section.

The serial temperatures showed that the isotherm of 40° was at a uniform depth of 980 fathoms throughout the section, and that the isotherm of 50° was at a mean depth of 420 fathoms, a little deeper at Madeira, but the isotherm of 45°, which was at a depth of 580 fathoms at Fayal, descended to 800 fathoms at Madeira. The isotherm of 55° was at a mean depth of 150 fathoms (see Diagram 3).

On the 14th July, at Station 82, the current buoy moored by the lead line indicated a southerly movement of the surface water at an average rate of a quarter of a mile per hour.

The deposits in this section were remarkable for the large quantity of pumice which they contained; no fragments of quartz or continental rocks could be detected. At 1000 fathoms, between San Miguel and Santa Maria, the deposit was chiefly made up of pumice and volcanic minerals. Pteropod shells were present in the shallower deposits, but quite absent in depths greater than 2400 fathoms. The relatively high percentage of carbonate of lime at 2660 and 2675 fathoms, viz., 62 and 66 per cent., is worthy of note; the carbonate of lime here consisted almost wholly of the broken shells of pelagic Foraminifera. The fragments of siliceous organisms did not exceed 1 per cent. in any of the deposits.

The dredging in 1000 fathoms was very productive, yielding many new species, over twenty being described in the Reports already published. In 2025 fathoms two specimens of *Archaster*, and in 1650 fathoms two more specimens belonging to the same genus, and a species of *Antipathes*, were dredged.

MADEIRA TO SAINT VINCENT, CAPE VERDE ISLANDS.

The intention of remaining a few days at Madeira was abandoned, in consequence of the prevalence of small-pox in Funchal: the ship consequently left the island for the Cape Verde Islands at 8 P.M. on the 17th July. A steamer which arrived at Funchal from the west coast of Africa at this time, was visited by Mr. Moseley and Dr. v. Suhm, who found a large number of monkeys, birds, and other animals on board, and purchased two of the common Grey Parrots (*Psittacus erithacus*), one of which accompanied the Challenger throughout the rest of the cruise, and became a great pet in the wardroom. It is still living, and is in the possession of the relatives of the late Dr. R. v. Willemoes Suhm.

The soundings in Funchal roads being rather sparse on the chart, boats were employed during the 16th and 17th in completing the survey of the anchorage.

The trade wind prevailed during the whole passage from Madeira to St. Vincent, and in the vicinity of the former island, and between it and the Canary group, was very strong; so much so, that in standing in under the lee of Palma Island on the 19th, to dredge off its shores, it was necessary to take two reefs in the topsails. To leeward of the islands this strong trade wind is not felt, and in Funchal Bay, Madeira, where, from the curling sea, it is evident that it exists outside, the weather is either quite calm or such light variable breezes prevail that it may be said to be calm; nor, apparently, does this strong trade wind extend to any great height, as at Madeira there was no appearance of wind on the hills. The force of the trade wind gradually decreased as the Cape Verde Islands were approached.

The weather experienced on the passage was fine, but generally misty; and farther southward these mists thickened into fogs. However, the morning after leaving Madeira was remarkably clear, that island being distinctly seen at sunrise, though then distant 70 miles.

The course pursued on this passage was varied in order to run under the lee of Palma Island to dredge and sound at Station 85 on the 19th July, and again to obtain another dredging on the submarine peak, which was discovered southeast of the Canary group on the passage to Sombrero.

On the 23rd and 24th July the sea had a greenish tinge, quite unlike its usual deep blue colour. Green coloured patches of water were also observed off the African coast during the return voyage of the Challenger in 1876. They have been referred to by other voyagers, and are well-worthy of further investigation.

On the Madeira–St. Vincent section nine soundings, seven serial temperature soundings, and three dredgings and one trawling were obtained; the bed of the ocean was somewhat irregular, the greatest depth obtained being 2400 fathoms (see Sheet 6 and Diagram 7).

The surface temperature, which was 70° at Madeira, rose gradually to 75° at St. Vincent.

The bottom temperature at depths exceeding 1800 fathoms was again remarkably uniform, varying only 0°·2, the mean being 36°·5 and the extremes 36°·4 and 36°·6.

The serial temperatures of this section showed some peculiarities, which, from previous experience, had not been expected. Up to this time the isothermal lines had run fairly parallel with the surface, no matter whether proceeding in an east and west, or north and south direction, unless some disturbing cause, such as the Labrador Current, interfered to prevent their doing so; but, in this section, the lower isotherms all rose towards the south. Thus, the isotherm of 40° maintained an average depth of 950 fathoms for 450 miles from Madeira, and then rose gradually, though somewhat irregularly, to 800 fathoms at St. Vincent. The isotherm of 45° rose irregularly from a depth of 700 fathoms at Madeira to 380 fathoms at St. Vincent; and the isotherm of 50° rose from 420 fathoms at Madeira to 200 fathoms at St. Vincent. The isotherms above 50° were nearly parallel with the surface.

No regular current observations were taken on the passage to St. Vincent, but it was noticed, whilst dredging under the lee of Palma Island, that the surface water was running to the northward, at an estimated rate of one mile per hour, and on the 26th July, at Station 92, it again had a northerly tendency.

On the 18th July, at Station 84, the velocity of the wind was 22 miles per hour by the anemometer, its force being registered as from 5 to 6.

At 11 P.M. on the 26th July the island of San Antonio was sighted, and the ship stood off for the night. On the 27th, as soon as the fog cleared off the land, a line of soundings was carried into the channel between the islands of St. Vincent and San Antonio (see Sheet 11), and the ship anchored in Porto Grande at 4.30 P.M.

The deposit to the west of the island of Palma in 1125 fathoms was a brown volcanic mud, containing about 6 per cent. of carbonate of lime. The size of the mineral particles rarely exceeded 0·25 mm. When the mud was passed through sieves the washings which remained were almost wholly made up of dead shells of Pteropods and Heteropods. In the dredge there were a few animals and several large fragments of a dead Gorgonoid Coral (*Corallium*), coated with manganese peroxide, similar to that obtained in 1525 fathoms about 200 miles further south on the Tenerife–Sombrero section (see page 125). The next sounding was in 2300 fathoms, a little to the west of the position where the depth of 1525 fathoms just referred to was observed in February. Here the deposit was a Globigerina ooze, containing 57 per cent. of carbonate of lime. Later on the same day, 21st July, a sounding and dredging were obtained in 1675 fathoms, on the same hard ground with dead coral, and in nearly the same position as in February, when the dredge brought up more of the black coral, fragments of a Polyzoon (*Nellia simplex*), one specimen of *Ophiomusium pulchellum*, one of *Ophiomitra carduus*, and two Peneid Shrimps. In 2300 and 2400 fathoms farther south a Globigerina ooze with 64 and 58 per cent. of carbonate of lime was obtained, containing no Pteropod or Heteropod shells. The mineral particles were


SOUNDINGS AND STATIONS
in the vicinity of the
CAPE VERDE ISLANDS
For explanation of abbreviations &c. see Appendix 1.
ST. ANTONIO
Tarrafal Bay
7400
ST. VINCENT
Porto Grande
St. Lucia
1209 ft.
Branca
976 ft.
Raza
316 ft.
(93) 1070 volcanic mud
(93a) 1000 volcanic mud
(93b) 465 volcanic mud
(93c) 52 coralline mud
103 (93d) coralline mud
85 (93e) coralline mud
260 (93f) volcanic mud
(93g) 675 volcanic mud
(94) 1150 volcanic mud
25° Long. West from Greenwich
17°
Engraved by Malby & Sons

chiefly volcanic, with a mean diameter of 0·07 mm., but here also small rounded grains of quartz were found for the first time since leaving the coasts of America. These appear to be wind-borne fragments, carried from Africa by the Harmattan winds (see p. 126). A trawling in 2400 fathoms gave a fragment of a Pennatulid, a red Holothurian with *Stylifer* in the cloaca, two Starfish, one belonging to a new genus (*Thoracaster cylindratus*, Sladen), several Polyzoa (*Bugula mirabilis*, *Farciminaria delicatissima*), *Scalpellum velutinum*, and a Lophioid fish (*Ceratias holbölli*), the last with a parasitic Copepod (*Lernæa abyssicola*) attached to it. Soundings in 2075 and 1975 fathoms gave a Globigerina ooze with 60 and 75 per cent. of carbonate of lime. About 2 per cent. of these deposits was made up of Radiolarians and fragments of other siliceous organisms, the remainder being composed of volcanic minerals, a few grains of quartz, and clayey matter.

Cape Verde Islands.

Saint Vincent.—The island of St. Vincent is about twelve miles long by six broad, and has an irregularly oval form, consisting of a flat central tract more or less broken by low hills, surrounded by a range of high land. The low central district is evidently the bottom of an ancient crater, of the wall of which the high surrounding range is the remains. The range is composed of strata dipping outwards from the ancient centre of eruption, and is cut up by a series of deep valleys, having a general radiate arrangement, into ridges of various heights, some of them of considerable altitude, which are again cut up by secondary transverse valleys so as to culminate in a series of irregular peaks. The Green Mountain is 2483 feet in height, and one other mountain, to the extreme south of the island, 2218 feet. A break in the encircling range to the northwest forms the harbour of Porto Grande, in the entrance to which lies a small island, called Bird Rock, a fragment of the range, once continuous in that direction.

More barren and desolate-looking spots than San Antonio and St. Vincent appear, as approached from seawards, after they have been suffering from their usual prolonged droughts, it is impossible to conceive. Their general aspect recalls Aden or some of the volcanic islands in the Red Sea. At the time of the Expedition's visit, no rain had fallen for a year at St. Vincent; sometimes it does not rain for three years.

The mountains are of black volcanic rock terminating seawards in precipices, in which the numerous dikes traversing them in all directions, stand out conspicuously owing to the weathering of the surrounding rock. Between the mountain ranges stretches a flat sandy plain, covered with sand dunes and with ranges of low rounded hills of a bright red ochre tint. The white plain terminates at the head of the harbour in a shore, where there is a miserable town. The whole glares in a fierce sun, and appears almost devoid of vegetation; but from the anchorage some black tufts can be made out with a telescope, which consist of small bushes of Lavender (*Lavandula rotundifolia*), the most abundant plant in the island, and on the summits of the higher hills a few *Euphorbia* bushes (*Euphorbia tuckeyana*) can be made out in the same way. On the sandy plain at one spot a thick growth of low Tamarisk bushes stretches from the shore inland, and amongst these, about half a mile from the shore, there is a group of half a dozen small Tamarind trees (*Tamarindus indica*). Some thorny Acacias (*Acacia albida*), and *Terminalia catappa*, which stand in an old enclosure in front of the ruins of a house, and are green and flourishing, show that much might be done by cultivation, even in St. Vincent. The plains were found to be covered all over with the spiny fruit of a small creeping plant (*Tribulus cistoides*). Almost the only plants retaining any living and green leaves were the lavenders, on the bushes of which were to be found here and there a green sprout, put forth apparently in anticipation of the wet season.

On June 30th a small party made an excursion up Green Mountain. The road led over the bottom of the old crater, and then up the steeper end of the mountain by a zigzag path, in places built up in steps and in others hewn out of the rock. The soft friable soil of the plain was in many places already converted into tenacious mud by the rain, which was then falling, one of the rarest events of the year. As the hillslopes were ascended from the plains, the plants became greener and more abundant. In a narrow gorge at the commencement of the ascent of the mountain, some small gardens were passed, at an elevation of about 200 feet above the sea level. They contained sugar cane, pumpkins, and a small date palm; and maize was just being planted in them. There were a few cotton bushes growing near. At 700 feet, Euphorbias and woody Composites commenced, and the hillside was covered with coarse dry grass. At 1000 feet, small Boraginaceous bushes with pink flowers (*Echium stenosiphon*) commenced, and at 1300 feet the first patches of moss and *Marchantia* were found, with a fern and a live snail. At 1700 feet a *Statice* (*Statice jovibarba*) was abundant on the cliff. The lavender grew right up to the top of the mountain, but there it was entirely fresh and green instead of black and withered as below. A leafless trailing Asclepiad (*Sarcostemma daltoni*) commenced at 900 feet. All the plants on Green Mountain appeared to extend their range of growth to the summit. On the summit there were several cottages, and the land was all more or less under cultivation; maize, potatoes, tomatos, and pumpkins were growing there.

On Bird Island, the rocks about tide mark are covered with a broad band of a dense incrustation composed of Corallinaceæ, which forms a striking feature in the appearance of the island as seen from the sea, and is more marked here than on the main island. The Corallinaceæ are seaweeds which secrete a dense skeleton of carbonate of lime. The incrustation on Bird Island is of several colours, white, bright pink, or cream colour, and is mainly composed of two species of calcareous Algæ (*Lithothamnion polymorphum* and *Lithothamnion mamillare*). This incrustation assumes very varied forms, being quite thin, and following the form of the rock surface on which it rests, or forming smooth rounded convex masses, or being covered with a closely set series of projections, sometimes of considerable length, and with a sinuous arrangement. On the whole, plant-life seems to play a much more important rôle than corals in accumulating carbonate of lime around the Cape Verde Islands; but the larger Foraminifera are of far greater importance than either in some places, the calcareous sand of the harbour of St. Vincent being mainly composed of them.

Notwithstanding the desolate nature of the island, St. Vincent is rising into importance, for it possesses the only safe and convenient anchorage in the Cape Verde group, or, in fact, anywhere between that group and the south coast of Spain; its situation also renders it a most suitable halting place for the mail steamers running between England and the ports in South America, or the Cape of Good Hope. Spacious coal stores have been constructed on shore, and piers have been run out into the bay to admit of loading boats rapidly. The coal, kept in bags, is conveyed to the ships in barges, and labourers can be hired from the shore to assist in passing the bags on board, so that vessels requiring to replenish their fuel here can do so without difficulty or delay. A submarine cable connects St. Vincent with Madeira and Pernambuco.

The town is well laid out, and there are a few respectable buildings in it, especially the custom house and the residence of the governor, but the great want of the place is water, which can only be obtained in small quantities from a few wells at the back of the settlement. The supply of provisions is extremely bad; no vegetables of any kind could be procured during the stay, nor, in fact, supplies of any kind, except coal and bread; the beef was so bad that the ship's company refused to eat it.

A quarantine establishment of some description is much required, as at present passengers from the fever-stricken ports of South America have to remain in an open boat in the bay until the health officer is satisfied that they are free from disease.

The climate, although warm, is, owing to its freedom from moisture, not unpleasant; the mean yearly temperature is about 74°, the mean temperature of the coldest month (February) being about 69°, and of the warmest (September) 79°. The trade wind is seldom interrupted, and frequently blows with considerable violence through the channel between the islands of St. Vincent and San Antonio.

The survey of the anchorage was not completed without some little difficulty. The trade wind was occasionally so strong, reaching on one occasion a force of 8, that the boats could not work, nor could a theodolite be set up on shore, except in a sheltered position; in fact, the squalls from the hills raised a mass of spoondrift over the whole of the bay and clouds of sand in the plains. A landing was effected and a station established on Bird Island, though not on the summit, the crumbling nature of the rock of which that islet is composed rendering it unadvisable to plant an instrument on its peak. The magnetic observations taken on shore were unsatisfactory, since a position was not found which was free from local attraction.

Observations on the current in the channel between St. Vincent and San Antonio gave the following results:—The movement of the water was tidal, the N.E.-going stream running five hours, and the S.W.-going stream seven hours. The alteration in the direction of the stream did not coincide with the times of high and low water at St. Vincent, for the N.E.-going stream commenced three hours before high water, and the S.W.-going stream two hours after high water. The maximum speed of the surface stream was one mile per hour. The current drag at the bottom indicated an equality in the hours of the stream there, as it ran six hours in each direction, the times of change being at half flood or ebb; it would, therefore, appear that the stream at the surface is affected by the trade wind, the N.E.-going tide being retarded and the S.W.-going tide accelerated. The maximum speed of the stream at the bottom was three-quarters of a mile per hour.

In the harbour of St. Vincent the deposit in depths from 7 to 50 fathoms was a calcareous sand, with 87 to 94 per cent. of carbonate of lime, chiefly made up of Foraminifera shells and calcareous Algæ. In some places the shells of *Amphistegina lessonii* made up fully two-thirds of the whole deposit. *Polystomella, Discorbina,* and *Orbiculina* were also abundant. The deposits around the islands from 200 fathoms down to a depth of 1150 fathoms were volcanic sands and muds, with from 13 to 50 per cent. of carbonate of lime, in which Pteropod and Heteropod shells were abundant.

Dr. v Willemoes Suhm writes as follows in his Journal:—"The following birds only were observed near the settlement:—the Egyptian Vulture (*Cathartes percnopterus*) and the common hooded crow, carrion crow and rook. The first of these, the sacred vulture of the east, appears to breed in December and January, for at the time of our visit (July) the young ones, recognisable by their brown plumage, were just beginning to moult. Among the tamarisk trees was a small *Platydactylus*, and also a lizard. A small black beetle was found under nearly every stone, and over a pool we observed two species of dragon-fly, whilst an *Acridium* was jumping and flying over many of the stony places. Where the tamarisk trees are high enough to afford shelter, insects are in greatest abundance. An Ant-lion (*Myrmeleon*) of which we obtained both the larva and imago, lies in wait for a small colonial species of ant. It somewhat resembles *Agrion*, but can be distinguished from it by its slow flight and its habit of folding its wings when sitting. Of Hymenoptera,[1] a large black Ichneumonid with yellow antennæ, and another wasp-like one may be mentioned. Diptera abound, especially the common meat-flies; an *Osmæa* was also noticed. Some fifteen or twenty species of Coleoptera were observed, which, with few exceptions (*Cicindela, Coccinella,* very common among the tamarisks), belong to the Melasomidæ, a family characteristic of the shores of the Mediterranean and the west coast of North and South America. There are some Silphidæ, more of which might perhaps be found beneath dead animals. Lepidoptera and Hemiptera seem to be scarce; one species only of the latter was found. A *Scolopendra*, possibly brought by ships, was not uncommon under stones; a *Geophilus* may also be noted. We observed no

[1] Among the Hymenoptera collected were two new species, *Priocnemis atlanticus*, Kirby, and *Polistes fortunatus*, Kirby, *Ann. and Mag. Nat. Hist.*, ser. 5, vol. xiii. pp. 408–410, 1884.

Scorpions, but the Araneidæ were comparatively abundant; one magnificent yellow species (of which both the female and the very small male were captured) extends its net among the tamarisk shrubs, where dwells also a small *Epeira*.[1]

"The poverty of animal life on the beach was disappointing, but one or two forms were of some interest. A small *Blennius* and a *Mugil* are common in the shore-pools, and are used by the boys as bait to catch the Sand-crabs (*Remipes*). These hide in the sand with nothing but their heads peeping out, but as soon as one of the little fish is thrown down they jump out to obtain it, and fall a prey to the juvenile sportsmen. The crab carries its ova with it, and in several I saw the large black eyes of an embryo which would probably develop into a zoea. Walking along the beach one observes holes of different sizes which are made by another interesting Crustacean (*Ocypoda ippeus*), which may now and then be seen running along like a piece of paper blown by a strong wind. We found it no light task to dig each separate crab out of its hole, but the fishermen, who use them for bait, obviate the difficulty by digging a large hole in the evening and placing a dead animal in it, and on returning in the morning they readily capture a large number of crabs. This species is also found in Egypt and Syria; its eyes are situated, not at the summit, but at one side of their pedicles, which are terminated by a tuft of brown hairs, these, however, are wanting in young specimens. Milne-Edwards had remarked a finely polished plate, fringed with hairs, between the fourth and fifth ambulatory legs, which he regarded as an arrangement for avoiding friction. Fritz Müller, however, who observed the animal in Brazil, has shown that it is a covering for the orifice of the branchial cavity, so that the crab can open or close it at will, and thus retain water or air; but notwithstanding this provision, it can live only a comparatively short time when deprived either of air or of water. The hairs which fringe the smooth plate are curious, and appear to belong to the so-called 'Riechhaare' (olfactory hairs) of Hensen.[2] A brown Sea-Urchin, and an *Aplysia*, with *Grapsus*, *Palæmon*, and *Pagurus* were also obtained. A fragment of amber was picked up on the beach in my presence, and Moseley found there a large Eunicid.

[1] The Rev. O. P. Cambridge gives the following notes on the Spiders from the Cape Verde Islands:—

"St. Iago.—*Argiope clarkii*, Bl. (also abundant from St. Vincent), *Artema convexa*, Bl., *Hersilia caudata*, Sav., *Marpessa nigrolimbata*, Cambr., and *Sparassus* sp.?, *Trochosa* sp.? (both young and probably indeterminable), *Cyrtophora opuntiæ*, Duf. St. Vincent.—Fourteen species of which I can as yet only certainly determine three; *Gnaphosa exornata*, C. L. Koch. *Argiope clarkii*, Bl., *Artema convexa*, Bl. Of the rest one is a very handsome, and, I think, new species of *Pasithea*, four are Drassidæ (*Drassus* and *Trachelas*), two Thomisidæ (*Misumena* and *Thanatus*), one *Epeira*, one Salticida (I think an *Icius* or *Marpessa*), and two *Tarantula*. There are also a *Dysdera* and several Drassids indeterminable from immaturity. There is no departure in the above collection from the South European type excepting in *Hersilia*, which connects them with the more tropical forms. *Hersilia* is found abundantly in Egypt and Bombay, where there are also other species of the same genus; a closely allied genus occurs in Algiers and Egypt. I should observe that *Marpessa nigrolimbata*, Cambr., is identified by Dr. T. Thorell, and probably rightly, with *Icius dissimilis*, C. L. Koch, and several other more recently described species (Studi sui Ragni Maltesi e Papuani, *Ann. Mus. Civ. di Genova*, tom. xvii. p. 461). It appears to be almost cosmopolitan, having been recorded from St. Helena, Java and Amboina, St. Thomas, W. I., Columbia, Brazil, Argentine Republic, and West Africa; I have received it also from the Isle of Wight."

[2] Facts for Darwin, p. 34.

"The dredge brought up a *Calappa*, which does not seem to differ much from the Mediterranean species, together with a *Galathea*, *Cancer*, *Squilla*, &c. A large *Cidaris* seems to cover the whole bottom, along with a fine red *Oreaster* and a small white Ophiurid.

"It may be of interest to anthropologists to learn that I visited a yellowish-black family, consisting of a healthy grandmother, and a mother and father, with several children, of whom two were interesting, as one, a girl twenty years of age, was an almost complete albino, and the other presented a case of hypospadias with cryptorchy, simulating hermaphroditism; he was seventeen years of age and ill-developed, being only about 4 feet high."

Two land shells (*Helix advena*, Webb and Berth., *Helix bollei*, Albers) were obtained.[1]

The rocks collected at St. Vincent belong to recent types, the basalts being especially prominent in them. These felspathic basalts present three types of structure,—(1) fine grained, (2) doleritic, (3) porphyritic. One rock obtained from a dike in the southwest of the island is an amphibolic andesite. Two specimens from Bird Island must be referred to the variety of basaltic rock known as pyroxenite, on account of the important part which augite plays in their formation.

A naval schoolmaster, who had come to St. Vincent to join the Challenger, was lost on one of the mountains just before the arrival of the ship, and died of exposure; his body was found only after the lapse of several months.

San Iago (*Santiago*).—On the 5th August, at 10 A.M., the ship left Porto Grande, and a course was shaped for Porto Praya, in the island of St. Iago, as it was desirable to obtain some fresh meat and vegetables for the ship's company, and also to investigate the nature of the bottom off that island, red coral being found there. In proceeding through the channel between the islands of St. Vincent and San Antonio, a line of soundings was carried to 1200 fathoms (see Sheet 11). Porto Praya was reached on the 7th August at 8 A.M., light winds and foggy weather having been experienced on the passage. The mean annual temperature at Porto Praya is 76°·1, the mean of the coldest month being 72°, and the warmest 80°.

Viewed from the sea, the island of St. Iago is almost as desolate looking as that of St. Vincent, but at an easy distance from the port there is a well-cultivated valley, in which are cocoanuts, abundance of vegetables, and a large variety of crops. Cocoanut trees also grow in small ravines on each side of the town, and artificially irrigated gardens are cultivated beneath their shade. Twelve miles N.E. of Porto Praya is the valley of San Domingo, where the scenery is green and delightful, and presents a striking contrast to the arid gravelly plains near the sea. Good beef and vegetables were procured at Porto Praya, and shooting parties brought back a few quails, pigeons, and guinea fowl. The seine was hauled in the evening with great success, notwithstanding the considerable swell breaking all along the beach. A small mole has been built to facilitate landing,

[1] E. A. Smith, *Proc. Zool. Soc. Lond.*, p. 276, 1884.

Plate II.

HORSBURGH, EDINBURGH. PERMANENT PHOTOTYPE.

BAOBAB TREE, SAN IAGO.

which is difficult at this season of the year, as the southwesterly monsoon sometimes reaches the island. The town is clean, and has a good supply of water, brought in by an aqueduct from the foot of the hills. Coal is stored on Quail Island, and can be procured if necessary, but it is not so cheap as at St. Vincent.

The country rises inland in a succession of terrace-like steps often remarkably flat at the top, and formed by successive flows of lava. The flat table-land nearest the sea was parched and had very little green upon it. Behind rises a succession of small conical hills and higher table-lands, which were brilliantly green.

There is a large Baobab tree (*Adansonia digitata*) near the town, which has been mentioned by travellers. Its stem is irregular in transverse section and short; it measured 42 feet in circumference at the time of the visit, when it was in full flower with no fruit as yet of any size. An excellent photograph of it was obtained (see Pl. II.).

Quails were not at all plentiful, being only migratory visitors to the island, and not having as yet arrived in numbers. The Kingfisher (*Halcyon erythrorhyncha*), mentioned by Darwin, is common; it is peculiar to the island, though very closely allied to an African species, and is a beautiful bird, brilliant blue and white with a red beak. Like many other kingfishers it is not aquatic in its habits, but feeds mainly on locusts and other small terrestrial animals; it has a terribly harsh laughing cry, a feeble imitation of that of its congener of Australia the Laughing Jackass. Birds of prey are very abundant in St. Iago; large falcons and hawks were very common, and eagles were seen in San Domingo valley. Ravens and crows were also very plentiful. It is difficult to understand on what so many predaceous birds can feed; possibly the falcons and hawks frequent the island in numbers only in the quail season. The Gecko, *Tarentola delalandii*, which had been found in Tenerife, was obtained here, as also a Skink (*Euprepes*).

An excursion was made by Mr. Moseley to the San Domingo valley, in the hopes that it would be found possible to ascend the highest mountain of the island, called San Antonio, 7400 feet in altitude, in search of the plants growing on its summit. The journey to the base, ascent, and return to the harbour in twenty-four hours was stated to be feasible by the townspeople, but it proved that such is by no means the case. The road led directly inland, and as the successive terraces were ascended the hills became greener and greener, being covered by a continuous carpet of seedling grass and other herbs as yet only two or three inches in height. The guide said that it would be a foot or eighteen inches high later on, and that then the quails would abound and the guinea fowl breed, so that the breeding season of these birds here appears to be in the autumn, and determined by the rainy season.

The valley of San Domingo into which the road at length led is deep, with precipitous cliffs and steep mountains on either side, rising 1000 to 2500 feet above sea level. The valley is broken here and there by lateral offsets and backed towards its head by irregular mountain masses. The view up the valley is very beautiful. Beneath the cliffs, which are encrusted with lichens and stained of various colours, often of a deep black, are steep talus slopes covered with oil trees with a few other shrubs sparingly intermingled. At the bottom of the valley is a strip of comparatively level land, on which are cultivated all sorts of tropical fruits, pineapples, bananas, oranges, lemons, guavas, cocoanuts, and coffee; with cassava, sweet potatoes, and sugar cane as field crops. All along the valley a little way up the slopes are small huts, where boys are stationed whose duty it is to keep off the monkeys which abound amongst the rocks, and the wild Blue Rock Pigeons (*Columba livea*), which are very numerous, and were seen flying about in flocks and alighting in the road. The fact of the existence of monkeys in the island is not mentioned in any published account of the place. They must be of some African species imported and run wild, but it would be important to determine what the species is, and future explorers would do well to try and procure a skin. The guide said that the monkeys never came out in wet weather, and so not one of them was seen. The boys kept up a constant shouting, which resounded through the valley.

At the bottom of the valley is a small stream running rapidly over the stones, like a trout stream, and everywhere very shallow, in which grow water cresses and several familiar English water plants; two ferns also were noticed on the banks. Two kinds of freshwater shrimps live in the stream under the stones, and are very abundant, notwithstanding the shallowness of the water. One is a *Palæmon*, a large prawn, as big as the largest specimens of our common river crayfish, and with long and slender biting claws. The other is a very different animal, somewhat smaller, and of the genus *Atya*, distinguished by having no nippers on the larger pairs of walking legs, but only simple spine-like ends to them, and by several very remarkable and characteristic features of structure. The genus is very widely spread, occurring in the West Indies, Philippines, Samoa, and Mexico. After the village of San Domingo, which consists of a few scattered thatched stone houses, had been passed, the road became very much worse and the ponies soon became completely tired out, so much so that a retreat had to be made on foot. Five hours had already been spent in the saddle and the place from which the ascent of the mountain commences was still a very long way off. A Portuguese inhabitant of the valley said that it was impossible to ascend the mountain in the rainy season, because of the falls of stones or stone avalanches which were common and dangerous. It is evident that an excursion to the summit of San Antonio, from the harbour of St. Iago, is possible only in three or four days; a good supply of provisions should be taken by any party attempting it. San Domingo valley, with its succession of mountain ridges and peaks becoming bluer and bluer in the distance, is one of the finest of mountain valleys, and the tropical vegetation with which it is clothed gives it an especial charm. The sight of such a place is particularly delightful to a traveller who has for weeks been trudging the arid hills and plains of St. Vincent, or one who has just ascended to it from the almost equally sterile plains about the coast of St. Iago.

Red, or precious, Coral occurs at St. Iago and also at St. Vincent, the fishery being carried on by Italians, Spaniards, and Americans. One ship, which was employed during the season with seven boats, is said to have taken thirty barrels of the Coral in the rough state. Professor Thomson and Mr. Murray dredged over the ground in the steam pinnace during the whole of the 8th August and were very successful. The Coral occurs in 80 to 120 fathoms, and is dragged for by rough nets and swabs, and a duty of a dollar per kilogramme is paid to the Government.

The insect fauna at St. Iago, so far as cursorily examined, was found to be the same as that at St. Vincent, though much richer.

The rocks collected at St. Iago are felspathic basalts and phonolite. The raised beach described by Darwin[1] appears as a conspicuous white streak underneath the cliffs surrounding the harbour. Immediately below the lava bed is a crystalline limestone cementing volcanic debris, in which appear small fragments of palagonite, and clastic grains of shells. Under the microscope it is seen that the organic structure of these shells has not entirely been lost. The fragments of volcanic origin enclosed in the limestone are small splinters of basalt, fragments of crystals of augite, olivine, hornblende, black mica, and magnetite. Some specimens of incrustation on the lava are almost entirely made up of carbonate of lime, present all the characters of a stalactitic deposit, and do not contain organic remains discernible under the microscope. The organisms found in the limestone are, as pointed out by Darwin, the same as those now living in the harbour.

[1] Darwin, Journal of Researches during the Voyage of H.M.S. "Beagle," pp. 4–6, ed. 1871.

CHAPTER VI.

Cape Verde Islands to St. Paul's Rocks and Fernando Noronha—Balanoglossus—The Echinoidea—Description of St. Paul's Rocks and Fernando Noronha—Coast of Brazil—Bathypterois—Surface Fauna of Guinea and Equatorial Currents—The Radiolaria—Bahia.

Cape Verde Islands to St. Paul's Rocks.

The Expedition left Porto Praya at 8 p.m. on the 9th August, and a course was shaped for St. Paul's Rocks. Owing to the season of the year in which the passage was made, the course was necessarily somewhat erratic; the ship proceeding to the southeastward along the African coast until the S.E. trade was reached in lat. 3° 8′ N., long. 14° 49′ W., and then standing over to the westward for St. Paul's Rocks. The soundings and temperatures obtained must, therefore, be divided into two sections,—1st, the southeasterly section towards the equator; and 2nd, the equatorial section.

From Porto Praya to the parallel of 7° N. the wind varied from W. by N. to S. by W. with cloudy, squally, rainy weather; from thence to the position where the S.E. trade was met with, viz., in lat. 3° 8′ N., long. 14° 49′ W., the wind was from S.S.W. to S., with fine weather, and from that position the S.E. trade was retained to St. Paul's Rocks.

On the section to the southeastward from Porto Praya to a position in lat. 3° 8′ N. long. 14° 49′ W. six soundings, eight serial temperature soundings, and one dredging and one trawling were obtained (see Sheet 12).

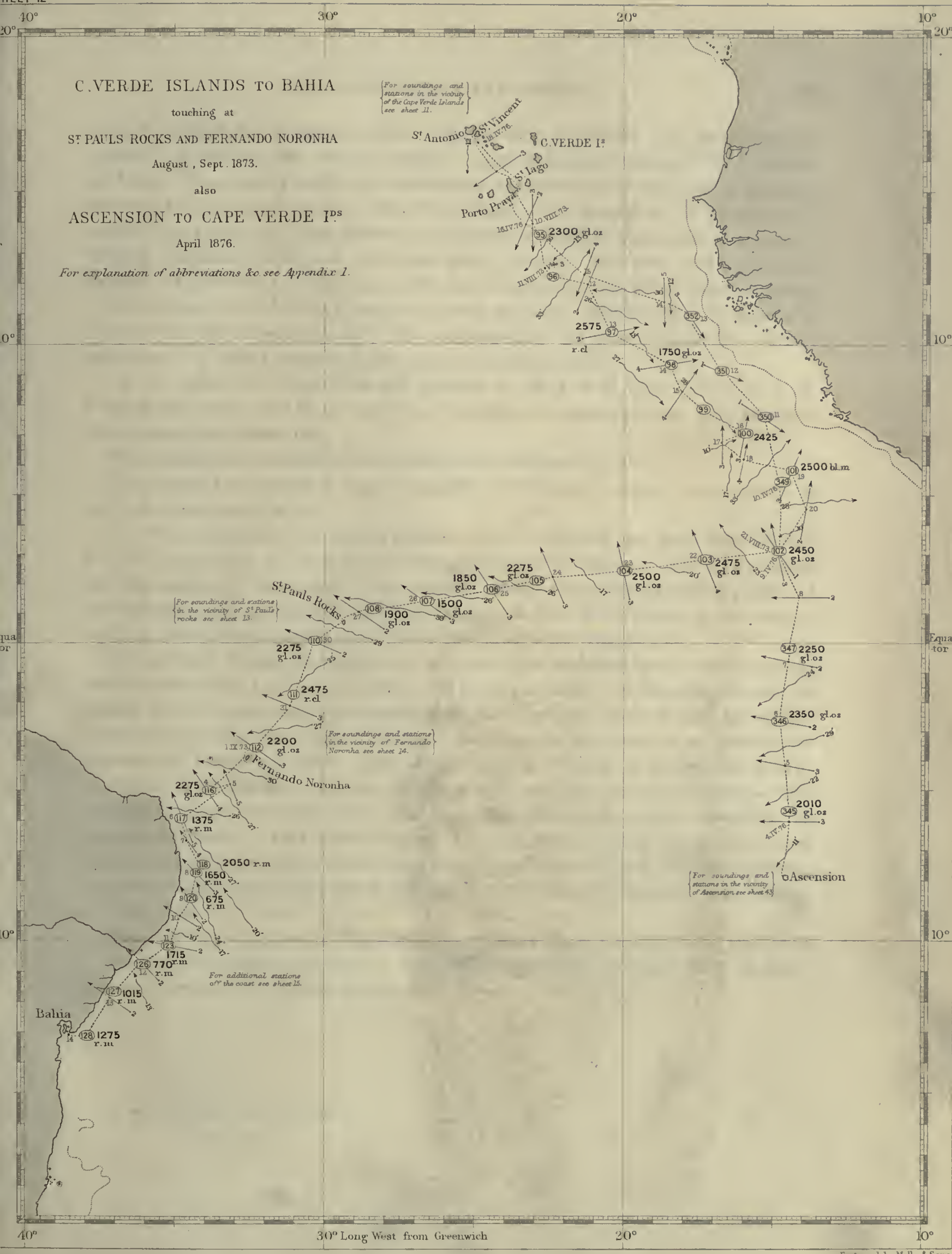
The surface temperature varied from 77°·7 to 79°·5.

The bottom temperature when the depth exceeded 1800 fathoms still continued remarkably uniform, the mean being 36°·5 and the extremes 36°·6 and 36°·4.

Serial temperature soundings showed that the isotherm of 40°, which was at a depth of 800 fathoms at St. Iago, rose gradually to the southward to 500 fathoms in the parallel of 3° N. The isotherm of 50° maintained an average depth of 180 fathoms, varying from 150 to 200 fathoms; but the isotherm of 55° approached at Station 96 to within 40 fathoms of the surface, although the surface temperature was 79°; thus showing a decrease of 24° in 40 fathoms.

On the 16th, at Station 100, the dingey was anchored by the sounding line, and the surface current was found running N. 70° E. half a mile per hour. The current drag at 50 fathoms indicated a set of 0·45 mile per hour, N. 17° E.; at 100 fathoms, N. 15° E. 0·3 mile per hour; and at 200 fathoms, N. 17° E. 0·2 mile per hour. On the 19th, at Station 101, the cutter was anchored by the trawl, and the surface current

HEET 12



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found running N.E. 1·3 miles per hour. On the 21st, at Station 102, the dingey was anchored by the lead line, and the surface current was found running N.W. 1·25 miles per hour. These results confirm the existence of the current as ascertained by difference between D.R. and observations. From Porto Praya to the parallel of 12° 30′ N. a S.W. current was experienced; from thence to the parallel of 4° 40′ N. the current was easterly, trending sometimes north, and sometimes south, by east. The total drift experienced between the parallels of 12° 30′ and 4° 40′ was 146 miles in a N. 88° E. direction (true), or at an average rate of three quarters of a mile per hour. Southward of the parallel of 4° 40′ N. the current was westerly. The temperature of the easterly or Guinea Current was 79° or 1°·5 higher than the Equatorial or westerly Current.

In the equatorial section from the position in lat. 3° 8′ N., long. 14° 49′ W. to St. Paul's Rocks, seven soundings, four serial temperature soundings, and three trawlings were obtained (see Sheet 12).

The surface water maintained an average temperature of 78°.

The bottom temperature at depths exceeding 1800 fathoms varied 0°·8 or from 36° to 36°·8, the mean being 36°·4.

The serial temperature soundings showed a rapid cooling of the water near the surface, for the isotherm of 60° was at an average depth of 70 fathoms. Below 70 fathoms the temperature fell more slowly, the isotherm of 50° occupying an average depth of 150 fathoms, varying from 130 to 180 fathoms, and that of 40° being at an average depth of 520 fathoms, varying from 430 to 550 fathoms (see Diagram 4).

On the 23rd August, at Station 104, the cutter was anchored by the trawl, and the surface current found to run west (true) 1·2 miles per hour. On the 25th August, at Station 106, the cutter was again anchored by the trawl, and at 10.30 A.M. the surface current was running west (true) 2 miles per hour, but in the afternoon its velocity had decreased to 1 mile per hour. The current drag at 10 A.M. at 75 fathoms showed no current, at 50 fathoms a current of half a mile per hour, and at 15 fathoms three quarters of a mile per hour, all to the west, thus showing how very superficial the Equatorial Current is. On the 26th August, at Station 107, the cutter was again anchored by the trawl, and the surface current found to be running west (true) 1·5 miles per hour, and it continued to run at that rate throughout the day instead of slacking in the afternoon as on the 25th.

The following anemometer observations were taken when, the ship being stationary for sounding or dredging purposes, a favourable opportunity presented itself for ascertaining the velocity of the trade wind:—

On August 21,	at Station	102,	velocity of wind was	13	miles per hour;	force registered	2 to 3
„ 22	„	103,	„	15	„	„	2
„ 23	„	104,	„	12	„	„	2
„ 24	„	105,	„	11	„	„	2
„ 25	„	106,	„	15	„	„	3
„ 26	„	107,	„	12	„	„	3
„ 27	„	108,	„	13	„	„	3
„ 28	at St. Paul's Rocks[1]		„	9	„	„	3
„ 29	„		„	10	„	„	4

On the 27th August, at 2 P.M., St. Paul's Rocks or islets were seen from the masthead at a distance of 18 miles, and at 3 P.M. from the deck, at a distance of 9 or 10 miles.

The depths in the section along the African coast varied from 2575 fathoms to 1750 fathoms. From the point where the course of the ship was turned to the westward a nearly level plateau extends for 500 miles, the depth being from 2300 to 2500 fathoms, after which a gradual elevation takes place to 1500 fathoms 150 miles east of St. Paul's Rocks, and then a depression to 1900 fathoms at a distance of 60 miles from the rocks.

The deposits at the two depths, 2575 and 2500 fathoms, near the African coast, contained respectively 30 and 6 per cent. of carbonate of lime, the small percentage in the latter being due to continental debris, but at all the other Stations there was over 50 per cent., and at 1850 fathoms in Mid Atlantic the amount reached 90 per cent. In all the deposits the carbonate of lime consisted chiefly of pelagic Foraminifera, Coccoliths, and Rhabdoliths, with a few fragments of Echinoderms and other organisms. An analysis of the mud from the dredge at Station 102 (2450 fathoms) gave 83 per cent. of carbonate of lime. A careful examination of a large quantity of this deposit showed that nearly the whole of the carbonate of lime present consisted of the dead shells of surface organisms, and it was estimated that of the 83 per cent. of carbonate of lime, 75 per cent. was due to pelagic Foraminifera, 6 per cent. to Coccoliths, and 2 per cent. to other calcareous Foraminifera, fragments of Echinids, and Ostracodes. *Pulvinulina menardii* and its variety *tumida* were the most abundant forms, but *Globigerina sacculifera*, *Globigerina dubia*, *Globigerina conglobata*, and *Sphæroidina dehiscens* were also very abundant. It is worthy of notice that the majority of the shells were very large; and the more delicate surface forms, as *Hastigerina* and *Candeina*, appeared to be quite absent. The typical *Globigerina bulloides* did not appear to be present. The Foraminifera here were thick-shelled and of large size, and it was precisely in this region that the largest specimens of pelagic Foraminifera were obtained on the surface by means of the tow-net. Many of the shells were broken and appeared to be in a crumbling con-

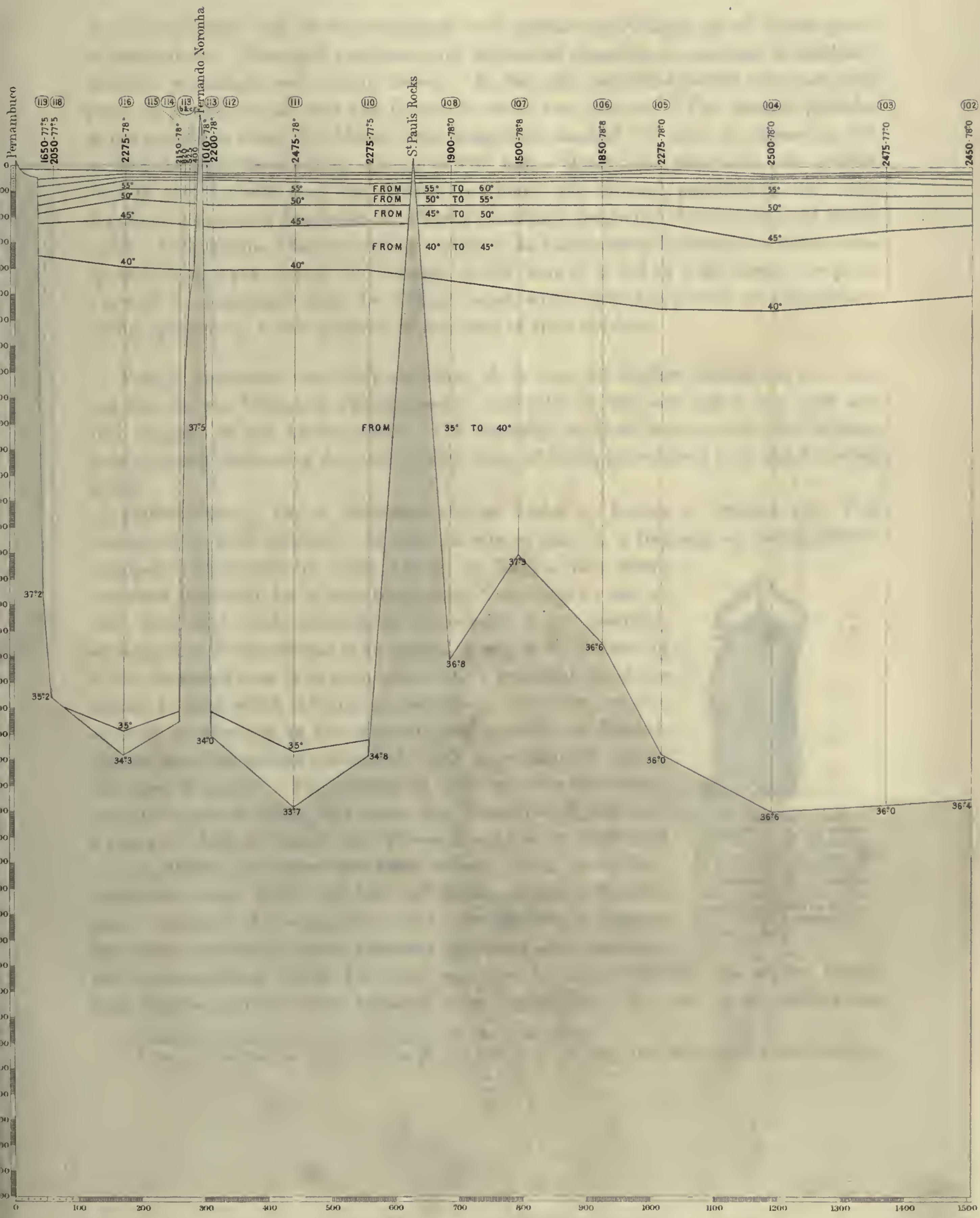
[1] The velocities at St. Paul's Rocks may be affected by the land to windward.

AM 4.

ATLANTIC OCEAN

Longitudinal Temperature Section. From a position in Lat. 3°8'N. Long. 14°39'W. to Pernambuco.

For explanation of Symbols see Appendix 1.



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dition. The finer and smaller fragments were almost wholly made up of broken pieces of larger shells. The small specimens and primordial chambers, so common in shallower deep-sea soundings, were nearly absent. In the same way Rhabdoliths were not complete, if present at all, and the Coccoliths were very minute. The mineral particles in the soundings along the African coast sometimes reached 0·7 mm. in diameter, but in Mid Atlantic they seldom exceeded 0·05 mm. Quartz and glauconite were present only in the deposits near the African continent, the mineral particles in the other deposits consisting of fragments of felspars (sanidine), magnetite, hornblende, and glassy rocks. Radiolarians, Diatoms, Sponge spicules, and arenaceous Foraminifera never made up more than 3 per cent. of the deposits, which were of a red or rose colour, except in a few of the soundings near the African coast, where they had a black or slate colour, owing, apparently, to the presence of fine mud or river detritus.

Pelagic organisms were very abundant at or near the surface throughout this trip, and the sea was brilliantly phosphorescent, especially on the evenings of the 14th and 16th August, off the African coast. The trawlings at 2500 fathoms and 1850 fathoms yielded many interesting deep-sea species, some of which are referred to in the following notes.

Balanoglossus. Dr. v. Willemoes Suhm writes as follows:—"Station 101, 19th August 1873, 2500 fathoms. Among the worms there is a fragment of *Balanoglossus.* Originally discovered by Delle Chiaje in Naples, this worm remained unknown for a long time, until Kowalewsky came to that place and made astonishing discoveries in its anatomy, showing that *Balanoglossus* is an animal in which the beginning of the intestinal tube is in connection with a branchial apparatus similar to that which is found in Ascidians. There are, besides, so many peculiarities in the structure and anatomy of *Balanoglossus*, that Gegenbaur established for it a special order among the class of worms. The interest in *Balanoglossus* was subsequently increased when, four years ago, Metschnikoff published a paper in which he stated that *Tornaria*—the larva discovered by Joh. Müller, and since that time believed to be an Echinoderm-larva—was really the larva of *Balanoglossus.*[1] Another paper confirmed this supposition,[2] and quite recently A. Agassiz has shown more fully, in an American species of *Balanoglossus*, the metamorphoses which *Tornaria* undergoes.[3] Two additional species are known from Naples, and one from Hellebek near Copenhagen. The one we got to-day was

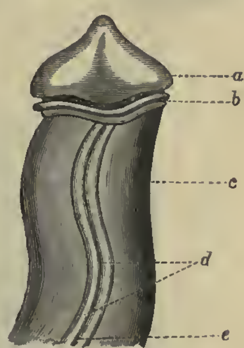


Fig. 78.—Fragment (head) of *Balanoglossus*, n. sp.; natural size. Station 101, August 19, 1873; lat. 5° 48′ N., long. 14° 20′ W.; depth, 2500 fathoms; *a*, proboscis; *b*, collar-like neck; *c*, body; *d*, walls of the branchial apparatus; *e*, median vessel. From a drawing by v. Willemoes Suhm.

[1] *Nachricht. v. d. Georg.-Aug. Univ. zu Göttingen*, No. 15, p. 287, 1869.
[2] *Zeitschr. f. wiss. Zool.*, Bd. xx. pp. 131–144, pl. xiii., 1870.
[3] *Amer. Acad. Mem.*, vol. ix. pp. 421–436, 1873.

probably of considerable length, but owing to the extreme softness of the tissues, only the anterior part remained in the dredge when hauled on board; it was distinguished by very lively colours, the proboscis *a* being yellow, the collar-like ring *b* bright red, and the body *c* yellowish-red. In the latter the two longitudinal folds *d* are the outer walls of the branchial apparatus, and between them *e* the so-called median vessel. In the lower part the beginning of the ovary was also observed. From

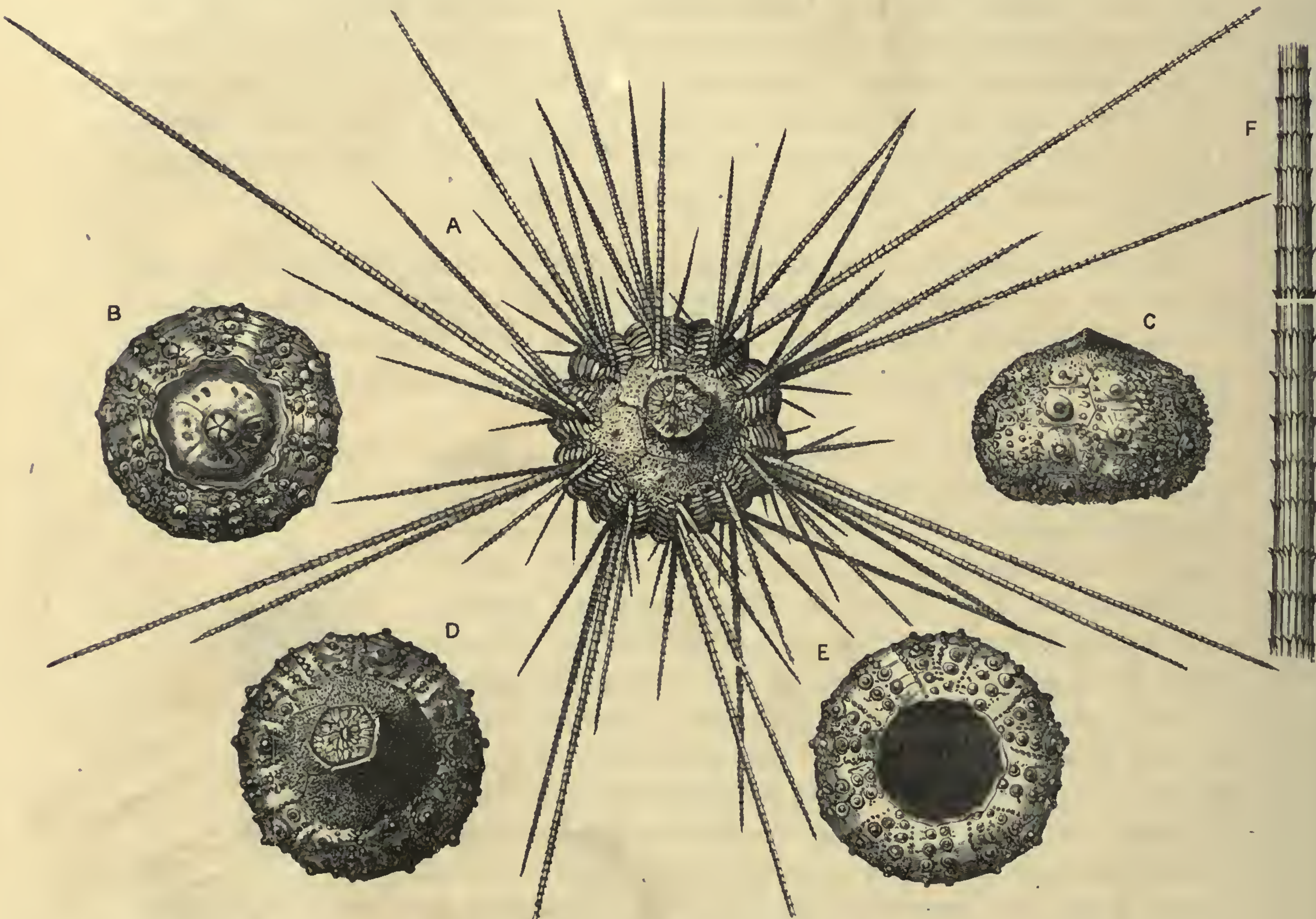


FIG. 79.—*Salenia hastigera*, A. Ag.

A, Abactinal view of specimen, measuring 14 mm. in diameter; B, young specimen, measuring 9 mm. in diameter, seen from the actina side; C, specimen seen in profile, denuded of spines, 13 mm. in diameter; D, the same, seen from the abactinal side denuded; E, the same seen from the actinal side; F, magnified portion of primary spine.

this fragment it would hardly be permissible to establish a new species. *Balanoglossus* is likely to be found often in deep-sea dredging, and even the shallower water species may be met with, since they are always inhabitants of deeper water of the coasts and true mud animals. Head 18 mm. wide, 11 mm. high.

"At Station 106, 25th August 1873, 1850 fathoms, there were again in the trawl red fragments of *Balanoglossus*, which show that the whole animal must have been of great length, at least 6 inches.

"Again, at Station 147, 30th December 1873, 1600 fathoms, large reddish fragments of a *Balanoglossus* were also brought up, in one of which the collar was preserved. Apparently these latter specimens belong to the same species, the head of which was obtained in the deep sea in the tropics. The whole animal must have had a length of from 3 to 5 inches, and have measured nearly $\frac{3}{4}$ths inch across the body."

The above extracts from Dr. v. Suhm's Journal, being of considerable interest as the only record which has been preserved of these deep-sea specimens, are inserted here, although since it was written great additions have been made to the knowledge of the structure and development of *Balanoglossus*, and the animal has assumed an importance which has rendered it familiar to all students of animal morphology.

The Echinoidea.—At 1850 fathoms there were two fine specimens of a new species of *Salenia*, described under the name of *Salenia hastigera* (see fig. 74) by Mr. Alexander Agassiz, who gives the following notes on the Echinoidea collected by the Expedition. "The importance of the additions made to our knowledge of the Echini by the Challenger collection is well shown from the fact that at the time Mr. Agassiz wrote his Report[1] the hauls of the Challenger presented no less than forty-nine new species out of a total of 297 known species. Although no new families were added to those discovered by the earlier expeditions of the U.S. Coast Survey, of the Swedes, and of the English, yet the number of new genera and species added to the lists were of the greatest importance in elucidating the affinities of a number of recent and fossil forms.

FIG. 80.—*Salenia varispina*, A. Ag.; four times the natural size.

"The number of new Cidaridæ was not great, but the dredging of a new *Porocidaris*, with its curved actinal spines and its long, smooth,

[1] Report on the Echinoidea of the Challenger Expedition, by Alexander Agassiz, Zool. Chall. Exp., part ix., 1881.

primary spines, was an interesting discovery. The existence of a new species of *Salenia* (*Salenia hastigera*) in the tropical Pacific has increased the number of living species of that genus to four, and we now have a fair knowledge of a type which has played an important part in the Echinoidal fauna of the Jurassic and Cretaceous periods. The singular structure of the apical system of the genus, consisting of large plates soldered together, and recalling the condition of the apical system in embryonic Echini, has led to important systematic comparisons.

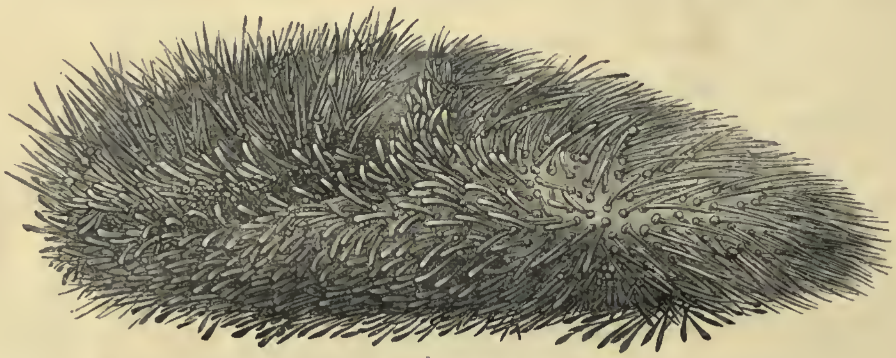


FIG. 81.—*Aërope rostrata*, Wyv. Thoms. Seen in profile; natural size.

"A number of specimens of *Cœlopleurus maillardi* were collected; their examination has thrown new light on the nature of the cap which tips the spines of the Arbaciadæ. In this genus it becomes developed to an extraordinary extent, four or five times the length of the spine proper. The immense triangular and curved spines thus formed probably served to raise the test as it were, on stilts, and enabled the sea-urchin to move with con-

FIG. 82.—*Pourtalesia phiale*, Wyv. Thoms. Seen from the actinal side (denuded); four times the natural size.

siderable rapidity. We find in several of the species of Echinothuridæ another form of development of the tip of the primary spines. In *Phormosoma hoplacantha*, for instance, the radioles of the actinal surface are tipped with broad conical shoes, which must give to these soft-tested Echini a sufficient number of points of support to raise them above the ground. This species is probably the largest sea-urchin known; it must have measured no less than 312 mm. in diameter when fully expanded. The Echinothuridæ, to which *Phormosoma* belongs, all have a more or less flexible test, made up of imbricating plates both on the actinal and coronal areas, a structural feature which in the Palæozoic Echini was quite common, and which is retained in modern Echini only in the bevel between adjoining plates. Many of the Echinothuridæ assume, when fully expanded, a globular outline, and when placed on deck the flexibility of the test

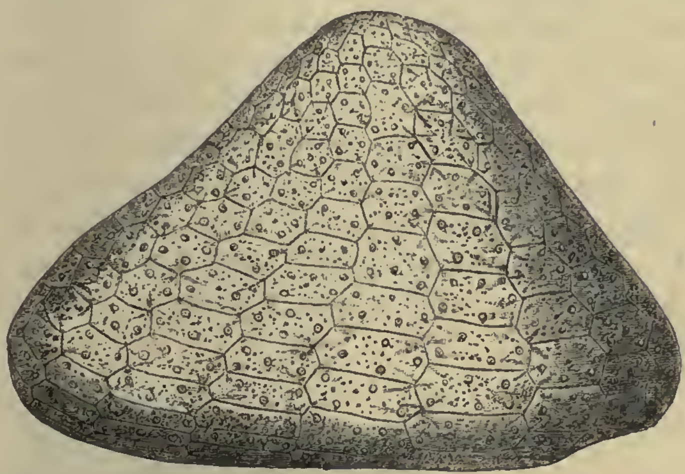


FIG. 83.—*Cystechinus wyvilii*, A. Ag. Seen in profile (denuded); natural size.

gives them peculiar vermiform movements. Their sharp spines, like those of the Diadematidæ, inflict serious wounds, and the sting of these huge Echini is very painful.

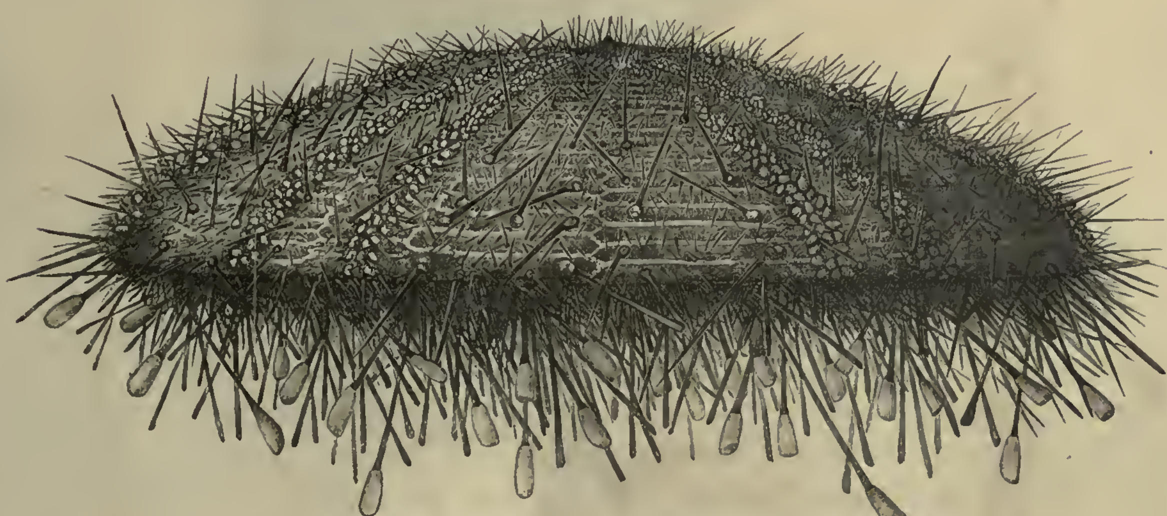


FIG. 84.—*Phormosoma luculentum*, A. Ag. Seen in profile; natural size.

This stinging property is not due to the action of the sharp spines alone, but also in part to the effect of the contents of the baggy envelopes which in a few of the species surround some of the sharp spines.

"The absence of the Clypeastroids from the deeper waters is interesting, indicating that they probably developed rapidly during the Tertiary period, and have always been (as they are to-day) inhabitants only of shallow seas.

"By far the most interesting Echini collected by the Challenger belong to the strictly deep-sea types, the Pourtalesiæ and Ananchytidæ, families of which the nearest allies were known only as fossils before the days of deep-sea dredging. The first family, Pourtalesiæ, was discovered by the late Count Pourtalès in the trough of the Gulf Stream, between Key West and Havana. The Challenger has added no less than twelve new species to this family. Some of the genera are of the most extraordinary shape, and, like the original Pourtalesiæ, seem to have little in common with the normal Spatangoids as we know them from their living and fossil representatives. The slipper-shaped *Echinocrepis*, and the *Galerites*-like *Urechinus* remind us of types which flourished in the Cretaceous Seas. One of the species of *Cystechinus*, with its thin flexible test, looks in alcohol more like a

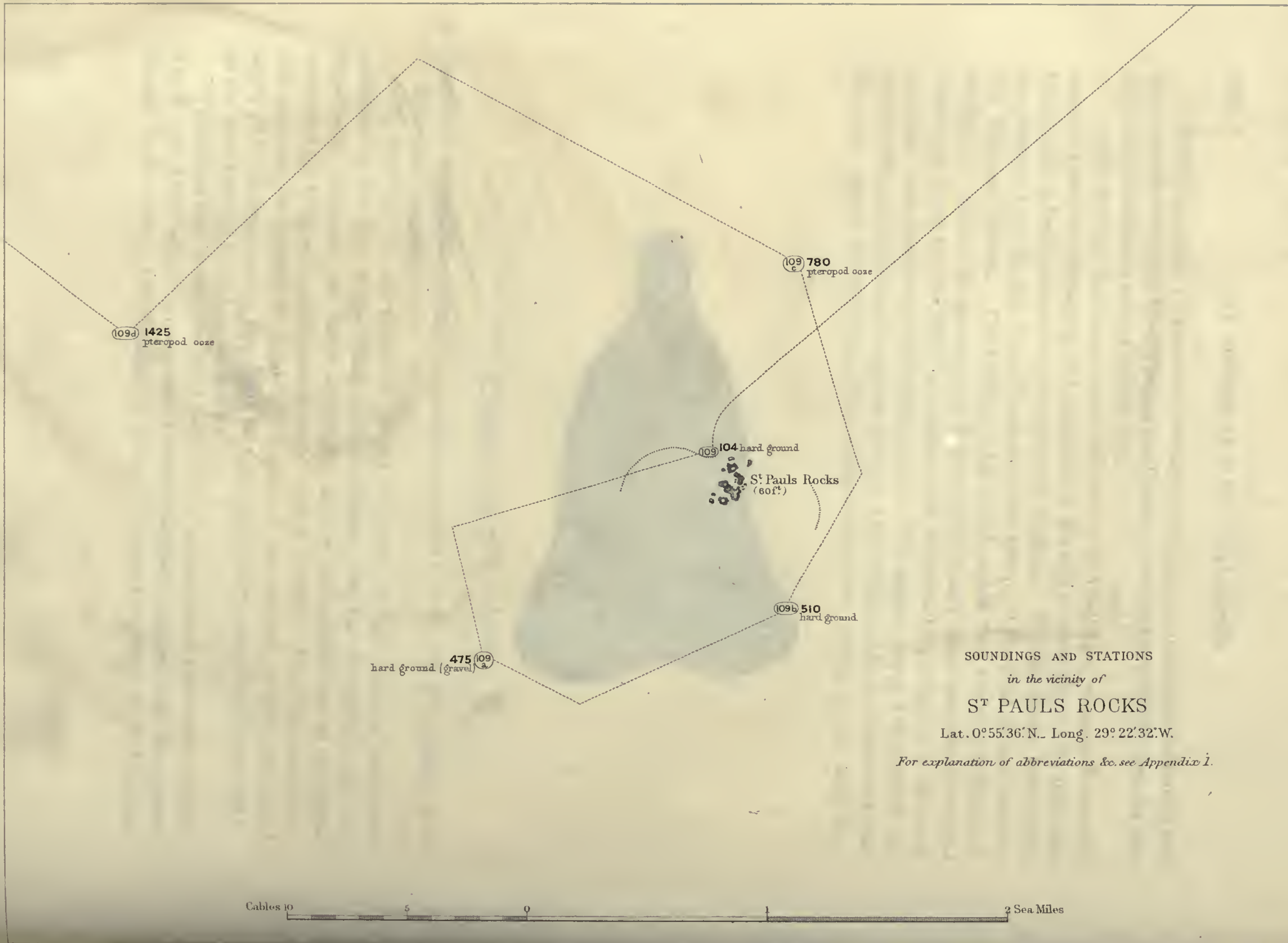
FIG. 85.—*Pourtalesia ceratopyga*, A. Ag. Seen from the abactinal side, covered with spines; natural size.

diminutive battered felt hat than the graceful sea-urchin it must have been judging from its hard-tested congener.

"No less than five new species of Ananchytidæ were brought home, a family once numerous in the time of the Chalk, and remarkable, like the Pourtalesiæ, for their imperfectly developed and simple ambulacra, and for the uniform size of the plates composing the ambulacral and interambulacral areas of the test. These two families are also noted for the absence or slight development of the fascioles, so characteristic of nearly all recent Spatangoids, but absent in many of the more recent fossil types and in all the other forms of extinct Spatangoids.

"Interesting from an embryological point of view are such novel and strange forms as *Aërope* and *Aceste*, which have assumed a facies absolutely identical with that passed through by the young of the Brissina of to-day. In these two genera the odd anterior

SHEET 13


109c 780
pteropod ooze
109d 1425
pteropod ooze
109 104 hard ground
St Pauls Rocks
(60ft)
109b 510
hard ground
475 109a
hard ground (gravel)
SOUNDINGS AND STATIONS
in the vicinity of
ST PAULS ROCKS
Lat. 0°55'36" N. Long. 29°22'32" W.
For explanation of abbreviations &c. see Appendix 1.
Cables 10
5
0
1
2 Sea Miles

ambulacrum is immensely developed, its suckers are of a gigantic size, entirely out of proportion to the rudimentary ones of the paired ambulacra.

"The colouring of the majority of the deep-sea species is a dark violet; those of shallower waters are more brilliantly coloured, and such species as *Cœlopleurus* and some of the *Saleniæ* are perhaps among the most beautiful and strikingly marked Echini."

The bathymetrical distribution of the Sea-urchins and their relationship to the previous Echinoid faunæ are fully discussed in Mr. Agassiz's Report.

St. Paul's Rocks.

As the rocks were approached, it was noticed that the equatorial current running past them, the velocity of which from observation was $1\frac{3}{4}$ miles per hour, caused a considerable ripple, amounting almost to a race, on each side. These ripples united at

Fig. 86.—H.M.S. Challenger at St. Paul's Rocks.

a distance of about a mile to the westward, raising a confused sea, and leaving a cone of comparatively smooth water, immediately to leeward of the islets.

As the wind and current concurred in direction, the islets were circled until the ship was directly to leeward of them, and in the cone of still water. The vessel then steamed slowly towards them, sounding without success. When within a cable's length of the S.W. point, midway between the ship and the shore, a sunken rock was observed from the foretop, which appeared to have about 3 fathoms over it, so the vessel was steered to the northward; experience proving that it was safe to steam close to the rocks, the vessel was secured by a hawser to a knob on the point of the northeast side of the little cove (see fig. 86). When so secured the bow was in 104 fathoms half a hawser's length from the shore. The Challenger remained quietly secured in this manner until the morning of the 29th, but it must be borne in mind that the circumstances which rendered it prudent to run the risk of remaining in such a position were peculiarly favourable: the wind being steady in direction and light in force; the sea moderate, although sufficient to cause a considerable break on the weather side of the rocks; a current coinciding in direction with the wind, of sufficient force, even to leeward of the rocks, to keep a uniform tension on the hawser; and the season of the year rendering it highly improbable that any change would take place.

St. Paul's Rocks consist of a number of small islets separated from each other by deep chasms (see Pls. III.–VI.) through which the sea is constantly pouring, as wave after wave strikes against this ocean pinnacle. The whole group occupies a space of two cables in length in a N.N.E. to S.S.W. direction, and one cable in breadth; its highest point is 64 feet above the level of the sea. The N.W. and S.E. sides are steeper than the S.W. side, for whereas depths of 500 fathoms are found nine cables from the islets in each of the former directions, the 500 fathom line of soundings is at a distance of over 2 miles to the S.W., and there appear to be also some shallow soundings (that is, soundings under 100 fathoms) at a distance of half a mile in that direction (see Sheet 13).

Between the two largest islets is a small cove 300 feet in length and 170 feet across (at its entrance), the depths in which vary from 5 to 10 fathoms. Constant rollers, produced by the swell recurving round the islets, enter the cove, and, meeting with the almost continuous stream of water coming through the narrow chasms, separating the islets, make a very confused sea, consequently, as the only landing is in the cove, it is necessary to be cautious. When once a man has succeeded in jumping on shore, a rope stretched across the entrance renders the operation comparatively easy, as then the boat can be steadied by the rope as it rises and falls with the swell.

Excellent astronomical and magnetic observations were obtained on shore, but no tidal register could be taken owing to the swell.

During the time the ship remained at these islets their dangerous character was more than ever apparent, for although their white guano-covered peaks when lit up by the moon, were plainly visible from the ship 100 yards distant, they were not sufficiently distinct to be recognised as land at a distance of over a mile, and, without the moon, would probably not be seen more than a quarter of a mile; in short, the sound

Plate III.

HORSBURGH, EDINBURGH. PERMANENT PHOTOTYPE.

ST. PAUL'S ROCKS.

of the breakers might be the first notice given to a passing ship, of their proximity. The birds, numbers of which make these islets their home, were remarkably quiet during the stay, and it was evident that no dependence could be placed on their giving warning; it is true that no lights were shown at night, lest a passing ship might be drawn into danger, and it is well known that birds are generally attracted by a ship's lights, round which they circle uttering their discordant cries, still, it would be an imprudent thing to trust to their doing so always, nor would they probably be attracted by a ship's lights until she was in dangerous proximity to the rocks. Under these circumstances, and looking to the fact that the islets are situated in the strength of the Equatorial Current, it is evident that nothing but their small extent has prevented their becoming the scene of numerous shipwrecks, for the lead is not of the slightest use in their vicinity.

A lighthouse erected here would be of great advantage to passing ships, for, not only would it divest the rocks of their present dangerous character, but it would render them of positive benefit to the navigator, as, owing to the depth of water surrounding them, ships would be able to run boldly for them, either by night or day, and so correct their chronometers. Nor would there be much difficulty in erecting a building, as there is a level space 100 by 40 feet on the large S.W. islet, which would afford ample room, and would require little preparation for the foundation. A derrick rigged out from the shore, or better still, a light bridge thrown across the cove, would render landing sufficiently easy in all weathers likely to be experienced in this locality, so that the work might proceed uninterruptedly. By erecting the lighthouse on the summit of one of the small rocky islets, an additional elevation of some 30 feet would be gained, but considerable labour would be required to cut a suitable flat for the foundations. Should a lighthouse ever be erected here, arrangements for condensing water would have to be made, as the only fresh water that could be possibly obtained on the rocks would be from passing showers.

Fish are plentiful and good,[1] and afford good sport with the rod, but the fishing line must not be weighted. Birds were seen hovering in thousands over the rocks as they

[1] In his Report on the Shore Fishes (Zool. Chall. Exp., part vi. p. 4, 1880) Dr. Günther gives the following list of the species collected :—

Holocentrum sancti-pauli, Günth.
Caranx ascensionis, Forst.
Glyphidodon saxatilis, Linn.
Cossyphus rufus, Linn.
Platyglossus cyanostigma, Cuv. Val.
Enchelycore nigricans, Bonnat.
Balistes buniva, Lac.

He states "evidently many more species might have been collected during a longer stay. The fauna is composed of West Indian forms, with some of the species found at Ascension and St. Helena. It is not surprising that a distinct, and apparently undescribed, species of the widely spread genus *Holocentrum* should prove to be peculiar to this isolated locality."

were approached. Only three species occur on them, two noddies and a booby. The Noddies (*Anous stolidus* and *Anous melanogenys*) are small terns or sea swallows, black all over, with the exception of a small white patch on the head. The Booby (*Sula leucogastra*) is a kind of gannet; the full-grown birds are white on the belly, with a black head and throat; the black ending on the neck, where it joins the white in a straight conspicuous line; the back is dark. The younger birds are brown all over. A few of both birds soon came off to have a look at the ship as she approached the rocks. On landing, the rocks were found to be covered with noddies and their nests, some containing eggs, whitish in colour, with red spots at the larger end, and others with young in them, little round balls of black down. The air was full of noddies and boobies circling about, and screaming in disgust at the invasion of their home.

The noddies' nests are made of a green seaweed (*Caulerpa clavifera*) which grows on the bottom in the bay and around the rocks, and which, getting loosened by the surf, floats, and is picked up by the birds on the surface of the water. The weed is cemented together by the birds' dung, and the nests, having been used for ages, are now solid masses, with a circular platform at the summit, beneath which hang down a number of tails of dried seaweed. The older nests, placed on the faces of the cliffs, project from the sheltered sides of the rocks, like brackets, having been originally commenced, as may be seen by the complete series of gradations existing, by a pair of birds laying an egg on a small projecting ledge of rock and adding a few stalks of weed. A series of these nests are seen in the photograph (Pl.III.), appearing like white patches on the perpendicular surface of the low cliff. If these white patches be closely examined, each will be seen to represent a bracket-like nest with dependent fringe, and in most cases to have a black noddy with a conspicuous white patch on its head sitting on it. A greater number of the noddies, however, place their eggs on the bare flat rocks in any slight hollow or chink. The two species of noddy are so nearly alike that it was not noticed during the stay of the Expedition that more than one was present, and it appeared as if, the cliff surface on the rocks being limited, only the stronger noddies were able to maintain their position in the bracket-like nests, whilst the weaker had to put up with the more exposed open rocks; but probably more careful examination would have shown that the bracket-like nests of seaweed belonged to one species of *Anous* only and the bare nests of the horizontal rocks to the other. A white peak on the western side of the bay forms the home of the boobies, which are not nearly so numerous as the noddies, and seem to be almost restricted to this one peak, out of the five of which the rocks are made up.

The whiteness of the rock is caused by the birds' dung, which in some places forms on the rocks, as described by Darwin, an enamel-like crust, which is hard enough to scratch glass. Some of this was found at about 45 feet above sea level. The rock is steep on the sheltered sides, and is there hung all over with the bracket-like nests of

Plate IV.

HORSBURGH, EDINBURGH. PERMANENT PHOTOTYPE.

ST. PAUL'S ROCKS.

the noddies. The weather side slopes more gently; and all over it, on every little flat space, are the boobies' nests, mere hollows, some containing two eggs, but the majority one only. The eggs are as large as a fowl's, sometimes dirty-white all over, sometimes blotched with brown. In many of the nests were young of all ages; some just out of the egg, ugly big-bellied black lumps, without a particle of down or feathers; then larger ones, as big as one's fist, covered with white down; then others, as large as a fowl, thickly clothed with down; then larger ones again, with brown wing feathers and brown feathers on the breast, the white down remaining only in patches, about the head especially, and finally birds with brown feathers all over, full-sized, and just beginning to fly. Around all the nests were small flying fish, which are brought by the old birds in their crops, and ejected for food for the young or for the females whilst sitting. Fitzroy visited St. Paul's Rocks on February 16th; Ross on May 29th; the Challenger on August 29th; and on all these occasions eggs and young birds were found; hence it would appear that breeding goes on all the year round. Some of the old boobies were found sitting on their young on the top of the peak when this was first visited. They would not move until actually pushed off the nest. Yet they are by no means so foolish as their name would imply, for late in the afternoon of the same day they had so far profited by experience that when it was desired to obtain a few specimens for stuffing, considerable difficulty was experienced in getting within shot of any of them.

The only terrestrial inhabitants of the rocks, besides the birds, are insects and spiders which infest them. These are to be found chiefly by breaking up the nests of the noddies. Darwin[1] mentions the following:—A pupiparous fly (*Olfersia*), living on the booby as a parasite, which belongs to the same group as the curious *Nycterybia*, so common on the bodies of fruit-eating bats. A Staphylinid beetle (*Quedius*), a tick, a small brown moth, belonging to a genus which feeds on feathers, and a wood-louse, living beneath the guano, and spiders, complete Darwin's list. Two species of spiders[2] were found which cover the rock in some places with their webs, and, in addition to the insects noted by Darwin, the larva of a moth, apparently a *Tortrix*, and a small Dipterous fly. Dr. v. Willemoes Suhm also found a *Chelifer*, but could not find either the beetle or the wood-louse. Besides these there are of course to be reckoned the lice, parasitic as usual upon the birds, and the list of air-breathing inhabitants seems then complete.

A closed glass tube was left on St. Paul's Rocks containing a page of the Navy List, with the names of the Challenger officers, and a notification on parchment as follows:—

[1] Darwin, Journal of Researches during the Voyage of H.M.S. "Beagle," p. 10, ed. 1879.

[2] Rev. O. P. Cambridge refers the spiders collected by the Expedition to the genus *Chiracanthium*, and adds, "the examples are immature, so it is impossible to be certain but they appear to be identical with, or at any rate nearly allied to, *Chiracanthium nutrix*, a Swedish species."

"Near this spot the officers of H.B.M.S. Challenger took magnetic observations, August 29th, 1873, dip 22–32. Caught plenty of fish."

A few successful dredgings were obtained by laying out the dredge in a boat astern of the ship while secured to the rocks, and heaving it back.

The soundings close to St. Paul's Rocks showed a hard or rocky bottom, or a Globigerina ooze containing numerous fragments of the rocks and olivine, enstatite, serpentine, magnetic grains, and actinolite.

A detailed Report on the Petrology of St. Paul's Rocks has been published in Volume II. of the Narrative of the Cruise,[1] to which the Reader is referred for details. The following note, giving the chief results of the investigation, has been furnished by Professor Renard, F.G.S.:—

"The position of St. Paul's Rocks, far removed from any continent, together with their aspect and lithological characters, caused them to be considered as the last trace of some vast district lost by submergence. Darwin, struck by the peculiar character of the mineral mass, denied its volcanic origin. He says:[2]—'It is not of volcanic origin, and this circumstance, which is the most remarkable in its history (as will hereafter be referred to), properly ought to exclude it from the present volume.' Speaking of the lithological character of these islets, he described them as composed of rocks unlike any which he ever met with, and would not characterise them by any name. He considered the northern rock of the group to be formed of a sort of "harsh stone," which breaks up into fragments so regular as to be mistaken for blocks of altered orthoclase, and, moreover, saw what he considered to be veins of serpentine running through the whole mass. The observers of the Challenger Expedition, following Darwin, classed the rocks composing the group as serpentine. In doing so they have placed them very nearly in the class they should occupy in the lithological series. Mr. Buchanan ascertained during the voyage that the rock contained magnesia, alumina, and peroxide of iron, and that many specimens gave off water on heating in a closed tube. The naturalists who have visited the island have drawn attention to the fact that the rocks to the south are covered over with a substance that gives them at a distance a dazzling white appearance. This is due in part to the excrement of an immense multitude of seabirds that gather on the rocks, and in part to a coating of a white, hard, brilliant material which will be described hereafter.

"The olivine rock of St. Paul's Rocks presents in general an unusually fresh appearance; showing signs of decomposition only along the crevices. This peridotite is perfectly homogeneous to the naked eye and very compact. Its colour is blackish-grey, bordering to green and black; splinters of the rock are translucent on the edges and of a greenish tint. The lustre varies from subvitreous to resinous; the splinters redden before the blowpipe, and are infusible; the streak is grey or greenish; in hardness it is inferior to felspar. An analysis by Dr. Sipöcz has given SiO_2, 43·84; Al_2O_3, 1·14; Cr_2O_3, 0·42; FeO, 8·76; MnO, 0·12; NiO, 0·51; CaO, 1·71; MgO, 44·33; H_2O, 1·06 = 101·89. On calculating this analysis we find that the rock contains 75 per cent. of olivine and 25 per cent. of enstatite. Thin sections from slightly decomposed specimens show that the rock is composed of olivine, enstatite, and chromic iron.

[1] Report on the Petrology of St. Paul's Rocks, by the Rev. A. Renard, Narr. Chall. Exp., vol. ii., App. B.

[2] Darwin, Volcanic Islands, p. 32, 1851.

HORSBURGH, EDINBURGH. PERMANENT PHOTOTYPE.

ST. PAUL'S ROCKS.

The structure is micrograuitoid; rarely the sections of olivine or enstatite assume dimensions large enough to produce a microporphyritic structure, which passes into a banded structure, the minerals constituting this rock never have crystallographic contours, but are elliptical or irregular. This feature and the banded structure give rise to a sort of lenticular arrangement, which resembles the so-called gneissic structure peculiar to some schists. Without entering on a detailed description of the individual minerals that constitute the rock, it may be stated that the microscopic examination of the specimens shows that the rock mass is almost entirely composed of granular olivine, thus confirming the deductions drawn from the chemical analysis.[1] After the olivine the most frequent ingredient is chromite; the sections of this mineral are generally transparent yellow or chestnut-brown and isotropic. Among the minerals playing a secondary part in the composition are hornblende and a rhombic pyroxene. The hornblendic mineral must be referred to the variety actinolite, of which it seems to possess the most characteristic properties; the rhombic pyroxene, on the other hand, must be classed as enstatite. These ellipsoidal sections of enstatite are polysynthetic, and composed of lamellæ of a rhombic pyroxene, between which are intercalated other lamellæ of a clinorhombic pyroxene.

"Certain features of the olivine, and more especially those shown in the enstatite sections, deserve attention. In some microscopic preparations of the rocks, with banded structure, the larger sections of olivine and enstatite are placed with their vertical axes in a line with the direction of the bands. At first sight it looks as if this disposition had been brought about by the motion of a plastic mass. In one case, where the fragments were in the direction of the band, a crystal has undergone a remarkable process of folding or curling back upon itself by fracture and displacement, it seems to have been partially softened, and looks as if a current had drawn it along and bent it into the shape of a U. The lamellæ composing the crystal are fractured at the summit of the arch of the curve, and the space between the fractures is filled up with the ground mass of the rock. Sections presenting the same appearance may, however, be found abundantly in the family of the schists. Among the analogies of microscopic structure between the schists and the peridote of St. Paul's Rocks may be enumerated the ellipsoidal form of the crystals, their entwinement by the bands in the fundamental mass, the disruption of the larger individuals, as well as their curvature and folding.

"Some of the specimens are highly altered. Along the capillary fissures cohesion diminishes, and serpentinous matter with magnetic iron is deposited in them, the rock being traversed at the same time by black, opaque, and slightly lustrous veins. These altered specimens are often composed of fragments of serpentine cemented together by phosphate of lime, which also often coats the external part of the rock, and to this circumstance these altered portions owe a particular stalactitic appearance. The white enamel that gives the south rock the dazzling appearance described by Darwin, was removed and subjected to a quantitative analysis. The quantity analysed (0·0175 gramme) was so minute, that the only certain results obtained were phosphoric acid, 33·61 per cent., and lime 50·51 per cent.; iron, magnesia, and sulphuric acid were also present. The composition is, therefore, essentially a tribasic calcic phosphate, with sulphate of lime, and perhaps also carbonate of lime, magnesia, and iron. Darwin and Mr. Buchanan regard this white coating as due to the accumulation of excrement of sea birds, the insoluble residue of which has been exposed during very long periods of time to the action of the sun's rays and of the waves of the ocean. This explanation seems the true one, and is

[1] For the mineralogical description of the Rocks, see Narr. Chall. Exp., vol. ii., App. B.

[2] *Ibid.*, fig. 2 of the plate.

applicable not only to the substance in question, but to all the concretionary phosphates found united with the olivine rock of which the islets are composed.[1]

"Some brecciated specimens of St. Paul's Rocks are coated on both sides with black bands, 7 or 8 mm. thick, presenting the mineralogical characters of manganese. Sir Wyville Thomson [2] describes this breccia. Mr. Moseley points out that MacCormick had already drawn attention to this black coating in the fissures of rock. Sir Wyville says that the coating, when triturated, gives a dirty-looking greenish-grey powder, which effervesces in hydrochloric acid, setting chlorine free, and colouring the acid in the same manner as protoxide of manganese. Moreover, Mr. Buchanan found in these breccias with black incrustation, phosphate and carbonate of lime, carbonate of magnesia, and traces of copper and iron, while the crust itself yielded water in the test-tube. I have been able to recognise traces of manganese in unaltered specimens of the olivine rock.

"With regard to the mode of formation of the rock, there are no other positive data than the lithological. Lithological constitution alone cannot always decide the question of origin, the uncertainty increases in proportion as new peridotic rocks are discovered, for fresh discoveries frequently upset views previously entertained. It may be admitted in a general manner that no objections can be raised, *à priori*, against the volcanic origin, pure and simple, of a peridotic rock; olivine can be crystallised artificially with the greatest facility by dry fusion. The igneous origin of this mineral is also proved by its presence in the lavas of active volcanoes; and in older rocks universally admitted to be pyrogenous. Not only can olivine, considered as a mineral, be unquestionably igneous, but some peridotites, if we are to judge from the investigation of competent observers, as Bonney, Hochstetter, &c., present positive characters of eruption. But while some peridotites are eruptive, it is no less true that many masses of olivine rock present characters from which an igneous origin cannot be demonstrated,[3] and it seems certain that very often true peridotites do not occur in the form of injected veins. From the data collected in the Report it is evident that one may admit for the peridotic rocks two modes of origin, and that the question of origin is on the whole to be decided rather by reference to the position of the rocks in relation to those among which they lie, than by mineralogical composition. Unfortunately, however, this very important element of the relation of the rock to those that encircle it is wanting in the case of St. Paul's Rocks. The rocks stand alone in mid-ocean, and of their connection with other rock masses we can state nothing definite.

"The reason that pleads in favour of the eruptive theory is the law of analogy. We know indeed that the small oceanic islands are either of volcanic or coral formation. May not the peridotite of St. Paul's Rocks be assimilated to the group of crystalline rocks represented by the syenite, diabase, and melaphyres forming the base of several volcanic islands of the Atlantic? An obvious argument in favour of an eruptive origin is afforded by the fact that the bottom of the Atlantic has been for long ages, in many points, the theatre of volcanic manifestations; and in particular, the region in which St. Paul's Rocks are situated has in comparatively recent times shown signs of eruptive phenomena. The isolation of these rocks might be adduced as a further proof of their eruptive origin. The soundings taken between St. Paul's Rocks and the nearest continent and other

[1] See analysis of a decomposed specimen impregnated by phosphate of lime, in Narr. Chall. Exp., vol. ii., App. B., p. 18, 1882.

[2] The Atlantic, vol. ii. p. 106.

[3] See the résumé of the results arrived at by the observers who have described peridotites found as regular intercalations in various formations, in Narr. Chall. Exp., vol. ii., App. B, p. 24, 1882.

Plate VI.

Horsburgh, Edinburgh.

Permanent Phototype.

St. Paul's Rocks.

islands, tend to show that they possess a purely local character, in perfect harmony with the theory of volcanic formation.

What can now be advanced to support the idea that this peridotite belongs to the schisto-crystalline series? We have stated that a great number of peridotites belong to the schisto-crystalline series, and that in respect of their mode of origin they cannot be separated from the rocks with which they are associated. In the peridotite of St. Paul's Rocks the banded structure, the position assumed by the crystals in the mass, their form, in short, all the peculiarities above-mentioned, are characteristically those of the schists. On the supposition that the rock belongs to the schists, we must suppose an upheaval of the earth's crust to have taken place. The beds, of more or less considerable thickness, which formed, on this supposition, the entire mass in which the peridotite was encased, must have risen above the water, and then being attacked by the erosive action of the waves, the outer portions which covered the peridotites have been disintegrated and removed, leaving behind them as a fragment of the primitive mass what we now see as St. Paul's Rocks. It may thus be supposed that, at the point now occupied by these rocks, there formerly rose a mass of ancient rocks, the dimensions of which may have been successively diminished by mechanical and chemical phenomena. Such an interpretation of the history of the locality is opposed neither to the nature of the rocks, nor to the details, still very incomplete, of their geological structure and relations. It is scarcely necessary to add that the opinion which tends to see in St. Paul's Rocks an outcrop of ancient strata, is not antagonistic to that which assigns to the oceanic basins a constancy in the general disposition, maintained during long geological ages. In regard to the possibility of the existence of a continental mass in the Atlantic at periods not very remote from our own, with which St. Paul's Rocks might be supposed to have been connected, it must be confessed that soundings have shown no trace of it, and that St. Paul's Rocks afford no proof of subsidence. There are no sedimentary formations, either fresh water or marine, to point to a greater extent of land surfaces in former geological ages."

Professor A. Geikie[1] and Mr. M. E. Wadsworth[2] have expressed opinions in favour of the probable volcanic origin of St. Paul's Rocks. To Mr. Wadsworth's criticism on his petrographical determinations, Professor Renard has already replied.[3]

St. Paul's Rocks to Fernando Noronha.

On the 29th August, at 7 A.M., the ship cast off from St. Paul's Rocks and proceeded round the islets to obtain soundings, leaving an officer on shore to take the bearing of the ship and masthead angle at each cast of the lead, the only method of fixing the correct position of the soundings. Whilst so employed observations were obtained on board with the dipping needle, and in the afternoon the ship was swung by azimuths of the sun to ascertain the deviation. At 3 P.M. the officer on the islet was recalled, and at 6 P.M. sail was made for Fernando Noronha.

On this section four soundings and two serial temperature soundings were obtained (see Sheet 12).

[1] *Nature*, vol. xxvii. p. 25, 1882.
[2] *Science*, vol. i. pp. 590–592, 1883.
[3] *Bull. Soc. Belge de Microscopie*, pp. 165–178, 1883.

The surface temperature remained nearly uniform at 78°.

The bottom temperatures varied with the depth, the coldest water being found at the deepest sounding, a result quite different from that hitherto obtained in the North Atlantic, where the temperature remained the same, or nearly the same, below 1800 fathoms no matter what the depth was. The lowest temperature registered in the section was 33°·7, the depth being 2475 fathoms.

The serial temperature soundings showed that the isotherms maintained a position as nearly as possible parallel with the surface, the isotherm of 40° being at a depth of 400 fathoms, that of 50° at a depth of 150 fathoms, and that of 60° at a depth of 70 fathoms.

On the 30th August, at Station 110, the velocity of the wind was 15 miles per hour by the anemometer, the force registered being 2. On the 31st, at Station 111, the velocity was 11 miles per hour, the force registered being 2 to 3. During the night of the 1st September, whilst at anchor at Fernando Noronha, the velocity was 9 miles per hour, and during the day on the 2nd, 15 miles per hour.

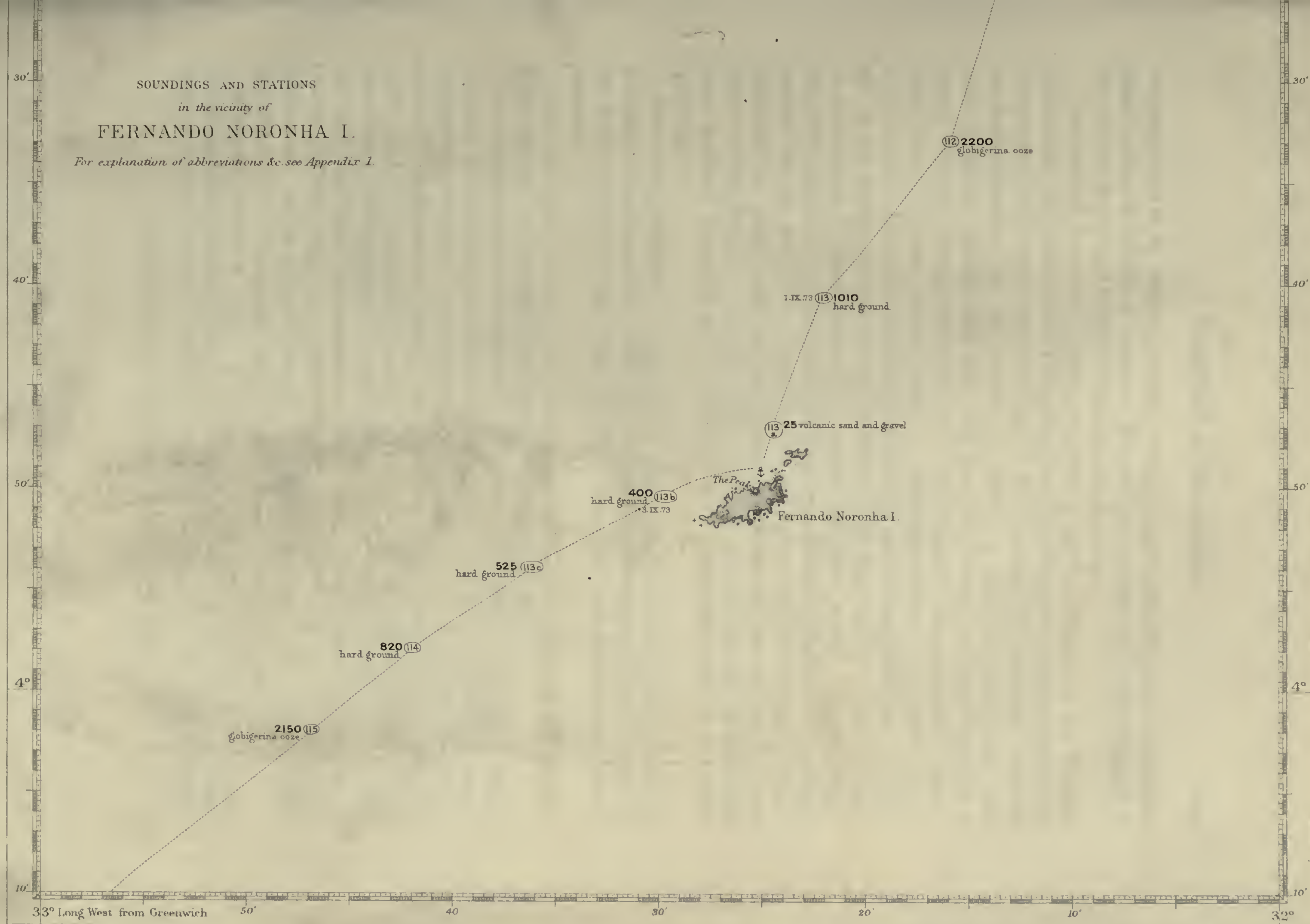
Between St. Paul's Rocks and Fernando Noronha there is a deep depression, the greatest depth recorded being 2475 fathoms. At this depth there was 36 per cent. of carbonate of lime in the deposit, while at the depths of 2275 and 2200 fathoms there were respectively 72 and 81 per cent. This is a good instance illustrating the diminution of carbonate of lime in the deposit with increasing depth, as here the surface conditions were the same, and the character and size of the mineral particles alike in all the soundings. The mineral particles did not exceed 0·05 mm. in diameter, and consisted of felspars, hornblende, augite, magnetite, and vitreous particles. Radiolarians, Diatoms, and fragments of other siliceous organisms made up from 2 to 4 per cent. of the deposits.

On the 1st September, at 6 A.M., the island of Fernando Noronha was sighted, and the day was devoted to obtaining a series of soundings to the shore (see Sheet 14). The ship anchored in San Antonio Bay at 3 P.M.

Fernando Noronha.

The intention was to have remained at this island for a week or ten days, to survey and explore it thoroughly, but, no previous notice having been given to the Brazilian Government, the Commandant would on no account take on himself the responsibility of permitting collections to be made on shore or soundings to be taken adjacent to the coast, although at first he appeared willing to allow this. Under the circumstances it therefore became useless to remain in the neighbourhood, and the ship left on the 3rd September for Bahia.

On the 1st and 2nd a landing was effected on the main island, as well as on the



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outlying islands of St. Michael and Rat. The surf that breaks everywhere on the main island renders it difficult of access; in fact, one of the ship's boats was capsized in Chaloup Bay, but on Rat Island the landing is much easier.

The island of Fernando Noronha is used as a penal settlement by the Brazilian Government. On it were about 1400 prisoners, 160 soldiers, and 4 officers, besides the Commandant or Governor, who at the time of the visit of the Expedition was a major in the Brazilian service. The prisoners are not confined in large buildings, but each man erects a hut for himself with laths and mud, so that the settlement occupies a considerable area. Its appearance would be much improved were more care taken in laying it out; at present, beyond leaving a clear road, but little attention has been paid to this matter. All the prisoners muster at morning and evening parade, and are "told off" in the morning for their allotted work during the day; some to attend the sheep or goats, others to labour in the fields, and others again to fish. The contrivance used by the fishermen is a kind of raft or catamaran, formed of four or five logs lashed together side by side, with a small stool on the top to keep the occupant dry; the catamarans are usually only large enough to support one man, but on one occasion a large one with three men on it was seen. There are no boats on the island, so that escape is almost impossible, as the catamarans are too small and unsafe to live in the open ocean.

There are plantations of sugar cane, maize, cassava, sweet potatoes, bananas, pumpkins, and melons on the island. The latter, both water and marsh, are remarkably fine, both in size and flavour; they cost about threepence each, and a large store was purchased.

From Rat Island the sea was seen to break over some rocks in Sponge Bay half-way to the Brothers, and the whole place appeared to be foul with rocks.

At about the middle of the northern coast of the main island is a remarkable column-like mass of bare rock, which projects to a height of 1000 feet, and is well known to navigators as "the Peak": it forms a most remarkable feature in the aspect of the island as viewed from the sea, and appears to overhang somewhat on one side. One other hill in the island is 300 feet in height. The southwestern extremity of the island runs out into a long narrow promontory, composed of a narrow wall of rock, in which, at one spot near high water line, a quadrangular opening is visible through which the sea dashes in a cascade. This opening, known as the "Hole in the Wall," can be seen from a considerable distance. At the opposite extremity the island terminates in a low sandy point with sand dunes upon it, beyond which stretch the outlying islets already referred to.

Fernando Noronha is thickly wooded, and appears beautifully green from the sea. The principal trees are what Webster,[1] who visited the island in 1828, calls the "laurelled Bara," which has dark green laurel-like leaves, and an abundant milky juice, the exact

[1] Webster, Voyage of the "Chanticleer," vol. ii. p. 331, London, 1834.

nature of which is unknown, as no specimen was procured, and a Euphorbiaceous tree, or rather tall shrub, called by Webster "Jatropha" or "Pinhao" (*Jatropha gossypifolia*). It has a pink flower, and at the time of the visit had only single tufts of young

Fig. 87.—The Peak of Fernando Noronha, sketched from the deck of H.M.S. Challenger, Sept. 3rd, 1873.

leaves immediately beneath the inflorescence, although in full flower. Its bare stems and branches render it a striking object amongst the green of the creepers when the forest is viewed from the sea. Webster says that it casts its leaves in July and August, that is, at the commencement of the dry season. It is evidently the tree mentioned by Darwin as occurring on the Peak.[1]

A horrible pest, a stinging plant, *Jatropha urens*, one of the Euphorbiaceæ, is everywhere very common; it has a thick green stem and leaves, resembling those of our common garden geraniums in shape, and a small white flower, and is covered with fine sharp white bristles, which sting most abominably. To gather specimens they had to be lassoed with a string, kicked up by the roots, and carried on board carefully slung on a stick. The stinging sensation produced by the plant lasts for more than two days, the pain being like that of the nettle, but far more intense.

Mount St. Michael is a conical outlying island mass of phonolite,[2] 300 feet in height. It is comparatively inaccessible, and owing to its steepness has never been cultivated, hence it seemed likely to yield a fair sample of the indigenous flora of the group. Most of the plants collected there proved, when examined at Kew, to be common Brazilian forms, but a Fig Tree (*Ficus noronhæ*) with pendent aerial roots like the Banyan, grows all over the upper parts of the rock, and in favourable spots forms a tree 30 feet in height; it proved to be a new species and peculiar to the island as far as is yet known.[3] A complete investigation of the flora of the group is a most urgent scientific necessity.

There is a dry and a rainy season on the islands, the latter extending from January to July, and the former from July to December. In the dry season there is occasionally want of water, but rain often falls; it rained heavily during the visit of the Expedition on September 2nd.

The principal bird inhabitants of the island were Boobies and Noddies of the same species as at St. Paul's Rocks, but far shyer here, and Boatswain-birds and Frigate-birds (*Tachypetes aquila*); these latter soared high overhead, looking, with their forked tails, like large kites. All these birds nest on the Peak. The woods are also full of flocks of reddish-brown Doves (*Peristera geoffroyi*), a species which occurs in Brazil, and has possibly been introduced into the island. They are in vast numbers, and being scarcely ever shot at, were so tame that stones had to be thrown at them to make them take wing. Many of them had nests and eggs, and they probably breed all the year round.

Two Lizards which are South American in their affinities occur in the islands,[4] *Thysanodactylus bilineatus*, one of the Iguanidæ, occurs also in South America; the genus is distinguished by a scaly projection on the outer side of the hinder toes; this Lizard, which was originally obtained on the island by the officers of H.M.S. "Chanticleer," was not met with. The other Lizard, *Euprepes punctatus*, belongs to the Scincidæ,

[1] Darwin, Journal of Researches during the Voyage of H.M.S. "Beagle," p. 11, ed. 1879.
[2] A typical phonolite composed of sanidine, augite, nepheline, magnetite, noseane, or hauyne and titanite.
[3] D. Oliver, F.R.S., Icones Plantarum, vol. xiii. p. 18, t. 1222.
[4] Gray, British Museum Catalogue of Lizards, p. 193, 1845.

and is peculiar to Fernando Noronha, its nearest ally, *Euprepes maculatus*, inhabiting Demerara; it is very abundant on the main island, and especially so on Mount St. Michael, where it is remarkably tame; some specimens are more than a foot in length. Rev. O. P. Cambridge says that two spiders from Mount St. Michael are *Argiope argentata*, Latr., and *Neon* sp. A new species of Lepidoptera (*Catochrysops trifracta*, Butler) was caught on Rat Island; it is interesting as being of a Malayan type.[1]

The rock at Rat Island is nepheline-basalt. In the southeast part of this island there is a tufa composed of carbonate of lime and of clastic grains of organic and mineral origin. The grains are rounded, and each is bordered with a little zone of calcite; the mineral particles are olivine, basalt, and palagonite. The rock of Platform Island is a felspathic basalt.

Professor Thomson and Mr. Murray dredged during the day in the steam pinnace in depths varying from 7 to 25 fathoms. The bottom was covered with a calcareous sand or gravel, of a mottled red and white colour, the fragments varying from 2 to 3 cm. in diameter, and consisting chiefly of calcareous Algæ with fragments of Echinoderms, Molluscs, Polyzoa, Corals, *Polytrema*, *Amphistegina*, and other Foraminifera.

Fernando Noronha to Bahia.

On the 3rd September, at 9.30 A.M., the ship left Fernando Noronha for Bahia, carrying a line of soundings to the westward to the depth of over 2000 fathoms (see Sheet 14).

During the passage to Bahia the wind for the first few days hung well to the southward, the average direction being S.S.E., force 4 to 5, squally, with passing showers; after passing the parallel of 8° S. it fell light and came more from the eastward.

In consequence of the trade wind being so far to the southward the ship approached the American coast on the 6th parallel, and then steamed along the land to Bahia, keeping at such distances from the shore as seemed suitable for sounding or dredging, and taking advantage of any slant of wind to economise fuel. Several whales were seen on the course southward.

On the 6th September, at Station 117, the Barrieras do Inferno could just be distinguished from the deck at a distance of 27 miles. From Station 117A, where the depth was 500 fathoms, and the distance from the shore 16 miles, the land could be plainly seen, but there were no objects sufficiently prominent to fix the position of the sounding by bearings. Later on the same day a cast was taken in 18 fathoms, 9 miles east of Point Moleque, with the right extremity of the Barrieras do Inferno N. 42° W. (true),

[1] In Mr Butler's paper (*Ann. and Mag. Nat. Hist.*, ser 5, vol. xiii. p. 195, 1884) this species is accidentally stated to be from "Rat Island, Straits of Malacca."

SHEET 15

Engraved by Malby &

Point Moleque N. 87° W. (true), and Formosa S. 36° W. (true), but even at this distance these objects were not readily distinguished (see Sheet 15).

On the 7th the ship was off the Rio Parahiba, where the land is better marked, the town of Parahiba standing on the first elevated land south of the river; some cocoanut trees on its northern side, which serve to point it out when the sun is at its back, and the lighthouse on the reef at the entrance of the river, are excellent marks; but the convent of Senhora di Guia cannot be seen unless the sun be shining on it. The Barreta do Arutu is well marked, and readily distinguished from the northward. At 4 P.M. on the 7th bottom was obtained in 16 fathoms, with Parahiba lighthouse S. 72° W. (true), Parahiba church S. 43° W. (true), and Barra Velha Point N. 53° W. (true), and depths of from 16 to 13 fathoms were obtained until 5.45 P.M., when Barreta do Arutu bore S. 23½° W. (true), Parahiba church S. 64° W. (true), and Parahiba lighthouse N. 51° W. (true), after which a course was steered to the southeastward, and the soundings deepened.

On the 8th September two deep soundings were obtained at distances of 45 miles and 34 miles from the shore at Stations 118 and 119. The ship was then steered towards the land, and Olinda Point sighted at 4 P.M. at a distance of 22 miles. At 6 P.M., when 15 miles from the shore, points could be distinguished with sufficient accuracy to fix the position of the ship by bearings. At this time Olinda summit bore W.S.W. (true), the fort on the S.E. point of Itamaraca Island W.N.W. (true), and a village (probably Catuame) N.W. (true). The ship was then in 22 fathoms, with a sandy bottom, and a course was steered S. (true) 12 miles until 9 P.M., when the depth was again 22 fathoms. From this place the course was S. 14° E. (true) until 4 A.M. on the 9th September, when, by observation, the ship was in lat. 8° 37′ S. and long. 34° 28′ W., the patent log showing 36 miles, since 9 P.M. At 10 P.M., 11 P.M., and midnight, soundings were obtained in 26, 26, and 40 fathoms. After sounding and dredging in lat. 8° 37′ S. long. 34° 28′ W. in 675 fathoms (Station 120) the ship proceeded a little further inshore, and sounded in 500 fathoms (at Station 121); from this position Cape San Agostinho could just be distinguished, distant 27 miles.

On the 10th September, at Stations 122, 122A, 122B, and 122C, the land was visible at a distance of about 23 miles, but the only objects that could be distinguished were the white cliffs of Barra Grande, and they disappeared in the afternoon when the sun no longer shone on them. The ground in this locality was foul, for all the nets sent to the bottom were torn. On the 11th September the land was not seen even from the masthead from Stations 123 and 124 at distances of 40 and 33 miles. On the 12th September, at Stations 125, 126, and 126A, the land about the Rio San Francisco was visible from the masthead at a distance of 17 miles, but not from the deck. On the 13th the land was seen at a distance of 12 miles from the deck between the Rio Real and Conde, appearing as a series of low hills marked here and there with white patches, which were very conspicuous, and would be very useful objects for fixing the position of passing vessels were they shown on the chart. About Conde there is a flat hill with a remarkable tree on its southwest end, and just south of this is a detached hill with a white sandy streak on its face. On the 14th, at Station 128, the sandy hills about Itapua were visible from the deck at a distance of 14 miles.

Between Fernando Noronha and Bahia twenty-two soundings, two serial temperature soundings, and nine trawlings were obtained (see Sheet 15), but for the section between Fernando Noronha and the American coast (Olinda Point, Pernambuco), only seven soundings and the two serial temperature soundings were available, the other depths having been obtained at varying distances from the coast as the ship proceeded southward along the land, from the parallel of 6° S. to Bahia.

The temperature of the surface water averaged from 77° to 78°.

The bottom temperature varied with the depth, as in the section from St. Paul's Rocks to Fernando Noronha, the lowest temperature being obtained at the greatest depth, viz., 34°·3 at 2275 fathoms.

The serial temperature soundings showed that the isotherms of 40° and 45° remained nearly parallel with the surface at depths of 400 and 220 fathoms, but the isotherms between that of 45° and that of 78° at the surface gradually deepened as the American coast was neared.

The current at Fernando Noronha was setting to the westward at an average rate of one mile per hour. On the 9th September, at Station 121, the cutter anchored by the trawl showed the surface current to be running N.N.W. (true), half a mile per hour.

Anemometer observations at Station 115, on September 3rd, showed the velocity of the wind to be 17 miles per hour, its force being registered as 4. On the 4th September, at Station 116, its velocity was 20 miles per hour, the force registered being 3 to 5. On the 6th September, at Station 117, its velocity was 24 miles per hour, and the force registered 4 to 5. On the 11th September, at Stations 123 and 124, its velocity was 9 miles per hour, and the force registered 2.

On the 14th September, at 6 A.M., the land about Bahia was sighted, and after obtaining a sounding the ship was steered in for the harbour. At noon the south end of the San Antonio Bank was rounded, and the coals having come to an end, the sea breeze had to be waited for to carry the vessel into port. Whilst waiting for the wind the ship was surrounded by myriads of butterflies, principally *Heliconius narceus*, but after the sea breeze set in, at 1 P.M., they nearly all disappeared. At 4.30 P.M. the ship anchored in the harbour.

Between Fernando Noronha and the American coast there is a deep depression, in which a depth of 2275 fathoms was obtained; and comparatively deep water extends to within 30 miles of the American shore.

The deposits along the coasts of Brazil differed in colour from those which the Challenger found along other continental shores. Here they were red, due, apparently, to the large quantities of ochreous matter carried into the sea by the Brazilian rivers. Usually the colour of deposits along continental shores is blue, with a surface layer of a red or brownish colour. The carbonate of lime in the soundings off this coast varied from 60 to 6 per cent. according to depth, distance from the coast, and whether or not opposite the *embouchures* of rivers. The mineral particles consisted of fragments of quartz, plagioclase, felspars, sometimes kaolinized, epidote, mica, augite, hornblende, fragments of rocks and vitreous particles, the size varying from 0·05 to 1 and 2 mm. in diameter. Radiolarians and Diatoms were nearly, if not quite, absent from these deposits, and when present they, along with siliceous Sponge spicules, did not appear to make up over 0·5 per cent. of the whole deposit. The apparently complete absence of glauconite along this coast was also remarkable.

The various dredgings and trawlings along the coast were very successful, and yielded a large number of new species belonging to nearly all the invertebrate groups. Here the first specimens of a new genus of fish, *Bathypterois,* were procured, of which Dr. A. Günther, F.R.S., remarks :—

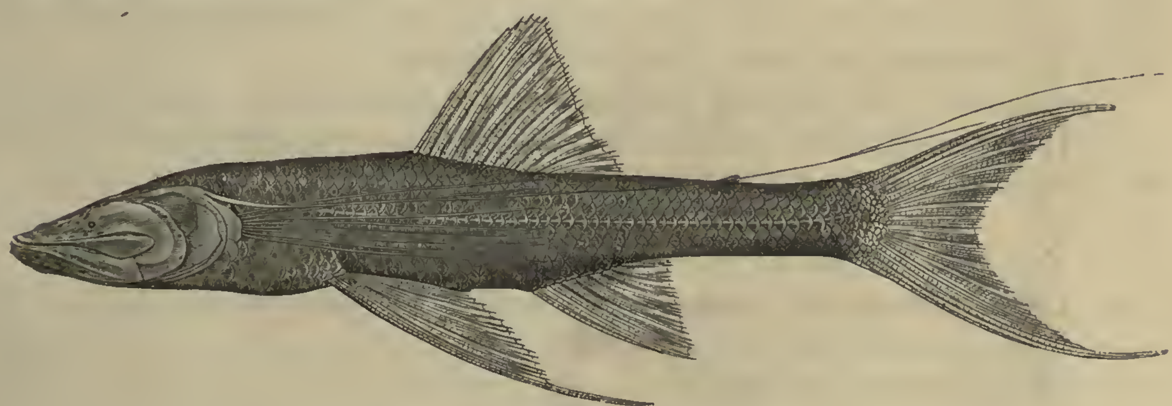


Fig. 88.—*Bathypterois longipes*, Günth.

Bathypterois.—" The fishes of this singular Scopeloid genus have retained much of the outward appearance of surface fishes, and without knowing their origin, we might take them as equally well organised for life in some quiet dark water near to the surface. They resemble somewhat a smelt in general contour of the body, which is covered with cycloid scales, more or less firmly adherent and of moderate size. The head is scaleless, ending in a depressed snout, with wide mouth, the lower jaw projecting beyond the upper. The teeth are very small, in villiform beads ; the eyes rudimentary.

" Very curious is the modification of the pectoral rays, which are much elongated, some of the upper even being separated from the remainder of the fin, and forming a distinct division. These rays are evidently tactile organs, by means of which the fish can examine and discriminate objects which are hidden in the ooze, and which it could not detect with its imperfect organ of vision. Several species were discovered in the South Pacific as well as the South Atlantic, at depths varying from 520 to 2650 fathoms."

When taken from the trawl these fishes were always dead, and the long pectoral rays were erected like an arch over the head, requiring considerable pressure to make them lie along the side of the body; when erected they resembled Pennatulids like *Umbellula*.

On the voyage from the Cape Verde Islands to Bahia the tow-net was worked with greater regularity and more successfully than during the early part of the cruise. The method of lowering and towing it at depths of 50 and 100 fathoms beneath the surface while the ship was dredging and sounding was adopted, and proved a great success. In this way many animals were taken during the day which had previously only been captured on the surface at night.

Except during calm weather, very few animals were found near the surface in the day time. Mr Murray's researches led him to conclude that the great majority of pelagic organisms live at various depths down to, and even deeper than, 100 fathoms during the day time and rough weather, and only come to the surface during the night and in calm weather. In this trip along the course of the Guinea and Equatorial Currents pelagic life was much more abundant and varied, both in individuals and species, than anywhere else in the North or South Atlantic.

The occurrence of the following organisms was noted during the trip. The greatest profusion of life was observed in the Guinea Current during calms, when the sea literally teemed with life, and the most magnificent displays of phosphorescent light occurred at night.

Trichodesmium, and other Oscillatoriæ.
Large specimens of *Coscinodiscus* and other Diatoms, free and attached to Copepods and other organisms.
Rhabdospheres, Coccospheres.
Pyrocystis noctiluca and *Pyrocystis fusiformis.*
Amœba and amœboid particles.
Peridinium tripos (single and in catena), and other species.
Vorticella, *Acineta*, *Podophrya* (on Pteropod shells), and other Infusoria.
Many Radiolaria (compound and simple).
Pulvinulina, *Sphæroidina*, *Globigerina*, *Hastigerina*, *Orbulina*, *Candeina*, and *Pullenia*.
Hydromedusoid stocks (on Pteropod shells).
Hydromedusæ.
Physalia, *Diphyes*, *Velella*, *Porpita*, and many other Siphonophora.
Semper's Cœlenterate larva.[1]
Scyphomedusæ.

[1] *Zeitschr. f. wiss. Zool.*, Bd. xvii. pp. 407–411, 1867.

Bipinnaria (with young starfish).
Echinid, Ophiurid, and Holothurian larvæ.
Planaria, *Distoma* (on *Sagitta*).
Sagitta (many with *Gregarinæ*).
Sipunculid larvæ.
Terebella, *Polynoe*, *Alciope*, *Tomopteris*, Aphroditacean and other Annelid larvæ.
Tornaria.
Corycæus, *Saphirina*, *Copilia*, *Setella*, and other Copepods.
Cythere, *Halocypris*, and other Ostracodes.
Hyperia, *Phronima*, *Rhabdosoma* and other Amphipods.
Squillerichthus.
Mysis, *Euphausia*.
Sergestes, *Leucifer*, *Amphion*, Phyllosoma, zoeas of Crabs.
Halobates.
Hyalea, *Cleodora*, *Cymbulia*, *Pleuropus*, *Spirialis*, *Pneumodermon*, *Styliola*, and other Pteropoda.
Ianthina, *Atlanta*, *Carinaria*, *Pterotrachea*.
Phylliroë, *Acura*, *Scyllæa*, *Glaucus*, and larvæ of other Gasteropods.
Cranchia, and other small Cephalopods.
Pyrosoma, *Salpa*, *Doliolum*, *Appendicularia*, *Fritillaria*.
Sternoptyx, small Scopelids, *Leptocephalus*, young Pleuronectids (*Plagusia*), young of *Exocetus*, other larval fish, and fish eggs.

The Radiolaria.—Professor Haeckel, who is engaged in the preparation of a detailed Report on the Radiolaria, which will shortly be published, has revised and amended the following notes on this group by Mr Murray :—" Of all the classes of marine animals, of which our knowledge has been extended by means of the acquisitions gained by the Challenger Expedition, the Radiolaria must be admitted to be, without doubt, amongst the richest and most interesting. Up to the time of the Expedition scarcely more than 600 species of this remarkable class of Rhizopoda had been recognisably described or portrayed, of which about one half were recent and one half fossil.

" The number of new species which Professor Haeckel has hitherto been able to distinguish in the rich collection brought home by the Challenger, amounts to more than three times this number, viz., over 2000. Amongst these are found not only very many highly curious and delicate forms, but also a great number of new types, which throw a bright light on the morphology of the whole class, and, as phylogenetic documents, have a special interest for the students of evolution.

" Our knowledge of the Radiolaria, which now appear to be the richest and most varied in form of all the classes of Protozoa, is scarcely more than half a century old. In

1834, Meyen made the first communication upon two Rhizopoda belonging to this group, *Physematium* and *Sphærozoum*, for which he constituted a special class of Infusoria (Palmellaria). In 1838, Ehrenberg described some fossil siliceous species, under the name *Polycystina*, and made the discovery eight years later (in 1846) that masses of rock in the island of Barbados contained a very large number (more than 300 species) of similar delicately perforated flinty skeletons. Ehrenberg subsequently discovered a great number of other skeletons belonging to this group, some of these being fossil in Tertiary formations, and others being found in deep-sea soundings. He concluded, wrongly, that these were the shells of highly organised animals related to the Polyzoa and Echinodermata.

"The first accurate observations and correct views upon living Radiolarian organisms we owe to Professor Huxley,[1] who, in 1851, carefully described several species, under the name *Thalassicolla*. Those examined by him in a living condition were partly solitary forms (really belonging to the present genus *Thalassicolla*), partly social forms (of the genera *Collozoum*, *Sphærozoum*, *Collosphæra*, *Siphonosphæra*). These Huxley recognised as Protozoa, from their being equivalent to single cells, and rightly described their central nuclei, also the vacuoles in the surrounding jelly, the yellow cells, &c.

"A far greater number of living species was soon after described by Johannes Müller of Berlin, who had observed them alive, during a period of ten years, especially in the Mediterranean. He observed, for the first time, the pseudopodia forming an anastomosing network, and radiating outwards from the unicellular body, and the flowing of the granules along them. This movement he compared, rightly, with that in the Foraminifera. His numerous and important discoveries he collected, shortly before his death, in his classic treatise, which appeared in 1858.[2] All these various forms, the discoveries for the most part of himself, were united by Joh. Müller under the name Radiolaria, and, as siliceous *Rhizopoda radiaria*, placed in opposition to the calcareous *Rhizopoda polythalamia*.

"The knowledge of the Radiolaria acquired by Joh. Müller was greatly extended by one of his pupils, Professor Ernst Haeckel of Jena, who published, in 1862, an exhaustive monograph of this group.[3] He first distinguished, as two principal constituents of the Radiolarian organism, the inner central capsule and the outer extracapsular sarcode with the pseudopodia. He gave the comparative morphology of the skeleton. In his classification fifteen families, containing 113 genera, were distinguished.

"The reproduction of the Radiolaria by means of swarmspores, which arise in the central capsule, was first clearly observed by Cienkowski in 1871.[4] He first propounded

[1] *Ann. and Mag. Nat. Hist.*, ser. 2, vol. viii. pp. 433–442, 1851.

[2] Ueber die Thalassicollen, Polycystinen und Acanthometren des Mittelmeeres, *Abhandl. d. k. Akad. d. Wiss. Berlin*, pp. 1–62, 1858.

[3] Monographie der Radiolarien, Berlin, 1862.

[4] Ueber Schwärmerbildung bei Radiolarien, *Archiv f. mikrosk. Anat.*, vol. vii. pp. 372–381, 1871.

the view, afterwards corroborated, that the yellow cells, which are to be found in the jelly round about the central capsule, do not belong to the organism itself, but are parasites or rather 'Symbiontes,' like the Gonidia of Lichens.

"The histology of the Radiolaria, which offers peculiar and difficult relationships, was first interpreted by Professor Richard Hertwig, a pupil of Haeckel. He published, in 1876,[1] the first accurate account and correct interpretation of their cell-nuclei, and demonstrated that the whole organism, in spite of very peculiar modifications, is to be regarded merely as a single cell. In his work, published in 1879,[2] Hertwig undertook a reformation of the whole classification of the Radiolaria, based upon important discoveries with respect to the structure of the central capsule, and divided the class into six different orders.

"Meanwhile Professor Ernst Haeckel had, in 1876, commenced the investigation of the extraordinarily rich material collected by the Challenger. The preliminary account of his investigations, and the changes which they rendered necessary in the current classification, were published by him in October 1881,[3] shortly before his journey to Ceylon. He then distinguished twenty-four families, including 630 genera. In 1883 Haeckel expounded the relationship of these families, and their arrangement, on phylogenetic grounds, in four primary groups.[4]

"Professor Bütschli gave, in 1882,[5] a good synopsis of all previous observations on the Radiolaria, as well as a number of valuable original investigations upon their siliceous skeletons. St. George Mivart had already, in 1877, given a short review of the subject in the Journal of the Linnean Society.[6]

"The morphology of the Radiolaria is now so thoroughly understood that we are no longer in doubt as to their relationship to the other Protozoa. It is certain that they are true Rhizopoda, distinguished from the other classes of this group (Foraminifera, Heliozoa, Lobosa) chiefly by the remarkable separation of their unicellular body into two principal constituents, namely, the inner 'central capsule' and the externally situated 'extracapsularium.'

"The important central capsule is a highly-organised cell, which is surrounded by a special membrane, and encloses one or more nuclei in its protoplasm, and sometimes other bodies in addition, such as oil-globules, crystals, pigment-granules, &c. At the time of reproduction, numerous swarmspores are developed in it, which are set free by the bursting of the capsule, and swim about by means of a flagellum.

"The extracapsularium consists of a voluminous gelatinous 'involucrum,' which encloses the central capsule, and numerous fine pseudopodia, which radiate through

[1] Zur Histologie der Radiolarien, Leipzig, 1876.
[2] Der Organismus der Radiolarien, *Denkschr. d. med.-nat. Gesellsch. Jena*, Bd. ii. p. 129, 1879.
[3] *Jenaische Zeitschr.*, Bd. xv. pp. 418–472, 1881.
[4] *Jenaische Sitzungsb.*, Feb. 16, 1883.
[5] Bronn, Klass. u. Ord. d. Thierreichs, Bd. i. Aufl. 2, 1882.
[6] *Journ. Linn. Soc. Lond.* (Zool.), vol. xiv. p. 136, 1877.

this outwards, from a thin layer of sarcode immediately surrounding the capsule. Outside the gelatinous envelope the pseudopodia form a network, and show the same granular movement as in other Rhizopoda, by means of which nutrition, locomotion, and perception are carried on. Their extreme terminations are free radial threads. Oil-globules, pigment-granules, vacuoles, &c., not unfrequently occur in the extra-capsularium.

"In many Radiolaria, but by no means in all, are found, in addition to these, scattered round about the central capsule, numerous yellow cells, which contain starch. These have been lately recognised as unicellular Algæ (*Zooxanthellæ*), which live in a state of symbiosis with the Radiolaria, just as do the Gonidia with the Lichens. They also have an independent power of reproduction.

"The inner protoplasm, which is enclosed in the central capsule, is intimately connected in two different ways with the outer sarcode which surrounds it. In the Holotrypasta (Acantharia and Spumellaria) the membrane is everywhere perforated by numberless small pores, through which the two communicate. In the Merotrypasta (Nassellaria and Phæodaria), on the contrary, there is only a single large opening in the capsule, through which the pseudopodia protrude. There are, however, not unfrequently found, beside this, two or more small accessory openings.

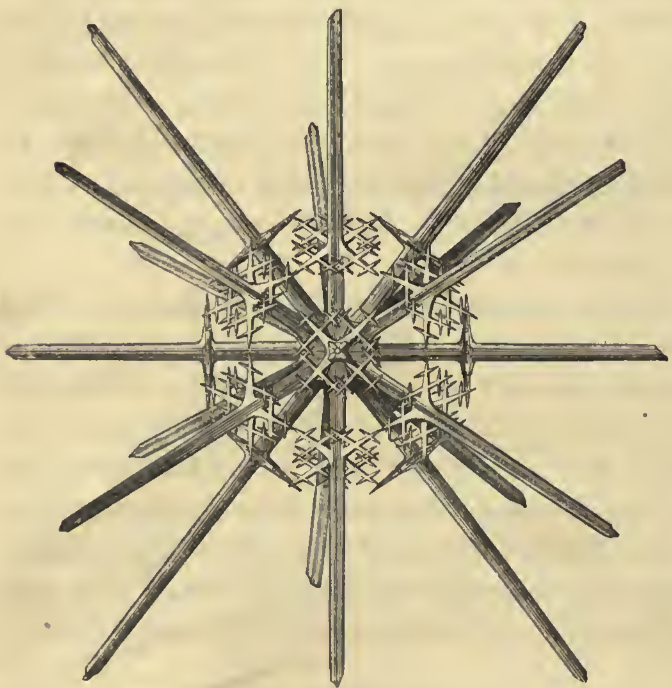


FIG. 89.—*Xiphacantha murrayana*, n. sp.

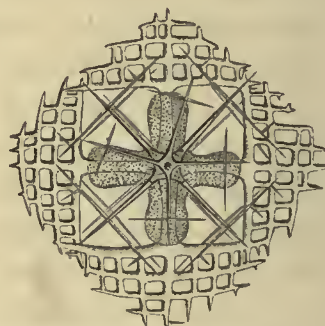


FIG. 90.—*Lithoptera darwinii*, n. sp.

"The great majority of Radiolarians, with indeed few exceptions, are remarkable for skeletons of the most varied and delicate forms. In one order (the Acantharia) these consist of acanthin, a peculiar organic substance related to chitin; in the other three orders, on the contrary, of silica or an organic silicate. In the Phæodaria the separate siliceous portions which constitute the skeleton are, for the most part, hollow tubes, but in the Spumellaria and Nassellaria (which are often united under the name Polycystina) they are solid rods or threads. In some cases the skeleton exists only outside the central capsule, whilst in others it is also found within it. The skeleton presents in most cases the appearance of a delicate lattice-work, and is armed with spines often resembling that of Sponges.

"The geometrical figure of the Holotrypasta is fundamentally a sphere (homaxon), but in the Merotrypasta it is conical or egg-shaped (monaxon).

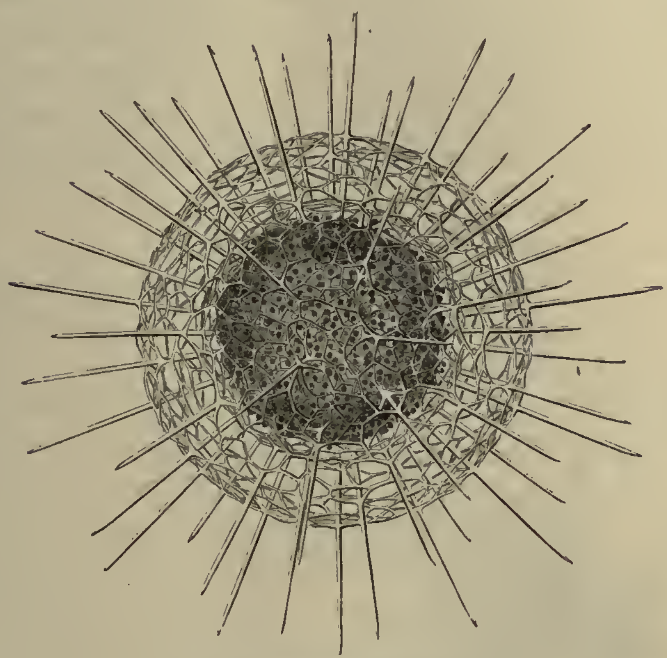


Fig. 91.—*Haliomma wyvillei*, n. sp.

Fig. 92.—*Hexancistra quadricuspis*, n. gen. et sp.

"The Acantharia, which are distinguished from all other Radiolaria by their organised skeleton of acanthin, have, for the most part, a spherical central capsule, whose simple membrane is everywhere perforated by fine pores. Their nucleus becomes early divided into numerous small spore-nuclei; and the skeleton always consists

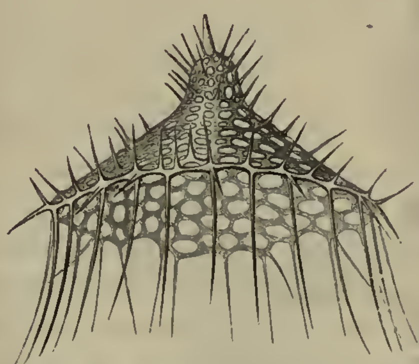


Fig. 93.—*Eucoryphalus huxleyi*, n. sp.

Fig. 94.—*Cinclopyramis murrayana*, n. gen. et sp.

of numerous radial spines, which meet in the centre of the capsule. In most cases, twenty such spines are present, and in accordance with a curious law, discovered by Johannes Müller, these are geometrically divided into five zones, each containing four of these spines (figs. 89, 90). In the Acanthometræ these give rise to no special perforated shell, whilst in the Acanthophractæ this is developed into many varied and delicate forms.

"The Spumellaria include that large group of Radiolaria whose simple capsular membrane is perforated by minute pores, and whose nucleus divides only at a later

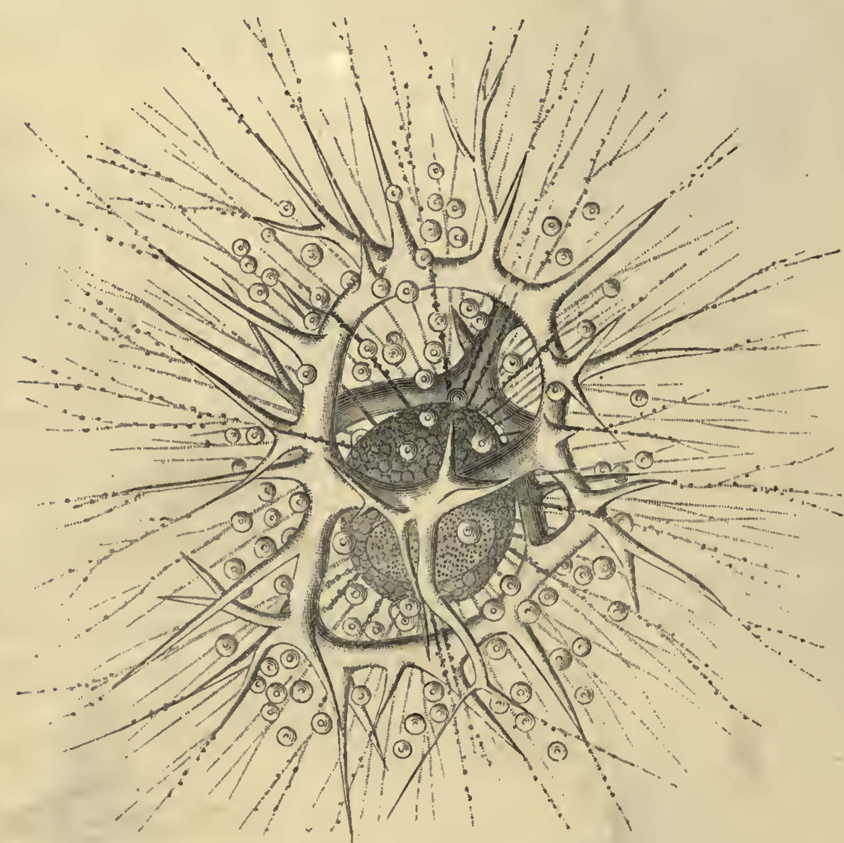


Fig. 95.—*Lithocoronis challengeri*, n. gen. et sp.

stage (at the time of reproduction) into numerous spore-nuclei. In only a few families (Thalassicollida, Collozoida) the skeleton is entirely wanting, or is reduced to single scattered spicules (Thalassosphærida, Sphærozoida). The skeleton usually consists of a latticed sphere (Sphæroida), which is developed into multifarious forms—stars, disks, concentric, sponge-like, flinty shells, &c. (see figs. 91 and 92). These are often rendered conspicuous by radial spines and processes of curious and varied form.

"The Nassellaria are distinguished from the two preceding groups by the peculiar structure of their central capsule, from which the pseudopodia protrude only at a perforated spot at one end of the longitudinal axis. The nucleus divides only at a late stage into numerous small spore-nuclei. The variously shaped skeletons consist mostly of a bell-shaped or conical perforated case, as in the Cyrtellaria (figs. 93, 94, 96). More rarely it consists only of a ring, or of a triradiate frame or a loose network of siliceous rods, as in the Plectellaria (see fig. 95). The principal division of this order is constituted by the family Cyrtida, in which the perforated shell is elongated in the direction of the principal axis, and is separated by one, two, or more constrictions into two, three, or more segments (see figs. 93, 94, 96).

"The Phæodaria have, like the foregoing group, only one primary opening for the protrusion of the pseudopodia, but there are usually, in addition, two (rarely, however, more) accessory openings. Around the primary opening, and outside the capsule, there is always a large mass of blackish or greenish-brown pigment, the 'Phæodium.' By means of this and of the double membrane of the central capsule, these are distinguished from all other Radiolaria. They are also, for the most part, much larger, and their flinty skeleton usually consists of hollow tubes. Up to the year 1872 only three genera of Phæodaria were known, namely, those described in 1862 by Professor Haeckel, under the designations *Aulacantha*, *Aulosphæra*, and *Cœlodendrum*. During the Challenger Expedition, however, a great number of new genera and species were discovered, many with very curious siliceous skeletons, these being, for the most part, inhabitants of the deep sea. The most remarkable of these are, perhaps, the Challengerida, several forms of which were briefly described and figured by Mr. Murray in 1876;[1] a number of species of two genera (*Challengeria* and *Tuscarora*) are shown in Pl. A. The unicellular, egg-shaped case has a peculiar structure, resembling that of the Diatomaceæ (Pl. A. figs. 1–7), and is, in most cases, armed about the mouth with spines and hollow tubes (Pl. A. figs. 1–12).

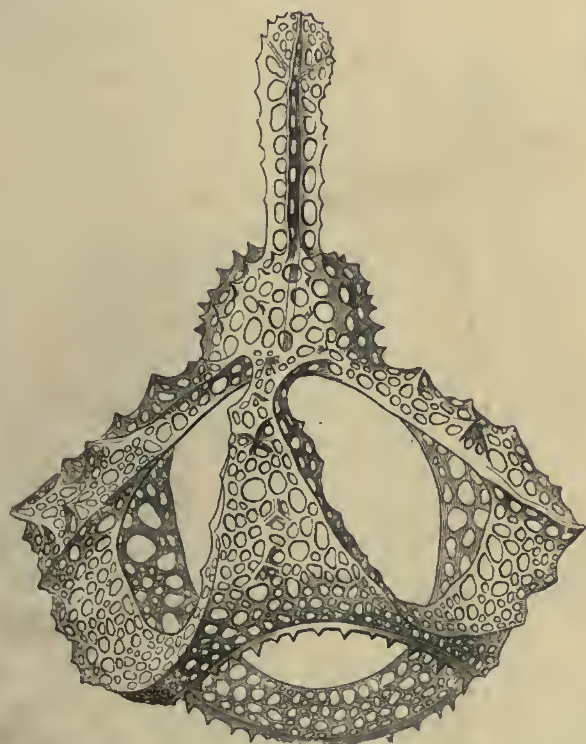


Fig. 96.—*Clathrocanium reginæ*, n. sp.

"The majority of the Radiolaria are found near the surface of the open ocean, where they frequently appear crowded together in large numbers. Many species are, however,

[1] *Proc. Roy. Soc.*, vol. xxiv. p. 535, 1876.

inhabitants of the deep sea. Still more astonishing are the vast numbers of their skeletons and shells which are found in the deposits at great depths, especially between 2000 and 4000 fathoms, and even to the greatest known depths. The area of their richest distribution is the tropical zone of the Pacific Ocean, between latitudes 20° N. and 10° S., and longitudes 140° W. and 140° E. At many of the Challenger Stations (particularly 225, 226, 266 to 274) the chief part of the deposit at the bottom of the sea

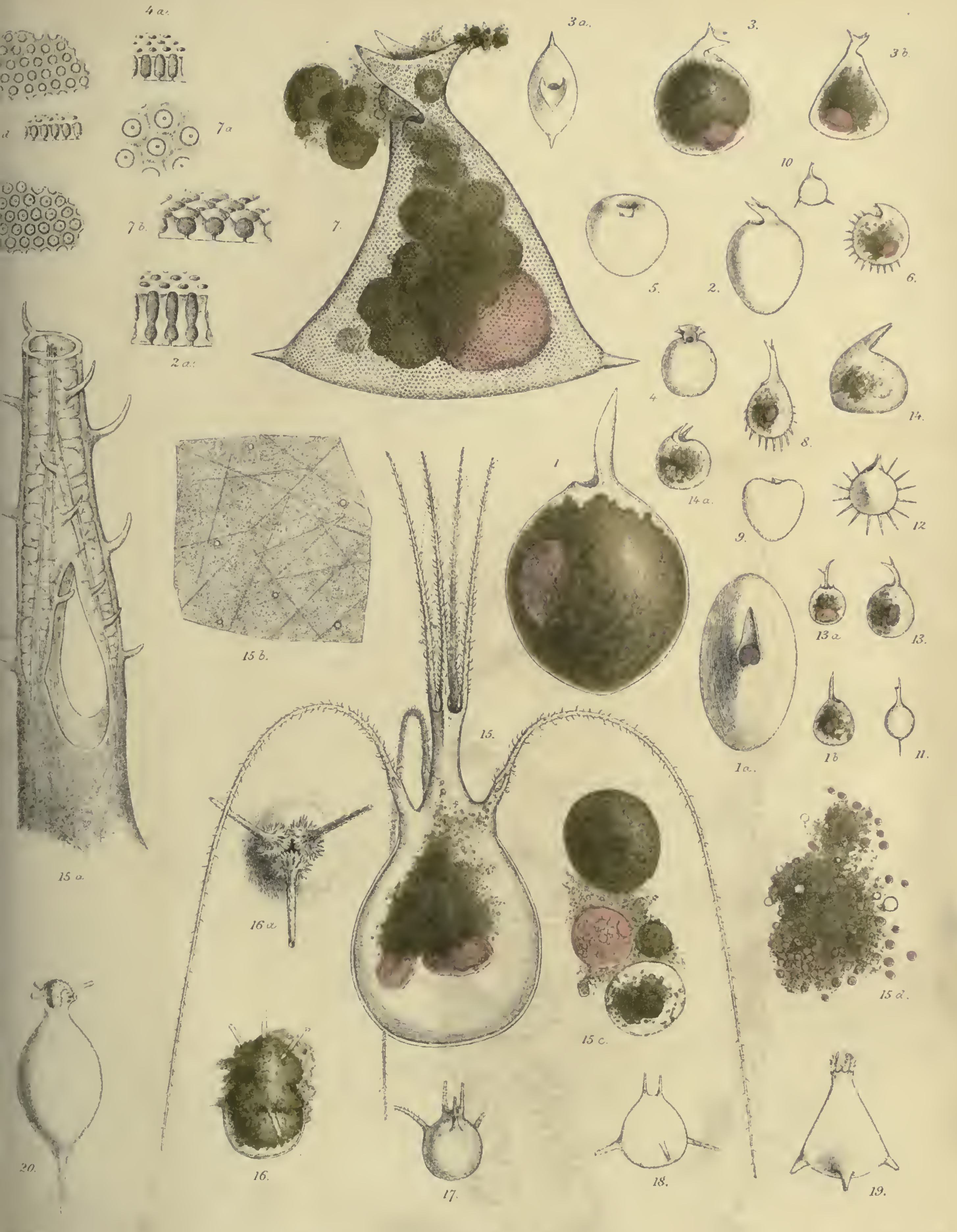
Explanation of Plate A.

Figs. 1-14. *Challengeria.*

Fig. 1. *Challengeria naresii*, seen from the flat side; magnified 60 diameters.
Fig. 1*a*. The same, seen from the upper surface; magnified 60 diameters.
Fig. 1*b*. Dwarf variety; magnified 60 diameters.
Fig. 1*c*, *d*, *e*. Portions of the shell, showing the pores; magnified 940 diameters.
Fig. 2. *Challengeria thomsoni*, seen from the flat side; magnified 60 diameters.
Fig. 2*a*. Portion of the shell, showing the pores; magnified 940 diameters.
Fig. 3. *Challengeria macleari*, seen from the flat side; magnified 60 diameters.
Fig. 3*a*. The same, seen from the upper surface; magnified 60 diameters.
Fig. 3*b*. Variety; magnified 60 diameters.
Fig. 4. *Challengeria aldrichi*, magnified 60 diameters.
Fig. 4*a*. Portion of the shell, showing the pores; magnified 940 diameters.
Fig. 5. *Challengeria bromleyi*, magnified 60 diameters.
Fig. 6. *Challengeria bethelli*, magnified 60 diameters.
Fig. 7. *Challengeria tizardi*, seen from the flat side; magnified 200 diameters.
Fig. 7*a*, *b*. Portions of the shell, showing the pores; magnified 940 diameters.
Fig. 8. *Challengeria carpenteri*, magnified 60 diameters.
Fig. 9. *Challengeria campbelli*, magnified 60 diameters.
Fig. 10. *Challengeria balfouri*, magnified 60 diameters.
Fig. 11. *Challengeria swirei*, magnified 60 diameters.
Fig. 12. *Challengeria channeri*, magnified 60 diameters.
Fig. 13. *Challengeria havergalli*, magnified 60 diameters.
Fig. 14. *Challengeria harstoni*, magnified 60 diameters.
Fig. 14*a*. Variety; magnified 60 diameters.
The species of *Challengeria* are named after the naval officers of the Expedition.

Figs. 15-20. *Tuscarora.*

Fig. 15. *Tuscarora belknapi*, magnified 20 diameters.
Fig. 15*a*. Basis of a tubular spine, magnified 200 diameters.
Fig. 15*b*. Small portion of the shell, magnified 200 diameters.
Fig. 15*c*. Central capsule and lumps of the phæodium, magnified 400 diameters.
Fig. 15*d*. Granules of the phæodium, magnified 140 diameters.
Fig. 16. *Tuscarora bisternaria*, magnified 10 diameters.
Fig. 16*a*. The same, mouth with three tubular spines, magnified 20 diameters.
Fig. 17. *Tuscarora tubulosa*, magnified 10 diameters.
Fig. 18. *Tuscarora porcellana*, magnified 10 diameters.
Fig. 19. *Tuscarora tetraedra*, magnified 10 diameters.
Fig. 20. *Tuscarora cygnea*, magnified 10 diameters.



CHALLENGERIDA (PHÆODARIA)

1-14, Various species of Challengeria. 15-20, Various species of Tuscarora.

was composed of the remains of Radiolaria, and these deposits have consequently been called Radiolarian ooze. The well known chalk-like rock from the island of Barbados and the Nicobar Islands resembles in many respects a Radiolarian ooze, and a somewhat similar formation is also found in parts of Greece, Sicily, and other places; it is chiefly made up of the delicate, and in most cases wonderfully preserved, perforated skeletons of Polycystina (Spumellaria and Nassellaria).

"It has been stated (p. 216) that the method of lowering the tow-net and dragging it at a depth of 50 and 100 fathoms proved a great success. No attempt was, however, made to drag the nets at still greater depths till the Expedition reached the western part of the Pacific, south of Japan, when they were lowered to 900, 1000, and even 2000 fathoms, and subsequently these nets were attached to the trawl, the dredge, and different parts of the dredging line. The immediate result of these experiments was the discovery of a large number of Rhizopodal organisms not hitherto met with in the shallower water, the most characteristic of which were the Phæodaria. The net never failed to bring up some of these species when sent down to great depths, in both the Pacific and Atlantic; but, on the other hand, they were never met with when the net was dragged within 100 fathoms of the surface, except on one or two occasions in the Antarctic Ocean."

Bahia.

The Expedition remained at Bahia ten days, the departure being somewhat hastened owing to one of the crew, who had been sleeping on shore, having caught yellow fever, from which he afterwards died. Yellow fever is nearly always prevalent at Bahia, nor can this be wondered at when the absence of sanitary arrangements in some parts of the town is considered, the streets having in many places no drains. Viewed from the sea, Bahia is a charmingly situated place.

Lying here during the stay was a small Brazilian ironclad of about 1000 tons, armed with two 150-pounder rifled guns and two 68-pounder smooth bores. The vessel had been engaged in the Paraguay war, and was reported to be a good one for river work or coasting in smooth water, but a bad sea boat; in fact the sister ship was swamped and went down, but the number of the crew lost could not be ascertained.

San Marcello do Mar, a circular fort built on a detached rock off the landing place, is used as a school for boys entering the Brazilian navy.

Into the wide bay of Bahia, which is twenty miles across in the broadest part, open several navigable rivers, on two of which steamers ply regularly. The Peruaguacu, the largest of these, is navigable for fifty-four miles up to a town called Caxoeira. At Caxoeira a railway was in process of construction. The English engineer of the line, Mr. Hugh Wilson, most hospitably offered to provide free passes by the steamer to Caxoeira, and the use of his own mules, and a guide for a trip thence up country, to any of the naval officers or members of the scientific staff. The invitation was accepted by Mr. Moseley, whose account of the excursions is as follows :—

"The river steamers are small paddle-boats, old and dirty. The Caxoeira boat was crowded with passengers, mostly Brazilians and negroes, but amongst them several German Jews going up to buy diamonds.

"The bay has all the appearance of an inland lake, there being several islands scattered about in it covered with green to the water's edge. Near its mouth the banks of the river are somewhat low but backed by hills, and here and there are mangrove swamps. As the river was ascended the hills and cliffs on either hand soon became higher. They are thickly covered with vegetation, but with cliffs and occasional rock masses showing out bare amongst it.

"The scenery on the whole is not unlike that of the Rhine, except that there are no castles ; but the white buildings of sugar estates perched here and there on the tops of the lower hills take their place. The far-off hills appear of the usual bluish green due to distance, and successive ranges become gradually yellower as they lie nearer to the eye of the observer, and show more and more plainly the forms of the vegetation clothing them ; only in the actual foreground do the palms and feathery bamboos, planted in long lines as boundaries, distinguish the scenery as tropical. The bamboos are especially conspicuous, from the bright yellow green of their foliage. The steamer left Bahia at 10 A.M., and reached Caxoeira at 4 P.M.

"Caxoeira consists of two towns, one on each side of the river, and both have the usual white-washed houses and two or three churches, one broad street and several narrow ones, with mostly dirty dilapidated two-storied houses, tailing off towards the country into one-storied hovels. On the river, canoes hollowed out of a single tree trunk, simple and trough-like in form and pointed at both ends, and large enough to contain six persons, ply between the town and its suburb.

"The hotel at which the night was spent consisted of a restaurant below and a long barn-like chamber above, with a passage down the middle, and a series of small bed-chambers on either hand, enclosed by partitions about twelve feet in height. As one lay in bed one looked up at the bare rafters and tiles, and was apt to receive unpleasant remembrances from the bats. Sleeping places arranged in the same manner are to be found in an hotel at Point de Galle, Ceylon, and it is closely similar in all Japanese houses. The great disadvantage is that the guest has to put up with the snorings and conversations of all in the hotel.

"In the evening, just outside the town, in a pond, a number of small toads were making a perfectly deafening noise. The sound is like a very loud harsh cat's mew, and it was difficult at first to believe that it could come from so small an animal. It is, however, not unlike the extraordinary moan made by the fire-bellied toad of Europe (*Bombinator igneus*), but much louder and with more distinct intervals between the sounds. The frog tribe made a horrible noise at night at Caxoeira, a Bull Frog (*Rana pipiens*) shouting the loudest with a deep bass voice.

"The trip commenced the next morning. It was to be to Feira St. Anna, about 28 miles from Caxoeira, to see the great fair held there every Monday, and from thence down to St. Amaro, a town on another river running into the bay, whence steamer could be taken for Bahia. Caxoeira, Feira St. Anna, and St. Amaro form with each other roughly an equilateral triangle, being each distant from the other about eight leagues.

"The guide was a German, who acted as interpreter on the railroad. He spoke English, French, Italian, Spanish, and Portuguese, and had been in Brazil about twelve years. He was a wild sort of young fellow, and had undergone various vicissitudes of fortune, having been once reduced to selling jerked beef, and once having been a dancing-master. He was a capital merry companion, knowing everyone on the road and having a joke for all.

"Our party rode extremely well-broken mules of large size, that ambled along, rendering it no labour to ride. The mules much prefer their natural rough trot to ambling, and try to make a tyro at mule riding put up with it. But a valuable animal would soon be ruined by letting him get into bad habits, and the regular thing to do is to dig in the spurs and jerk back his head with the bit at the same time. This receipt never fails to make the poor brute so thoroughly uncomfortable that he ambles as softly as possible at once.

"The road led up the steep side of the river valley to the table land above. From the top of the hill there is a fine view of the river and its valleys, and the white town below. Some trees, the leaves of which turn scarlet before dropping, set off the green of the rest of the landscape. In their action on foliage and plant life generally, the wet and dry seasons take the place of summer and winter at home, and many plants become bare of their leaves at the dry season, and only burst out again into leaf at the commencement of the wet season. This condition is far more marked in other regions of South America. Humboldt observed that certain trees anticipated the coming wet season, and put out their leaves some weeks before there was any appearance of its approach.

"The road was very much like an English green lane; in places quite a slough of mud, in others dry and sandy; it was broad, but usually more or less overgrown with grass and weeds, with a narrow track picked out along the best ground by the mules. There were numerous cottages along the road, and fields of tobacco, maize, and cassava. Every now and then a bit of wood was passed with beautiful flowers growing about it, and amongst them numerous forms of Melastomaceæ, with their characteristic three-veined leaves.

"Here were seen most of the plants collected at Fernando Noronha growing as road-side weeds. As we rode on, a splendid *Iguana*, about three feet in length, ran across the road, the brilliancy of which was astonishing.

"Every now and then a village was passed. In the first, as it was Sunday, the villagers were enjoying a cock-fight; every villager keeps a fighting-cock. Good Lisbon wine is sold along the road; the drinking-places consist of a hole about a yard square in the gable end of the usual mud-walled cottage, placed at such a height as to be convenient to a man on horseback, who thus gets his drink without dismounting. Ladies travel along the road either in the saddle or in a sedan chair slung between two horses or mules by means of a long pole.

"A thick growth of myrtles and shrubs which was passed, was pointed out as having been the hiding-place of a notorious highway robber, a negro named Lucas, who used to waylay merchants on their way to the fair at St. Anna; he was the terror of the district, and committed several murders and worse atrocities. Though he was caught and executed in 1859, stories about him are already beginning to assume a mythical dress, and it was said that miraculous flowers grew out from a tree to which he bound one of his victims, a white girl, leaving her to die of exposure.

"Seven and a half hours were consumed over the 28 miles to Feira St. Anna. The town consists of three long parallel streets, with a broad cross street, or rather open oblong space, on which the small dealers erect their booths on fair day. The party rode into the town at about five o'clock in the evening.

"The girls were all dressed in their best, expecting home their several sweethearts who are away all the week in search of cattle, and only come to town on Sundays in time for the fair on Monday Several of them greeted the guide as an old friend, as the party rode up a long street to the other end of the town. Here is an open common-like space surrounded by houses, which acts as tobacco and cattle market. We stopped at an inn close to the market.

"The inn was a one-storied house, consisting of an eating room fronting the street, and two sleeping rooms and a kitchen behind. The eating room had large windows, with jalousies but no glass, looking out upon the market. It had a cement floor, a trestle table at one end for eating on, a small table opposite with a red curtained box upon it, containing the household gods, the Virgin in plaster, and Santa Antoinetta in china, and a half round table with an inkstand for the use of those customers who could write.

"The host, an old Brazilian, greeted us with great politeness, and we bowed according to custom to the assembled guests. The company consisted of about half a dozen cattle dealers, who were in animated discussion concerning the prices of stock. One of them, who was quite black, was evidently the sharpest of the lot, and a wag. Presently there came in a dirty coarse-looking grey-haired man with a black skull-cap on; he wore a dilapidated black garment something like an Inverness cape. He was chief vicar of the town; he was in considerable excitement, and addressed himself to the black cattle dealer, who produced a letter for him. The reverend gentleman had not got his spectacles with him, so the host proceeded to spell out the letter aloud. It appeared that the vicar did a bit of general trading, and had sent some horses, mules, and slaves to a neighbouring fair, in hopes of a good price. The letter was to inform him that he had made a bad speculation, and that no buyer had been found. The vicar was in a great rage, and made an excited oration about the hardships of his position, and the terrible depreciation in the value of slaves, and left. He was said to receive £60 per annum as stipend, and fees in addition.

"We had some excellent fresh beef for dinner, fried in small pieces with garlic and potatoes and carrots, and with it farinha, the coarse meal made from cassava root, the fine siftings from which are tapioca. The farinha (farina) is universally used here, and is very good with gravy.

"The sleeping apartment was a space about 8 feet square, separated from the front room by a low partition. In it were three light cane-bottomed sofas, one at each end, and one opposite the door; they were packed so close together as to touch one another. A neatly folded small coverlet and a pillow were placed in the middle of each.

"Here we turned in, the third bed being occupied by a very dirty dealer in tobacco. Rendered sleepless by the fleas, I lay awake most of the night, listening to the mingled crying of children, barking of dogs, croaking of frogs in the marsh below, and squeaking and groaning of the axles of the ox-carts bringing merchandise to the fair.

"Though other charges were comparatively cheap, we had each to pay two shillings for our beds, as did also some of the cattle dealers who slept in a small house over the way; rented by the host for that purpose, and to keep the guests' saddles and bridles in.

"At 6 A.M. there was no bustle or signs of the fair, and not till 9 or 10 o'clock did strings of mules, laden each with a pair of bales of tobacco, arrive opposite the inn. The mules carry about seven or eight arrobas (an arroba = 25 lbs.). The tobacco comes to the market compressed and cut into neat rectangular bundles; the merchants test it by pulling some from the bundle and rolling a rough cigar.

"In the broad open street in the middle of the town were rows of small booths, at which farinha, fruit, vegetables, and jerked beef, imported largely from Buenos Ayres, were for sale; the dried beef varies in price from six to two milreis an arroba (1 milreis = 2s.). It seemed singular that it should pay to bring it to a place where fresh meat was so abundant.

"Other stalls offered needles and thread, sweet stuff for children, &c.; but most trying to a naturalist's eye, were stalls where various rodents and other small native animals were for sale, spitted on wooden skewers, roasted and dried for eating. Amongst these I saw at least a dozen of the tree-climbing Ant-eater, the Tamandua, and many Three-toed Sloths: the skulls of all were split open, and they were utterly lost to science. The flesh is supposed to cure various diseases.

"Makers of the long riding boots so fashionable here wandered about the fair trying to sell their handiwork, and I bought from a similar wanderer one of the vaqueiros leather hats, which did me the best of service in thick and thorny forests throughout the remainder of the cruise; with this on my head I could butt my way head first into any bush with impunity.

"Close by the market-place was the church of the vicar already mentioned, which had a mosque-like dome ornamented with variously coloured dinner and tea plates set in patterns in cement, a very original form of decoration.

"In the leather market quantities of skins of leather were exposed for sale, and also tanned puma skins used for saddle-cloths, and boa-constrictor skins also tanned, used to make boots and said to be remarkably waterproof.

"But the great sight of the fair is the cattle market, the situation of which has already been described. The cattle are bred at estates far up the country, where they run wild in the bush and are caught and branded, and drafted for market every two years. The men who look after and drive the cattle are termed 'vaqueiros' in Portuguese. They are of all shades of colour, from black to white; they are dressed when at work from head to foot in undyed red brown leather; they wear leather breeches, high leather boots with huge spurs, a leather coat like a longish jacket, and a leather hat with rounded close-fitting crown and broad brim; they ride small rough horses, which are worth at Feira St. Anna from £4 to £5, with saddles of the form commonly called Mexican or Spanish. The vaqueiros receive as payment from the owners every tenth head of cattle brought to market. They are, of course, extremely expert riders, and it is marvellous what work they get out of their small horses. The breeders rarely bring the cattle to market on their own account, but sell them to dealers, who take them to Feira St. Anna, and hand them over to other dealers again, who sell them in Bahia or Caxoeira. The cattle are driven by the vaqueiros, who use a short leather thong to strike them with. Bands of from 20 to 50 head of cattle were being driven into the market as we approached. A vaqueiro rides in front of each herd, one on each side, and one or more behind, and they keep up a constant shouting, bringing the animals along at a fair pace.

"Every now and then, a beast wilder than the rest, or less exhausted by the long journey from the interior, breaks away, and goes off at full gallop over the open market-place or up the street. Off gallop two or three vaqueiros, in full chase, with outstretched arms, spurring their horses to the utmost. They try to drive the beast back into the herd, and often succeed forthwith. But often it gets in amongst another herd, and then it is wonderful to see how rapidly they manage to single it out, get it on the outside of the herd, and start it afresh. Sometimes the animals are very fresh and wild, and make off at full pace, and cannot be headed. The vaqueiros then strain every effort to come up behind them, catch hold of their tails, and spurring their horses forward so as to get up alongside the beasts, give a sudden violent pull, which twists the animal round and throws it sprawling on its side. The cattle, though they fall so heavily that this expedient is resorted to as little as possible at the fair, because it bruises the meat, are often up after a fall and off again in an instant; but two or three falls knock the breath out of them, and they are then driven back to the herd quietly. Sometimes even this treatment does not subdue them, and then they are lassoed round the horns and dragged back.

"The various herds were driven in compact bodies against the walls bounding the market, and some of the vaqueiros dismounted, and kept the cattle together by the use of their thongs and shouting; but one at least at every herd remained mounted, ready to chase any animal which might break away. The scene was most exciting. Often three or four cattle were loose at once and careering madly in all directions, jumping over obstacles like deer, and with two or three vaqueiros after each, at full gallop, spurring their little horses to the utmost, twisting and turning with wonderful dexterity. One wild cow went right up the main street. She was very fast, and five vaqueiros had a sort of race after her; now one gained a little, now another, and it appeared as if the beast were going to make off altogether; but at last a big black vaqueiro shot ahead, and threw her sprawling in the road. I kept close to a sheltering corner, ready to retreat round it when a beast came in my direction.

"The cattle dealers rode round from herd to herd, on their mules and horses, and most of the dealing was done on horseback. As soon as a herd was sold, it was driven off, one or more vaqueiros accompanying the drovers, according to the wildness of the cattle.

"In the middle of the open space horses and mules were being sold. The sellers of the horses were mounted on them, and were showing off their paces in an open lane formed amongst a crowd of buyers and on-lookers. The sellers made their horses amble full pace up the lane, turn sharp round, and return: and on reaching the starting-point, stop suddenly, without slacking pace in the least beforehand, in doing which the animals were thrown almost back upon their haunches. The ability to stop thus suddenly when in full pace is one of the points most admired in horses by Brazilians.

"The horses are small, but well made. Good well-trained horses cost about £40. Good riding mules are worth as much or even more. The Brazilians of the better class ride their ambling horses with their legs straight and stiff and carried right forward, with the toes turned up and the tips of the toes only resting on the stirrup irons. The vaqueiros, however, ride much in the usual English fashion.

"Sheep are used as beasts of burden in a small way in Feira St. Anna. I saw three or four laden with small barrels of water slung across their backs. They were driven by children, who were thus taking water from the well outside the town round to the various houses. The sheep seemed perfectly trained, and went along at a smart pace. Sheep are used as beasts of burden in Ladak to transport goods over the mountains of Little Thibet, and carry from 20 to 30 lbs.[1]; but their use for this purpose is very uncommon.

"In the crowd we met with a German farmer, who was a friend of my companion, and he invited us to pass the night at his house, his farm lying on the road to St. Amaro, by which we were to travel. We had our mules brought up to the inn door, and there gave

[1] The Middle Kingdom, Williams, vol. i. p. 204.

them a feed of maize to make sure that they got it. We saddled them ourselves in front of the inn, and after much ceremonious shaking of hands with the host and many polite speeches, rode off.

"On the road we passed several herds of cattle, which were being driven towards Bahia. In one of these some of the cattle were very wild. There were three vaqueiros in charge of it, a man and two lads of from sixteen to eighteen years of age. There was thick bush on either side of the road, and every now and then the cattle broke away into this. The use of the rough lurcher-like dogs which follow the vaqueiros now appeared. In the thick scrub the vaqueiro could do nothing without his dog. The cattle are out of sight in an instant, and go off dashing full pace through the bushes. The dogs are after them at their heels at once, and drive them to the vaqueiros, who dash off into the thick of the bushes in pursuit, bending right forward in the saddle, and stooping till their heads are beside their horses' necks, to avoid the branches.

"One cow came full charge down the road behind me, and I had only just time to back my mule into the bush out of the way. One of the lads was after her. He seized her tail just as he was opposite to me, held on for about 20 yards, and then, digging in his spurs and shooting forwards, turned her over with a thud. She was up, however, again, and off into the bush in an instant, and he after her with the dog in full pursuit, and I saw him disappear under the branch of a tree with his body laid right back on his horse's rump to avoid it.

"We passed about sunset through a village, where there is a hospital, a very substantial building, erected by the vicar, who for many years diligently collected subscriptions for that purpose. The church was lighted up and the people were going to vespers. One of the villagers was pointed out to me by the German farmer as being the hereditary owner of a large estate worth several thousand pounds, and a number of slaves. He was quite black and dressed in tatters, looked like a slave himself, and was driving cows along the road. He could neither read nor write.

"Our host was an emigrant from the Hartz district. He had been out in Brazil about fourteen years, and had a farm of several hundred acres, most of which was grass land; the grass growing where sugar had once been planted. He bought cattle and sheep at Feira St. Anna, kept them some time on his farm, and then killed them and sold the meat in St. Amaro and the district. He also grew a large patch of sugar cane, which was ground at a large mill close by, he receiving half the sugar produced as his share. He had bought one slave: all foreigners, except English, being allowed to possess slaves in Brazil. The slave was married to a girl, who was principal servant in the house and whom the farmer had assisted to buy her freedom. Frau Wilkens, his wife, who had no children, described the girl as most trustworthy, honest, and deeply attached. Her small child, a chubby little negro, was a great pet in the house. The greater part of the work on the farm was done by slaves hired from the owners of neighbouring plantations. There was a row of about thirty very small wooden houses or huts on a neighbouring hill, where the slaves belonging to the owner of the sugar mill lived.

"Cassava or Mandioca (*Jatropha manihot*), a Euphorbiaceous plant, allied to our Common Spurge, was also grown on the estate, and there was a small manufactory of farinha; it is an indigenous South American plant, though now widely spread in the tropics, and was cultivated in Brazil by the original inhabitants, before they were molested by Europeans. The plant is not unlike the Castor-oil plant in appearance, and is planted in rows slightly banked up; the tubers are long and spindle-shaped. The preparation of them was conducted in a small hut, a large fly-wheel being turned by a negro, and driving, by means of a band, at a rapid rate, a small grinding wheel provided with iron cutting teeth. The cassava root, which had been peeled and washed by a negress, was reduced to a coarse meal by means of the grinding wheel; the meal was then put into a wooden trough, and a board was tightly pressed upon it by means of a lever, heavily weighted with stones. The cassava was thus left in the press for twelve hours, in order that the poisonous juice which it contains should be expressed. The mass was then taken out and dried on a smooth stone surface, beneath which a wood fire was burning. The resulting chalky-white meal, when sifted, yields samples of three degrees of fineness; the finest, a white flour-like powder, is tapioca, *i.e.*, true, original tapioca, an imitation of which, made from potato starch, is commonly sold in England; the intermediate sample is used in starching clothes and cooking; and the coarsest substance, which is coarser than oatmeal, and consists of irregularly-shaped dried chips of the roots, is called farinha, and is, as before described, commonly eaten with gravy at dinner, taking the place of bread, and forming a staple article of food.

"Our host was well to do; he had thriven better than any of the emigrants who came out with him, and, having no family to provide for, talked of going home soon. An old German was staying in the house, an idler, whose real occupation was gardening, his father having been imperial gardener, as he informed us with great pride; he also did a little trade in the way of peddling books. He had landed, more than twenty years before, at Rio, and had reached Bahia on foot. He was now travelling from estate to estate, and staying at each as long as he could, under pretence of doing up the garden, but although he had been two months at the farm, the few square yards of garden were as yet untouched. He had been too lazy to learn Portuguese, and understood very little. He seemed, however, a favourite at the farm, and was well taken care of, tea being made as a special luxury for him, and he had many stories to tell, and quaint sayings, and had amusingly strong Prussian sympathies.

"The farmer guided us to a large tract of primitive forest close by, which was extremely difficult to penetrate. Here I caught, with a butterfly net, a curious Bat (*Saccopteryx canina*), which has remarkable glandular pouches on the under sides of the wings, at the elbow-joints; these pouches are well developed only in the males, rudimentary in the females, and secrete a red coloured strongly smelling substance, supposed to act as a sexual attraction. The bat was resting on a bare tree-trunk, asleep, the dense forest growth overhead making this exposed situation quite dark enough for it.

"On our way back to the farm, we watched some ants carrying off bits of cassava leaves to their holes. One cannot go a walk anywhere in the neighbourhood of Bahia without seeing these Leaf-cutting Ants (*Œcodoma*) at work. Their habits have been described by many observers, and recently by Mr. Belt[1] at great length. A new Hymenopterous insect (*Pepsis collaris*, Kirby)[2] was obtained during the excursion.

"The further road to St. Amaro lay through sugar estates all the way. I left St. Amaro early next morning by steamer, and reached Bahia at 10 A.M."

During the stay at Bahia the steam pinnace was engaged several days dredging in the bay. In some places the deposit was a white quartz sand, containing fragments of felspar, mica, magnetite, hornblende, and other minerals, and also fragments of Echinoderms, Polyzoa, *Serpulæ*, and other organisms. In other places it was a dark mud, containing, along with fine argillaceous matter, all the above mentioned minerals and organisms. The dredgings were very successful, animals belonging to all the principal invertebrate groups being taken. Astrophytons and Ophiurids were especially abundant.

[1] Thos. Belt, The Naturalist in Nicaragua, p. 71 *et seqq.*, London, John Murray, 1874.
[2] *Ann. and Mag. Nat. Hist.*, ser. 5, vol. xiii. p. 408, 1884.

CHAPTER VII.

Bahia to the Tristán da Cunha Group—Ipnops—Account of Tristan Island and the Settlement—Inaccessible and Nightingale Islands—Tristan Group to the Cape—The Cephalopoda—The Holothurioidea—The Cape—Peripatus—The Cetacea—The Chitons.

Bahia to the Tristan da Cunha Group.

On the 25th September, at 4 p.m., the Challenger left Bahia for the Tristan da Cunha group of islands, and proceeded to the southward until the 30th, without sounding or dredging, as it was desirable to get into cool weather at once to avoid any risk of yellow fever spreading amongst the ship's company.

The S.E. trade wind continued to the 22nd parallel; from thence to the 34th parallel the wind had an easterly tendency, varying from N.E. by N. to S.E. by E. On the 9th October, in lat 34° S., long. 24° W., after a gale from the eastward, the wind shifted round by north to west, and continued between south and west till Tristan da Cunha was reached. North of the 30th parallel the weather was fine, afterwards it was cloudy, with passing rain squalls. The sea was moderate throughout. The first albatross was seen on the 2nd October, in lat. 25° S., long. 34° W., but no Cape Pigeons until the 7th, in lat. 29° S., long. 26° W.

As no soundings were taken until the 20th parallel was reached, the section was drawn from Abrolhos Island on the American coast to Tristan da Cunha. On this section six soundings, six serial temperature soundings, two dredgings, and three trawlings were obtained. The dredge rope parted on the 30th September, at Station 129, before the dredge was off the bottom; and when trawling on the 3rd October, at Station 130, great difficulty was found in heaving in the trawl rope, only a few fathoms being gained at a time. After a long struggle the trawl was lifted off the bottom, but the strain on the accumulators, which were elongated to the full length of the safety pendant, indicated that something weighty was in the net. By careful manipulation, however, the trawl was brought to the surface, the beam and part of the net being visible from the deck, but when on the point of hooking the burton to hoist it on board, the iron swivel, between the rope and the span from the beam, parted, and the trawl with its contents sank to the bottom. This was a great mortification, as intense curiosity had been excited to learn the cause of the strain on the rope.

The surface temperature ranged from 78° at Bahia to 52°·8 near lat. 36° 7′ S., long. 14° 27′ W., at 8 a.m. on the 13th October, and thereafter rising to 53°·5 at Tristan da Cunha.

The temperature of the water at the bottom ranged from 34°·2 to 36°·0; but the indications of the coldest water being at the greatest depth, were not so marked as between St. Paul's Rocks and the American coast, for the temperature of 34°·2 was found at the depth of 2150 fathoms, whilst at 2350 fathoms there was a temperature of 34°·7. The former temperature, however, rests on the indication of one thermometer, whilst the latter is the mean of two, and the thermometer that gave the temperature of 34°·2 at 2150 fathoms gave a temperature of 34°·4 at 2350 fathoms. It is probable, therefore, that the temperature of 34°·2 may be 0°·5 too low.

The serial temperature soundings showed that, notwithstanding a change of surface temperature of 24°, and of latitude of 18°, the isotherm of 40° was nearly parallel with the surface, its average depth being 410 fathoms, and its range 80 fathoms, viz., from 380 to 460 fathoms. Above the isotherm of 40° the temperature increased gradually to the surface (see Diagram 5).

No observations on currents were made, except the ordinary ones of ascertaining its direction and strength, by means of the difference of the position of the ship, by observation and dead reckoning.

On the 3rd October, at Station 130, the velocity of the wind was 18 miles per hour in the forenoon and 20 in the afternoon, the force registered being 4; on the 6th October, at Station 131, the velocity was 12 miles per hour, the force registered being 3; and on the 14th October, at Station 134, the velocity was 11 miles per hour, the force registered being 2. On the 15th October, at anchor off Tristan da Cunha, the velocity was 16 miles per hour, the force registered 4 to 5.

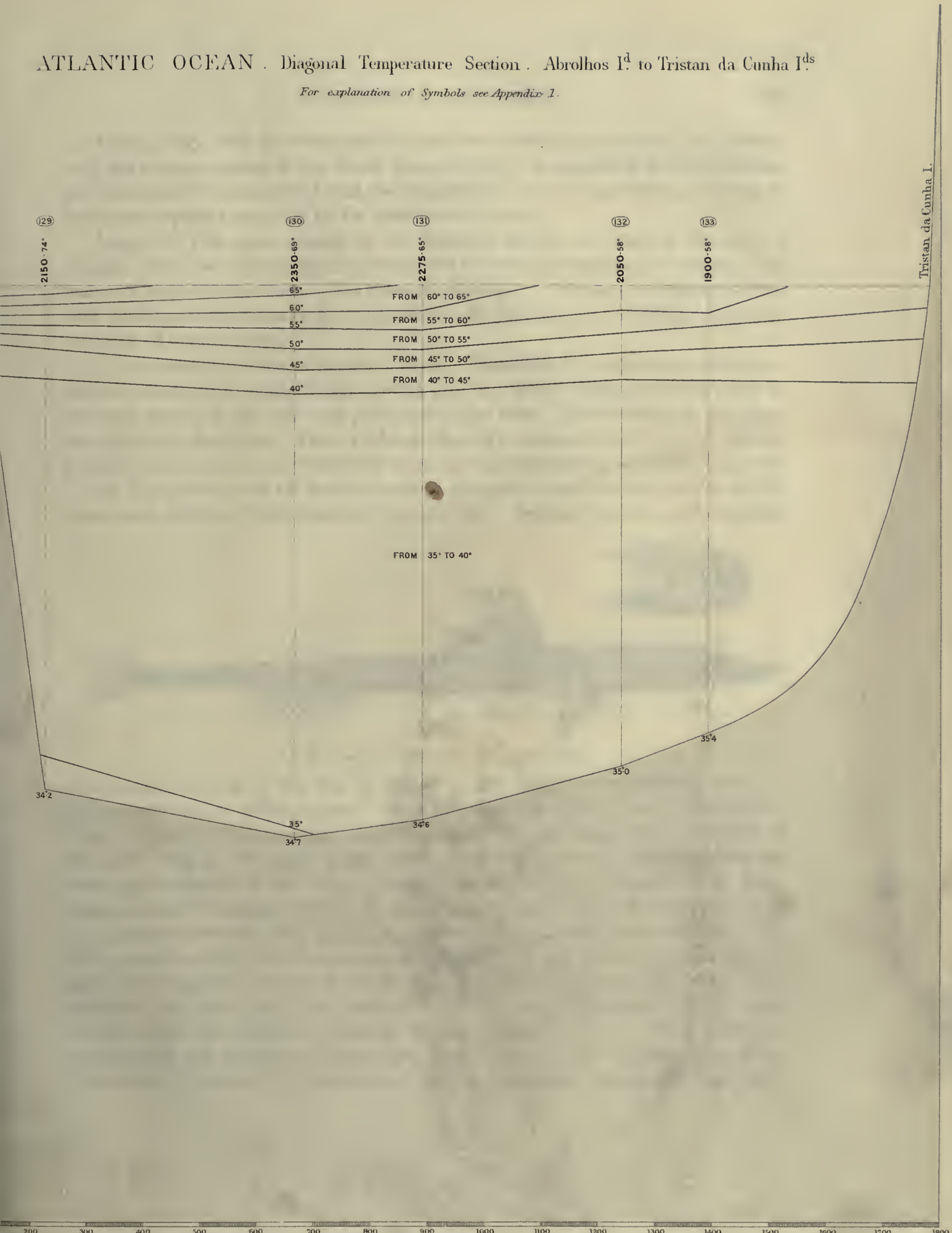
On the 14th October, at daylight, the peak of Tristan da Cunha was sighted, bearing S.S.W., distant 54 miles, and at 7 A.M. the ship stopped to sound and dredge at Station 134 (see Sheet 16). At 3 P.M., having completed dredging, a course was shaped for the island, the weather being fine; and at 10 P.M. the vessel was stopped off it, and "laid to" for the night. The peak of Tristan was visible in the early morning, but clouded over at 8 A.M., and was not seen during the remainder of the day, except for a short interval at 5 P.M.

Between the coast of America and Tristan the greatest depth obtained was 2350 fathoms. There were many indications of an extensive plateau surrounding the Tristan group, with depths varying from 1425 to 2000 fathoms.

The deposits in depths less than 2100 fathoms on the Tristan plateau contained from 85 to 95 per cent. of carbonate of lime, which was almost wholly composed of the shells of pelagic organisms, whilst the three soundings in depths greater than 2100 fathoms towards the American coast contained from 35 to 55 per cent. It was observed that as the ship proceeded southward the Foraminifera in the deposits became dwarfed, and some tropical species disappeared. There were quartz fragments in the deposits near the American shores, but these disappeared or were exceedingly rare in the deposits towards the centre of the South Atlantic.

ATLANTIC OCEAN. Diagonal Temperature Section. Abrolhos I^d. to Tristan da Cunha I^ds.

For explanation of Symbols see Appendix 1.



Engraved by Malby & Sons

The trawlings, with the exception of the failures mentioned above, were very productive, and a large number of new forms were procured. At a trawling in 1900 fathoms, 400 miles west of Inaccessible Island, two specimens of a very remarkable new genus of fishes were captured, described by Dr. Günther as follows:—

Ipnops.—"This genus belongs to the Scopeloid family; the shape of the body is elongate, subcylindrical, the caudal portion much exceeding the abdominal in length. The scales are large, but deciduous. Fins normally developed. The head is depressed, with a long, broad, spathulate snout; the mouth wide, with the lower jaw projecting, and armed with rows of minute teeth.

"The structure of the eyes is quite unique. Externally they appear as a continuous flat cornea-like organ, longitudinally divided into two halves, which covers the whole of the upper surface of the snout and partly overlie the bone. The functions of the organ are difficult to determine. From Professor Moseley's examination it seems at present probable that it is an organ of modified vision and not of luminosity as I at first believed."

Mr. John Murray was the first to examine by means of sections the structure of the organs, and point out their remarkable peculiarities. Professor Moseley, who has lately

Fig. 97.—*Ipnops murrayi*, Günth. 1600 to 1900 fathoms.

re-examined the eyes of this fish by means of Mr. Murray's preparations, writes:— "Their structure is quite unique. They are flattened out to an extraordinary extent, closely united together along a straight line traversing the middle line of the snout, and at first sight appear like a single white patch or label covering the whole upper surface of the snout. Each eye is covered by a transparent flat membrane probably the representative of the cornea, beneath which, and separated from it by a shallow chamber filled with fluid, is a retina of very remarkable structure. The retina extends over the whole area covered by the cornea, and is composed of a layer of remarkably long rods, without, as far as can be detected, any cones. The rods, which break up with more than usual readiness into transverse disks, have their free ends turned towards the pigmented choroid. A very thin layer of nerve fibres intervenes between them and the light, and apparently represents the entire remaining layers of the retina usually present. The choroid is divided into a series of hexagonal areas which are concave towards the cavity of the eye, and on these areas the ends of the rods rest; the rods being seen to be aggregated into corresponding bundles in transverse sections. It is not improbable that these curious expansions of the recipient surface of the eye and its retina are a device for detecting the presence of very small quantities of light, at the expense of all apparatus for forming an image."

Tristan da Cunha Group.

On the 15th October, at 3 A.M., the ship proceeded towards Tristan Island, and at daylight the three islands of the group were seen. At 8 A.M. the ship was anchored in 19 fathoms in Falmouth Bay, and parties landed, with a view of exploring the island and obtaining observations; but as the weather looked threatening in the afternoon, and a swell got up, it was considered inadvisable to risk remaining at anchor, and the ship left Falmouth Bay proceeding towards Inaccessible Island, with the view of landing on it should the prognostication of bad weather prove incorrect. This was accomplished, for on the 16th, the wind being light and the sea smooth, exploring parties were landed, and the ship steamed round Inaccessible Island, obtaining soundings and dredgings, and finally anchoring on its northeast side for the night. On the morning of the 17th October the vessel left Inaccessible Island for Nightingale Island, and the day was devoted to fixing its position, and surveying and sounding its coast; but dusk coming on before a suitable anchorage could be found, the ship remained under weigh during the night of the 17th, and the 18th was devoted to sounding and dredging between Nightingale and Tristan Islands, the vessel finally leaving the group for the Cape of Good Hope at 6 P.M. on the 18th (see Sheet 17).

During the four days' stay the wind varied from N.W. through W. and S. to S.E., the force never exceeding 5, and being frequently 1. The weather was cloudy and the sea moderate. The temperature of the surface water was on an average from 2° to 3° higher than that of the air, the maximum temperature in the shade registered being 56°, the minimum 46°, and the mean 51°; whilst the mean temperature of the surface water was 53°·6. The air was dry and invigorating, the relative humidity averaging 77.

The islands known as the Tristan da Cunha group (three in number) were originally discovered by the Portuguese about 1506, who named the largest "Tristan da Cunha" (since contracted to Tristan) Island. The Dutch appear to have described them in 1643, but M. d'Etchevery, in "L'Etoile du Matin," appears to have been the first to land on them in 1767. He named the western island "Inaccessible," and the southern "Nightingale"; and anchored off, and landed on, both Nightingale and Tristan Islands. Since that date many of H.M. ships, as well as merchant vessels, have touched here; but it was not until they were visited by Captain Denham, H.M.S. "Herald," in 1852, that their exact geographical position was known; and even in 1873, the precise position and

extent of the two smaller islands had not been ascertained. As the Challenger completed the exploration of the group, it appears desirable to give an exact account of it here, compiled partly from old publications[1] and partly from these more recent observations.

Tristan Island, the northernmost, largest, and highest island of the group, has a nearly circular form, with the apex 7640 feet above the level of the sea in its middle; in fact, if a circle with a radius of 3½ miles be described, using the summit of the island as a centre, the circumference of the circle will be found to touch the salient points all

FIG. 98.—The Island of Tristan da Cunha.

round, except in one part, viz., in the eastern quadrant, where the coast will be found to project half a mile beyond the circumference.

Precipitous cliffs, 1000 to 2000 feet in height, rise directly from the sea everywhere, except in the northwest quadrant, where there is, in front of the cliffs, an irregular flat, 100 to 200 feet above the sea level, 2½ miles in length and half a mile in breadth. From the top of the high cliffs the island has the appearance of rising gradually on all

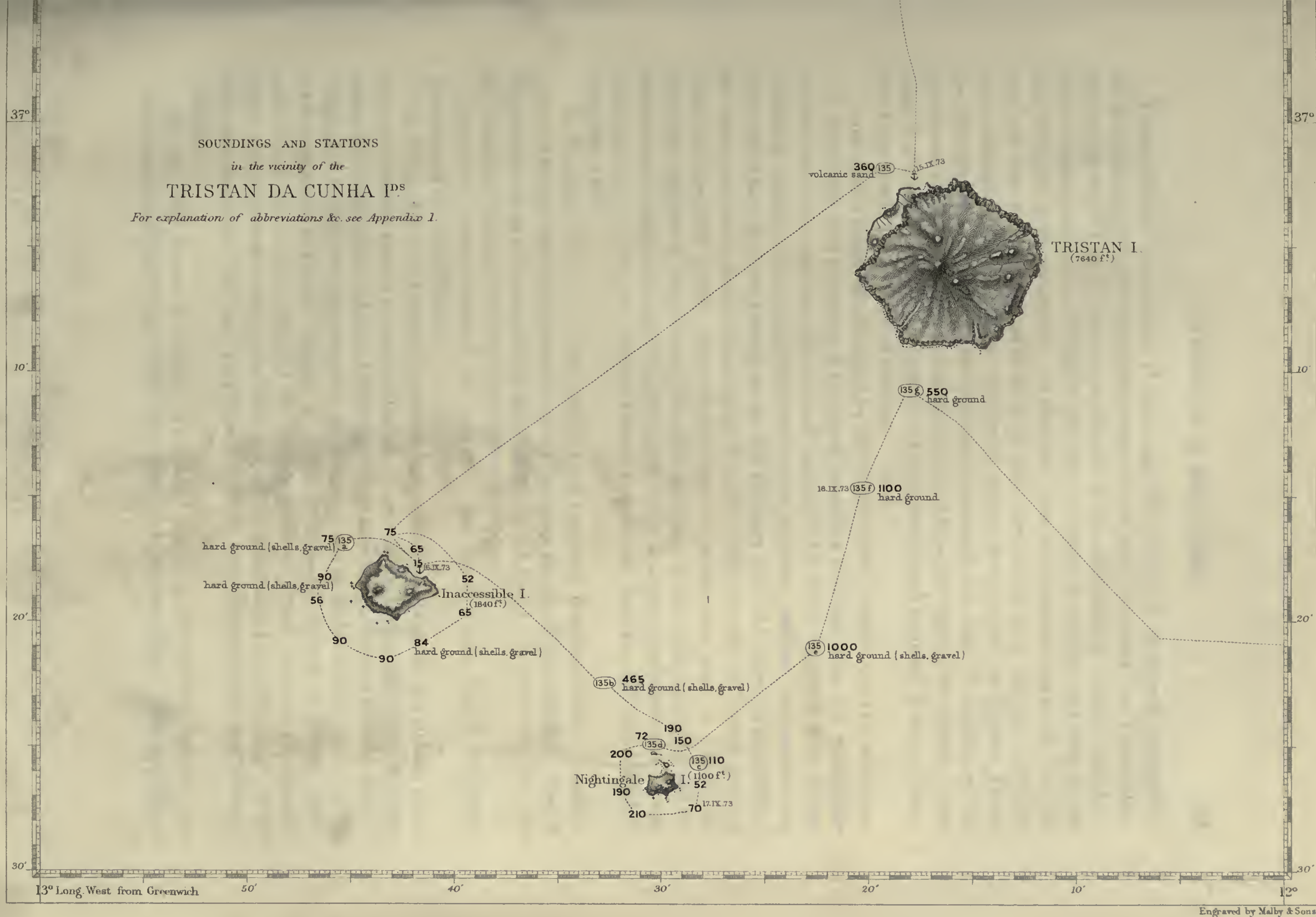
[1] *Nautical Magazine*, vols. iii., iv., viii., xxii. (1853), xxv. (1856), xxxi. (1862); Morrell's Voyage of the "Antarctic"; Account of Tristan da Cunha, by the Rev. W. F. Taylor, 1856; Voyage of H.M.S. "Galatea," 1867; Parliamentary Papers, 1876; and Documents in the Hydrographic Department.

sides to the apex, but does not really do so, as the slope from the peak, besides being divided by numerous ravines, has on it several small extinct craters. The peak has, so far as is known, never yet been ascended by any one except the sure-footed islanders, although it has been occasionally attempted by others, notably by Lieutenant Rich in 1816 and Commander Nolloth in 1856. It is said to terminate in a cone, consisting of black and deep red lava ashes, in the centre of which is an extinct crater, nearly circular, a quarter of a mile in diameter, now partially filled with fresh water, the depth of which has not been ascertained. There is a depression on one side of the cone, probably the effect of an eruption. In several of the small craters there are also lakes or ponds of fresh water, and some lodes of stiff yellow clay fit for brick making.

It appears curious that the lake in the crater on the summit should not be frozen, as the peak is seldom free from snow; and Lieutenant Rich, in his partial ascent in 1816, found that the thermometer registered 33° in the sun, in the middle of the day, in September.

The geographical position of Tristan, long in doubt, was satisfactorily ascertained by Captain Denham in H.M.S. "Herald." The summit is in lat. 37° 5′ 50″ S., long. 12° 16′ 40″ W., and Herald Point, the N.W. angle of the island, an eligible position for obtaining observations, is in lat. 37° 2′ 45″ S., long. 12° 18′ 30″ W.; and here one cannot but refer to the general accuracy of some of the old navigators, especially to the pains taken by some of them to ascertain the position of islands and shores, for Mr. Lewis Fitzmaurice—of H.M.S. "Semiramis," Captain Richardson—remained on shore here, in March 1813, four days taking observations, and made the lat. 37° 5′ S., long. 12° 11′ W., variation 9° 51′ W.; and Captain Wauchope, of H.M.S. "Eurydice," in November 1817, when at anchor 1 mile N.N.E. of the Cascade, made the position of his ship lat. 37° 1′ S., long., by mean of 20 lunars, 12° 1′ W., and by chronometer, 12° 23′ W.

Rising abruptly from the sea as Tristan does, except in one small portion of its circumference, its coast may fitly be described as ironbound. Vessels may approach it to within a mile, or even closer, with perfect safety so far as depth of water is concerned, for the soundings deepen quickly to 100 fathoms, so much so, that boats fishing at anchor in 20 fathoms not infrequently swing into depths exceeding 100 fathoms. Small beaches at the foot of deep ravines afford, with certain winds, landings here and there all round the island, but the adventurous seaman who endeavours thus to explore the coast line will find himself confined entirely to the strip of pebbly ground on which he stands, for the precipitous nature of the cliffs prevents his mounting to the higher land or walking along the base, the only exception being on the strip of comparatively level ground on the northwest side, where the landing is good in all but northerly winds, and from here the highlands may be reached and explored. All round the coast, and in some cases extending a considerable distance from it, grow large quantities of Kelp.


SOUNDINGS AND STATIONS
in the vicinity of the
TRISTAN DA CUNHA I^DS.
For explanation of abbreviations &c. see Appendix 1.
TRISTAN I.
(7640 f^t.)
360 (135)
volcanic sand
15.IX.73
(135 g) 550
hard ground
18.IX.73 (135 f) 1100
hard ground
(135 e) 1000
hard ground (shells, gravel)
(135 b) 465
hard ground (shells, gravel)
Inaccessible I.
(1840 f^t.)
75 (135 a)
hard ground (shells, gravel)
hard ground (shells, gravel)
hard ground (shells, gravel)
16.IX.73
Nightingale I.
(1100 f^t.)
(135 c) 110
(135 d)
17.IX.73
37°
10′
20′
30′
13° Long. West from Greenwich
50′
40′
30′
20′
10′
12°
Engraved by Malby & Sons

Tristan, like the other islands of the group, was, when first discovered, uninhabited. Its first inhabitant was Captain John Patten of the ship "Industry" of Philadelphia, who landed with a part of his crew in August 1790, and remained on shore until April 1791, collecting seal skins, in which he was very successful, shipping in that time no less than 5600 for the China market. At that time there were goats on the island, but how they got there is unknown; most probably they were landed by a passing vessel, but it is quite possible that they may have swum ashore from a wreck, for Captain Patten saw the remains of different wreck, such as the bowsprit and mast of a cutter, several spars, some of which were worm eaten, some iron hoops and other pieces of iron, but no remains or traces of huts or habitations. If they were landed purposely it seems strange that there should be no record of the fact.

From 1790 Tristan Island appears to have been deserted until about 1810, when three men landed and took possession of the island, intending to remain some few years there for the seal and sea elephant fisheries, and trusting to be able to dispose of their labours to passing vessels. By a singular and curious edict, Jonathan Lambert, an American, one of the three men, declared himself, on the 4th February 1811, the sovereign proprietor of the group, and set to work to clear the land on the northwest side of Tristan, planting about 50 acres with various kinds of seed, some of which were sent to him by the American minister at Rio Janeiro, but although some of the seeds sprang up and the settlement appeared prosperous, Lambert shortly after abandoned his possessions, leaving only one man behind, viz., Thomas Currie, a native of Leghorn, who had landed in December 1810.

In November 1814 Currie was joined by a Spaniard, Bastiano Poncho Comilla, a native of Mahon, but there appears to be no record of the vessel from which he landed. At this time there were numerous flocks of goats on the island and some wild pigs, but by whom these latter animals were landed does not appear.

Such is a short account of the history of the island to the time it was taken possession of by Great Britain.

In 1816, after the Emperor Napoleon had been incarcerated in St. Helena, it was deemed advisable to send a guard to Tristan, to prevent its being made a base of operations against the former island. Accordingly Rear-Admiral Sir Pultney Malcolm, K.C.B., despatched a frigate to take possession of the group and to land a detachment. On the 14th August 1816, Captain Festing, of H.M.S. "Falmouth," arrived at Tristan Island, and proceeding on shore annexed the islands to Great Britain with all the requisite formalities, and constituted, by Sir Pultney's orders, Lieutenant David Rich, R.N., as the first Commandant. The only people on the island were Thomas Currie and Bastiano Comilla.

On the 15th August 1816, the "Falmouth" landed a lieutenant of marines, four midshipmen, and thirteen men under the orders of Lieutenant Rich. This detachment remained until the 28th November of the same year, when they were relieved by Captain Josiah Cloete of the 21st Regiment of Dragoons, and some troops from the Cape of Good Hope. Captain Cloete then succeeded Lieutenant Rich, as Commandant, and remained until the settlement was finally abandoned by the British Government in November 1817. During his four months' stay on shore Lieutenant Rich kept a journal, from which the following interesting particulars have been extracted :—

The "Falmouth" remained five days in the vicinity of the group, landing stores, provisions, and other necessaries for the men on shore; and during her stay Captain Festing, with a laudable anxiety to explore Tristan Island, started in a gig to pull round it, and the master of the ship sounded out the anchorage, which he named Falmouth Bay, a name which it has since retained, although the original name appears to have been Reception Bay. Captain Festing was unfortunate in his weather, for at 2 P.M. on the day he started, the wind and sea had become strong enough to necessitate his return to his ship, and they increased so rapidly as to threaten the total loss of the boat. After struggling against these adverse circumstances for some hours, Captain Festing perceived that the only chance of safety for his exhausted crew was to endeavour to land, and in this he succeeded at 10 P.M., but not without his boat being capsized, and stove against the rocks, and his crew receiving a considerable number of bruises before they extricated themselves from the surf. Captain Festing and his boat's crew remained in a very unpleasant position on the rocks for two days, living on Penguins, before they could be rescued, for the sea and wind were sufficient to force the "Falmouth" to slip from her anchors to avoid being driven on shore. Fortunately he had means of making a fire with flint and steel, and plenty of Tussock Grass around him to burn, so that they were able to cook their food.

After the "Falmouth" left the group, Lieutenant Rich employed his men in regular working parties, in cutting wood and building huts, in catching fish, in killing and boiling down Sea Elephants for oil, and curing their skins to make caps and moccasins, and in preparing a large piece of ground for the reception of vegetables and cereals.

The fishing parties were always successful; they fished with hook and line from a boat at anchor. The party cutting wood and building the huts met with some difficulties owing to the smallness of the trees, there being only one species of tree on the islands (*Phylica nitida*), the wood of which is weak and small. After the first hut was built and the stores removed into it, they found that continuous rain for a day made their thatch of Tussock Grass so heavy that it bent the uprights on which the roof rested, consequently they had to begin their work over again, and build smaller huts, which they floored with staves of casks and other materials.

The agricultural party cleared a large patch of ground, and planted some wheat, potatoes, and a large quantity of cabbages, in addition to the ground already under cultivation by Thomas Currie, who had grown a considerable number of potatoes, cabbages, and carrots, which had a most healthy appearance.

Two attempts were made by Lieutenant Rich to cross the mountain ranges, but they both failed, as the rugged nature of the ground rendered it necessary to pass the nights on the hills; and he found it so cold and damp, that without some shelter he considered it unadvisable to pass more than one night away from the tents, and the difficulty of transport prevented his taking a tent with him, besides which the clouds hanging over the mountain envelop it in fog, so that there is great danger of losing the way. A few goats and numbers of wild pigs were seen by Lieutenant Rich in these mountain excursions; but their capture was difficult, owing to their frequenting the least accessible parts of the island.

From a register kept during Lieutenant Rich's stay, it appears that from the 15th to the 31st August 1816 the mean temperature was 56° and the extremes 82° and 42°. On 14 of the 17 days rain fell, on 5 days gales of wind or strong breezes blew, landing was safe in Falmouth Bay on 13 days, and the direction of the wind was S.W. for 7 days, W. 5 days, N.W. 2 days, E. 1 day, and variable 2 days.

During September 1816 the mean temperature was 55° and the extremes 80° and 40°. Rain fell on 25 days, and strong breezes or gales were registered on 15 days. On 16 days the landing was safe, and the direction of the wind was S.W. for 17 days, N.W. 4 days, N.E. 2 days, N. 1 day, E. 1 day, W. 1 day, and variable 4 days.

During October 1816 the mean temperature was 58°, the extremes being 80° and 47°. Rain fell on 17 days, and strong winds or gales were registered on 13 days. Landing was safe on 17 days, and the direction of the wind was N.W. for 9 days, S.W. 7 days, W. 4 days, N.E. 2 days, N. 1 day, S.E. 1 day, and variable 7 days. From the 1st to the 27th November 1816 the mean temperature was 56° and the extremes 74° and 43°. Rain fell on 16 days, and strong winds or gales were registered on 12 days. Landing was safe on 17 days, and the direction of the wind was S.W. for 8 days, N.W. 5 days, W. 4 days, E. 1 day, S. 1 day, and variable 8 days. The temperature was registered four times a day—at sunrise, 8 A.M., noon, and sunset; occasionally also at 2 P.M. The register of the landing refers to the beach in Falmouth Bay.

During Lieutenant Rich's period of command only two vessels were sighted from the island before the "Falmouth" came to take them off on the 26th November 1816, having on board a detachment of troops, under the command of Captain Cloete, amongst whom were several men of the Royal Artillery skilled in various trades. The detachment, about 100 in number, was accompanied by 17 women, wives of the soldiers, and was well provided with horses, cattle, sheep, poultry, and pigs.

The "Falmouth" having landed the troops, embarked Lieutenant Rich and his party, and left Captain Cloete as Commandant or Governor of this military colony. The troops only remained in occupation of the island for a year, for, finding by the reports of the various men of war who visited the group that its want of shelter for ships, and the difficulty of communicating with the shore, rendered it almost impossible to make any island of this group a base of operations for facilitating the escape of the Emperor from St. Helena, the Government determined to withdraw the garrison, and leave the islands once more in the occupation of sea birds and seals. Consequently two vessels were despatched to bring off the troops and their baggage, viz., the sloop "Julia," Captain Jenkin Jones, and the frigate "Eurydice," Captain Wauchope.

The "Julia" arrived at the island first, anchored in Falmouth Bay, and commenced receiving stores; but on the night of October 2nd, 1817, whilst at anchor, a heavy swell set in about midnight from the northward, and drove her on shore, when fifty-five out of her crew of ninety-five perished. The captain, it appears, was on shore, not having gone off to his ship in the evening; and it is reported that neither he nor any of the troops knew of this sad catastrophe until one or two of the men who were fortunate enough to escape drowning ran up the bank and told them; which, if true, does not say much for the vigilance of the sentries on the island. The "Julia" had visited the island on a previous occasion in December 1816, and had then anchored rather too close to the shore; but it must be borne in mind that, until her loss, it was not known that the first warning of a northerly gale is a heavy surf setting in during a calm, and that even when the gale is at its height its force is not much felt at the settlement, owing to the influence of the high perpendicular cliffs immediately to leeward of the anchorage.

A month after the loss of the "Julia," the "Eurydice" arrived, anchored in Falmouth Bay (4th November), and commenced embarking stores and luggage. On the night of the 5th, however, Captain Wauchope, taking warning by the sad fate of the "Julia," slipped his cable at 10.30 P.M. at the beginning of an easterly wind, and it was fortunate for him he did so, for until the 18th he was unable to return to the bay and complete the embarkation of the troops and their baggage, being engaged for thirteen days in battling against strong breezes, gales, and dirty rainy weather.

On the 18th, however, the "Eurydice" was enabled to return to the anchorage, and having completed the embarkation by 2 P.M. on the 19th, left the bay just as another northerly wind commenced; even then it was not found possible to hoist in the boats before making sail, but this was put off until the safety of the ship was secured.

Captain Wauchope, whose careful and laborious operations in obtaining the temperature of the sea at considerable depths have been rescued from oblivion by Professor Prestwich, F.R.S.,[1] made careful observations on the weather. He was the first to point out that, owing to the peculiar formation of the coast, a northerly gale is not felt at the anchorage, but that the swell setting in with resistless violence would certainly cause the loss of any sailing vessel that might be caught at anchor in Falmouth Bay; and this statement has since been confirmed by the settlers, who say that north and northwest winds are not felt at the settlement, but southwest winds are exceedingly violent and destructive. Captain Wauchope also says in one of his reports, "that in fine weather nothing

[1] *Phil. Trans.*, vol. clxv. p. 595, 1875.

can be more beautiful or picturesque than Tristan, with its lofty peak covered with snow, the sea as smooth as the stillest lake, just rippling against the fine volcanic black sand on the beach, and a cascade of the purest water falling over a cliff directly into the sea; but it must not be forgotten that in the course of an hour this calm and placid scene may be rendered one of the most terrific in nature, and prove in an unmistakable way the power of the ocean, for in that short time the beach, so lately covered with fine sand, has forced up on it immense stones, which, tossed against one another by the surf, create a noise resembling thunder, and so quickly are these large stones cast up that a fortnight after the wreck of the 'Julia' she was almost entirely buried beneath them."[1]

When Captain Cloete received orders to abandon the settlement, and return with his men to the Cape of Good Hope, one of his soldiers, Corporal William Glass, in charge of the detachment of the Royal Artillery, asked, and received, permission to remain on the island with his wife and family. He persuaded two other men, John Nankivall and Samuel Burnell, both natives of Plymouth, to join him, and form a kind of partnership, in which he was to be the principal. One of the officers drew up a form of agreement between the three men, which they signed, and in November 1817, after the departure of the troops, these three men, with Glass's wife and two children, remained for some considerable time the only inhabitants of the group.

From 1817 to the present time Tristan Island has always been occupied either by the original settlers, their descendants, or other people, who from time to time have become fascinated by the primitive life of this interesting community. To the time of his death, which happened in 1853, Corporal Glass, who appears to have been a man of some education, considerable industry, mild temper, and strong religious principles, was considered the chief of the settlement, and was commonly designated as the Governor by the other residents, who invariably bowed to his decisions. In 1849, previous to the death of Glass, a gentleman interested in the welfare of this remote colony, remitted to the Society for the Propagation of the Gospel a sum of £1000, to be expended in providing the inhabitants of Tristan Island with a resident clergyman for five years, who would fulfil the office of teacher as well as minister. The Society selected the Rev. W. F. Taylor for the task, and he reached the island in 1851, and remained there until 1857, when he left for the Cape of Good Hope in H.M.S. "Geyser," and took with him forty-five of the inhabitants, who thought they could better themselves in that colony. After the death of Corporal Glass, the Rev. Mr. Taylor was, of course, considered the chief of the settlement until his departure, since which time a man named Peter Green has been acknowledged as such.

For the first three years of its existence this little colony had few communications with the outer world; they lived very happily together, Mrs. Glass attending to the dairy and other such suitable work, and the three men looking after the cattle and sheep, and

[1] M.S. Report in Hydrographic Department of Admiralty.

cultivating the ground. In December 1820, the colony received an addition to its number, for a small sloop, the "Sarah," being wrecked there in that month, three of her men resolved to remain on the island, and in June 1821, three additional men were landed by H.M.S. "Satellite." In July 1821, the "Blenden Hall" was wrecked on Inaccessible Island, and in November of that year some of the crew managed to cross over to Tristan and make known the fact to Glass, who immediately started to the relief of the shipwrecked men, and succeeded in transporting them all to his own island, where they were treated with the utmost kindness and consideration, and from whence they were eventually taken to the Cape of Good Hope by the barque "Susanna" and the brig "Narina," but not without leaving behind them a welcome addition to the colony, for one of the crew having fallen in love with a servant maid on the voyage, the two married, and settled on the island, thus providing Mrs. Glass with a companion of her own sex.

After the wreck of the "Blenden Hall," the colonists became ambitious of possessing a small vessel of their own, in which they might carry their surplus produce to the Cape of Good Hope, and bring back such necessaries as could more easily be purchased than grown or manufactured on their own island. They accordingly bought a small schooner for £700, which they paid from the produce of the cargoes they sent to Cape Town; but the vessel was, unfortunately, totally lost through carelessness in Table Bay in 1823, since which time the inhabitants of Tristan Island have entirely depended on passing vessels for their communication with the outer world.

Before the schooner was wrecked she had brought four new settlers to the island, including a woman and a middle-aged doctor suffering from dipsomania, whose friends thought that a residence in Tristan might cure him. These constituted, with the original settlers and their descendants, the inhabitants when the island was visited by the "Berwick" in 1823. The doctor, however, soon got tired of his enforced sobriety, and managed to leave the island before he had been there twelve months, and some of the other men also became wearied of their primitive mode of life, and left, so that in 1824 the population was reduced to four men, two women, and the children. In this year, however, they received an accession to their number, for a gentleman, named Earle, a naturalist and artist, who landed to explore the island whilst the ship in which he was a passenger was lying off for the purpose of receiving supplies, was accidentally left behind, owing to the wind suddenly increasing to such a degree that the ship was obliged to leave the group; he remained at the settlement eight months before he could obtain a passage in a passing vessel, and, like a good fellow making the best of his circumstances, acted as parson and schoolmaster during his enforced residence.

In 1826 there were seven men and two women besides children on the island. Seeing that the five unmarried men were in want of wives, a Captain Anim made a bargain with them by which he bound himself to proceed to St. Helena and endeavour to procure five women who should return with him to Tristan in search of husbands. In April 1827 he brought the women, and they were married to the five bachelors of the settlement, bringing the total number of families up to seven, and these were the residents when the group was visited and described by Captain Morrell of the "Antarctic."

In 1828 American whalers first began to visit the neighbourhood of the Tristan da Cunha group in search of spoil, and they have continued to do so more or less ever since. Requiring, as they do, a constant supply of fresh meat and vegetables, and having always on board surplus quantities of flour, coffee, tea, sugar, &c., a brisk trade ensued between their crews and the islanders, which reached its maximum in 1840, and has since gradually declined, for the whales, harassed by the attacks of the numerous ships employed in their capture, have gradually departed to localities less easy of access, and, naturally, the ships have endeavoured to follow them.

The visits of these whaling vessels were of considerable benefit to the colony, for not only did they bring news of what was going on in the world, but they afforded opportunities to the boys (descendants of the original settlers) of occasionally taking a cruise, thus becoming acquainted with other communities, and working off the natural wish of most young men to wander for a time; they also supplied opportunities of marriage to the young women, of which some took advantage; and, above all, by reminding the inhabitants that, did they feel discontented with their simple mode of life, an opportunity of escaping from it was frequently to be had for the asking, made them year by year less inclined to sacrifice their numerous comforts to enter the race of life amongst communities less bound together by ties of interest and consanguinity than themselves.

How the inhabitants of this remote dependency of the British Crown have prospered can be better seen by referring to the following table of statistics than by any description. Their flocks and herds have increased after supplying all their wants, and their vegetable produce has always been greater than the consumption, while their food and cooking have been described, by those visitors who have enjoyed their hospitality, as most excellent. The table gives the names of the ships whose captains have made reports on the state of the group, the date of their visit, the number of inhabitants, the produce of the island, and a column has been added showing in what publication these reports appear *in extenso*, so that reference can be made to them should it be necessary to ascertain exactly what was said of the settlement at any particular date.

The occasional decrease in the number of the inhabitants shown by this table is due to emigration, and not to disease or death. The residents are remarkably healthy and vigorous, and invariably decline to receive a medicine chest.

From all the ships mentioned in the following table a description of the settlement, more or less diffuse, has been given, from which an excellent idea of the condition of the island can be gathered.

Date.	Ship's Name.	Captain's Name.	Number of Inhabitants. Men.	Women.	Children.	Total.	Live Stock on Island.	Vegetables on Island.	Remarks.
1817	When abandoned by troops.		3	1	2	6	Cattle, sheep, pigs, goats, poultry	Potatoes, cabbages, carrots	Narrative of Rev. Mr Taylor, published by S. P. G. in 1856.
1823	Berwick	Jeffery	22	3	–	25	Cattle, sheep, pigs, goats	Potatoes, cabbages, &c.	Findlay's Directory for South Atlantic Ocean.
1829	Antarctic	Morrell	7 families				Cattle, pigs, goats, rabbits, poultry	Potatoes, cabbages, beetroot, parsnips, carrots, onions, pumpkins	Butter, cheese, eggs, and milk also offered for barter; peach and apple trees.[1] Morrell's Voyage.
1833	Diana and Mary	...	6	6	28	40	... ...	... ...	Findlay's Directory for South Atlantic.
1835	Wellington	Liddell	–	–	–	41	50 cattle, 75 sheep, pigs and poultry.	... ...	Naut. Mag., 1836.
1852	H.M.S. Herald	Denham	–	–	–	85	Cattle, sheep, pigs, poultry	Plenty, but names not mentioned	Eggs, butter, and milk; peach and apple trees. Naut. Mag., vol. xxii., 1853.
1856	H.M.S. Frolic	Nolloth	–	–	–	71	200 cattle, 300 sheep, pigs, poultry, goats	Potatoes	Peach and apple trees. Naut. Mag., vol. xxv., 1856.
1862	H.M.S. Cyclops	Pullen	6	11	19	36	Cattle, sheep, fowls, ducks, pigs	Potatoes, cabbages, onions	Apples and peach trees. Naut. Mag., vol. xxxi., 1862.
1867	H.M.S. Galatea	Duke of Edinburgh	–	–	–	53	500 cattle, 200 sheep, fowls; no goats	Potatoes, parsnips	Strawberries. The Cruise of H.M.S. "Galatea."
1873	H.M.S. Challenger	Nares	–	–	–	84	600 cattle, 600 sheep, fowls, geese, pigs	Potatoes, and other vegetables	15 houses; beef 4d. per pound, potatoes 4s. per bushel, eggs, milk. Personal observations.
1875	Sappho	Digby	–	–	–	85	Cattle, sheep, pigs, poultry	Potatoes, and other vegetables	Parliamentary Papers, 1876.
1875	Diamond	Bosanquet	15	18	52	85	Cattle, sheep, pigs, poultry	Vegetables only mentioned	Do., do.

[1] It is very unlikely that peach or apple trees, if planted, would grow to any size, or the fruit ripen. The subsequent writers who mention these trees have probably copied Morrell.

Plate VII.

HORSBURGH, EDINBURGH. PERMANENT PHOTOTYPE.

PENGUIN ROOKERY, INACCESSIBLE ISLAND.

Life at Tristan is by no means without its advantages, since it does not necessitate any considerable amount of labour. Vegetables, such as potatoes, cabbages, carrots, and parsnips, can be raised in considerable quantities, but the fields in which they are planted must be small and walled all round to protect them from the wind; fish can readily be caught in almost any quantity; fur seals, though scarce, are occasionally captured; the cattle provide meat, milk, butter, and cheese. There were between 500 and 600 head of cattle, and about as many sheep, on the island when it was visited by the Expedition; but the cattle are often lost in the very cold weather from exposure. The sea birds provide large numbers of eggs; passing vessels exchange flour, coffee, sugar, and other articles of luxury, for the surplus produce of the island, mainly potatoes and meat; and, in short, the settlers on this remote spot are not badly off. The wild goats and pigs have been entirely killed off, and the wild rabbits, formerly numerous, appear to be now quite extinct.

The character of the inhabitants stands deservedly high; they have invariably assisted, to the best of their ability, all shipwrecked persons, and they also fed, and provided for the wants of, forty prisoners landed by the "Shenandoah" during the American Civil War, although they naturally enough remonstrated against such a sudden influx of visitors. This high character appears to be in a great measure due to the judicious example of the late Corporal Glass, who was much respected by the Rev. Mr. Taylor and by all the captains of vessels touching at the island. The Rev. Mr. Taylor also always spoke in the highest terms of the moral character of the community, and said he failed to trace a vice amongst them. Since his departure, and probably owing to the want of such a man as Glass to set them an example, the inhabitants appear to have deteriorated slightly from this high standard. Captain Pullen of H.M.S. "Cyclops" states that when he visited the island in 1862, some of them were decidedly excited by liquor towards evening.

The houses forming the village, fifteen in number, are built very solidly of huge rectangular blocks, cut out of a soft red tufa, fitted together without mortar (see Pl. IX.), the walls being about 8 feet high and 3 feet thick; the roofs are raftered with wood obtained from American vessels, and then thatched with Tussock Grass, a most excellent material which outlasts the rafters. Small gardens surround the cottages, walled in to shelter them from the violent southwest winds, and roses and other flowers are successfully cultivated.

There can be no doubt that the habitation of Tristan Island is of immense advantage to the sailor, and it would be a great pity were the island ever to be abandoned. Many shipwrecked crews have been hospitably received by the settlers, and their wants supplied without any recompense being required. Should this group be made a dependency of the British crown, a resident clergyman or schoolmaster might be appointed to act as Governor.

With respect to men-of-war calling, there need be no apprehension of danger. Gales of wind are, of course, common at all seasons, but the islanders can nearly always communicate with ships if they stand close in, and now-a-days, with steam ever at command, there is no chance of a vessel sharing the "Julia's" fate. One precaution should, however, always be taken by vessels anchoring—steam should invariably be kept up, and the cable ready for slipping at a moment's warning.

The cliffs of the main island show a very regular stratification, and are composed throughout of a series of beds lying nearly horizontally, but dipping slightly towards the shores, at least they appear to do so east and west of the anchorage. The beds, which are conspicuously marked, are alternately of hard basalt and looser scoriaceous lava, with occasional beds of a red tufa. The whole section is traversed by numerous dikes, mostly

FIG. 99.—Settlement of "Edinburgh," Tristan da Cunha. (*From a Photograph.*)

vertical and usually narrow in appearance, and is not unlike that exposed in the Grand Cural at Madeira. The rock specimens collected were large grained felspathic basalts sometime bordered with layers of black basaltic glass (sideromelan) passing to palagonite, basaltic tufa, augite-andesite, pyroxenite, and amphibolic andesite containing sanidine.

Streams, or rather cascades, which come dashing down to the sea during the constant heavy rains, have eaten their way into the cliffs, and their beds form conspicuous features in the view as narrow gullies, descending the rocks in a series of irregular steps. At the foot of the cliffs, immediately opposite the anchorage, are débris slopes and irregular rocky and sandy ground, forming a narrow strip of low shore land.

The settlement lies on a broader and more even stretch of low land which extends westwards (see fig. 99). At the margin of this lower tract a small low secondary cliff has been formed by the waves. Steep slopes of débris lead to the settlement above from the cliffs, here and there broken into ledges and deep gullies, by which ascent to the summit is easy. At the landing-place the beach is formed of black volcanic sand, but elsewhere in the neighbourhood, of coarse basaltic boulders.

The cliffs have a scanty covering of green, derived mainly from grasses, sedges, mosses, and ferns, with darker patches of the peculiar trees of the island (*Phylica nitida*), and the Crowberry (*Empetrum nigrum*, var. *rubrum*); these dark patches become more and more marked towards the summit. Conspicuous patches of bright green are formed under the cliffs at the foot of the water-courses by a Dock (*Rumex frutescens*). Further, dotted about amongst the other herbage, are rounded tufts of pale bluish-green, consisting of the tall reed-like Tussock Grass (*Spartina arundinacea*), which is peculiar to the Tristan da Cunha group, St. Paul and Amsterdam Islands. On nearer inspection the damp foot of the cliff is found to be covered with Mosses and Liverworts, which latter form, in favourable situations, continuous green sheets covering the earth beneath the grass. Many Ferns were collected; *Asplenium obtusatum*, growing in the clefts of the rocks, just as does our home *Asplenium marinum*, and *Lomaria alpina* growing abundantly under the cliffs.[1] The *Lomaria* plants, where situated on stony slopes, and comparatively starved, were all provided with fertile fronds, whilst when growing in rich vegetable mould, they were commonly without fructification. The commonest flowering plants under the cliffs are Wild Celery (*Apium australe*)—a plant abundant here, in Tierra del Fuego, and in the Falkland Islands, —the Crowberry (*Empetrum nigrum*, var. *rubrum*), the common Sow-thistle (*Sonchus oleraceus*), a cosmopolitan weed,—and a plant with strongly scented leaves (*Chenopodium tomentosum*), called "tea" by the islanders, and used as such, a decoction of the leaves being drunk with milk and sugar. Creeping amongst the damp moss is the narrow-leaved plant with small bright red berries (*Nertera depressa*), so common in English conservatories.

The streams running down the cliffs, which vary from violent dashing cascades in rain time, to narrow rills fed only by the melting of the snow above in dry weather, were small at the time of the ship's visit; the water soaks into the banks of sand at the foot of the cliffs and on the shores, and is mostly lost, but in some places reappears in the shape of shallow freshwater ponds close to the sea beach. The water of the streams had a temperature of 50°, whilst that of the ponds was higher, 54°. The temperature of the lower regions of the island is no doubt constantly reduced by the descent of the cold water from the snow far above; in the gully above the settlement, shrubs of *Phylica nitida* commence at about 400 feet elevation. The trees in this locality have all been cut down for firewood, but there is still plenty of wood on the island. *Phylica nitida* is a species found in the Tristan da Cunha group, Gough Island, and in the far-off island of Amsterdam, 3000 miles distant; as well as in Bourbon, Mauritius, and perhaps Mada-

[1] For detailed list, see Bot. Chall. Exp., part iii. pp. 162–170, 1884.

gascar. The genus belongs to the natural order of the Buckthorns (Rhamnaceæ), and other species occur at the Cape of Good Hope, but they are low and shrubby. The foliage of the tree is of a dark glossy green, with the under sides of the narrow almost needle-like leaves white and downy, hence the tree, which in habit is very like a Yew, presents as a whole a mixture of glaucous grey and dark olive green shades; it bears berries of about the size of sweet-peas, which are eaten by the Finch living on the islands. The constant heavy gales do not permit the tree to grow erect; the trunk is usually procumbent at its origin for several feet, and then rises again, often at a right angle, and is always more or less twisted or gnarled. In sheltered places, as under the cliffs on the northeast of Inaccessible Island, the tree is as high as 25 feet, but it is not nearly so high on the summit of the island, though the trunks are said there to reach a length of 30 feet or more. The largest trunk seen was about a foot in diameter, but they are said to grow to 18 inches. The wood of the tree is brittle, and when exposed, rapidly decays, but is serviceable when dried carefully with the bark on. The German settlers on Inaccessible Island used it even for handles to their axes and other tools.

Inaccessible Island, next in size to Tristan, and the most westerly of the group, receives its name from its appearance; and certainly this name seems most applicable when the island is viewed from a distance of 2 or 3 miles. A nearer approach, however, discloses the fact that beaches exist, here and there, at the foot of the almost perpendicular cliffs, all around the island, and on the northeast and northwest sides these beaches are occasionally so wide as to afford space for building purposes, or pitching tents; and from two points where the cliffs are somewhat broken it is possible, by the aid of the Tussock Grass, which grows on every available spot, to climb to the undulating table top of the island.

Inaccessible Island is quadrilateral in shape, the sides being nearly equal, each about 2 miles in length, and the angles pointing in the direction of the cardinal points of the compass. Its highest point, on the west side, is 1840 feet above the level of the sea; from here it slopes irregularly towards the coast, terminating on all sides in precipitous cliffs averaging 1100 feet in height. On the south point is a remarkable rocky cone 1140 feet, and on the southwestern side another cone 690 feet, in height, but separated from the cliffs by V-shaped chasms, apparently the effect of rain. Separated from the south point by a channel, a cable wide, is a pyramidal rock 60 feet in height, close to which is a smaller rock only 3 feet above the level of the sea, and off the southwest coast of the island are three detached rocks over which the sea is constantly breaking. On the southeast side is a conical rock 230 feet in height, just off the coast, and a cable off the east point is a rock 3 feet above the level of the sea. On the northeast side of the island are two waterfalls, the easternmost being the larger and more conspicuous (see fig. 100), and off a point in the centre of the northeast coast is a rock 2 feet above the level of the sea, half a cable from the beach. The position of this rock is lat. 37° 17′ 50″ S., long. 12° 42′ 10″ W. The northwest coast has no rocks off it above water, but there are rocky shelving points projecting from the beach, which extends the whole length of this side of the island.

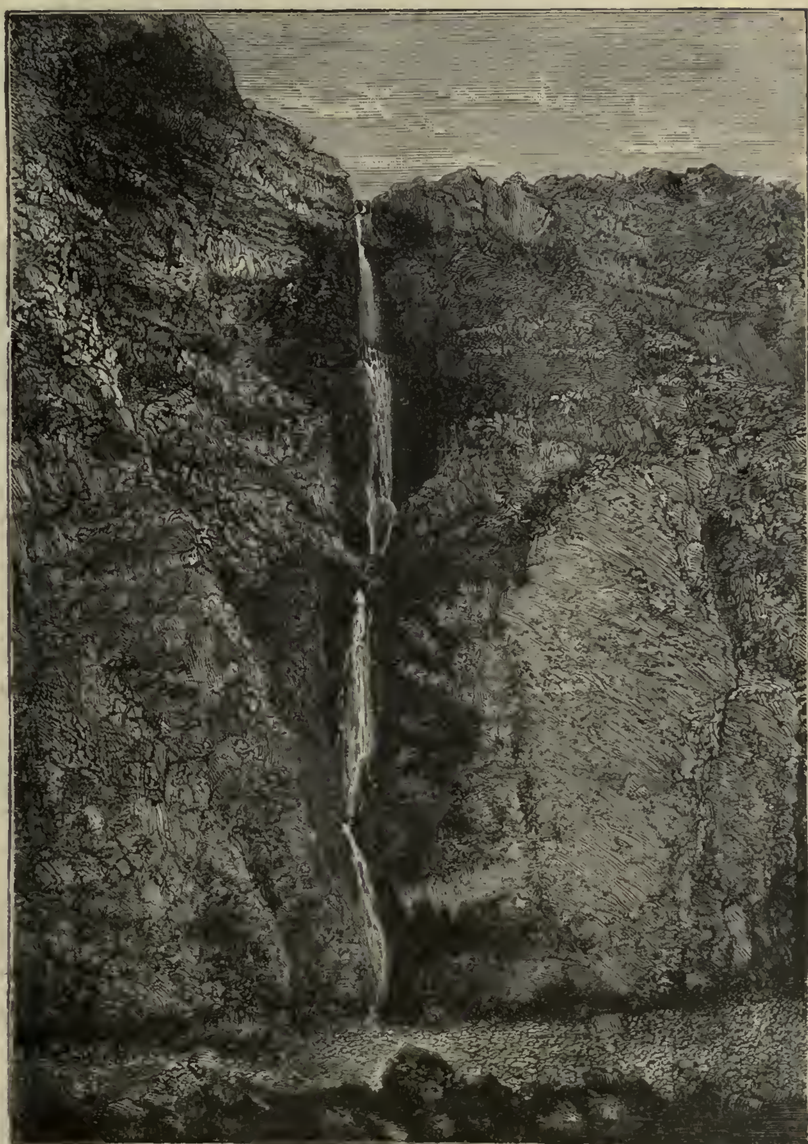


Fig. 100.—Waterfall, Inaccessible Island. (*From a Photograph.*)

Between Inaccessible and Tristan Islands is a perfectly safe channel, 20 miles across. Soundings of from 50 to 90 fathoms were obtained at distances of from 1 to 2 miles round Inaccessible Island. Kelp was observed growing on the northeast side, extending to a distance of half a mile from the coast. Owing to the detached rocks on the southwest coast extending to a distance of nearly three quarters of a mile, the island should not be approached on this side within 2 or 2½ miles; but on the other sides 1 mile is a safe distance in a steam vessel, and anchorage can be obtained off the 2 feet rock on the northeast coast, but no sailing vessel should use it.

The island was surveyed by placing a boat in position off the east point; the Challenger then steamed round obtaining soundings and angles. At every sounding the ship was stopped, and at a given signal her masthead angle taken by the officer in the boat, the bearing of the boat being taken on board (as well as the angles) whilst the ship was stationary.

Captain Richardson, of H.M.S. "Semiramis," was the first, as far as there is any record, to effect a landing on Inaccessible Island, when in 1813 he visited the group and explored the three islands. The forbidding aspect of Inaccessible has prevented any attempt to settle on it, and it appears to have been rarely visited until the "Blenden Hall" was wrecked there in 1821. Since that time, however, a boat from Tristan has gone over nearly every year. The crew and passengers of the "Blenden Hall" remained on the island nearly six months before they were rescued; they must, therefore, be considered its first inhabitants. This ship, bound to Bombay from London, was lost on the 23rd July 1821. It appears that her captain wished to sight the group to verify his chronometer, and stood towards the land, notwithstanding the unfavourable state of the weather, which was thick, with a considerable swell and light breeze. At about 9 A.M. kelp was reported and he tried to tack, but owing to the light wind missed stays, and before he could get his boats ahead to tow, breakers were reported, and then high land was seen through the mist. The boats had no power to tow the ship against the swell, and, failing to anchor, the vessel was drifted on shore, and soon broke up, but not until all the crew and passengers, with the exception of two men, had been safely landed. Some sails thrown up on the beach enabled them to erect tents; the Sea Elephants and other Seals, Penguins, and numerous sea birds supplied them with an ample quantity of food, which though unpalatable is sufficiently nourishing, and as water is plentiful, they were better off than most people who have the misfortune to be wrecked. After being three months on shore, a boat was constructed with the aid of some surgical instruments, from the remains of the wreck, in which six men started for Tristan. Bad weather drifted them away from the group, and they were picked up by a passing vessel, whose captain, it appears, was not humane enough to return to Inaccessible to take off the castaways. By the 8th November those left on Inaccessible Island had succeeded in constructing a second boat, which reached Tristan in safety. Corporal Glass, directly he heard of the wreck, started immediately to their relief, and succeeded in transporting them all to his own island, from whence they were taken by passing vessels to the Cape of Good Hope.

Corporal Glass, in view of the probability of other vessels being lost on Inaccessible

Plate VIII.

HORSBURGH, EDINBURGH. PERMANENT PHOTOTYPE.

SEA CLIFF, INACCESSIBLE ISLAND

Island, landed on it, shortly after the wreck of the "Bienden Hall," some goats and pigs; the progeny of the latter still flourish on the plateau above the cliffs of the island, but as they live almost entirely on sea birds and their eggs, their flesh has a peculiar fishy flavour, and is very unpalatable, so much so that the men in the Challenger could not eat it.

From 1822 Inaccessible remained deserted until the 27th November 1871, when two Germans (brothers), named Frederic and Gustav Stoltenkoff, landed there for the purpose of collecting sealskins, and remained on the island until taken off by the Challenger in October 1873, after a residence of nearly two years.[1]

As the vessel lay off Inaccessible Island, the Penguins were to be heard screaming all night on shore and about the ship, and when parties of them passed by, they left vivid phosphorescent tracks behind them as they dived through the water alongside. In the morning the island was in full view, and presented on this side a range of abrupt cliffs, of much the same structure as those of Tristan, viz., successive layers of basalt, traversed by vertical or oblique dikes, mostly narrow vertical ones. At the foot of the cliffs are some very steep débris slopes, extending in one place a long way up the cliff, but not so as to render the ascent possible (see Pl. VIII.). In front of these stretches a strip of narrow uneven ground, formed of large detached rocks and detritus from the cliffs above, which terminates seawards in a beach of black boulders and large pebbles. In one place, where the cliff is somewhat lower than elsewhere, there is a waterfall, which at the time of the visit was scantily supplied with water, but, from the marks left by it on the rocks and vegetation, it evidently attains much greater dimensions in rainy weather. The cascade pours right down from the high cliff above into a dark pool of peaty water on the beach below. The rocks about its course are covered with mosses and green incrusting plants. The face of the cliff generally is sprinkled over with green, the vegetation consisting principally of Tussock Grass (*Spartina arundinacea*), Wild Celery (*Apium australe*), Sow-thistle (*Sonchus oleraceus*), Dock (*Rumex frutescens*), a small Sedge (*Carex insularis*), and Ferns; with dark green patches of *Phylica nitida* on the débris slopes and ledges.

Amongst the grass are several patches or small coppices of *Phylica nitida* trees, which keep the ground beneath them free from Tussock, it being covered instead with a thick growth of Sedges, Ferns, and Mosses, forming an elastic carpet on the dark peaty soil. Amongst the moss creeps *Nertera depressa*, with its bright red berries, and the *Potentilla*-like *Acæna sanguisorbæ* grows here and there, together with the "tea-plant" of the islanders. The stems and branches of the *Phylica* trees are covered with lichens in tufts and variously coloured crusts, and the branches of the trees meeting above these little islands, as it were, in the seas of tall grass, afford most pleasant shady retreats, which

[1] Two Years on Inaccessible Island, by R. R. Richards, Esq., R.N., *Cape Monthly Magazine*, Cape Town, J. C. Juta 1873.

seem a perfect paradise after the terrible struggle and fight through the Penguin rookery, which it is necessary to endure in order to reach them.

In landing it was necessary to pass through a broad belt of water, covered with the floating leaves of the wonderful seaweed already referred to, *Macrocystis pyrifera*, termed "Kelp" by seamen, which here, as at Tristan and Nightingale Islands, forms a sort of zone around the greater part of the island, and which was afterwards met with in great abundance at Kerguelen Island.

As the shore was approached, a shoal of what looked like extremely active very small Porpoises or Dolphins was seen moving through the water. They showed black above and white beneath, and came along in a drove of fifty or more, from the sea towards the shore at a rapid pace, by a series of successive leaps out of the water and splashes into it again, describing short curves in the air, taking headers out of the water and headers into it. They landed on the black stony beach, and there struggled and jumped up amongst the boulders, and revealed themselves as wet and dripping Penguins. It would have been impossible for any one previously unacquainted with them to have believed the animals to be birds, had he seen them only thus in rapid motion in the water.

The beach was bounded along its whole stretch at the landing place by a dense growth of Tussock, a stout, coarse, reed-like grass, growing in large clumps, which have at their bases large masses of hard woody matter, formed of the bottom of old stems and the roots. In Penguin rookeries, the grass covers wide tracts with a dense growth like that of a field of standing corn, but denser and higher, the grass reaching high over a man's head. The Falkland Island "Tussock" (*Dactylis cæspitosa*) is of a different genus, but it has a similar habit. In the Tristan group there is a sort of mutual-benefit-alliance between the Penguins and the Tussock. The millions of Penguins sheltering and nesting amongst the grass, saturate the soil on which it grows with the strongest manure, and the grass thus stimulated grows high and thick, and shelters the birds from wind and rain, and enemies, such as the predatory Gulls. On the beach were to be seen various groups of Penguins, coming from or going to the sea. There is only one species of Penguin in the Tristan group (*Eudyptes chrysocome*). The birds stand about a foot and a half high, and are covered, as are all Penguins, with a thick coating of closely set feathers. They are slaty grey on the back and head, snow white on the whole front, and from each side of the head a tuft of sulphur yellow plumes projects backwards. The tufts lie close to the head when the bird is swimming or diving, but they are erected when it is on shore, and then almost seem, by their varied posture, to be used in the expression of emotions, such as inquisitiveness and anger. The bill of the Penguin is bright red, and very strong and sharp at the point, as the legs of the various exploring parties testified before the day was over; the iris is also red, and remarkably sensitive to light. When one of the birds was standing in the zoological laboratory on board the ship, with one side of its head turned towards the port, and the other away from the

Plate IX.

Horsburgh. Edinburgh. Permanent Phototype.

House-building, Tristan-da-Cunha.

light, the pupil on the one side was contracted almost to a speck, whilst that on the other was widely dilated. The birds are subject to great variations in the amount of light they use for vision, since they feed at sea by night as well as by day. It seems remarkable that there should be only one species of Penguin at the Tristan da Cunha group, since in most localities several species occur together. It would seem probable that a species of Jackass Penguin (*Spheniscus*) should occur on the islands, since one species (*Spheniscus magellanicus*) occurs at the Falkland Islands and Fuegia, and another (*Spheniscus demersus*) at the Cape of Good Hope, intermediate between which two points Tristan da Cunha lies. The connection between these two widely-separated *Sphenisci* is wanting; perhaps it once existed at the Tristan group, but has perished. Most of the droves of Penguins made for one landing place, where the beach surface was covered with a coating of dirt from their feet, forming a broad track, leading to a lane in the tall grass about a yard wide at the bottom, and quite bare, with a smoothly beaten black roadway; this was the entrance to the main street of this part of the "rookery," for so these Penguin establishments are called. Other smaller roads led at intervals into the rookery from the nests near its border, but the main street was used by the majority of the birds. The birds took little notice of their visitors, allowing them to stand close by, and even to form them into a group for the photographer. A very successful photograph of a group of the birds standing near one of the entrances into the forest of Tussock forming the rookery is reproduced in Pl. VII. This kind of Penguin is called by the whalers and sealers "rockhopper," from its curious mode of progression. The birds hop from rock to rock with both feet placed together, like men jumping in sacks, but they scarcely ever miss their footing. When chased, they blundered and fell amongst the stones, struggling their best to make off.

Immediately on entering the main street of the rookery the explorer is as if in a maze, and cannot see in the least where he is going. Various lateral streets lead off on each side from the main road, and are often at their mouths as big as it; moreover, the road sometimes divides for a little and joins again, hence it is the easiest thing in the world to loose the way, and this is quite certain to occur to persons inexperienced in Penguin rookeries. The Germans who acted as guides, accustomed to pass through the place constantly for two years, were perfectly at home in the rookery, and knew every street and turning. It is impossible to conceive the discomfort of traversing a big rookery, hap-hazard, or "across country" as one may say. A plunge is made into one of the lanes in the tall grass, which at once shuts out the surroundings from view. You tread on a slimy black damp soil composed of the birds' dung. The stench is overpowering, the yelling of the birds most annoying and discordant. You lose the path, or perhaps are bent from the first in making direct for some spot on the other side of the rookery. In the path only a few droves of Penguins, on their way to and from the water, are encountered, and these stampede out of your way into the side valleys. The instant you leave the road you are on the actual breeding ground. The nests are placed so thickly that you cannot help treading on eggs and young birds at almost every step. A parent bird sits on each nest with its sharp beak erect and open, ready to bite, yelling savagely "caa, caa, urr, urr," its red eyes gleaming and its plumes at half-cock, quivering with rage. No sooner are your legs within reach than they are furiously bitten, often by two or three birds at once: that is if you have not got on strong leather gaiters, as on the first occasion of visiting a rookery you probably have not. At first you try to avoid the nests, but soon find that impossible; then maddened almost, by the pain, stench, and noise, you have recourse to brute force. Thump, thump, goes your stick, and at each blow down goes a bird. Thud, thud, is heard from the men behind as they kick the birds right and left off the nests, and so you go on for a bit,

FIG. 101.—Penguins at home.

thump, smash, whack, and thud, "caa, caa, urr, urr," and the path behind you is strewed with the dead and dying and bleeding. But you make miserably slow progress, and worried to death, at last resort to the expedient of stampeding as far as your breath will carry you. You put down your head and make a rush through the grass, treading on old and young hap-hazard, and rushing on before they have time to bite. The air is close in the rookery and the sun hot above, and out of breath, and perspiring with running you come across a mass of rock fallen from the cliff above, and sticking up in the ground; this you hail as "a city of refuge." You hammer off it hurriedly half a dozen Penguins who are sunning themselves there, and are on the look-out, then mounting on the top take out your handkerchief to wipe away the perspiration and rest a while, to see in what direction you have been going, how far you have got, and in what direction you are to make the next plunge. Then when you are refreshed, you make another rush, and so on. If you stand quite still, so long as your foot is not actually on the top of a nest of eggs or young, the Penguins soon cease biting at you and yelling. One must cross the rookeries in order to explore the island at all, and collect the plants, or survey the coast from the heights. These Penguins make a nest which is simply a shallow depression in the black dirt, scantily lined with a few bits of grass or not lined at all. They lay two greenish white eggs about as big as duck eggs, and both male and female incubate.

After passing through the rookery, one of the small coppices already described was entered. Hopping and fluttering about amongst the trees and herbage were numbers of a small Finch and a Thrush, but no other land birds were seen. The Finch (*Nesospiza acunhæ*), a genus peculiar to the Tristan da Cunha group, looks very like a Green Finch, and is about the same size. The Thrush (*Nesocichla eremita*), a genus also peculiar to

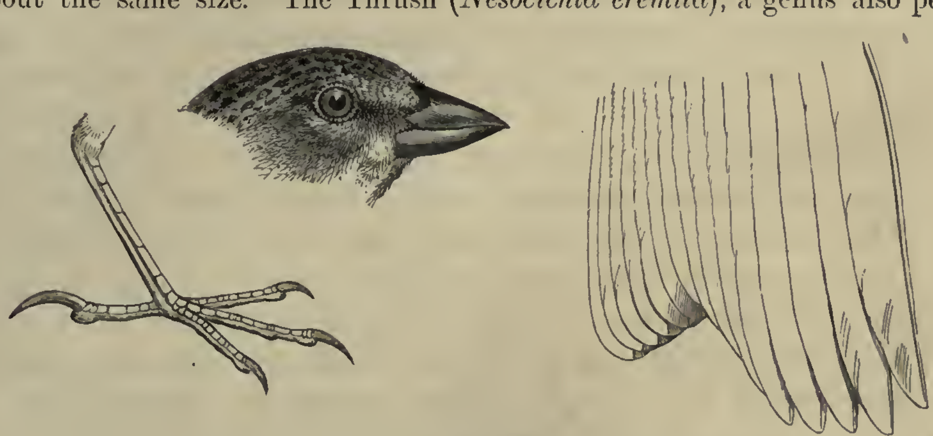


FIG. 102.—Head, foot, and wing of *Nesospiza acunhæ*, Cabanis.

this group, looks like a very dark-coloured Song Thrush, but it is peculiar for its remarkably strong and acutely ridged bill. The bird feeds especially on the

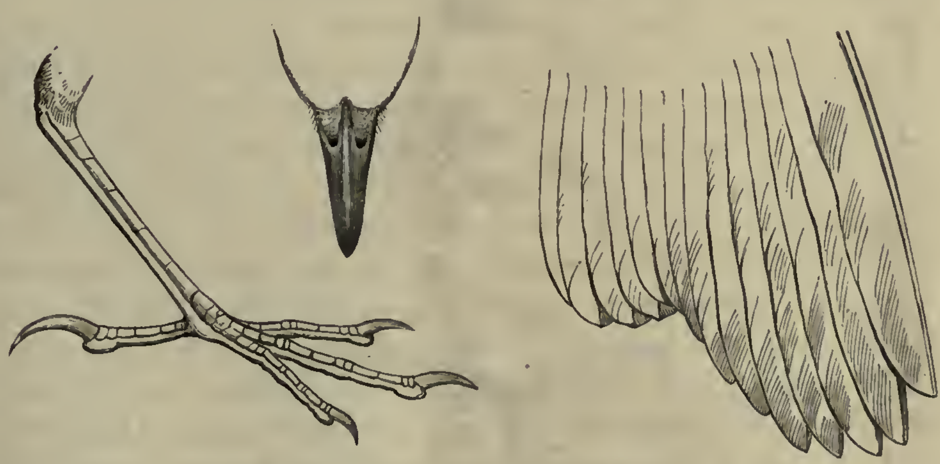


FIG. 103.—Head, foot, and wing of *Nesocichla eremita*, Gould.

berries of *Nertera*, but is also fond of picking the bones of the victims of the predatory Gull (*Stercorarius antarcticus*). The Finch eats the fruit of the *Phylica*, and seems to have become extinct in Tristan Island itself. Dr. v. Willemoes Suhm was told that the

Tristan people had tried to introduce the bird into their island without success. The only other land bird of the group, a kind of Water Hen (*Gallinula nesiotis*), which is found also on the higher plateau at Tristan Island, and is described by the inhabitants as scarcely able to fly, was not met with. Only very few inhabit the low land under the cliffs at Inaccessible Island, and the exploring parties were unable to land at the only place from which the higher main plateau of the island is to be reached. The Germans said that the Inaccessible Island bird is much smaller than *Gallinula nesiotis*, and differs from it in having finer legs and a longer beak. This is, however, hardly probable, since the Tristan species occurs at Gough Island.

Sitting on the tree tops with the Thrushes were numerous Noddies, of the same two species as those of St. Paul's Rocks. It was strange to see birds which one had met with on the equator living in common with Boobies, here mingling with antarctic forms. The Noddy, however, ranges far north also, occasionally even to Ireland. The whole of the peaty ground underneath the trees in the *Phylica* woods is bored in all directions with the holes of smaller sea birds, called by the Germans "night birds," a *Prion* and a *Puffinus*. These burrows are about the size of large rats' holes, and they traverse the ground everywhere, twisting and turning, and undermining the surface so that it gives way at almost every step.

The rocks of Inaccessible Island are felspathic basalt (some specimens of this basalt have porphyritic augite), dolerite, augite-andesite, sideromelan, and palagonite.

Nightingale Island, the smallest and southernmost island of the group, consists of one large and two small islets, with several rocks immediately adjacent to the coast, and, unlike Tristan and Inaccessible Islands, rises in low cliffs, from the top of which the land slopes upwards, terminating in two peaks, one of which (1100 feet high) is rugged and steep, whilst the other (960 feet high) slopes gently towards the coast all round, except immediately to the southward, where its descent is precipitous. Nightingale Island is one mile long east and west, and three quarters of a mile wide; the other two islets lie to the northward of Nightingale, and are each a third of a mile in length and a sixth in breadth; they were named by the Challenger, "Stoltenkoff" and "Middle" Islands; Stoltenkoff, the farthest from Nightingale, being 325 feet high, with a flat top, and Middle Island 150 feet high, with an undulating top.

Nightingale Island was first landed on by M. d'Etchevery in 1767, who anchored his vessel "l'Etoile du Matin" off it in 33 fathoms, with the centre of the island W.S.W. He described Stoltenkoff Island as having the appearance of a ruined fort, a description which holds good to the present day. Nightingale Island has, so far as is known, never been inhabited, although it has been visited frequently for the purpose of shooting Seals, numbers of which used to frequent the caves hollowed out in its low cliffs; but the reckless manner in which the Seals were slaughtered caused them to desert this breeding place, so that visits to Nightingale Island have of late years much diminished in frequency. The same small tree and Tussock Grass found on Tristan and Inaccessible Islands grow here, and the island is also frequented by the same birds. Water was not so plentiful as on the other two islands, and goats have not been landed, a subject of much regret, as they would certainly flourish. The island was surveyed in a somewhat similar manner to Inaccessible. An officer was stationed on the summit of Middle Island, who took the bearing of the ship and her masthead angle, at given signals, viz., when the ship was stationary, sounding and obtaining observations. The day being fortunately less cloudy than usual, sights for longitude, latitude, and true bearings were obtained, and angles to the summits of the various salient points on Inaccessible and Tristan Islands, by which the correct relative positions of the three islands of the group with regard to each other were ascertained. The observation spot, the summit of Middle Island, was found to be in lat. 37° 25′ 50″ S., long. 12° 29′ 45″ W.

Between Inaccessible and Nightingale Islands there is a perfectly safe passage, 10 miles in width, in which a sounding of 465 fathoms was obtained by the Challenger; and between Nightingale and Tristan Islands there are depths of 1000 fathoms and upwards.

Landing at Nightingale can easily be effected in moderate weather on the rocks at its northeast point; here, as in all the other islands of the group, a belt of kelp prevents the swell from breaking, and the boat rises and falls alongside the cliffs without danger, if care be taken to cast a line over some projecting knobs to prevent the surging backwards and forwards, which is certain to be experienced in all cases where the sea runs along the side of a cliff. There are no beaches on Nightingale Island.

The whole of the lower land of the island, and all but the steepest slopes of the high land and its actual summits, are covered with a dense growth of Tussock, which occupies also even the ledges and short slopes between the bare perpendicular rocks of the Peak. The lower ridge is covered with the grass on all except its very summit, where, amongst huge irregularly piled boulders of basalt, grow the same ferns as are found on Inaccessible Island, and *Phylica nitida* trees. The summit of the higher ridge appears to have a similar vegetation, the Tussock ceasing there. In the sea of tall grass, clothing the wide main valley of the island on its south side, are patches of *Phylica* trees, growing in many places thickly together as at Inaccessible Island, with a similar vegetation devoid of Tussock beneath them. The appearance of the tall grass, when seen from a distance, is most deceptive; as the island was viewed from the deck of the ship about a quarter of a mile off, a green coating of grass was seen, coming everywhere down to the verge of the wave-wash on the rocks, and stretching up comparatively easy looking slopes towards the peaks. The grass gave no impression of its height and impenetrability. On closer inspection, however, the real state of the case might be inferred, for there was plainly visible a dark sinuous line leading from the sea right inland through the thickest of the

Tussock. This was a great Penguin road, for the whole place was one vast Penguin rookery, and the grass that looked like turf was higher than a man.

The rocks of Nightingale Island are augite-andesite passing to amphibolic andesite and tufa of the same rocks. The caves in the low cliffs are so numerous as to form a striking feature in the appearance of the island as it is approached, and indicate an elevation of the island; they are not apparent, however, at Inaccessible or Tristan Islands. The caves, with the sloping ledges leading up to them, are frequented, as was said, by Fur Seals. Four years before the visit of the Expedition, 1400 seals had been killed on the island by one ship's crew. Seals were very much scarcer in 1873, but the

FIG. 104.—Nightingale Island from the North.

island was visited regularly once a year by the Tristan people, as was also Inaccessible Island. The Germans only killed seven Seals at Inaccessible Island during their stay, but the Tristan people killed forty there in December 1872.

At the entrance to the rookery the hard rock was actually polished, and had its irregularities smoothed off where the feet of the birds had worn it down at the commencement of the street. No doubt the Diatom skeletons present in the food and dung of the Penguins, and always abundant in the mud of their rookeries, adhering to their dirty feet, act as polishing powder and assist the wearing process. The street did not open by a single definite mouth towards the sea, but split up into numerous channels leading down to a number of easy tracks through the rocks. A little way in there was a clear open track 6 feet wide, and in places as much as 8 or 10 feet in width. On each side narrow alleys led nearly at right angles to the rows of nests with which the whole space on either side of the main street was taken up.

Amongst the Penguins here were numerous nests of the Yellow-billed Albatross, *Diomedea chlororhyncha*, Gmelin,[1] called by the Tristan people "Mollymauk," variously spelt in books, Molly Hawk, Mollymoy, Mollymoc, Mallymoke. It is, as

FIG. 105.—Nightingale Island from the South.

are most of the sealers' names in the south, a name originally given to one of the Arctic birds, in this case to the Fulmar, and then transferred to the Antarctic forms from some supposed or real resemblance. The Mollymauk is an albatross about the size of a goose, head, throat, and under part pure white, the wings grey, and the bill black with a yellow streak on the top and with a bright yellow edge to the gape, which extends right back under the eye, and shows out conspicuously on the side of the head (it is not thus shown in Gould's coloured figures). The birds are extremely handsome. They take up their abode in separate pairs anywhere in the rookery, or under the trees where there are no

[1] This is called *Thalassiarche culminata* in Mr. W. A. Forbes' Report on the Tubinares, Zool. Chall. Exp., part. xi., 1882.

Penguins, which latter situation they seem to prefer. They make a neat and round cylindrical nest, which stands up from the ground, of tufts of grass, clay, and sedge. There is a shallow concavity on the top for the bird to sit on, and the edge overhangs somewhat, the old bird undermining it, as the Germans said, during incubation, by pecking away the turf of which it is made. One nest measured was 14 inches in diameter and 10 inches in height. The nests when deserted and grass-grown make most convenient seats. The birds lay a single egg about the size of a goose's, or somewhat larger, but elongate, with one end larger than the other, as are all Albatross' eggs. The birds when approached sit quietly on their nests or stand by them, and never attempt to fly; indeed they seem, when thus bent on nesting, to have almost forgotten the use of their wings. Captain Carmichael, in his account of Tristan da Cunha, relates how he threw one of the birds over a cliff and saw it fall like a stone without attempting to flap; and yet these birds will soar after a ship over the sea as cleverly as any other Albatross; indeed, the same peculiarity occurs in the case of the large Albatross when nesting. When bullied with a stick or handled on the nests, the birds snap their bills rapidly together with a defiant air, but they may be pushed or poked off with great ease. Usually a pair is to be seen at each nest, and then, by standing near a short time, one may see a curious courtship going on. The male stretches out his neck, erects his wings and feathers a little, and utters a series of high-pitched rapidly repeated sounds, not unlike a shrill laugh; as he does this he puts his head close up against that of the female. Then the female stretches her neck straight up, and turning up her beak utters a similar sound, and rubs bills with the male again. The same manœuvre is constantly repeated. The Albatrosses sometimes make their nests in the very middle of a Penguin road, but the two kinds of birds live perfectly happily together. No fighting was observed, though, small as the Penguins are, they could evidently drive out the Mollymauks if they wished. The ground of the rookery is bored in all directions by the holes of Prions and Petrels, which thus live under the Penguins. Their holes were not so numerous in the rookery at Inaccessible Island as here. The holes add immensely to the difficulties of traversing a rookery, since as one is making a rush, the ground is apt to give way, and give one a fall into the black filthy mud amongst a host of furious birds.

Besides the Mollymauks and Petrels, one or two pairs of Skuas (*Stercorarius antarcticus*) had nests on a few mounds of earth in the rookery. How these mounds came there it is difficult to explain.

The rookery had evidently once been larger than at the time of the visit, since a good part of the tall grass then not occupied by birds, had old deserted nests amongst it; probably the number of birds varies considerably each season. It is a remarkable fact that the Penguins are migratory. They leave Inaccessible Island, the Germans said, in the middle of April, after moulting, and return, the males in the last week of July, the females about August 12th; and it is improbable that the Germans could have been mistaken. Whither can they go, and by what means can they find their way back? The question with regard to birds that fly is difficult enough, but it may always be supposed that they steer their course by landmarks seen at great distances from great heights, or that they follow definite lines of land. In the present case the birds can have absolutely no landmarks, since from sea level Tristan da Cunha is not visible from any great distance; the birds cannot move through the water with anything approaching the velocity of birds of flight; they have, however, the advantage of a constant presence of food. The question of the aquatic migration of Penguins and Seals seems a special one, and presents difficulties quite different from that of the migration of birds of flight. The Penguins certainly do not go to the Cape of Good Hope nor to St. Helena.

Although there is little fresh water on Nightingale Island, one pond was observed in the rookery, but the water was undrinkable. In a cave near the landing-place also, there was a scanty trickling spring of excellent water filling a small basin; water enough to keep three or four persons alive might be got here. On a small open patch in the centre of the rookery, free from Tussock, was found a bed of a yellow-flowered Composite plant, which has since been determined as a new species of *Cotula* (*Cotula moseleyi*), as far as yet known peculiar to Nightingale Island. A representative of the genus (*Cotula* [*Leptinella*] *plumosa*) is, however, abundant in Kerguelen Island and in the Antarctic region generally.

With the exception of the Journal and Meteorological Register of Lieutenant Rich, for the four months he was Commandant of the garrison in 1816, no regular record of the weather has been kept at the Tristan group of islands. This is much to be regretted, for, lying as these islands do far south in the Atlantic, in the immediate track of vessels bound to Australia and the Cape of Good Hope, and midway between that Cape and Cape Horn, a register of the weather here would be of the utmost importance, and the Rev. W. F. Taylor would have conferred a great boon on seamen had he devoted a small portion of his time, during his five years' residence at Tristan, to keeping a daily record of meteorological phenomena.

From the description of some of the more intelligent of the inhabitants of Tristan Island, and from the remarks of vessels visiting the group and cruising in its vicinity, more especially from the notes of some of the captains of H.M. ships in the early part of this century, a fair idea can be given of the average state of the weather throughout the year.

The prevailing winds are westerly, strong breezes being the rule, and light winds or calms the exceptions. In the winter months the wind is usually northward of west, and in the summer months southward. August, September, and October are the worst months of the year, and it is then no unusual thing for gales to continue for a fortnight at a stretch. December to March is the fine season; and in January and February rollers are frequent, so that landing is sometimes impossible. Easterly gales are rare, but are occasionally experienced at all seasons. North and northwest gales are not felt much at the settlement, as the wind is then blowing directly against the face of the cliffs at the back, but with these winds there is a heavy surf in Falmouth Bay; the southwest wind sweeping fairly across the level strip is most destructive, and has been known to unroof the houses, solidly built as they are. The climate is mild, the temperature averaging 68° in summer, and 55° in winter, occasionally falling to 40°. Rain is frequent; in fact, situated as these islands are, and rising as they do to a height of over 7000 feet, it would be extraordinary if rain were not frequent, as clouds almost continuously cover the higher parts of the land. Hail and snow fall occasionally, but rarely, and the sky is usually cloudy, but the air is not excessively humid. Little is known about the movements of the barometer in the locality; the islanders possess an instrument, but do not record its readings. Captain Wauchope states that during his stay in H.M.S "Eurydice" in the vicinity of the group, the pressure varied from 29·75 to 30·35 in the months of October and November 1817; but he could form no opinion as to the future condition of the weather from the height of the barometric column. During the four days' visit of the Challenger in 1873, the pressure was unusually great, the mercurial column varying from 30·605 to 30·233 inches, and the weather, though cloudy, was on the whole fine, the wind being light. That the climate is very healthy is beyond a doubt, for the inhabitants do not appear to suffer much from sickness; Lieutenant Rich says that they all suffered from inordinate appetites.

The time of high water, at full and change, is given by Lieutenant Rich as at 2 hours with a rise and fall of 8 feet. Captain Nolloth, in his visit in 1856, made it, high water, full and change, at 12 hours, rise and fall 4 feet, and the islanders state that it never exceeds that amount. No register has, however, been kept; and it would be exceedingly difficult to erect a tide pole in a sufficiently sheltered position, although, could it be done, a record here would be of decided scientific value.

There appear to be some discrepancies in the various accounts given as to the tidal stream or current. Some of the old navigators say that they observed a regular east and west going stream when at anchor in Falmouth Bay. Others say the current always sets to the northeast; whilst the islanders assert that inshore the stream changes, but that outside the current is always northeasterly. Against this assertion, however, must be placed the fact, that Captain John Patten found a great deal of driftwood on the east coast of the island and none on the west side in 1790. Captain Nolloth was, however, told that a sofa was made on the island from a log of wood (mahogany) that grounded on the west coast of Tristan Island, and says, that at the time of his visit, there was a tree thickly covered with barnacles on "the sea side." This latter observation is, however, rather obscure, as it is difficult to tell which is not a sea side at Tristan. The current experienced by the Challenger whilst in the vicinity had certainly a northeasterly tendency, but it is of greater force westward than eastward of the group.

A collection of the terrestrial Invertebrata of this group was made, which has not yet been entirely worked out, but up to the present time it has yielded the following:—Mollusca,[1] *Balea* (*Tristania*) *ventricosa*, Gray, and *Balea* (*Tristania*) *tristensis*, Gray, previously known to inhabit these islands, and in addition *Limax canariensis*, d'Orb., *Limax gagates*, Drap., *Helix* (*Hyalinia*) *exulata*, Smith.

Coleoptera,[2] *Lancetes varius*, Fabr., *Cercyon littorale*, Gyll., *Quedius fulgidus*, Fabr., *Palæchthus glabratus*, Waterhouse, *Palæchthus cossonoides*, Waterhouse, and *Pentarthrum carmichaeli*, Waterhouse. Rev. O. P. Cambridge has recognised the following spiders from the collection:—*Tegenaria derhamii*, Scop., *Steatoda versuta*, Bl., *Linyphia leprosa*, Ohl. (European species, the two last British), from Tristan Island, and *Theridion* sp.? (allied to *Theridion formosum*, Clk., a widely-spread European species), *Steatoda versuta*, Bl., *Neriene* sp.? (probably new, but scarcely in good enough condition for description), from Inaccessible Island. In addition to these Dr. v. W. Suhm notes in his diary:—"*Julus* and *Scolopendra* common everywhere; two specimens of a bug underneath the bark of trees in Inaccessible Island, and a small whitish Cicad, Nightingale Island. A Noctuid from Nightingale Island, also seen on Inaccessible Island; caterpillars, probably of a *Vanessa* (?), Microlepidoptera. *Musca* sp.; a *Culex*-like animal was seen but not obtained; *Pulex* parasitic in the nests of Penguins and Albatrosses on Nightingale Island. A Thysanurid was found on a dead Puffin. No Orthoptera nor Hymenoptera were found. *Oniscus*, *Gammarus* everywhere under stones, as also *Lumbricus*."

Many hauls of the dredge and trawl were taken around and between the islands of the Tristan da Cunha group in depths from 60 to 1100 fathoms. There was generally a coarse shelly bottom, composed of fragments of Polyzoa, Lamellibranch and Gasteropod shells, Brachiopods, Echinoderms, Pteropods, *Serpulæ*, and a few pelagic and other Foraminifera. The mineral fragments were exclusively of volcanic origin. A large number of animals of all groups came up in the trawl and dredge: Primnoas, Gorgonias, Caryophyllias, Hydroids, Sponges, Starfish, and Molluscs; altogether a mass of material much like what is found in shallower water off the coast of Great Britain.

The Cephalopoda.—On the return of the Expedition to England the collection of Cephalopoda was sent to Professor Huxley, who hoped to be able to prepare a Report on the whole of this group. In 1882, owing to the many demands on his time, Professor Huxley decided to limit his Report to the genus *Spirula*, and the remainder of the collection was handed over to Mr. W. E. Hoyle for examination, who writes as follows:—

"Regarded as a whole, the collection of Cephalopoda is quite as remarkable for its deficiencies as for the types represented in it. It might have been expected

[1] Smith, E. A., *Proc. Zool. Soc. Lond.*, pp. 278, 279, 1884.
[2] Waterhouse, C. O., *Ann. and Mag. Nat. Hist.*, ser. 5, vol. xiii. pp. 276–279, 1884.

that on a voyage, during which careful and systematic use was made of the surface-net, pelagic forms would have been captured in large numbers. Such, however, was not the case; the genus *Tremoctopus*, for instance, was preserved on only four occasions, *Ommastrephes* on five, *Onychia* on six, and *Cranchia* on three or four.[1] Mr. Murray informs me that this is to be accounted for by the astonishing activity of these animals, which is so great that they were only captured when the vessel was sailing rapidly, a condition in general unfavourable to the use of the tow-net.

"Professor Steenstrup has divided both the Octopod and Decapod Cephalopoda into two groups, *littorales* and *pelagici*, and as in so many other divisions of the animal kingdom, while pelagic forms belong to but few species, each of which has a wide range of distribution, littoral genera are represented by very many species, each confined within a narrow area.

"The latter portion of this statement was well illustrated by the genus *Octopus*; of which almost every resting-place of the Expedition seems to have furnished a distinct type: about twelve of which belong to species hitherto undescribed. The littoral habits of this type are most clearly demonstrated, for out of twenty-eight species collected, sixteen came, not from dredging stations, but from the shore collections; and of those obtained by the dredge or trawl, only two were found in depths exceeding 500 fathoms, and there is, of course, no conclusive proof that these were actually brought up from the depth reached by the dredge.

"Indeed the difficulty of deciding whether the dredge really captured at the bottom the animals eventually found in it, or whether they became entangled in it during its upward or downward progress, was felt to be extremely great in the case of the Cephalopoda, for only in one or two instances were such structural peculiarities found as appeared to demonstrate that the animals were really abyssal in their mode of life.

"Many very interesting species of *Sepia* were captured; some of which have been hitherto known only by their shells. All the specimens of this genus brought home by the Challenger Expedition (including some ten new species) were obtained between Stations 163 and 232, that is to say, during the cruise from the eastern coast of Australia through the Malay Archipelago to Japan; a strong confirmation of the fact that the Indo-Pacific region is beyond all question the metropolis of this genus, for out of some thirty species previously known, no less than twelve are from this portion of the globe, although it has been much less explored than many others.

"Among pelagic Cephalopods very noteworthy additions have been made to the genus *Cirroteuthis*, which has hitherto been represented only by comparatively few specimens from the coast of Greenland, the largest being one in the Copenhagen Museum, which does not exceed 18 inches in extreme length. During the cruise in the Southern

[1] *Cranchia* was very frequently obtained in the surface-nets, but, like many other common surface forms, was not always preserved.—J. M.

Ocean, however, a very fine new species (*Cirroteuthis magna*), measuring between 2 and 3 feet, was dredged from a depth of 1375 fathoms at Station 146. Unfortunately it was not so well preserved as to be fit for minute anatomical examination, but the form of the dorsal cartilage, which is elongated transversely instead of longitudinally, is quite sufficient to establish its specific distinctness from the typical *Cirroteuthis mülleri*.

"Two other specimens, each representing a distinct species (*Cirroteuthis pacifica* and *Cirroteuthis meangensis*), together with a fragmentary and a young animal, were found at different points in the Pacific Ocean.

"One of the most remarkable forms in the collection is apparently somewhat allied to this genus; it is a small creature obtained on the surface in the neighbourhood of the Kermadec Islands, which has been named *Amphitretus pelagicus* (see fig. 106). It differs, however, from all Cephalopods hitherto known in that the mantle is firmly united to the

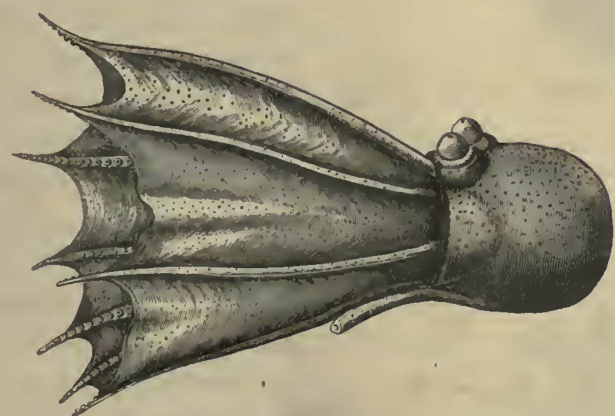


FIG. 106.—*Amphitretus pelagicus*, n. gen. et sp.; somewhat enlarged.

siphon, leaving two openings into the branchial cavity, one on either side, immediately below the eyes, which are closely approximated on the dorsal surface. The arrangement of the suckers in a single row, and the webbing of the arms, almost as far as their extremities, are points of resemblance to *Cirroteuthis*, but the cirri characteristic of this latter genus are wanting.

"In the South Atlantic (Station 126) there was found in the dredge a curious gelatinous specimen, of pale yellowish-grey colour, with red chromatophores. The body is prismatic, the dorsal surface being flat and the ventral rising into a median rounded ridge. The eyes are prominent, and situated about midway between the extremities of the arms and the posterior end of the body (see fig. 107). It seems desirable to make this the type of a new genus, and the name *Japetella prismatica* is given to it. Resembling this last in the consistency of the body and some other characters, and possibly congeneric with it, is another form represented by a single specimen from the surface of the Pacific, north of Papua (*Japetella diaphana*). The genus *Bolitæna*, Stp., is perhaps the nearest ally of these two forms, but its differences from them are many and important.

FIG. 107.—*Japetella prismatica*, n. gen. et sp.; natural size.

"The genus *Eledone* furnished two new species, both characterised by a short stumpy contour and by arms webbed half-way to the extremities; one was obtained near the Antarctic Circle, depth 1950 fathoms, the other in the South Atlantic (Station 320) from a depth of 600 fathoms; while some portions of a large Octopod, which were picked up on the surface of the North Atlantic, beyond all reasonable doubt once formed part of an individual of the curious *Alloposus mollis*, Verrill.

"The Decapoda yielded, on the whole, fewer striking novelties than the Octopoda. One of the most curious is a small creature from the Southern Ocean, which has been called *Bathyteuthis abyssicola* (see fig. 108); it measures about 5 cm. in length excluding the tentacles; the body is subcylindrical, tapering to a blunt point behind, where are situated two small rounded fins. The head is broad, with prominent eyes, and there is a very large oral membrane provided with suckers. The arms are very short, the longest not quite reaching 1 cm., and the suckers are minute and arranged biserially; the tentacles about equal the body in length, and have no clubs, but gradually taper to a point armed with numerous very small suckers like those of many *Sepiæ*. The funnel is provided with a valve, and the pen resembles that of *Ommastrephes*.

FIG. 108.—*Bathyteuthis abyssicola*, n. gen. et sp.; natural size.

"The structure of this form seems to adapt it for life at great depths, and to justify the belief that it really came from the depth reached by the dredge (1600 fathoms); the small fins are in marked contrast to those of pelagic species, while the small suckers and delicate tentacles are equally little fitted for raptorial purposes; but, on the other hand, the large circumoral lip would seem well suited for collecting nutritive matters from an oozy bottom.

"A new genus has also been erected for the reception of another interesting Decapod, *Promachoteuthis megaptera*, which has a rounded body not much longer than the head; two large fins are attached to the body for fully half its length, and united with each other to some extent behind it, their combined breadth exceeding the length of the body. The head is small, as are also the eyes, which are scarcely at all prominent. The longest (lateral) arms are slightly longer than the body, and bear two rows of globular suckers, with lateral apertures, recalling those of *Sepiola* and *Rossia*. The tentacles have unfortunately lost their extremities; but they are very stout, and about half as long again as the arms (see fig. 109). The single specimen comes from Station 237 (North Pacific), perhaps from 1875 fathoms, but more probably from the surface.

Fig. 109.—*Promachoteuthis megaptera*, n. gen. et sp.; natural size.

"A rare, if not new, form was dredged on the *Hyalonema*-ground south of Japan, in 345 fathoms (Station 232); it is generically, if not specifically, identical with *Calliteuthis reversa*, Verrill, hitherto known only from the eastern coast of North America, of which *Loligopsis ocellata*, Owen, is possibly only a synonym.

"A type somewhat allied to this, and apparently intermediate between it and the genus *Histioteuthis*, was obtained in the South Atlantic (Station 333); the web is very small in comparison with that of this genus, not extending quite half way to the tips of the arms. In the present state of our knowledge it seems impossible to refer this form to any type hitherto described, and the name *Histiopsis atlantica* is therefore given to it, although it is possible that other Cephalopods will be discovered which will bring it into closer relation with known forms.

"Among the Challenger collection is also one mutilated individual of *Taonius hyperboreus*, Stp., a genus hitherto known only from examples in the Copenhagen Museum;[1] there are also two medium sized specimens and a small one which appear to be referable to the same genus. It is remarkable that many of the most interesting specimens are mere fragments; among others may be mentioned part of a tentacle of *Mastigoteuthis agassizii*, Verrill, which was found adhering to the dredge rope, and numerous pieces of a long gelatinous pen, taken from the stomach of a shark; these latter seem to resemble nothing hitherto known so nearly as the pen of *Chiroteuthis lacertosa*, Verrill,[2] though if this determination be correct that species must sometimes attain a length of several feet.

[1] The specimen which Verrill figures (*Trans. Connect. Acad.*, vol. v. p. 302, pl. xxvii. figs. 1, 2, 1882) is certainly not *Taonius hyperboreus*, Stp.; I hope elsewhere to adduce arguments for believing it to be *Taonius pavo* (Les.).

[2] *Ibid.*, p. 408, pl. lvi. figs. 1 *a*, *a'*, *a''*, 1881.

"Specimens of *Nautilus pompilius* and *Spirula australis* were obtained, and will be alluded to in connection with their respective captures.

"Such is a very brief notice of the more interesting and remarkable Cephalopoda obtained during the cruise; those who require more detailed information are referred to the forthcoming memoir upon the group in the series of zoological reports. The collection is not lacking in novelties, though it has by no means fulfilled the expectations of those who hoped that forms hitherto known only as fossils would be brought home among the spoils. One of the naturalists tells us that 'even to the last every Cuttle-fish which came up in our deep-sea net was squeezed to see if it had a Belemnite's bone in its back;'[1] but no such precious discovery was made, and our knowledge of the anatomy of these interesting animals must still be gleaned piecemeal from exceptionally well-preserved fossil specimens."

Tristan da Cunha Group to the Cape of Good Hope.

On the 18th October, at 6 P.M., the Challenger left the Tristan da Cunha group for the Cape of Good Hope.

On the 28th October, at daylight, the land in the vicinity of False Bay was observed, and having obtained a sounding and some temperature observations, the ship proceeded to Simon's Bay, arriving and mooring there at 3.20 P.M.

During the passage the wind was variable from north round west to south and southeast, occasionally shifting suddenly, and its strength was as unsteady as its direction, but on no occasion did it exceed a moderate gale in force. The weather was cloudy and squally, with passing showers. On the 23rd, at 5 P.M., a large mass of seaweed was passed 700 miles from Tristan Island.

Between Tristan Island and the Cape of Good Hope five soundings, five serial temperature soundings, and two dredgings were obtained (see Sheet 16).

The dredging on the 20th October, at Station 136, was on hard ground, for the sounding rod brought up only a fragment of manganese, and the dredge caught at the bottom directly it was attempted to drag it along, giving much trouble and anxiety. In heaving in, the line parted, but, owing to the smartness of the man attending the stopper, the end was caught and spliced again, so that the dredge was saved. It came up empty, the nature of the bottom being evidently unfavourable for such work.

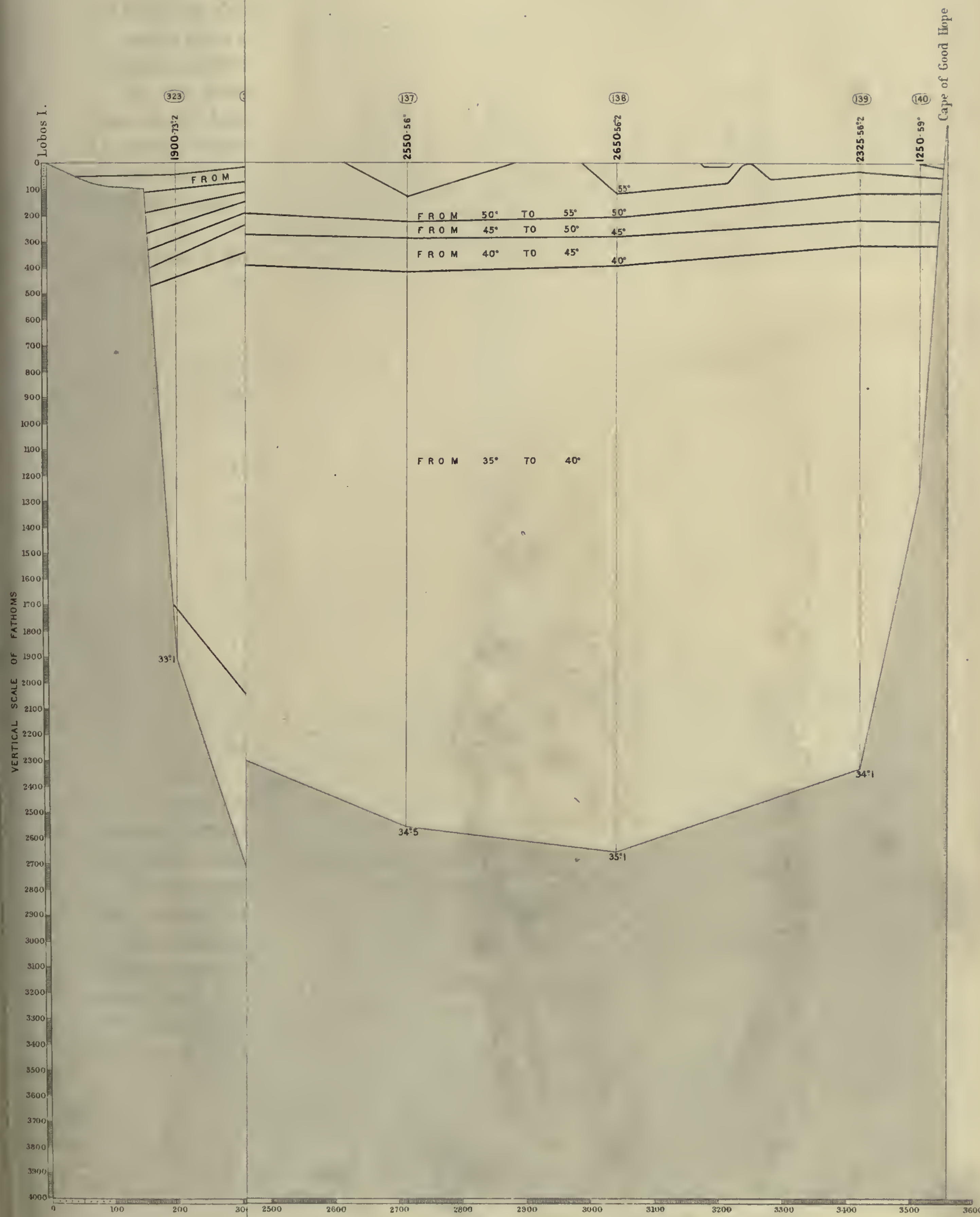
The depths increased gradually from 2100 fathoms at a distance of 200 miles from Tristan, to 2600 fathoms 500 miles west of the Cape of Good Hope, from whence they diminished to 2325 fathoms at a distance of 130 miles from the Cape, and afterwards gradually to the edge of the 100 fathom bank (see Diagram 6).

The temperature of the surface water varied from 53° at the Tristan group to 59° at

[1] Moseley, Notes by a Naturalist on the Challenger, p. 586, London, 1879.

DIAGRAM 6

and Cape of Good Hope.



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the Cape, but the alteration was by no means gradual, for on one day it varied more than 5°; and as these variations did not take place on those days which were bright and sunny, it was concluded that they were due to the Agulhas Current.

On the 28th, at 7 A.M., a series of temperatures at intervals of 10 fathoms down to 100 fathoms was taken. At noon on the same day a second series was taken 15 nautical miles to the southwest of the Cape of Good Hope, and it was found that in the interval the ship had passed into the loop of the Agulhas Current, which curls round the Cape close to the land. The contrast between the two series is remarkable.

A Series of Temperature Observations taken just before, and one taken immediately after, entering the Agulhas Current, October 28th, 1873.

Depth.	7 A.M.	Noon.
Surface.	58°·2	62°·0
10 fathoms.	58·5	62·8
20 "	58·0	62·2
30 "	58·0	61·5
40 "	56·8	60·5
50 "	54·5	58·5
60 "	54·2	57·0
70 "	52·9	56·0
80 "	52·9	55·0
90 "	53·0	54·0
100 "	52·9	51·8

The temperature of the air likewise rose perceptibly, the thermometer in the shade indicating at noon 58°·8, nearly three degrees above the average of the same hour during the previous week.

The temperature of the bottom water varied from 35°·2 to 34°·2, the lowest result being obtained at 2325 fathoms 130 miles west of the Cape.

The serial temperatures showed that the isotherm of 40° occupied a mean depth of 370 fathoms, varying from 320 to 400 fathoms, the maximum depth being in the centre of the section, and the minimum at the Cape. The isotherms of 45° and 50° indicated this peculiarity in a still more marked degree, for they may be said to be bow-shaped. The isotherm of 55° was irregular (see Diagram 6).

No observations for current could be obtained, except in the ordinary way, viz., by difference between the dead reckoning and observed position of the ship.

On the 20th October, at Station 136, the velocity of the wind was on an average 14 miles per hour.

Between the Tristan plateau and the south of Africa, there is a wide and deep depression, where depths of 2550 and 2650 fathoms were obtained. The deposits at these depths contained 35 and 26 per cent. of carbonate of lime, consisting of pelagic Foraminifera and their broken parts. The mineral particles were rather abundant, making up 50 per cent. of the whole deposit at the greater depth, and consisted of rounded and angular fragments of quartz, orthoclase, hornblende, tourmaline, and augite. These mineral fragments, some of which were fully one millimetre in diameter, indicate that these soundings are within the area which is occasionally affected with Antarctic ice. The two soundings in 2325 and 1250 fathoms contained 47 and 50 per cent. of carbonate of lime; the mineral particles seldom exceeded 0·07 mm. in diameter, and consisted of quartz, glauconite, felspar, augite, and magnetite. About 5 per cent. of these deposits were made up of Radiolarians, Diatoms, and Sponge spicules.

A dredging at 2100 fathoms, near the edge of the Tristan plateau, was unproductive, the bottom appearing to be hard or rocky. A trawling in 2550 fathoms yielded two small Starfish, a bivalve Mollusc, and a few Crustaceans.

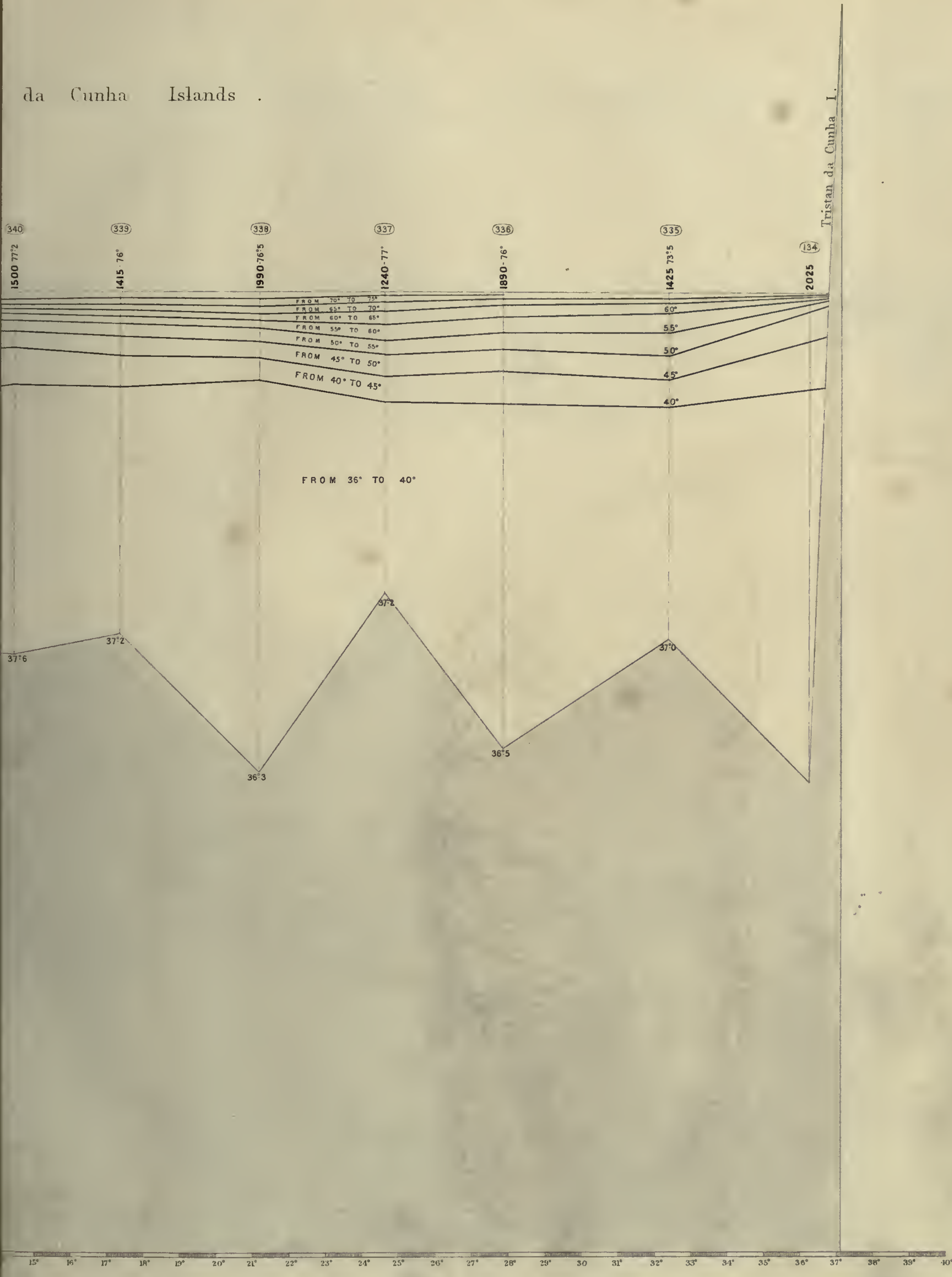
The tow-nets did not yield such a variety of forms as in the sections across the tropical portions of the Atlantic.

The Holothurioidea.—Dr. Hjalmar Théel, of Upsala, gives the following summary of his Report on the Holothurioidea collected by the Expedition, the first part of which has been published:—[1]

"The Holothurians are very widely distributed in the sea, and representatives of them are found from the shores down to the greatest depths all over the bottom of the ocean. Before the Challenger Expedition set out, our knowledge was limited almost exclusively to such forms as live on, or in the neighbourhood of, the shores; but from the investigations of the Expedition, not only has our knowledge of the shallow water forms been considerably increased, but the obscurity which involved the abyssal fauna has been greatly dispelled. It seems to be a fact that only a comparatively small number of Holothurians nearly related to the true shallow water forms are met with in the deep sea. The majority of Holothurians dredged from the bottom of the ocean present such important peculiarities, and differ so strikingly from the shallow water forms, that it has been necessary to arrange them in a new order, Elasipoda, equivalent to the orders Apoda and Pedata, already known. This summary is intended to show how far our knowledge of the Holothurians has been increased by the Challenger Expedition, which

[1] Report on the Holothurioidea,—the Elasipoda, by Hjalmar Théel, Zool. Chall. Exp., part xiii., 1881.

da Cunha Islands .



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will best be done by briefly pointing out the peculiarities in the external and internal organisation of the Elasipoda. The shallow water Holothurians have not been at all overlooked, for a large collection of such forms was brought home from different localities; but these Holothurians, being mostly already known, are not of sufficient interest to deserve mention here. However, to give an idea of what the Challenger Expedition has done with regard to the shallow water forms, it may be noted that a great number of new species has been dredged, previously known species have been found in many new localities, and several interesting biological observations made.

"Only three Elasipoda were previously known, viz., *Elpidia glacialis*, *Kolga hyalina*, and *Irpa abyssicola*, all obtained from the North Atlantic Ocean and the Arctic Sea; but the Challenger Expedition has so far extended our knowledge of this peculiar group of animals, that no less than fifty-two species and three varieties, divided into nineteen genera, have been described.[1] Only eight of these species were found at depths less than 1000 fathoms—not a single one from a depth less than 50 fathoms—the remainder being

FIG. 110.—*Peniagone wyvillii*, Théel.

obtained from depths exceeding 1000 fathoms. The greatest depth at which any living Holothurid has been obtained is 2900 fathoms. The Elasipoda are distributed throughout all seas, especially *Oneirophanta mutabilis*, which is almost cosmopolitan. Therefore there seems to be every reason for the opinion that the Elasipoda are highly characteristic of the deep-sea fauna, for, as above pointed out, this order is almost unrepresented in the shallow water fauna, and, besides, presents forms perhaps the most aberrant met with in any group of deep-sea animals. With regard to their geographical distribution, the peculiar fact may be noted that some species are obtained from very distant localities. Thus, for instance, *Elpidia glacialis* occurs in the North Atlantic Ocean and the Arctic Sea, but was also obtained by the Challenger Expedition at Station 160, south of Australia, and *Lætmogone violacea* was first dredged by the same Expedition close to Sydney, and lately it has been found in great abundance by the 'Knight Errant,' between the Færöe Islands and the coast of Scotland.

"Thus the Elasipoda represent the deep-sea forms among the Holothurioidea, while

[1] Zool. Chall. Exp., part xiii., 1881.

the Apoda and Pedata, of course with several exceptions, belong to the shores. The more important peculiarities in the organisation of the Holothurioidea, especially of the Elasipoda, may now be pointed out.

"It is known that a large majority of the so-called shallow water forms, viz., the Apoda and most of the Dendrochirotæ, have a cylindrical or fusiform body, the former destitute of all pedicels and processes, the latter provided with small cylindrical pedicels, either irregularly scattered all over the body or arranged in rows along the ambulacra. Consequently, no clear distinction between the dorsal and ventral surfaces is here marked out. In the rest of the Dendrochirotæ and the Aspidochirotæ, on the contrary, more or less clearly marked dorsal and ventral surfaces are present, carrying processes or pedicels scattered or in rows.

"A glance at the figures given in this account, and representing types of the three families into which the Elasipoda are divided, will clearly show that they are characterised by a ventral and dorsal surface, distinctly marked the one from the other, and, in general, by the bilateral symmetry of the body,—characters which they have in common with the Aspidochirotæ and part of the Dendrochirotæ; but above all, by the unusual symmetry in the arrangement of the pedicels and processes. The following peculiarities cannot be too clearly expressed as characterising the Elasipoda:—The ambulacral appendages of the ventral surface alone are intended for locomotion, these being in the typical Elasipoda particularly large, and arranged in a single row on each side of the body; and the locomotor organs of the one side are accurately opposed to those of the other side, so as to form distinct pairs, almost recalling the legs of an insect or the locomotor organs of one of the Polychæta. As a rule the locomotor organs of the Elasipoda are not to be compared with such true pedicels as are common in other Holothurids, but are rather to be regarded as processes or 'ambulacral papillæ.'

"These locomotor organs show the most evident tendency to appear in fixed places and in a fixed number in every species of the more typical Elasipoda, and their number is often limited, as, for instance, in *Elpidia glacialis*, which has always four pairs of pedicels, *Scotoplanes globosa*, which has seven pairs, &c.

"The dorsal appendages are so modified as to perform functions far different from those of the ventral appendages. These dorsal appendages, like the ventral ones, have a tendency to become definite in number, so that every species may have a certain number situated in certain fixed positions on the back.

"From the size of the pedicels and their incapability of extension, and from the fact that the pedicels mostly lack a terminal plate, and sometimes even a sucking disk, the Elasipoda seem to be unable to move in the same manner as most of the Echinoderms, by attaching the suckers to surrounding bodies. Besides, their often firm external skeleton, and the shortness of their body-form, probably prevent them from moving by the extension and contraction of their bodies. From the size of the pedicels and their arrangement in pairs, it seems most probable that they use them in the same manner as the more highly organised animals commonly do their limbs. Besides, there is no doubt that these animals, with their large and powerful pedicels, are able to move more rapidly and to dig easily into the soft ooze or clay of the bottom of the deep sea.

"What is the use of the very large and characteristic processes or lobes situated on the dorsal surface? The correct answer to this question is very difficult to give, but many things—especially the unusual abundance of nerves in them—seem to prove that they perform the function of tactile organs. There is much reason to believe that these organs are particularly suited to bring the animals into relation with surrounding bodies.

"The tentacles, like those in the Aspidochirotæ, are so slightly modified as to constitute

FIG. 111.—*Scotoplanes globosa*, Théel.

a disk with some larger or smaller processes, supported by a stem; thus, their shape in general proves that they do not perform the function of prehensile organs in the same manner as, for instance, those in the Dendrochirotæ, which use their thread-like branched tentacles to collect the proper food, and to bring it into the mouth. It seems most probable that the Elasipoda move along the bottom of the ocean with the mouth open, thus perpetually filling the alimentary canal with Globigerina ooze, Diatom ooze, clay or mud, in which operation the tentacles assist. The whole alimentary canal, from mouth to anus, is always filled up and highly distended by such matters, of which only a small portion can be used as food, while the rest must be pressed out through the posterior aperture at the same time as new materials are taken in.

"It is an already well known fact that the various tissues composing the body of the Echinoderms secrete calcareous matters which take a distinct form, and that the perisome especially possesses this secreting function in a very high degree. Even in the very early stages of development, the Echinoderms are characterised by possessing calcareous deposits, which almost always take the form of simple or branched spicules, which, as the larvæ grow larger, change their form and become more or less complicated. Thus it is a fact that many of the fully-developed shallow water Holothurians have their body-wall supported by plates, crowns, anchors &c., and that their calcareous ring, which is often very firmly constructed, is made up of a solid calcareous network. It is of importance to note that the Elasipoda, with few exceptions, present a singular resemblance to the larval forms as to their calcareous deposits in the perisome as well as in the ring surrounding the gullet, these deposits having been arrested at a very low degree of development.

"The water-vascular system is very well developed in the Elasipoda, and has sometimes a more complicated conformation than is met with in the pedate shallow water Holothurians, their ampullæ, which are sometimes branched, having attained a very considerable size and being enclosed within the perisome. All the manuals of invertebrate zoology indicate, as an important character distinguishing the Holothurians from the rest of the Echinoderms, that the water-vascular system in the former communicates with the interior of the peritoneal cavity by the madreporic canal, while in other Echinoderms the same canal opens into an exterior madreporic tubercle, thus placing the ambulacral system in direct communication with the surrounding medium. This character must now be omitted, since it has been observed that many of the Elasipoda are remarkable in having the water-vascular system in persistent communication with the exterior, and that too not only by one pore but sometimes by a great number of pores crowded closely together, so as to form a kind of external madreporic tubercle. The larvæ of the Apoda and Pedata have the madreporic canal in communication with the surrounding medium by an opening on the dorsal surface; but eventually this canal looses its connection with the exterior, so that it hangs loosely in the peritoneal cavity of the adult animal. Thus the Elasipoda, even in this respect, obviously resemble the larval state of other Echinoderms.

"The respiratory trees are present in all the Pedata and in some of the Apoda, but in most of the latter the respiratory trees are supplied with "ciliated cups." The true function of these peculiar organs is unknown, though it seems probable that they subserve an excretory function. The Elasipoda seem to be devoid of every trace of these organs. Many authors seem to attach so much importance to the respiratory trees, that two orders have been founded, Pneumonophora and Apneumona, on the presence or absence of these organs. For my own part, I think that the presence or absence of ambulacral appendages—that is to say, a more or less complicated ambulacral system—is of far greater systematic importance, considering that the water-vascular system is one of the most characteristic peculiarities of the Echinoderms in general, and doubtless plays a much greater rôle in their life.

"With regard to the sensory organs of the Elasipoda, it is very remarkable that auditory organs in the shape of small sacs, with a greater or smaller number of otoliths, are often very abundantly developed, while no traces of eyes are apparent, and that these organs are in connection not only with the nerve ring but also with the two lateral ventral nerve stems. Possibly the well-developed auditory organs, together with the tactile organs, viz., the dorsal processes, can to some extent supply the want of eyes. With good reason it may be asked why many species are so richly provided with auditory organs—some species have fifty sacs or more—while other forms are totally devoid of them. As is well known, only a few shallow water Holothurians are furnished with auditory vesicles, but these have always their place at the nerve-ring.

"In the Elasipoda, as in the majority of the Holothurioidea, the sexes are distinct. The embryo of the Echinoderms commonly leaves the egg in a condition very different from the adult state, and their larvæ live under conditions totally different from those under which the adult passes its existence. Thus, while the adult animal moves slowly along the floor of the bottom, the larvæ are found living on the surface of the sea, carried about by winds and currents, until they have reached that stage in their evolution, when it becomes necessary for their existence and further development to retire to the shores or the bottom of the sea. In some Echinoderms the embryo passes into the adult condition without any free larval stage, which seems to be the case with several shallow water Holothurians, and doubtless even with the Elasipoda. If these latter were subject to a more complicated metamorphosis, it is most probable that their larvæ would not be able to live at the surface of the sea, but keep close to the floor of the ocean. It may be stated here that during the Challenger Expedition some particularly inter-

FIG. 112.—*Psychropotes longicauda*, Théel.

esting observations were made concerning the development of some shallow water Holothurians, viz., *Cladodactyla crocea* (Lesson), from Stanley Harbour, and *Psolus ephippifer*, from Corinthian Harbour in Heard Island (see pp. 379–384). In the females of the former the young were closely packed and adhering to the dorsal pedicels, while in the latter the embryos were developed within a kind of marsupium, situated on the dorsal surface and formed by its calcareous plates. There can be little doubt that the eggs are impregnated either in the ovarium or immediately after their extrusion, and that the free larval stage is omitted.

"Though the remains of Echinodermata are found abundantly as fossils, our knowledge of the fossil Holothurians is very unsatisfactory. Only a few calcareous spicules, believed to belong to Holothurians, occur in the Mesozoic rocks; but it must be remembered that these deposits are very fragmentary and difficult to refer to any distinct genus or species. However, some anchors, wheels, and other deposits are found, which seem to prove that the Apoda are older than the Pedata; but, as above mentioned, our knowledge is too incomplete to decide the question. No fossil remains of the Elasipoda have been detected, but nevertheless the opinion that the order is very old seems justified, and from the fact that it has retained more peculiarities characteristic of the larvæ of the Holothurians than the Apoda and Pedata, it seems to follow that it does not bear any direct genetic relation to the present representatives of these two orders.

"Thus I have endeavoured to give in a few words an account of this peculiar group of Holothurians, which passes its existence in the great depths at the floor of the ocean. Those readers who wish to get a clearer view of the different forms and their organisation, are referred to the Report"[1]

The Cape of Good Hope.

The Challenger remained moored in Simon's Bay from the 28th October till the 2nd December, when she proceeded to Table Bay. After a stay of ten days at Table Bay the ship returned to Simon's Bay till the 17th December. At Simon's Bay the ship was refitted, a deck house built for the convenience of the Naturalists, and the necessary stores taken on board for the Antarctic trip.

The Governor of Cape Colony, Sir Henry Barclay, and the inhabitants received the Expedition with great hospitality, and many receptions and entertainments were given in honour of the visit to Cape Town. Several excursions were arranged to enable the members of the Expedition to see the interior of the country, and to make collections. It was not, however, the practice to make any extensive collections at places like the Cape Colony, where the Botany and Zoology were well known.

[1] Zool. Chall. Exp., part xiii., 1881.

Some crania of Bushmen were procured at the Cape, and along with them several stone implements, shaped into lance heads, and a large perforated stone ball. A description of the skulls has been given by Professor Turner in his Report on the Human Crania.[1] He found them to possess the mesaticephalic and orthognathous proportions characteristic of this race.

The zoological and other specimens collected during the year 1873 were carefully packed, catalogued, and landed in sixty-one large cases in the dockyard for transmission to England.

Captain Nares remarks as follows on the temperature observations at the Cape:[2]—

"Our observations indicate that the broad and comparatively sluggish 'South Atlantic drift current,' running to the eastward before the continuous westerly winds, accumulates its water against the west coast of Africa, raising the level of the sea sufficiently to prevent the Agulhas current continuing its course, and swallows or diverts nearly the whole of it; a very small portion escaping to the northward round the Cape during the southerly winds, intermixing with the colder water of the drift current, which also throws out an offshoot to the northward, as it strikes against and meets the African coast and Agulhas stream. Great variations in temperature may naturally be looked for when two such oppositely constituted currents meet and intermingle. It is well known at the Cape that the warm current seldom extends as far to the north as Table Bay, the water there being much colder than in Simon's Bay.

"During our stay the wind was blowing nearly continuously from the southeast, and the temperature of the sea in Simon's Bay was from 62° to 64°, the same temperature, and therefore water derived from the same source, as we found outside close to the land. But on one occasion during a northwesterly gale this warm water was driven out of Simon's Bay, being replaced in about six hours by water of a temperature of 51°; and this applies, not only to the surface water, but to that at the depth of nine fathoms, in which water the ship was anchored, and to which the observations extended. The current usually circles round the bay from Cape Agulhas to Cape Point; on this occasion, whilst the water was gradually cooling, a current was circling round the bay in the opposite direction, running to the eastward from Cape Point towards Cape Agulhas. From this I can only conclude that during northwesterly gales the pressure of the wind is sufficient to overpower and drive the narrow branch or horn of the Agulhas current, which at other times is found touching the Cape, to the southward, with the rest of the stream. Immediately the pressure from the northwesterly wind was withdrawn the water in Simon's Bay gradually increased in temperature, indicating the return of the warm Agulhas stream. It is remarkable that the surface water of a temperature of 51° found in Simon's Bay during the northwesterly gale was colder than that found at any Station to the westward

[1] Zool. Chall. Exp., part xxix., 1884.
[2] Report to the Hydrographer, December 1873.

during our run across, except at a depth of 50 fathoms; the lowest surface temperature being 54°. Immediately previous to our arrival there had been few southerly winds, afterwards they blew with great regularity for a fortnight, and if they extended any distance southwest of the Cape colder water might naturally be looked for."

Peripatus.—During the stay at the Cape, one of the most important of the zoological discoveries of the voyage was made by Mr. Moseley, namely, that of the affinities of a remarkable animal well known to naturalists under the name of *Peripatus*, believed at the time to be a peculiar and aberrant form of earthworm. The uncertainty and misapprehension as to its affinities had arisen from the fact that it had never been examined by any professed naturalist in the fresh condition, but was only known from specimens preserved in spirit. Professor Moseley writes:—

"The animal has the appearance of a black caterpillar, the largest specimens being more than 3 inches in length, but the majority smaller. A pair of simple horn-like antennæ projects from the head, which is provided with a single pair of small simple eyes. Beneath the head is an opening surrounded by plicated lips, leading into a space which may be termed the præoral cavity. Within this cavity lie a pair of muscular organs each

FIG. 113.—*Peripatus capensis*; viewed from the dorsal surface (after Balfour).

bearing two stout horny jaws behind which is situated the mouth. The animal has seventeen pairs of short conical feet, provided each with a pair of hooked claws. The skin is soft and flexible, and not provided with any chitinous rings.

"The animal breathes air by means of tracheal tubes like those of insects, but these, instead of opening to the exterior by a small number of apertures,—'stigmata' arranged at the sides of the body in a regular manner as in all other animals provided with tracheæ,—are much less highly specialised. The apertures are in *Peripatus* scattered more or less irregularly over the greater part of the surface of the skin. In the freshly killed animal the tracheæ, being distended with air, are readily seen, whereas in specimens which have been steeped in spirit, and in which the air is absent, they are almost invisible.

"The sexes are distinct in *Peripatus capensis*. The males are much smaller and fewer in number than the females. The females are viviparous, and the process of development of the young shows that the horny jaws of the animal are the slightly modified claws of a pair of limbs turned inwards over the mouth as development proceeds, in fact 'foot-jaws' as in other Arthropoda. In many points of internal anatomy *Peripatus* proves itself to be a most archaic form, and the early stages in the development of the egg have been shown by Balfour[1] and Sedgwick[2] to be of a most remarkable character. It is probable that we have existing in *Peripatus* a form nearly allied to the ancestral progenitors of all insects, and that the condition of the tracheæ in *Peripatus* represents an early stage in the history of the development of these organs which was passed through by the ancestors of all forms respiring by means of tracheæ. The tracheæ were probably developed in the first tracheate animals out of skin glands scattered all over the body. In the higher forms they have become restricted to certain definite positions by the action of natural selection.

"That *Peripatus* is a very ancient form is proved by its wide and peculiar geographical distribution. Species of the genus occur at the Cape of Good Hope, in Australia, New Zealand, in Chili, in British Guiana, in the Isthmus of Panama and its neighbourhood, and in the West Indies.

"The animal is provided with a pair of large glands, secreting a viscid fluid, which

Fig. 114.—A right leg of *Peripatus capensis*; viewed from the anterior surface (after Balfour).

Fig. 115.—A left leg of *Peripatus capensis*; viewed from the inner surface (after Balfour).

it has the power of projecting from two papillæ placed one on either side of the mouth. When it is irritated it discharges this fluid with great force and rapidity in fine thread-like jets, which form a sort of network in front of the animal, resembling a spider's web with the dew upon it, and appears as if by magic, so instantaneously is it emitted.

"The viscid substance, which is not irritant when placed on the tongue, is excessively tenacious like bird lime, and the jets of it are apparently used, not only for defence, but also to procure small insects for prey.

[1] *Quart. Journ. Micr. Sci.*, N.S., vol. xix. pp. 431-433, 1879.
[2] *Ibid.*, vol. xxiii. pp. 213-259, 1883.

"The animal is nocturnal in its habits. Its gait is exactly like that of a caterpillar, the feet moving in pairs and the body being entirely supported on them. During the day time it is to be found coiled up in hollows in decayed wood."

The Cetacea.—During the stay of the ship at Cape Town, the skull of an adult *Mesoplodon layardi*, without the lower jaw, and the end of the rostrum with the corresponding part of the lower jaw and the two mandibular teeth of a second specimen, were collected by Mr. Moseley, and the same gentleman subsequently procured, at the head of Port Sussex, on the west coast of East Falkland Island, the skeleton of a young example of the same animal. At a later stage of the voyage, whilst the ship was in New Zealand, a skull of *Ziphius cavirostris* and some of the bones of the Humpback and Right Whales of the southern seas were presented by the Colonial Museum, Wellington. These specimens were reported on at some length by Professor Turner,[1] and his Report may be referred to for the anatomical details, including the microscopic structure of the teeth both of *Mesoplodon layardi* and *Mesoplodon sowerbyi*. It may be sufficient to state in this place that although a specimen of *Mesoplodon layardi* had previously been procured at the Cape, and other specimens at the Chatham Islands, New Zealand, and Australia, the discovery of a skeleton in the Falkland Islands, which Professor Turner determined to be an immature example of that Cetacean, has extended the geographical range of this animal considerably to the westward. No specimen has up to this time been obtained to the north of the equator.

The skull of the *Ziphius cavirostris* had been marked *Epiodon chathamiensis* by the authorities of the Colonial Museum, but the comparison which Professor Turner has made of this skull with an undoubted specimen of *Ziphius cavirostris* from Shetland, in the Anatomical Museum of the University of Edinburgh, has satisfied him that differences do not exist between them sufficient to justify him in classifying them as distinct species. He considers that the present state of knowledge of this Cetacean strengthens the statement which he had made in a memoir on *Ziphius cavirostris*, published in 1872[2] that certain exotic as well as European crania, which had up to that time been described, were examples of that species, and that the geographical distribution of this animal is equal to that of the sperm whale.

The Chitonidæ.—Professor A. C. Haddon, who is preparing a short Report on the small collection of Chitons made during the Expedition, has sent the following note:—

"The number of specimens of Chitons collected by the Challenger Expedition was small, considering the frequency and wide distribution of the group. This is to be accounted for by the fact that the majority of Chitons are strictly littoral in

[1] Report on the Bones of Cetacea, Zool. Chall. Exp., part iv., 1880.
[2] *Trans. Roy. Soc. Edin.*, vol. xxvi. pp. 759–780, 1872.

their habit, and the Challenger Expedition occupied itself mainly with deep-sea dredging. About eighty specimens were collected, which are referable to some twenty-eight species, of which four were previously undescribed, and two are described in the late Dr. P. P. Carpenter's MS.

"The distribution of the shore Chitons is now fairly well known. The specimens collected by the Expedition present us with no new features of interest, and, unfortunately, an insufficient number was collected to give instructive series.

"Three species of Chitonellidæ were collected, viz., *Cryptoplax striatus*, Lam., *Chitonellus fasciatus*, Quoy and Gaim., and *Chitonellus oculatus*, Quoy and Gaim. There has been much confusion concerning this last species, chiefly owing to the fact of Reeve describing a *Cryptoplax striatus* under that name. Quoy and Gaimard's description is sufficiently lucid, but unfortunately they only figure the under surface and one separate valve. It is therefore very satisfactory to be able to restore this beautiful lost species.

"The deep-sea Chitons belong mostly to the genus *Leptochiton*. The following is a list of the species collected by the Expedition of that genus.

	Station	Date.	Depth. faths.	Latitude.	Longitude.	Nature of Bottom.	Bottom temp.
Leptochiton alveolus, Sars,	241	June 23, 1875	2300	35° 41′ N.	157° 42′ E.	Red clay.	35°·1
Leptochiton alveolus, Sars,	205	Nov. 13, 1874	1050	16° 42′ N.	119° 22′ E.	Blue mud.	37°·0
Leptochiton, n. sp.,	149c	Jan. 19, 1874	60	49° 32′ S.	70° 0′ E.	Volcanic mud.	...
Leptochiton, n. sp.,	310	Jan. 10, 1876	400	51° 27′ S.	74° 3′ W.	Blue mud.	46°·5
Leptochiton, n. sp.,	145A	Dec. 27, 1873	310	46° 41′ S.	38°.10′ E.	Volcanic sand.	...

"It is interesting to find that the only really deep-sea captures both belong to the same species, *Leptochiton alveolus*, Sars. The following localities have been recorded for this species :—

"Bergen, Lofoten, Finmark, 150 to 300 fathoms (Sars).

"Gulf of St. Lawrence, off Cape Rosier, 220 fathoms (Whiteaves).

"Gulf of Maine, 150 fathoms (U.S. Fish Commission, 1872, Dall).

"East Coast of United States, 'ranges northwards along the American coast, beyond New England waters,' $99\frac{1}{2}$ to 640 fathoms (Verrill).

"North Pacific (P. P. Carpenter, MS.).

"This species has thus hitherto only been recorded from Scandinavia (150 to 300 fathoms) and the northeast coast of North America in the region swept by the Arctic currents (99 to 640 fathoms). Carpenter's MS. locality is very vague. W. H. Dall has described a very closely allied species, if indeed it be really distinct, *Leptochiton* *belknapi*, from the North Pacific, lat. 53° 8′ N., long. 171° 19′ W., 1006 fathoms, black sand and shells, bottom temperature 35°·5 F. We are now in a position to state that *Leptochiton alveolus* is found in the North Pacific at great depths as far south as lat. 16° 42′ N.

"*Placiphora setiger*, King, was found at a depth of 345 fathoms, blue mud, bottom temperature 46°, Station 306A; and *Euplaciphora simplex*, Carp. MS., was collected on the shore, and dredged from 110 fathoms at Tristan da Cunha."

CHAPTER VIII.

Cape of Good Hope to Prince Edward and Marion Islands—The Crinoidea and Myzostomida—The Crozet Islands—The Petrels—Arrival at Kerguelen.

Cape of Good Hope to Prince Edward and Marion Islands.

On the 17th December 1873, the Challenger left Simon's Bay for the southern cruise, at 6.30 A.M. As the vessel steamed out to the open sea considerable differences in the temperature of the surface water were observed. In Simon's Bay it was 64°·5, but at 10 A.M., when the Cape of Good Hope bore W. by N., distant 5 miles, it had fallen to 55°·5, and was accompanied by a corresponding decrease in the temperature of the air, which fell 3°·8. At noon, when Cape Hangklip bore N. 78° E., and Zwart Kop N. 14° E., the surface temperature had again risen to 65°·0, and there was also a rise in the temperature of the air. At 1.30 P.M. a sounding and dredging in 98 fathoms, and serial temperatures at every 10 fathoms, were obtained. The dredging was very successful. The deposit consisted of a green glauconitic sand, containing 50 per cent. of carbonate of lime, which was composed chiefly of Foraminifera, fragments of Molluscs, Polyzoa, *Serpulæ*, and Echinoderms. At 6 P.M. sail was again made and a course shaped to the southward.

On the 18th, at 6 A.M., sails were furled, and the ship sounded and dredged in 150 fathoms, and at 8.30 A.M. again made all sail to the southward towards Marion Island. The deposit was nearly the same as on the preceding day. Glauconite is exceptionally abundant in these deposits on the Agulhas Bank; the grains are about one millimetre in diameter, and are isolated or agglomerated into phosphatic nodules several centimetres in diameter. Besides these grains, the Foraminifera are often filled with a pale green glauconitic substance, which only rarely shows all the typical characters of glauconite. In these deposits there was much green-coloured amorphous matter, which, when heated on platinum, burned like an organic substance, became black, then red, and gave off an organic smell.

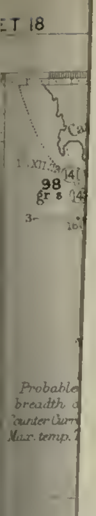
On the 19th, at 1 A.M., the temperature of the surface water rose from 65° to 72°, and remained at from 72° to 73° all day. At 6 A.M. a sounding and dredging were obtained in 1900 fathoms, as well as serial temperatures and specimens of the water from several depths (see Sheet 18). The deposit was a Globigerina ooze, containing 90 per cent. of carbonate of lime, which consisted almost entirely of pelagic Foraminifera. In the dredge were several irregular brown-coloured phosphatic nodules, containing 49 per cent. of tricalcic phosphate. Whilst sounding and dredging, the current was found setting to the westward and northward at an average rate of 1 mile per hour, and the velocity of the wind was on an average 11 miles per hour from 7 to 9 A.M. At 4 P.M., the dredging being completed, sail was again made, and a course shaped to the southeastward.

On the 20th the wind hauled round to the westward and gradually freshened, the surface temperature remained at about 72° until noon, and the current experienced since the previous day at 4 P.M. was 26 miles N. 74° W. At 1 P.M. the surface temperature fell to 68°, and varied between 67°·0 and 69°·5 till 8 P.M. At 4.40 P.M. observations showed that the current had changed to the eastward. At 10 P.M. the surface temperature again rose to 70°·5, and at midnight was 72°·0.

On the 21st a moderate gale was experienced all day with thick weather and rain squalls. The surface temperature continued at 72°·0 until 4 A.M., but fell suddenly to 61°·0 at 6 A.M., and then gradually to 57°·0 by midnight. No astronomical observations could be obtained until the afternoon, but a double altitude at 2 and 4 P.M. showed a current of 40 miles N. 65° E. in 28 hours, or about $1\frac{1}{2}$ miles per hour, agreeing precisely with the rate ascertained by afternoon observations yesterday. Large numbers of Terns, a few Petrels and Albatrosses in sight. The height of the waves from crest to hollow was 20 feet, the ship rolling through an arc of 35°—$4\frac{1}{2}$ rolls per minute.

On the 22nd the gale still continued, with fine cold weather, varied occasionally by rain squalls; the height of the waves 18 feet; the surface temperature gradually falling from 57°·0 to 48°·0, but always warmer than that of the air. The observations showed a current of only 7 miles to the northeastward.

The current experienced on the 20th and 21st shows in a remarkable manner the recurving of the Agulhas Current, which on the 20th was running rapidly to the westward, and on the 21st just as rapidly to the eastward. The exact position of the change in direction was not ascertained, the weather being so gloomy that astronomical observations could not be obtained with sufficient frequency. From the sights that were taken it is certain, however, that the direction of the current changed between 9 A.M. and 5 P.M. on the 20th; and as a considerable change in the temperature of the surface water took place at noon, it appears highly probable that the changes in the direction of the stream coincided with this change of temperature. The width, therefore, of the west going stream is 80 miles. The width of the east going current is much more difficult to determine, as no observations were obtained until 2 P.M. on the 21st. A reference to the surface temperatures shows a sudden fall of 10° between 2 and 4 A.M., and then a gradual decrease of 5° to midnight. Now, from 4 P.M. on the 21st until 6 A.M on the 22nd there was no current; the small amount registered on the 22nd being experienced after 6 A.M. The probability therefore is that the east going stream was entered between 2 and 4 A.M. on the 21st, when the fall of 10° in the surface temperature took place, the subsequent gradual decrease being accounted for by change of latitude; if so, the width of the east going stream must be 60 miles, and its velocity



ET 18
98
Probable
breadth
Max. temp.

$2\frac{1}{2}$ miles per hour. The maximum temperature of the east going stream differed but slightly from that of the west going stream, for it attained its highest temperature after 5 P.M. on the 20th, at which time it was quite certain that the current was easterly. These remarks, of course, only refer to that part of the Agulhas Current crossed by the Challenger between the meridians of 19° and 23° E., and the parallels of $36\frac{1}{2}$° and 39° S. Outside the space enclosed between those lines the direction and strength may be, and doubtless are, considerably modified [1] (see Diagram 8).

On the 23rd the surface temperature became lower as the ship proceeded to the southward, but was still higher than the air, owing probably to the southerly direction of the wind. The day was fine, with slight rain squalls. In the evening the barometer fell, the wind backed to the northward and became very squally.

On the 24th, at 10 A.M., the wind being light and the weather fine, a sounding and temperatures were obtained in 1570 fathoms. The deposit was a Globigerina ooze containing 92 per cent. of carbonate of lime, and a few Diatoms, Radiolarians, and mineral particles chiefly of volcanic origin. At 2 P.M. sail was again made towards Marion Island. Whilst sounding, a Penguin was seen swimming about 50 yards from the ship. The surface temperature was steady at from 42° to 43°, and about the same as that of the air. At 3 P.M. the weather became gloomy and the wind backed from N.W. to N.E. and E., a true cyclonic movement; the barometer fell rapidly, reaching its lowest point at 1 A.M. on the 25th, when there was but little wind. After 1 A.M. it rose again and the wind shifted to south and southwestward, thus retaining its cyclonic movement, and freshened to a moderate gale. At noon Marion Island was sighted bearing S. by E., and shortly after Prince Edward Island. The ship stood towards the land until 6 P.M., and then wore and stood to the northwestward until midnight. At 6 P.M. Ross Rock bore S. 68° E., right extremity of Prince Edward Island S. 52° E., Boot Rock south, and the right extremity of Marion Island S. 30° W. The peaks of the islands could not be seen, being shrouded in mist.

Prince Edward and Marion Islands.

At daylight (4 A.M.) on the 26th, the left extremity of Prince Edward Island being E. by S. $\frac{1}{3}$ S., and the left extremity of Marion Island S.W., a course was shaped towards Boot Rock, the vessel passing about $1\frac{1}{2}$ miles to the northward of it, steering careful courses, and registering the distances sailed by patent log in order to fix the relative position of the two islands, and make a running survey of them.

Marion and Prince Edward Islands were discovered on the 13th January 1772, by M. Marion du Fresne, who named the northern "Ile de la Caverne," in consequence of the large cave he observed in the cliffs of its eastern coast, and the southern "Ile de

[1] For the temperature observations, see Narr. Chall. Exp., vol. ii. p. 423, 1882.

l'Esperance," in the hope that this island would prove an outlying sentinel of the Antarctic continent, which was then being constantly sought for, and the necessity for the existence of which was firmly fixed in the minds of the geographers of that age. M. Marion tried for anchorage without success, and after remaining five days in the vicinity, abandoned his researches owing to the loss of the bowsprit and a mast of his consort "Le Castries," and some sails in his own ship "Le Mascarin."

These islands were next sighted on the 12th December 1776 by Captain Cook, who sailed between them, and not knowing the names given to them by M. Marion, called them the "Prince Edward Islands," which designation is still retained by the northern and smaller of the two.

From the year 1776 to the present time both islands have been much frequented by whalers and sealers, who as early as 1802 had establishments on shore on both islands; for Captain Fanning in the narrative of his voyages mentions them as if they were well known at that date. Sir James Ross received information to the effect that whaling vessels sometimes anchored off the east side of Prince Edward Island in 8 or 10 fathoms, with the cave W.N.W., the N.E. point N.E. by E., and the S.E. or Mary's Point S.W. ½ S.

From the records of M. Marion, Captain Cook, Sir J. Ross, and Captain Cecille, and the survey of the Challenger, the following account of these islands has been compiled:—

Marion Island, the southern and larger of the two, is 33 miles round; in shape an irregular parallelogram, whose sides are east and west, and N.E. by N. and S.W. by S., the sides running east and west averaging 11 miles in length, and the others 7 miles, with an area of 70 square miles, its summit rising upwards of 4200 feet above the level of the sea. Its geographical position has now been well ascertained, for good observations were obtained on shore by the Challenger's surveying officers. It lies between the parallels of 46° 48′ S., and 46° 56′ S. latitude, and the meridians of 37° 35′ and 37° 54′ E. longitude. The observation spot close to the landing place just west of the N.E. point of the island is in lat. 46° 49′ 30″ S., long. 37° 49′ 22″ E., and Boot Rock, a remarkable islet off its north end, in lat. 46° 48′ N., long. 37° 43′ 45″ E. (see Sheet 19).

Prince Edward Island, the northern and smaller, is 15 miles round, circular in shape, with an area of 16 square miles. Its summit rises to the height of 2370 feet, and it lies between the parallels of 46° 34′ and 46° 39′ S. latitude, and the meridians of 37° 53′ and 38° 1′ E. longitude. On its northern side are three detached rocks (Ross Rocks), and on its eastern side a remarkable cave. Seen from the westward it shows a rounded summit, the land sloping gradually to the southward and terminating in a precipitous cliff about 1500 feet in height. On the north side the slope is more abrupt, and the north point is a wedge-shaped hill, which from a distance appears detached from the island; this hill is but slightly higher than the Ross Rocks which lie off it.

Both islands are surrounded by kelp, of which there is considerably more on the

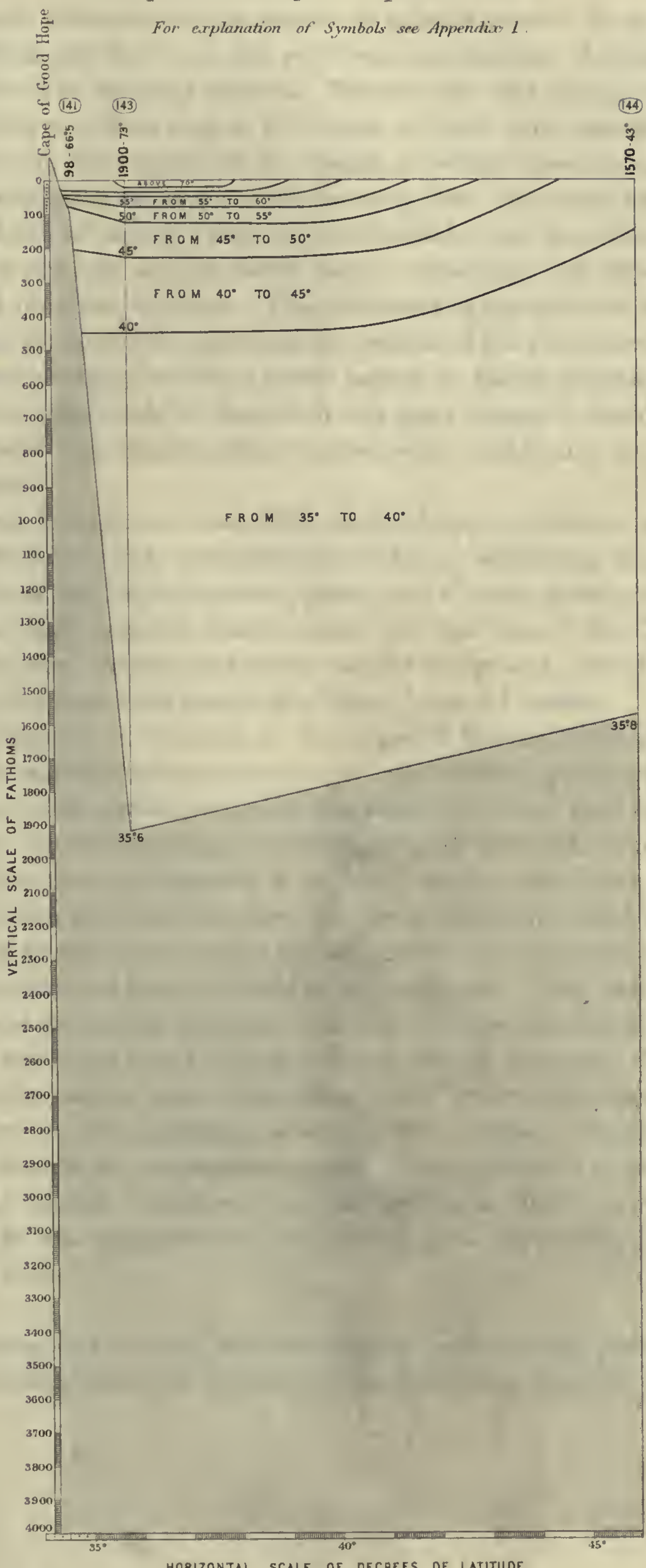
DIAGRAM 8

INDIAN OCEAN

Meridional Temperature Section

Cape of Good Hope to the parallel of 46° S.

For explanation of Symbols see Appendix I.



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eastern or leeward sides than on the western or weather coasts. In no case, however, does it extend far from the shore, nor has any been seen between the islands. The vicinity of the kelp should be carefully avoided. Between the two islands is a channel 12 miles in width perfectly free from danger, the depths in which vary from 90 to 130 fathoms.

The weather in the vicinity of the islands is seldom favourable, for owing to their height, their position in the open ocean far away from any larger tract of land, and the general prevalence of strong winds in their latitude, they are seldom free from fog or mist, and their summits are but rarely visible, whilst days may elapse before a landing can be effected on either of them. The prevalence of fog and mist not only renders the islands difficult to see, but also prevents the position of the vessel approaching them being ascertained with certainty, so that a course cannot be shaped to make them, or pass at a given distance on either side of them with any great degree of confidence, it is therefore advisable to avoid their neighbourhood unless some considerable object is to be gained by visiting them.

Viewed from the sea, the coast cliffs showed layers of compact and brecciated lavas of no great thickness, and were surmounted by an undulating country covered with herbage, which, as the height increases, passes into a barren mountain-cluster with many sharp and sometimes perfectly conical peaks. At the time of the Challenger's visit the highest of these were covered with snow, and for the greater part of the day enveloped in mist; the lower ones were mostly of a bright brick-red colour.

The snow commenced, as usual, on the slopes of Marion Island as patches lying unmelted in sheltered hollows, succeeded by a general thin coating or powdering over, through which the black rock showed out in all directions, and above this, again, on the highest cones and peaks, formed a continuous sheet of glistening white. The summits were enveloped in clouds, which lifted or dispersed in a partial manner from time to time. Amongst the patches of snow and below the snow line, the slopes of the island were covered with a coating of green, in striking contrast to the dark cliffs and red lower cones, which were almost destitute of verdure and had very little snow upon them. Here and there large patches of yellow showed out amidst the green, and were conspicuous even at some distance from the shore. It was found that these patches were formed of mosses. The mosses, indeed, occurring thus in patches, some dark, some nearly white, and others yellow, form the principal features in the vegetation as seen from a distance, showing out amongst the very uniform mixture of phanerogamic plants. The small rocky projections on the rough surfaces of the modern lava-flows, standing out dark above the verdure, have at a distance exactly the appearance of low bushes with dark foliage, and were at first believed to be such.

Marion Island.—At 6 A.M. sails were furled, and the ship proceeded under steam looking for a landing place and anchorage; the former was found at the northeast point of Marion Island, but the deep water extended so close to the shore that it was deemed unadvisable to anchor, although it was concluded that it would be practicable to do so in case of necessity. At 9 A.M. observing and exploring parties were landed, each member of the latter being provided with a heavy stick, as it was expected that Fur Seals might be met with. The day was fine, and equal altitudes, circummeridian altitudes, true bearings, and magnetic observations for declination were obtained, whilst the ship took up stations between the two islands, and sounded and dredged; the position of the ship being fixed by bearings and masthead angles from the observing station at each sounding, at which time angles and bearings were taken from the ship to objects on shore.

On the shore near the observing station, the remains of huts with a few cooking utensils, some tubs, and iron work were found scattered about. One of these huts was built in a cave, the other on the open ground close to a Penguin rookery. They had evidently been occupied by parties landed from whaling and sealing vessels engaged in the fishery, and used in making Penguin oil. As the boat pulled on shore, cormorants flew about overhead in numbers. A gull also was common, probably the same as at Kerguelen Island (*Larus dominicanus*). The Giant Petrel or "Break-bones" (*Ossifraga gigantea*) was also wheeling about over the water, and also a few large Albatrosses. As the boat neared the beach a bird, like a small white hen, was seen eyeing the party inquisitively from the black rocks, against which a considerable swell was washing. This bird was the "Sheath-bill" (*Chionis minor*), so frequently met with afterwards in Kerguelen Island.

A female Elephant Seal was met with on the shore, which was killed forthwith, under the impression that it was a Fur Seal. The ruthless manner in which Fur and Elephant Seals were destroyed by the sealing parties in the early part of this century has had the effect of almost exterminating the colony that used these desolate islands for breeding purposes.

The walking on shore was extremely tiring; the bank was steep and the soil saturated with moisture, consisting of a black slimy mud with holes everywhere full of water. The thick rank herbage concealed these treacherous places, and the ground was covered with *Azorella* tufts, which gave way under the feet and rendered progression excessively wearying. Further, the sun coming out bright and hot every now and then made the party, who had gone on shore thickly clad, perspire very freely.

The large White Albatross or "Goney" (*Diomedea exulans*) had been seen from the ship as she steamed in towards the landing place; but now they could be examined more closely, for there were many of them all around. They were scattered irregularly all over the green in pairs, looking in the distance not unlike geese on a common (see Pl. XIV.). Their nests are in the style of those of the Mollymauks (see pp. 265, 266), but much larger, raised from the ground, and a foot and a half at least in diameter at the top. They are made of tufts of grass and moss, with

Plate XIV.

Horsburgh, Edinburgh. Permanent Phototype.

NESTS OF THE WANDERING ALBATROSS,
MARION ISLAND.

plenty of adhering earth beaten and packed together, and are not so straight in the sides as those of the Mollymauks, but more conical, with broad bases. The female Albatross is sprinkled with grey on the back, and is thus darker than the male, which is of a splendid snow-white colour, with the least possible grey speckling, and was now, of course, seen in his full glory and best breeding plumage; the tails and the wings of both birds are dark. The Albatrosses met with at sea are most frequently birds in young plumage or bad condition, and have a rather dirty draggled look. The brooding birds are very striking objects, sitting raised up on the nest, commonly with the male birds beside them. They sit close on the nest when approached, and snap their bills savagely together, thus making a rather loud noise, and will lay hold of a stick with their bills when it is pushed against them, but need a good deal of bullying with the stick before they stand up in the nest and let the intruder see whether they have an egg there or not. Then the egg is seen to appear slowly out of a sort of feather pouch, in which it is held during incubation. Only one egg is laid, which is about five inches long, as big as a swan's, and white with specks of red at the large end. In most of the nests there were fresh eggs; in some, however, nearly full grown young birds. The old birds never attempted to fly, though persistently ill-treated, but merely waddled heavily over the ground; the old males tried to run away when frightened, but never even raised their wings. It is amusing to watch the process of courtship: the male standing by the female on the nest raises his wings, spreads his tail and raises it, throws up his head with the bill in the air, or stretches it straight out forwards as far as he can, and then utters a curious cry, like that of the Mollymauk, but in a much lower key, as would be expected from his larger larynx. Whilst uttering the cry, the bird sways his neck up and down; the female responds with a similar note, and they bring the tips of their bills lovingly together. This sort of thing goes on for half an hour or so at a time. Occasionally an Albatross sailed round and alighted upon the grass, but none were seen to take wing.

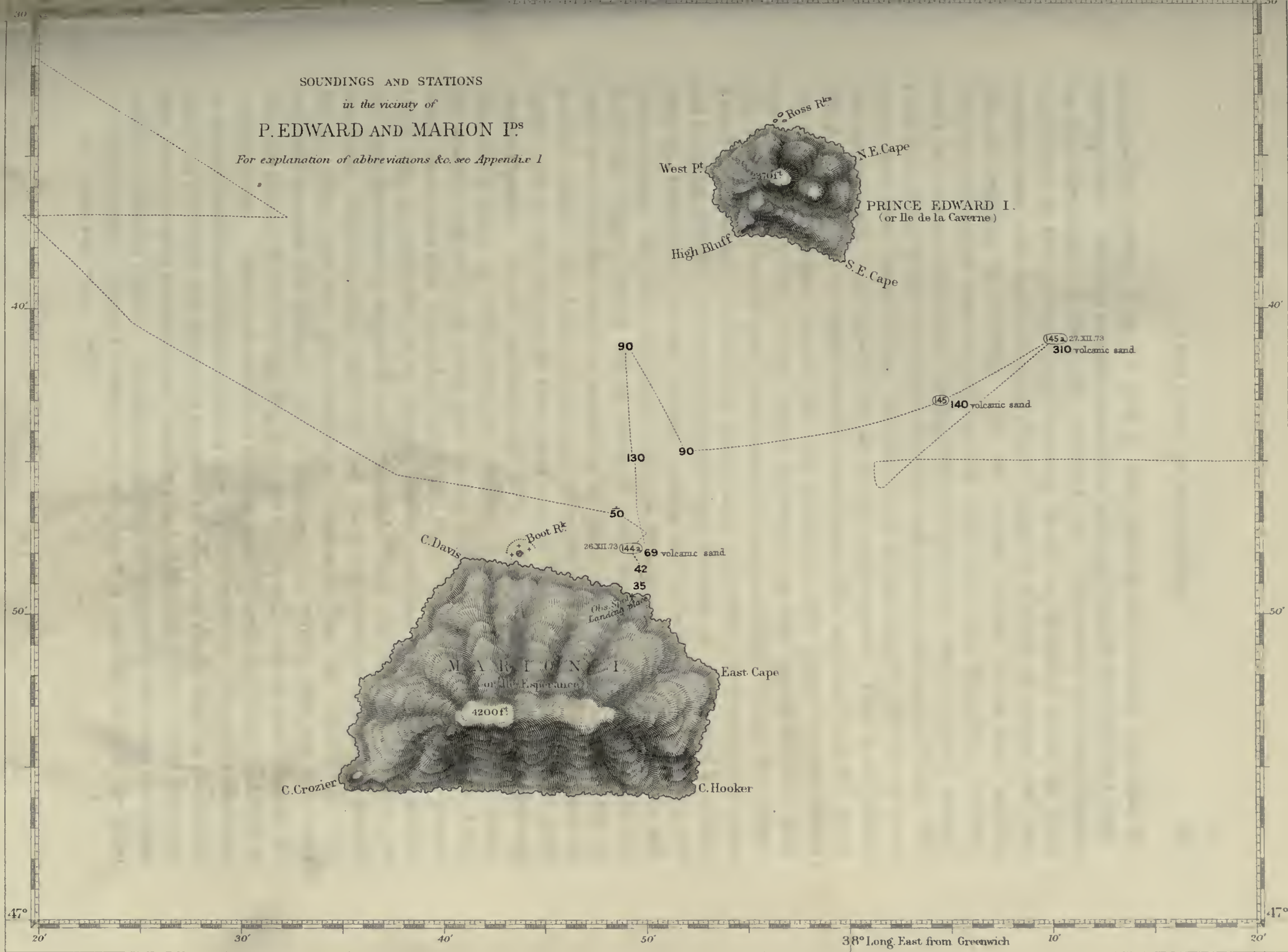
There were numerous nests of the Skua about amongst the herbage in dry places. The nests of these birds are never built near together; thus they always have a wide range of hunting ground round their nest. The Skuas in Marion Island were extremely bold and savage, as they were also in Kerguelen Island.

Three kinds of Penguins were abundant on the island. One kind (*Aptenodytes* [*Pygosceles*] *tæniatus*), called by the sealers the "Johnny," the "Gentoo" of the Falkland Islands, is much larger than the Crested Penguin, in fact, nearly as big as the King Penguin. The beak is bright red, long and sharp-pointed, the back dark, the breast white; the colour of the back is continued on to the head, but a white patch on the top of the head in contrast with the dark colouring is the marked feature about the bird. These Penguins were nowhere met with nesting, but were often associated with the King Penguins. They were usually to be met with here and in Kerguelen Island in parties of a dozen or twenty or thirty on the grass, close to the shore, and were apparently moulting at the time of the visit. At Christmas Harbour, Kerguelen Island, small droves of them "camped" as the sealers term it, at 100 feet at least, up the steep but green hillside at the end of the harbour. These Penguins do not hop, but run, and when closely pursued throw themselves on their bellies on the ground, and struggle along, rowing themselves with violent blows of their wings on the sand or mud, dashing the mud into the eyes of their pursuers. When in the water, as they come to the surface, they make a sort of very feeble imitation of the leap of the Crested Penguins, never throwing the whole of the body out of the water, but only the back. They are also to be seen swimming about when undisturbed with their head and back out of the water, and the body horizontal.

Another Penguin, the "Rockhopper" (*Eudyptes chrysocome*), the same species that occurs at Tristan da Cunha, was nesting about the low cliffs on the shore. The ground on which the nests were made was very wet and filthy, and the nests were like those of the Jackass Penguins at the Cape of Good Hope, made of small stones, raising the egg about an inch from the mud. These Penguins were exactly like the Tristan ones in their cry, and quite as savage, but they were in full sight, and not amongst grass; for though there was plenty of grass just over them, nearly a foot in height, they prefer to build where the ground is quite bare. The birds therefore for some reason have adopted slightly different habits from those of the representatives of the species at Tristan da Cunha.

Most interesting, however, by far, amongst all the rookeries was one of King Penguins (*Aptenodytes longirostris*), met with a little further along the shore. The rookery was on a space of perfectly flat ground about an acre in extent, and was divided into two irregular portions, a larger and smaller, by some grassy mounds. The flat space itself had a filthy black slimy surface; but the soil was trodden hard and smooth. About two-thirds of the space of the larger portion of the rookery was occupied by King Penguins, standing bolt upright, with their beaks upturned, side by side, as thick as they could pack, and jostling one another when disturbed. The King Penguins stand about 3 feet high, and are distinguished at once not only by their size, but by two narrow streaks of bright orange yellow, one on each side of the glistening white throat. These Penguins were to be seen coming from and going to the sea from the rookery, but singly, and not in companies like the Crested Penguins. The King Penguins, when disturbed, made a loud sound like "urr-urr-urr." They run with their bodies held perfectly upright, getting over the ground pretty fast, and do not hop at all. A good many were in bad plumage, moulting, but there were plenty also in the finest plumage. The smaller area of the rookery, which consisted of a flat space sheltered all round by grassy slopes, forming a sort of bay amongst these, and communicating with the larger area by two comparatively narrow passages, was the breeding establishment.

These Penguins are said by some observers to set apart different spaces in their



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rookeries for moulting birds, for birds in clean plumage not breeding, and again for breeding birds. Here the breeding ground was quite separate and the young and breeding pairs were confined to this smaller sheltered area. This was the only King Penguin rookery seen in full activity during the entire voyage; at Kerguelen Island the King Penguins were only met with in scattered groups of a dozen or twenty, and they were not breeding, but moulting. On this breeding ground, at its lower portion, numbers of Penguins were reclining on their bellies, and it was thought at first they might be covering eggs, but on driving them up, they were seen to be only resting. There was a drove of about a hundred Penguins with young birds amongst them. The young were most absurd objects; they were as tall as their parents, and moved about bolt upright with their beaks in the air in the same manner. They were covered with a thick coating of a light chocolate down, looking like very fine brown fur, which was at least two inches deep on the birds' bodies, and gave them a curious inflated appearance. They had a most comical appearance, as they ran off to jostle their way in amongst the old ones; they seemed to run rather better than the adults. Absurd in appearance as were these young, those that were just dropping the down and assuming the white plumage of the adults were far more so. Some were to be seen with the brown down in large irregular patches, and the white feathers showing out between these. In others the down remained only about the neck and head, and in the last stage a sort of ruff or collar of brown remained sticking out round the bird's neck, and then, when it cocked up its head, it looked like a small boy in stick-up collars. The birds in this stage of moulting had a peculiar expression of vanity, and as they ran off on their short stumpy legs, it was impossible to resist laughing outright. At the farthest corner of the breeding space, in the most sheltered spot, was a clump of birds, a hundred or more, most of them in a slightly stooping posture, and with the lower part of their bodies bulged out in a fold in front. When these birds were approached and bullied with a stick they shifted their ground a bit, with an awkward sort of hopping motion, with the feet held close together. The idea immediately suggested itself that they were carrying eggs with them, in accordance with the peculiar habit of this species as described in works on natural history. Their gait was quite peculiar, and different from the ordinary one, and evidently laboured and difficult. One of them was struck with a stick, and after some little provocation she let her egg drop from her pouch, and then at once assumed the running motion. These birds carry their egg in a pouch between their legs, and hold it in by keeping their broad webbed feet tucked close together under it. They make absolutely no nest, or even mark from habitually sitting in one place, but simply stand on the rookery floor in the stooping position above described, and shift their ground a little from time to time, as occasion requires. The egg is probably not dropped till the young one begins to break the shell. Charles Goodridge, who was one of a searching party on the island in 1820, and spent two years on the Crozets,[1] says that the period of incubation is seven weeks, and that they commenced laying in the Crozets in November, and continued to lay, if deprived of their eggs, till March. Unfortunately no close examination of the exact structure of the pouch was made, and as it was not in the least suspected that this was to be the only opportunity of observing the breeding habits of this bird during the voyage, no brooding females were specially prepared to show it. Goodridge compares it to the pouch of a kangaroo. Probably the larger species of the genus, the Giant Penguin (*Aptenodytes forsteri*) of the far south, which has to hatch its egg on the ice, secures it from being killed by the cold in a similar manner. The birds with eggs were sitting close together, and when frightened so that some were driven against the others, savage fights ensued, and blood was drawn freely; the birds whose ground was invaded striking out furiously with their beaks. Round about the brooding birds were others, apparently males, in considerable numbers, who probably feed the females with which they are paired. There were also some young downy birds, and if one of these latter were driven in amongst the brooders it was at once pecked almost to death. The young ones utter a curious whistling cry, of a high pitch and running through several notes, quite different from the simple bass note of the adults. The rookery was only inhabited to about a quarter of its extent, but it was strewed everywhere with the bones of the Penguins in heaps, and on the verge of the rookery was a small ruined hut, without a roof, and overgrown with weeds, containing an iron pot and several broken casks, and some hoop iron, evidently an old sealer's hut. The sealers had probably employed their spare time in making penguin oil, and perhaps taking skins, which are made up into rugs and mats at the Cape of Good Hope, often only the yellow streaked part about the neck being used. Hence the many bones and emptiness of the rookery. The egg of the King Penguin is more than ordinarily pointed at the small end; it is greenish-white, like other penguin eggs.

Living also about the rookery was a flock of about thirty Sheath-bills (*Chionis minor*). The instant they saw the party approaching they came running in a body over the floor of the rookery in the utmost excitement of curiosity, up to within reach of a stick, uttering a "cluck, cluck," which with them is a sort of half-inquisitive, half-defiant note. Several were knocked over with big stones and sticks; but the remainder did not become in the least alarmed. They just fluttered up off the ground to avoid a stone as it was sent dashing through the thick of them, but immediately pitched again, and ran up, as if to see how the stone was thrown. At the rookery they were living on all sorts of filth dropped by the Penguins, and were the scavengers of the place, and when some of the brooders were driven off their eggs, and an egg or two got broken, the Sheath-bills, who had followed closely, notwithstanding the slaughter done amongst them, came and pecked at the eggs almost between the explorer's legs.

1 Narrative of a Voyage to the South Seas, &c., by C. M. Goodridge, pp. 22, 23. London, Hamilton & Adams, 1833.

Plate XV

HORSBURGH, EDINBURGH. PERMANENT PHOTOTYPE.

VIEW IN KERGUELEN ISLAND,
WITH HUMMOCKS OF (*Azorella selago.*)

Near this rookery was a shallow freshwater lake, on which some young Albatrosses were swimming. There were numerous White Albatross's nests scattered about, but they did not extend more than 100 feet above sea level, and hardly anywhere as high up as that. High up, at about 500 feet elevation, were some four or five Sooty Albatrosses (*Diomedea* [*Phœbetria*] *fuliginosa*, the "Piew" or "Pio" of sealers), soaring about the tops of the cliffs; probably they nest there. This bird is continually to be seen flying about cliffs and higher mountain slopes, and never seems to nest low down like the Mollymauk and Goney.

In holes in the banks at this elevation, a Prion (*Prion banksi*) was extremely abundant, but it was also pretty common down about sea level. Its peculiar angry cry, somewhat like the snarling of a puppy, uttered as it hears footsteps about its hole, is very puzzling at first as listened to coming up from the ground at one's feet.

The rocks, about high-water mark, are covered with a dense growth of the large brown seaweed (*Durvillea utilis*), which is of great assistance in breaking the surf. The plant has stout stems, as thick as the wrist, attached to the rock by large conical boss-like suckers, and with large spreading leaves on the stalks, provided with floats composed of a series of honeycomb-like air-cells within a thickened frond. Beyond the ordinary reach of the sea, but still within the beach-line, the rocks are covered with a Crassulaceous plant (*Tillæa moschata*), which occurs also in Kerguelen Island. Above the beach is a thick growth of herbage investing a swampy black peaty soil, which covers the underlying rock more or less thickly everywhere on the lower ground, and extends up with the herbage almost to the snow. The principal plants forming the thick growth are *Acæna adscendens*, by far the most abundant plant on the island, *Azorella selago*, forming bright green patches in intervals between the *Acæna* or cake-like masses at its roots, and a grass *Poa cookii*. *Azorella selago* is a characteristic plant of the southern islands, and will be frequently referred to in the sequel (see Pl. XV.). It belongs to the Umbelliferæ, and forms large convex masses often several feet in diameter, which are compact and firm, and when on solid ground yield little to the tread. The masses are made up of the stems and shoots of the plants closely packed together side by side, with their flowering tips and small stiff and tough leaves forming an even rounded surface at the exterior, being all of the same length; the interior of the masses is full of dead leaves and stems. The whole, where growing in abundance, formed sheets and hummocks which invest the soil, sometimes for acres in extent at Kerguelen Island, with a continuous elastic green coating. An allied plant, *Bolax glebaria*, forms similar masses at the Falkland Islands, and there is a tendency in many Antarctic plants to assume a similar habit, as in the case, *e.g.*, of *Lyallia kerguelensis*.

Pringlea antiscorbutica (see Pl. XVI.), the Kerguelen Cabbage, is, at least in the part of the island explored, by no means so abundant as at Kerguelen Island. It was some time before a plant was found; subsequently a good many were met with, but growing in groups of only four or five. Some were found on the very verge of the shore, within reach of the spray, and the rest on the banks of a small rivulet. The Cabbage was mostly in full flower and bud, with sepals and anthers complete; no plants were found with seed at all ripe, and the last year's seeds were decayed. This plant at least would appear to have a regular summer flowering-season, since Sir Joseph Hooker found only the fruit at Kerguelen Island in the winter.

Hymenophyllum tunbridgense var. *wilsoni*, the well known British Fern, and *Polypodium* (*Grammitis*) *australe* grow abundantly on the sheltered sides of the projecting rock-masses already mentioned, but are dwarfed and almost hidden amongst the mosses; they grow in greatest luxuriance on the damp banks of the stream.

The mosses are in most striking abundance,[1] and, in some very wet places, form continuous sheets over the ground many square yards in extent. Lichens are not in very great quantity, except the incrusting forms, which are tolerably abundant on the rocks.

An attempt was made to reach the actual upper limit of vegetation, but failed from being commenced too late in the day. The ascent was up the bed of the small stream already mentioned, which lay at the verge of one of the modern lava-flows, where it abutted on a low cliff exposing a more ancient flow in section. The more recent flow had a very gradual inclination of not more than 8°. When the swampy moss-covered ground, the uniformly dull green colour of which was relieved here and there by the snowy plumage of the nesting albatrosses, had been left behind, the stream was found to flow over an apparently very recent stream of black cellular lava, the ripples and eddies in which were still perfectly fresh, except in the very centre, where they had suffered some slight abrasion; there was no trace of any hollowing action on the part of the water, the windings and little waterfalls being still determined by the original inequalities of the solidifying rock. The lava was basaltic, containing much olivine. Close by the bed of the stream rose several of the above mentioned red conical hills. One of these, the highest within reach, consisted of a heap of loose scoriæ disposed in layers, dipping away on all sides at a regular and very steep angle. Few of these pieces of scoriæ were more than six inches in diameter; and had it not been for the occasional clumps of moss which alone afforded a sure footing, the ascent would have been a matter of considerable time. At the top was a perfectly conical pit, and slightly below the summit, on the north side, were three smaller and similar pits. The scoriæ of which the hill is made up consisted of a highly cellular red ground mass, with indications of augite, without, however, any perfect crystals being discernible. Besides the red scoriæ, there were some of a chocolate-brown colour, with frothy exterior and compact kernel. The form of some of them resembled the almond-shaped bombs found in many volcanic districts; but none were noticed with the dense outside and highly cellular core so characteristic of the

[1] Thirty-one species were collected, five of which are described by Mr. Mitten as new in Bot. Chall. Exp., part ii., 1884.

Plate XVI.

Horsburgh, Edinburgh. Permanent Phototype.

Vegetation Kerguelen Island.
(Pringlea antiscorbutica.)

true volcanic bomb. Besides this hill, there were five or six others precisely similar in appearance, and rising out of the same valley or depression in the ground. From the top of the hill this depression could be seen to be bounded, towards the interior, by a semicircular cliff of rock, in some parts columnar, and open towards the sea. Above this cliff rose the snow-covered cones and peaks of the interior, which, wherever the snow had been removed, showed the same red colour and steep sides, so that there can be little doubt of their being similarly formed to those on the lower ground. On leaving the stream bed and returning to the eastward over the spur of the mountain, the cliff had to be skirted, and it was found to consist of a light grey compact doleritic rock.

From these few observations it may be concluded that the island consists of a foundation of older lava ruptured and surmounted by recent volcanoes. That these have been active at no very ancient date is rendered probable by the perfect preservation of the forms of the cones with their summit craters, and by the fact that the mossy vegetation, so luxuriant at their base, and retaining this luxuriance on the certainly older mountain spurs to an elevation at least equal to that of the top of the cone ascended, has as yet spread up their sides only in straggling isolated patches. The evidence afforded by the want of erosion deserves all the more weight when the position of the island is remembered, where of necessity the rainfall must be considerable.

The first scattered patches of snow were encountered at about an elevation of 800 feet. A patch of the Cabbage was met with at 1000 feet. The highest point reached was at an elevation of about 1500 feet, where patches of snow were frequent. Here *Ranunculus biternatus* had disappeared, and where growing a little lower down was very much dwarfed. The *Azorella*, with a few mosses, formed the principal vegetation; but the green was merely dotted over the bare rock and stones. The *Azorella* appeared from this point to continue on for about 300 feet more, becoming scantier and scantier. The absolute limit of vegetation may probably be placed at about 2000 feet. The part explored was somewhat sheltered. A red cone of scoriæ more exposed was quite bare of green from about 1000 feet elevation upwards.

At about 1400 feet elevation, the water in a shallow pool exposed to the sun was found to have a temperature of 65° F., the temperature of the air in the shade being 44°. At 900 feet a similar pool, but one which had a small stream of colder water running into it from the cliff, had a temperature of 55°, the air there being 45°, while the thermometer when plunged into the midst of a rounded mass of *Azorella*, rose to 50°. It is therefore evident that these mounds retain and store up a considerable quantity of the sun's heat; and this fact probably yields a partial explanation of their peculiar form, which is that of so many otherwise widely different Antarctic plants, and of some Swiss and New Zealand Alpine plants (*Raoulia*, *Haastia*). No doubt power of resistance to wind is also gained by the assumption of this form.

At 6 P.M. the surveying and exploring parties returned, and the ship worked to windward under easy sail between the two islands during the night.

On the 27th the weather in the morning was thick and cloudy, so that it was unadvisable to proceed towards the land or to send exploring parties on shore; the day was therefore devoted to dredging, which proved very satisfactory. The islands were occasionally seen through the mist, thus enabling the position of the soundings to be fixed. In the afternoon they were both seen for a short time. The dredgings between the island showed that the bottom, in depths less than 100 fathoms, was covered with great masses of Polyzoa, the dredges and swabs being filled and covered with them; Mr. George Busk records sixteen species from this locality, eight of which are new. There were also numerous animals belonging to all the marine invertebrate groups. In 130 and 310 fathoms there was a volcanic mud containing 15 to 20 per cent. of carbonate of lime, shells, many Diatoms, and many volcanic minerals and lapilli of vitreous basaltic rocks.

Marion Island to the Crozet Islands.

At 6 P.M. on the 27th December, sail was made for the Crozet Islands, and the 28th December, the day after leaving Marion Island, was bright and sunny, with a smooth sea, moderate northerly wind, and a high and steady barometer.

On the 29th the weather still continued fine, but was misty, the mist at times amounting to a light fog. Advantage was taken of this fine weather to sound and trawl in 1375 fathoms; serial temperature soundings were also obtained (see Sheet 18). Four Penguins appeared on the water close to the ship while dredging was going on, and stopped in the vicinity for some time.

On the 30th, the weather still continuing fine, a sounding and trawling were obtained in 1600 fathoms with excellent results (see Sheet 18). At 10 P.M. Hog Island of the Crozet group was seen. During the night a large cetacean came close to the ship but soon disappeared.

The trawlings at the two Stations on this section, in depths of 1375 and 1600 fathoms, were probably the most productive of the cruise; between one and two hundred animals, belonging to nearly all the marine groups, were taken at each of the hauls, and with few exceptions they belonged to genera and species discovered for the first time by the Expedition. In the memoirs already published, 7 new genera and 35 new species are described from the trawling in 1375 fathoms, and 9 new genera and 29 new species from 1600 fathoms; among these, 12 species are common to both Stations. It is probable that these new species do not represent more than one-third of the whole number discovered, but this cannot be said with certainty till all the specialists have completed their reports.

The deposit at 1375 fathoms was a Globigerina ooze, containing 81 per cent. of carbonate of lime, the residue being almost wholly remains of Diatoms and Radiolarians. At 1600 fathoms there was only 35 per cent. of carbonate of lime, 40 per cent. of Diatom and Radiolarian remains, and 25 per cent. of minerals and argillaceous matter. There were a few rounded quartz particles in each of the deposits, but the great majority of the mineral particles were of volcanic origin. The carbonate of lime in these deposits consisted chiefly of Globigerinas and Coccoliths. Neither Orbulinas nor Rhabdoliths were observed in the deposits, nor at the surface, so that these Stations are probably beyond the southern limit of these organisms.

Dr. P. H. Carpenter and Professor L. v. Graff, of Graz, refer to some of the Crinoidea and Myzostomida, found at these Stations, in the following summaries of their Reports on these groups[1] :—

The Crinoidea.—" Twelve genera of recent Crinoids are now known to science, six of which are usually classed as 'Stalked Crinoids,' while the other six belong to the group of Feather-stars, or Comatulæ. Species of every genus, with the exception of *Holopus* (see p. 153), were obtained by the Challenger, while the number of existing genera was increased by one half, four being added to the eight previously known. The most familiar of these is the beautiful *Pentacrinus*, a type closely allied to the well-known Liassic fossils *Extracrinus briareus* and *Extracrinus subangularis*, specimens of which have been found with stems from 50 to 70 feet in length. There are several Jurassic and Cretaceous species of *Pentacrinus*, but only eight living ones are known. Four of these have not been met with out of the Caribbean Sea, while two inhabit the Atlantic and two the Pacific. The surveys of the U.S.C.S. steamer 'Blake' have discovered *Pentacrinus* in depths as shallow as 42 fathoms, while it was found to be remarkably abundant in 175 fathoms off Havana, one haul of the dredge and its appendages bringing up no less than 120 individuals. There would seem, therefore, to be regular forests of them upon the sea bottom in this and other localities, just as must have been the case in the Liassic seas. Although *Pentacrinus* was only once met with in the Caribbean Sea at a greater depth than 500 fathoms, both the Pacific species were obtained by the Challenger between 500 and 630 fathoms, one of them possibly coming from 1350 fathoms. Failing this last, *Pentacrinus wyville thomsoni*, which was dredged by the 'Porcupine' (1870) off the coast of Portugal in 1095 fathoms, is the deepest *Pentacrinus* known.

"The stem of this genus bears whorls of cirri which may be some distance (forty joints) apart, as in *Pentacrinus wyville thomsoni* (fig. 117), or very close together, as in the *Pentacrinus maclearanus* (fig. 116) from Station 122 (350 fathoms). The union of the nodal or cirrus-bearing stem-joints with those beneath them is slightly different from that found in the other parts of the stem, and is more easily severed ; and although individuals have sometimes been found with their stems attached to telegraph cables by a slightly spreading base, yet in other cases the stem appears to be free, having broken across below one of the nodal joints, which becomes rounded off and closed up by a subsequent

[1] Report on the Crinoidea, by P. H. Carpenter, D.Sc., Zool. Chall. Exp., part xxxii., 1884 ; Report on the Myzostomida, by Dr. L. von Graff, Zool. Chall. Exp., part xxvii., 1884.

calcareous deposit. This is the case with the individuals represented in figs. 116 and 117, and it would seem that under these circumstances the animal practically becomes a free

Fig. 116.—*Pentacrinus maclearanus*, Wyv. Thoms.

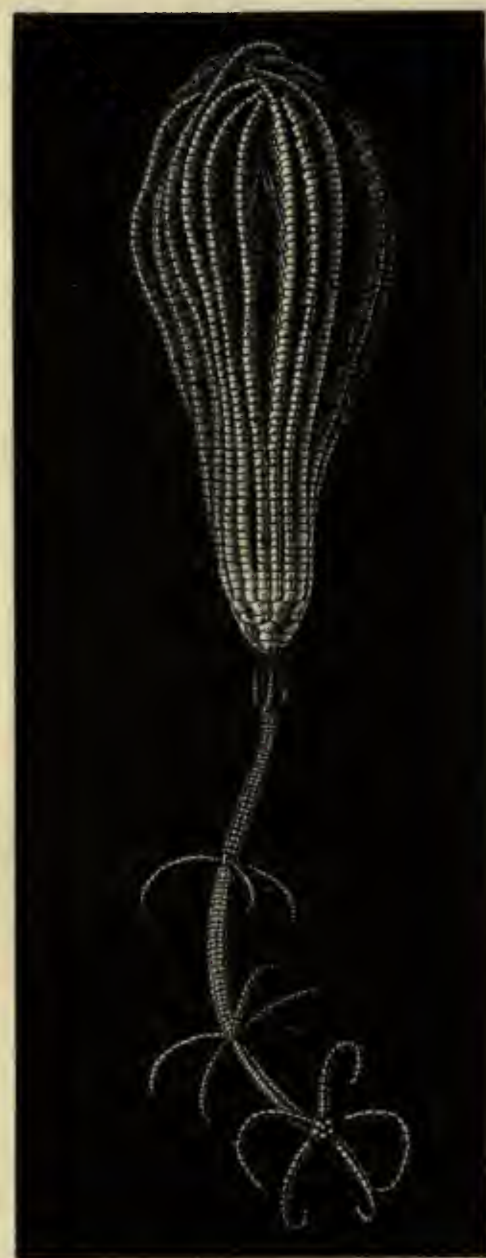


Fig. 117.—*Pentacrinus wyville thomsoni*, Jeffreys.

Crinoid like a Feather-star, with the power of swimming about and temporarily fixing itself again; while if the trailing stem gets caught or injured in any way, it can be broken across at a nodal joint, and the body with the upper part of the stem liberated, eventually to attach itself elsewhere by means of its cirri.

FIG. 118.—*Metacrinus wyvillii*, P. H. Carpenter.

FIG. 119.—*Rhizocrinus lofotensis*, M. Sars.

"The lowest part of the cup which rests upon the top of the stem is formed of a more or less complete ring of basal plates. Alternating with the basals, and resting upon them, are the first radials, and second radials are attached to these by muscular joints, bearing in their turn the third radials or axillaries. Each of these bears two primary arms, which either remain single or divide again more or less frequently; but there are rarely more than forty or fifty arms altogether, the forking taking place much less often than in certain Comatulæ.

"The recent dredgings in the Atlantic and in the Caribbean Sea have yielded six species of *Pentacrinus;* but only two were obtained in the Pacific, one of them, however, occurring at such widely separated localities as the Kermadecs (Station 170) and the Philippines (Station 214). At both these Stations, and also at others near them, several species were met with of a new genus of Pentacrinidæ, for which the name of *Metacrinus* is proposed (fig. 118). It is a close ally of *Pentacrinus,* but instead of three, has four or six radials, the second of which is a compound (syzygial) joint and bears a pinnule, as do all the following joints below the axillary. The 'Vega' obtained a species of this genus in 65 fathoms, in the bay of Yeddo, Japan, and eleven species were found by the Challenger distributed among four Stations in the Pacific, between 500 and 630 fathoms, Stations 192 and 214, being those where, like *Antedon,* it was found to be most abundant.

"The family Bourgueticrinidæ is well represented in the Atlantic, though no member of it has yet been obtained in the Pacific. Two species of the genus *Rhizocrinus* (fig. 119), so well known on the Norwegian coast, have been found at several localities in the North Atlantic (including Station 122), and in the Caribbean Sea, while there are several fossil forms in the Tertiary deposits. The special interest of *Rhizocrinus* is due to its being a dwarfed and degraded representative of the familiar chalk fossil *Bourgueticrinus ellipticus,* and this is itself a similarly dwarfed member of the large group of Pear-encrinites or Apiocrinidæ, which are so abundant in the Bradford Clay and the other Jurassic rocks, but seem to have died out before the middle of the Cretaceous period. The calyx of *Rhizocrinus* is comparatively long, owing to the height of the basals, while the radials are relatively small. These bear five simple arms, the joints of which are immovably united to one another in pairs by a kind of suture, which is known as a syzygy. Only the upper joint of each pair bears a pinnule, and there are no pinnules at all upon the first four or five pairs.

"Two species of *Bathycrinus* (fig. 120) were dredged by the Challenger in the Atlantic, where it has the widest distribution of all the Stalked Crinoids. The genus had hitherto been known only by a single immature specimen (fig. 121), which was brought up in 1869 by the 'Porcupine's' dredge, from a depth of 2435 fathoms, in the Bay of Biscay. Like *Bourgueticrinus* and *Rhizocrinus,* it is attached by a more or less spreading root, and its dice-box shaped stem-joints are very similar to those of these two genera. But the basals are quite low, and so closely united that the sutures between them are invisible externally, except in young individuals. The radials, on the other hand, are comparatively large, and are united by a muscular joint to broad second radials. To the upper surfaces of these are articulated the third radials or axillaries, but by ligaments only and without the intervention of muscles. Each axillary bears two arms, so that

Fig. 120.—*Bathycrinus campbellianus*, Wyv. Thoms., M.S.

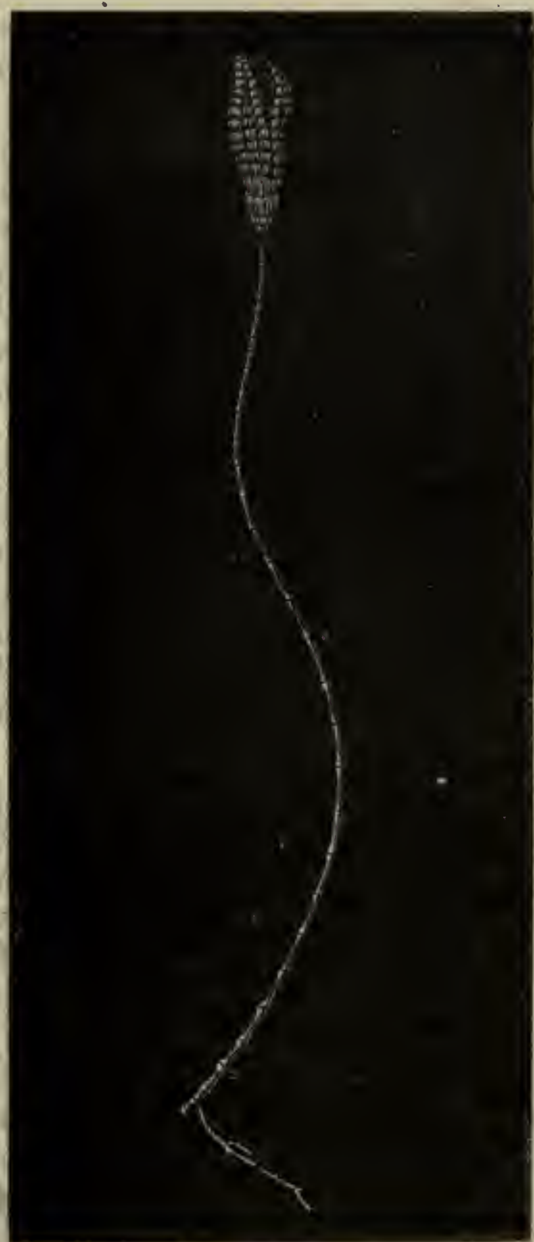


Fig. 121.—*Bathycrinus gracilis*, Wyv. Thoms.

there are ten arms in all, and not five only as in *Rhizocrinus*. As in this genus, too, the arm-bases bear no pinnules, and most of the joints are united in pairs. The union, however, is not an immovable syzygy, as in *Rhizocrinus*, but the same peculiar form of articulation as occurs between the second and third radials.

"The individual represented in fig. 120 was obtained in Mid Atlantic, just north of the equator (Station 106, 1850 fathoms). It was originally regarded by Sir Wyville Thomson as identical with a species which was dredged in considerable abundance in the Southern Sea (Stations 146, 147, 1375 and 1600 fathoms), and was named by him *Bathycrinus aldrichianus;* and the accompanying figure appeared under this name in 'The Atlantic.' Subsequently, however, Sir Wyville seems to have distinguished the two species, for the name *Bathycrinus campbellianus* occurs in his handwriting on the plate in which the individual from Station 106 is represented.

"A fourth species (*Bathycrinus carpenteri*) has since been dredged in the North Atlantic by the Norwegian North Atlantic Expedition. The genus ranges in depth from 1050 to 2435 fathoms, while *Rhizocrinus* has not been found deeper than 955 fathoms, and occurs at 80 fathoms in the Norwegian fjords. No fossil species of *Bathycrinus* are known.

"But for its resemblance to *Rhizocrinus*, it is probable that this genus would hardly be regarded as related to the Apiocrinidæ. The novel form (*Hyocrinus*[1] *bethellianus*) which was found associated with it at Station 147, is still more unlike the Pear-encrinite type, and though originally referred to it, is rather to be regarded as representing a new family altogether. The mode of attachment of the stem is unknown. Its component joints are short, cylindrical, and differently marked from those of *Bathycrinus*.

"The cup (fig. 122A, B) is composed of two alternating tiers of thin plates, the basals below and the radials above. The latter are broad and spade-shaped, with a slight blunt ridge running up the centre and ending in a narrow articulating surface for an almost cylindrical first brachial. The five undivided arms are composed of long cylindrical joints deeply grooved within, and intersected by syzygial junctions. The first three joints in each arm consist each of two parts separated by a syzygy; the third joint bears at its distal end an articulating facet, from which a pinnule springs. The fourth arm-joint is intersected by two syzygies, and thus consists of three parts, and so do all the succeeding joints; and each joint gives off a pinnule from its distal end, the pinnules arising from either side of the arm alternately. The proximal pinnules are very long, running on nearly to the end of the arm, and the succeeding pinnules are gradually shorter, all of them, however, running out nearly to the end of the arm, so that distally the ends of the five arms and the ends of all the pinnules meet nearly on a level.[2] This is an arrangement hitherto entirely unknown in recent Crinoids, and there is nothing exactly like it in any fossil species.

"The mouth is in the centre of the disk (fig. 122c) and protected by a pyramid of five

[1] Named after Hog Island, one of the Crozets near which it was found.

[2] The greater part of the preceding description is taken *verbatim* from the original account of *Hyocrinus* which was published by Sir Wyville Thomson. The Atlantic, vol. ii. p. 95, 1877.

movable triangular plates, between which and the edge of the cup is an irregular pavement of smaller plates. Four of these large oral plates are seen erect in fig. 122B, protecting the delicate tentacles round the mouth, which leads into a funnel-shaped gullet; and the intestine terminates in a short plated tube near the margin of one of the interradial spaces on the disk (fig. 122C). *Hyocrinus* has little in common with any other recent Crinoid, and is not known to occur in the fossil state. Only one entire specimen was obtained at Station 147, together with a few fragments, though portions of a stem were dredged from a depth of 1850 fathoms in Mid Atlantic, lat. 1° 47′ N. (Station 106), together with *Bathycrinus campbellianus*.

"The Feather-stars, or *Comatulæ*, as they were termed by Lamarck, differ from the so-called 'Stalked Crinoids' in being unprovided with a stem in the adult condition, although they possess one when young. But at a certain period of development, which varies considerably in different species, the cup containing the visceral mass detaches itself from the stem, retaining, however, the top joint or centro-dorsal which closes the cup below. Before its severance from the remainder of the stem it becomes larger than the other

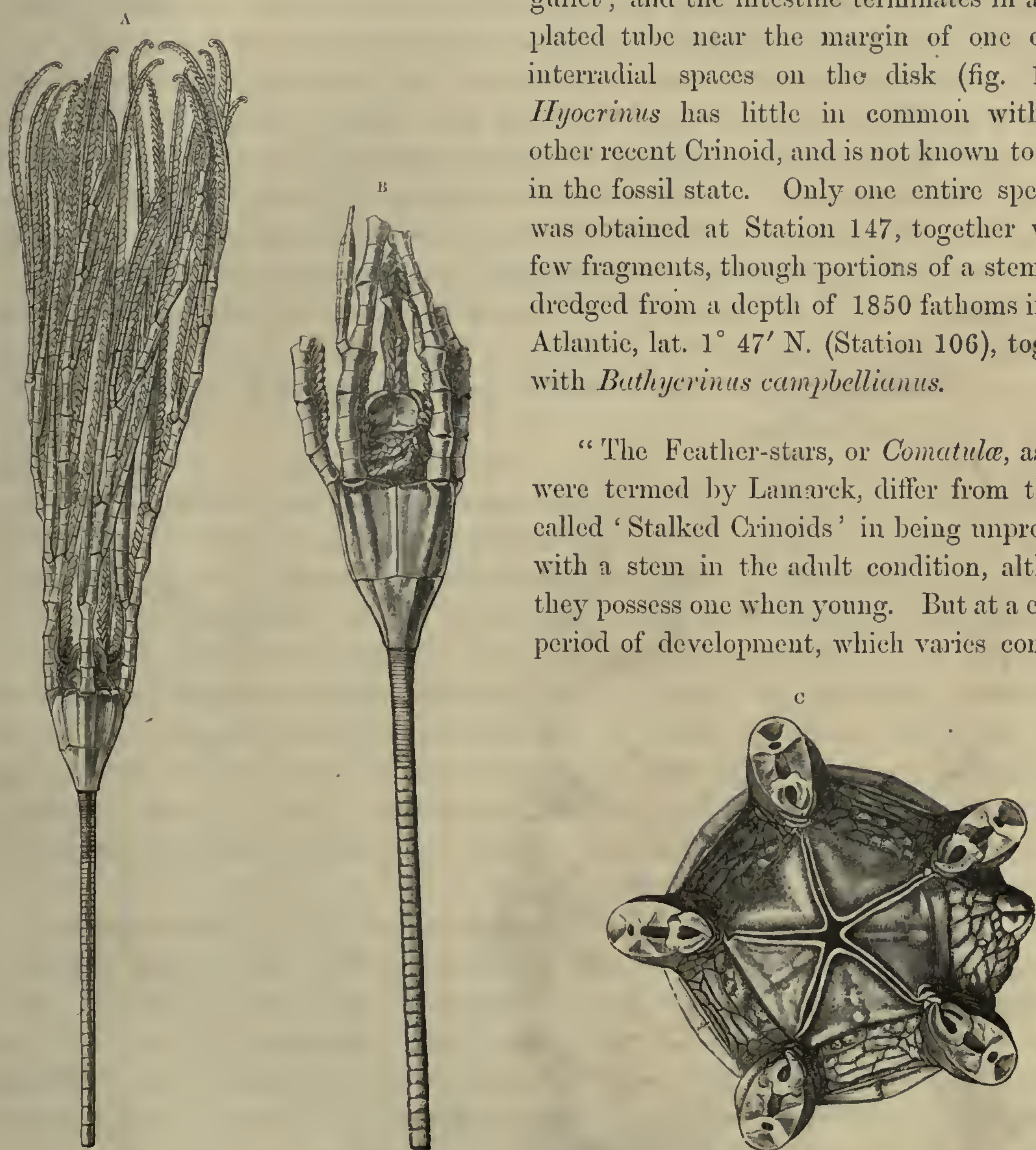


FIG. 122.—*Hyocrinus bethellianus*, Wyv. Thoms.

joints below it, and a number of clawed hooks, the cirri, are pushed out from it. These serve as grapnels, fixing the Feather-star to rocks or even to seaweeds, branching corals, sea-firs, and sometimes to telegraph cables. The attachment is only a temporary one, however, for the Feather-star may loosen its hold and swim about for a while, with a very regular alternating movement of its arms, eventually settling down somewhere else.

"The Comatulæ are probably more abundant at the present time than in any former period of the earth's history, rather more than four hundred species being known to science. By far the greater number of them belong to one or other of the two genera *Antedon* and *Actinometra*. These have five radial plates, resting directly upon the centro-dorsal, and meeting one another laterally so as to form the greater part of the cup. The rays borne by these plates may remain simple, as in the rare genus *Eudiocrinus;* but more commonly they fork, sometimes only once or twice, sometimes six or seven times, so that the number of arms may vary from 10 to 100 or more. The mouth may either be in the centre of the upper surface of the disk, as in *Antedon*, or it may be more or less excentric, as in *Actinometra*.

"The two species dredged at Station 48 belong to the first-named genus, and are closely allied to the familiar rosy Feather-star of the British seas. They are both well known Arctic forms, having been obtained by H.M.S. 'Discovery,' in 80° N. lat. Of all the genera of recent Crinoids, *Antedon* is the one which has the widest range, both bathymetrically and geographically. While some species live in 5 fathoms of water or less, others have been dredged at 2600 and 2900 fathoms,—depths from which no Stalked Crinoid has been obtained. These, however, are isolated cases, for Feather-stars are but rarely met with at depths exceeding 200 fathoms. All the European and Arctic Comatulæ, with two exceptions,[1] and in fact the greater number of those inhabiting the temperate zones, belong to this genus, which ranges from 80° N. lat. to 52° S. lat. Fossil representatives both of it and of *Actinometra* occur in the Inferior Oolite of Gloucestershire, and are the oldest known Comatulæ.

"The dredgings at Cape York yielded a great number of the Feather-stars with an excentric mouth, belonging to the genus *Actinometra*. The range of this type, both bathymetrically and geographically, is much more restricted than that of *Antedon*. It is almost exclusively a tropical genus, its northern limit being about 30° N. lat., and its southern about 40° S. lat. Isolated species are known on the South African and South Australian coasts; but it is in the Caribbean Sea, in the Western Pacific, and especially among the Philippines and the Moluccas, that the greatest variety is found. The largest Comatulæ yet known belong to this genus, and also those with repeatedly branching arms. Few species of *Antedon* have more than forty arms, while there are several *Actinometræ* with one hundred arms, or even more.

[1] *Actinometra pulchella*, Pourtalès, a Caribbean species which the "Porcupine" found near Gibraltar; and *Eudiocrinus atlanticus*, Perrier, which was dredged by the "Travailleur."

"Nearly all the Challenger species of *Actinometra* were obtained at depths of less than 20 fathoms; but several of those dredged by the U.S.C.S. steamer 'Blake' were found at from 100 to 300 fathoms. Below the latter depth, however, there are but few records of the occurrence of any *Actinometra*, none being known below 533 fathoms.

"The Cape York Comatulæ of both genera are remarkable for the loose way in which the disk or visceral mass is attached to the calyx, a feature which is also noticeable in the common rosy Feather-star of the British seas. Several specimens of the isolated disk were obtained, and Sir Wyville Thomson watched them performing slow creeping movements on their own account. On the other hand, the disk-less cup with the arms attached will continue to swim about just as readily as an entire animal does. The discovery of one of these isolated disks caused much interest some fifteen years ago, for the specimen was described as a recent Cystidean. Although the Challenger dredgings have rendered this idea no longer tenable, there is much to be said for the view which was held by Sir Wyville Thomson respecting the possible interpretation of the fossil Agelacrinitidæ as the isolated disks of Palæocrinoids, and not as independent organisms to be classed with the Cystidea.

"Three new genera of Comatulæ were discovered by the Challenger, in addition to several new species of the three previously known, *Antedon*, *Actinometra*, and *Eudiocrinus*. All of them present characters of considerable morphological importance.

"One of these types, for which the name *Atelecrinus*[1] has been proposed, was obtained at Station 122, together with *Pentacrinus maclearanus* and *Rhizocrinus lofotensis*. It seems to retain throughout life certain characters which mark transitional stages in the development of ordinary Comatulæ, and it is thus best described as a permanent larval form. *Atelecrinus balanoides*, the species dredged at Station 122, has since been found in the Caribbean Sea, by the officers of the U.S. Coast Survey and Count Pourtalès obtained a fragment of another off Cuba in 1868, while a third was met with by the Challenger in the South Pacific.

"Another very interesting new genus, for which the name *Promachocrinus*[2] has been proposed, was dredged at Station 147, in the Southern Ocean, from a depth of 1600 fathoms. It is distinguished from all other recent Crinoids by having ten primary radials instead of five only. Three species were obtained during the cruise, two of them in the Southern Ocean, together with *Bathycrinus* and *Hyocrinus*, and one at 500 fathoms, among the Philippine Islands (Station 214). That dredged at Station 147 (*Promachocrinus abyssorum*) seems to be confined to great depths, as it was also found at 1800 fathoms (Station 158), and like the abyssal species of *Antedon* is of small size. But a comparatively large species was found to be abundant in the shallow water round Kerguelen. Its calyx is represented in fig. 123. In the side view (A) are shown some of the ten first radials, five of which rest directly upon the centro-dorsal and correspond to

[1] ἀτελής, incomplete. [2] πρόμαχος, "Challenger."

the radials of other Crinoids, while the other five, alternating with them, are partly separated from the centro-dorsal by the basals, the ends of which appear externally beneath the middle lines of these additional radials. The upper faces of the radials are

Fig. 123.—*Promachocrinus kerguelensis*, P. H. Carpenter.
The calyx. A, from the side; B, from above.

all alike, however; and they form an elegant decagonal funnel which supports the centre of the disk (fig. 123 B). Except in the presence of five additional radials, *Promachocrinus* does not differ in any essential characters from *Antedon*.

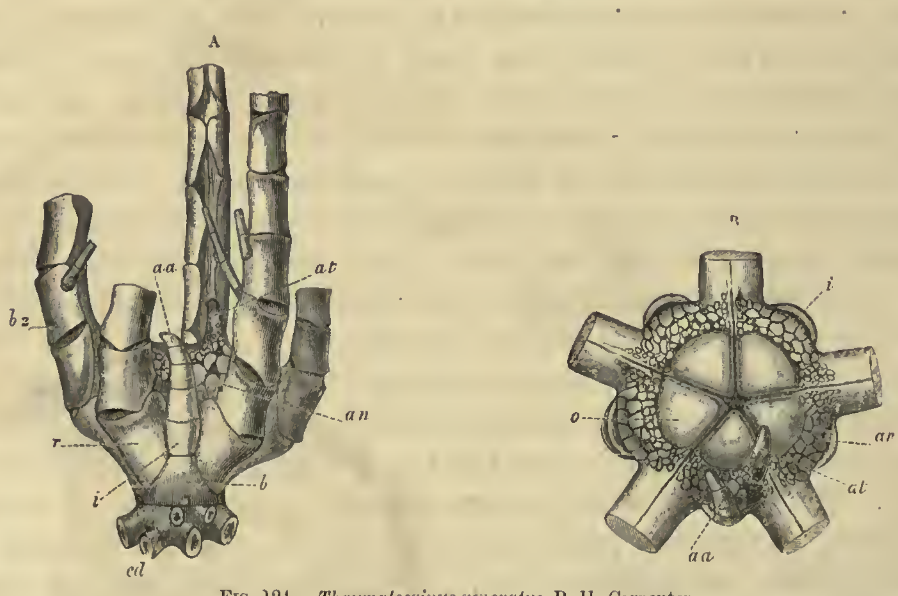


Fig. 124.—*Thaumatocrinus renovatus*, P. H. Carpenter.
A, The calyx, anal side. B, The disk from above. *aa*, anal appendage; *an*, anambulacral plates; *at*, anal tube; *b*, basal; b_2, second brachial; *cd*, centro-dorsal; *i*, interradial; *o*, oral; *r*, radial

"Together with *Promachocrinus abyssorum* there wafs ound, at Station 158, another *Comatula* of a very singular type, for which the generic name *Thaumatocrinus*[1] has been proposed (fig. 124 A, B).

[1] θαῦμα, wonder.

"Like all the deep-sea Comatulæ, it is of very small size. As in *Eudiocrinus* there are five undivided arms, but they are unfortunately broken off quite short. The radials which bear them are not, however, in contact either with the centro-dorsal or with one another, for they rest on a ring of five basal plates, which alternate with them in position (fig. 124A, *b*). There is only one other genus of recent Comatulæ (*Atelecrinus*) in which this is the case; but there is no Neocrinoid, either recent or fossil, in which the radials do not meet one another laterally, and form a closed ring. In *Thaumatocrinus*, however, every two radials are separated by an interradial plate, which rests on a basal (fig. 124A, B, *i*). This is a character which is limited to certain Palæozoic Crinoids belonging to the family Rhodocrinidæ. One of these interradials in *Thaumatocrinus*, that on the anal side, bears a short and tapering jointed appendage, which looks somewhat like an undeveloped arm (fig. 124A, B, *aa*); and it is only in some of the Palæocrinoids, *e.g.*, *Reteocrinus*, *Taxocrinus*, and *Onychocrinus*, which reach back to the Lower Silurian period, that any similar structure is to be found.

"Besides reproducing these singular characters of long extinct Palæocrinoids, *Thaumatocrinus* presents another structural feature, which is peculiar to itself among Comatulæ, although appearing in the stalked *Rhizocrinus* and *Hyocrinus*, viz., the existence of a pyramid of oral plates protecting the mouth (fig. 124B, *o*).

"The combination of these various characters in an abyssal Crinoid, which is not stalked, however, but belongs to the specialised *Comatula*-type, is a point of very considerable interest; and, in my opinion, *Thaumatocrinus* is by far the most remarkable of all the Crinoids obtained by any of the recent deep-sea exploring expeditions."

The Myzostomida.—"On some specimens of *Hyocrinus* and *Bathycrinus* which were dredged at Stations 146 and 147 from depths of 1375 and 1600 fathoms, Dr v. Willemoes Suhm discovered a remarkable species of Myzostomida (fig. 126E) which constitutes an entirely new group of these Crinoid parasites.

"These specimens and the other Myzostomida collected during the voyage,[1] together with material subsequently transmitted to him by Dr. P. H. Carpenter, have enabled Professor v. Graff to throw a new light upon the structure and mode of life of these animals.

"The accompanying diagram (fig. 125) displays the structure of the Myzostomida in so far as it was known before the publication of Professor v. Graff's Report. The typical *Myzostoma* is a disk-shaped, bilaterally symmetrical, unsegmented animal of from 0·5 mm. to 1 cm. in diameter; it possesses five pairs of unsegmented parapodia, and four pairs of suckers both situated upon the ventral surface; upon the margin of the body

[1] At Stations 146, 147, 170, 174, 186, 187, 190, 192, and 214.

are numerous cirri which serve as tactile organs and organs of attachment; each parapodium contains a hook-apparatus with a complicated musculature. The tree-like ramified alimentary canal opens close to the anterior end of the body by the mouth, through which the pharynx can be extruded; the anus is situated close to the hinder margin, and

FIG. 125.—Diagram showing the Structure of *Myzostoma*.

C_1-C_{10}, the 10 pairs of cirri; *Cl*, cloacal opening; *i*, intestine; *M*, mouth; *N*, central nervous system (blue), with *n*, œsophageal ring; *ov*, ovarian tubes (yellow); P_1-P_5, the five pairs of parapodia; *Ph*, pharynx; *R*, the rectum; S_1-S_4, the four pairs of suckers; *t*, testicular follicles; *U*, opening of the uterus into the rectum; *V*, stomach; ♂ the two lateral male genital openings.

receives also the duct of the branched ovarian tubes. The male sexual organs consist of two ramified testes which open on either side of the body by a separate opening. The nervous system forms a compact ventrally situated ganglionic mass, from the anterior end of which is given off a simple nerve ring enclosing the pharynx. This description holds good for all the species of *Myzostoma* hitherto known, the differences between them consisting mainly in the number and length of the cirri and in the relative thickness, transparency, and mobility of the body; thus *Myzostoma glabrum*, the first species ever described, which was discovered in 1827 by F. S. Leuckart attached firmly by its hooks to the disk of *Antedon rosacea* (*Comatula mediterranea*), is distinguished by possessing a thick opaque disk and small wart-like cirri; another species—*Myzostoma cirriferum*—discovered in 1834 by J. V. Thompson, has a delicate transparent disk and long cirri; it is found upon the same species of *Antedon*, and moves about freely over the disk and arms of its host. A third species, *Myzostoma costatum*, was found upon *Comatula multiradiata* of the Red Sea by Leuckart in 1836. Finally, nine new species collected by Professor Semper in the Philippines were described by Professor v. Graff in his Monograph on the group published in 1877.

FIG. 126.—A, *Myzostoma horologium* from the dorsal surface; B, the same, from the ventral surface; both figures are magnified 6 diameters. C, *Myzostoma quadrifilum*, from the ventral surface; magnified 12 diameters. D, *Myzostoma folium*, from the ventral surface, with the pharynx far extended; magnified 12 diameters. E, *Stelechopus hyocrini*, strongly compressed; magnified 18 diameters.

"The Report upon the Challenger collection[1] contains a description of 52 new species in addition to the 15 already known, and also considerably increases our knowledge of the anatomy and mode of life of the Myzostomida. The two most remarkable forms are *Stelechopus hyocrini* (fig. 126E) already mentioned, and *Myzostoma folium* (fig. 126D); both these species by their elongated form and the absence of suckers differ considerably from the known species and appear to form a transition between the Myzostomida and the Tardigrada; the Myzostomida have been regarded by different authors as allied to the Trematodes, Hirudinea, Chætopoda, Crustacea, or Tardigrada; Dr. v. Graff's obser-

[1] Zool. Chall. Exp., part xxvii., 1884.

vations appear to give additional support to the hypothesis which connects this group more closely with the Tardigrada. Another interesting form is *Myzostoma horologium* (fig. 126A, B), which was taken in great numbers from specimens of *Actinometra jukesi* and *Actinometra strota*, P. H. Carpenter, dredged at Stations 186 and 187; the disk has a curious resemblance to the face of a watch, owing to the arrangement of the pigment on the dorsal surface; the parapodia and suckers are very stout and cirri are entirely absent.

"Fig. 126C, represents another remarkable species, *Myzostoma quadrifilum* (host: *Antedon bidentata*, P. H. C., Station 186), distinguished by the possession of four long caudal appendages; there are many allied species which possess respectively two, four, or six of these appendages.

"Certain endoparasitic forms, obtained for the first time at Station 170, and subsequently at Stations 176 and 192, are of the highest interest, and differ greatly from all other endoparasitic species by the peculiarities of their sexual organization, and by the remarkable malformations which they produce upon the body of their hosts; they may be divided into two groups. The first group is hermaphrodite like the ectoparasitic Myzostomida, but the male sexual apparatus, instead of being disposed symmetrically on either side of the body, is only developed upon one side; one to three individuals of similar size and form are met with in the same cyst (fig. 127A, B, *Myzostoma pentacrini* and *Myzostoma deformator*). In the second group the sexes are completely separated, and the males and females differ from each other in external appearance, the former being very small and delicate, while the latter are large and stout; a single pair are found associated together in each cyst (fig. 127C, D, E, *Myzostoma tenuispinum*, *Myzostoma willemoesii*, and *Myzostoma murrayi*).[1]

"The malformations produced by these species are of various kinds. In some cases there are independent cyst-like swellings of the skin, as for instance the cyst of *Myzostoma murrayi* (fig. 127E), which hangs down from the disk of *Antedon radiospina*, P. H. C.; in other cases the parasite causes more or less conspicuous swellings of the arms of the Crinoid in the interior of which it lives; *Myzostoma pentacrini* (fig. 127A) and *Myzostoma tenuispinum* (fig. 127C) form cysts of this description, the former upon the arms of *Pentacrinus alternicirrus*, P. H. C., the latter upon *Antedon angusticalyx*, *Antedon basicurva*, *Antedon incisa*, and *Antedon inæqualis*, P. H. C. Other species attach themselves to the pinnules, which become variously swollen and contorted. *Myzostoma asymmetricum* produces only a simple swelling and enlargement of the pinnules of

[1] The following is from the journal of the late Dr. R. v. Willemves-Suhm, under date 14th July 1874:—"On the pinnulæ of the Comatulæ we found *Myzostoma* under rather peculiar conditions. Some of the pinnulæ had enlarged excrescences and were rolled up so as to form a cavity, in which, in two cases, a larger and a smaller *Myzostomum* were found. This reminds me very much of Trematodes, which, as in the case of *Monostomum faba* in the skin of birds, live always in cases or sacs in pairs, one individual being much larger than the other, the one acting probably as male and the other as female, which in some cases, as in *Distoma okeni* on the branchiæ of *Brama rayi*, leads to a perfect diversity of sexes. Perhaps something very similar takes place in *Myzostomum*, which is hermaphrodite, and has many affinities with the Trematodes."

Pentacrinus alternicirrus, P. H. C.; whereas the pinnules of *Antedon basicurva* and *Antedon inæqualis*, P. H. C., become swollen and spirally coiled owing to the presence of *Myzostoma willemoesii* (fig. 127D), forming thus a central cavity in which the parasites are found. The pear-shaped swellings of the pinnules of *Pentacrinus alternicirrus*, P. H. C. (fig. 127B), caused by the presence of *Myzostoma deformator*, are no less remarkable.

"Many Crinoids are liable to the attacks of several distinct species of *Myzostoma*; *Pentacrinus alternicirrus*, P. H. C., for example, harbours an ectoparasitic species besides the three endoparasitic Myzostomida just mentioned; similarly, *Antedon triquetra*, Semper MS., is infested by no less than six ectoparasitic forms. On the other hand a given species of *Myzostoma* is by no means always confined to the same host; many

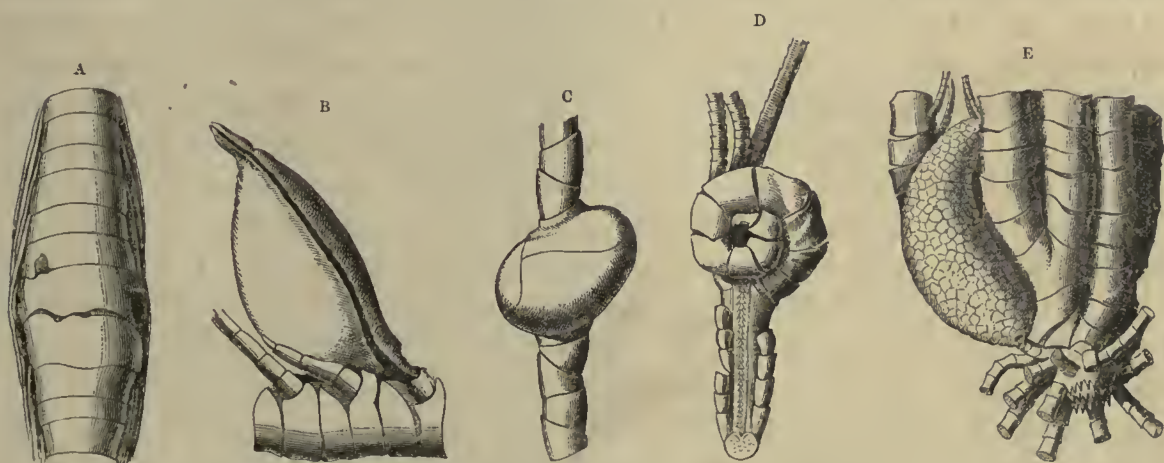


FIG. 127.—Malformations upon Crinoids caused by Myzostomida; all magnified about 5 diameters.

A, Arm swelling of *Pentacrinus alternicirrus*, P. H. C., inhabited by *Myzostoma pentacrini*. B, swollen pinnule of the same, inhabited by *Myzostoma deformator*; C, arm swelling of *Antedon inæqualis*, P. H. C., inhabited by *Myzostoma tenuispinum*; D, malformed pinnule of the same, inhabited by *Myzostoma willemoesii*; E, cyst on the disk of *Antedon radiospina*, P. H. C., inhabited by *Myzostoma murrayi*.

indeed are found upon two, three, or even four distinct species of Crinoids. The only genera of Crinoids upon which Myzostomida have been found are *Antedon*, *Actinometra*, *Pentacrinus*, *Bathycrinus*, *Metacrinus*, and *Hyocrinus*.

"The presence of malformations upon many fossil Crinoids[1] indicates that in the earlier periods of the earth's history as well as now these parasites existed."

The Crozet Islands.

On the 31st December, at 1.30 A.M., the vessel tacked and stood off Hog Island under easy sail until daylight. At 3.30 A.M. she tacked again and stood towards the land, but the weather becoming thick, at 6 A.M. again stood off under topsails and jib. Shortly after noon the fog lifted a little and sail was made, and the island was sighted again at 3 P.M., but

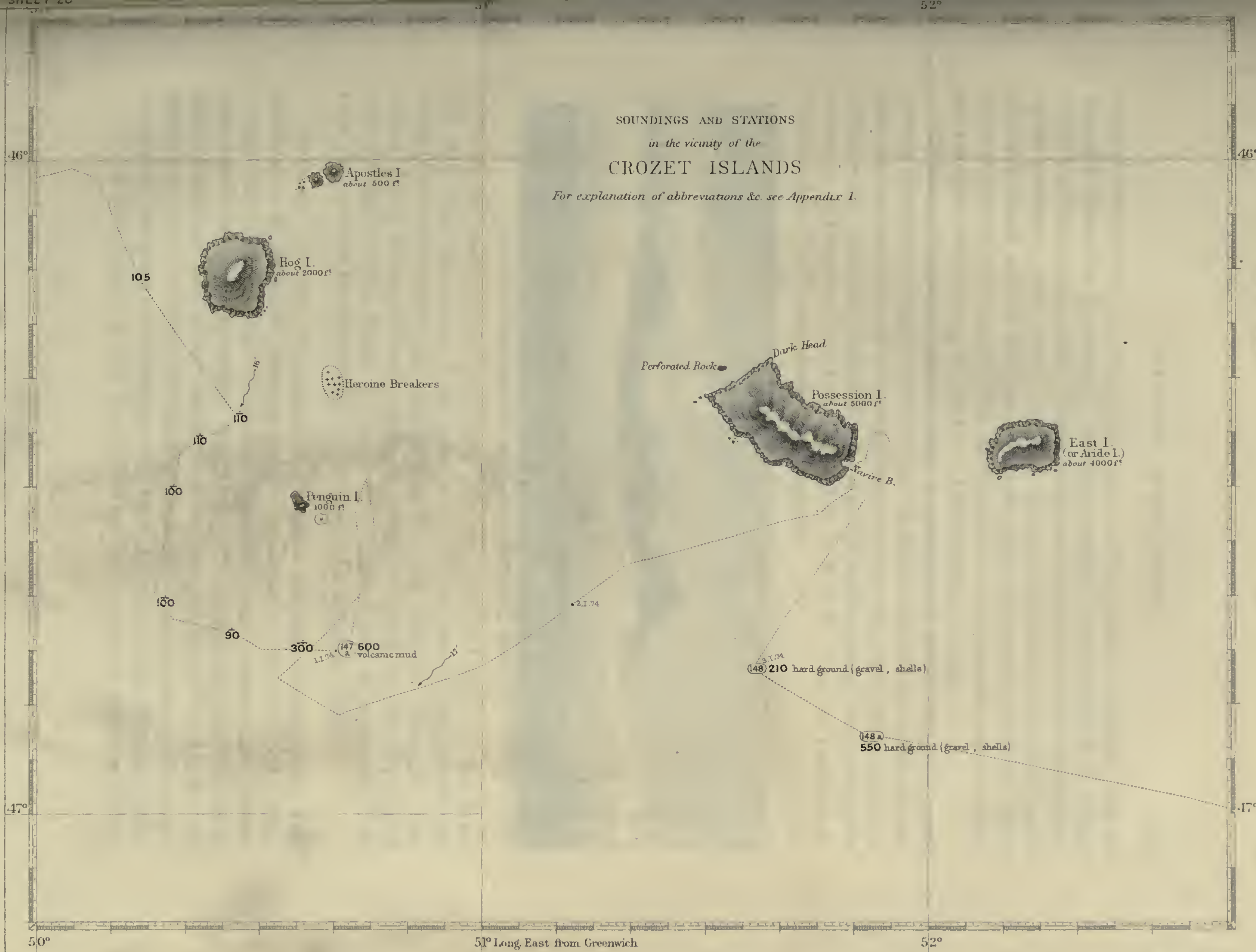
[1] See Zool. Chall. Exp., part xxvii. p. 2, 1884.

only the coast and breakers were visible. The ship ran along the western shore to the southward, and obtained a sounding of 105 fathoms 5 miles from the land. At 5 P.M. Penguin Island was seen through the mist, and at 6 P.M. sail was shortened to double-reefed topsails, and the vessel hauled to the wind on the starboard tack for the night. At 7 P.M. a dense fog surrounded the ship so that one could see only a few yards.

On the 1st January 1874 the fog still continued over the water, although overhead the sky was clear. Observations were obtained, but the horizon was badly defined, so that they could not be implicitly relied on. At 3 P.M. a sounding was obtained in 600 fathoms, and shortly afterwards the fog lifted and Penguin Island was observed bearing N. by E., but only for a few minutes. At this time the wind, which during the day had been light and variable, shifted to E.S.E. and gradually freshened to a royal breeze accompanied by rain. At 5 P.M. the ship tacked and stood to the southward, off the land, under single-reefed topsails, the weather being thick and rainy (see Sheet 20). The observations this day placed Penguin Island 5 miles N.W. by N. of the position assigned it by Captain Cecille; these observations have been subsequently confirmed by H.M.S. "Wolverene."

On the 2nd January at 2 A.M. the wind shifted to W.S.W. through south, and freshened to a moderate gale, the weather still continuing foggy. At 7 A.M. the wind began to moderate, and the vessel bore up for Possession Island. At noon the weather though misty was fine and the wind light. At this time a sight was caught of the high peaks of Possession Island, for a few minutes, over the mist which completely enshrouded the lower parts of the island; at 3.30 P.M. they were seen again, and more clearly; they were sharp, and, contrary to expectation, were found to be quite free from snow. Their height was estimated to be about 5000 feet, but it was impossible to obtain angular measurements owing to the fog.[1] At 4 P.M. the breakers were seen against the weather shore of Possession Island, and a few minutes afterwards the coast of the island itself became visible through the mist. The ship was steered to pass round its south side, and it was noticed as the island was rounded that the sun was shining on the lee side of the land, the weather side only being covered with fog. At 6 P.M. three points on the S.W. side of the island were in line N. 9° W., and the southwest point bore N. 70° E. From this position 3 miles from the shore the details of the coast could be clearly distinguished through the mist, especially the waterfalls, which were very numerous. After rounding the southwest point the vessel passed completely out of the fog, which formed a dense bank behind, whilst ahead was another dense bank coming round the northeast side of the island. To the eastward the peaks of East Island were visible over the mist, which completely obscured its lower parts (fig. 128); some snow was observed in the crevices of these rugged eminences. At 7 P.M. the ship stopped off the cove on the southeast coast of Possession Island, and a hut and some boats

[1] This estimate may be considerably in error; for when the lower parts of the land are shrouded in mist it is extremely difficult to estimate heights.



Engraved by Malby & Sons

being observed on the beach at its head, a gun was fired to attract attention; the hut appeared, however, to be deserted. The slopes appeared from the ship to be covered with a vegetation similar to that of Marion Island, which did not, however, extend so high up the mountains. They were covered with Albatrosses (*Diomedea exulans*) nesting as at Marion Island, and the birds seen about the ship were the same as at that island. There occurs here, however, in addition, the Kerguelen Teal (*Querquedula eatoni*), which is not known to extend its range to the Prince Edward group of islands.

The cross swell prevented the Challenger anchoring outside Navire Cove, so the vessel steamed along the land hoping to find anchorage in America Bay, but on rounding the east point the long swell indicated too clearly the hopelessness of the search under the present circumstances, and it was decided to proceed to the southwestward. At 8.40 P.M. the extremities of Possession Island bore N.W. and N. by E. $\frac{1}{4}$° E.; from which position the vessel stood to W.S.W. under double-reefed topsails.

FIG. 128.—East Island, Crozet Group, seen from H.M.S. Challenger, January 2nd, 1874.

On the 3rd January another short, sharp gale was experienced, similar to that of the 2nd, which lasted three hours. It had passed over by 9 A.M., when the ship sounded and dredged in 210 and 550 fathoms southwards of Possession Island (see Sheet 20). The weather during the day, although not foggy, was still too thick to allow anything of either Possession or East Islands to be seen at a distance of from 15 to 20 miles. At 4 P.M. the vessel left the neighbourhood of the Crozets for Kerguelen Island.

The Crozets (see Sheet 20), a group of six islands with some outlying rocks, were discovered by M. Marion du Fresne on the 23rd January 1772. He first saw the northwestern islands of the group now designated "Hog Island" and "Apostles Island," which were named by him "Les iles froides," and afterwards the southeastern islands, which he called "Possession" and "Aride" islands, the latter now designated "East Island." M. Marion sent an officer on shore at Possession Island and left a bottle there with a paper in it claiming the group as an appanage of the King of France. From 1772 until 1802 the Crozets do not appear to have been visited, but in that year an American whaling vessel, the "Catherine," Captain Henry Fanning, landed a gang of sealers on Possession Island, since which time the group has been constantly visited at intervals by these adventurous navigators. In 1820 a cutter called the "Princess of Wales" was wrecked on Possession Island whilst engaged in the seal fishing, and from one of her crew named Charles Goodridge an interesting account of their two years' residence was obtained and published in 1833.[1] Previously to 1820, hogs were landed on the island which now bears that name, but by whom or how is doubtful, and Goodridge relates that large numbers of them were seen in that year. In 1838 the islands were visited by Captain Cecille of the French sloop "Heroine," which vessel had been despatched to assist and report on the French deep-sea fisheries. Captain Cecille anchored in Navire Cove, which he surveyed, and he also fixed the position and made a running survey of all the islands. Captain Cecille found on Possession Island the crews of two American vessels, which had been lost, and a French ship, the "Bordelais," in Navire Bay.

In 1840 the group was visited by Sir James Ross in the "Erebus," who found a sealing party of eleven men on Possession Island, one of whom had been there three years.

Since the visit of the Challenger the Apostles Islands have been the scene of a terrible calamity, the wreck of the "Strathmore," in July 1875, which has resulted in the group being visited by H.M.S. "Wolverene" on her passage to Australia. From the several descriptions published from time to time, and from information received from the whalers and sealers at Kerguelen, the following account of the islands has been drawn up:—

The Crozet Islands are situated between the parallels of 46° 0′ and 46° 35′ S. latitude, and the meridians of 50° 20′ and 52° 20′ E. longitude, and they may be said to consist of two groups, an eastern and western. The western group consists of four islands, lying in a north and south direction from each other—the two Apostles, Hog, and Penguin or Inaccessible Island, and the Heroine Breakers; the eastern group consists of Possession and East or Aride Islands, with a few outlying rocks in no case exceeding a distance of 3 miles from the shore. Hog Island is round-backed, the summit rising to an elevation of certainly 2000 feet above the level of the sea; the north point is a perpendicular cliff some 200 feet in height, the south point being low, with several detached rocks close off it. Against its western shore the constant westerly swell breaks violently, rendering landing impossible on that side; on the leeward or eastern side it is occasionally accessible, but even here it is frequently very dangerous, as the rollers often come round both ends, and even the experienced crews of whaling boats are sometimes swamped and drowned. There were no pigs in 1873, but the whole place was overrun with rabbits. The Apostles Islands do not exceed 500 feet in height; they are only separated by a narrow chasm, and have the appearance of being a number of islands from seaward owing to their rising in detached boulder-like peaks, twelve in number, hence their

[1] Narrative of a Voyage to the South Seas, &c., by C. M. Goodridge. London, Hamilton & Adams, 1833.

name. Penguin Island (sometimes called Inaccessible) is a solitary basaltic islet, which rises in castellated pinnacles 900 or 1000 feet above the level of the sea. On it may usually be seen numerous Penguins and other birds. Owing to its small extent and the constant swell, landing is almost impossible; off its southern end is a rock under water, over which the sea was seen to break by the officers of the "Wolverene." Between Hog and Penguin Islands are the Heroine Breakers, first seen by Captain Cecille, a dangerous group of rocks, the precise position of which has not yet been ascertained.

The two eastern islands are high and rugged, their sharp, well-defined peaks rising to heights of 4000 and 5000 feet above the sea level. Their coasts are in most cases rocky and precipitous, especially that of East Island, and off the north end of Possession Island is a remarkable perforated rock, through which it is said a vessel might sail. Landing may generally be effected on Possession Island either in the cove on its southeast end or in some of the bays on its northeast side, but sometimes days have passed without the sealers being able to launch a boat. It is usually difficult to land on East Island. In the passage between Possession and East Islands a depth of 85 fathoms was found by Sir James Ross. Navire Cove has sufficient depth of water for a vessel to anchor, but it is so small and exposed that even schooners should be cautious in running the risk of entering it; in fact, some vessels have been wrecked there when trying to ride out an easterly wind. The "Heroine" in 1838 and recently the "Wolverene" anchored just outside the cove for a short time. The eastern, like the western, group is of igneous origin, and columns of basalt are common to all the islands. Their upper portions are barren, but their lower parts are covered with a thick herbaceous vegetation resembling in appearance that of Marion Island, with here and there Tussock Grass and the Kerguelen Cabbage; Penguin Island, however, appeared very bare.

From all sides of the precipitous black cliffs, cataracts fall over into the sea, and water is found in numerous ponds all over the group. The islands are frequented by Elephant and Fur Seals, although these are not so plentiful as formerly, and as there is no lack of water there is no danger of shipwrecked mariners dying of starvation. The blubber of the Elephant Seal and the skins of Penguins with the adherent fat furnish the material for fire, and the flesh of the Seals and birds, the eggs of the latter, together with the Kerguelen Cabbage, form a nourishing diet on which the sealers residing at times on one or other of the islands have usually lived, and with which they appear to have been contented.

As before mentioned, pigs have been landed on Hog Island, but they are now exterminated, for the sealers found them unpalatable in consequence of their habit of eating Penguins. In Goodridge's time the wild hogs were very fierce and dangerous to approach single-handed, having very large tusks. The sealers are against the introduction of pigs into the Southern Islands, as they destroy the birds, which are the main chance of support of castaway mariners. Rabbits, however, flourish, though they are said to be strong in flavour and unpalatable, goats also thrive well on the Tussock Grass. There are at present no goats on any islands of the group. It certainly would be an advantage if some were landed on each island, for although it is decidedly dangerous to navigate in their neighbourhood, and vessels running down their easting would do well to avoid them, it appears highly probable that so long as seal-skins fetch a high price in the market, and vessels bound to Australia go south at all risks in order to shorten the time in making the passage, so long will this group be the occasional scene of dire shipwrecks, which may be even more disastrous than that of the "Strathmore," more especially now that fast steamers run to Australia *via* the Cape of Good Hope. Charles Goodridge, in his account already referred to, describes the discovery by his party, at the distance of more than a mile above the reach of the tides, of several trunks of trees about 14 feet long, and from 14 to 18 inches in diameter, lying on the ground as if thrown up by the sea. The wood was close, heavy, and hard, but being split up with wedges made very good clubs; hence it was not fossil wood. Goodridge concluded that it was drift wood thrown up so far during some volcanic convulsion.

The weather in the vicinity of the Crozet Islands may be described generally as bleak, boisterous, and foggy. No regular meteorological observations have been kept by the parties who have temporarily resided on these islands whilst collecting seal-skins; in fact, the subject of meteorology has been hitherto much neglected by whaling vessels generally, although there are some notable instances to the contrary. The prevalent wind is westerly, but easterly winds occasionally blow for a short time, and although, generally, they do not last long or acquire much force, they have been known, as before mentioned, to be strong enough to wreck vessels that have taken shelter in Navire Cove. The great obstacle to navigation in the vicinity of this group is, however, the almost constant state of fog and overcast sky which, besides concealing the islands from view, prevents the position of the vessel being ascertained, and as icebergs have been seen near these islands by M. Marion du Fresne in January, by Ross in May, and by H.M.S. "Wolverene" in November, this is another feature of danger to be considered by the seamen who take the route to Australia recommended by Maury.

The climate of the islands, though rigorous, appears to be equable, owing probably to the temperature of the sea, which has been found here to be pretty constant at 40° to 42°. When first seen by Marion in January the mountains were covered with snow, and Captain Cecille also speaks of them as snow clad. Sir James Ross does not mention whether they were clear or not when he saw them, but when the Challenger was in their vicinity little or no snow could be seen during the short time the higher parts of the islands were visible. This would seem to indicate that the snow can never attain any considerable thickness at this group; at any rate, the icebergs seen in their vicinity cannot be formed by glaciers descending from their summits.

The Petrels.—A large collection of these birds, obtained for the most part in the Southern Ocean, was handed to the late Professor Garrod for anatomical examination, and on his death was transferred to the late Mr. W. A. Forbes, who made an exhaustive report upon their structure and affinities. The following paragraphs contain his most important conclusions:—"The propriety of the division of the entire order Tubinares into two main families, which must be termed the Oceanitidæ and Procellariidæ,[1] first proposed by Professor Garrod in 1873, has been fully borne out by my further investigations into the structure of these forms. To the differences in their myological formulæ, and in the presence or absence of cæca, may now be added numerous other points, both external and internal.

"The Oceanitidæ agree together in having the following peculiarities which are not shared in—with one or two exceptions marked by an *—by any of the Procellariidæ:—

"The number of secondary remiges is never more than ten. The tarsi are not uniformly reticulate, but are either ochreate, or covered by large transversely-oblique scutes anteriorly. The claws are very flat, depressed, and lamellar. There are no colic cæca * (absent in *Halocyptena* only of the Procellariidæ). There is a peculiar *expansor secundariorum* muscle. The tendon of the *tensor patagii brevis* is quite simple throughout. The *semi-tendinosus* muscle has a well-developed accessory head. The *ambiens* muscle, when present, does not pass over the knee, but is lost on the cnemial process of the tibia. The number of cervico-dorsal vertebræ is twenty-one. The clavicles have a long, curved, symphysial process. The leg bones are longer than the wing bones. The tarsus is longer than the mid-toe* and ulna, and at least twice as long as the femur. The tibia is at least twice as long as the humerus, and much longer than the manus. The basal phalanx of the middle toe is as long as, or longer than, the next two taken together.

"The Oceanitidæ also agree together in having no basipterygoid processes, no uncinate bone, a peculiarly short and stout humerus, radius, and ulna, a single circular nasal aperture, a sternum with its posterior margin quite or nearly entire, a larger *gluteus primus*, as well as in numerous other smaller details already noticed. All these characters never coexist together in any Procellarian form, and, if my observations are correct, the Oceanitidæ further differ from the Procellariidæ by having a *biceps brachii* muscle of the normal form, with no patagial slip.

"The Procellariidæ, on the other hand, have the following characters:—

"The number of secondary remiges is never less than thirteen, and is usually much greater. The tarsi are pretty uniformly covered with small hexagonal scutellæ. The claws

[1] *Cf. Proc. Zool. Soc. Lond.*, p. 737, 1881.

are sharp, curved, and compressed. Short colic cæca are present.[1] There is no *expansor secundariorum* muscle. The termination of the tendon of the *tensor patagii brevis* is never quite simple, and may become very complicated. There is no accessory head to the *semi-tendinosus*. The *ambiens* muscle (only absent in *Pelecanoïdes*) always crosses the knee. The number of cervico-dorsal vertebræ is not less than twenty-two. The clavicles have only a very small symphysial process. The leg is shorter than the wing. The tarsus is not larger than the mid-toe (except in *Procellaria*), and is shorter than the ulna. It is never twice as long as the femur. The tibia is only a little, or not at all, longer than the humerus or manus. The basal phalanx of the middle toe is shorter than the two next joints. Basipterygoid facets may or may not be present, and the same is true of the uncinate bone. The humerus, radius, and ulna have a shape different from that of the Oceanitidæ. The form of the nostrils, and of the posterior margin of the sternum, varies extensively. The *gluteus primus* is always very small, and there is a peculiarly formed patagial slip derived from the *biceps* muscle.

"Thus in spite of the general superficial resemblance of the Oceanitidæ to the smaller forms of Procellariidæ, with which all ornithologists previous to Garrod had confounded them, the differences between the two families are, it will be seen, numerous and important. The special points of resemblance which the Oceanitidæ have with such Procellarian genera as *Procellaria* and *Cymochorea*—such as the general small size, style of coloration, form of skull, comparative simplicity of the *tensor patagii* arrangement, simple sternum and syrinx (the last three peculiarities being also common to *Pelecanoïdes*)—may best be explained by supposing that these small Procellarian forms are on the whole less specialised than the larger ones (Fulmars, Albatrosses, Shearwaters, &c.), and so retain more of the characters possessed by the primitive and now extinct common form from which both the Procellariidæ and Oceanitidæ must have been derived."

The Oceanitidæ are a small and on the whole compact group, with but few differences of importance between the four genera contained in it. These genera are *Garrodia*, *Oceanites*, *Pelagodroma*, and *Fregetta*.

"The Procellariidæ, comprising as they do by far the greater number of species and genera of the group, show much more divergence *inter se* than is the case with the Oceanitidæ."

They are divided into two groups, of which the Diomedeinæ or Albatrosses, containing the three genera, *Diomedea*, *Thalassiarche*, and *Phœbetria*, are the more aberrant, and present the following peculiarities :—

[1] *Halocyptena* is apparently an exception to this rule, but as *Cymochorea* has only one cæcum, there is nothing surprising in the reduction being carried a step further. As therefore all the congeners of *Halocyptena* have cæca, it may be safely assumed that their disappearance in it has been very recent, and has occurred since it acquired the rest of its Procellarian characters. This loss of cæca therefore by it does not in any way really approximate it to the Oceanitidæ.

"The lateral position of the nostrils.[1] The presence of a distinct *gluteus quintus* muscle. The formation of the *biceps humeri* muscle, which gives off a patagial slip from its coracoidal head. The characteristic sternum. The absence of hæmapophyses on the dorsal vertebræ. The pneumatic *os humeri.* The generally pneumatic condition of the skeleton. The proportion of the manus to the humerus and ulna."

FIG. 129.—Base of Beak of *Diomedea exulans*, to show the form and position of the nostril.

The Procellariinæ, which compose the rest of the Procellariidæ, contain the following genera:—*Procellaria, Cymochorea, Halocyptena; Œstrelata, Puffinus, Adamastor, Majaqueus, Bulweria; Prion; Daption, Pagodroma, Aeipetes, Thalassœca, Fulmarus, Ossifraga; Pelecanoïdes.* These, with the exception of *Pelecanoïdes*, form a natural group distinguished by the following characters from the Albatrosses (Diomedeinæ):—

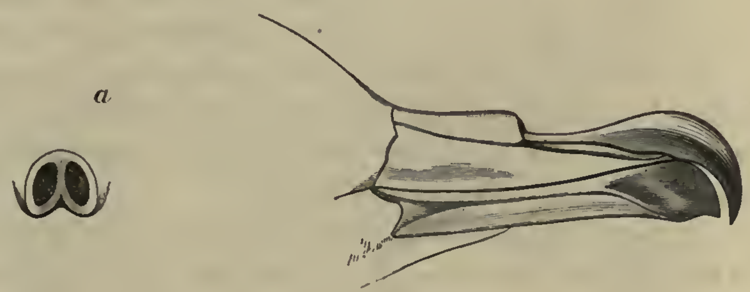


FIG. 130.

FIG. 131.

FIG. 130.—Beak of *Thalassœca glacialoides*. *a*, the aperture of the nasal tubes, from the front. Natural size.
FIG. 131.—The same parts of *Aeipetes antarcticus*.

"The more or less dorsal position of the nostrils, the form of which however varies, as has already been described, though they are never lateral. The absence of a *gluteus*

[1] This feature, in which the Albatrosses are apparently more primitive than are either the Oceanitidæ or the other Procellariidæ, can hardly, if my views about the relationships of these groups to each other be correct, be considered to have been a character of the common Petrel-ancestor. It may be more probably explained as due to arrested development during embryonic life, as a study of the development of the nostrils of other Petrels would probably show that these are actually, at some time, lateral, and subsequently coalesce.

quintus. The peculiar form of the *biceps brachii* muscle, which is in two separate parts, the humeral head forming a patagial slip. The presence of hæmapophyses on the dorsal vertebræ, the centres of which are marked by more or less developed pneumatic depressions. The non-pneumatic humerus. The different pterylosis, and the nearly equal size of the lobes of the liver. The greater size of the hallux, which always has a distinct nail externally (quite absent in *Pelecanoïdes*).

"*Pelecanoïdes* stands alone (amongst the Procellariidæ) in the absence of the *ambiens* muscle; the peculiar disposition of the femoral vein; the absence of a hallux; and the single interclavicular air-cell. Moreover, as in *Bulweria* only of other Tubinares, its myological formula is A.X., there being no accessory head to the femoro-caudal muscle.

"The Tubinares as a group may be shortly defined as follows:—

"Holorhinal schizognathous birds with a large, broad, depressed, pointed vomer, and truncated mandible; with the anterior toes fully webbed, and the hallux either very small and reduced to one phalanx, or absent; with a tufted oil-gland and large supra-orbital glands furrowing the skull; with the external nostrils produced into tubes, usually more or less united together dorsally; with an enormous glandular proventriculus and small gizzard of unusual shape and position, and with the commencing duodenum ascending; with a completely double great pectoral muscle, and a well-developed *pectoralis tertius*; with the femoro-caudal and *semi-tendinosus* muscles always present, and the *ambiens* and accessory femoro-caudal only exceptionally absent.

"Some at least of these characters—the structure of the hallux, the formation of the nostrils,[1] and the form of the stomach—are quite peculiar to the Tubinares, not being found in any other birds, though of universal presence in these. These features alone would at once suffice to distinguish them from any other Avian order, whilst the combination of other characters is as unique. It is therefore a difficult task to assign to this group a satisfactory position in any arrangement of the class Aves, owing to its much isolated position.

"Most previous writers have considered the Petrels as more or less closely connected with the Gulls (Laridæ), but the grounds for any such collocation are very slight, in my judgment, now that the structure of the two groups is better known.

"The Gulls exhibit no trace of any of the characteristic peculiarities of the Petrels,[2] and differ widely from them in the important feature of being schizorhinal.[3] The peculiar disposition in two quite separate layers of the great pectoral muscle in the Tubinares is quite unlike anything seen in the Gulls or their allies, whilst the large *pectoralis*

[1] The Caprimulgine genus *Siphonorhis* (Sclater, *Proc. Zool. Soc. Lond.*, p. 78, 1861) perhaps approaches the Tubinares more nearly in this point than any other bird known to me.

[2] I cannot understand Professor Huxley's remark (*Proc. Zool. Soc. Lond.*, p. 455, 1867) that "the Gulls grade insensibly into the Procellariidæ."

[3] *Cf.* Garrod, *Proc. Zool. Soc. Lond.*, p. 37, 1878; Collected Papers, p. 128.

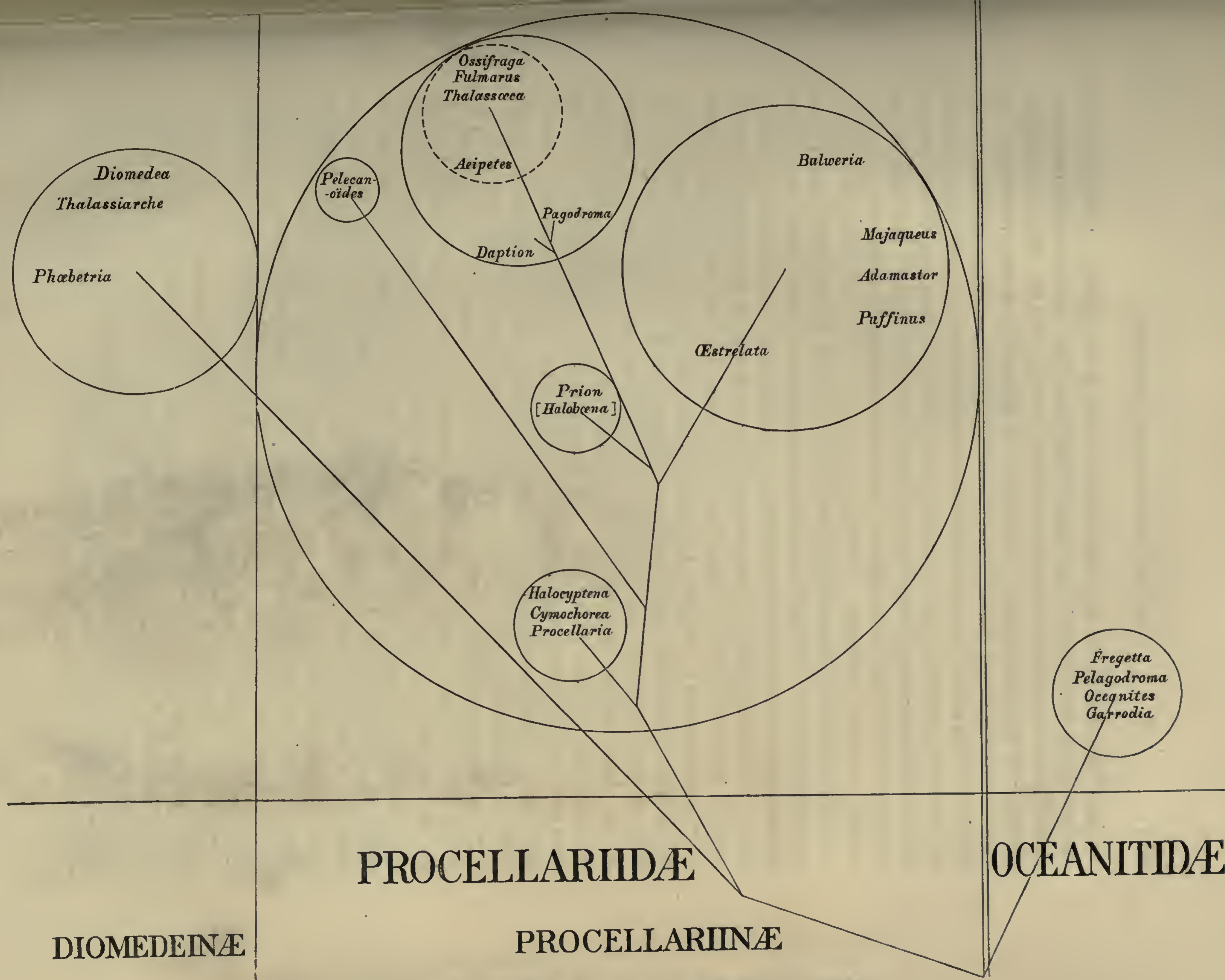


Fig. 132.—Diagram representing Mr. Forbes' view of the Classification of the Tubinares.

tertius of the Petrels is altogether unrepresented in the Laridæ. The character of the cæca in the two groups is also quite different, and there are no special osteological resemblances between the two groups so far as I can see, for the mere schizognathous character of the palate is, we now know, not necessarily a mark of affinity. The character of the young plumage, the condition of the young birds, and the number, shape, and coloration of the eggs—points on which some stress may be laid in questions of this kind—are totally dissimilar in the two groups, as indeed are the habits of the adult birds themselves, though no doubt both are "web-footed" and more or less pelagic in habit. Such resemblances, however, can hardly be seriously considered as indicating any real affinities.[1]

"L'Herminier, A. Milne-Edwards, and Huxley have all, in describing various points in the osteology of the Tubinares, pointed out similarities of various kinds between their osseous structure and that of various forms of the Steganopodes, though they still kept them close to the Laridæ. Eyton, on the other hand, places the various Petrels he describes in the family "Pelecanidæ," the Gulls forming a separate family by themselves.

"But no one will be prepared, I think, to dispute that the Steganopodes are allied to the Herodiones, including under that name the Storks and Herons, with *Scopus*, only. Thus, on osteological grounds alone, there is sufficient ground for placing the Tubinares in the vicinity of the Steganopodes and Herodiones. And, in fact, neglecting the desmognathous structure of the palate,—the taxonomic value of which *per se* is becoming more and more dubious as our knowledge of the structure of birds increases,—there is little in the characters assigned to the groups Pelargomorphæ and Dysporomorphæ by Professor Huxley (*l.c.*, p. 461) that is not applicable to the general Petrel type.

"The completely double great pectoral muscle is a characteristic only found, as already observed, in the Ciconiidæ, Cathartidæ, the Steganopodes (except *Phalacrocorax*), and the Tubinares, and in all these forms it is associated with short colic cæca of peculiar shape (absent altogether in the Cathartidæ, as in some of the Tubinares), more or less completely webbed feet, tufted oil-gland (except in the Cathartidæ), holorhinal nostrils, a tendency of the palatine bones to unite behind the posterior nares, truncated mandible, broad, strong, well-developed sternum, and strongly curved, well-developed clavicles. These birds also agree together in being 'Altrices,' the young birds being quite helpless after birth, and requiring to be fed for a long time by their parents—and in generally laying eggs of a white, or nearly white, colour.

"The group so constituted, of which the Ardeidæ and Falconidæ must also be considered as aberrant members,—the first family being closely related to the Ciconiidæ through *Scopus*, whilst the Falconidæ are probably, though much more remotely, connected with

[1] No views regarding the affinities of the Petrels other than that to the Laridæ already discussed, and that to the Ciconiiform birds, have, so far as I know, been seriously advanced by ornithological writers, Professor Garrod having abandoned his early idea that the Tubinares were probably related remotely to the Anseres and their allies (*cf. Proc. Zool. Soc. Lond.*, p. 112, 1874 ; Collected Papers, pp. 220 and 521).

the Steganopodes,—corresponds to the Ciconiiformes of Garrod,[1] with the addition, as he had already himself suggested,[2] of the Tubinares.

"But his earlier definition of that group, in so far as it relates to the absence in it of the accessory femoro-caudal muscle (B), will have to be modified, inasmuch as this muscle is, as shown above, generally present in the Tubinares. These too, differ markedly from the other Ciconiiformes in the well-developed *pectoralis tertius* (very small or absent in the others), in the large size of the vomer, and the non-desmognathism of the palate, though as regards this latter character it has already been pointed out that the Albatrosses are nearly desmognathous, whilst the desmognathism of the Cathartidæ is of a different kind to that prevalent in the other forms concerned.

"The two existing groups of Petrels are clearly related to each other so much more nearly than to any other group of birds that it is evident that they must have had a common ancestor that possessed the peculiar features characterising the Tubinares as an order. Such a form may therefore be safely assumed to have had—

"1. The characteristic nostrils of the group.

"2. The equally characteristic stomach and duodenum.

"3. Webbed feet, with a small hallux of a single phalanx.

"4. A double great pectoral muscle, and large *pectoralis tertius.*

"5. A formula AB.XY, a *gluteus primus* and an *ambiens* muscle.

"6. Short colic cæca of characteristic shape.

"7. A tufted oil-gland, and the pterylosis characteristic of the group.

"8. A holorhinal schizognathous skull, with large depressed vomer, great supra-orbital glandular depressions, no basipterygoid facets, and a truncated mandible.

"9. A short, broad, deeply-keeled sternum, more or less entire behind, with strong clavicles.

"10. A peculiar humerus, and tibia with large cnemial crest.

"No living Petrel has this combination of characters; the Oceanitidæ having lost their colic cæca, the Procellariidæ the accessory semi-tendinosus (Y) muscle, and both groups having become specialised in other ways.

"Such an ancestral form as here indicated may be supposed to be an early, and in some respects—as shown by the large vomer, schizognathous palate, large third pectoral muscle and formula AB.XY—more primitive form, that diverged from the common stock of the Ciconiiform birds very early, when the latter had only acquired the most prevalent of the characters now existing in the various groups of that suborder. One branch of this stock has since become greatly modified in the Tubinarial direction, whilst the other branch, loosing "B" and the large vomer, and becoming desmognathous, split up and gave origin, at different times and in different ways, to the remaining families of the group.

[1] *Proc. Zool. Soc. Lond.*, p. 120, 1874; Collected Papers, p. 218.

[2] Collected Papers, p. 521.

The definiteness of the characters of these, and the amount of specialisation they show, indicate not only a great antiquity for the whole group, but also the great amount of extinction that has gone on amongst its members in the past, in the process of which nearly all the intermediate and less specialised forms have disappeared."

The Crozets to Kerguelen.

On the 4th, 5th, and 6th January the ship was running before a northwest gale for Kerguelen Island, the velocity of the wind, which was fairly steady in strength, being 30 miles per hour, the waves varying from 18 to 22 feet in height from hollow to summit, and 420 to 480 feet in length from crest to crest. So far as was determined, the wave undulations had a velocity of 29·5 miles per hour, very nearly equal to that of the wind.

The length of the waves was measured by veering a canvas balloon called a Burt's nipper astern until it rose on the crest of the advancing wave at the same moment that the ship's stern was on the crest of the wave preceding it; the height was estimated by the observer taking up such a position in the ship that when in the trough of the sea his eye could just see the horizon over the crest of the wave nearest the ship; the speed of the undulation was calculated by the number of waves that passed the ship in a given time, allowing for the velocity of the ship through the water, and the length of waves, which for this purpose was assumed as 450 feet. To these undulations the Challenger rolled through an arc of from 25° to 50°, that is, from 12° to 25° each side of the perpendicular, 5 to 5½ rolls per minute, the average speed through the water being 9 knots per hour.

The weather during these three days was fairly clear, passing showers of rain or snow were occasionally experienced, and as Kerguelen Island was approached the temperature of both air and sea decreased to 39°, a good preparation for the cruise southward towards the ice. Notwithstanding a gratuitous issue of warm clothing the sick list amounted to twenty-four, due principally to colds (a large percentage); the stokers felt the cold most.

Owing to the strong wind and high sea the ship neither sounded nor dredged, a matter of considerable regret to all, as it would be most interesting to know the depth of the channel that separates the Crozets from Kerguelen Island. It will be seen, however, by referring to the Chart of the World which accompanies this narrative, that the depth is assumed as being greater than 1000 fathoms.

On the 6th January, at noon, Bligh's Cap was 74 miles off. Such was the confidence in the determination of its position by Captain Cook that, like Sir James Ross, notwithstanding the misty state of the weather, the ship ran straight towards it, and at 7 p.m. it was observed ahead. At 8 p.m. Bligh's Cap being S.E. by E., about 5 miles distant, the ship was brought to the wind under double-reefed topsails for the night. At this time glimpses were caught of the Cloudy Islands through the mist, and the waves could be seen breaking violently against Bligh's Cap to the height of at least 100 feet.

On the 7th January, at 3.30 A.M., with Bligh's Cap S.W. ½ S., about 12 miles, sail was made, and a course shaped for Christmas Harbour. At 6 A.M., when Bligh's Cap bore N. 72° W., the mainland of Kerguelen Island was seen to the southward; at 8 A.M. sails were furled, and the ship steamed for Christmas Harbour, anchoring there at 8.45 A.M.

CHAPTER IX.

Kerguelen Island—Proceedings of the Expedition—History of previous Exploration—Geology, Meteorology, Zoology and Botany of the Island—The Spheniscidæ.

The island of Kerguelen is throughout mountainous, made up of a series of steep-sided valleys separated by ridges and mountain masses, which rise to very considerable heights. Mount Ross, the highest, is 6120 feet in altitude, Mount Richards 4000 feet, Mount Crozier 3250, Mount Wyville Thomson 3160, Mount Hooker 2600, and Mount Moseley 2400.

The island thus, when viewed from the sea at a distance, presents a remarkable jagged outline of sharp peaks, which is most striking when observed from the south. The valleys run down everywhere to the sea, broadening out as they approach it. The whole coast is broken up by deep sounds or fjords, which resemble closely in form the fjords of Norway and other parts of the world. They are long channel-like excavations of the coast line, occupied by arms of the sea, often shallower at the mouths than nearer to the upper extremities, and bounded on either hand by perpendicular cliffs.

Christmas Harbour, almost on the extreme north of the island, is a small example of one of the Kerguelen fjords; it is a deep inlet with dark frowning cliffs on either hand at its entrance. The land on either side runs out into long narrow promontories, separating the harbour from another similar fjord on the south and from a bay on the north. The promontories thus formed are high and bounded throughout almost their entire extent by sheer precipices on either hand. On the northern side only of Christmas Harbour, somewhat above its mouth, does the land rise in a steep broken slope, which can be ascended directly from the sea. (See Frontispiece of Christmas Harbour.)

At the seaward termination of the southern promontory is the well-known arched rock of Christmas Harbour, a roughly rectangular oblong mass, evidently at some former period directly continuous with the rest of the promontory, but now separated from it, except at its very base, by a chasm, and perforated so as to form an arch. Above the high cliffs on the south side of the harbour towers a huge and imposing mass of black-looking rock with perpendicular faces, named Mount Havergal; this overhangs somewhat towards the harbour from the weathering out of soft strata beneath it, and looks as if it might fall and fill the upper part of the harbour. On the north side rises a flat-topped rocky mass 1215 feet in height, called Table Mountain.

At the head of the harbour is a sandy beach and small stretch of flat land, such as exists at the heads of all the fjords, and beyond this the land rises in a series of steps, separated by short cliffs towards the bases of Table Mountain and Mount Havergal. The appearance of the whole is extremely grand, and the marked contrast between the blackness of the rocks and the bright yellow green of the rank vegetation clothing all the lower region of the land, so characteristic of all these so-called Antarctic Islands, renders the general effect in fine weather very beautiful.

The observing parties were fortunate enough to obtain on the same day all the observations required at Christmas Harbour, for, although the morning was cloudy, the sun was visible nearly the whole day after 8 A.M. From the summit of Table Mountain, in the forenoon, the mountain ranges on the east end of the island, distant 50 miles, were distinctly visible, but before angles to them could be obtained the clouds hid them from view. The scud was flying fast over the land, and occasionally enveloped the surveying party on the summit of Table Mountain for a short time, whilst all the islands to leeward appeared free from mist. The islands to the northwest, named by Cook the Cloudy Islands (a very significant appellation), were enveloped in thick mist, so much so that it was only by remaining five hours on the summit of the hill, and watching for breaks in the mist, that the requisite angles were obtained to their summits and salient points. This was probably the first time an angle had been obtained to Bligh's Cap from Table Mountain. It was with surprise that Cook was found to be considerably (nearly two points) out in his bearing of Bligh's Cap from Cape François.

Magnetic observations were obtained on the beach at the head of Christmas Harbour on Ross' old observing spot. The astronomical observations were taken on the east side of a low bluff on the north coast of the harbour, close to the beach head.

On the 8th January, at 5 A.M., the Challenger left Christmas Harbour for Accessible Bay in a snow-storm, making sail and banking the fires when outside the harbour. The day was cloudy and bleak, with a fresh northwest wind and occasional showers of snow, but little or no mist. After passing between Swain Island and Howe's Foreland, which being unmistakably an island will in future be called "Howe Island," a line of soundings was carried and angles taken to all the salient points of the coast, to facilitate the construction of a chart after a sufficient number of stations for triangulation had been taken up. Here groups of rocks were seen on both bows; those to the northward, about 6 feet high, were named "Glass Rocks," and those to the southward "Bird Rocks," after two of Ross's officers. Large patches of Kelp surrounded the Bird Rocks, extending some considerable distance seaward from them. At noon Mount Campbell and the Chimney Top Hill to the southward were sighted. The former is a remarkable hill, 460 feet high, in shape somewhat like a truncated cone, standing alone in a plain of considerable extent, and when once seen cannot be mistaken. The Chimney Top, 2400 feet high, is apparently a basaltic mass on one of the peaks of a considerable range of hills, the highest point of which (Mount Crozier) rises to a height of 3250 feet above the level of the sea. After passing the Bird Rocks, a course was shaped towards the small and low Kent Islands, which were sighted at 3 P.M., and passed at 4 P.M. in a rain squall, and the ship then steamed into Accessible Bay, looking for Betsy Cove, which was entered at 6 P.M. The cove looked very small, but letting go an anchor in 9 fathoms in the middle of the entrance, with the east cliff of Elizabeth Head shut in behind the northeast point of the harbour, and veering three shackles of cable the ship just swung clear of the kelp that lines the shore, the stern being in 6 fathoms.

On the 9th, early in the morning, the boom boats were got out, and at 8 A.M. the surveying and exploring parties left the ship. The weather was cloudy and unfavourable, and on the tops of the hills the wind was fresh and very cold; no astronomical observations could be obtained, but angles were taken from Elizabeth Head, Mount Campbell, Cape Anne, and a flat-topped hill inshore; the distant peaks were, however, clouded over all day.

On the 10th January the weather was much more favourable, and equal altitudes and circummeridians were obtained at Elizabeth Head. A base was measured by sound between the Rocks of Despair and the observing station, and angles obtained at several prominent points. Table Mountain was not seen from Mount Campbell, as the weather was misty, but the high ranges to the southward culminating in Mount Wyville Thomson could be distinguished, as well as the glacier on Mount Richards to the westward.

Sunday the 11th was a beautiful, bright, sunny day, with a light breeze, more like a May day in England than the foggy weather of the Southern Ocean. The ship's company were allowed a run on shore to stretch their legs for the first time since leaving the Cape, and the number of ducks shot by the officers and naturalists was sufficient to provide for all hands.

On the 12th, at 4 A.M., the barometer, which had been high and gradually falling, began to do so rapidly, going down 0·25 inch between 4 and 6 A.M. At this time, although the weather was gloomy and foggy, with drizzling rain, there was but little wind, but shortly after 6 A.M. a sudden squall from N.E. came down, swinging the ship across the cove, and sending a nasty swell into Accessible Bay. The cove was too narrow to allow more than the three shackles of cable that were out to be veered, so that it was necessary to lay a hawser out to the north shore, and let go the second anchor under foot as a precaution. Had the anchor dragged or the cable parted, the ship would certainly have grounded, as the cove was so small that the stern was but a few feet from the coast; fortunately, the holding ground was good, and the wind shifted gradually to the westward and cleared up by 10 A.M., when in order to swing in less room the vessel was moored. This would have been done before had a breeze from the northeast been expected, but as strong winds were only expected from the westward, and seeing there was plenty of room with westerly winds, it was considered superfluous to do so until experience taught the necessity of taking this precaution. The weather in the afternoon was sufficiently fine to allow the survey to be proceeded with, and at 6 P.M. there was not a cloud in the sky. The barometer continued falling till 9 A.M., after which it again rose, but slowly.

On the 13th the weather was bright and clear, with a fresh cold wind. The surveying parties were engaged in sounding the cove and Cascade Harbour, delineating the coast line, &c.; the sounding boats' crews found it very cold work on account of the wind.

At 8 P.M. a whaling schooner (the "Emma Jane") came into the cove from Island Harbour, Royal Sound. Her captain (Bailey) said that a barque called the "Roman," Captain Swain, was in the neighbourhood, and that there were two other schooners engaged in the fishery hereabouts, viz., the "Roswell King," Captain Fuller, and the "Charles Coldgate." The Kerguelen whale and seal fishery would appear to have dwindled very considerably since the time of Sir James Ross. At the time of the Challenger's visit (1874) it employed a barque, two schooners, and a party of twenty-nine men on Heard Island. The barque and schooners belong to New London, Connecticut; the schooners remain at Kerguelen, whilst the barque (the "Roman") keeps up the communication with America, bringing out supplies and taking back the season's oil and seal-skins. The "Roman" arrives at Kerguelen every year in September, and meets the two schooners ("Roswell King" and "Emma Jane") at Island Harbour, Royal Sound. They then start for Heard Island, and remain in its vicinity until the Elephant Seal season is over,—about the middle of December,—after which they return to Kerguelen, when the "Roman" leaves for America, and the schooners hunt for whales until the end of June. Just now, another schooner (the "Charles Coldgate") had come to the island fishing on her own account. The men engaged in the fishery are Americans and Portuguese, the latter from the island of Brava, one of the Cape Verde group. They sign articles for three years, and are relieved, so many annually, by new hands brought out in the "Roman."

The 14th was squally and misty, with a considerable swell outside, so much so that the steam pinnace, which had started with a surveying and exploring party to the westward, was obliged to return, being unable to face the sea. The surveying operations were limited to completing the soundings in the cove.

On the 15th equal altitudes were obtained, which gave rates for the chronometers, and boom boats were got in ready to start for either Christmas Harbour or Royal Sound, as the weather permitted.

On the 16th the ship left Betsy Cove at 7 A.M., but had scarcely got outside when the wind freshened considerably, so that with two boilers sufficient headway could not be made, and it was therefore necessary to make sail to single-reefed topsails and courses, and work out of Accessible Bay under sail and steam. At 9.30 A.M. the land was cleared, and sail shortened to single-reefed topsails, and the fires banked; but at 10 A.M. the weather was so misty that the land was completely obscured, and the wind having now freshened to a gale, the ship was laid to under triple-reefed fore and main topsails on the port tack until the wind should moderate, and the mist clear off, sounding from time to time, and obtaining no bottom at 50 fathoms. The sun was occasionally visible, but the atmosphere continued misty. At 9 P.M. the gale was at its height, the force of the wind being 10.

On the 17th, shortly after midnight, the gale moderated. At daylight (3.30 A.M.), the ship wore and made sail to double-reefed topsails and courses, and stood in towards the land, which was seen at 7 A.M. through the mist, and Mount Peeper, a round-backed hill, 650 feet high, with an ill-defined summit, distinguished; Mount Campbell was looked for, but it was afterwards found that when south of Cape Digby it is hidden by a low range of hills between it and that Cape, that is, to vessels near the coast, farther off, it can be seen over these low hills. At 8.30 A.M. the Prince of Wales Foreland, the hills on the south side of Royal Sound, and Mount Crozier were distinguished, and were all free from cloud. When within 3 miles of Cape Sandwich the ship ran to the southward along the land towards Royal Sound, carrying a line of soundings, and keeping about 3 miles from the coast, which was low between Cape Sandwich and Charlotte Point. From Charlotte Point the low land continued until it turned to the westward into Shoal Water Bay, the turning point being marked by a low cliff. Between Charlotte Point and Bluff Point (at the entrance to Shoal Water Bay), $1\frac{3}{4}$ miles inland, is a remarkable low hill, named Mount Bungay, with two conspicuous boulders on its flat summit. All along the coast kelp was observed, stretching in some cases a considerable distance from the shore; the soundings varied from 25 to 30 fathoms, the bottom being mud, and the lead frequently bringing up fragments of Sponges. At noon the ship was off the Prince of Wales Foreland, and the wind being then quite light, and the weather fine, sail was shortened, and steam got up to dredge, and surveying parties sent away to take up stations on the Foreland, and on the flat-topped rock four miles to the southward (Balfour Rock). The landing on Balfour Rock was difficult owing to the swell, but at the Foreland it was easy. From the station on the Foreland an excellent view was obtained, the snow-clad summit of Mount Ross being distinctly visible, but before all the angles to the numerous peaks could be obtained, the mist again came on.

Prince of Wales Foreland, the peninsula marking the northern entrance to Royal Sound, is a long-backed hill, the highest part of which is 840 feet above the sea level. On its south side are precipitous cliffs; on its north side it slopes gradually down to the coast of Shoal Water Bay; a remarkable boulder stands out conspicuously on a whity-brown patch against this northern slope which is covered with moss; walking up the side of the hill is rendered laborious in consequence of the leg frequently sinking knee-deep into this moss. The Foreland is joined to the mainland by a low isthmus which separates Shoal Water Bay from Royal Sound. In Shoal Water Bay (which derives its name from its comparative shallowness), is a conspicuous rocky little island (Matelot Island), and the greater part of the bay is overgrown with kelp. Off the eastern point of Prince of Wales Foreland a ledge of rocks extends about a quarter of a mile. Harston

SHEET 21


SOUNDINGS AND STATIONS
in the vicinity of
KERGUELEN I.
For explanation of abbreviations &c see Appendix I
Gr. Long East from Greenwich
Swain I.
Saddle or West Island
Royal Sound
Hillsborough Bay
Bismarck Pen.
Prince of Wales Foreland
Mt. Ross 6120 ft.
Long Island
C. Bourbon
C. Challenger
C. George
C. Pennare
Mingan I. or Round I.
Tremaree Is. or Benodet Is.
Solitary I.
Fortune I.
Volcano hereabouts
Greenland Hr.
Shoal Water Bay
Mt. Campbell
Rocks of Despair
Royal Bay
C. Sandwich
C. Digby
C. Francis
Irish Bay
Table Bay
Iceberg Bay
Sprightly Bay
Cloudy Islands
Bligh's Cap
C. Aubert
C. d'Estaing
Christmas Hr.
Prince Adalbert I.
Foundry Branch
Swains Haulover
Buchanan I.
Murray I.
Marianne Str.
Mussel B.
C. St. Louis
Mt. Evans
Mt. Lizard
Mt. Wyville Thomson
Mt. Crozier
Mt. Moseley
Mt. Ricard
Mt. Hugh Jones
Mt. Kerguelen
Mt. Bungay
Mt. Ryder
Mt. Stanley
Mt. Campbell
C. Prompt
Mt. Cadot
Thunder Hr.
Accessible Bay
Outer Rook I.
Rook I.
Channel
Charlotte Pt.
Sol Pt.
Hay Pt.
Seven Bays
C. Sandwich
Rockhopper Bay
Pisaunic Bay
Fairway I.
Henry I.
Bird Rk.
Sibbald I.
Hale Bay
Port Palliser
Bale Rk.
Ross Head
Glass Rk.
Dewar I.
Dorset Hr.
Spry Mt.
Swain I.
Alexander
Long B.
Tweeding
volcanic mud
Mt. Crosier
Mt. Moseley
C. Sandwich
Gazelle Basin
Mt. Taylor
Mt. Paris
Mt. Stanley

and Balfour Rocks are two flat-topped islets, about 20 feet high, apparently free from danger, at the entrance to Royal Sound, the depths between which are 14 to 25 fathoms with a rocky bottom; two miles outside the outer rock (Balfour) a depth of 52 fathoms was obtained (see Sheet 21).

The southern side of the entrance to Royal Sound is formed by a large peninsula (50 square miles in extent) of rugged mountainous land, culminating in Mount Wyville Thomson, 3160 feet above the level of the sea. On the spurs descending from Mount Wyville Thomson are several conspicuous conical peaks, Thumb Peak, Sugar Loaf, Cat's Ears, and Mount Wild, varying from 1200 to 2500 feet in height; and off its northern coast are several peaked islands, Buchanan, Murray, and Suhm, from 200 to 500 feet above the sea level. This peninsula is joined to the mainland by a low, narrow isthmus, separating Royal Sound from Greenland Harbour. At 5.30 P.M. the surveying parties returned to the ship, which then proceeded up Royal Sound for Island Harbour, carrying a line of soundings, and carefully avoiding all kelp. At 7.30 P.M. a schooner, the "Charles Coldgate," was observed at anchor in the harbour; and at 8 P.M. the ship anchored there in 11 fathoms. From the captain of the "Charles Coldgate" no information could be obtained; he was a sulky kind of fellow, and seemed much disappointed that the Expedition knew so much about Kerguelen. He supposed the Challenger to be a few thousand miles out of her reckoning, and to have mistaken Royal Sound for one of the harbours of New Zealand.

On the 18th, shortly after midnight, the barometer began to fall, and the weather became thick and rainy. At noon a sudden gale sprang up from the northward, and the wind blew with considerable force (9) for two hours, after which it moderated rapidly, and there was a fine sunset.

The 19th was a fine day, so that astronomical observations were obtained from the summit of Hog Island, and various stations taken up at suitable points, in the sound, in prosecution of the survey. From the elevated stations on the summit of Hog Island, Suhm Island, and the western extremity of the spur from Mount Wyville Thomson, magnificent views were obtained of the mass of islands in what Cook fittingly designated a "Royal Sound." A base was measured by sound between Mouse and Hog Islands, and a survey of Island Harbour commenced on a large scale, whilst the stations on elevated points enabled the positions of the numerous islands westward of Island Harbour to be fixed, if not with absolute accuracy, still near enough for all present requirements.

The morning of the 20th was very fine, without a cloud in the sky or over the land, and the clearness of the atmosphere was very remarkable, every peak and spur from the mountain range sharply defined, and hills 15 or 20 miles off appearing only half that distance away, not a breath of air stirring, and the sea as smooth as glass. The calm continued until 9 A.M., after which a breeze sprang up from the northward, and the sky gradually clouded over. Advantage was taken of the fine weather to complete the survey of Island Harbour, and the outer part of Royal Sound. In the afternoon the ship left Island Harbour and sounded and dredged until 5 P.M., and then anchored for the night off Murray Island, where the surveying boats returned, having completed the survey so far as practicable in the time.

Royal Sound is a magnificent sheet of water, extending a distance of 20 miles from its entrance to its head, and, with its various arms, occupies an area of nearly 200 square miles. A portion of this area is taken up by an archipelago of islands of various sizes, the largest being 6 miles in length and 2 miles in breadth, and the smallest little more than a rock. These islands are congregated towards the head of the sound, and between them there appears to be deep water; in fact, in some of the channels the depths are considerable, for 95 fathoms were obtained in the arm running to the southwestward towards Greenland Harbour. They are all flat-topped, with erratics on their upper surfaces, and they appear to increase gradually in height towards the head of the Sound. They are of the same form as the hills about Betsy Cove, and if the great valley there were submerged, the hills on its northern side projecting as islands would give a miniature representation of those in Royal Sound (see Pl. XVII.).

There seems but little doubt that the whole of these islands in Royal Sound were once connected, and that there was thus a broad sheet of lava rock with a gentle inclination from inland towards the sea. This slope may have been once covered with a huge glacier, which was bordered by the mountain ridges now bounding the Sound to the north and south, and perhaps deposited some of the talus at present forming part of the ridge above Mutton Cove. After grinding the whole surface of its bed, the glacier probably shrunk and cut deeper channels between masses of rock, which were left standing, and thus formed the present islands. Either during this period, or after glaciation had ceased, the whole may have been submerged till the upper surfaces of all the islands were under the sea, and then ice drifting seawards from the remnants of the shrunken glaciers at the heads of the fjords, dropped upon the rock surfaces the erratics which at present lie upon them, and at this time all the moraines were washed away. At the base of the hills about Betsy Cove, the bottoms of the secondary valleys are as distinctly glaciated as the main valleys themselves, and the slopes of the smoothed surfaces seem to lead towards the cavity and mouth of the present Cascade Harbour.

About Betsy Cove thin beds of a red earthy matter a foot or two in thickness are very common, underlying beds of basalt and weathering out in the cliffs so as to leave ledges and low-roofed caverns. They occur in exactly the same manner as the beds of coal at Christmas Harbour; and when this coal is burnt in the fire it bakes to a compact mass of red earthy matter, exactly resembling that above referred to. There seems no doubt that these red beds, as well as the coal beds, represent old land surfaces. The soil consisting of black peaty matter as now, not many feet thick, has been overflowed by

Plate XVII

HORSBURGH, EDINBURGH. PERMANENT PHOTOTYPE.

TRAP HILLS, KERGUELEN ISLAND.

lava streams, which in the case of the coal have been only hot enough to char all the vegetable matter, while in the other case they have burnt it to an ash.

Eleven miles from the entrance of Royal Sound is a well-protected anchorage called Island Harbour, formed by a group of four islands,—Hog Island, Grass Island, Cats Island, and North Island, the passages into which are all safe and deep, except that between Hog and Grass Islands; this passage, besides being shoal, is blocked with kelp, which also marks the edge of the danger line round the other islands.

Island Harbour is the headquarters of the whaling vessels at Kerguelen. Here they rendezvous yearly to receive supplies and get rid of their oil; here they have erected two huts (on Hog Island) for convenience in boiling down the oil; and from here they start for Heard Island. From the entrance of the sound to Island Harbour the depths vary from 15 to 30 fathoms over a muddy bottom. Above that harbour the soundings are irregular.

Midway between the entrance to Royal Sound and Island Harbour, and on the south side of the sound, is an anchorage called Mutton Cove, sometimes used by the sealing schooners; from their description of its position it would appear to be on the west side of Murray Island.

One and a half miles outside Buchanan Island, at the entrance to the sound, is Pearcey Rock, upon which the sea breaks when there is any swell. With this exception, no danger was seen in Royal Sound, but it is highly probable that rocks exist in it; for it is unlikely that, over such a large area, where so many islands exist, there will not be also some submarine pinnacles; fortunately, these dangers will, to a certain extent, be indicated by kelp, for it is very rare to see a rock in a sheltered place at Kerguelen which has not a mass of this weed attached to it. The golden rule, therefore, in navigating these waters is to avoid that weed; and this more especially applies to screw steamers, for it is sometimes so thick and strong that there is danger of its disabling the propeller.

On the 21st January, at 6 A.M., the ship left Royal Sound and proceeded towards Cape George, in order to fix the south extremity of the island. Passing between Buchanan Island and Pearcey Rock, a line of soundings of from 20 to 35 fathoms was obtained; as the vessel proceeded to the southward the wind freshened and the weather became thick and squally. On nearing Cape George the land opened out to the southward, proving that this cape was not the southern extremity of Kerguelen, as was supposed by Captain Cook; but the weather was so unfavourable, and the swell from under the lee of Cape George so considerable, that the ship was unable to proceed farther at this time; and consequently bore up for Greenland Harbour, and after obtaining a haul of the dredge in 30 fathoms at its entrance, anchored at noon in 11 fathoms. The weather was very squally, the willywaughs coming down from the hills with much force and raising a quantity of spoondrift.

Greenland Harbour is a fjord, 7 miles in length, and a little over a mile in breadth, which separates the mountain masses of the Wyville Thomson Peninsula from those of the peninsula next south of it. At its head is a narrow neck of land, separating it from Royal Sound; similar low isthmuses, dividing capacious harbours, or inlets, from each other, exist in many parts of Kerguelen, and from the custom the whalers and sealers have adopted of hauling their boats over them, are called by these men "Haulovers."

The sides of Greenland Harbour rise abruptly from the water's edge and half-way up the hills on both sides, the horizontal line where all verdure ends is very well marked at a height of about 600 or 700 feet above the sea level. This line is to be seen more or less in all the mountain ranges of Kerguelen, but not in such a conspicuous manner as in this harbour.

Four miles inside the entrance to the harbour is a reef of rocks, which appeared to extend across the channel, but it was learnt afterwards, from Captain Fuller of the schooner "Roswell King," that there was a deep channel between this ledge and the south side of the harbour. If so, the anchorage in the upper part would be well protected in all kinds of wind and weather; otherwise Greenland Harbour cannot be recommended, as below the reef it is open to the southeast winds.

On the 22nd, at 5 A.M., the ship left Greenland Harbour in a shower of sleet and snow, which succeeded a promising sunrise, of which advantage was taken to land on the small green islet at the entrance of the harbour, and obtain a true bearing. Outside the harbour the weather was unfavourable for proceeding to the westward round Cape George, consequently the vessel bore up and ran along the land to the northward, in order to proceed to Christmas Harbour, there to deposit in a cairn a tin can containing the result of the investigations as to the locality best adapted for observing the Transit of Venus. After passing Royal Sound the weather was much finer, but the mist and rain squalls could be seen at Cape George. After rounding Cape Sandwich the wind hauled to the northward, when the ship had to work to windward for Christmas Harbour. At 9 P.M., Mount Campbell bearing S.S.W. about 12 miles distant, sail was shortened to topsails and jib, and the ship stood off on the port tack for the night. During the afternoon clouds came over the land.

On the 23rd, at 2 A.M., the ship wore and stood in for the land, and at daylight (3.30 A.M.) sail was made. At 4 A.M. the barometer began to fall, and the wind freshened, until at 5.30 A.M., when the ship was about 20 miles eastward of Swain Island, it had increased to a moderate gale with thick weather, necessitating shortening sail and standing off until it cleared. The gale and thick weather continued all day (force of wind 8 to 9). The soundings gave depths of from 50 to 60 fathoms, and several patches of detached kelp were seen at intervals, which being collected in a mass floating well out of the water, cannot be easily mistaken for kelp attached to rocks. The sea was short and heavy, so much so, that at 5 P.M. a sea which struck the ship on the port bow stove in a main deck port, and washed away a sounding platform and part of the head berthing. In the first watch the wind moderated, and shifted more to the westward.

On the 24th, at 2 A.M., the ship again stood in for the land, made Mount Campbell at 3 P.M., and then proceeded for Cascade Reach, anchoring there at 7.30 P.M.

On the 25th the barometer low and falling, the weather outside looking dirty, and a swell setting into Cascade Reach, the ship steamed round to Betsy Cove, anchoring there at 6 A.M., and it was fortunate that this was done, for at 9.45 A.M. a sudden gale from the westward sprang up (force 8), which necessitated a second anchor being let go. The wind was fresh and squally all day, the sky clear overhead, but the hills capped with clouds, and the scud flying rapidly over in detached masses.

On the 26th, the weather being more settled, with a N.W. wind, the ship left Betsy Cove at 6 A.M., and worked to windward for Port Palliser, reaching Hopeful Harbour and anchoring there at 5 P.M. in 15 fathoms. The dangers hereabouts are well marked by kelp, so that the passages into the harbour may readily be followed with security. When opposite Hillsborough Bay it was observed that Fairway Island was low and devoid of verdure, being evidently waterwashed. Henry Island and those immediately adjacent to it are remarkable rectangular blocks readily distinguished. Harbour Island is high. Several whales were seen during the day.

On the 27th, at 5 A.M., the ship left Hopeful Harbour and worked to windward towards Howe Island, in a moderate northwest wind with slightly misty weather. The clouds collected principally over Mount Crozier, but above it, leaving its summit clear and apparently blue sky to the southward over Royal Sound. At noon two whaling schooners were seen standing out from under Swain Island, and the ship stood towards and communicated with them; and finding from their report that good anchorage existed south of Howe Island, followed them into Fuller Harbour after dredging in 95 fathoms just outside it, in Rhodes Bay.

One of the whaling schooners was the "Roswell King" before referred to, commanded by Captain Fuller, a most intelligent and obliging man, who readily answered all questions, and gave the benefit of his large experience in the neighbourhood of Kerguelen, where he had been engaged in sealing and whaling for nearly ten years.

On the 28th the ship remained at anchor in Fuller Harbour, and the surveying parties took up several stations on Howe Island and adjacent salient points, to connect the southern part of Kerguelen with the northern portion. The early part of the day was fine, and a true bearing and angles were obtained to the mountain ranges of Crozier, Wyville Thomson, and Mount Campbell. The northern hills, Table Mountain, Mount Havergal, &c., were also free from cloud, so that the triangles were completed, joining Mount Wyville Thomson to Christmas Harbour.

The wind during the day was moderate, but the weather was very cold on the top of the hills, rendering it wretched work standing in an exposed position by a theodolite for three or four hours; towards evening the weather changed to mist and rain.

On the 29th, between 1 and 4 A.M., the weather was very squally, but at 6 A.M. the wind had moderated, and the ship left Fuller Harbour, proceeding through the Aldrich Channel for Christmas Harbour; after 8 A.M. the weather cleared up and a beautiful sunny day succeeded. North of Howe Island some hauls of the dredge were obtained, in depths varying from 45 to 127 fathoms. Looking up London River and White Bay, a fine view of the glacier descending from Mount Richards was obtained, but the summit of that hill could not be seen as it was covered with cloud and mist.

The Aldrich Channel, though narrow, is deep and free from danger; on the southeast side of M'Murdo Island, and between it and the islets facing Rhodes Bay, there appeared to be good anchorage. Off Breaker's Bluff is a flat rock and rock awash; on the west side of the channel there was little or no kelp. At 5 P.M. the ship anchored in Christmas Harbour.

On the 30th the morning was very fine, a little mist on the highest and western hill tops, the rest of the island clear. Mount Ross was seen from the top of Mount Havergal, but not the actual summit, which was hidden by intervening clouds. Equal altitudes were obtained at the observing station, which gave rates for the chronometers. Towards evening the weather changed and became thick, Swain Island being hidden.

On the 31st the morning was cloudy and gloomy, with passing showers. At noon, having completed tracings of surveys and copies of remarks, these were soldered in a tin case, and deposited in a cairn on the north side of the harbour. At 3 P.M. the ship left Christmas Harbour under sail and proceeded towards Cape Digby; at 8 P.M. passed the Bird Rocks, and then steered southeast for 36 miles, when, as the ship cleared the land and got away from Cape François, the weather cleared considerably. It had been the intention to pass down the western coast of Kerguelen from Christmas Harbour, to make a running survey of it, but the weather was unfavourable and the time could not be spared to wait, for the summer was now at its height, and every day was precious if any researches were to be prosecuted farther south in the neighbourhood of the Antarctic ice.

On the 1st February, at 1 A.M., sail was shortened and the ship hove to till daylight. At 4 A.M. sail was again made and the ship steered along the land to the southwestward towards Cape George. It was a peculiar heavy looking morning, with high clouds, and a pale green sky before sunrise; the Mount Crozier range was capped with clouds, but the Wyville Thomson range and the hills to the westward were clear, and Mount Ross very distinct. At 11 A.M. the wind fell light, so sails were furled and the ship proceeded under steam. After passing Cape George the westerly swell prevented the ship proceeding farther west without expending more coals than could be afforded, so it was thought sufficient to cut in the land from the ship, and fix the position of the southern Cape of Kerguelen—Cape Challenger. Cape Challenger is a ragged point, at

Fig. 133.—Cape Challenger, Kerguelen Island, with Mount Ross in the distance.

the extremity of which are two pinnacle rocks, of considerable height, evidently joined at one time to the high land in the neighbourhood, but probably separated by the action of water. Between Cape Challenger and Cape George the coast is high and precipitous, midway between them is a break in these cliffs, which forms a small cove, Big Belly Bay, from which a deep ravine runs up to the northwestward towards Mount Crosbie. Westward of Cape Challenger the coast is not so precipitous, descending less abruptly from the ridge of hills, on the top of which stands the double peak, Mount Tizard, 2720 feet high, and the single cone, Mount Evans, 2600 feet high. The projecting points of the coast between Cape Challenger and Swain's Bay have each of them tapering basaltic columns near their extremities, of considerable height; off the point at the end of the spur from Mount Evans are two low islands. The details of the coast westward of Swain's Bay could not be distinguished, but the land was seen about Cape Bourbon, which satisfactorily proved that Cape Challenger was the southern point of the main island. At 3 P.M. the fires were banked and sail made for Heard Island.

The island of Kerguelen,[1] including all outlying dangers, lies between the parallels of 48° 27′ and 49° 50′ S. latitude, and the meridians of 68° 30′ and 70° 35′ E. longitude. It was originally discovered by M. de Kerguelen on the 12th February 1772, who on that day sighted Solitary Island. Early the next morning the Fortune Islands and the whole of the coast from Cape St Louis to Cape Bourbon came in sight, and Kerguelen standing towards Cape Bourbon passed between it and Mingan Island, his consort, "Le Gros Ventre" preceding his own ship "La Fortune"; but the weather suddenly becoming thick and the wind freshening, he was obliged to stand off the land; and, after remaining in its vicinity until the 18th, battling against strong winds and foggy weather, in a ship whose masts were badly sprung, wisely returned to Mauritius without prosecuting his researches in a disabled vessel. His consort "Le Gros Ventre," Captain Saint Allouran, succeeded in sending a boat on shore in charge of M. de Boisquehennen, who landed in a bay which he named "Loup Marine," and took possession of the island in the name of the King of France, leaving on shore a bottle containing a paper giving an account of his visit. The precise position of Loup Marine Bay is doubtful, it is probably the first inlet east of Cape Bourbon, and may be that known at present as Sprightly Bay. As nothing has been heard of the bottle, with its enclosed papers, since it was deposited by M. de Boisquehennen, it may possibly yet be found, and serve to identify the spot in Kerguelen Island first visited by man. Kerguelen describes the coast between Cape St. Louis and Cape Bourbon as very high, Mingan Island as low, and about 3 miles round, and the Tremarec or Benodet Islands as rocks over which the sea broke furiously.

[1] Kerguelen's Voyage, 1782; Cook's Voyage, 1785; Page's Voyage; Morrell's Voyage; Ross's Antarctic Voyage; Wreck of the "Favourite"; "Venus" Expedition, Father Perry; Annalen der Hydrographie, 1875; Proceedings of the Royal Society, 1876; Reports to Hydrographic Office by Sir G. S. Nares, and documents in the Hydrographic Department of the Admiralty.

In 1773 Kerguelen was despatched from France in command of a squadron to complete his discoveries in the neighbourhood of the island that bears his name, which he sighted again on the 14th December, making the land on the parallel of 49° 10′ S. just north of Cape St. Louis, from thence he stood north, discovered the Cloudy Islands and Bligh's Cap, and rounded the north end of the main island ; but although he remained in the vicinity until the 18th January 1774, never anchored. A boat from one of his consorts succeeded in reaching the shore, and M. de Rosnevet landed in Christmas Harbour, and again took possession of the island in the name of the King of France, leaving a bottle with a paper in it, which was afterwards found by Cook in his third voyage. Kerguelen gave names to the Cloudy Islands and the capes at the northern end of the island, which they still retain with two exceptions. The islet which he called "Reunion," being now known as Bligh's Cap, and "Bay de l'Oiseau" as Christmas Harbour.

On the 24th December 1776, Captain Cook, then on his third celebrated voyage, made the island, and on the 25th anchored in Christmas Harbour, thus accomplishing in one day what Kerguelen had failed to do in a month. On the 29th December, after watering and cutting grass for his sheep and cattle, Cook left Christmas Harbour and proceeded to the southeastward along the leeward side of the island. His track can be traced from the bearings given in his narrative; some of these bearings are, however, referred to the true and some to the magnetic meridian. Passing outside Howe Island, and between it and the Dayman Islands, dangerously close to the Spry Rock, which he did not see, and steering outside Sibbald Island, he found himself amongst a large field of kelp, and thick weather coming on, thought it unwise to proceed further, so anchored for the night in a harbour which he named Port Palliser. Leaving Port Palliser on the 30th, Cook proceeded in his exploration of the leeward side of the island, and steered towards a conspicuous hill which he named Mount Campbell, and which he well describes as appearing like an island when seen from a distance. After passing the Kent Islands, he rounded Capes Digby and Sandwich, and stood southward as far as Cape George, giving the names of Royal Sound, Prince of Wales Foreland, Charlotte Point, &c., to the conspicuous inlets and capes on the southeast side of the island, and being satisfied from the swell coming round Cape George that the land could not trend much further, if at all, to the southward, he bore up for Tasmania.

From 1776 to the present date Kerguelen Island has been more or less frequented by whaling and sealing vessels, whose captains have explored the whole of its coasts, and anchored in most of its numerous harbours, the positions of which they have delineated on rough charts for their own use, giving names to the different anchorages and points, often quaint but frequently appropriate. The vessels generally employed in the seal and whale fishery at this island were strongly built ships, of from 300 to 400 tons burthen ; they usually took out with them, in their holds, in pieces, a cutter or two of about 40 tons burthen, which they put together on reaching a secure harbour. Sealing and whaling were then carried on by means of these cutters and the ship's boats, which were stationed in a kind of cordon round the island, the cutters visiting the boats, taking them supplies, and collecting the skins and blubber, which they took to the ship, where it was boiled down. The men on shore remained at times months away from their vessel, their only shelter being their boat turned bottom up on the beach, with the leeward side elevated and built round with peat cut from the boggy moss which covers the ground. The small cutters frequently circumnavigated the group, and doubtless their crews experienced many anxious moments, especially when on the windward side. Meanwhile, the parent ship lay snugly in some landlocked port; thus, the "Hillsborough," Captain Rhodes, wintered in Winter Harbour, the "Frances" and "Royal Sovereign" in Greenland Harbour, the "Favourite" in Marianne Strait, the "President," "Emerald," and "Kingston" in Iceberg Bay, the "Vansittart" in Table Bay, and the "Emily" and "Kingston" in Swain's Bay.

At the present date sealing and whaling operations are confined almost entirely to the leeward side; the weather side is, however, occasionally visited by Captain Fuller in the "Roswell King," who is thoroughly acquainted with the whole island. He starts about September from Christmas Harbour, and passing to windward of the Cloudy Islands, visits all the anchorages from Cape d'Aiguillon to Greenland Harbour. Some idea of the danger of this enterprise may be formed from the fact that the "Roswell King," a schooner of 100 tons, carries for use on the weather side of Kerguelen Island, an anchor and cable of the same size as that used in the Challenger, a vessel of 1420 tons, and that no harbour on that side can be left except with a northerly, or leading wind, for the high swell continually breaking against the iron-bound coast renders it certain destruction to leave the shelter of an anchorage unless a sufficient offing can be gained before the westerly wind begins.

Although well known to the whaling and sealing vessels, whose crews talk of Thunder Harbour, William's Bay, Marianne Strait, &c., with the same familiarity as of Spithead or Plymouth Sound, no accurate information respecting the island was obtained from the time of Cook's visit until 1840, when Sir James Ross touched at Christmas Harbour to obtain magnetic observations, and during his stay—from May 12th to July 20th—explored the inlets between that harbour and Howe Island, whilst Dr. MacCormick investigated the geology, and Sir Joseph Hooker the botany of this desolate spot.

From 1840 to the date of the visit of the Challenger to ascertain the most suitable site for the observation of the transits of Venus (in 1874 and 1882), no additional information appears to have been published. The southeastern portion of the island was surveyed by the Challenger from the entrance of Hillsborough Bay to Cape Challenger, and Ross's work connected with that of this Expedition. Since then the German frigate "Gazelle" has surveyed that part of the coast between Howe Island and Hillsborough Bay, thus completing the leeward side, and the "Volage" has added somewhat to the knowledge of the southern coast, but all the western or windward side is still imperfectly explored, and is at present delineated on the charts from the rough sketches of the whaling vessels; so that, notwithstanding the lapse of a century since its discovery, Kerguelen Island is far from being thoroughly known, and the interior has been seldom visited, as the difficulty of travelling is so great, owing to the severity of the climate, the absence of trees or wood of any kind, the want of supplies, and the rugged nature of the ground, that long excursions inland are all but impracticable. The temperature, even in the summer season, is but a few degrees above freezing point on the coast, rendering it requisite for an exploring party to carry tents and blankets, besides fuel, in addition to their provisions; and these necessaries have to be transported over ground covered with a boggy vegetation, into which the leg sinks ankle, and frequently knee-deep, which renders the work of exploration very laborious, and reduces the distance that can be travelled over in a day very considerably, a walk of 10 miles in Kerguelen being fully equal to one of 25 or even 30 miles on hard ground.

The island appears to be the upper portion of a submerged plateau of considerable extent, for Sir James Ross found depths of 70 to 80 fathoms extending 100 miles north-east of Cape François, and the Challenger found depths of 50 to 60 fathoms 45 miles northeast of Cape Digby, and of 80 to 150 fathoms between its south coast and Heard Island, whilst the German frigate "Gazelle" sounded in 125 fathoms 40 miles west of Bligh's Cap, and in the same depth 80 miles north of Swain Island. It is therefore probable that Heard Island is the southern peak of the backbone of this submerged plateau, for a reference to the chart shows that the main watershed of Kerguelen Island, of which the culminating point is Mount Ross, 6120 feet above the level of the sea, runs in a N.W. by N. and S.E. by S. direction; and as the summit of Heard Island lies 260 miles S.E. by S. of Mount Ross, and comparatively shallow water has been obtained between them, it may be concluded that they both belong to the same system of mountains, although part of the range is submerged.

As before mentioned, the main watershed of the island runs in a N.W. by N. and S.E. by S. direction, and consequently the general direction of the ravines and water-courses is N.E. and S.W., the northeastern slope being more gentle than the southwestern, where the descent is sometimes very abrupt. The summit of the watershed is perpetually snow-clad, and from it glaciers descend on each side, occasionally reaching the sea. The most notable glaciers are those from Mount Richards, which fall on the east side into London River, and on the west side into Thunder Harbour,—a bay deriving its name from the noise made by the frequent fall of large pieces of ice over the cliffs into the sea. Owing to the almost perpetual cloud and mist covering the snow-clad summits of the main ridge of the island, the glaciers are seldom visible; they may, however, under favourable circumstances be seen and even visitod, as an exploring party from the "Gazelle" reached the foot of the glaciers, descending the valleys into Whale Bay Irish Bay, &c. The glacier, visited from Whale Bay ended in a steep wall of ice about 70 feet high, and at its foot, partly underlying it, was a small lake, supplying a rapid brook flowing into the sea. The glacier next south of that descending into Whale Bay slopes gradually, and feeds a stream, hidden by the ice, which only betrays its existence by the noise of the falling water. It is full of crevasses, caused probably by the sharp curve of the mountain slope, which renders travelling on it difficult and dangerous, as the explorer has frequently to jump across these crevasses. The glacier descending into Irish Bay fills the whole valley about 200 feet above the sea level. All these glaciers show distinct traces of having receded, for the furrows left by them on the rocks of the lower parts of the valleys can be traced distinctly.

On the western side of the island there is still an active volcano, while a mineral pitch has been met with, and petroleum and hot water springs, the temperature of which is said to be high, have been found by the sealers.

From a ship anchored in Christmas Harbour an excellent general view of the arrangement of the rocks can be obtained; they are seen to be arranged in apparently perfectly horizontal beds, the separating lines of the different beds being easily traced all round the harbour. Where the sides are not precipitous, the summit of the ridge is attained by a series of terraces, and it is, as might have been expected, almost perfectly flat. The continuity of the flat-topped surfaces, both of the northern and of the southern ridges, is broken by the two most conspicuous objects in the landscape, namely Table Mountain on the north, and Mount Havergal on the south. This rock-mass does not project above the horizontal hilltop but rather appears to stand out from it like a huge boulder. The summit of the ridge is formed of the ordinary bedded rock, this "neck" of conglomerate not reaching any greater height than that of the contiguous parts of the ridge. These hills belong to a class representatives of which were found again in the south in Greenland Harbour, and as they resemble each other closely they will be described together. In both places they protrude through the horizontal beds of basalt, without having caused any apparent disturbance in the arrangement of the beds which surround them. The horizontal beds which form the mass of the land are basaltic, and vary from 10 to 20 feet in thickness, being generally compact; but in ascending the hill, beds are frequently met with which contain large amygdaloid cavities filled with zeolites, principally analcite and stilbite. These minerals are very plentiful in this part of the island, and when rounded by the action of water form remarkable white pebbles on the otherwise dark-coloured sand. Up to the summit the alternation of beds of compact subcolumnar rock of amygdaloid is pretty regular. The amygdaloid is of two kinds; in one the cells are small, very thickly disseminated, and completely filled up by a zeolitic mineral; the other has larger cavities, less thickly spread, and generally only coated with crystals, while seams filled with crystalline matter are also frequently met with. The cavities contain generally analcite, the seams stilbite. The ridge on the southern side is higher than that on the northern, and from it, on a clear day, a very extensive view of the island towards the southward can be obtained. The coast on this side being much indented by fjord-like inlets, the horizontal bedding of the rocks in which they are enclosed can be distinguished, even at great distances, by the consequent terracing of the hillsides, which is especially conspicuous on the shoulders and promontories. The heights of the ridges appear to differ very little from each other, the effect produced being that of a vast table-land quarried into deep indentations running down to the sea. Out of this plateau rise many peaks of considerable altitude, and often so sharp and steep in outline that they resemble volcanic cones. A nearer view of them, however, showed them generally to consist of similar horizontally bedded rock; and it was impossible to avoid the impression that they might be the remnants of a higher plateau, of which all but these peaks had been removed by weathering and erosion.

Fossil wood is found on the south side of Christma Harbour imbedded in the igneous rock, and occurs in stumps and smaller branches. The colour varies from yellowish white to chocolate-brown and black; its hardness is also very variable, and even in the perfectly white pieces there is still much organic matter remaining. The bark has been transformed into a brown crystalline mass of greasy appearance, which effervesces with acid. The inside of one rather large trunk, the core of which had probably rotted away, was entirely filled up with a mass of igneous rock with elongated cavities filled with crystals. Pieces of iron pyrites were occasionally observed. Parts that internally consisted of nothing but trap-rock often presented on the outside the fibrous appearance of the simply silicified wood; the thickness of this rind, however, was insignificant. A species of brown coal occurs on the south side of Christmas Harbour between two layers of basalt, and only a few feet above the sea. It is practically of no use, being too poor to burn alone.

Near the eastern point of Howe Island much amygdaloid was found, the geodes here consisting almost exclusively of agate. The tops of the hills were thickly strewed with those which, in the lapse of time, had been weathered out of the matrix. Many of these presented a very striking appearance, one of the corners of the cast of the cavity having been neatly planed off, and in some instances even highly polished, in others covered with a natural etching of great beauty. The occurrence of these abraded faces may furnish evidence of the recent prevalence of ice-action over the whole island.

It is worthy of remark that, although amygdaloids are common along the north-eastern side of the island, the nature of the geodes is different in different localities. In Christmas Harbour they are almost exclusively zeolites; in Cumberland Bay those who have visited it report numerous cavities in the rock filled with quartz crystals, and, indeed, one of the promontories in it is called Crystal Point; while at Howe Island the silica with which the cavities were filled occurred entirely in compact masses of agate and chalcedony. The cavities were usually quite full, the geodes being solid and forming an accurate cast of the cavity. Where this was not the case the interior presented a finely mammillated surface. Quartz crystals were not observed either here or at Christmas Harbour; nor were the zeolites, so common in the last-named locality, found either at Howe Island or Betsy Cove.

Prince of Wales Foreland is an elevation formed by slender basaltic columns, many of which are clustered together into what, if perfect, would have formed spherical agglomerations. The basalt contained large cavities filled with olivine like that of Unkel on the Rhine. Behind this rocky point the usual flat-topped range of hills stretches inland, consisting of the same basalt with much olivine, not columnar however, but in tabular masses with almost slaty cleavage.

Nearly opposite Prince of Wales Foreland, and on the other side of the entrance to Royal Sound, is a very remarkable hill of a castellated appearance, called "Cat's Ears," belonging to the same class of hills as Table Mountain in Christmas Harbour. The ruggedly worn rock at the crest gives it its castellated look; this rock consists of a light-coloured ground, enclosing large crystals of augite and pieces of the recent scoriaceous lava which occurs immediately beneath it. The augite crystals, though apparently perfect when imbedded in the rock, were not found otherwise than broken when weathered out; and in places inside these natural battlements, where there was free play for the usually boisterous wind, all the lighter sand had been blown away, leaving the ground covered by a jet-black gravel. Both these crystals and the rocks show the abrading effect of blown sand, the crystals having lost their regularity of form, and the rocks having acquired a more definite shape than would have been the case had the weathering proceeded equally on all sides. Here, however, and still more remarkably in Heard Island (see pp. 372, 373), the constant and violent westerly winds, wherever they have an opportunity of charging themselves with sand, sculpture the rocks into shapes of apparently unnatural regularity. From this hill another similar but smaller one could be seen close to the base of the "Sugar-loaf." It resembled more a circle of Druidical stones protruding through the moorland than a hill; it was impossible, however, to visit either it or the imposing Sugar-loaf, the structure of which appeared from a distance to be quite peculiar.

On entering Greenland Harbour, which at its head is only separated by a narrow neck of land from Royal Sound, the eye is at once struck by the strange protrusions of light grey rock through the ordinary horizontal basaltic beds which form the hill ranges. The most extensive of them, on the summit of the range on the western side of the harbour, has at a distance a very strong resemblance to a ruined castle. Two of them were examined, one on the summit and one nearer the landing place, both on the west side of the harbour. The rock in both of them is identical, and consists of a light greenish white phonolite protruding through the horizontal beds of augitic rock. These cylindrical masses of phonolite are columnar at the outer edges, the columns lying horizontally and being arranged radially; this columnar structure, however, disappears a few feet from the outside, and the rock is massive. The effect of weathering has been to split it up into loose blocks, which lie thickly scattered over the ground enclosed. The whole outside line being constructed of horizontal columns, forms a sort of natural cyclopian wall, much more capable of resisting the degrading influence of the weather than the massive inside; hence it might be expected that as they always protrude on a hillslope, the rock being disintegrated in the centre would slip down the hill, forming a heap or talus of rubbish below, and overwhelming the wall encircling the lower edge, but at the same time falling away from the wall of the upper edge, which, owing to its columnar structure, is able to keep its fragments together; and, in fact, this is what was observed. The upper wall of the more distant one, which stands out a prominent object on the summit of the ridge, is over 50 feet high, and presents a perfectly smooth wall face to the outside. As it stretches down the hillslope, which is here very steep, its height diminishes irregularly until it is lost in the heap of loose stones covering the lower wall and the whole inside.

The rock is hard and compact, of a light greenish grey colour, with much of the appearance, though without the ring, of phonolite. Near the outside, or in the columnar part, the rock is closer grained than in the centre, and has a distinct cleavage in a plane perpendicular to the length of the columns. It gelatinizes partially with hydrochloric acid, and the solution contains much soda and some sulphuric acid. It is therefore probable that both nepheline and nosean are present.

Another prominence on this side of the harbour is formed of precisely similar material. It is a round, greenish grey hill covered with phonolitic rock lying about in angular fragments, generally of a size to be easily lifted. The rock is very similar to that of the hills just described; and it seems to belong to the same class, differing from the others in the complete disappearance of the outside wall, large pieces of which lie scattered on the slope like portions of dislodged masonry.

It is to be remarked that in neither of these cases was there any distortion in the beds in which the phonolite occurred. The line of junction of the highest one with the augitic rock was very well shown, and specimens were obtained from it. For a few feet from the line of junction the basalt is considerably altered, the large crystals of augite and olivine disappearing as the line of junction is approached. This line is in general quite decided; there are many angular particles of the phonolite completely surrounded by the basalt, whereas basalt imbedded in phonolite was not observed. Further, the grain of this basalt, in immediate proximity to the junction, is very fine, becoming rapidly coarser, till the basalt at 10 feet from the junction has the porphyritic appearance which it presents at other parts of the hill. These two facts appear to point to the phonolite as being the more ancient of the two, and to the basalt as having flowed round it. There is no necessity for supposing that the portions of these phonolitic masses should be sections of cylinders; they may equally well be sections of domes.

The other view that the phonolite had burst through the lava appears to be untenable in view of the facts above stated.

Of the similar hills in Christmas Harbour, Table Mountain consists of columnar basalt with large cavities filled with olivine. The columns starting normally to the cylindrical surface of the enclosing rock curve upwards, and, unlike the phonolite, are continued well into the mass of the hill; the top of this hill is covered with loose fragments of basaltic columns. Specimens were not obtained from the junction of the columnar with the bedded rock; in fact there appeared to have been next to no fusion between the two. The corresponding hill on the south side of the harbour is formed entirely of volcanic conglomerate, intersected here and there by dikes, some of which show on the outside the obsidian-like bands produced by rapid cooling, which were observed in considerable abundance at Tristan da Cunha.

The rocks collected at Kerguelen were felspathic basalt, dolerite, anamesite, augite-andesite, phonolite, nephelinic rocks; trachyte, limbargite and palagonitic tufa.

The weather at Kerguelen is cold and boisterous, the prevailing wind being northwest (W. by N. true) at all seasons of the year, but this wind is often deflected on the lee side by the steep valleys and fjords which intersect the island; usually taking the direction of the valleys, which act as funnels, the wind descends in heavy gusts or willywaughs, raising large masses of spoondrift. So violent are these gusts that Sir James Ross observes he was frequently obliged to throw himself on the ground, and the man whose duty it was to register the tides was actually driven into the water and nearly drowned, whilst the vessels moored at the head of Christmas Harbour were sometimes laid over on their beam ends, and the sheet anchor had always to be kept in readiness. On one occasion the whole body of his astronomical observatory was moved nearly a foot, and had not the lower framework been sunk to a good depth it would probably have been blown into the sea. The astronomers who visited Kerguelen for the purpose of observing the transit of Venus also complained of the violence of these squalls, which on one occasion tore a heavy shutter off one of the observing huts and carried it to a distance of more than 30 yards, and two of the "Volage's" boats were capsized when under sail. The westerly wind meeting the island is divided, curving round Capes François and Challenger, so that on the lee side the wind has a northerly tendency north of Mount Campbell and a southerly southward of that mountain.

Vessels proceeding from Royal Sound towards Christmas Harbour with a S.W. wind will probably meet with a N.N.W. wind off Cape Digby, or bound to Royal Sound with a N.W. wind after rounding Cape Digby will meet the wind at S.W.

During the continuance of the northwest wind the weather is squally with passing showers of rain or snow, the sky cloudy, but not so cloudy as altogether to exclude the sun, and the tops of the hills are frequently cloud-capped. On the western or weather side of the island the air saturated with moisture impinging on the steep mountain ranges causes frequent showers of snow, hail, or rain, and the clouds arrested by the hills accumulate and sink down causing mists and fogs; whilst, as is usually the case, on the eastward or lee side of the island the air is generally dry and there is but little fog.

The difference between the amount of rainfall on the weather and lee sides of Kerguelen is well illustrated by the snow on the hills, for whilst the main range (the mean height of which cannot exceed 3500 feet) is always capped with snow and ice, the leeward hills, Mount Crozier, Mount Wyville Thomson, &c. (which exceed 3000 feet), are entirely free from snow in the summer season.

The prevailing westerly wind is sometimes interrupted by northeast and north winds (N. by E. to N.W. by N. true) which blow with considerable violence, and during their continuance the sky is overcast and the weather thick and rainy, they usually follow a high barometer and fine weather. Just before they commence the barometer falls rapidly and the thermometer rises, and their duration is inversely as the rate of descent of the mercurial column. On one occasion in Betsy Cove the Challenger experienced a sudden northeast gale which only lasted three hours, the barometer falling a tenth of an inch per hour for four hours. These northeasterly and northerly winds are called by the whalers "northers," and their liability to blow occasionally at all seasons of the year should be borne in mind in selecting an anchorage, for inlets such as Cascade Reach and Accessible Bay are open to these winds; Betsy Cove is, however, protected from them.

When the wind veers to the westward or southwestward (S.W. by W. and S. by W. true) the thermometer falls and the barometer rises, whilst the sky becomes fairly clear, but there are still occasional snow squalls.

It must be borne in mind by vessels visiting or navigating in the vicinity of Kerguelen Island that strong winds are the rule and moderate or light breezes the exception, and that though clear weather prevails immediately to leeward of the group, the land is not extensive enough to cause much alteration in the general condition of the atmosphere hereabouts, which is thick and foggy. During the 68 days Ross spent in Christmas Harbour in the depth of winter, it blew a gale on 45 days, and only three days were entirely free from snow and rain. In the 26 days spent here by the Challenger in January, strong breezes or gales prevailed for 16 days; and whilst the "Volage" was at the island attending on the Transit of Venus party from the 9th October 1874 to the 27th February 1875, in October 7 days' gales were registered, in November 14, in December 16, in January 10, and in February 12.

Occasionally, but very rarely, the usual boisterous weather is interrupted by a calm, or a light easterly wind, when the sky is perfectly free from clouds, and the atmosphere is remarkably clear, every hill-top being distinctly visible; but this fine enjoyable weather seldom lasts twenty-four hours, and is quickly succeeded by a gale. No strict rule can be laid down as to the connection between the state of the weather and the height of the mercurial column. Generally, the wind is inclined to increase in strength with a falling, and decrease with a rising barometer. Bad weather may be expected with an unsteady, and fine weather with a steady pressure, no matter whether the height of the column be high or low.

The mean pressure at the island is probably about 29·70, and the extreme range from 30·30 to 28·40, or nearly 2 inches.

The climate of Kerguelen is much the same throughout the year, the mean summer temperature being about 45°, and the mean winter temperature 36°. Although the thermometer even in the depth of winter seldom descends below freezing point, and the snow never remains on the low ground more than two or three days at a time, a heavy fall is of no uncommon occurrence at all times of the year, even in the height of summer. In spite of cold, wind, and rain, the island is very healthy, the most general complaint being an excess of appetite.

As the mean winter temperature is nearly the same as that of the Falkland Islands, where sheep farming has lately been carried on with much success, and as the sheep landed from the "Erebus" and "Terror" in the depth of winter in Christmas Harbour, and those landed from the "Volage" in Royal Sound in summer, throve exceedingly well, and got very fat, there appears every reason to believe that the breeding of these useful animals at Kerguelen would prove a commercial success.

At the suggestion of Sir George Nares some rabbits and goats were landed by the Transit of Venus Expedition, and were doing well when the "Volage" left the island in February 1875.

A large party landed at the head of Christmas Harbour on the morning of the first arrival of the Expedition at Kerguelen, all eager to kill a Fur Seal; as the boat grounded on the black volcanic sand, some greyish-brown forms were made out, lying amongst the grass just above the beach. A rush was made to the spot, but they were found to be only four Elephant Seals, reclining beside a small stream which runs down here from a little lake, on a small plateau above, into the sea.

The Elephant Seals, when stirred up, raised their heads and put on the usual savage expression that they exhibit when disturbed, which is effected by contracting the facial muscles about the nose, so as to throw it into a series of very prominent transverse folds. They opened their mouths, showed their teeth and uttered a roar, consisting of a series of quickly succeeding deep guttural explosions. They bit savagely at a stick, and twisted it out of one's hands, but made no attempt to go to sea, making on the contrary into the stream, and up it inland, moving by a regular flop-flop motion of the body, like that of the common British Seal, but more clumsily performed.

Whilst the party was either looking at these Elephant Seals, or beating the ground for ducks, on a shot being fired the head of an animal raised high above the grass on the flat close to the beach, was seen about a hundred yards off. It contrasted most strongly in its appearance and gait with the Elephant Seal, and was soon made out to be a Fur Seal (*Arctocephalus gazella*). It was an old male, covered with greyish-brown shaggy hair, and with a short greyish mane about the neck. It moved its head up and down uneasily when disturbed, just as a bear sways its head. On one of the party running up too close to the beast thinking it as helpless as the Elephant Seal, he was forced to retreat in a hurry, for it made a savage dash at him, open-mouthed.

Two of the whaling schooners met with at the island killed over 70 Fur Seals on one day, and upwards of twenty on another, at some small islands off Howe Island to the north. It is a pity that some discretion is not exercised in killing the animals, as is done in St. Paul Island in Behring Sea, in the case of the northern Fur Seal. By killing the young males, and selecting certain animals only for killing, the number of seals may even be increased;[1] the sealers in Kerguelen Island kill all they can find. They said that the southern Fur Seals sometimes eat Penguins, and that they had found the remains of them in their stomachs, and the sealers also said that sometimes, but very rarely, they found another kind of Seal, somewhat like the Fur Seal, which they called the "Sea Dog." A second species of Eared Seal probably thus occurs as a rarity at Kerguelen Island.

Professor Peters of Berlin identified the skull of a Fur Seal procured by the Challenger at Kerguelen as belonging to his new species *Arctocephalus gazella*. The skeleton of a specimen called by the sealers "Sea Leopard" has not yet been determined, but Professor Turner states that it is not a *Stenorhynchus*.

The flat stretch of land at the head of Christmas Harbour is covered with a thick rank growth of grass (*Poa cookii*), and a Composite herb with feathery leaves and yellow flower (*Cotula* [*Leptinella*] *plumosa*), also with *Azorella* and *Acæna* as at Marion Island (see Pl. XV.). The soil is black and peaty and saturated with water. It is almost impossible to find fuel; the *Azorella* is the only thing that will burn, and sometimes pieces of this may be found that are dry enough, in places where the bunches overhang small precipices, so that the water can drip away.

The feature which distinguishes the general appearance of the vegetation of Christmas Harbour from that of Marion Island is the presence of the Kerguelen Cabbage (*Pringlea antiscorbutica*) in large quantities. The plant grows on the slopes and bases of the cliffs in thick beds, and resembles a small garden cabbage, but often with a long trailing stalk. It is, however, not annual but perennial, and the flowering stalks instead of coming out from the centre of the head, come out laterally from the sides of the stalks between the leaves. The old flower stalks die and wither, but do not drop off. On one Cabbage at Betsy Cove were counted 28 flowering stalks, of different ages, three of them only being of the current year's growth and fresh; they appeared to belong to

[1] J. A. Allen, The Eared Seals. *Bull. Mus. Comp. Zoöl.*, vol. ii. pp. 1–88, 1870–71.

eight successive years. The Cabbage about Christmas Harbour was either in flower or green fruit, mostly the latter; it was only to the south of the island, about Royal Sound, that ripe seed was met with, but there, especially at Mutton Cove, it was abundant. This Cabbage, which like the familiar vegetable is a Cruciferous plant, is peculiar to the Prince Edward, Crozet, Kerguelen, and Heard Islands, and belongs to a genus with no near ally (see Pl. XVI.).

The ascent of the slope towards Table Mountain is up a succession of steps, the successive flat ledges presenting glaciated surfaces scattered over with stones fallen from above. The thick rank vegetation ceases at about 300 feet altitude, and then becomes more sparse. *Colobanthus kerguelensis*, a Caryophyllaceous plant, peculiar to Kerguelen and Heard Islands, affects the more barren stony ground at this elevation, whilst at Heard Island it grows at the sea level. At about 500 feet elevation, a very handsome Lichen (*Neuropogon taylori*) commences rather abruptly; it is a very conspicuous plant, being of a mingled bright sulphur-yellow and black colour, of large size, and is abundant everywhere on the higher rocks. *Azorella* and the Cabbage grow up to about 1000 feet, the height of the ridge from which the rocky mass forming the top of Table Mountain rises; here the Cabbage ceases, but *Azorella* is continued in very small quantities to the top of the mountain, growing on its very summit, but only in very sheltered corners between the rocks, and much dwarfed. *Azorella*, the Cabbage, and a Grass (*Agrostis magellanica*), were the only flowering plants growing at 1000 feet, and these only very sparsely. The land at this height presented a series of ridges of barren rock and piles of stones. At Mutton Cove and about Royal Sound, a very marked line, at about 1000 feet, separates the green lower slopes from the barren stony ridges and peaks above. It is probably the line above which snow lies for the greater part of the year unmelted, though the hills just above it, at Mutton Cove, were quite free from snow at the time of the visit.

A comparatively low ridge separates the head of Christmas Harbour from the sea directly beyond. On a flat expanse of this ridge are two small freshwater lakes, in which grow two water plants, *Limosella aquatica* and *Nitella antarctica*, both widely spread plants, the first occurring, amongst other places, in England, and the second being very closely allied to a common English species.

Crawling about the heart of the Cabbages, and sheltering there, are to be found swarms of the curious wingless Fly (*Calycopteryx moseleyi*), likewise peculiar to Kerguelen Island and the other localities where the Cabbage is found. It is simply a long-legged brown dipterous Fly, with very minute rudimentary wings, and crawls about lazily on the Cabbage. Another dipterous Fly (*Amalopteryx maritima*), with wings rudimentary but larger in proportion to the body than in the other, is found among the rocks on the sea shore, where it jumps about when hunted, like a small grasshopper. It is the same as was found by Dr v. Willemoes Suhm at Marion Island. Probably the *Calycopteryx* exists also at Marion Island, but Cabbages were not abundant there, and it was not noticed; but it is possible also that the Fly does not extend there, for no Teal were seen on Marion Island, though they exist in abundance on the Crozets, and especially on Possession Island, where, as the sealers said, there is a lake full of them. However, only a very small tract of Marion Island was examined, and similar tracts are to be found in Kerguelen Island, with very few Cabbages, and consequently without Teal. A wingless Gnat (*Halirytus amphibius*) also inhabits the sea shore, living amongst the seaweed constantly wetted by the tide. A similar wingless Gnat, and a Fly apparently closely allied to the Kerguelen *Amalopteryx*, were found by the Expedition at the Falkland Islands.[1] A Spider (*Myro kerguelenensis*, Cambr.), already described from the Transit of Venus Expedition,[2] was obtained.

The Teal of Kerguelen Island (*Querquedula eatoni*) is peculiar to that island and the Crozets; it is somewhat larger than the common English Teal, and of a brown colour, with a metallic blue streak, and some little white on the wing. It is enormously abundant all about Kerguelen Island, near the coast; four or five guns used to bring back usually over 100 birds. They feed mainly on the fruit of the Kerguelen Cabbage, and are extremely good eating. They are to be found in flocks, except when breeding, when they occur in pairs; where they have not been shot at by sealers, they are remarkably tame, and almost require to be kicked up to afford a shot. Several of them were breeding at the time of the visit; some with young full-fledged and already away from the nest, others with eggs. Five eggs were found in one nest. The nest is a neat one, placed under a tuft of grass, and lined with down torn from the breast of the parent bird. The duck, when put up off the nest, to effect which the nest requires to be almost trodden upon, or when found with her young away from the nest, flutters a few yards only, as if maimed, and pitches again, and cannot be frightened into a long flight. It is curious that the bird should have retained this instinct where there are no four-footed or human enemies; possibly she finds it a successful ruse when the brood is attacked by the Skuas, to which ever-watchful enemies the young must constantly fall a prey, for in most cases only a single young one was found following the mother. There were no young met with in the condition of flappers, and the general breeding season was probably only about to begin, as was the case with many birds of the island; the greater part of them were yet in flocks.

The whole beach was covered with droves of the Johnny Penguin (*Aptenodytes* [*Pygosceles*] *tæniatus*) and the King Penguin (*Aptenodytes longirostris*), and encampments of these birds were to be seen on small level grassy spaces far up the hill slope. On the talus slopes beneath the cliffs, along the whole south side of Christmas Harbour, are vast Penguin rookeries, the Penguins here nesting amongst the stones where vegeta-

[1] A Moth with rudimentary wings (*Embryonopsis halticella*, Eaton) was found by the Transit of Venus Expedition at Kerguelen; see *Phil. Trans.*, extra vol. clxviii. pp. 228, 235, 1879.

[2] *Phil. Trans.*, extra vol. clxviii. p. 225, 1879.

tion is entirely wanting; and to the north of the harbour at its entrance are other similar rookeries. Towards the upper part of the harbour, the rookeries are those of the Smaller Crested Penguin (*Eudyptes chrysocome*) called "Rockhopper" by the sealers, the same as that at Marion Island, but nesting scattered amongst these is another kind of Penguin (*Eudyptes chrysolophus*), the "Macaroni" of sealers. This bird has a most beautiful golden crest, showing conspicuously on the middle of the upper part of the head, commencing just behind the beak, and with a plume on each side as in the bicrested species. The bird is larger than the Rockhopper, and is further distinguished from it by the presence of a naked, somewhat tumid space, at the base of the beak, which is of a light pink colour, in other colouring it resembles the Rockhopper. This Penguin occurs at the Falkland Islands, where it nests as at Kerguelen Island, in small numbers amongst the Rockhoppers. These birds, however, only thus nest amongst the other Penguins where they are few in number, towards the head of the harbour. and under the natural arch they have enormous rookeries of their own, where singularly enough a few of the Rockhoppers nest as guests amongst them; they have extensive rookeries also in Heard Island, where their eggs are gathered in large quantities by the sealers for eating. No breeding places of King Penguins were met with at Kerguelen Island.

On several occasions during the stay at Kerguelen Island, excursions were made for the purpose of digging up birds and eggs for the natural history collections. Parties of stokers were always ready to volunteer for this work, which they thoroughly enjoyed and performed admirably, and by the help which they gave very many of the birds of Kerguelen were most readily procured. The beaten ground beneath the *Azorella* is perforated everywhere with holes of various Petrels; those of the Prion (*Prion desolatus*) are most numerous. They are about big enough to admit the hand, but the nest and egg are nearly always far out of reach, the holes going in sometimes a yard and a half. This Prion is a small grey bird, a Petrel from the form of the nostrils, but with a broad boat-shaped bill, with extremely fine horny lamellæ, projecting on either margin of the bill inside. The bird flies like a swallow, and was nearly always to be seen in flocks about the ship, or cruising over the sea, or attendant on a whale to pick up the droppings from its mouth, hence it is termed by sealers the "Whale Bird." It lays a single white egg.

Besides the Prion there is the "Mutton Bird" of the whalers (*Œstrelata lessoni*), a large Procellarid as big as a Pigeon, white, brown and grey in colour. It makes a much larger hole than the Prion, six inches in diameter, and long in proportion. At the end is a round chamber with a slight elevation in the centre, where is the nest, somewhat raised, with a deeper passage all round. The old bird is very savage when pulled out, makes a shrill cry and bites hard, the sharp decurved tip of the upper mandible being driven right through a man's finger if he be not careful in handling it. The egg is white, and about the size of a hen's.

Another Petrel (*Majaqueus æquinoctialis*), which also was often to be seen cruising after the ship, but then always solitary, is called the "Cape Hen" by ordinary sailors, and "Black Night Hawk" by the whalers. It makes a hole, larger a good deal than that of the Mutton Bird, and nearly always with its mouth opening on a small pool of water, or in a very damp place. The hole is deep under the ground and very often two yards or more in length. The birds seem to make their holes in certain places in company, at one place on the shores of Greenland Harbour, a number of such holes were found, all within a small area. The bird utters a peculiar prolonged and high pitched cry, either when the nest is dug into and it is handled, or when it goes into the hole and finds its mate there.

More interesting is the diving Procellarid (*Pelecanoïdes urinatrix*), a Petrel which has given up the active aerial habits of its allies, has taken to diving, and become specially modified by natural selection to suit it for this changed habit, though still a Petrel in essential structure. The habits of the bird, which also occurs in the Strait of Magellan, are described by Darwin in his Journal.[1] It is to be seen on the surface of the water in Royal Sound when the water is calm, in very large flocks. On two days when excursions were made in the steam pinnace, the water was seen to be covered with these birds in flocks, extending over acres, which were black with them. The habits of the northern Little Auk are closely similar to those of this bird; so close is the resemblance, that the whalers have transferred one of their familiar names for the Little Auk to the Diving Petrel. These Petrels dive with extreme rapidity, and when frightened, rise, flutter along close to the water, and drop and dive again; it is a curious sight to see a whole flock thus taking flight. The birds breed in enormous quantities on the islands in Royal Sound, making holes in the ground like the Prions; they are readily attracted by a light, and some were caught on board through coming to the ship's lights. The single egg is white with a few red specks at one end.

The remarkable habits of the Sheath-bill (*Chionis minor*) have already been referred to (see p. 298). These birds, the "Paddy" of the sealers, are present everywhere on the coast, and from their extreme tameness and inquisitive habits, are always attracting one's attention, a pair or two of them always forming part of any view on the coast. They are pure white, about the size of a very large pigeon, but with the appearance rather of a fowl. They have light pink coloured legs, with partial webbing of the toes, small spurs on the inner side of the wings, like the Spur-winged Plover (they are related to the Plovers), and a black bill with a most curious curved lamina of horny matter projecting over the nostrils. Round the eye is a tumid pink ring bare of feathers; about the head are wattle-like warts. On sitting down on the rocks where there are pairs of Sheath-bills about, one soon has them round, uttering a harsh, half warning, half inquisitive cry on first seeing the intruder, and venturing gradually nearer and nearer, standing and gazing up at him with their heads turned on one side. The birds come frequently within reach of a stick, and can often be knocked over in that way, or bowled over with a big stone,

[1] Journal of Researches during the Voyage of H.M.S. "Beagle," p. 290, ed. 1879.

as they will sit quietly and allow half a dozen stones almost as big as themselves to be thrown at them. At length, only after being narrowly missed several times, they take flight, and make off, uttering their harsh note several times in succession. If a bird be knocked over with a stick, it is usually only stunned, for the Sheath-bills are very tenacious of life, and if the one thus caught be tied by the leg with a string and allowed to flutter on the rocks, the neighbouring Sheath-bills will come at once to fight with it and peck it, and can be knocked over one after another. When courting one another, the birds show all the attitudes of pigeons, the male bowing his head up and down, strutting, and making a sort of cooing noise. The birds eat seaweed and shell-fish, mussels and limpets, besides acting as scavengers. They carry quantities of the limpet and mussel shells up to the clefts or holes under the rocks which they frequent. They readily feed in confinement, and several were kept on board the ship, running about quite at home, one of them established itself in one of the cutters for a short time, and used to fly about during the voyage to Heard Island always returning to the ship. The birds, though usually to be seen running on the rocks, can fly remarkably well, their flight resembling that of a pigeon; they were seen at a great height about the cliffs of Christmas Harbour.

Mr. Moseley relates the following incident showing the relations of the various birds to one another in the struggle for existence:—"A Cormorant was seen to rise to the surface of the water and lifting its head, make desperate efforts to gorge a small fish which it had caught, evidently knowing its danger, and in a fearful hurry to get it down. Before it could swallow its prey, down came a Gull, snatched the fish after a slight struggle and carried it off to the rocks on the shore. Here a lot of other Gulls immediately began to assert their right to a share, when down swooped a Skua from aloft, right on to the heap of Gulls, seized the fish, and swallowed it at once. The Shag ought to learn to swallow under water, and the Gull to devour its prey at once in the air."

During the month of January 1874, the Challenger took many soundings and dredgings in the bays and several miles off the east coast of Kerguelen, in depths varying from 20 to 120 fathoms. In all cases the deposit was a greenish mud with a strong smell of sulphuretted hydrogen, and composed principally of mineral particles and the skeletons of siliceous organisms. Generally these muds did not effervesce with weak acid, sometimes, however, a few spots of effervescence were observed. The carbonate of lime never appeared to make up more than about 1 per cent., and consisted of a few fragments of Echinids, Mollusc shells, Polyzoa, and Foraminifera. These last were *Miliola*, *Uvigerina*, and *Discorbina*; no pelagic Foraminifera were noticed. The mineral particles made up from 50 to 75 per cent. of the muds, and consisted of fragments of felspars, plagioclases, augite, magnetite, hornblende, olivine sometimes decomposed with red tint, lapilli, pumice, and brown volcanic glass. The size of these particles varied from 0·5 mm. to 0·2 mm.

in diameter, the larger sized particles being found in those soundings nearest the coasts. The frustules of Diatoms made up in every case a large part of the deposit, and along with the siliceous spicules of Sponges, probably as much as 50 per cent. in some of the samples; the soundings farthest removed from the coast contained generally much the larger proportion of siliceous remains. These muds contained but little clayey matter, and when dried were grey-green, slightly coherent, and earthy in aspect.

The dredgings along this coast gave many Sponges, Hydroids, Comatulas, Starfish, Ophiurids, Echinids, Holothurians, Annelids, *Serolis*, Pycnogonids, Lamellibranchs, Gasteropods, Nudibranchs, Polyzoans, Ascidians and Teleosteans; siliceous Sponges (*Rossella*) were in some cases most abundant, over one hundred large specimens being taken in one haul. The absence of Decapod Crustaceans (except one Schizopod, *Pseudomma roseum*) in all these dredgings is very remarkable.

The Spheniscidæ.—A considerable number of Penguins, of different species, was collected at various points of the cruise, and handed to Professor Morrison Watson, F.R.S., who made an elaborate investigation into their anatomy,[1] of which he has furnished the following brief summary:—

"The skeleton of the Spheniscidæ is remarkable in that the bones of the wing are modified in accordance with the alteration of function of that organ, and its conversion from an instrument of aerial to one of aquatic progression. These modifications are manifested in the enormous size of the scapula, which thus affords attachment to the powerful muscles of the shoulder-joint; in the great strength of the coracoid bone, which in *Spheniscus* and *Eudyptes* is perforated by a foramen for the transmission of the nerve to the pectoralis medius muscle; in the lateral compression of all the bones of the wing, a character which obtains among certain other diving birds, but which only reaches its maximum in this group; in the presence of two sesamoid bones, developed in connection with the tendon of the triceps muscle; in the peculiar form and mode of articulation of the carpal bones; in the union of the first or radial metacarpal which, although independent in the embryo, becomes inseparably anchylosed with the second metacarpal bone in the adult; and in the absence of a free pollex.

"The muscular system of the Penguins is characterised by the great development of the cutaneous muscles, which present an arrangement quite peculiar to the group. It has been suggested to me that the large development of the cutaneous muscles is probably a means whereby water may be readily expelled from the interstices of the plumage so soon as the bird quits the water. Were it otherwise, in the low temperature of the Antarctic region which the majority of these birds inhabit, the plumage would soon be frozen into an icy mass, the high temperature of the bird being of itself insufficient to obviate this, seeing that the ready conduction of heat from the interior of

[1] Report on the Anatomy of the Spheniscidæ, Zool. Chall. Exp., part xviii., 1883.

the organism is prevented by the great development of the subcutaneous fatty layer which is found in every member of the group. The muscular system is further characterised by the great strength of all, and the peculiar disposition of certain of the extensor muscles of the vertebral column, more especially of the biventer cervicis, which extends from the iliac bone to the skull, these peculiarities being associated with the erect attitude of the Penguin when on land; by the presence and arrangement of the transverse cloacal muscle; by the great strength of the muscles which act at the shoulder-joint, that is upon the wing as a whole; by the peculiar disposition of the brachialis internus muscle; and by the almost complete atrophy of the muscles which act upon the fore-arm and hand, the last-mentioned peculiarities being associated with the alteration which has taken place in the function of the wing. As regards the muscles of the leg, the Penguins do not differ essentially from other Palmipedes.

"The peculiarities of the arterial system are no less striking than are those of the bony and muscular systems. They consist in (*a*) the presence of two common carotid arteries of equal size, symmetrically disposed on either side of the middle line; (*b*) the peculiar mode of distribution of the subclavian artery, which breaks up into an axillary and brachial rete mirabile from which branches are derived for the supply of the fore-arm and hand; (*c*) in the absence of the sciatic artery as a direct branch of the abdominal aorta, and its substitution by a branch of the crural artery.

"The respiratory organs closely resemble those of other birds in their general arrangement. In one important particular, however, they differ from all with the exception of those of the Procellariidæ. The presence of a tracheal septum, which more or less completely divides the air-tube into two lateral chambers, is met with only in the Spheniscidæ and in the Procellariidæ. This tracheal septum is usually but not constantly present in the Spheniscidæ. I found it in all the forms which I examined, with the exceptions of *Eudyptes chrysocome* from Tristan da Cunha and *Spheniscus minor*. The occasional absence of a tracheal septum, therefore, shows that this structure, *per se*, cannot be considered as a constantly reliable anatomical character of this group any more than of the Procellariidæ.

"The geographical distribution of the Spheniscidæ is of interest.[1] The various members of the group are entirely confined to the southern hemisphere, not one single species of Penguin being found north of the equator. In the southern hemisphere, however, their distribution is very extensive, reaching from the Galapagos Islands on the equator southwards to the Antarctic Islands. Of the various species of Penguin collected by the Expedition and referred to in the Report, *Spheniscus demersus* is confined to the vicinity of the Cape of Good Hope, *Spheniscus magellanicus* to that of Cape Horn, *Spheniscus mendiculus* to the coast of Chili, while *Spheniscus minor* inhabits the South Pacific, in the neighbourhood of Australia and New Zealand. The genus *Eudyptes*

[1] Wallace, Geographical Distribution of Animals, vol. ii. p. 366, 1876.

includes, according to ornithologists, the two separate species *Eudyptes chrysocome* and *Eudyptes chrysolophus*, along with others which I have not had an opportunity of examining. Of these *Eudyptes chrysocome* has much the more extensive geographical range, being met with as far north as the Island of Tristan da Cunha, whence it extends southward to Kerguelen Island. *Eudyptes chrysolophus* inhabits Kerguelen Island, whence it extends southward to the islands of the Antarctic.[1] The genus *Aptenodytes* (including *Pygosceles*) has a wide geographical range in the southern hemisphere, extending from the Falkland Islands to the islands of the Antarctic Ocean. The limitation of the geographical range of the group to the southern hemisphere is not a little remarkable, and so far as I am aware no explanation of the fact has hitherto been offered.

"That it does not depend on temperature alone seems probable from the fact that they are met with from the equator southwards to the Antarctic Ocean. At the same time, it is interesting to observe that Penguins reach the equator only on the coasts of Chili and Peru. Along these coasts the cold Peruvian Current from the Antarctic Ocean carries a low temperature northward as far as the Galapagos Islands. This current, as shown by the position on the map of the isocheimal or cold water line, extends from the Antarctic Ocean along the west coast of South America, and has a surface temperature at the equator of from 62° to 68°, whereas elsewhere the equatorial region of the Pacific Ocean has a temperature varying from 81° to 88°. Now, it will be observed that the most northern geographical limit of the Penguins corresponds with that of this cold Peruvian Current, and it seems not improbable that while temperature does not directly affect the distribution of these birds, it may do so indirectly, inasmuch as this cold current passing from the pole to the equator will facilitate the passage northward of those cold water organisms which, inhabiting the Antarctic Ocean, constitute the food of the Penguins. The home of the Penguins is undoubtedly in the cold regions of the Antarctic, but their food supply being carried northward by means of the cold Peruvian Current, the area of distribution of the Spheniscidæ has been correspondingly extended, and now reaches from the Antarctic Ocean to the equator.

"The fact that the Challenger officers seldom noticed these birds more than 40 or 50 miles from land[2] or ice, seems to show that having once adopted a residence, they are very far from being addicted to those migratory habits which their peculiar structure and mode of life seem so well adapted to encourage.

"With regard to the distribution in time of the Spheniscidæ, we know very little at present, our knowledge of fossil forms being limited to a humerus, coracoid, and tarso-metatarsal bone, which were discovered in the Eocene formation of New Zealand.[3] The metatarsal bone has been described by Professor Huxley,[4] who established the genus

[1] Gray, Handlist of the Genera and Species of Birds, part iii. p. 98, 1871.
[2] Sclater, Zool. Chall. Exp., part. viii. p. 132, 1880.
[3] Hector, J., *Trans. New Zealand Inst.*, vol. v. p. 438, 1872.
[4] *Quart. Journ. Geol. Soc.*, vol. xv. p. 670, 1859.

Palæeudyptes for the reception of the bird of whose skeleton it formed a part. It apparently belonged to a bird closely allied to the genus *Eudyptes* of the present day, but evidently of much larger size than any living species of that genus. If the nature of the deposit (Eocene) from which this fragment was excavated has been correctly interpreted, it shows that the family of Spheniscidæ is one of great antiquity, and that it had even at that time deviated so far from the primitive avian stem as to present those modifications in structure which have remained unaltered down to the present time. This fact goes far to explain the difficulty which every one must acknowledge in attempting to allot to the Spheniscidæ their proper place in any classification of recent birds, a difficulty which will only disappear as the geological record is more fully deciphered, and the intermediate forms which at one time undoubtedly connected the Penguins with the primitive avian stem are brought to light. I have examined the following species of Penguins:—

Family.	Genus.	Species.	Variety.
SPHENISCIDÆ, . .	*Spheniscus*	*demersus*	*magellanicus.*
		mendiculus	
		minor	
	Eudyptes	*chrysocome*	*Eudyptes chrysocome*, from Tristan da Cunha. *Eudyptes chrysocome*, from the Falkland Islands. *Eudyptes chrysocome*, from Kerguelen Island.
		chrysolophus ?	
	Aptenodytes	*longirostris*	
		tæniatus	

"Of the various members of the genus *Spheniscus* enumerated above, it appears to me that *Spheniscus demersus* and *Spheniscus magellanicus* ought to be regarded as two varieties of one and the same species, while *Spheniscus mendiculus* and *Spheniscus minor* are undoubtedly distinct species. *Spheniscus minor* is moreover possessed of several cranial characters which approximate it to *Eudyptes*.

"Of the so-called species associated together by ornithologists under the genus *Eudyptes*, I have examined two, *Eudyptes chrysocome* and *Eudyptes chrysolophus*. Of these two species, *Eudyptes chrysocome* presents three varieties, which are met with at the Tristan da Cunha Group, the Falkland Islands, and Kerguelen Island respectively. That *Eudyptes chrysolophus* ought to be regarded as a species distinct from *Eudyptes chrysocome* is not doubted by any ornithologist, but an examination of the entire anatomy both of *Eudyptes chrysolophus* and of *Eudyptes chrysocome* appears to me rather to lend support to the view that they are simply two well-marked varieties of one and the same species of *Eudyptes*. The decision of this point must depend on the relative value attached by various ornithologists to difference in size and similarity of anatomical structure as elements in the determination of species as distinguished from variety.[1]

[1] "To discuss the question of the comparative values of external appearance and anatomical structure as elements in the determination of species as distinguished from variety, would extend this abstract beyond reasonable dimensions. I would merely wish to direct the attention of naturalists to the fact that, as it seems to me, sufficient weight has not hitherto been allowed to structure in the determination of species.

"The genus *Aptenodytes* includes the two species which I have examined, *Aptenodytes longirostris* and *Aptenodytes tæniatus.* The last named has been accepted by ornithologists as a type of another genus, *Pygosceles*, but I see no reason on anatomical grounds

"As shown in the Report on the Spheniscidæ, we have in *Eudyptes chrysocome* and *Eudyptes chrysolophus* examples of two birds which, differing much in size and weight as well as in the form and mode of coloration of certain feathers, nevertheless present an almost complete similarity of anatomical structure. I am inclined, moreover, relying upon my own observations, not, however, specially directed to the elucidation of this point, to think that a corresponding similarity of structure obtains in the case of many other birds which, solely on the ground of difference in form and mode of coloration of the tegumentary appendages, are regarded by ornithologists as undoubtedly specifically distinct. The question therefore arises—What is the relative value of tegumentary appendages on the one hand, and of anatomical structure on the other, in the determination of species as distinguished from varieties? To answer this question conclusively is at present impossible, nor shall we arrive at the solution of the problem until our knowledge of the structural details of a number of these so-called species is much more exact than it is at present. But even if we suppose such an anatomical investigation to have been completed, it appears to me exceedingly doubtful whether the question—What constitutes specific distinctness? will ever be solved by the aid of morphology alone. Rather it seems probable that in the last resort the determination of species will rest upon physiological rather than upon morphological grounds, in other words, upon the impossibility of the production of fertile offspring by the sexual union of the members of two undoubtedly distinct species.

"But while I would insist on the necessity of taking into consideration the details of its anatomical structure in attempting to solve the question of the specific distinctness of any given species, I do not deny that in the present state of our knowledge the external appearance of an organism forms a safer foundation for the determination of species than does its anatomical structure. In corroboration of this view I may refer to the case of two of our most common birds, the Thrush (*Turdus musicus*) and the Blackbird (*Turdus merula*). These are undoubtedly distinct species, and have been decided to be such by ornithologists, not upon the physiological ground of the infertility of the offspring resulting from the union of members of the two species, nor upon any structural difference, but solely upon the difference in form and coloration of their feathers. And yet the entire structural anatomy of these two species is, as shown by Macgillivray (History of British Birds, pp. 82 and 128), almost identical. The same remark holds good of other species of birds, and the further question arises—How does it happen that two organisms are so different physiologically and in their external appearance while their anatomical structure is almost identical?

"It would appear at first sight that the influence of external conditions would in the first place influence the external appearance of an animal rather than its internal anatomy, and yet we find that under the influence of exactly similar external conditions in the case of the two species just referred to, their external appearance is quite different and yet their internal anatomy remains the same, this latter similarity being accompanied by specific physiological distinction. It appears to me that there can only be one explanation of these apparently anomalous facts, and that is, that there must be some embryological or physiological connection between the genital glands and the integument. So far as embryological connection is concerned, we know of none except that both the genital glands and the skin are derived from the mesoblast, unless indeed we take into consideration the hitherto inexplicable fact of the pathological occurrence of dermoid cysts in the ovaries. That, however, there is some intimate physiological connection between the genital organs and the skin is shown by the changes which are undergone by the tegumentary appendages at the time of sexual maturity, changes which are more pronounced in the skin than in any other part of the organism, and more especially by the occurrence of these remarkable phenomena included by Darwin within the category of secondary "sexual characters," such as the occasional assumption by the female of the male plumage, and *vice versa*, in birds, and the observed difference in coloration of the yolk of the egg, associated with a corresponding alteration in the colour of the tegumentary appendages (Darwin, Animals and Plants under Domestication, vol. ii. pp. 252 and 274 London, 1868). All these facts point to the existence of some more intimate connection between the sexual organs and the integument than between the sexual organs and the rest of the organism, and upon this supposition alone, as it seems to me, is it possible to account for the coincidence of variation in the integument with specific physiological distinction at the same time that the latter is unaccompanied by any marked morphological change of other parts of the organism.

"It seems possible on these lines to explain the facts recorded in the monograph on the Spheniscidæ with respect to the similarity of structure of two Penguins (*Eudyptes chrysolophus* and *Eudyptes chrysocome*), which nevertheless on the strength of difference in the form and coloration of their plumage and dermal appendages have without hesitation been regarded by ornithologists as specifically distinct.

"It may thus be true that, after all, tegumentary appendages are of more account in the determination of species than are the details of anatomical structure, the former being correlated with deep seated sexual and specific peculiarities, why it should not be included along with *Aptenodytes longirostris* as another species of one and the same genus.

"Lastly, in their affinities the Penguins appear to be more closely allied to the Palmipedes than to any other group of birds, but the numerous important deviations which they present from every one of the various groups included within that very heterogeneous assemblage appear to show that the Spheniscidæ must have diverged at an early period from the primitive avian stem, and the connecting links having been lost, it seems at present hopeless to attempt to establish the exact affinities of the Penguins to other birds. At first sight, indeed, it appears that the nearest allies of the so-called wingless birds of the southern are to be found in the wingless birds of the northern hemisphere, but the researches of Professor Owen[1] on the osteology of the Great Auk (*Alca impennis*), abundantly show that the two groups have but little in common. We are compelled therefore to postpone the accurate determination of the affinities of the Spheniscidæ till the progress of Palæontology shall have made us acquainted with the intermediate forms connecting the Spheniscidæ with the primitive avian stem from which both they and the other Palmipedes were originally derived."

whilst the latter may only express the fact that under similar circumstances and the necessity of adopting similar modes of life the details of anatomical structure of two specifically distinct organisms tend also to become similar.

"I would only farther remark that an investigation into the entire subject of the relation which the sexual organs bear to the skin and tegumentary appendages on the one hand, and to the rest of the organism on the other, in different forms of animal life, is one which is likely to be productive of valuable results in enabling us to determine the essential morphological as distinguished from the physiological characteristics of a species."

[1] Description of the Skeleton of the Great Auk or Garfowl (Alca impennis), *Trans. Zool. Soc.*, vol. v. p. 317, 1866.

CHAPTER X.

From Kerguelen to McDonald Islands and Heard Island—Notes on the reproduction of certain Echinoderms from the Southern Ocean—Heard Island to the Antarctic Circle and Australia—Icebergs of Antarctic Regions.

Kerguelen to McDonald Islands and Heard Island.

On the 2nd February, the day after leaving Kerguelen Island, the weather in the forenoon being fine and clear, a successful sounding and dredging were obtained in 150 fathoms, on a hard bottom (Station 150). The bottom was covered with a coarse gravel; the dredge brought up a large number of stones, fragments of rocks of irregular form, varying in size from 1 to 7 centimetres in diameter, with the angles more or less rounded, but much less so than those of ordinary rolled pebbles. They were blue-black, and the majority had a compact structure and were fine grained, while others were porous with a rough surface. Macroscopically they appeared to be basalts or basaltic lavas, but examined with the microscope it was seen that they belonged to the felspathic basalts (dolerite); among these volcanic fragments were noticed two or three pieces of granite and one of sandstone. The majority of these stones were overgrown by Foraminifera, Sponges, Actiniaria, Brachiopods, Ascidians, *Serpulæ,* and Polyzoa.

The dredge procured representatives of nearly all the invertebrate types. In the zoological Reports already published there are described twenty-two new species and three new genera from this locality. Of these there are seven new species of Tunicata including a new genus; seven new species of Gasteropoda, including a new genus, four new species of Ophiuroidea, and a new genus of Actiniaria. At noon the ship again proceeded under sail towards Heard Island, but at 1 P.M. a dense fog came on, so that at 3 P.M. it became advisable to bring to on the port tack under double-reefed topsails, as it was deemed imprudent to proceed further, not only on account of the uncertain position of the islands, but also because it is no unusual thing for icebergs to be seen in this locality; in fact the captains of the whaling schooners met at Kerguelen said that they passed two on their passage from Heard Island in January. At 5 P.M. no bottom was obtained at 425 fathoms, but at midnight a sounding was obtained in 92 fathoms.

On the 3rd February, at 6 A.M., bottom was again obtained in 80 fathoms, but previously, at 1, 2, 3, and 4 A.M., ground was not struck with 130 fathoms of line. This indicates the rocky, uneven nature of the bottom between Kerguelen and Heard Islands. As the weather remained thick and foggy all day, it was impossible to prosecute the search for Heard Island. The wind was light and variable with a long westerly swell. The fog lifting for a few minutes at 9.30 A.M., an observation of the sun was obtained.

On the 4th, at 4.30 P.M., the ship wore and stood to the southward, with the intention of getting into the parallel of Heard Island and then steering east. At 10 A.M. the fog lifted and an observation was obtained. The weather remained fine during the afternoon, and the evening was quite bright and clear, which enabled the men to dry their wet clothes, the ship's sails, and decks. Unfortunately the wind was very light, so that the vessel was unable to make much progress towards the island under sail, and coal could not be afforded for steaming. At 3 P.M. no bottom was obtained at 120 fathoms, nor at 11 P.M. at 130 fathoms. During the afternoon the ship was surrounded by Penguins, uttering their discordant cry.

On the 5th, at 3.30 A.M. (daylight), sail was again made to the southward; but unfortunately, at 7 A.M., the weather became as thick as ever. As at this time the ship was on the supposed parallel of Heard Island, Captain Nares stood on to get to the southward of it before "laying to" again, trying for soundings at 7.30 A.M. with 200 fathoms of line, and at noon with 300 fathoms without success. At noon sail was shortened and the ship brought to the wind. At 1.30 P.M. the mist and drizzle broke slightly, and what was thought to be land was seen in an E. by S. direction. Towards evening the breeze died away, and at 9 P.M. a westerly wind sprang up, which freshened to a moderate gale by midnight, but also fortunately dispelled the fog.

On the 6th, at 3.40 A.M., the vessel bore up for the supposed position of Heard Island, the weather fairly clear with a westerly gale blowing. At 6 A.M., just as observations were being obtained, the M^cDonald Islands were seen through the mist bearing east, distant about 13 miles. A course was immediately shaped to pass round their northern side, in fact to circumnavigate them as nearly as the direction of the wind permitted; and the horizon being clear and the sun breaking frequently through the clouds, it was possible to fix their position accurately, as, besides other observations, a longitude was obtained when they bore south, and a latitude when they bore west, and the islands are so small that little beyond this was required.

McDonald Islands.

The McDonald Islands, 24 miles west of Cape Laurens, the northwest extremity of Heard Island, consist of two small islands, N. by E. and S. by W. (true) from each other, and an outlying sugar-loaf rock named Meyer's Rock, 1 mile N. 50° W. (true), from their north extremity; the islands are very small, and appear to be inaccessible. They were discovered by Captain McDonald of the British ship "Samarang," in January 1854. Captain McDonald also sighted Heard Island, but as it had been originally seen by the "Oriental," it bears the name of her captain.

Meyer's Rock, 450 feet high, is in lat. 53° 1′ 20″ S., long. 72° 30′ 30″ E.; the highest part of the McDonald Islands is a saddle hill, 630 feet high, the two peaks of which are in line on a north and south bearing. The channel between the two McDonald Islands is only about a cable in width. Seen from a distance these islets appear three in number, as a low neck of land joins the N.E. and S.W. points of the larger of the two islets, and is only distinguished on a nearer approach. Rounding this group, at a distance of from 3 to 5 miles, no off-lying danger could be detected, either from the masthead or deck of the Challenger.

Since the discovery of the M^cDonald and Heard Islands, they have been frequently sighted by passing vessels, and until a knowledge of their existence was widely disseminated, each captain who saw them looked on them as unknown land. In 1857 Captain Meyer, of the German ship "Rochelle," was apparently not aware of their existence, and gave an account of them as unknown islands, which was published by Dr. Neumeyer in Petermann's Mittheilungen for 1858.

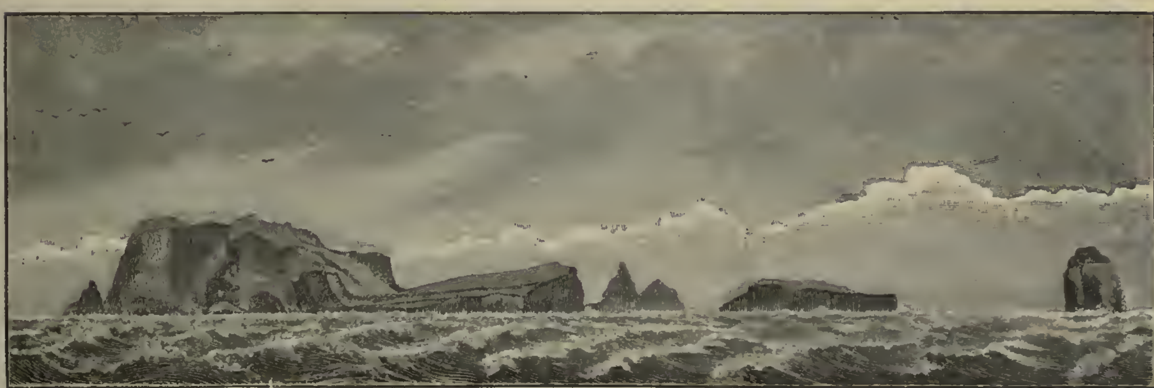


FIG. 134.—M^cDonald Islands and Meyer Rock, as seen from H.M.S. Challenger, 6th February 1874.

HEARD ISLAND.

Having rounded the M^cDonald Islands, and obtained a sounding of 105 fathoms, hard ground, 4 miles eastward of them, the ship was steered S. ½ W. (S.E. true) for the supposed position of Heard Island. At noon the northern end of Heard Island was sighted and the course altered to pass round it, other observations of the sun being obtained at 2 P.M., when Red Islet, off its north point, bore south. Steering along the east coast the vessel eventually anchored in Corinthian Bay at 3.40 P.M. in 10 fathoms. A gale of wind blew all day, and the squalls off the high land of Heard Island were very violent, raising large quantities of spoondrift; in Corinthian Bay the wind was steady, both in direction and force, as it came over low land, which connects the high northwest promontory with the main island. The weather though not foggy was misty, for Shag Island was not seen until the ship was anchored in the bay. Clouds completely covered the high land, above the height of 1000 to 1500 feet, but the lower hills and the M^cDonald Islands were clear, so that their heights could be ascertained.

Heard Island[1] (see Sheet 22), discovered by Captain Heard of the American ship "Oriental" in November 1853, is of considerable extent, being 25 miles in length, and 9 miles in width, occupying an area of 100 square miles. Its northwestern extremity (Cape Laurens) is in lat. 53° 2′ 45″ S., long. 73° 15′ 30″ E., and its southeastern in lat. 53° 14′ S., long. 73° 52′ E.

The summit of the island was not seen from the Challenger, but is estimated as being at least 6000 feet above the level of the sea; the mountain is called "Big Ben" by the sealers, and from it large glaciers descend, and in many places reach the sea; but, as the temperature of the surface water is above 32°, the waves dashing against the edge of the glaciers wear away the base, and so form overhanging ledges of ice, which break off by their own weight when forced sufficiently forward by the gradual descent of the glaciers. Here and there low hills, separate from the main mountain mass, offer an obstruction to the ice, and prevent its covering the land on their lower

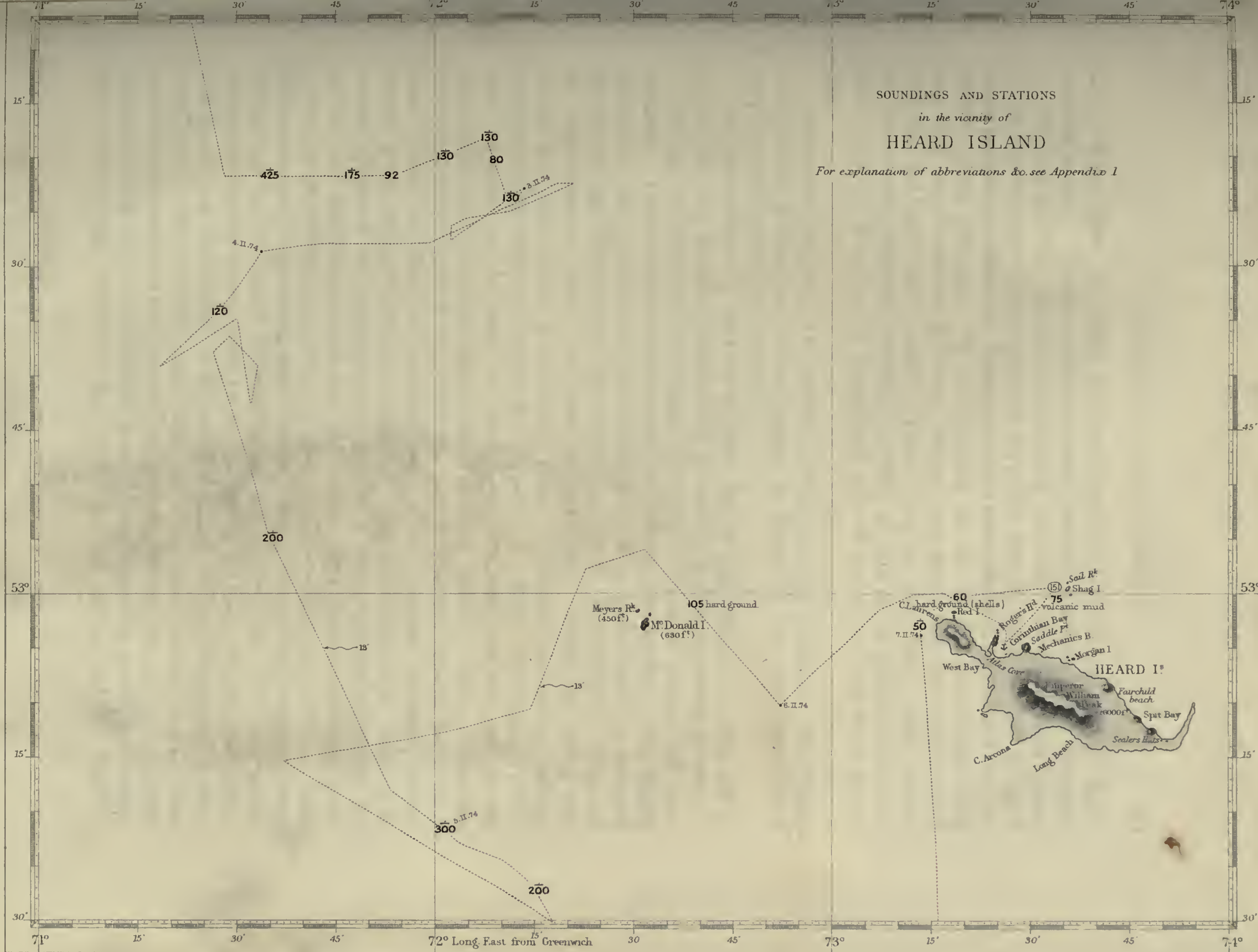
FIG. 135.—Glacier, Corinthian Bay, Heard Island, as seen from H.M.S Challenger, 6th February 1874.

sides; such a hill blocks the glacier on the southeast side of a narrow low isthmus 5 miles from Cape Laurens.

To the southeast of the ship as she lay in the small bay at anchor was seen the succession of glaciers descending right down to the beach from this mountain, and separated by lateral moraines from one another; six of these glaciers were visible from the anchorage, forming by their terminations the coast line eastwards. They rose with a gentle slope with the usual rounded undulating surface, upwards towards the interior of the island, but their origin was hid in the mist and cloud.

One of them, that nearest to the ship, instead of abutting on the sea shore directly with its end as did the others, presented, towards its lower extremity, its side to the

[1] *Nautical Magazine*, vols. xxiii., xxiv., xxvii.; *Mercantile Magazine*, vols. v., xii.; *Petermann's Mittheilungen*, 1858; Personal Observations by Members of the Expedition.


SOUNDINGS AND STATIONS
in the vicinity of
HEARD ISLAND
For explanation of abbreviations &c. see Appendix 1
425
175
92
130
130
80
130
3.II.74
4.II.74
120
200
300
5.II.74
200
Meyers Rk.
(450ft.)
Mc Donald I.
(630ft.)
105 hard ground
6.II.74
50
7.II.74
60
C. Laurens
hard ground (shells)
Red I.
Rogers Hd.
151
Sail Rk.
Shag I.
75
volcanic mud
Corinthian Bay
Saddle Pt.
Mechanics B.
Morgan I.
West Bay
Atlas Cove
HEARD I.
Fairchild beach
Spit Bay
Sealers Huts
Long Beach
C. Arcona
6000ft.
72° Long. East from Greenwich
Engraved by Malby & Sons.

action of the waves, and ending somewhat inland, formed a well-marked but scanty terminal moraine. To the sea shore this glacier presented a vertical wall of ice, resting directly upon the black volcanic sand composing the beach. In this wall was exposed a very instructive longitudinal section of the glacier mass, in which the series of curved bands produced by differential motion were most plainly marked, and visible from the distance of the anchorage. The ice composing the wall or cliff was evidently being constantly bulged outwards by internal pressure, and masses were thus being split off to fall on the beach, and be melted or floated off by the tide. The ice splits off along the lines of the longitudinal crevasses, and falls in slabs of the whole height of the cliff; a freshly fallen slab, a longitudinal slice of the glacier, was lying on the beach.

Some stones dredged in 150 fathoms between Kerguelen Island and Heard Island were believed to have been recently dropped by floating ice from Heard Island; they were not as yet penetrated by the water.

The other glaciers in sight cut the shore line at right angles, and thus had no terminal moraines, the stones brought down by them being washed away by the sea.

The glaciers showed all the familiar phenomena of those of Europe with exact similarity. There are here the same systems of crevasses, more marked in some regions than others, and dying out towards the termination of the glacier where the surface is smooth and generally rounded. The crevasses were of the usual deep blue colour, and the ridges separating them of the usual fantastic shapes. Above, the glaciers were covered with snow, which, as one looked higher and higher, was seen to gradually obliterate the crevasses, and assume the appearance of a névé. The extent of glacier free from snow was very small, the region in which thawing can take place to any considerable extent being confined to range not far above sea level. Here and there were to be seen on the surface of the glacier the usual deep vertical pipe-like holes full of water. These were lined by concentric layers of ice, composed of prisms disposed radially to the centres of the holes and produced by successive night frosts. Cones of ice covered with sand, and appearing as if composed of sand alone, but astonishing one by their hard and resistant nature when struck with a stick, were also to be seen on the glacier, just as on European glaciers; but here the sand was black and volcanic. Small table-stones were not uncommon upon the glacier, and in fact, all the phenomena caused by thawing from the action of direct radiant heat were present. The usual narrow longitudinal lines or cracks caused by the shearing of the ice in its differential motion were present, and gave evidence of the grinding together of the closely opposed surfaces forming them. The dirt and stones on the surface of the ice were as usual more abundant towards the termination of the glacier and the moraine, but they were not very numerous, and there were no large stones amongst them, nor were any to be seen in the moraine. The terminal moraine showed the usual irregular conical heaping, and also marks of recent motion of the stones and earth composing it, due to the thawing of the ice supporting them; a small stream running from the glacier-bed cut its way to the sea through a short arched tunnel in the ice, as so commonly occurs elsewhere. A small cascade poured out of an aperture about half-way up the ice-cliff on to the sea shore. The lateral moraines were of the usual form, with sharp ridged crests and natural slopes on either side, and formed lines of separation between the contiguous glaciers. They were somewhat serpentine in course, and two of them were seen to occur immediately above points where the glaciers on either hand were separated by masses of rock *in situ*, which showed out between the ice-cliffs on the shore and had the ends of the moraines resting on them. All the moraines showed evidence of the present shrinking of the glaciers.

The view along the shore of the successive terminations of the glaciers was very fine, a coast line composed of cliffs and headlands of ice. None of the glaciers came actually down into the sea, the bases of their cliffs resting on the sandy beach, and only just washed by the waves at high water or during gales of wind.

Captain Nares, accompanied by Mr. Buchanan and Mr. Moseley, effected a landing on a smooth sandy beach bounding a sandy plain, being helped by six dirty-looking sealers who had made their appearance on the rocks, rifle in hand, as soon as the ship entered the bay, and had gazed on her with astonishment. The "boss" said, "I guess you are out of your reckoning," and they evidently thought no one could have come to Heard Island on purpose who was not in the sealing business.

The island here is very narrow, not more than a mile broad, and the sandy plain stretches from sea to sea; in fact, it forms the heads of three bays, namely, Corinthian Bay facing to the northeast, West Bay, and Atlas Cove. The connection of the two promontories with the main island by means of this sandy plain is so low that a depression of a few feet would suffice to separate them from each other and from the mainland. The sand is very dark-coloured and highly magnetic, and was being blown with such violence by the southwest wind then prevailing, that it was necessary, when exposed to it, to use some protection for the face. Nowhere can the abrading power of blown sand be better seen than on the isolated rocks which have rolled down from the heights above and remained fixed in the sandy plain, exposed to the constant strong southwesterly gales, driving the sharp volcanic sand against their sides. In this way they have frequently been cut and dressed as by a mason's chisel (see fig. 136). It is, however, not the southwesterly winds alone which produce this effect; but from their great predominance they have given the rocks the peculiar "sheared" appearance, much resembling that assumed by the trees growing on a coast exposed to the trade winds. If favourably placed rocks be carefully examined, the effect of every prevalent wind will be observed in the facets which it has produced on the surface. The largest facet, and the one which determines the general appearance of the rock, is the one turned towards the west; and the areas of the others would doubtless afford useful information as to the relative prevalence of other winds.

The sandy plain stretches back from the bay as a dreary waste to a small curved beach at the head of another inlet of the sea. Behind this inlet is an irregular rocky mountain mass forming the end of the island, on which are two large glaciers very steeply inclined, one of them terminating in a sheer ice-fall. At its back this mountain mass is bounded by precipices with their bases washed by the sea.

The plain is traversed by several streams of glacier water coming from the southern glaciers. These streams are constantly changing their course, as the beach and plain are partly washed about by the surf in heavy weather. At the time of the visit the main stream stretched across the entire width of the plain and entered the sea at the extreme

FIG. 136, from a sketch by Mr. Buchanan, represents a rock embedded in the black sand. The side towards the west, with the high light on the woodcut, is being rapidly worn down by the sharp sand blown against it, which has cut an irregularly fluted pattern in it.

western verge of the beach; it was about 20 yards across, knee-deep, and had therefore to be forded. The water was intensely cold, brown, opaque, and muddy, charged with the grindings of the glaciers. Running into the sea it formed a conspicuous brown tract, sharply defined from the blue-green sea water, and extending almost to the mouth of the bay.

The sandy plain seemed entirely of glacial origin, and was in places covered with yielding glacial mud, very heavy to walk upon. It was strewn with bones of the Elephant Seal and the Sea Leopard (*Stenorhynchus leptonyx?*), those of the former being most abundant. There were remains of thousands of skeletons, and a good many tusks of old males were gathered. The bones lay in curves looking like tide lines on either side of the plain above the beaches, marking the rookeries of old times and the tracks of slaughter of the sealers.

On the opposite side of the plain from that bounded by the glacier is a stretch of low bare rock with a peculiar smooth and rounded but irregular surface. This rock surface appears from a distance as if glaciated, but on closer examination it is seen to show very distinct ripple marks and lines of flow, and the rock mass is evidently a comparatively recent lava flow from a small broken-down crater which stands on the shore close by. The remains of the crater are now in the form of three fantastic irregularly conical masses, composed of very numerous thin layers of scoriæ, conspicuous because of their varied and strongly contrasted colours and very irregular bedding. The lava flow is seen in section in the low cliffs forming the coast line of the harbour.

The rocks collected at Heard Island have been referred to augite-andesite, felspathic basalt, and tufa, composed of basaltic fragments and minerals. Some specimens are transitional between basalt and augite-andesite.

Fig. 137, from a sketch by Mr Buchanan, represents the mountainous promontory forming the northwestern end of the island. The top of the mountain was enveloped in cloud, below which the greater part of its sides were covered by a glacier descending to the edge of the precipitous rock cliffs over which the ice masses fell thundering. The sketch was taken from the shoulder of a red conical hill against which the ice, descending from the main mountain of the island to the sea, splits and passes on both sides of it.

The present condition of Heard Island is evidently that which obtained in Kerguelen Island formerly. Glaciers once covered Kerguelen Island almost entirely and dipped down into the sea. It is, however, an extraordinary fact that Heard Island, only 300 miles south of Kerguelen Island, should thus still be in a glacial period, whilst in Kerguelen Island, a very much larger tract, the glaciers should have shrunk back into the interior, and have left so much of the land surface entirely free from ice, the ice epoch being there already a thing of the past. The great height of Big Ben, and consequent largeness of the area where snow constantly accumulates and cannot be melted, no doubt accounts to a considerable extent for the peculiar conditions in Heard Island. A similar rapid descent of the snow-line within a few degrees of latitude occurs in the Chilian Andes,[1] so great is the cooling influence of the vast Southern Ocean. Heard Island is in a corresponding latitude to Lincoln; possibly when England was in its last glacial epoch Heard Island enjoyed a much milder climate, and it was probably then that the large trees grew, the trunks of which are now fossil in Kerguelen Island, and that the ancestors of *Lyallia* and *Pringlea* flourished.

A stretch of land on the northwest side of the plain was covered pretty thickly with green, which on closer examination was seen to be composed of patches of *Azorella* growing on the summits of mud or sand hummocks, separated from one another by ditches or cavities, of usually bare brown mud. Some of these *Azorella* patches were of considerable extent, and the plant was evidently flourishing and in full fruit. On some hummocks grew tufts of the grass, *Poa cookii*, in full flower and with the anthers fully developed; and on the sheltered banks the Kerguelen.Cabbage (*Pringlea antiscorbutica*) grew in considerable quantity, but dwarfed in comparison with Kerguelen specimens, both in foliage and in the length of the fruiting stems. Most of it was in fruit, but some still in flower, as at Kerguelen Island. Around pools of water in the hollows grew a variety of a British plant, *Callitriche verna* (var. *obtusangula*), in quantity, and it occurred also in abundance submerged, in company with a Conferva. In the same sheltered spots grew *Colobanthus kerguelensis*, in greater abundance even than at Kerguelen Island. These five flowering plants,[2] all occurring also in Kerguelen Island, were the only ones found in the island, and it is improbable that any others grow there. Heard Island has thus a miserably poor flora, even for the higher latitudes of the southern hemisphere. The Falkland Islands, in lat. 51° to 52° S., have one hundred and nineteen phanerogamic plants, and Hermit Island, far to the south of Heard Island, in lat. 56° S., has eighty-four phanerogams, and amongst them trees which there reach their southern limit.

About the sides of the hummocks already described grew scantily four species of Mosses, one of which (*Grimmia* [*Schistidium*] *insularis*, Mitt.) proved to be new and peculiar to the island. The greater part of the land surface of Heard Island free from ice, besides the green tract described, is entirely devoid of vegetation. Only on the talus slopes of the hills on their sheltered sides, are seen scattered in a very few places scanty patches of green. These, composed mainly of *Azorella*, stretching up the slopes, terminate at an elevation of a few hundred feet in bright yellow patches, which are composed of Mosses just as at Marion Island on the high slopes. Lichens were searched for in vain.

At Corinthian Bay large masses of seaweeds were banked up on the sandy shore;

[1] Grisebach, Die Vegetation der Erde, Bd. ii. p. 467, Leipzig, 1872; Darwin, Journal of Researches during the Voyage of H.M.S. "Beagle," p. 244, ed. 1879.

[2] Professor Oliver, F.R.S., *Journ. Linn. Soc. Lond.*, vol. xiv. p. 389, 1875.

eight species were collected which have been described by Professor Dickie.[1] Amongst them were two new ones, and three which occur at Kerguelen Island, whilst the remainder occur in Patagonia and Chili. The main mass appeared considerably different from the masses of Algæ found on the Kerguelen shore. *Durvillea utilis* grew attached to the rocks under the cliffs, but the Kelp (*Macrocystis pyrifera*) does not grow at all about this group of islands according to the sealers, which is a remarkable fact, when its great abundance at Kerguelen's Land is kept in mind.

The only insects seen at the island were the large apterous Fly of Kerguelen Island (*Calycopteryx moseleyi*), which shelters itself, as there, in the heart of the Kerguelen Cabbage, and a single dead specimen of a small beetle, found amongst the *Azorella*, which was unfortunately lost.

The water is deep all round Heard Island, except off the southeast point, where a bank of black mud and sand is said to extend to a great distance; off the coast are a few detached rocks and islands. Red Island, off the north point, is a small dome-shaped mass of dark red lava, about 200 feet high, separated from the coast by a channel, half a mile in width, which did not appear navigable. One and a half miles north of Red Island the depth is 60 fathoms, the bottom being shelly. In Corinthian Bay is a black steeple rock, about 30 feet high, which has been named Church Rock, standing in front of a whitish blue glacier. Four miles east of Saddle Point, the eastern end of Corinthian Bay, are three small dark islands, named "Morgan Islands." Seven and a half miles northeast of Rogers' Head are three small islets, named "Shag Islands," the highest of which is about 200 feet high; a mile west of them the depth is 75 fathoms. The central Shag Island is in lat. 52° 59′ 30″ S., long. 73° 35′ 30″ E.

Shortly after its discovery, viz., in March 1855, Heard Island was visited by Captain Rogers of the American whaler "Corinthian" and his four tenders, the "Atlas," "Mechanic," "Exile," and "Franklin." They anchored in Corinthian Bay, and reaped a rich harvest of Elephant Seals, procuring in one day four or five hundred barrels of oil. The names of the ships composing Captain Rogers' squadron were given to the various conspicuous headlands, bays, and islets of the group, and still serve to record the visit of the seamen who first landed there.

Since 1855 an Elephant Seal fishery has been regularly established at Heard Island, but, owing to the want of a well-sheltered anchorage, it has been found necessary to land a party for the purpose. At the time of the Challenger's visit there were forty men on the island, distributed in parties along the coast, the largest number at the south end. At Corinthian Bay there were only six men, who were living in huts sunk in the ground, partly to protect them against the strong westerly winds, which blow through the gap separating the mountain in the northwest promontory from the main mountain, with much violence, and partly for warmth, as in winter they cover them with snow.

[1] *Journ. Linn. Soc. Lond.*, vol. xv. p. 47, 1876; Bot. Chall. Exp., part ii. p. 256, 1884.

They appeared to have a good stock of food and supplies of all kinds, the ground in the vicinity of their huts being strewn with casks, tanks, sledges, hand-carts, and old pots, and they vary their diet of salt beef, &c., with Penguins, which they look on as excellent food; for fuel they use the skin and fat of the Penguin.

The men stationed at the different points of the island have considerable difficulty in keeping up communication with each other, and in transporting their blubber to such parts of the coast as are accessible to the sealing schooners. If they walk along the beach they occasionally have to go under the overhanging ledges of ice from the glacier, which may break off at any time and annihilate them; in fact, one boat's crew was lost in this way on the south side of Corinthian Bay, and in travelling over the glacier the numerous crevasses obstruct their progress considerably. It is requisite also for them to endeavour to get the Elephant Seals to land on those beaches which can be most readily communicated with, for it is no use their killing the animals and collecting their blubber unless they can transport it to the place of shipment, so they have to watch the coast constantly and try to beat off the Elephant Seals from the least accessible parts in order to get them to land on beaches favourable for transport. The blubber collected at Long Beach is transported over the ice to Spit Bay.

The Elephant Seals are reported to be nearly as plentiful as ever, and the whalers reason that other islands must therefore exist hereabouts where they keep up the breed, but one would think that had they any other place of resort they would abandon this island, so much are they harassed; in fact, they are now only to be found on the weather shore, as they seldom attempt to land on the lee side. Their favourite breeding place is Long Beach, on the southwest coast. The males land first, and the females some few days after. The male Elephant Seals, like the males of other Seals, constantly quarrel and fight with each other, the largest full-grown animals beating the smaller, and driving them into the sea; these large fighting males are called by the sealers "Beach Masters."

The sealing settlements are visited annually by the barque "Roman" and her two tenders, the schooners "Roswell King" and "Emma Jane." They generally arrive in Corinthian Bay in October, and, naturally, their coming is looked forward to by the men on shore as the great event of the year; much rejoicing takes place when they meet their comrades, and a considerable consumption of whisky follows, so that this rendezvous is as frequently called "Whisky" as "Corinthian" Bay. The schooners anchor in Mechanic's Bay, Morgan Bay, and Spit Bay, to collect the blubber, which is rafted off to them, and remain at the island until about the end of December; but this work is extremely hazardous as east winds are by no means uncommon, and the island, lying in a northwest and southeast direction, does not afford any very great protection against the prevailing westerly swell.

The weather in the vicinity of Heard Island is foggy and boisterous, and, although the prevailing wind is westerly, gales from the northward and eastward are not at all uncommon. As a rule the westerly winds bring moderately clear weather, the easterly much fog and mist. December is the finest month, and at this season of the year a fortnight's really fine weather may be sometimes experienced, but it cannot be depended on. In the winter the whole island is snow-clad, and the sealers at the settlement have to melt snow or ice to obtain water; in the summer the lower lands, protected by elevations from the descending glacier, are free from snow, but at all seasons a fall may take place at any moment. The icebergs occasionally seen in the neighbourhood are not generated by the glaciers from either Kerguelen or Heard Islands, for the sea water in the vicinity is too warm to permit the base of the glacier to remain undissolved, and consequently only small pieces of ice, comparatively speaking, can be derived from this source.

Landing at Heard Island is always difficult and frequently impracticable. Only the one boat's party above referred to landed during the Challenger's stay, the weather having become unfavourable immediately afterwards.

With reference to the direction of the wind and state of the weather, it may perhaps be as well to draw attention here to the fact that easterly winds seldom if ever blow at Kerguelen Island, but 100 miles south of it and in the neighbourhood of Heard Island they are quite common. It would appear, therefore, unadvisable for sailing vessels running down their easting to adopt a route south of Kerguelen, even supposing the chances of meeting icebergs were equal on both sides of that island, but considering the much less danger of meeting those obstructions to navigation on the northern side, there can hardly be a doubt as to which is the preferable route.

On the 7th February shortly after midnight the barometer began to fall rapidly, the wind became light, and snow fell all the middle watch. At 4 A.M. the wind shifted to the southeast, a slight swell came into Corinthian Bay, and the weather being thick and misty it was considered unadvisable to remain longer at anchor in such an exposed position, so steam having been got up the anchor was weighed at 5 A.M. and the ship proceeded towards Shag Island to ascertain its position by a patent log distance from Rogers' Head. At 7 A.M. the vessel stopped off Shag Island, being then within half a mile of it, but the weather was so thick that its outline could only just be discerned through the mist. There being little wind, a sounding and dredging were obtained here in 75 fathoms.

At 9 A.M. the ship steamed towards Red Island, which was rounded at 10.30 A.M., obtaining no bottom with 45 fathoms. The course was then altered gradually to the southward, the weather remaining thick, so that the land could not be distinguished at any distance. At noon a breeze sprang up from the northwest and sail was made to the southward, the fires being banked. At 12.15 P.M. the land was completely obscured, although the ship was but 2½ miles from the coast, and nothing more was seen of it. The wind freshened quickly to a gale, so that it was necessary to reef the topsails and courses, and at 11 A.M. the ship "laid to" under triple-reefed topsails; it was then blowing a hard westerly gale, and it was a matter of congratulation that the ship had left the insecure anchorage of Corinthian Bay.

The necessity for leaving Heard Island without thoroughly exploring it was a source of much regret. Had it remained fine for a few days, a survey might have been completed which would have been all that was requisite for passing vessels, but the unfavourable state of the weather prevented anything more being done than fixing the position of its northern end, the remainder of the island being depicted from a sketch-map made by the American sealing captains. The glaciers and peculiar formation of the land, also, are well worthy of investigation, more especially the sickle-shaped spit running to the northward from its southeast extremity, from which shoal water is said to extend. The report of this shoal water prevented the Expedition passing down the east side of the island, for it would have been dangerous for the ship to have become entangled amongst shoals in the thick weather experienced, even had the wind been moderate.

The deposit in 75 fathoms off Shag Island was a blackish green volcanic mud, composed essentially of black volcanic sand and remains of organisms. There was apparently not more than 1 or 2 per cent. of carbonate of lime, consisting of *Miliola*, *Discorbina*, *Uvigerina*, and one or two *Globigerina* shells, along with fragments of Polyzoa, Molluscs, Echinoderms, &c. The mineral particles had a mean diameter of about 0·6 mm., and formed a black sand consisting chiefly of fragments of brown and red glass—sometimes decomposed, sometimes massive and enclosing microliths of olivine, and sometimes porous—with fragments of felspar, plagioclase, augite, and magnetite. There were also very many Diatoms and Sponge spicules in the mud.

The dredge brought up many specimens of Sponges, Alcyonarians, Holothurians, Ophiurids, *Euryale*, Asterids, *Brisinga*, Echinids, Annelids, Amphipods, Polyzoa, Gasteropods, Cephalopods, and many other invertebrates resembling closely those obtained in the dredgings around Kerguelen.

Among the Echinoderms dredged at this Station was *Psolus ephippifer* described by the late Sir Wyville Thomson in the following interesting notes on the reproduction of certain Echinoderms from the Southern Ocean :—" Adhering to the fronds of *Macrocystis* there were great numbers of an elegant little cucumber-shaped Sea-slug (*Cladodactyla crocea*, Lesson, sp.) from 80 to 100 mm. in length by 30 mm. in width at the widest part, and of a bright saffron-yellow colour. The mouth and excretory opening are terminal ; ten long, delicate, branched oral tentacles, more resembling in form and attitude those of *Ocnus* than those of the typical Cucumariæ, surround the mouth; the perisome is thin and semitransparent, and the muscular bands, the radial vessels, and even the internal viscera can be plainly seen through it. The three anterior ambulacral vessels are approximated, and on these the tentacular feet are numerous and well developed, with a sucking-disk supported by a round cribriform calcareous plate, or more frequently by several wedge-shaped radiating plates arranged in the form of a rosette; and these three ambulacra form together, at all events in the female, a special ambulatory surface.

"The two ambulacral vessels of the 'bivium' are also approximated along the back, and thus the two interambulacral spaces on the sides of the animal, between the external trivial ambulacra and the ambulacra of the bivium, are considerably wider than the other three; consequently, in a transverse section, the ambulacral vessels do not correspond with the angles of a regular pentagon, but with those of an irregular figure in which three angles are approximated beneath and two above. In the female the tentacular feet of the dorsal (bivial) ambulacra are very short; they are provided with sucking-disks, but the calcareous support of the suckers is very rudimentary, and the tubular processes are not apparently fitted for locomotion. In the males there is not so great a difference in character between the ambulacra of the trivium and those of the bivium; but the tentacles of the latter seem to be less fully developed in both sexes, and I have never happened to see an individual of either sex progressing upon, or adhering by, the water-feet of the dorsal canals.

"In a very large proportion of the females which I examined, young were closely packed in two continuous fringes adhering to the water-feet of the dorsal ambulacra (fig. 138). The young were in all the later stages of growth, and of all sizes from 5 up to 40 mm. in length; but all the young attached to one female appeared to be nearly of the same age and size. Some of the mothers with older families had a most grotesque appearance—their bodies entirely hidden by the couple of rows, of a dozen or so each, of yellow vesicles like ripe yellow plums ranged along their backs, each surmounted by its expanded crown of oral tentacles; in the figure the young are represented about half-grown. All the young I examined were miniatures of their parents; the only marked difference being that in the young the ambulacra of the bivium were quite rudimentary—they were externally represented only by bands of a somewhat darker orange than the rest of the surface, and by lines of low papillæ in the young of larger growth; the radial vessels could be well seen through the transparent body-wall; the young attached themselves by the tentacular feet of the trivial ambulacra, which are early and fully developed.

"We were too late at the Falklands (January 23rd) to see the process of the attachment of the young in their nursery, even if we could have arranged to keep specimens alive under observation. There can be little doubt that, according to the analogy of the class, the eggs are impregnated either in the ovarial tube or immediately after their extrusion, that the first developmental stages are run through rapidly, and that the young are passed back from the ovarial opening, which is at the side of the mouth, along the dorsal ambulacra, and arranged in their places by the automatic action of the ambulacral tentacles themselves.

"The very remarkable mode of reproduction of certain members of all the recent classes of Echinodermata by the intervention of a free-swimming bilaterally symmetrical 'pseudembryo' developed directly from the 'morula,' from which the true young is subsequently produced by a process of internal budding or rearrangement, has long been well known through the labours of a host of observers, headed and represented by the late illustrious Professor Johannes Müller of Berlin.

"At the same time it has all along been fully recognised that reproduction through

FIG. 138.—*Cladodactyla crocea* (Lesson). Stanley Harbour, Falkland Islands. Natural size.

the medium of a 'pseudembryo' is not the only method observed in the class, but that in several of the Echinoderm orders, while in a certain species a wonderfully perfect and independent bilateral locomotive zooid may be produced, in very nearly allied species the young Echinoderm may be developed immediately from the segmented yelk without the formation of a 'pseudembryo,' or at all events with no further indication of its presence than certain obscure temporary processes attached to the embryo, to which I have elsewhere given the name of 'pseudembryonic appendages.'[1]

"This direct mode of development has been described in *Holothuria tremula* by MM. Koren and Danielssen, in *Synaptula vivipara* by Professor Oersted, in a 'viviparous sea-urchin' by Professor Grube, in *Echinaster* and in *Pteraster* by Professor Sars, in *Asteracanthion* by Professor Sars, Professor Agassiz, Dr. Busch, and by myself, in *Ophiolepis squamata* by Professor Max Schultze, and in 'a viviparous Ophiurid' by Professor Krohn. No less than four of these observations were made on the coast of Scandinavia. In temperate regions, where the economy of the Echinoderms has been under the eye of a greater number of observers, the development of the free-swimming larva appeared to be so entirely the rule that it is usually described as the normal habit of the class; while on the other hand, direct development seemed to be most exceptional. I was therefore greatly surprised to find that in the Southern Ocean and sub-antarctic regions a large proportion of the Echinoderms of all orders, with the exception perhaps of the Crinoids (with regard to which we have no observations), develop their young after a fashion which precludes the possibility, while it nullifies the object, of a pseudembryonic perambulator, and that in these high southern latitudes the formation of such a locomotive zooid is apparently the exception.

"This modification of the reproductive process consists in all these cases, as it does likewise in those few instances in which direct development has already been described, of a device by which the young are reared within or upon the body of the parent, and are retained in a kind of commensal connection with her until they are sufficiently grown to fend for themselves. The receptacle, in cases where a special receptacle exists in which the young are reared, has been called a 'marsupium' (Sars), a term appropriately borrowed from the analogous arrangement in their neighbours the aplacental mammals of Australia. The young do not appear to have in any case an organic connection with the parent; the impregnated egg from the time of its reaching the 'morula' stage is entirely free; the embryos are indebted to the mother for protection, and for nutrition only indirectly through the mucus exuded from the surface of her perisome, and through the currents of freshly aerated water containing organic matter brought to them or driven over them by the action of her cilia.

"Animals hatching their eggs in this way ought certainly to give the best possible opportunities for studying the early stages in the development of their young. Unfortunately, however, this is a kind of investigation which requires time and stillness and passable comfort; and such are not the usual conditions of a voyage in the Antarctic Ocean. Specimens have been carefully preserved with the young in all stages; and I hope that a careful examination of these may yield some further results.

"*Cladodactyla crocea* is one of the forms in which there is no special marsupium

[1] *Phil. Trans.*, p. 517, 1865.

formed; it is possible that the comparatively genial condition of the land-locked fjords and harbours of the Malvinas, and the additional shelter yielded by the imbricating fronds of *Macrocystis*, may render such exceptional provision unnecessary.

"Five at least of these directly developing Echinoderms representing five principal divisions of the sub-kingdom, were dredged at the Falklands, and several others were found earlier in the voyage in the sub-antarctic regions of the Southern Ocean. It will perhaps give a better idea of the diversity of means by which practically the same end is attained, if I give here a brief description of the principal modifications of the process which were exhibited.

FIG. 139.—*Psolus ephippifer*, Wyv. Thoms. Corinthian Harbour, Heard Island. Three times the natural size.

FIG. 140.—*Psolus ephippifer*, Wyv. Thoms., some of the plates of the marsupium removed. Three times the natural size.

"To give a second example from the Holothurioidea, on the morning of the 7th of February 1874, we dredged at a depth of 75 fathoms, at the entrance of Corinthian Harbour (*alias* 'Whisky Bay') in Heard Island (so far as I am aware the most desolate spot on God's earth), a number of specimens of a pretty little *Psolus*, which I shall here call, for the sake of convenience, *Psolus ephippifer*, although it may very possibly turn out to be a variety of the northern *Psolus operculatus*.

"*Psolus ephippifer* (figs. 134, 135) is a small species, about 40 mm. in length by 15 to 18 mm. in extreme width. In accordance with the characters of the genus, the ambulatory area is abruptly defined, and tentacular feet are absent on the upper surface of the body, which is covered with a thick leathery membrane in which calcareous scales of irregular form are imbedded. The oral and excretory openings are on the upper surface, a little behind the anterior border of the ambulatory tract, and a little in advance of the posterior extremity of the body respectively. A slightly elevated pyramid of five very accurately fitting calcareous valves closes over the oral aperture and the ring of oral tentacles, and a less regular valvular arrangement covers the vent.

"In the middle of the back in the female there is a well-defined saddle-like elevation formed of large tessellated plates somewhat irregular in form, with the surfaces smoothly granulated (fig. 139). On removing one or two of the central plates we find that they are not, like the other plates of the perisome, imbedded partially or almost completely in the skin, but that they are raised up on a central column like a mushroom or a card-table, expanding above to the form of the exposed portion of the plate, contracting to a stem or neck, and then expanding again into an irregular foot, which is imbedded in the soft tissue of the perisome; the consequence of this arrangement is that when the plates are fitted together edge to edge, cloister-like spaces are left between their supporting columns. In these spaces the eggs are hatched, and the eggs or the young in their early stages are exposed by removing the plates (fig. 140). At first, when there are only morules or very young embryos in the crypts, the marsupium is barely raised above the general surface of the perisome, and the plates of the marsupium fit accurately to one another (fig. 139); but as the embryos increase in size, the marsupium projects more and more, and at length the joints between the plates begin to open, and finally they open sufficiently to allow the escape of the young. The young in one marsupium seem to be all nearly of an age. In *Psolus ephippifer* the marsupium occupies the greater part of the dorsal surface, and its passages run close up to the edge of the mouth, so that the eggs pass into them at once from the ovarial opening without exposure.

"In the male there is, of course, no regular marsupium; but the plates are arranged in the middle of the back somewhat as they are in the female, except that they are not raised upon peduncles; so that it is not easy at once to distinguish a male from an infecund female.

"Although we have taken species of *Psolus* sometimes in great abundance in various parts of the world, particularly in high latitudes, southern and northern, I have never observed this peculiar modification of the reproductive process except on this one occasion.

"On the 28th of January 1876 we dredged from the steam pinnace in about 10 fathoms water off Cape Pembroke, at the entrance of Stanley Harbour, Falkland Islands, a number of specimens of a pretty little regular sea-urchin, *Goniocidaris canaliculata*, A. Agassiz.

"The genus *Goniocidaris* (Desor) seems to differ from the genus *Cidaris* in little else than in having a very marked, naked, zigzag, vertical groove between the two rows of plates of each interambulacral area, and one somewhat less distinct between the ranges of ambulacral plates. It includes about half a dozen species, which appear to be mainly confined to the colder regions of the southern hemisphere, although two of the species extend as far to the northward as the East Indies and Natal.

"This species (fig. 141) has a general resemblance at a first glance to the small Mediterranean variety (*affinis*) of *Cidaris papillata*,[1] but the radioles are thinner and much shorter, and differ wholly in their sculpture; the shell is even more depressed; the secondary tubercles are more distant; and a very regular series of short club-shaped rays seated on miliary granules are interposed in the rows between the spines of the second order. The ovarial openings are extremely minute, and are placed close to the outer edge of the ovarial plates. The upper part of the test is quite flat, the flat space including not only the ovarial plates and the plates of the periproct, but the first pair, at least, of the plates of each interambulacral area. Articulated to the primary tubercles of these

FIG. 141.—*Goniocidaris canaliculata*, A. Agassiz. Stanley Harbour, Falkland Islands. Twice the natural size.

latter are two circles of radioles, the inner more slender and shorter, the outer stouter and longer, but both series much larger than radioles usually are in that position on the test.

"These special spines are cylindrical, and nearly smooth, and they lean over towards the anal opening, and form an open tent for the protection of the young, as in *Cidaris nutrix*, a species presently to be described, but at the opposite pole of the body. In this species the eggs are extruded directly into the marsupium; and I imagine, from the very small size of the ovarial openings, that when they enter it, they are very minute, and probably unimpregnated. In the examples which we dredged at the Falkland Islands, the young were, in almost every case, nearly ready to leave the marsupium; we were too late in the season to see the earlier stages, young in the same marsupium are nearly all of an age, some somewhat more advanced than others. The diameter of the test is from 1 to 1·5 mm., and the height about 0·8 mm.; the length of the primary spines

[1] *Dorocidaris papillata* of A. Agassiz.

is, in the most backward of the brood, 0·5 mm., while in the most advanced it equals the diameter of the test. The perisome, in which the cribriform rudiments of the plates of the corona and the young spines are being developed, is loaded with dark purple pigment, which makes it difficult to observe the growth of the calcareous elements. About thirty primary spines arise on the surface of the corona almost simultaneously in ten rows of three each: they first make their appearance as small papillæ covered with a densely pigmented ciliated membrane; and when they have once begun to lengthen, they run out very rapidly until they bear to the young nearly the same proportions which the full-grown spines bear to the mature corona. Very shortly some of the secondary spines, at first nearly as large as the sprouting primary spines, make their appearance in the interstices between these; and a crowd of very small spines rises on the nascent scales of the peristome. Successively five or six pedicellariæ are developed towards the outer edge of the apical area, which at this stage is disproportionately large; the pedicellariæ commence as purple papillæ, which are at first undistinguishable from young primary spines; the first set look enormously large in proportion to the other appendages of the perisome. Almost simultaneously with the first appearance of the primary spines, ten tentacular feet, apparently the first pairs on each ambulacrum of the corona, just beyond the edge of the peristome, come into play; they are very delicate and extremely extensile, with well-defined sucking-disks; and with these the young cling to and move over the spines of the mother, and cling to the sides of the glass vessel, if they are dislodged from the marsupium. This species seems to acquire its full size during a single season. We dredged it at the close of the breeding season, and took no specimens intermediate in size between the adult and the young.

"Among the marine animals which we dredged from the steam pinnace on the 19th of January 1874, at depths of from 50 to 70 fathoms in Balfour Bay (a fine recess of one of the many channels which separate the forelands and islands at the head of Royal Sound, Kerguelen Island), there were several examples of a small *Cidaris*, which I will name provisionally *Cidaris nutrix*[1] (fig. 142).

"This species resembles *Cidaris papillata* in the general form and arrangement of the plates of the corona, in the form and arrangement of the primary tubercles of the interambulacral areas and of the secondary tubercles over the general surface of the test, in the form of the plates of the apical disk and of the imbricated calcareous scales of the peristome, in the form, sculpture, and proportionate length of the primary spines, and in the form of the different elements of the jaw-pyramid and in that of the teeth; but the test is more depressed, the secondary spines which articulate to the ambulacral plates and cover the pore-areas are longer and more cylindrical, not so much flattened as they are in *Cidaris papillata;* the large tulip-like pedicellariæ and the long thin tridactyle pedicellariæ mixed with the secondary spines in the northern species are wanting, or in very

[1] Described by Alex. Agassiz as a variety of *Goniocidaris canaliculata*, Zool. Chall. Exp., part ix., p. 44, 1881.

small number; and the minute pedicellariæ of the peristome are much fewer. The ovaries, which in *Cidaris papillata* have the walls loaded with large expanded calcareous plates, contain only a few small branched spicules; and the calcareous bodies in the wall of the intestine are small and distant. The perforations in the ovarial plates in the female are somewhat larger than in *Cidaris papillata*; and the ripe ova in the ovary appear to be considerably larger.

"The eggs, after escaping from the ovary, are passed along on the surface of the test towards the mouth; and the smaller slightly spatulate primary spines which are articulated to about the first three rows of tubercles round the peristome, are bent inwards over

Fig. 142.—*Goniocidaris canaliculata* (*Cidaris nutrix*, Wyv. Thoms.). Balfour Bay, Kerguelen Island. Natural size.

the mouth, so as to form a kind of open tent, in which the young are developed directly from the egg without undergoing any metamorphosis, until they have attained a diameter of about 2·5 mm.; they are then entirely covered with plates, and are provided with spines exceeding in length the diameter of the test. Even before they have attained this size and development, the more mature or more active of a brood may be seen straying away beyond the limits of the 'nursery,' and creeping with the aid of their first few pairs of tentacular feet out upon the long spines of their mother; I have frequently watched them return again after a short ramble into the 'marsupium.'

"I am not aware that a free pseudembryo, or 'pluteus,' has been observed in any species of the restricted family Cidaridæ; but I feel very certain that *Cidaris papillata* in the northern hemisphere, except possibly in the extreme north, has no marsupial arrangement such as we find in the Kerguelen *Cidaris*. There have passed through my hands during the last few years hundreds of specimens of the normal northern form, of the Mediterranean varieties *Cidaris hystrix* and *Cidaris affinis* (*stokesii*), and of the American *Cidaris abyssicola*,[1] from widespread localities and of all ages; and I have never found the young except singly, and never in any way specially associated with breeding individuals.

"In Stanley Harbour we dredged many specimens of an irregular urchin, much resembling in general appearance *Brissopsis lyrifera*, the common 'fiddle urchin' of the boreal province of the British seas, and probably to be referred to *Hemiaster philippii*, Gray.[2]

Fig. 143.—*Hemiaster cavernosus* (Phil.). Accessible Bay, Kerguelen Island. Twice the natural size.

"These urchins were not breeding when we were at the Falklands, but on the 9th of January 1874 we dredged from the pinnace in shallow water, varying from 20 to 50 fathoms, with a muddy bottom, in Accessible Bay, Kerguelen Island, innumerable samples of apparently the same species.

"The test of a full-sized example (fig. 143) is about 45 mm. in length and 40 mm. in width; the height of the shell in the female is 25 mm., in the male it is considerably less. The apex is nearly in the centre of the dorsal surface; the genital openings are three in number, in the female very large; the bilabiate mouth is placed well forward on the ventral aspect; and the excretory opening is posterior and supramarginal. The odd anterior ambulacrum is shallow, and the tube-feet which are projected from it are large and capitate. The anterior paired ambulacra are somewhat longer than the posterior. The whole of the surface of the test is covered with a close pile of small spines of a dark green colour; those fringing the ambulacral grooves are long and slightly curved, and they bend and interdigitate so accurately over the ambulacra that one might easily overlook the grooves at a first glance. The peripetalous fasciole is somewhat irregular; but in those examples in which it is best defined it forms a wide arch, extending backwards on each side a little beyond the lateral ambulacra of the trivium, and then, contracting a little, forms a rudely rectangular figure round the bivium. The paired ambulacral grooves in the male are shallow, not much deeper than the anterior ambulacrum (fig. 145); in the female the pore-plates of the paired ambulacra are greatly expanded and

[1] These are regarded by Alex. Agassiz as varieties or developmental stages of *Dorocidaris papillata*; see Zool. Chall. Exp. part ix. p. 44, &c., 1881.

[2] Described by Alex. Agassiz as *Hemiaster cavernosus* (Philippi), *loc. cit.*, p. 177.

lengthened, and thinned out and depressed so as to form four deep, thin-walled, oval cups sinking into and encroaching upon the cavity of the test, and forming very efficient protective 'marsupia' (fig. 144). The ovarial openings are, of course, opposite the inter-

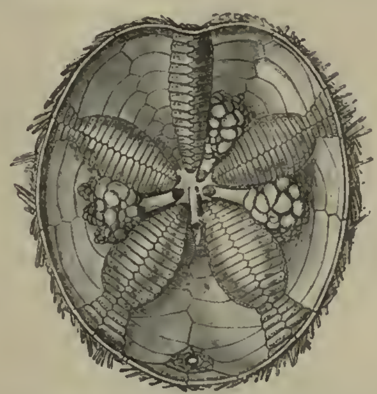


FIG. 144.—*Hemiaster cavernosus* (Phil.). The apical portion of the test of the female seen from within. Slightly enlarged.

FIG. 145.—*Hemiaster cavernosus* (Phil.). The apical portion of the test of the male seen from within. Slightly enlarged.

radial areas; but the spines are so arranged that a kind of covered passage leads from the opening into the marsupium; and along this passage the eggs, which are remarkably large, upwards of a millimetre in diameter when they leave the ovary, are passed, and are arranged very regularly in rows on the floor of the pouch, each egg being kept in its place by two or three short spines which bend over it (fig. 146).

FIG. 146.—*Hemiaster cavernosus* (Phil.). The arrangement of the eggs in one of the marsupial recesses. Five times the natural size.

"Among the very many examples of this *Hemiaster* which we dredged in Accessible Bay, and afterwards in Cascade Harbour, Kerguelen, there were young in all stages in the breeding pouches; and although from the large size and the opacity of the egg and embryo it is not a very favourable species for observation, had other conditions been favourable, we had all the material for working out the earlier stages in the development of the young very fully. The eggs, on being first placed in the pouches, are spherical granular masses of a deep orange colour, enclosed within a pliable vitelline membrane, which they entirely fill. They become rapidly paler in colour by the development of the blastoderm; they then increase in size probably by the imbibition of water into the gastrula-cavity; and a whitish spot with a slightly raised border indicates an opening which, I have no reason to doubt, is the permanent mouth; but of this I cannot be absolutely certain. The surface now assumes a translucent appearance, and becomes deeply tinged with dark purple and greenish pigment; and almost immediately, without any definite intermediate steps, the outer wall is filled with calcified tissue, it becomes covered with fine spines and pedicellariæ, a row of tentacular feet come into action round the mouth, the vent appears at the posterior extremity of the body and the young assumes nearly the form of the adult. These later changes take place very quickly; but they are accompanied by the production of so much heavy purple and dark green pigment that it is difficult to follow them. The viscera are produced at the expense of the abundant yelk; and the animals at once take a great start in size by the imbibition of water into the previsceral cavity. The young urchins jostle one another on the floor of the breeding pouch, those below pushing the others up until the upper set are forced out between the rows of fringing spines of the pouch; but even before leaving the marsupium, on carefully opening the shell of the young, the intestine may be seen already full of dark sand, following much the same course which it follows in the adult. The size of the test of the young on leaving the marsupium is about 2·5 mm. in length by 2 mm. in width.

"We took along with the last species in Stanley Harbour several specimens of a large species of *Asteracanthion* which formed a marsupium after the manner so well described by Sars in *Echinaster sarsii*, Müller, by drawing its arms inwards and forwards, and forming a brood-chamber over the mouth. In some samples of this species the young were so far advanced that when the mother was placed in a jar they crept out of the nursery and wandered over the glass wall of their prison; this brood had entirely lost the 'pseudembryonic appendages,' but in their younger condition these are very apparent, though scarcely so well developed as in the young of *Asteracanthion violaceus* on our own coast.

"On the 27th of January 1874, at Station 149, off Cape Maclear on the southeast coast of Kerguelen Island, we dredged a handsome starfish allied to *Luidia* or *Archaster*, which has since been described by Mr. Edgar Smith, from specimens brought home by the Rev. Mr. Eaton, under the name of *Leptychaster kerguelensis* (fig. 147).

"A well-grown example is from 100 to 120 mm. in diameter from tip to tip of the arms; the length of the arm is about three times its width near the base, and three times the diameter of the disk. The marginal plates are long and narrow, running up with a slight curve outwards from the edge of the ambulacral groove until they meet the border of the dorsal perisome above; they are closely set with short blunt spines, which become gradually a little longer towards the radial groove; and at the edge of the groove each plate bears a tuft of about six rather long spines: these tufts in combination form a scalloped fringe spreading inwards on each side over the groove. The dorsal surface of the body is covered with a tessellated pavement composed of capitate paxilli. The heads of the paxilli in close apposition combine to form a mosaic with rudely hexagonal facets; and as they are raised upon somewhat slender shafts, whose bases, like the plinths of columns, rest upon the soft perisome, arcade-like spaces are left between the skin and the upper calcareous pavement. The eggs pass into these spaces from the ovarial openings: on bending the perisome and separating the facets, they may be seen in numbers among the shafts of the paxilli. There is a continual discharge of ova into the passages, so that eggs and young in different stages of development occupy the spaces at one time. The young do not escape until at least six ambulacral suckers are formed on each arm; they

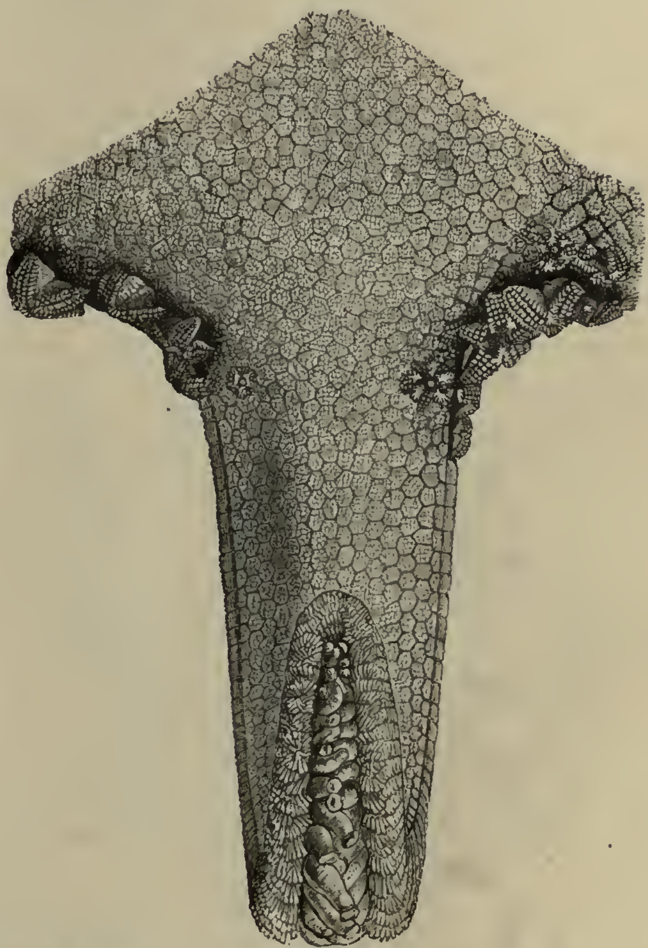


FIG. 147.—*Leptychaster kerguelensis*, E. A. Smith. Off Cape Maclear, Kerguelen Island. Twice the natural size.

may then be seen pushing their way out by forcing the paxilli to the side, and squeezing through the chink between them. While it is extricating itself the oral surface of the young is always above: and the centre of the star with the mouth is usually the part which first protrudes; then the arms disengage themselves one after another, many of the brood remaining for a time with one or two arms free and the others still under the paxilli. When the young have become disengaged, they remain for a considerable time attached to the parent by the centre of the dorsal surface. I could never satisfy myself by what means this is effected; the attachment is very slight, and they are removed by the least touch. In this attached stage until they entirely free themselves, which they do when the number of tentacular feet on each arm has reached about twenty, they cluster in the re-entering angles between the arms of the mother, spreading a little way along the arms and on the dorsal surface of the disk; the young escape from the marsupium chiefly in the neighbourhood of the angles between the rays. The madreporiform tubercle is visible in the young near the margin of the disk between two of the arms; but in the mature starfish it is completely hidden by the paxilli, and no doubt it opens into the space beneath them.

"We took *Leptychaster* in the act of bringing forth young on that one occasion only; and the weather was so boisterous at the time that it was impossible to trace the early stages in the development of the embryo. It is evident that the process generally resembles that described by Professor Sars in *Pteraster militaris,* O. F. Müll.; and it is quite possible that, while there is certainly not the least approach to the formation of a locomotive bipinnaria, as in that species, some provisional organs may exist at an early period.

"In The Depths of the Sea (p. 120) I noticed and figured a singular little starfish from a depth of 500 fathoms off the north of Scotland under the name of *Hymenaster pellucidus.* This form was at that time the type of a new genus; but the researches of the last three years have shown that, with the exception perhaps of *Archaster, Hymenaster* is the most widely distributed genus of Asterids in deep water. It is met with (sparingly, it is true, only one or two specimens being usually taken at once in the trawl) in all parts of the great oceans; and it ranges in depth from 400 to about 2500 fathoms.

"On the 7th of March 1874 we dredged an extremely handsome new form, to which I shall give provisionally the name of *Hymenaster nobilis,* in lat. 50° 1′ S., long. 123° 4′ E., 1099 miles southwest of Cape Otway, Australia, at a depth of 1800 fathoms, with a bottom of Globigerina ooze, and a bottom temperature of 0°·3 C.

"*Hymenaster nobilis* (fig. 148) is 300 mm. in diameter from tip to tip of the rays; the arms are 55 mm. wide; and, as in *Hymenaster pellucidus,* a row of spines fringing the ambulacral grooves are greatly lengthened and webbed, and the web running along the side of one arm meets and unites with the web of the adjacent arm, so that the angles between the arms are entirely filled up by a fleshy lamina stretched over and supported by spines, the body thus becoming a regular pentagon. The upper surface of the body, the disk, and the arms,—all the surface except the smooth membrane between the arms,—are covered with fascicles of four to six diverging spines. These spines are about 3 mm. in height; and they support and stretch out a tolerably strong membrane clear above the surface of the perisome, like the canvas of a marquee, leaving an open space beneath it. A close approach to this arrangement occurs also in *Pteraster.*

"At the apical pole the upper free membrane runs up to and ends at a large aperture, 15 mm. in diameter, surrounded by a ring of five very beautifully formed valves. These valves do not essentially differ from the ordinary radiating supports of the marsupial tent; a stout calcareous rod arises from the end of the double chain of ossicles which form the floor of the ambulacral groove. From the outer aspect of this support three or four spines diverge in the ordinary way under the tent-cover; but from its inner aspect six or eight slender spines rise in one plane with a special membrane stretched between them. When the valves are raised and the pentagonal chamber beneath them open, these spines separate from one another, and, like the ribs of a fan, spread out the membrane in a crescentic form (fig. 148); and when the valves close, the spines approximate and are

Fig. 148.—*Hymenaster nobilis*, Wyv. Thoms. Southern Ocean. Half the natural size.

drawn downwards, the five valves forming together a very regular, low, five-sided pyramid (fig. 149). Looking down into the chamber when the valves are raised, the vent is seen on a small projecting papilla in the centre of the floor; and between the supporting ossicles of the valves, five dark open arches lead into the spaces opposite the re-entering angles of the arms, which receive the ducts of the ovaries. In the particular specimen to which I have referred, which is considerably the largest of the genus which we have yet met with, there were one or two eggs in the pouch, but they were apparently abortive. It seemed that the brood had been lately discharged; for some oval depressions still remained on the floor of the central chamber, in which the eggs or the young had evidently been lodged. I have on three occasions in species of the genus *Hymenaster* found the eggs beneath the membrane in the angles of the arms, and, in a more advanced stage, congregated in the central tent, but never under circumstances such that I could keep and examine them; exposed or loosely covered eggs or embryos, or any soft and pulpy organs or appendages, are always in a half disintegrated state when they are brought up from such great depths, if they have not been entirely washed away.

"As I have already said, *Hymenaster* is closely allied to *Pteraster:* the arrangements of the marsupium are nearly the same in both; and it is highly probable that, in *Hymenaster*, as in *Pteraster militaris,* a provisional alimentary tract may be developed in the early stages of the embryo.

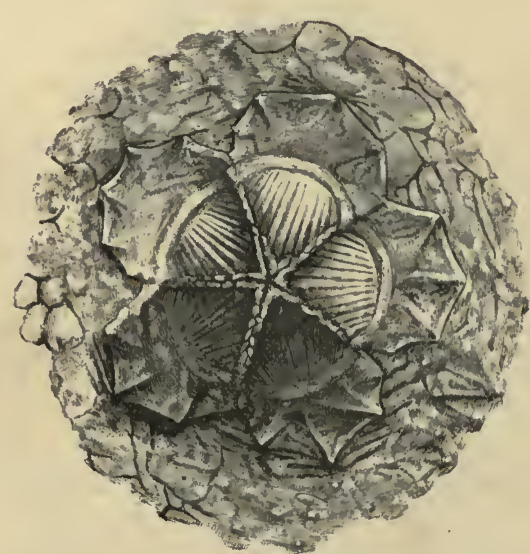


FIG. 149.—*Hymenaster nobilis,* Wyv. Thoms. The marsupial tent with the valves closed. Twice the natural size.

"There are several fine species of *Hymenaster* within reach of British naturalists in the deep water at the entrance of the Channel and off Cape Clear; but I fear there will be great difficulty in determining this point unless the genus turn up somewhere in shallower soundings where specimens can be taken alive.

"In Stanley Harbour, on the roots of *Macrocystis,* and also brought up free by the dredge, there were numerous examples of an Ophiurid which appears to correspond with *Ophiacantha vivipara,* Ljungman; we had previously got either the same or a very closely allied form in great abundance in the fjords of Kerguelen. The Kerguelen variety has been noticed by Mr. Edgar A. Smith,[1] under the name of *Ophioglypha hexactis,* and I have called it, provisionally, in a paper in the Proceedings of the Linnæan Society, *Ophiocoma didelphis,* from its opossum-like habit of carrying its young upon its back.

[1] *Ann. and Mag. Nat. Hist.,* ser. 4, vol. xvii. p. 3, 1876.

I do not think that it can properly be relegated to any genus at present defined, but it will doubtless fall into its place when the Ophiurids shall have been revised.

"The disk is about 20 mm. in diameter; and the arms are four times the diameter of the disk in length. The disk is uniformly coarsely granulated; the arm-shields, which are well defined through the membrane, are rounded in form and roughly granulated like the remainder of the disk. The character which at once distinguishes this species from all the others of the genus is, that the normal number of the arms is six or seven instead of five, which is almost universal in the class. The number of arms is subject

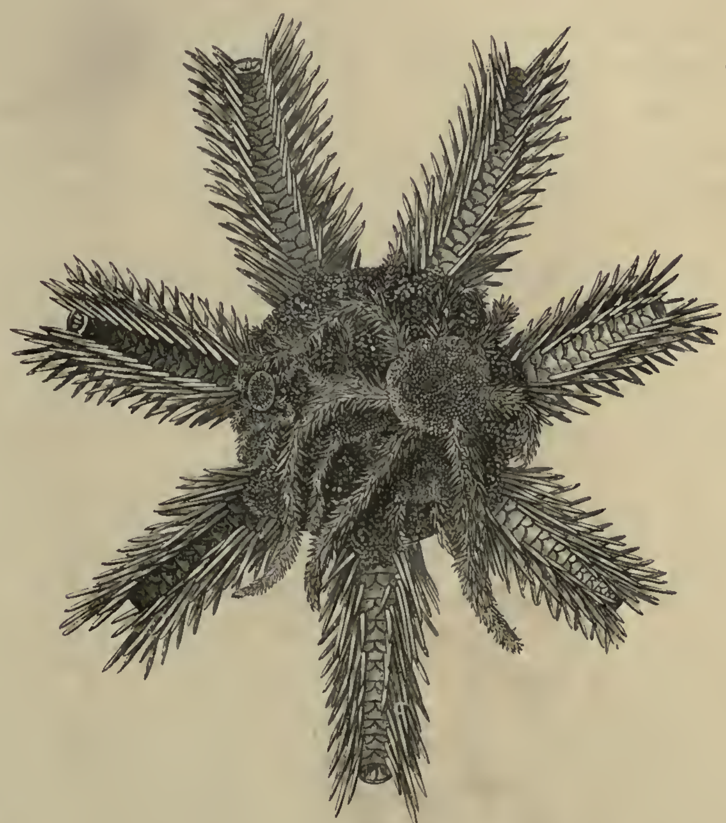


FIG. 150.—*Ophiacantha vivipara*, Ljungman. Falkland Islands. Twice the natural size.

to certain variation. I have seen from six to nine, but never fewer than six. The arm-spines are numerous and long. The general colour of the disk and arms is a dull greenish brown.

"A large proportion of the mature females, if not all of them, had a group of from three to ten or twelve young ones clinging to the upper surface of the disk by their arms: the largest of these were about a quarter the size of their mother; and they graduated down in size until the smallest had a diameter of less than 1·5 mm. across the disk. The largest and oldest of the progeny were always uppermost, farthest from the disk, the series decreasing in size downwards, and the supply evidently coming from the genital clefts beneath. In several specimens which I examined, although by no means in all, there were groups of eggs and of young in still earlier stages, free in the body-cavity in the interbrachial spaces.

"It thus seems that in this case the true 'marsupium' is a portion of the body-cavity, and that the protection afforded by it is supplemented by the attachment of the young to the surface of the disk, maintained for some time after their extrusion or escape.

"The process of propagation in *Ophiacantha vivipara* differs from most of the other cases described, in the eggs being successively hatched, and the young being found consequently in a regularly graduated series of stages of growth. Although I had not an opportunity of working the matter out with the care and completeness I could have wished, I feel satisfied, from the examination of several of the young at a very early period, that in this case no provisional mouth and no pseudembryonic appendages whatever are formed, and that the primary aperture of the gastrula remains as the common mouth and excretory opening of the mature form. From the appearance of the ovaries and of the broods of young, I should think it probable that this species gives off young in a continuous series for a considerable length of time, probably for some months.

"I have selected these illustrations of the development of the young of Echinoderms from the egg without the intervention of a locomotive 'pseudembryo' from a much larger number. As I have already said, I cannot, on account of the unfavourable conditions for carrying on such investigations under which the majority of the species were procured, say with certainty that no trace of pseudembryonic appendages or provisional organs exist in any of these instances, but I feel satisfied that none such occurs in *Psolus ephippifer*, in *Hemiaster cavernosus*, or in *Ophiacantha vivipara*. Neither am I in a position to state that in these southern latitudes direct development is universal in the sub-kingdom. I believe indeed that it is not so; for species of the genera *Echinus*, *Strongylocentrotus*, and *Amblypneustes* run far south, and a marsupial arrangement seems improbable in any of these. It is, however, a significant fact that, while in warm and temperate seas 'plutei' and 'bipinnariæ' are constantly taken in the surface-net, in the Southern Ocean they are almost entirely absent."

From Heard Island to the Antarctic Circle and Australia.

It will doubtless be interesting to navigators to know how the Challenger fared when cruising in the little-known region of the Antarctic and among the ice, therefore the various movements of the ship are here given in detail.

On the 8th February, at 1 A.M., a heavy sea struck the ship and stove in the two


SOUNDINGS AND STATIONS
in the neighbourhood of the
ANTARCTIC CIRCLE
between the 78th & 98th Meridians of E.Longitude
showing the position of Pack ice
and floating Bergs encountered
Feby 1874.
For explanation of abbreviations &c. see Appendix 1.
80°
85°
90°
95°
100°
60°
65°
85° Long. East from Greenwich
First Iceberg seen 2000 ft long 219 ft high
1260
diatom ooze
Whales seen
Sea a dirty green colour
Sea an olive green colour
One or two Whales seen
A few Whales
1675
blue mud
Pack Ice and Bergs
A few Whales
Pack Ice
Pack Ice
Numerous Whales and Grampus
Pack Ice and Bergs
Wind Var ble
1800
blue mud
Icebergs from 150 to 200 feet high
Calm
Calm
Calm
1975
diatom ooze
26.II.74
28.II.74
10.II.74
15.II.74
Pack Ice
1300
blue mud
Pack Ice
88 Icebergs in sight at Sunset
Assumed position of Termination Land
(Not seen in H.M.S. Challenger)
Pack Ice 1840
Track of U.S.S. Vincennes 1840

foremost ports on the starboard side of the main deck, floating everything out of the sick-bay, but fortunately there was no one ill enough to be occupying the swinging cots. The gale broke shortly after this accident, and the barometer beginning to rise, at 4 A.M. courses were set and the vessel bore up to the southward. At 8 A.M. the wind had moderated sufficiently to allow of all plain sail being made, and the day was beautifully clear, with a fairly dry atmosphere, which was appreciated after the five days' mist in the vicinity of Heard Island. This fine weather enabled the ship to keep running south all night, a sharp look-out being kept for icebergs, but none were seen although the vessel was in lat. 56° S.

On the 9th the weather still continued fine and clear, and the breeze moderate. A few light squalls accompanied with snow were experienced, during which the minimum thermometer fell to freezing point. No icebergs were sighted. In the afternoon the weather appeared very settled, with high clouds and a steady barometer (29·017 inches), and a view of from 15 to 20 miles was commanded from aloft.

On the 10th a fresh breeze was experienced all day till 6 P.M., the anemometer giving a velocity of 19 miles per hour, the barometer standing at 29·050 inches, but seeming towards evening inclined to rise. Mean temperature in shade 33°·8; position at noon, lat. 60° 2′ S., long. 77° 20′ E. No ice seen. The direction of the wind (S.W. by W.) prevented the ship being steered towards the spot in lat. 60° S., long. 72° E., where Biscoe and Kemp reported the appearance of land in 1833–34, and the absence of icebergs appeared to indicate that they were deceived. Occasional snow squalls were experienced, which limited the range of vision to from two to four miles.

On the 11th, at 2.50 A.M., the first iceberg was sighted. At 5 A.M. sails were furled,

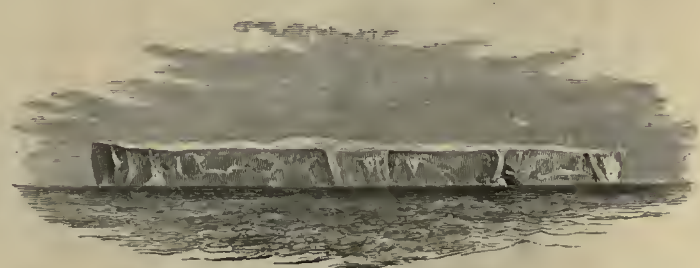


FIG. 151.—Iceberg first seen, 11th February 1874.

and a sounding, trawling, and serial temperatures were taken in 1260 fathoms, Diatom ooze, Station 152 (see Sheet 23). The cutter moored to the trawl line showed the surface current to be setting N.E. true, one-third of a mile per hour, agreeing in direction, though not in velocity, with the result obtained by astronomical observation. The position of the ship was lat. 60° 52′ S., long. 80° 20′ E. The iceberg originally seen was in sight during the trawling operations, and was found to be, by angular measurement, 219 feet high and 2100 feet in length; if a cube, its depth under water would be about 1800 feet. It was one of the table-topped bergs, and appeared to be quickly disappearing, for it calved in the forenoon, making a considerable commotion in the water near it.

Considerable difficulty was experienced in obtaining any satisfactory temperature observations, as the thermometers, when lowered to greater depths, came up showing the same result as at 50 fathoms.

At 2.30 P.M. the trawl came up fouled, although with a few specimens. Whilst trawling two pieces of drift ice were seen to the eastward; as these were not visible when sounding operations were commenced, and the ship remained stationary whilst trawling, they must have drifted into view. At 3.30 P.M. sail was again made to the southward. At 9 P.M. a piece of drift ice was passed about 100 feet long and 6 feet high, probably the remains of an old berg. The weather during the day was cloudy, but the sun was visible occasionally for a few minutes, so that the position could be ascertained; the horizon was clear and the sea moderate, and a view of 15 or 20 miles commanded from the masthead. A White Petrel was seen during the first watch. The barometer rising; temperature of air, 34°·7.

On the 12th, at 9.50 A.M., a peaked berg about 100 feet high was seen to the E.S.E., and at 5.40 P.M. two others, one to the southward, and the other to the westward; at 6 P.M. the ship passed close by the southward berg, which was about 60 feet high, with a little drift ice in its vicinity, and of a beautiful cobalt blue colour near its base. At 8 P.M. no ice was in sight. A little before midnight another berg was seen to the southward. The weather during the day was overcast, with a drizzling rain, which on one occasion was so thick as to necessitate laying to, for vision was limited to from a quarter of a mile to 4 miles, the wind being northerly in direction and variable in strength. The barometer stood at 29·500, but fell to 28·862 inches at midnight. No Penguins had been seen since leaving Heard Island. At 11 P.M. the vessel "hove to" until daylight, just in time to avoid collision with an iceberg.

On the 13th, at 2.45 A.M. (daylight), sail was again made to the southward; two icebergs in sight. In the morning watch three others were passed, in addition to several pieces of wash ice. At noon, in lat. 64° 38′ S., long. 80° 0′ E., one berg only was in sight. In the afternoon two additional bergs were sighted and passed, and at 7.40 P.M. the ship passed within a cable's length of the seventeenth berg, which was a peaked one about 100 feet high. Between 8.30 P.M. and 10 P.M. two more bergs were passed, and at 11 P.M. the vessel ran into a quantity of brash ice, with numerous bergs to the southward, and so hauled to the wind on the starboard tack for the night. The weather on this day was fairly fine, the sun visible from noon until 3 P.M., and the horizon clear. The wind moderate; the barometer steady at 28·781 inches. Temperature of the air 34°, of the sea surface 33°, but this fell to 29°·5 when the brash ice was entered. No Albatrosses seen, but numerous Cape Pigeons and Prions, and a few Whales.

Plate X.

Horsburgh, Edinburgh. Permanent Phototype.

ANTARCTIC ICE.

On the 14th, at 3 A.M., the ship wore and stood in towards the brash ice, and at 6 A.M. sails were furled, steam got up, and a sounding, dredging, and serial temperatures were taken in 1675 fathoms, blue mud, Station 153 (see Sheet 23). Pack ice and numerous bergs were in sight to the southeastward, the position of the ship being lat. 65° 42′ S., long. 79° 49′ E.

The serial temperature observations on this date were very successful, as some of the brash ice could be collected, and the thermometers cooled before immersion. Each thermometer when immersed showed a temperature of 30°·2, both on the maximum and minimum sides. At 50, 100, and 200 fathoms they came up registering 30°·2 on the maximum side, and 29° on the minimum side, showing that to the depth of 1200 feet the water was at a uniform temperature of 29°. The thermometers sent down to the depth of 300 and 500 fathoms, and to the bottom, gave different results, for at 300 fathoms the maximum index registered a temperature of 32° and the minimum 29°; at 500 fathoms the maximum index registered 32°·8 and the minimum 29°, and at the bottom the maximum was 33° and the minimum 28°·8. These results show that below the depth of 200 fathoms the temperature of the water rose gradually to 32°·8 at about 500 fathoms, but, unfortunately, it was impossible to tell what happened below that depth, as the thermometer came up showing the same result as at 500 fathoms. It was a matter of much regret that the bottom temperature could not be ascertained with certainty, it cannot, however, be less than 28°·8 nor more than 33°. It is remarkable that the water retains a temperature of 29° to 200 fathoms, or a depth slightly less than that of the icebergs, and that the temperature of the surface water was 33°, or the same as that of the warm underlying strata a few miles northward of the edge of the brash ice and icebergs, which would point to the conclusion that the cold upper layer was only local, and that it did not sink to the bottom, the greater specific gravity, due to its lower temperature, being more than counterbalanced by the admixture of the snow water from the bergs.

At 3.30 P.M., after heaving in the dredge, sail was made, the ship standing to the westward along the edge of the pack ice. At 6 P.M. there were forty-seven bergs in sight, and the pack extended from south to east, with apparently open sea to the southwestward. At 8 P.M. more pack ice was seen extending from W.N.W. to S.E., so at 10.30 P.M. the ship hauled to the northward under easy sail. The weather during the day was cloudy (occasionally misty), with passing snow showers, the wind light and variable, the barometer steady at 28·765 inches, mean temperature of the air 32°·5, the range of vision limited to about four miles.

On the 15th the wind was light and variable all day with a smooth sea and a clear horizon. Barometer steady at 28·827 inches, mean temperature of air 29°, of sea surface 30°·7. Position at noon, lat. 65° 59′ S., long. 78° 24′ E. Pack ice and numerous icebergs seen throughout the day. The icebergs seen on this and the previous day were mostly tabular, from 100 to 200 feet in height.

During the calm weather numerous Cape Pigeons were observed on the tabular bergs, and had they not been seen breeding at Heard Island it might have been fancied that they used the ice for the purpose.

On the 16th, at 2 A.M., the ship again running into a quantity of brash ice, which was apparently thick from S.W. to W. by N. the vessel wore round to the northwards. At 4 A.M. a large number of icebergs were in sight; one being pyramidal in shape and of a peculiar blue colour like a turquoise; at 7 A.M. it fell calm, and the sea being smooth steam was got up in order, if possible, to effect a landing on the ice, and obtain a series of magnetic observations free from the local errors of the ship. Although the sky overhead was clouded the atmosphere was remarkably clear, so that objects 20 miles distant appeared only five or six miles off, so much so that icebergs at that distance seemed from the masthead to be a line of unbroken pack, or a large floe, but on steaming towards them always turned out to be the usual tabular bergs. Some of these were very large, at least four miles in length, but all about the height of 200 feet, and all with steep, inaccessible sides. At 10 A.M., seeing no chance of effecting a landing on the ice, the small pieces in the pack rising and falling with the swell, and the bergs being inaccessible, sail was made and the vessel stood to the southward. Although the sky overhead was covered with an impervious cloud all the forenoon, so that the position of the ship could not be ascertained by astronomical observation in the early part of the day, the sun was shining on all the distant bergs, and there were no clouds of any description near the horizon from S.W. to S.E. (true).

At 2.30 P.M., having stood 10 miles southward of the Antarctic Circle, the vessel tacked and stood to the northward. At this time there was no pack ice in sight but a large number of icebergs as far as the eye could reach, some of them certainly two or three miles in length. The clear sky to the southward was just what could have been wished had the object been to attain a very high latitude, for land of any elevation would certainly have been seen at a distance of 50 or 60 miles had it existed. The object, however, was not to attain a particularly high latitude, but merely to make observations on the temperature and depth of the sea in the vicinity of the ice, and it would have been foolish to go farther south in an unfortified ship with only six months' provisions on board. At 3.30 P.M. the sun shone out, and at 5 P.M. a double altitude was obtained which gave the position. At 2.30 P.M., when the ship tacked to the northward, the position was lat. 66° 40′ S., long. 78° 22′ E. The absence of pack ice at the turning point indicated that the pack seen on the two previous days was a detached floe. A number of Penguins on small detached pieces of ice were passed during the day, and several Whales were seen. The weather was fine all day, calm in the forenoon, an easterly breeze in the afternoon, which gradually freshened; the barometer steady at 28·800 inches till noon, after which it fell; the mean temperature of the air 29°, and of the surface water 30°·5. At 8 P.M. the topsails were double reefed, and at 11 P.M. the ship hove to, the weather having become misty and snow squalls passing over.

Plate XI.

Horsburgh, Edinburgh. Permanent Phototype.

ANTARCTIC ICE.

On the 17th, at 3 A.M., the vessel stood to the eastward, close hauled on the starboard tack. At 4 A.M. there were two icebergs in sight, at 8 A.M. one, and at noon none. At 4 P.M. a small berg was passed, after which the vessel appeared to be to the northward of the chain. It is fortunate that the number of icebergs diminishes so rapidly from the pack ice; on running to the southward only seventeen icebergs were passed in 200 miles, and then the ship ran into a chain of them within 15 or 20 miles of the edge of the pack. Cook and Wilkes remark the same peculiarity. On the previous evening the vessel ran quite out of the chain of bergs, and during the night never more than two were in sight at one time. A fresh breeze was blowing with cloudy, gloomy weather and occasional snow squalls all day, the limit of vision being two to three miles, the wind shifting gradually to S.E. and S. (true), the barometer standing fairly steady at 28·639 inches, temperature of the air 29°·7, of the surface water 32°·5, the sea a dirty green colour; towards evening the weather cleared so that the ship was enabled to stand on all night, there being few bergs in sight. Position at noon, lat. 65° 5′ S., long. 78° 55′ E.

On the 18th at daylight three bergs were in sight, and at 4 A.M., five. At 6.40 A.M. the pack ice was seen to the southward, with a quantity of stream ice off it, and from 7 A.M. until noon the ship was passing through this stream ice. At noon the vessel passed out of the stream ice, but the pack remained in sight until nearly 4 P.M., and numerous bergs were visible, twenty being counted at 2 P.M. This pack ice was quite close, no lanes of water through it being seen from the masthead. At 4 P.M. the pack was lost sight of astern. At 8 P.M. the ship hove to for the night in consequence of a heavy snowstorm obscuring the view. The weather during the day was fine until 8 P.M. with a S.S.W. wind (true), the barometer rising slowly and steadily from 28·704 to 28·879 inches, mean temperature of air 25°·6, of surface water 30°·8. Position at noon, lat. 64° 44′ S., long. 83° 26′ E. The minimum thermometer fell to 22°. The atmosphere was rather misty round the horizon, the upper parts of some of the distant bergs being capped with mist, but the sun broke through the clouds occasionally. Close to the pack the surface temperature was 27° to 29°, at a little distance from it 32° to 33°. The stream ice, through which the ship passed in the forenoon, consisted of lumps of water ice some 20 to 30 feet in diameter with snow on their upper sides; the vessel came into collision with a piece now and then which gave her a good bump.

On the 19th, at 2 A.M., sail was again made and the ship stood to the eastward, but the wind having died away by 8 A.M. steam was got up and a sounding and serial temperatures were taken in 1800 fathoms, blue mud, Station 154, in lat. 64° 37′ S., long. 85° 49′ E. (see Sheet 23). The serial temperatures gave much the same result as on the 14th, the temperature falling to 29° at 50 fathoms, and remaining at that to 200 fathoms, afterwards rising to 33° at 300 fathoms. At noon sail was made on the port tack to a light easterly breeze, but at 4 P.M., there being many icebergs in sight, the ship tacked and stood to the northward to get into a clearer sea before dark, and at 10.30 P.M.

hove to until daylight. At 6 P.M. forty bergs were counted from the masthead. The weather continued fine during the day, with a smooth sea and a moderate east wind (true), the clouds were more detached than usual, the sun being visible at intervals during the whole day. The atmosphere rather misty, the barometer steadily falling from 28·880 to 28·515 inches, temperature of air 29°, of surface water 32°·4.

On the 20th, at 3 A.M., sail was made on the starboard tack, the easterly wind preventing the ship getting towards Wilkes' Termination Land as quickly as was desired. Numerous bergs were in sight all day, at one time sixty-nine were counted, but no pack ice was seen. At 10.30 P.M. the vessel was again obliged to heave to under topsails and jib for the night. A moderate breeze blew from the southeast all day, the sky being overcast, and the sea smooth, the barometer gradually rising from 28·533 to 28·828 inches. Temperature of the air 29°·5, and of the sea surface 32°·6. Some Penguins and Whales were seen in addition to the usual sea birds.

On the 21st the weather was calm all day, cloudy and misty in the forenoon, but

FIG. 152.—Iceberg seen 21st February 1874.

clear in the afternoon and evening. Numerous icebergs were in sight, seventy-eight being counted from the deck. At 4 P.M., the weather still remaining calm, steam was got up and the ship proceeded towards an iceberg about one mile distant; stopping close to the berg it was photographed, and afterwards the 12-pounder was fired at it. The first shot was directed at a low part of the berg about 100 feet from the ship, and striking against pure ice split off a great mass from the ice-cliff, which, tumbling into the water between the berg and the ship, created quite a commotion. The second shot was directed at the upper part of the berg about a third of the distance below the summit, which was 180 feet high, and striking against the softer part merely buried itself in the snow-cliff. The sun shining out at this time the opportunity was taken of swinging the ship to ascertain

Plate XII.

Horsburgh, Edinburgh

Permanent Phototype

ANTARCTIC ICE.

the deviation and variation of the compass, this being the first opportunity experienced of doing so since leaving the Cape of Good Hope. Having completed swinging at 7 P.M. the vessel proceeded under easy steam to the eastward. At 10 P.M. a fine aurora lit up the surrounding icebergs. During the afternoon serial temperatures were obtained at every 10 fathoms to 50 fathoms, which showed a gradual decrease from 32° at the surface to 29°·3 at 40 fathoms. The barometer was steady at about 28·810 inches, temperature of the air 29°·8, temperature of sea surface 32°·4; position at noon, lat. 63° 30′ S., long. 88° 57′ E.

On the 22nd, the weather continuing calm all the forenoon, and steam being up, the ship was swung to ascertain the errors of the dipping needle, which took until 2 P.M., when a westerly breeze having sprung up all sail was made towards Termination Land. Numerous icebergs were in sight all day, thirty-two being counted at 4 P.M., but no pack ice was seen. Several of the bergs passed had perpendicular fractures extending

FIG. 153.—Iceberg seen 23rd February 1874.

from the summit some way down their sides. The weather during the day was fine with a light wind and smooth sea, cloudy in the forenoon, but bright and sunny in the afternoon, the barometer rising slowly and steadily from 28·796 to 29·096 inches. Mean temperature of air 31°·4, of sea surface 32°·8. On the 21st and 22nd there was a heavy bank of clouds to the northward; the view on the latter date was uninterrupted from east round south to west, but was limited to about 8 or 9 miles in the northern part of the horizon. The position at noon was lat. 63° 30′ S., long. 91° 11′ E.

On the 23rd the ship hove to just after midnight until 2 A.M., the horizon ahead being darkened by a heavy bank of clouds. At daylight the weather cleared, and the day was remarkably fine with smooth water and a clear atmosphere. The wind falling light at noon steam was got up and the vessel proceeded towards Termination Land, then distant about 45 miles. Numerous icebergs were in sight. During the afternoon the ice blink was seen ahead, and at 6 P.M. the pack was plainly in sight from E. by S. to S. by W. (true). At 7.30 P.M. the ship stopped off the edge of the pack in lat. 64° 18′ S., long. 94° 47′ E., but although the horizon was clear to the eastward nothing was seen of Wilkes' Termination Land, the supposed position of which was then 20 miles east. The pack preventing the vessel steaming farther east, a sounding was obtained in 1300 fathoms, blue mud, Station 155 (see Sheet 23), and then the ship laid to for the night under gaff mainsail and jib. At 5 P.M. eighty-eight icebergs were counted from the deck. At sunset the horizon was remarkably clear to the southward and eastward, but to the northward there were dense masses of cumulus cloud, and the sky had a hard appearance. The barometer rose from 29·103 to 29·163 at 2 P.M., and then fell to 29·039 inches at midnight. Mean temperature of the air 31°·3, of the sea surface 32°·1. During the day an iceberg was passed with a large rock on it, the first hitherto seen, the berg was too far off to distinguish the nature of the rock, or whether it had on it more than one. The bergs passed were nearly all tabular.

On the 24th, at 4 A.M., the dredge was put over, but the barometer falling quickly

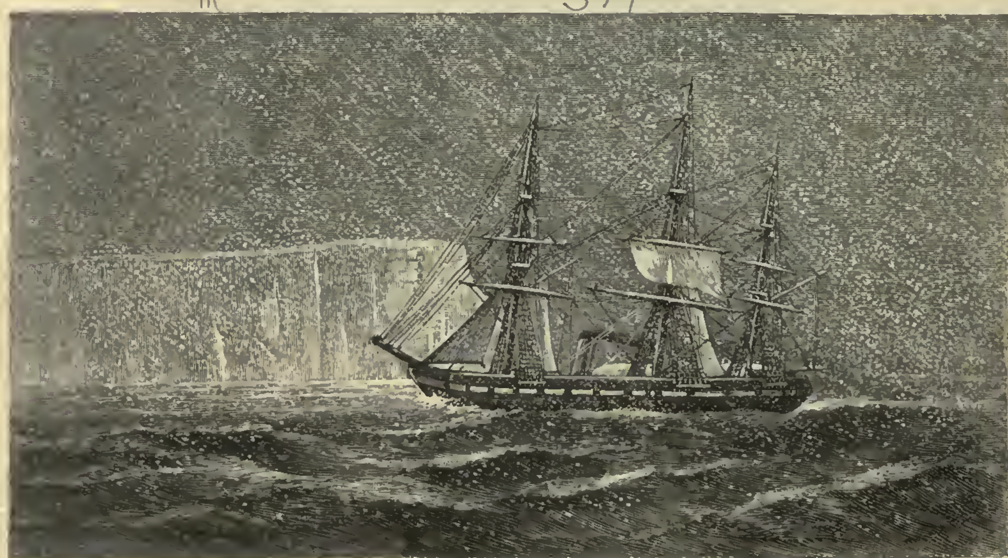
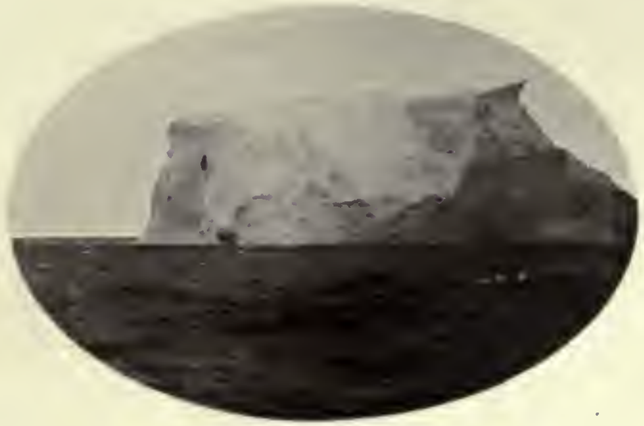


Fig. 154.—H.M.S. Challenger after collision with an iceberg, 24th February 1874. From a sketch by Lieut. Aldrich, R.N.

and a southeasterly wind springing up and rapidly increasing to a gale, it was hove up at 9 A.M. empty. At this time the weather looked very threatening, and snow began to fall, so the ship steamed under the lee of a berg and the topsails were close-reefed. Whilst keeping head to wind under the berg, steaming slowly, a sudden lull for a minute, by removing the force against which the screw was acting, caused the ship to gather headway, and before the engines could be stopped the vessel ran into the berg and carried away the jib-boom, martingale, and one of the whiskers. The ship was

Plate XIII.



Horsburgh, Edinburgh. Permanent Phototype.

ANTARCTIC ICE.

backed astern clear of the berg, and having finished reefing and furled the topsails, laid to under fore and aft sails on the port tack to get in the wreck of the jib-boom. The weather continued to get gradually worse, and the heavy snowfall obscuring the view, rendered the position an anxious one. From 8 to 9 A.M. the velocity of the wind was 24 miles per hour, from 9 A.M. to noon 37 miles per hour. At noon steam was got up in all four boilers, and the main deck ports barred in to prepare for all emergencies, the velocity of the wind was 42 miles per hour, and the vision limited to a distance of a quarter of a mile by the heavy snowfall.

At 2.45 P.M., in the thickest part of a squall, the loom of a large iceberg was seen at the lee bow. As the ship was drifting down on it, and there was no room to steam ahead, the vessel went full speed astern, took in the fore trysail and staysail, and set the weather clue of the main topsail aback, the yards having been previously laid. Fortunately, the ship gathered stern-way, and kept fairly broadside to the wind until the berg was cleared. An attempt was then made to steam up under the lee of this iceberg and use it as a breakwater, but with full power steam and close-reefed after sails the ship refused to face the wind, so it was again necessary to lay to and drift. After doing so for about half a mile another large berg was seen during a lull in the snowfall half a mile ahead. The ship was accordingly allowed to drift towards it, and the wind moderating slightly, was able to tack under its lee with steam and fore and aft sails, and then return towards the berg which had been nearly fouled. Having proved the space between the two bergs to be free from danger, the anxious night was spent going from one to the other. At 4 P.M. the velocity of the wind decreased from 42 to 37 miles per hour. At 7 P.M. the snow squalls ceased, and the limit of vision was increased to three or four miles; there were then thirteen bergs in sight. After 8 P.M. the wind began to moderate.

The barometer fell rapidly as the wind freshened, reaching its lowest point (28·508 inches) at 10 P.M.; the mean temperature of the day was 25°·8, falling to 22°·8 at 6 P.M.; the sea surface temperature was 31°·6. It was extremely fortunate that the gale broke and the snow ceased before night; had it continued with sufficient force to prevent the ship maintaining a position between two known bergs during the darkness, it would have been very difficult to avoid a collision with the ice.

On the 25th, at 3 A.M., the wind having moderated to force 5, and the weather being fairly clear, sail was again made towards Termination Land; as the vessel proceeded towards the pack the berg was passed which had been fouled early on the previous day, the score on its surface made by the jib-boom remaining well-defined notwithstanding the heavy fall of snow. At 9 A.M., being close to the edge of the pack, which was here very loose, the ship ran into it for a distance of a mile, to get as near Termination Land as practicable, and to examine the nature of the ice composing the pack. A boat was lowered and some pieces of the ice collected, some of which was of a dirty yellow colour, caused, as was afterwards found, by the number of Diatoms, Foraminifera, and other surface animals in it.

The pack was precisely similar to that described by Ross when he entered it on 5th January 1841. It consisted chiefly of small floes of last winter's formation, with a quantity of hummocky ice of much older date, forced by great pressure into heavy masses. The floe pieces were usually some 30 to 50 feet in diameter, and from 3 to 7 or 8 feet in thickness, much honeycombed, and with their surfaces covered by a thin layer of snow about a foot in thickness. It appeared to be decaying rapidly, but would still evidently give a ship a dangerous squeeze if massed against a berg by a strong wind, and a ship sailing through it should be prepared for an occasional hard knock. To avoid collision with these lumps the ship entered and left the pack under very easy sail. It was hoped that a suitable piece of ice would be found on which to

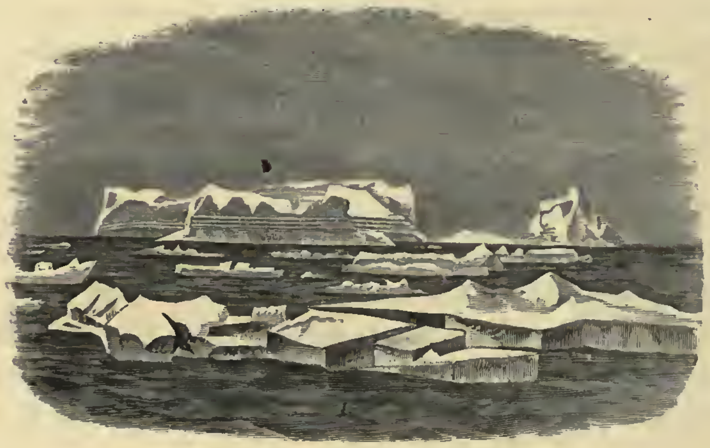


Fig. 155.—Iceberg and Pack Ice, seen 25th February 1874.

obtain magnetic observations, free from the influence of the ship's iron, but no opportunity of doing this presented itself. The westerly swell caused too much motion amongst the floe pieces, even had they been large enough to bear the weight of the instruments and observers, and the swell broke too heavily against the sides of the bergs; besides which a fit place for landing was never found, even on their leeward sides. In the middle of a pack Ross found the floes he landed on had motion, although not sufficient to prevent his observing, and Moore, like the Officers of the Challenger, did not succeed in meeting a suitable platform amongst the ice for taking observations. The southern pack is certainly much more dangerous to a ship during bad weather than the northern, as there the floes are usually sufficiently large to permit a dock to be cut. In the Antarctic no shelter can be obtained. Again, the northern ice is easier of navigation, for a breeze off the land will often open a channel for 20 or 30 miles, whereas in the Antarctic as soon as one piece is blown to leeward its place is occupied by another; however, except in a very heavy pack, there is more chance of escaping collision with a berg in the Antarctic than in the Arctic. The temperature of the water in the pack was 29°. Ross generally registered 28°. After getting clear of the pack at 11 A.M. the ship sailed along its edge until noon, being from 10 A.M. until that time within about 15 miles of the supposed position of Wilkes' Termination Land, but neither from the deck nor masthead could any indication of it be seen. The limit of vision as logged was 12 miles, and had there been land sufficiently lofty for Wilkes to have seen it at a distance of 60 miles (which was the distance he supposed himself off it), either the clouds capping it or the land itself must have been seen. If Wilkes' distance was overestimated, that of the Challenger would be increased, and it may still be found, but as the expression in Wilkes' journal is "appearance of land was seen to the southwest, and its

FIG. 156.—Iceberg and Pack Ice, seen 25th February 1874.

trending seemed to be to the northward," and not that land was actually sighted, and a bearing obtained, it is probable that Termination Land does not exist; still it is curious that pack ice and a large number of bergs should have been found in nearly the same position as by Wilkes in 1840, and this would seem to indicate that land cannot be very distant. At noon the northern part of the pack was reached, and it was found to trend to the southeast (true), the position being lat. 63° 49′ S., long. 94° 51′ E. As no advantage was to be gained by following the pack 80 miles to the eastward, until it joined Wilkes' main pack, and as Moore, Cook, and Wilkes had seen much ice north of this position, the vessel stood to the northward with a fine southwesterly breeze.

It is a fair indication of the limit to the navigable season in the Antarctic if the dates each explorer has turned his ship's head to the northward and left the edge of the pack be compared, as in the following table :—

Explorer.	Year.	Date of turning North.	In Lat.
Cook, ...	1773	January 17th	67°
Wilkes, ...	1840	,, 26th	65°
Cook, ...	1774	,, 30th	71°
Weddel, ...	1823	February	74½°
Wilkes, ...	1840	,, 24th	64°
Nares, ...	1874	,, 25th	63½°
Moore, ...	...	March 3rd	64½°
Ross, ...	1843	,, 5th	71½°
Ross, ...	1842	,, 7th	64°
Ross, ...	1841	,, 20th	65°

Both Ross and Cook were running along the 60th parallel considerably after the date mentioned, but they both speak of the danger of doing so during the dark nights. Unless favoured by the moon or clear weather, no vessel should attempt to proceed on her voyage between 8 P.M. and 4 A.M. whilst among icebergs; that is, south of about lat. 58° S.

At 8 P.M. sail was shortened and the ship hove to for the night. The weather during the day was cloudy and gloomy, but the sun shone out for a few minutes now and then, so that the position could be ascertained by astronomical observation. The wind was moderate and the sea smooth, the barometer rising steadily from 28·537 to 29·023 inches; the mean temperature of the air 28°·6, of the surface water 31°·9. Numerous icebergs were in sight all day.

On the 26th, at 3 A.M. (daylight), sail was made, and the vessel stood to the northward. At 9 A.M., the weather being fine with a high barometer for these regions, showing that in all probability this fair weather would not continue, advantage was taken of it and a sounding and trawling were obtained, the depth being 1975 fathoms, Diatom ooze, Station 156 (see Sheet 23). At noon the position of the ship was lat. 62° 26′ S., long. 95° 44′ E., and there were thirty icebergs in sight, but no pack ice.

The same difficulty was experienced in obtaining serial temperatures as before, although the thermometers were cooled by a mixture of ice and salt before immersion. The surface temperature was 33°, the temperature at 100 fathoms 31°·9, at 150 fathoms 34°, and below the depth of 150 fathoms the thermometer came up showing on the maximum side 34° and on the minimum 31°·9, hence it is impossible to say what the precise temperature of the sea was below 150 fathoms; all that can be asserted is that it ranges between 34° and 31°·9. It is true the bottom thermometer showed 34° on the maximum side and 31°·3 on the minimum, but as it was cooled before

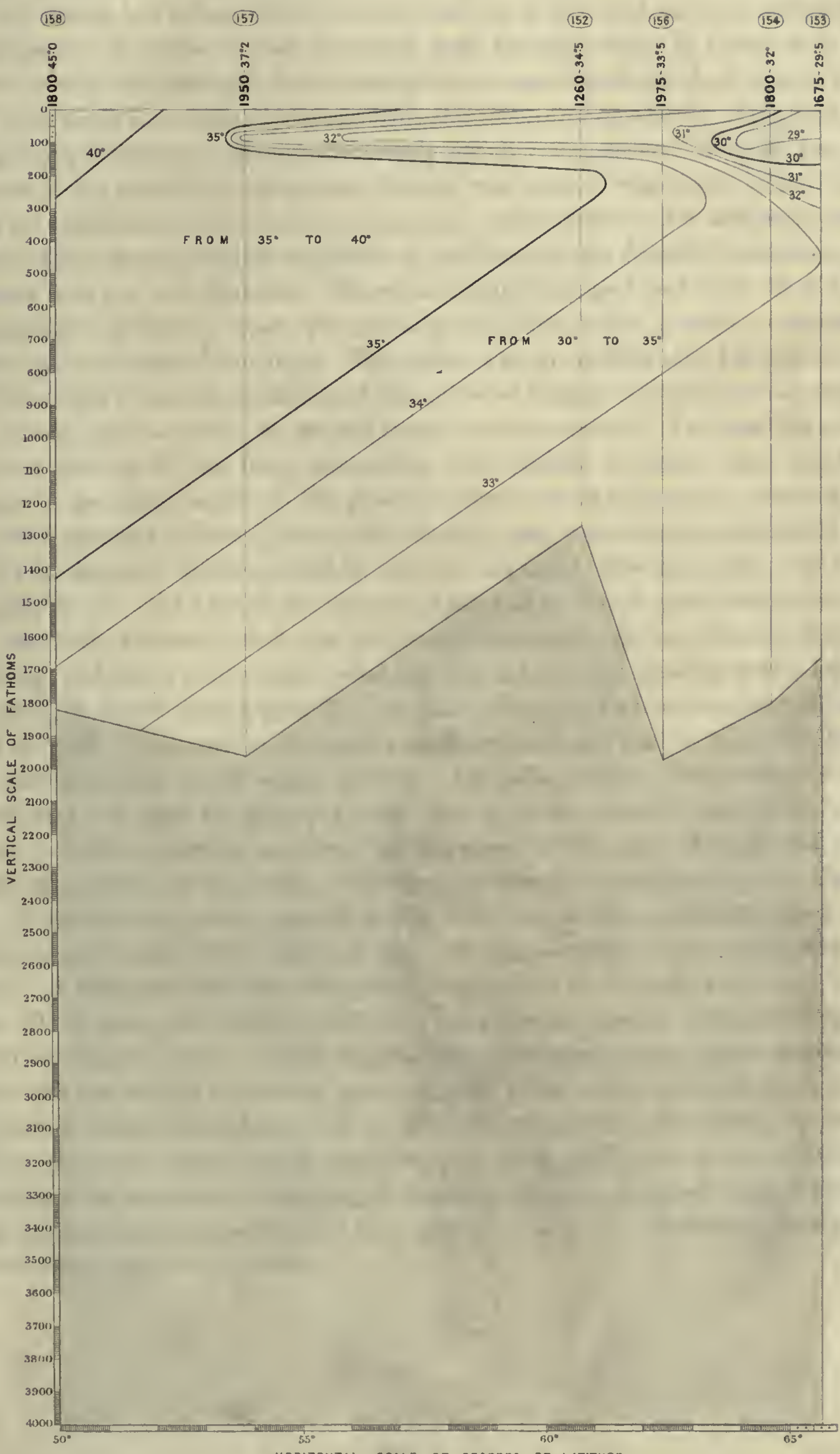
DIAGRAM 9

SOUTHERN INDIAN OCEAN

Meridional Temperature Section

Between the Parallels of 50° and 65° South Lat.

For explanation of Symbols see Appendix 1.



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immersion, and, unfortunately, the height of the indices was not noted, it is not certain that it did not stand at 31°·3 before it entered the water. At 4 P.M. the weather, which had been hitherto fine, began to look threatening, and the barometer, which at noon stood at 29·182 inches, had fallen slightly, so after heaving in the trawl, sail was made to double-reefed topsails and courses on the starboard tack, the wind being N. (true), as it was expected to shift to the eastward; forty icebergs were counted from the deck at 4.30 P.M., but shortly afterwards snow began to fall, limiting the vision to a quarter of a mile, and necessitating getting steam up in three boilers ready for all emergencies. At 6.30 P.M., during a decrease in the snowfall, a very large iceberg was seen to windward, and so the ship worked up towards it under steam and sail, and when under its lee sails were furled for the night, the officers being as thankful to get behind this friendly breakwater as one sometimes is to get into harbour. The wind rapidly increased to force 9 by 8 P.M., and the barometer still falling, steam was raised in the fourth boiler in order to maintain the position under the lee of the berg. The night was an anxious one, but not so bad as that of the 24th February, as the wind was never so strong as to prevent the ship facing it, and it was only necessary to use full steam on one occasion. The wind blew in fierce gusts over the top of the berg, alternating with periods of almost calm, rendering it necessary to use great caution in the power of steam, which had to be constantly varied as the wind changed in force, giving the officer in the engine-room considerable trouble. After 8 P.M. the snow was succeeded by rain and a partial thaw for a time, the temperature rising to 35°. At 11 P.M. the barometer reached its lowest point, 28·785 inches.

On the 27th February, at 3 A.M. (daylight), the vessel left the friendly breakwater, the iceberg, and made sail to close-reefed topsails and foresail, steering to the northward, the wind N.W. by W. (true), force 9. At 8 A.M. the wind had moderated sufficiently to allow two reefs to be shaken out and reefed mainsail set, and at noon the force was 6 to 7, the ship being under single reefs and top-gallant sails. The average velocity of the wind at 8 A.M. was 28 miles per hour, during the forenoon 25, and in the afternoon 22; that is without allowing anything for the speed of the ship through the water, as the wind was nearly on the beam. The limit of vision during the day was about four miles. Numerous bergs were passed as the ship ran to the northward seven or eight miles per hour, but few were visible at any one time owing to the misty state of the weather. It was fortunate that this gale did not shift to the east and south, as had it done so all the ropes and blocks would have been frozen together after the sludgy snow that fell during the night. After experiencing two heavy gales whilst surrounded by icebergs, one can readily realise the great dangers which a sailing vessel must encounter in navigating these seas, and can to a certain extent appreciate the feelings of the purser of Wilkes' ship, who, when called upon for his written opinion as to the expediency of prosecuting their researches further south, immediately after they had successfully battled against weather somewhat similar to that experienced in the Challenger during the last few days, answered that he failed to see the utility of proceeding when there was so great a probability of no one living to carry home the tale. At 8 P.M. sail was shortened to double-reefed topsails, and the ship continued working for the night between two icebergs separated from each other five or six miles, the space between them being free from danger. A fresh breeze blew all day, with a cloudy sky, the barometer rising slightly, its mean height 28·940 inches, and the mean temperature of the air 34°·1, of the sea surface 33°·7. The position at noon, lat. 62° 2′ S., long. 97° 6′ E.

On the 28th, at 3 A.M., sail was made and the northerly course resumed; numerous icebergs were passed, the greatest number in sight at any one time being twenty-four. At 5.30 P.M. sail was shortened to triple-reefed topsails and courses. At 8 P.M. the courses were taken in, and it being moonlight the ship proceeded under easy sail until 11.30 P.M., and then laid to for the night. There was a strong breeze all day, with a westerly swell, the barometer rising from 29·076 to 29·335 inches at 10 A.M. and falling to 29·195 inches at midnight; the weather was clear in the morning, but cloudy and gloomy, with snow showers during the rest of the day. A strong northerly current was observed. Mean temperature of the air 34°·6, and of the surface water 34°·4; position at noon, lat. 59° 56′ S., long. 99° 14′ E.

On Sunday, March 1st, 1874, at 3.30 A.M., sail was made and the course resumed towards Melbourne. Between 4 and 8 A.M. four icebergs were seen, but at noon no ice was in sight, the position being lat. 58° 5′ S., long. 101° 56′ E. At 4 P.M. one berg was seen to the northwestward (true), distant four or five miles. At 8 P.M. and midnight no ice was in sight. The ice having decreased so rapidly, it was not considered necessary to shorten sail and heave to during any part of the night, more especially as by the aid of the moon objects could be seen at a distance of three quarters of a mile distinctly. The wind was fresh all day, force 8 at 1 A.M., moderating gradually to force 5 by midnight, the weather being thick and gloomy, the sky covered with an impervious cloud, a moderate westerly swell. Barometer rising from 29·149 to 29·520 inches, mean temperature of the air 36°·2, of the surface water 35°·1.

On the 2nd, at 3 A.M., the ship passed close to a large iceberg and the course had to be altered to clear it; this was the only one seen throughout the day. The wind continued fresh up to 4 P.M., after which it shifted to the southwestward and died away; the weather continued cloudy and gloomy till 6 P.M.; the barometer rising steadily from 29·530 to 29·948 inches; the mean temperature of the air 38°·2, of the surface water 37°·5; the position at noon, lat. 55° 38′ S., long. 106° 10′ E.

On the 3rd, the wind being light and the sea moderate, a sounding, trawling, and temperatures were obtained in 1950 fathoms, Diatom ooze, Station 157 (see Sheet 24). The serial temperatures obtained showed that, from the surface to the depth of 60 fathoms, the water remained at 36°·6, but at 70 fathoms it had cooled to 33°, and at 80 fathoms to 32°·5. Below that depth the temperature could not be ascertained with

precision, as the thermometers when brought to the surface showed, with one exception, the same temperature on the maximum side as on immersion, and on the minimum side the same as at 80 fathoms. The bottom thermometer gave a result of 32°, which is probably the bottom temperature, being slightly colder than the results above that depth. Whether this be so or not, it is at any rate certain that the bottom temperature was not below 32°. At 4 P.M., after heaving in the trawl, sail was made. The day was fine, but cloudy, the wind gradually falling until at 6 P.M. it was quite calm, the barometer steady at 30·045 inches, the mean temperature of air 36°·9, of sea surface 37°·5, the sea smooth; the position of the ship at noon, lat. 53° 55′ S., long. 108° 35′ E. No ice of any description was seen during the day. At 11.45 P.M. a brilliant aurora was observed stretching in four concentric arcs from E.S.E. to W.S.W. between the zenith and an altitude of 30°.

On the 4th a southeasterly breeze sprang up, and shifted gradually to the northeast and north, freshening towards midnight. The weather was fine in the morning and forenoon, but cloudy in the afternoon, and misty and foggy in the evening. The barometer steady at 30·053 inches, but inclined to fall; mean temperature of the air 38°·6, and of the surface water 38°·9. At noon an iceberg was seen to the northward, and it was passed at 6 P.M. This proved to be the last berg seen on the voyage, and it was evidently fast breaking up, being a round-backed piece of ice, in shape somewhat like a capsized vessel, and not much larger.

On the 5th and 6th March a steady northerly breeze was experienced, mean force 5, with a smooth sea, and a southwesterly swell, the barometer fairly steady, the temperature both of air and sea increasing.

On the 7th a sounding, trawling, and temperatures were again obtained, the depth being 1800 fathoms, Station 158 (see Sheet 24). It was found that the nature of the bottom had changed from Diatom ooze to Globigerina ooze. The serial temperature sounding showed that, at this position, lat. 50° 1′ S., long. 123° 4′ E., the temperature of the sea decreased gradually from the surface to the bottom, or from 45° to 33°·5, as is generally the case (see Diagram 10). The ship had therefore now got to the northward of the peculiar condition as regards temperature of the sea in the Antarctic basin. The weather during the day was fine, but cloudy, and occasionally misty. The wind still steady in direction (N. true), but increasing in force towards midnight; the barometer falling somewhat, the mean temperature of the air 47°·4, of the sea surface 45°·3.

On the 8th the northerly wind still continued, force 6, with fine weather and smooth water, barometer fairly steady at 29·831 inches. Mean temperature of the air 50°·2, of sea surface 48°·8. The velocity of the wind by the anemometer was 23 miles per hour. At midnight the patent log when hauled in was found entangled in a large piece of kelp covered with barnacles. As the vessel was then in the parallel of Kerguelen, and there is no kelp at Heard Island, it is probable that this weed may have drifted from

Kerguelen. Three strata of clouds were noticed during the day, the upper stationary, the middle floating from the northwest, and the lower from the north.

On the 9th, the northerly wind gradually decreased, until at noon it was nearly calm. Shortly after a slight southeast wind sprang up, the sea being smooth, the weather cloudy in the forenoon, but fairly clear in the afternoon, the barometer steady at 29·887 inches; mean temperature of the air 51°·2, of the surface water 50°·6; position at noon, lat. 58° 18′ S., long. 130° 4′ E.

On the 10th, the wind continuing light from the eastward, the barometer falling, the weather dark, gloomy, and misty, advantage was taken of the smooth sea and the light breeze to sound, trawl, and obtain temperatures. The depth was 2150 fathoms, Globigerina ooze; bottom temperature 34°·5, Station 159 (see Sheet 24). The trawl when hove to the surface contained some shrimps and fishes, but apparently had not reached the bottom. One of the fishes belonged to a new genus, thus described by Dr Günther:—

Echiostoma.—"The fishes of the family Stomiatidæ, to which this genus belongs, are armed with formidable teeth, a certain indication of their voracity and predaceous habits.

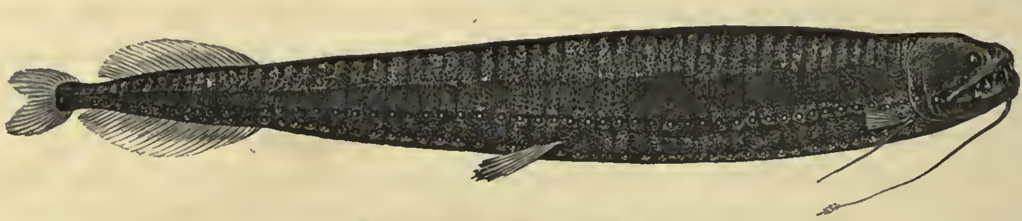


FIG. 157.—*Echiostoma micripnus*, Günther; 2150 fathoms.

Their elongate body is covered with a smooth, scaleless skin of an intensely black colour. The vertical fins are close together, near the end of the tail, as in the pike, forming a powerful propeller, by a single stroke of which these fishes are enabled to dart with great rapidity to a considerable distance. A long filament is suspended from below the chin, and, as it is frequently fringed at its extremity, it evidently serves as a lure for other fishes or animalculæ. Series of luminous globular bodies run along the lower half of the body and tail, and some others of larger size occupy the side of the head, generally below the eye or behind the maxillary bone. The species figured has, besides, the lower pectoral ray prolonged and detached; it probably acts as an organ of touch."

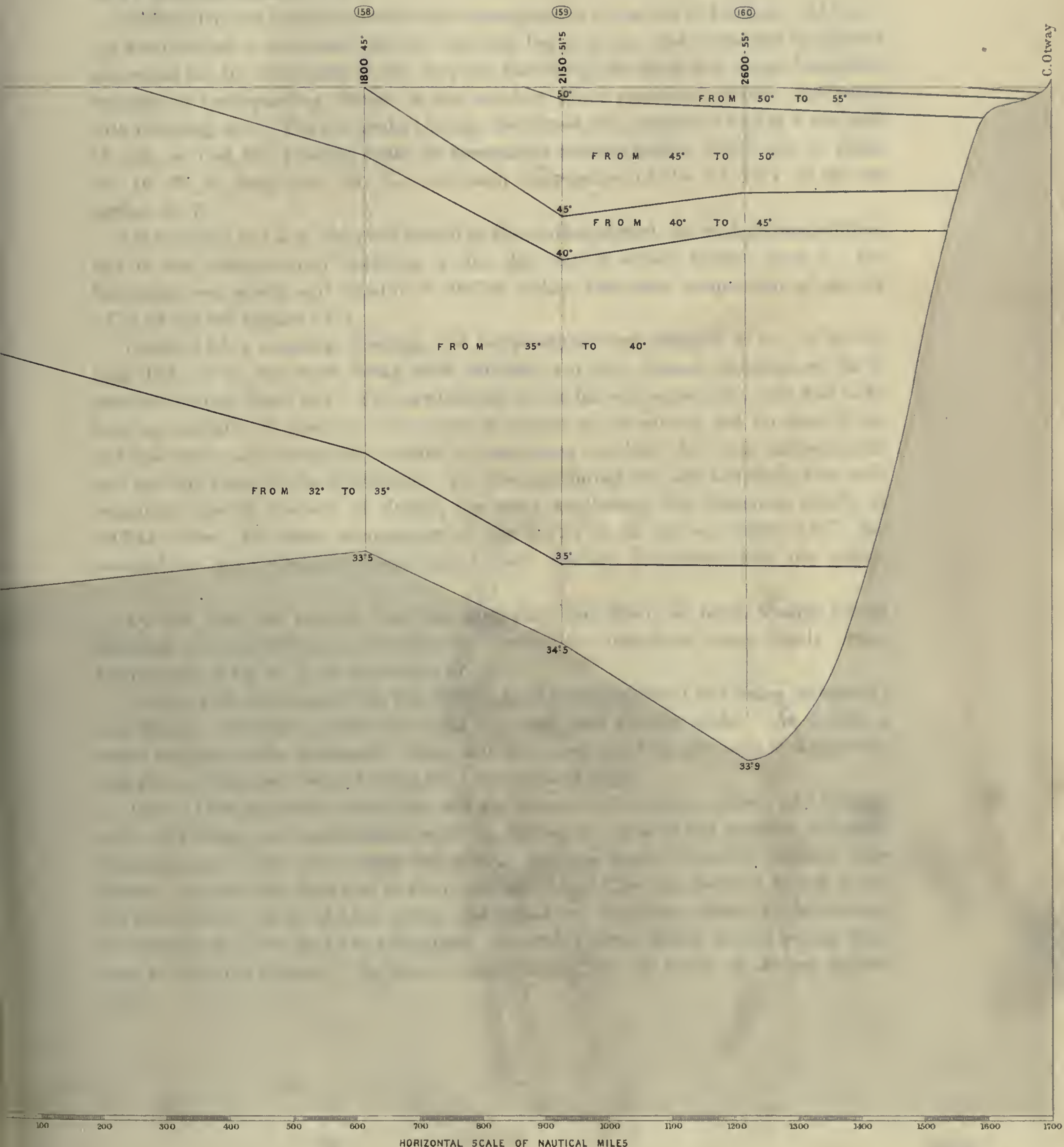
The specimen was 16 inches in length. The end of the barbel, which was thickened, was flesh-colour with a rose tint; there was also a rose tint on the dorsal and anal fins. The rest of the animal was of a dark colour with a perceptible slate-coloured tint. The phosphorescent spots along the belly and radial and lateral line were red, as was also that below the eye.

At 4 P.M. sail was made to double-reefed topsails and courses in anticipation of a gale; the wind was easterly working to the northward, force 4; drizzly, misty weather;

SOUTHERN INDIAN OCEAN

Diagonal Temperature Section. From a Position in Lat. 53°55′S. Long. 108°35′E. to C. Otway.

For explanation of Symbols see Appendix 1.



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barometer 29·871, at 1 A.M., falling to 29·449 inches at midnight; mean temperature of air 51°·2, of sea surface 51°·2.

On the 11th, the barometer reached its lowest point at 6 A.M. (29·316 inches). At 8 A.M. the wind shifted to northwest, and the mercury began to rise and continued its upward movement for the remainder of the day, but the change of wind and rising barometer brought no corresponding change in the weather, which continued gloomy and misty with drizzling rain. The sun broke through the clouds for a minute or two at 9 A.M. and 11 A.M., so that the position could be ascertained astronomically, which was at noon, lat. 46° 37′ S., long. 129° 56′ E.; the mean temperature of the air 52°·7, of the sea surface 51°·7.

On the 12th, at 7 A.M., the wind shifted to the southwestward, the mist gradually lifted, and it was, comparatively speaking, a fine day with a steady breeze, force 4; the barometer rose slowly and steadily to 29·700 inches, the mean temperature of the air 51°·3, of the sea surface 53°·1.

On the 13th a sounding, trawling, and temperatures were obtained in lat. 42° 42′ S., long. 134° 10′ E., the depth being 2600 fathoms, red clay, bottom temperature 33°·9, Station 160 (see Sheet 24). The trawl caught at the bottom occasionally, and had to be hove up carefully; it was much torn when it arrived at the surface, but fortunately the cod was whole, and contained a number of manganese nodules. At 6 P.M. sail was made and the ship stood on for Melbourne. The weather during the day was fairly fine, with occasional passing showers of drizzle, the wind southwest; the barometer steady at 29·741 inches; the mean temperature of the air 51°·6, of the sea surface 55°; the atmosphere drier than any experienced since leaving Kerguelen with one exception.

On the 14th the weather was fine, with the wind steady in force, though not in direction, veering between south and southwest; the barometer rising slowly, mean temperature of air 52°·9, of sea surface 57°·8.

On the 15th the weather was fine with a light southwest wind and rising barometer; and the air thoroughly dried the decks, the first time for six weeks. At 4 P.M. a vessel was seen to the northward, which, with the exception of the schooners at Kerguelen, was the only ship seen since leaving the Cape of Good Hope.

On the 16th, the wind falling light, and the barometer having risen slowly and steadily to 30·205 inches, which, combined with the fine settled look of the weather, indicated a continuance of the calm, steam was got up and the vessel proceeded towards Cape Otway. At noon the high land to the northward of that Cape was observed, and at 5 P.M. the Cape itself. At 8 P.M. Cape Otway was passed and the course altered for Melbourne. The weather was fine, and the atmosphere remarkably clear, Mount Sabine having been seen at 60 miles distance; the mean temperature of the air 58°·6, of the sea surface 61°·2.

On the 17th, at daylight, the whole of the land in the vicinity of Port Philip was distinctly visible. A high saddle peak was noticed north of Geelong, no mention of which is made in the sailing directions; probably it is not often seen, for the atmosphere was remarkably clear; the ship passed the Narrows at 8 A.M., and was moored in Hobson's Bay at 2 P.M.

CHAPTER XI.

History of Southern Exploration—Antarctic Temperatures—Density of the Sea Water south of the 60th parallel—Icebergs—Deposits—Surface Organisms—The Hexactinellida—The Tetractinellida.

Five expeditions only have been despatched from this or other countries to explore the Antarctic regions, viz., those of Cook 1772–75, Bellingshausen 1819–21, D'Urville 1837–40, Wilkes 1838–42, and Ross 1839–43.

Our knowledge of the Antarctic Ocean does not, however, rest on the reports of the commanders of these expeditions, as other captains, though not despatched expressly for the purpose, have penetrated beyond the Antarctic Circle in search of Whales or Seals, or for some scientific purpose, and have published narratives or papers of their proceedings, accompanied in many instances by charts showing their tracks. The most notable of these voyages are those of Smith and Bransfield 1820, Powell 1821, Weddell 1822–24, Morrell 1823, Foster 1828–29, Biscoe 1830–32, and Balleny 1839.[1]

Of these Antarctic voyagers three only have succeeded in crossing the parallel of 70° S. Cook, in January 1774, penetrated to 71° 10′ S. on the meridian of 106° 54′ W., but was then stopped by field ice, which, to use his own words, "extended east and west as far as the eyes could see, amongst which ninety-seven icebergs were counted in addition to those outside the field, many of them very large and looking like ridges of mountains rising one above the other until they were lost in the clouds." From this description it appears probable that Cook really saw land, covered by an ice cap, although he does not expressly say so.

Weddell, in February 1823, penetrated to the parallel of 74° 14′ S. on the meridian of 34½° W., and then had only four icebergs in sight, although he had passed numerous bergs previously farther north. Evidently, therefore, a much higher latitude might have been reached had it been Weddell's object to proceed as far south as possible, but being on a sealing and not on an exploring voyage, he turned back at the 74th parallel, and proceeded to South Georgia to complete his cargo.

Ross passed the 70th parallel on three occasions and in three different years. First, in January 1841 on the meridian of 174½° W., when he penetrated to the parallel of 78° S., where he was stopped by an icy barrier, consisting of cliffs of ice 150 to 200 feet in height, which he traced in an east and west direction for a distance of 300 miles. Second, on the meridian of 169° W., on the 7th February 1842, when he again reached the parallel of 78°, again to find himself arrested by the icy barrier 70 miles east of his easternmost position in 1841; and the third time on the meridian of 16½° W., when he

[1] See Cook's Voyage, Bellingshausen's Voyage, D'Urville's Voyage, United States Exploring Expedition, 1838–42; Ross's Antarctic Voyage, Weddell's Voyage, Morrell's Voyage, Voyage of the "Chanticleer"; *Nautical Magazine*, vols. iv., viii., and ix.; *Proceedings of the Royal Geographical Society*.

reached the parallel of 71° 30′ S. on the 5th March 1843, where he met an impenetrable pack.

Of the other explorers Bellingshausen reached within a few miles of the 70th parallel on three occasions, viz., on the meridians of 2° W., 77° W., and 93° W. D'Urville's highest latitude was 66° 30′ S. on the meridian of 140° .E, and Wilkes just reached the 70th parallel on the meridian of 100° W. The highest latitude reached by Morrell was 70° 14′ S., in March 1823, on the meridian of 40° W., by Foster 63° 45′ S. on the meridian of 62° W., by Biscoe 69° 20′ S. on the meridian of 13° E., and by Balleny 69° S. in 172° E.

It must be borne in mind that none of the ships despatched for southern exploration were properly fortified except those of Sir James Ross, and that, therefore, they were not justified in attempting to sail through a close pack as Ross did on each occasion when he penetrated to the 78th parallel.

Nearly all the Antarctic voyagers have discovered land south of the 60th parallel. Cook, as before observed, probably met with land in 71° S. 107° W. Bellingshausen discovered the islands of Alexander and Peter the Great; D'Urville discovered Adelie Land; Wilkes discovered land extending from the 100th to the 160th meridian of east longitude, and between the parallels of 65° and 67° S. Ross discovered Victoria Land, extending from the 70th to the 78th parallel and between the meridians of 160° and 171° east longitude. Smith and Bransfield discovered the South Shetlands, Powell the South Orkneys, Biscoe Enderby's Land, and Balleny the Balleny Islands and Sabine Land. Weddell and Morrell did not discover any land, and Foster only visited the South Shetlands for scientific experiments. Although so many of these bold navigators have seen land, and numbers of them have visited the islands immediately south of Cape Horn, viz., the South Shetlands, South Orkneys, &c., which appear to be accessible nearly every season, Ross and D'Urville are the only explorers who have actually landed on any portion of the Antarctic regions proper, that is on land south of the Antarctic Circle. Wilkes, Biscoe, and Balleny never succeeded in reaching the shore, although Wilkes could not have been far from it when in the "Vincennes" he struck soundings in 30 fathoms in Pincis Bay. Neither Ross nor D'Urville remained longer on shore than was sufficient to enable them to gather specimens of the rocks, &c., for the nature of the coast, and the numerous icebergs, precluded the possibility of the vessels anchoring, so that a quick return was necessary to avoid being separated by one of the frequent fogs or short, sharp gales that prevail in the Antarctic seas. All explorers agree in describing the Antarctic land as being icebound; sometimes a line of icy cliffs 150 to 200 feet in height runs along the coast, rendering hopeless any attempt to obtain a footing on the shore, whilst in other places a solid mass of land ice, which is not more than 5 or 6 feet above the surface, and, therefore, probably not more than 50 feet in thickness, stretches a considerable distance into the sea.

Ross, D'Urville, and Wilkes saw both kinds of ice in the vicinity of the land, and both Ross and D'Urville agree in stating that the icy cliffs, which are now known as the "Ice Barrier," are not to be seen when the land is high and mountainous; for instance, Ross saw no barrier until he reached the extremity of the ridge of mountains running irregularly north and south through Victoria Land, and D'Urville saw no icy barrier opposite Adelie Land, but traced it for 60 miles on the coast of what he supposed to be Clarie Land, where Wilkes also saw it. Wilkes himself does not say where he saw the ice cliffs and where the land ice, but calls them both the icy barriers. That they both form a barrier to the land is undeniable, and so Wilkes was entitled to call both descriptions of ice the "Barrier"; still it would have been an advantage to succeeding investigators had Wilkes distinguished between the land ice which may by heavy gales or some cause be broken up occasionally, and the ice cliff which one might as well attempt to pass or to sail through as the Cliffs of Dover, and which is now the only description of ice called the "Barrier." It does not appear that any other explorer except Ross, D'Urville, and Wilkes has seen the icy barrier, although most southern explorers have seen the ice extending from the foot of the land.

From the fact that two explorers only have succeeded in effecting a landing on Antarctic shores proper, and that the land there is almost entirely covered with perpetual snow and ice, it is evident that our knowledge of the geography and geology of the Antarctic regions must necessarily be very limited. That a very considerable tract of land exists south of the 65th parallel and between the meridians of 100° E. and 180° E., and also between the meridians of 45° and 60° E., cannot be doubted, but whether this land is continuous or broken up into a series of islands with shallow water between cannot at present be stated with any great degree of certainty, for the ice in the vicinity of the land so blocks up all approach to the coast and hides the shore that it is next to impossible to say, with accuracy, where the land begins. It can, therefore, only be conjectured from the state of the ice and the observed temperatures what the condition of the land is.

Antarctic Temperatures.—The mean temperature of both the air and sea surface south of the parallel of $62\frac{1}{2}°$ S. is, even in summer, at or below the freezing point of fresh water.[1] Between 60° and $62\frac{1}{2}°$ S. a sensible rise takes place, and a reading as high as 38° has been recorded of both air and sea in March between these parallels. Temperatures below the surface south of the 60th parallel had been taken by Cook, Ross, and Wilkes before the Challenger Expedition, but as the thermometers used were not protected from pressure, the results obtained are not of much value, as they are combinations of temperature and pressure due to depth. There is, however, one marked peculiarity about the results obtained with these unprotected thermometers,

[1] Contributions to our knowledge of the Meteorology of the Antarctic Regions. Published by authority of the Meteorological Committee, 1873.

viz., that by all three observers the temperature at 100 fathoms was either the same or lower than that at the surface, and was at or below the freezing point of fresh water, whilst at 150 fathoms the mean temperature was only on one occasion less than that of the surface, or below 32°, the mean of the sixteen observations at that depth being 34°·3, and higher than the temperature of the surface. The coldest submarine temperature obtained was by Wilkes, who registered 27½° at a depth of 320 fathoms,[1] but as serial temperatures were not obtained there is no reason for believing that this temperature existed at the depth of 320 fathoms, as the thermometer might, and probably did, pass through a stratum of water at that temperature before it reached the depth of 100 fathoms.

During the voyage of the Challenger from Kerguelen to Australia five serial temperature observations were obtained south of the 60th parallel; and as these observations are highly important, a full notice of them is appended in order to afford every possible facility for future discussion, and also to indicate the data still required as well as the kind of instrument necessary to obtain those data. The general result of the observations seems to show that from the most southerly Station a wedge of cold water stretches northwards for more than twelve degrees of latitude, underlying and overlying strata at a higher temperature than itself. The temperature of the water below the lower warm stratum is uncertain, because it lies between the maximum and minimum observed at lesser depths. These results receive confirmation from the imperfect observations of Cook, Ross, and Wilkes (see Diagram 9).

On the 14th February 1874, in lat. 65° 42′ S., long. 79° 49′ E., the most southerly Station at which temperature observations were obtained, the temperature of the surface water was 29°·5 and that of the air 33°. The ship was about 1½ miles from the edge of the pack ice with many icebergs around, forty-eight being counted within a horizon of 4 miles; the average height of the bergs out of the water was 150 to 200 feet, most of them were tabular, and had changed little from their virgin state, they must, therefore, have extended to a depth of from 200 to 300 fathoms below the surface. The temperature of the water at 50, 100, 200, 300, 500, and 1675 fathoms (bottom) was determined. For this purpose two thermometers, Nos. 66 and 67, were sent successively to each of these depths, having been cooled to a temperature of 30°·2 before immersion. At 50 and 100 fathoms each thermometer registered a slight change in the maximum index, which is probably due either to an error in reading off or to a slight defect in the instruments, as it has been frequently found that the maximum indices alter their positions slightly on entering cold water.[2] The minimum index of each fell to 29° proving that they had entered or passed through a stratum of cold water. At the greater depths of 300, 500, and 1675 fathoms the thermometers registered a decidedly

[1] Wilkes' U. S. Expl. Exp., vol. ii. p. 299, 1845.

[2] Or this may be due to the glass contracting suddenly before the temperature has reached the spirit in the bulb of the thermometer, and so forcing the index up slightly.

higher maximum temperature, showing distinctly that they had entered or passed through a warmer stratum of water than had been indicated between the surface and a depth of 200 fathoms. The minimum indices all registered 29°, agreeing exactly with what had been found at lesser depths. At 200 fathoms the thermometers both showed a slight, but only a very slight, rise in the maximum index; but as they both agreed exactly, it is probable that at this depth the warm underlying strata commenced. It is impossible that the thermometers could have been affected in their momentary passage through the air (which was at a temperature of 33°) from the sounding bridge to the surface of the water, as the utmost care was taken to keep the outer case filled with the cooling mixture until the instrument was immersed, and on recovering each thermometer it was detached and read off before the mercury had sufficient time to attain a higher temperature than that of the surface water (29°·5), besides, if they were affected by the air, all the instruments would have registered higher on the maximum side, whereas only those lowered to depths exceeding 200 fathoms did so. The temperature of the bottom water ranged between 33° and 28°·8, these being the temperatures registered by the maximum and minimum indices of the instrument sent to 1675 fathoms.

On the 19th February, in lat. 64° 37′ S., long. 85° 49′ E., the temperature of the surface water was 32°, and that of the air 30°. A large number of icebergs were in sight. At a depth of 50 fathoms the maximum index, which before immersion registered 31°·4, rose to 32° (the temperature of the surface water), and the minimum index fell to 29°·2, indicating a colder stratum of water. At 100 fathoms the maximum index rose to the temperature of the surface water, the minimum fell to 29° which was slightly colder than that at the depth of 50 fathoms; but as two other instruments sent down to greater depths, which, therefore, passed through this cold stratum did not register 29°, the temperature of 29°·2 has been adopted for 100 fathoms. The maximum index of the one thermometer sent to 300 fathoms rose from 33° to 33°·8, but as the two sent to the bottom, which must have passed through this stratum, only registered 33°, that reading has been adopted. On the other hand, this might indicate that the stratum of 33°·8 F. is so limited that the bottom thermometers passed through it without attaining the full temperature. The bottom temperature at 1800 fathoms, as registered by two thermometers, was between 33° and 29°.

On the 21st February, in lat. 63° 30′ S., long. 88° 57′ E., and under the same circumstances of air and surface water temperature, a few observations showed a regular decrease in the temperature from 32° at the surface to 29°·3 at 40 fathoms.

On the 26th February, in lat. 62° 26′ S., long. 95° 44′ E., the temperature of the air was 35°·5, and that of the surface water 33°. A large number of icebergs were in sight. Previously to immersion the thermometers were cooled with ice and salt to a low temperature. At 100 fathoms the thermometer indices remained the same as on immersion, viz., 31°·8 and 32°, although this temperature was lower than that of the surface water, owing probably to their having passed too quickly through the narrow belt of superheated water. A third instrument which, before immersion, was set at 32°·5 was afterwards sent to the same depth, when the maximum index registered 32°·8, or approximately the surface temperature; and the minimum 31°·8, or the same temperature as previously obtained. This reading has, therefore, been assumed as the temperature at 100 fathoms. At 150 fathoms two thermometers registered a warm stratum of 34°, and the minimum indices showed that they had passed through the cold intermediate stratum of 32°. This was also confirmed by the two instruments lowered to 200 fathoms and the one sent to the bottom, for each of them registered a maximum temperature of 34°, and a minimum of at least 31°·8. The bottom thermometer, indeed, registered on its minimum side 31°·3, but unfortunately its temperature on immersion was not noted, and as it was cooled by the mixture of salt and ice, it may have stood at the temperature of 31°·3 when immersed. The bottom temperature is, therefore, uncertain, but must be between 34° and 31°·3.

On the 11th February, during the passage southward, in lat. 60° 52′ S., long. 80° 20′ E., with three icebergs in sight, serial temperatures were taken. The temperature of the air was 35°·5, and that of the sea surface 34°·2. Before immersion the thermometers, with the exception of those sent to the bottom and to the depth of 25 fathoms, were cooled to as low a temperature as was deemed necessary. The lowest temperature registered was 32° at 50 fathoms, and this continued certainly to the depth of 100 fathoms. At 150 fathoms the thermometer registered 36° on the maximum side and 31°·8 on the minimum. At 200 fathoms the thermometers registered from 35° to 35°·8 on the maximum side and 32° to 32°·8 on the minimum. At 300 fathoms the thermometer gave the same result as at 200 fathoms. Here, therefore, a rise of temperature took place at 150 fathoms, which reached its maximum at 200 fathoms. The bottom temperature is uncertain, as the thermometers which, on immersion, registered 41° came up showing 41° on the maximum and 32° and 33° on the minimum side.

On the 3rd March, in lat. 53° 55′ S., long. 108° 35′ E., the temperature of the air being 37°·8, and that of the sea surface 37°·2, serial temperatures were again obtained. No icebergs were in sight, but some were seen on the 2nd, and one was passed on the 4th. The thermometers were lowered to every 10 fathoms from the surface to 100 fathoms, and showed little alteration to the depth of 60 fathoms, registering there 36°·6, or only 0°·6 less than the surface temperature. At 70 fathoms a sudden fall of 3½° took place, and at 80 fathoms the temperature was 32°·5, below this depth the temperature is uncertain, as the instruments registered on their maximum side the temperature of immersion, and on their minimum the temperature at 80 fathoms. If a stratum of warm water commenced at 150 fathoms of the same temperature as that of the 26th February, viz., 34°, as there is every reason to believe, it could not, owing to the construction of the instruments, be detected, for, as the thermometers had passed through the surface stratum of 37°·2 and the cold stratum at 80 fathoms of 32°·5, they were unable to record any alteration between those temperatures at greater depths.

The bottom thermometers showed the temperature of immersion on their maximum side, and 32°·2 and 32°·0 on the minimum. As this is a colder result than any other instrument showed between the surface and 500 fathoms, it is probably justifiable to assume the mean (32·1) to be the correct bottom temperature at this position.

The result of the foregoing observations may be briefly stated thus:—

On the passage towards Cape Otway the cold intermediate stratum was traced as far north as 54° S., where its temperature was 32°·5 at a depth of 80 fathoms. Farther south it decreased until in lat. 66° S. it was 29° from immediately below the surface to a depth of 200 fathoms, or nearly as low as the freezing point of salt water.

The warmer stratum of oceanic water underlying it also gradually decreased in temperature as higher latitudes were reached, and it is possible that farther south the temperature of the water from the surface to the bottom will be found nearly uniform at probably 29° or 30°; but in that case it is somewhat difficult to account for the rise in temperature of the bottom water to 33°·5 in lat. 50° S., long. 123° E., only about 1200 miles from its source, as it is known that this temperature is retained with little alteration for 3000 miles, for Captain Shortland obtained bottom temperatures of 33½° in the Arabian Sea with unprotected thermometers. This will be referred to again when discussing the specific gravity of the sea water of the Southern Ocean.

During the winter season the ice at the surface must necessarily be colder than the water underlying it; it seems therefore highly probable that the cold wedge of water found near the surface is merely the remains of the winter-cooled sea, which has not sufficient time during the short summer to recover its temperature; it is also probable that during winter the solar-heated surface belt is entirely removed, and that the sea as far north, at least, as the 63rd parallel of south latitude becomes frozen over, the frequent gales breaking up the field ice and converting it into pack. It is noticeable that the temperature of the underlying stratum was on each occasion found to be warmer than the surface water. This fact is also confirmed by the observations of Cook, Ross, and Wilkes.

The fact that the cold wedge above referred to extended north just as far as the icebergs did in March 1874 points to there being some connection between the temperature and the presence of melting icebergs. The lowest bottom temperature registered between the Cape of Good Hope and Melbourne, north of the 54th parallel, was 33°·5, at the 54th parallel it was 32°·1, and at all Stations farther south of this, it cannot be said with absolute certainty what the bottom temperature was, as the thermometers below 300 fathoms came up with exactly the same readings as at that depth.

During the time the ship was near the edge of the pack ice the surface temperature was from 28° to 29°, and remained uniform to a depth of upwards of 200 fathoms, rising to 33° or 34° at 300 fathoms. At a short distance from the pack, but when surrounded by icebergs, the surface temperature was generally about 32°, but decreased to 29° at a depth of 40 fathoms, and retained that temperature to nearly 300 fathoms as in the pack.

Table of Temperatures obtained in the Antarctic Regions.

Depth. In Fathoms.	14th February. Lat. 65° 42′ S.				19th February. Lat. 64° 37′ S.				21st February. Lat. 63° 30′ S.				26th February. Lat. 62° 26′ S.				11th February. Lat. 60° 52′ S.				3rd March. Lat. 53° 55′ S.			
	Before Immersion.	Maximum.	Minimum.	Accepted Result.	Before Immersion.	Maximum.	Minimum.	Accepted Result.	Before Immersion.	Maximum.	Minimum.	Accepted Result.	Before Immersion.	Maximum.	Minimum.	Accepted Result.	Before Immersion.	Maximum.	Minimum.	Accepted Result.	Before Immersion.	Maximum.	Minimum.	Accepted Result.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
Surface	–	–	–	29·5	–	–	–	32·0	–	–	–	32·0	–	–	–	33·0	–	–	–	34·5	–	–	–	37·2
10	–	–	–	–	–	–	–	–	32·0	32·0	31·5	31·5	–	–	–	–	35·5	35·5	34·0	34·0	40·0	40·5	36·8	36·8
20	–	–	–	–	–	–	–	–	32·0	32·0	31·0	31·0	–	–	–	–	35·8	35·8	33·5	33·5	42·0	42·0	36·8	36·8
25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
30	–	–	–	–	–	–	–	–	35·0	35·0	30·0	30·0	–	–	–	–	–	–	–	–	40·8	40·5	36·6	36·6
40	–	–	–	–	–	–	–	–	32·5	32·5	29·3	29·3	–	–	–	–	–	–	–	–	41·0	41·0	36·6	36·6
50	30·2 30·2	30·0 30·5	29·0 29·0	29·0	31·4	32·0	29·2	29·2	32·5	32·5	29·3	29 3	–	–	–	–	35·5	35·6	32·0	32·2	41·0	41·0	36·6	36·6
60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	36·5	36·5	32·2	32·2	40·5	40·5	36·6	36·6
70	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	36·0	35·2	32·2	32·2	41·5	41·5	33·0	33·0
80	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	34·5	34·5	32·5	32·2	42·5	42·0	32·5	32·5
90	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	35·0	34·8	32·8	32·2	42·0	42·0	32·5	32·5
100	30·2 30·2	30·0 30·5	29·0 29·0	29·0	31·6	31·8	29·0	29·0	–	–	–	–	31·8 32·0 32·5	31·8 32·0 32·8	31·8 32·0 31·8	31·9	35·0 35·0 35·8	34·0 34·8 35·8	32·0 32·0 32·0	32·0	40·5 43·0	42·5 43·2	32·7 32·8	32·5
150	–	–	–	–	–	–	–	–	–	–	–	–	33·5 33·0	34·0 34·0	32·0 32·0	34·0	35·5	36·0	31·8	35·0	–	–	–	
200	30·2 30·2	30·5 30·5	29·0 28·8	30·5	–	–	–	–	–	–	–	–	31·0 32·5	34·0 34·0	31·0 31·8	34·0	34·0 34·0 35·5	35·0 35·2 35·8	32·0 32·8 32·0	35·3	42·5	43·0	33·0	
250	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	Uncertain.
300	30·2 30·2	32·0 32·0	29·0 29·0	32·0	33·0	33·8	29·4	33·8	–	–	–	–	–	–	–	–	34 0	35·5	32·2	35·3	42·5	42·5	33·0	
400	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	42·8	43·0	32·6	
500	30·2 30·2	32·8 32·8	29·0 28·8	32·8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	42·5	42·5	32·8	
Bottom	30·0 30·0	33·0 33·0	28·8 28·8	Uncertain.	31·0 31·5	32·9 33·0	29·3 29·0	Uncertain.	–	–	–	–	–	34·0	31·3	Uncertain.	41·0 41·0	41·0 41·0	32·0 33·0	Uncertain.	41·0 41·0	41·0 41·0	32·0 32·2	32·1

Density of the Sea Water.—The observations of the density of the water in this part of the cruise are of considerable interest. They are collected in the following table, which contains all the observations made on water from the bottom or intermediate depths with the density of the surface water at each Station. They are reduced to their value at 60° F. (15°·56 C.)—distilled water at 39°·2 F. (4° C.) being unity.

Density of Water at 60° *F.* (*Distilled Water at* 39°·2 *F.* = 1).

Depth from which water was taken.	A Station 143	B Station 144	C Station 147	D Station 154	E Station 156	F Station 157	H Station 158	K Station 160	L Station 152	M Station 153	N Station 159
Surface,	1·02653	1·02508	1·02506	1·02452	1·02501	1·02501	1·02514	1·02560	1·02505	1·02409	1·02554
50 fathoms,	623	...	...	527	...	499	511	563	...	...	...
100 ,,	611	515	504	140 fths. 1·02542	552	529	533	554	...	...	...
200 ,,	587	524	523		557	...	538	563	...	...	...
300 ,,	566	524	526	553	556	...	534	550	...	...	...
400 ,,	572	530	528	555	556	...	...	546	...	...	...
Bottom,	601	514	542	520	507	550	545	559	552	560	553
Depth (fathoms),	1900	1570	1600	1800	1975	1950	1800	2600	1260	1675	2150
Latitude S.,	36° 48′	45° 57′	46° 16′	64° 37′	62° 26′	53° 55′	50° 1′	42° 42′	60° 52′	65° 42′	47° 25′
Longitude E.,	19° 24′	34° 39′	48° 27′	85° 49′	95° 44′	108° 35′	123° 4′	134° 10′	80° 20′	79° 49′	130° 32′

Immediately on leaving the Cape, the course of the ship passed through the well-known Agulhas Current, the water of which is warm and dense. The first deep sounding was in 1900 fathoms, rather to the westward, or on the Atlantic side of the Agulhas Bank. Here the current coming from the Indian Ocean bends round the Cape, and its waters enter the Atlantic. The sounding was taken in a position where great changes of surface temperature are frequently observed (see p. 290), which indicate the meeting and imperfect mixture of waters brought from sources remote from each other. The densities observed at this Station are given in column A of the Table. It will be seen that they are all higher than those in any of the other columns. The temperatures also observed at the different depths are higher than at the other Stations. The water from the surface to the bottom bears evidence of having been warmed and concentrated in tropical regions. Between this Station and B the temperature and the density of the surface water fall at first gradually then rapidly, the great fall taking place while the ship was passing through a strong current, setting to the north and east between the 40th and 45th parallels. At Station B, which is already within the zone where icebergs may be met with at any season of the year, the surface density has fallen to 1·02508. During the whole sojourn of the ship in Antarctic waters, the surface density varied between 1·0250 and 1·0248, except where pack ice was met with, and then both the temperature and the density of the surface water were lower, the temperature being from 29° to 30°, and the density 1·0240. Station D, the most southerly where serial waters were collected, shows the distribution of density in the neighbourhood of the pack. The comparatively light stratum of water at the surface is of but little thickness, at 50 fathoms the density has already risen from 1·02452 (its value at the surface) to 1·02527; at 140 fathoms it is 1·02542, and at 300 fathoms 1·02553. While thus the density steadily increases with the depth, at least as far as 400 fathoms, the temperature of the water falls from 32° at the surface to 29°·2 at 50 and 29°·0 at 100 fathoms; at 300 fathoms it has risen to 33°·8. At Stations B and C, both approximately on the same parallel, the rise of density with increasing depth is less marked, and there is no such irregularity in the distribution of temperature. At Station C, which is 14° of longitude to the west of B, the temperature at all depths is very decidedly lower than at the corresponding depths at B, while much farther east, at Station H, the water is much warmer and denser than even at B, though the position is 5° farther south. No serial waters were obtained on the way south between the 47th and the 64th parallel. At Stations D and E, waters and temperatures were taken in the vicinity of the pack. It will be seen that the temperature falls to a minimum at about 100 fathoms, while the density rises to about 1·0255 at that depth, and remains nearly constant at greater depths, while the temperature rises to 33° or 34° at 300 fathoms according to the latitude. The density of the bottom water was usually from 1·0254 to 1·0256. The observations at B, D, and E are exceptions. At B and E the densities observed are almost identical with those of the surface water at the same locality, and at D it is identical with that of water between the surface and 50 fathoms. The only risk attending the collection of bottom water is that due to the possibility that the water-bottle may close at or near the surface, and thus enclose surface water which it would take to the bottom and bring back again. Although there is no reason for believing that this took place at each of these three Stations, it is possible that it may have done so, and the results may be considered as doubtful, and the bottom water may be assumed to have an average density of 1·0255. It must be observed that the collection of the intermediate water is attended by no such danger. At the bottom the temperature was, owing to the nature of the thermometers, uncertain, but there can be little doubt from the indications which it was possible to have, that it was lower than at 300 fathoms, though it may not have reached the minimum of 29° observed in the superficial water. In regions free from ice the temperature of the bottom water was found to be somewhat above the freezing point of fresh water, namely, 33°, and as this temperature persists at the bottom without sensible alteration as far as equatorial regions, it is probable that the bottom water in the deeper regions of the Antarctic Ocean is due to a mixture of water cooled to a low temperature in these regions with water drawn in from a lower latitude and with a higher temperature. This will be easily understood if the effect which will be produced on a sea when its surface is frozen be considered. For this purpose some knowledge of the nature of sea water ice is necessary.

During the short time spent in the neighbourhood of the ice pack, Mr. Buchanan made a number of experiments principally with the view of deciding the question whether sea water ice is or is not a mixture of pure fresh ice with brine. The experiments consisted in determining the temperature at which sea water ice melted, and the amount of chlorine contained in the water so formed.

The ice made by freezing sea water in a bucket was found to have formed all round the bottom and sides of the bucket, forming a pellicle on the surface, from which and from the sides and bottom the ice had formed in hexagonal planes, projecting edgewise into the water. The water was poured off, the crystals collected, washed with distilled water, pressed between filtering-paper, and one portion melted. It measured 9 c.c., and required for the precipitation of its chlorine 4 c.c. silver solution, corresponding to 0·0142 gramme chlorine, or 1·5780 gramme per litre. The other portion was used for determining the melting point. The instrument used was one of Geissler's *normal* thermometers, divided into tenths of a degree Centigrade, the zero of which had been verified the day before in melting snow. The melting point of the ice crystals was found to be 29°·7 (−1°·3 C.). The temperature of the melting mass was observed to remain constant for twenty minutes, after which no further observations were made.

In the same way the melting point of the pack ice was determined. The fresh ice began to melt at 30°·2 (−1° C.); after twenty minutes the thermometer had risen to 30°·4 (−0°·9 C.), and two hours and a half afterwards it stood at 31°·5 (−0°·3 C.), having remained constant for about an hour at 31°·3 (−0°·4 C.). The temperature of another portion of the ice rose more rapidly, and when three-fourths of the ice was melted the thermometer stood at 32° (0° C.).

The piece of pack ice examined was clear, with many air-bells, most of them rather irregularly shaped. Two portions of this ice were allowed to melt at the temperature of the laboratory, which ranged from 35° to 45°. The melting thus took place very slowly, and made it possible to examine the water fractionally. The experiments consisted in determining the chlorine in the water by means of tenth-normal nitrate of silver solution, and observing the temperature of the ice when melting.

A lump which, when melted, was found to measure 625 c.c., was allowed to melt gradually in a porcelain dish. When about 100 c.c. had melted, 50 c.c. were taken for the determination of the chlorine; they required 13·6 c.c. silver solution, corresponding to 0·0483 gramme chlorine. When 560 c.c. had melted, 50 c.c. were titrated, and required 1·6 c.c. silver solution, corresponding to 0·0057 gramme chlorine. The remainder (65 c.c.) of the ice was then melted and 60 c.c. titrated; they required 0·39 c.c. silver solution, corresponding to 0·0014 gramme chlorine. There were then in the first 50 c.c. 0·0483 gramme chlorine, in the next 510 c.c. 0·0579 gramme, and in the last 65 c.c. 0·0015 gramme. Hence the whole lump (625 c.c.) contained 0·1077 gramme chlorine, or, on an average, 0·1723 gramme chlorine per litre. A qualitative analysis of the water showed lime, magnesia, and sulphuric acid to be present.

Another piece of the ice was pounded and allowed to melt in a beaker. When about half was melted, the water was poured off and found to measure 95 c.c.; 75 c.c. were titrated with silver solution, and required 1·9 c.c. The remainder, when melted, measured 130 c.c., and required 0·9 c.c. silver solution. Hence the first portion of water (95 c.c.) contained 0·0085 gramme chlorine, and the second (130 c.c.) 0·0032 gramme chlorine. The whole quantity (225 c.c.) of ice therefore contained 0·0117 gramme chlorine, or, on an average, 0·0520 gramme per litre.

These determinations of the temperature of melting sea water ice show that the salt is not contained in it only in the form of mechanically enclosed brine, but exists in the solid form, either as a single crystalline substance or as a mixture of ice and salt crystals. Much additional light has recently been thrown upon this subject by the investigations of Dr. Pettersson, published in the Reports of the "Vega" Expedition under Nordenskiöld. Dr. Pettersson observed that sea water ice exhibited the extraordinary property of contracting with heat at temperatures a little below its melting point; he also noticed that the latent heat of sea water ice is much inferior to that of pure ice. In the course of his chemical investigations he also found that specimens of sea water ice vary greatly in their composition, and the result of his investigations may be summarised as follows:—

Ocean water is divided by freezing into two saliniferous parts, one liquid and one solid, which are of different chemical compositions. The most striking feature of the freezing process is that the ice is richer in sulphates and the brine in chlorides. The extraordinary variation both in saltness and in chemical composition of every individual specimen of sea-ice and sea-brine depends on a secondary process by which the ice seems to give up its chlorides more and more but to retain its sulphates. Hence the percentage of chlorine is no indication of the saltness of the ice, though it may to a certain extent be taken as an index of its age.

Professor Guthrie in his work on cryohydrates[1] gives the following Table:—

Cryohydrate of	Contains	Solidifies at
Chloride of Sodium, ...	76·39 per cent. water.	– 22° C.
Chloride of Potassium, ...	80·00 ,, ,,	– 11°·4 C.
Chloride of Calcium, ...	72·00 ,, ,,	– 37°·0 C.
Sulphate of Magnesia, ...	78·14 ,, ,,	– 5°·0 C.
Sulphate of Soda, ...	95·45 ,, ,,	– 0°·7 C.

Supposing that these cryohydrates are formed in the freezing of sea water, it is easy to see how as the temperature rises the chlorides melt out first and leave the ice richer and richer in sulphates.

[1] *Phil. Mag.*, ser. 4, vol. xlix. p. 1, 1875.

Dr. Pettersson analysed a large number of samples of sea water ice and found the ratio $Cl : SO_3$ to vary from 100 : 12·8 to 100 : 76·6, the average proportion in sea water being 100 : 11·88.

In the act of freezing, sea water separates into ice which contains less salt and into brine which contains more salt than the parent sea water, and it may be assumed that both the ice and the brine have the same temperature (29° F.). The brine being denser than the surrounding water sinks into it and by mixing with it renders it more salt and at the same time lowers its temperature. The tendency is in a sea isolated from circulation to produce a uniform temperature of about 29° throughout its depth, and this is actually what is observed in the Arctic regions in the Norwegian Sea, which is separated from the Atlantic by a ridge with a maximum depth of 300 fathoms of water over it.

In the portion of the Antarctic Ocean traversed by the Challenger there is only a very slight and gradual shoaling of the water from the Indian Ocean towards the Antarctic Circle. Hence there is no impediment to the free circulation of the water between high and low latitudes. The effect of the winter cold in high latitudes is in one respect the same as that of heat in tropical regions, it removes water from the sea and thus produces concentration; in the tropics the water is removed as vapour; in the polar regions it is removed as ice, leaving a salter water at the freezing temperature of the ice, which sinks and cools the deeper water by convection. In summer, when the ice breaks up, some of it melts and forms a layer of less saltness but low temperature at the surface. This layer, along with the melting pack ice floating in it, is generally driven in part far to the northward of the place where it was formed. Its place must be supplied from below by water coming from lower latitudes, unless the supply of land ice from the Antarctic continent were sufficient to supply the deficiency, which is very unlikely. On the return of winter the surface water will still be less dense than that below, and the brine separated from it on freezing will also be less dense, and therefore have less power to penetrate the deep water.

Further, the covering of ice is a very powerful protection to the water below. The thickness of the ice formed round the "Vega" during the winter that she was frozen in, in the Siberian Sea, was 162 centimetres, and the water below it was no colder than it had been in summer. Pettersson has found the latent heat of freezing sea water to be less than that of fresh water; but even if it were identical with it, the formation of 162 centimetres (0·875 fathoms) of ice would only be thermally equivalent to the reduction of the temperature of 125 fathoms of water, by 1° F. Such an effect is much inferior to that produced by the moderate winters of temperate latitudes where no ice is produced. In order that the winter cold at the surface be freely transmitted to the deeper water, it is important that the salinity of the surface water be greater than that of the water below it. The importance of this factor in promoting convection downwards was pointed out by Mr. Buchanan in a paper on the Vertical Distribution of Temperature in the Ocean,[1] in which more especially attention is paid to the effect of the surface climate on the waters of the subtropical North Atlantic. Here the surface of the ocean is exposed to the action of the northeast trade wind, which blows from colder to warmer regions, so that while it is continually taking up moisture it is continually increasing its power of doing so. In this region the removal of water from the ocean is effected in the form of vapour, in polar regions it is effected in the form of ice. In whichever way it is removed the effect is the same, the remaining water is salter than the original water, and therefore denser at the same temperature. In other words, the concentrated water will have the same density as the original water at a higher temperature, and it will have power to sink into or penetrate the original water before it has sunk to the same temperature. In this way the high winter temperatures of subtropical regions and the low temperature of freezing sea water, tend to be propagated downwards. In the Atlantic, Indian, and Pacific Oceans, there are return currents of dense warm water from tropical seas, along the eastern shores of South America, Africa, and Australia. The high salinity of this water gives it when cooled great penetrative power, as it can bear much dilution and still sink through the water of high latitudes at the same temperature.

It is probable therefore that the cold water at the bottom of the ocean, in so far as it is drawn from the southern hemisphere, leaves the surface between the parallels of 40° and 55° of south latitude. From this zone the water is drawn northwards to make good deficiencies, and it no doubt flows southward also in order to replace the ice and cold surface water drifted northward in the summer. The comparatively warm water which reaches the Antarctic Circle at a depth of 300 fathoms can only come from such a source. Its temperature is of course lowered by being drawn into polar regions, but it probably persists as a warmer stratum until it is arrested by the shoaling of the water. If within the Antarctic Circle there are seas like the Norwegian Sea within the Arctic, that are almost completely shut off from the general oceanic circulation, their waters will certainly have the same low temperature of about 29° F. from surface to bottom. In the Arctic Ocean a brisk superficial circulation is kept up by the warm North Atlantic current which penetrates it along the eastern side of the Norwegian Sea, and is in a measure compensated by cold polar currents which leave the Arctic Ocean along the eastern coast of Greenland and by Baffin's Bay along its western side, removing with them a large portion of the winter's ice. A circulation similar to this appears to be entirely wanting in the Antarctic regions; hence their ice-bound character.

Icebergs.—Sir James Ross, in his celebrated voyage, having discovered Victoria Land, sailed along its coast to the southward as far as the 76th parallel, where he

[1] *Proc. Roy. Soc. Lond.* vol. xxiii. p. 124 (1874), 1875.

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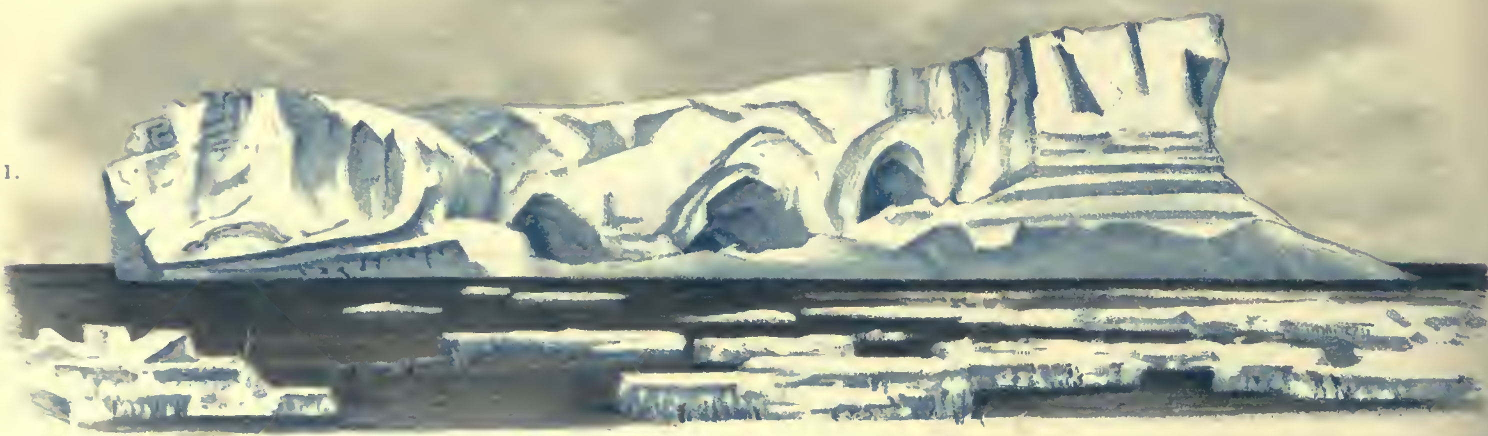

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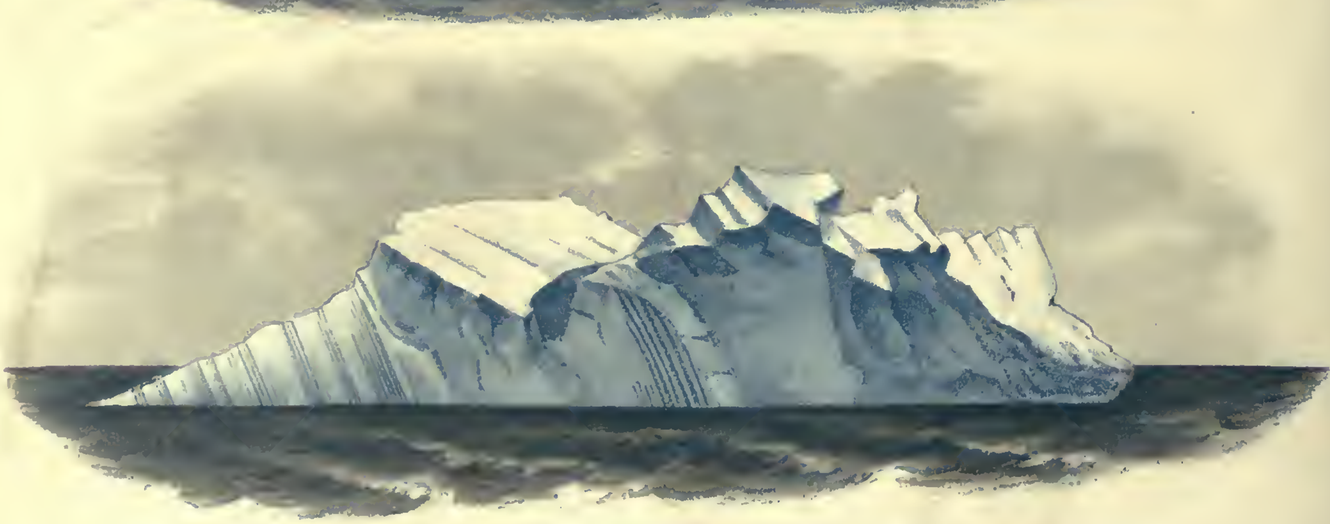

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ANTARCTIC ICEBERGS.

1-3, seen February 14th 1874, Lat. 65° 42' S., Long. 79° 49' E. 4, seen February 15th 1874, Lat. 65° 59' S., Long. 78° 24' E.

was stopped by an icy barrier extending upwards of 300 miles east and west, the perpendicular cliffs of which attained an altitude of from 150 to 200 feet, whilst the depth of water close outside these cliffs ranged between 180 and 410 fathoms. This icy barrier began at the foot of Mounts Erebus and Terror, which appear to be the southern peaks of a range of hills stretching irregularly to the northward at moderate distances from the coast as far as Cape North, in lat. 71° 30′ S. Off the coast of this high land there was pack ice; and here and there, descending from the ravines of the mountain ranges, were glaciers which extended some distance into the sea, and ended in perpendicular cliffs of considerable height, but there was no such barrier as extended west from the foot of Mount Terror.

That the edge of the icy barrier seen by Ross is nearly, if not quite, water-borne, and therefore just in a condition to generate icebergs is evident, for the height of the ice cliffs above the water-line varies from 150 to 200 feet (mean 175 feet), whilst the depth of water within a mile of them is 260 fathoms. Now, supposing the specific gravity of ice at 32° to be 0·92, and that of sea water at the same temperature to be 1·027 (distilled water at 39° being equal to 1), an iceberg floating will have 89·6 per cent. of its volume immersed, that is supposing it to be of the same temperature and consistency throughout, or in round numbers 90 per cent. of volume will be under water, and 10 per cent. above. Taking this as the basis of calculation, it is found that the icy cliffs of the barrier will be water-borne at 260 fathoms, or precisely the depth found by Ross close to them. This also will be the draught of water of a tabular iceberg detached from the barrier whose height above water is 175 feet. This uniform height, about 175 feet, of the tabular icebergs in high latitudes cannot fail to strike even the most ordinary observer, and can only be accounted for by supposing them to have been generated by the icy barrier.

The highest berg seen by Cook was in lat. 59° S., long. 92° E., 300 to 400 feet high, but was only half a mile round. Ross does not mention any very high iceberg, and Wilkes estimates his highest at 500 feet, but this was not a tabular berg, and although very high table-topped icebergs have been seen far north, they were always in a rapid state of dissolution. In fact they sometimes break up in high latitudes, for Biscoe observed one fall asunder in lat. 65° S., long. 116° W.

The icebergs met with in the Challenger were usually from a quarter to half a mile in diameter, and about 200 feet high; the highest measured was 248 feet, but it was evidently an old berg floating on a large base. The largest, which was seen farthest south in latitude 66° 40′, was 3 miles in length, and was accompanied by several others nearly as large. It is remarkable how few were fallen in with to the westward of the 80th meridian of east longitude, or to the northward of the pack ice there, which was probably a detached pack, similar to that sailed through by Ross in 1841.

To the eastward of the meridian of 92° E. icebergs were very numerous, and continued so as the ship ran to the eastward even at a distance from the pack. Their absence farther to the westward, between 70° and 80° E. longitude, except when close to the pack edge, was so marked that, coupled with their absence on the same meridians in lower latitudes as shown by the ice chart, it seems to indicate that there can be no land for a considerable distance south in that neighbourhood, and that a very high latitude could be gained there if desired.

The pack ice consisted chiefly of small salt water ice pieces, which could scarcely be called floes, from 30 to 50 feet in diameter; 100 miles within the pack edge Ross found them to be 600 feet in diameter. The single season's ice was about 3 feet in thickness, the hummocky ice, formed by several layers heaped one upon another and frozen compactly together, was from 7 to 8 feet thick, the upper surface of each piece being covered by a layer of snow about a foot in thickness. Scattered about in the pack were a few blue coloured berg pieces of all sizes, some of them frozen into the salt water ice. All the latter was much honey-combed by melting, but the ice was evidently still of sufficient strength to give a very dangerous blow if impelled against a vessel's side, or to a vessel forcing her way through the pack. A properly fortified ship could nevertheless have easily made way through it.

In the pack were numerous icebergs, but they were not in greater numbers than in the open water, and certainly not numerous enough by themselves to create the nucleus for the pack to form around.

A very large proportion of the bergs were, as stated, flat-topped and maintained their original balance. Very many were bounded by a single range of cliffs washed by the waves all round (fig. 122 p. 377; Pl. D. fig. 3). In some these ranges were evidently old and very much indented. Many were highly complex, combining two stories, lines of caves, talus slopes, and evidences of having been tilted to various angles from the original line of flotation once or twice (Pl. B. fig. 1; Pl. D. fig. 4); some were excessively worn and weathered, having apparently been long in warmer regions, and were pinnacled and broken up by deep gullies or channels bounded often by rounded ridges projecting at their mouths on either side. One much weathered pinnacled berg was passed which had its entire surface shining and polished as if it had recently toppled, and no fresh snow had fallen since this had occurred. Several were seen with the parts which had been below water partially exposed by tilting; the surfaces of these were always polished and smooth; but no berg was seen to tilt or turn over during the voyage. One was noticed divided into three separate columnar masses so far as the part above water was concerned, no connection between the columns being visible.

The platforms under water at the bases of the bergs often run out into spurs and irregular projections, and these may be dangerous to ships going too near. Soundings were taken on one of these platforms and gave 7 fathoms at some distance from

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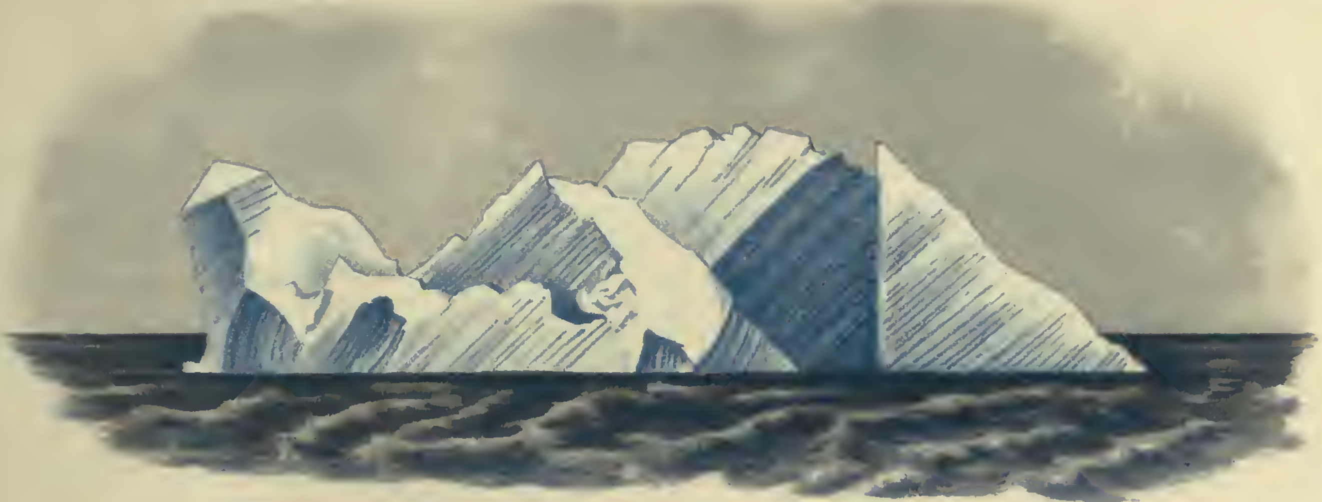

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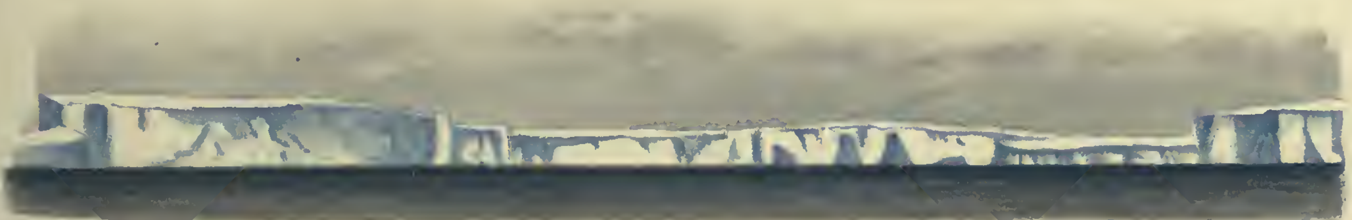

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ANTARCTIC ICEBERGS.

1, seen February 15^th 1874, Lat. 65° 59′ S., Long. 78° 24′ E. 2-4, seen February 16^th 1874, Lat. 66° 40′ S., Long. 78° 22′ E.
5, seen February 19^th 1874, Lat. 64° 37′ S., Long. 85° 49′ E.

the berg and $3\frac{1}{2}$ fathoms nearer in. Nearly all the flat-topped bergs showed numerous crevasses in their cliffs near their summits, and these were always widest towards the summits, and were irregularly perpendicular in general direction. The flat tops of the bergs had usually rather uneven surfaces, being covered with small hillocks, apparently formed by the drifting of snow, or showing irregularities where they covered over the mouths of crevasses. The surfaces in fact, looked just like those of the "Firn" or "Névé," the cracked snow-fields at the heads of European glaciers, and appeared as if they would be equally dangerous to traverse, except by a party roped together. The second stories of bergs were always covered with snow, which had fallen on them after their emergence.

The stratified structure of the bergs is best seen in the case of flat-topped rectangular bergs, where an opportunity is afforded of examining at a corner two vertical cliff faces meeting one another at a right angle. The entire mass shows a well-marked stratification, being composed of alternate layers of white opaque-looking, and blue, more compact and transparent, ice. The late Dr E. L. Moss, R.N., Staff-Surgeon on the recent Arctic Expedition, describes a similar stratification as occurring in Arctic ice. He had opportunities of examining the ice closely at leisure, and describes each stratum as consisting of an upper white part merging into a lower blue part, the colour depending on the greater or less number and size of the air-cells in the ice.[1]

Towards the lower part of the cliffs, the strata are seen to be extremely fine and closely pressed, whilst they are thicker with the blue lines wider apart, in proportion as they are traced towards the summits of the cliffs. In the lower regions of the cliffs the strata are remarkably even and horizontal, whilst towards the summit, where not subjected to pressure, slight curvings are to be seen in them corresponding to the inequalities of the surface and drifting of the snow. In one berg there was in the strata at one spot the appearance of complex bedding, somewhat resembling that shown in the Æolian calcareous sand formations of Bermuda. The strata were often curved in places, but always in their main line of run, horizontal, *i.e.*, parallel to the original flat top of the berg. The strata in the cliff at the level of the wash-line of a rectangular berg 80 feet in height were so thin and closely packed that they looked almost like the leaves of a huge book at a distance, for by the lap of the waves the softer layers had been to some extent dissolved out from between the harder. In one berg where the face of the cliff was very flat and seen quite closely with a powerful glass, the fine blue bands were seen to be grouped, the groups being separated by bands in which no lines were visible, or where these were obscured by the ice fracturing with a rougher surface, not with a perfectly even and polished one, as existed where the blue bands showed out. The cliff surfaces, where freshly fractured, showed an irregular jointing and

[1] Observations on Arctic Sea Water and Ice, *Proc. Roy. Soc. Lond.*, vol. xxvii. p. 547, 1878.

cleavage of the entire mass, very like that shown in a cliff of compact limestone. In one or two bergs a fine cleavage lamination was noticed like that of slate or shale, the laminæ being parallel to the face of the cliff, and breaking up at their edges with a zigzag fracture, resembling diamond cleavage of slate; this condition may have been produced by a peculiar exertion of pressure in these particular bergs.

When the lower cliff of a two-storied berg (Pl. D. figs. 1, 2) had a shot fired into it, large masses of ice fell, raising a considerable swell in the sea. The pieces of the cliff split off in flat masses parallel to the face of the cliff, just as was noticed in the case of the splitting of the glacier cliffs at Heard Island, and did not tumble forward but slid down the face of the cliff, keeping their upper edges, parts of the old plateau surface, horizontal. The ice floated round the ship in some quantity; it was opaque and white-looking, somewhat like white porcelain, and the shattered fragments had remarkably sharp angular edges, showing that the ice was very hard and compact, far more so than its appearance in mass would lead one to suppose, since it looked at a distance as if it were hardly consolidated, but merely closely pressed snow. Its manner of cleavage only gives evidence at a distance of its very compact nature. Many of the floating fragments were traversed by parallel veins of transparent ice, those which, when seen on a cliff surface, looked blue.

During the short time that the ship was amongst the icebergs not one was met with that bore upon it any moraines or rocks which could with certainty be determined as such, but on the 24th February a large rock was reported on one. The scarcity of such appearances has been remarked by former voyagers. Nevertheless, there are numerous instances in which observers have met with rocks on southern bergs. Wilkes and Ross saw many; and the latter on one occasion landed a party on a berg on which there was a volcanic rock weighing many tons, and covered with mud and stones.[1] Mr. Darwin published a note on a rock seen on an Antarctic iceberg in lat. 61° S.[2] Dr. Wallich[3] remarks on the similar scarcity of the appearance of stones or gravel on northern bergs; not one in a thousand shows dirt, stones, or rocks. He attributes this to the very small disturbance of their centres of gravity which icebergs undergo when floating freely. Stones and gravel may be present in most cases, but generally remain invisible under water in the lower parts of the bergs.

On three occasions discolorations of bergs were seen. In one case there was a light yellow band on one surface of a cliff high up, possibly the result of birds' dung which had fallen on the snow when the layer was formed, or it might have been due to a fall of volcanic dust; it was too high up to be due to Diatoms. On another occasion two bergs were passed at a distance, which showed conspicuous black-looking bands, appa-

[1] Ross's Antarctic Voyage, vol. i. p. 173, London, 1847.

[2] C. Darwin, Notes on a Rock seen on an Iceberg in lat. 61° S., *Geogr. Soc. Journ.*, vol. ix. pp. 528, 529, 1839; see also Journal of Researches during the Voyage of H.M.S. "Beagle," p. 251, ed. 1879.

[3] G. C. Wallich, The North Atlantic Sea Bed, pt. i. p. 56, London, 1862.

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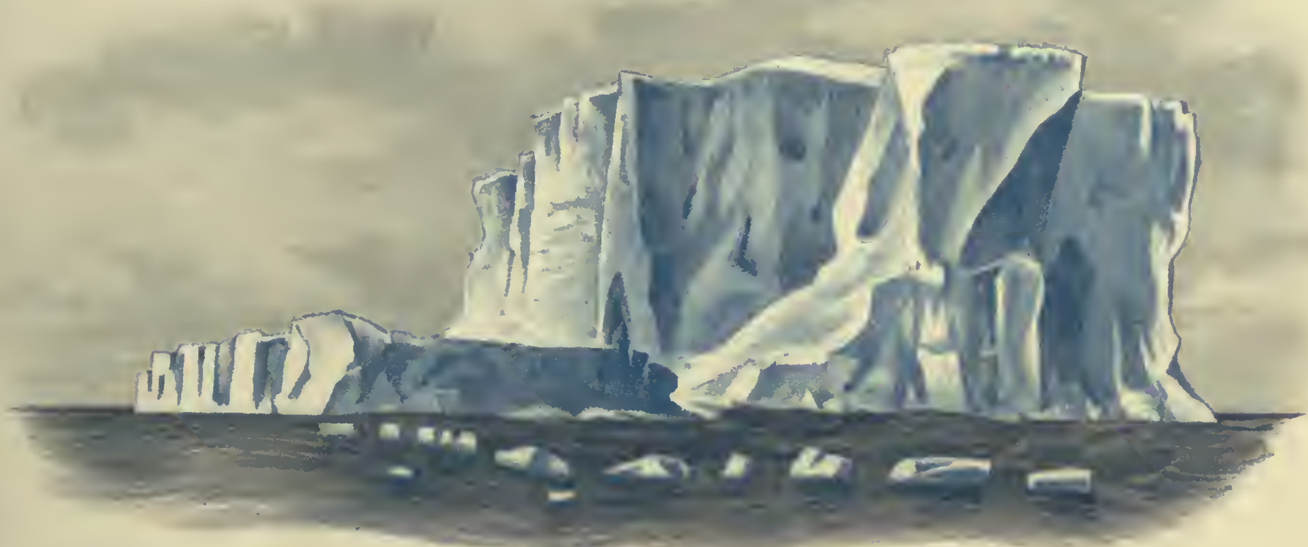

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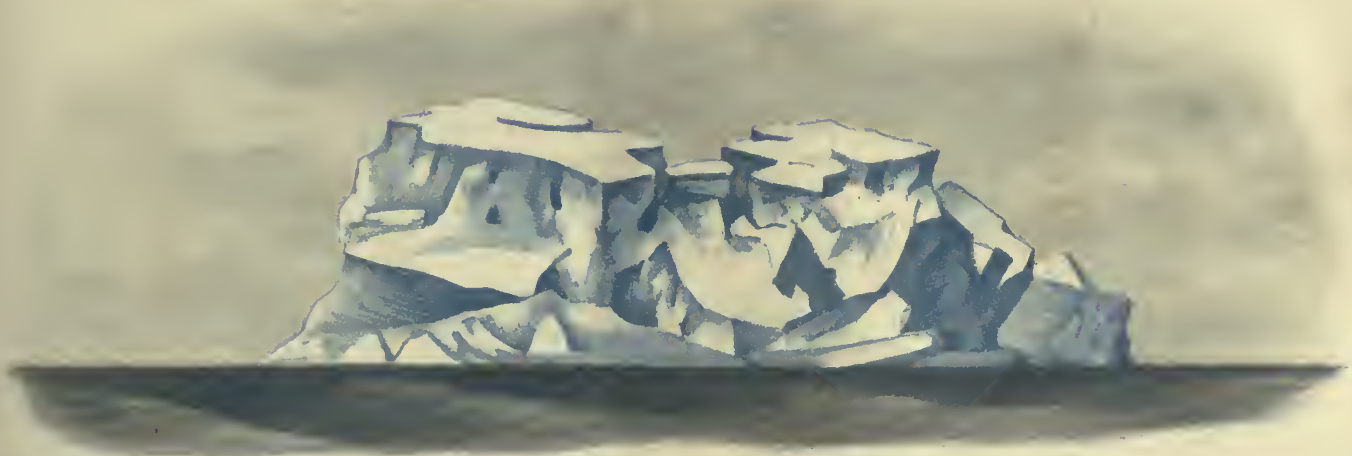

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ANTARCTIC ICEBERGS.

1 & 2, seen February 21st 1874, Lat. 63° 30′ S., Long. 89° 6′ E. 3, seen February 22nd 1874, Lat. 63° 30′ S., Long. 90° 47′ E.

4, seen February 25th 1874, Lat. 63° 49′ S., Long. 94° 51′ E

rently dirt bands. In one of the bergs there were two or three such bands, very broad, parallel to the blue bands, and separated by considerable intervals, in which the berg showed the usual stratification. In another two black bands existed at one end of the berg and one at the other. Both were parallel in direction to the blue bands, but the stratification at the end where the two black bands were situated was inclined at an angle to that of the remainder of the berg, as if a dislocation of a part of the berg had taken place. These bergs were too far distant to allow of the exact nature of the black bands being determined.

In none of the numerous bergs was there seen any bending or curved vertical bands, giving evidence of a former differential motion in the mass, such as are to be seen on every land glacier. How far the absence of these characteristic lines of motion may be explained by the fact that only about the uppermost tenth of the entire height of the bergs is seen, it is difficult to say.

The colouring of the southern bergs is magnificent. The general mass has an appearance like loaf sugar, with a slight bluish tint, except where fresh snow resting on the tops and ledges is absolutely white. On this ground colour there are parallel streaks of cobalt blue, of various intensities, and more or less marked effect, according to the distance at which the berg is viewed. Some bergs with the blue streaks very definitely marked have, when seen quite close, exactly the appearance of the common marbled blue soap. The colouring of the crevasses, caves, and hollows is of the deepest and purest azure blue possible (Pl. B. figs. 1, 3). None of the artists on board was able to approach a representation of its intensity; it seemed a much more powerful colour than that which is to be seen in the ice of Swiss glaciers. In the case of the bergs with all their sides exposed, no doubt a greater amount of light is able to penetrate than in glaciers where the light can usually only enter at the top. A large berg full of caves and crevasses, seen on a bright day, is a most beautiful and striking object. One small berg was passed at a distance which was of a remarkable colour; it looked just like a huge crystal of sulphate of copper, being all intensely blue, but it seemed as if attached to, and forming part of, another berg of normal colour. Possibly it was part of the formerly submerged base, and of more than ordinary density. Only one other such berg was seen. The intensity of the blue light received from the bergs is ordinarily such that the grey sky behind them appears distinctly reddened, assuming the complementary tint, and the reddening appears most intense close to the berg. At night bergs appear as if they had a very slight luminous glow, suggesting that they are to a very small extent phosphorescent. The sea at the foot of the bergs usually looks of a dark indigo colour, partly, no doubt, in contrast to the brighter blue of the ice. Where spurs and platforms run out under water from the bases of the berg cliffs, the shallow water is seen to be lighted up by reflection of the light from them.

The surf beats on an iceberg as on a rocky shore, and washes and dashes in and out of the gullies and caverns, and up against the cliffs. Washing in and out of the caves, it makes a resounding roar, which, when many bergs surround the ship, is very loud. So heavy is the surf on the bergs, and so steep are they as a rule, that none was seen on which landing could have been effected from a boat. As the waves wash up into the wash-lines of the bergs they form icicles, which are to be seen hanging in rows from the upper border of these grooves. A line of fragments is always to be seen drifting away from a large berg; these are termed wash-pieces. They are very instructive as showing the vast relative extent of submerged ice required to float a small portion above water, the parts of the fragments below water being visible from a ship's deck.

The scenic effects produced by large numbers of icebergs, some in the foreground, others scattered at all distances to the horizon and beyond it, are very varied and remarkable, depending on the varying effects of light and atmosphere. On one occasion, as the pack ice was being approached, some distant bergs were seen to assume a most intense black colour. This was due to their being thrown in shade by clouds passing between them and the sun, and the heightening of this effect by the contrast with brilliantly lighted up bergs around them. They looked like rocks of basalt.

Deposits.—In the cruise between Heard Island and Australia four kinds of deposits were met with, viz., blue mud, Diatom ooze, Globigerina ooze, and red clay.

The first of these was found in depths of 1675, 1800, and 1300 fathoms at the most southern latitude reached by the Challenger, between lat. 64° and 66° S. (see Sheet 23). These blue muds contained less than 11 per cent. of carbonate of lime, which consisted chiefly of the dead shells of *Globigerina dutertrei*, and about 20 per cent. of the remains of siliceous organisms, chiefly Diatoms. The mineral particles consisted of quartz, felspars, hornblende, garnets, glauconite, mica, tourmaline, and fragments of granitic, amphibolic, and other rocks. From the depth of 1675 fathoms the dredge brought up many kinds of rocks and pebbles, some of them showing distinct marks of glaciation, and many of them having a coating of peroxide of manganese on that part which had projected above the mud when lying at the bottom. The rocks belonged to the following lithological types:—granitites, quartziferous diorites, schistoid diorites, amphibolites, mica schists, grained quartzites, and partially decomposed earthy shales.

To the northward of the Stations at which blue mud was found between lat. 64° and 53° S., in depths of 1260, 1975, and 1950 fathoms, the deposit was a Diatom ooze, usually of a yellowish-straw colour, which when dried had the aspect of flour, the particles being extremely fine, and the whole taking the impress of the fingers when pressed, gritty particles being now and then recognisable. One of the samples contained as much as 22 per cent. of carbonate of lime, consisting chiefly of the dead shells of *Globigerina bulloides*, *Globigerina inflata*, and *Globigerina dutertrei*. The mineral particles were similar to those in the blue muds just mentioned, and appeared to make up from 15 to 20 per cent. of the deposit, the whole of the remainder consisting of the frustules of Diatoms and the skeletons of Radiolarians. The dredgings in these deposits yielded, in addition to all the varieties of rocks mentioned in the blue muds farther south, several fragments of pumice stone, basaltic volcanic rock, palagonite, and one or two fragments of a compact limestone and sandstone.

Between lat. 53° and 47° S. two soundings were obtained in 1800 and 2150 fathoms. The deposit in each case was a whitish Globigerina ooze, containing respectively 85 and 89 per cent. of carbonate of lime, which consisted chiefly of Coccoliths, Coccospheres, and pelagic Foraminifera belonging to the species *Globigerina bulloides*, *Globigerina inflata*, *Globigerina dubia*, *Pulvinulina micheliniana*, and *Orbulina universa*, together with other Foraminifera and fragments of Echinoderms. The mineral particles appeared to make up 2 to 4 per cent. of the deposit, and consisted of hornblende, magnetite, felspar, vitreous fragments, and a few quartz grains. There were 4 or 5 per cent. of Diatoms and Radiolarians in these Globigerina oozes.

The remaining variety of deposit (red clay) was obtained in lat. 42° S. at a depth of 2600 fathoms. It contained 18 per cent. of carbonate of lime, consisting of fragments and perfect shells of *Globigerina bulloides*, *Globigerina inflata*, *Globigerina rubra*, *Pulvinulina micheliniana*, *Orbulina universa*, a few other Foraminifera, Coccoliths, and fragments of Echinoderms. The mineral particles made up 19 per cent. of the deposit, and consisted of felspars, hornblende, augite, magnetite, pumice, and fragments of volcanic glass, grains of peroxide of manganese, with a mean diameter of about 0·05 mm., while a few rounded fragments of quartz reached a diameter of 0·5 mm. The remainder of the deposit consisted essentially of argillaceous matter with very minute fragments of crystals and pumice. There was a larger percentage of carbonate of lime in the upper layers of the deposit than in the lower ones. The trawl brought up 10 or 12 litres of manganese nodules, pumice stones, fragments of palagonite, ear-bones of Cetaceans, and Sharks' teeth.

From the foregoing description it appears that the deposits forming at the most southerly points reached by the Challenger are composed chiefly of continental débris carried into the ocean by the floating ice of these regions, and that this material makes up less and less of the deposit as the distance from the Antarctic Circle increases until it completely vanishes about lat. 46° or 47° S. The deposits along the Antarctic Ice Barrier, which have been called blue muds, resemble in many respects the deposits formed at similar depths off the Atlantic coast of British North America. The nature of the rock fragments dredged in these latitudes conclusively proves the existence of continental land probably of considerable extent within the Antarctic Circle. One of the fragments of gneiss dredged from a depth of 1950 fathoms measured 50 by 40 centimetres, and weighed more than 20 kilogrammes. In the region occupied by the Diatom ooze, northward of the blue muds, the predominant feature of the deposit is due to the innumerable frustules of Diatoms and skeletons of Radiolarians which have fallen from the surface and subsurface waters of the ocean. Farther north again the pelagic Foraminifera predominate in the deposit, except at the depth of 2600 fathoms, where the greater part of them has been removed by the solvent powers of the sea water, as is usual at the great depths in the ocean.

Surface Organisms.—South of lat. 50° S. Diatoms were occasionally met with in the surface nets in enormous abundance. The most abundant were various species of *Chætoceras*, but there were also many other genera. The tow-nets were on some occasions so filled with these that large quantities could be dried by heating over a stove when a whitish felt-like mass was obtained. Associated with the Diatoms were many species of Radiolarians.

At other times, when the sea was of a pale greenish colour, the water was filled with little spherical jelly-like bodies, about 0·1 mm. in diameter, which usually contained four greenish or yellowish spots. When held in a certain light in a glass jar, these little spheres could be seen by the naked eye filling the water. Similar minute Algæ have been found in the Arctic regions. Whenever the ship passed out of the greenish bands of water these minute spheres could not be observed. Coccospheres and Rhabdospheres, which were found so abundantly in the surface water of the warmer parts of the Atlantic and Southern Oceans, were not met with south of lat. 50° S., either on the surface or in the deposits at the bottom. The same remark applies to *Orbulina universa*, *Pulvinulina*, and several species of *Globigerina*. South of lat. 50° S. the only pelagic Foraminifera found on the surface were *Globigerina bulloides*, *Globigerina dutertrei*, and *Globigerina inflata*, and these were the only pelagic species found in the deposit at the bottom. Copepods, Ostracodes, Hyperids, *Euphausia*, *Alciope*, *Tomopteris*, *Sagitta*, Pteropods, *Salpa*, and *Appendicularia* were also met with in considerable abundance in the surface nets south of lat. 50° S.

The following birds were noticed while the Challenger was amongst the Antarctic ice :—

Oceanites oceanicus, Kuhl.
Thalassæca glacialoides, Smith.
Thalassæca (Aeipetes) antarctica, Gm.
Ossifraga gigantea, Gm.
Pagodroma nivea, Gm.
Daption capensis, Linn.
Prion desolatus, Gm.
Diomedea (Phœbetria) fuliginosa, Gm.
Stercorarius antarcticus, Less.

Penguins were very often seen in the water, and on one occasion sitting on the ice, but it was impossible to make out the species. Off the pack ice, and especially near the Antarctic Circle, whales (apparently all of one species, a "Finner," probably *Physalus* *australis*) were very abundant. Smaller Cetaceans, probably a kind of Grampus (*Orca*), were also abundant near the Antarctic Circle, with a high dorsal fin placed at about the middle of the length of their bodies.

The dredgings and trawlings during the Antarctic voyage were exceedingly productive, and yielded many new genera and species belonging to nearly all the invertebrate groups. In the Zoological Reports already published, species are described belonging to about twenty-five new genera and fifty new species.

Fig. 158.—*Tægeria pulchra*, n. gen. et sp. a representative of the Euplectellidæ.

The Hexactinellida.—Professor Franz Eilhard Schulze, who is engaged in preparing a Report on the Hexactinellida collected during the Expedition, has supplied the following notes :—

"The Hexactinellida collected by the Challenger Expedition, which were entrusted to me for the purpose of scientific investigation, were dried, or more or less well-preserved in alcohol of various degrees of strength. Only a few specimens, however, were quite perfect, most of them having been injured in some way or other. Sometimes there were parts entirely wanting, sometimes the sponge was torn, crushed, or the outside had been rubbed off, or sometimes the soft parts had suffered from the invasion of mud or had become dried, as indeed might have been expected considering how most of the specimens had been obtained. Of many species only fragments, and of others only isolated spicules were obtained. It was a fortunate circumstance that no means of cleansing, such as washing, maceration, or the like, had been adopted ; by these processes the specimen gains, it is true, in elegance, but, in general, the isolated spicules which are so important for the scientific determination of the species are lost. For the study of the soft parts of the Hexactinellida, which were hitherto almost unknown, and in the present instance demanded special attention, those specimens which had been hardened in absolute alcohol proved specially favourable; also those portions which had been preserved in a relatively large volume of spirit of the usual strength had to some extent retained their original structure, better when voluminous or very compact than when thin and loose in structure.

FIG. 159.—*Caulophacus elegans*, n. gen. et sp., a representative of the Ascouematidæ.

"A serious drawback, however, arose from the fact that the isolation of the different species had not always been found possible. Even in the operation of dredging the different sponges had undoubtedly come into violent contact with each other; in many instances fragments of one sponge remained attached to the surface of another, or whole portions of one had penetrated into the body of another. But in those cases in which several individuals had been preserved in the same vessel it was afterwards found that the microscopic siliceous spicules, which are so important for diagnostic purposes, had, in consequence of their lying loosely scattered in the soft parts, become separated from one sponge and embedded in another lying either beside or beneath it. Obviously such intruding strangers, which may be only too easily mistaken for natives, materially increase the difficulty of fixing the character of the species or the determination of a solitary portion, especially when new and hitherto unknown forms are being treated of, whose characteristic spicules must be determined for the first time. It is true this danger of error is materially diminished by comparative examination of the various portions of the same sponge, or better still of several specimens of the same species if they are to be had, but even then there remain quite a sufficient number of instances in which a certain conclusion can be drawn only by the preparation of numerous fine sections, in which the disposition of the spicules in question will decide whether they are really in their normal situation.

FIG. 160.—*Hyalonema elegans*, n. sp., a representative of the Hyalonematidæ.

"The investigation began by a careful separation and arrangement of all the specimens; these were then placed according to the order of the dredging stations, and then one by one, thoroughly studied both with respect to their coarser as well as to their microscopic structure. The numerous preparations, drawings, and notes which were accumulated by this last difficult and tedious task form the foundation of the whole work. It was desirable not only to establish the characters of the various species, but, as far as possible, to discover the general plan of organisation of this curious and little known group of animals. Only by the application of various oftentimes very complicated methods (often newly devised for this special purpose) and instruments was it possible to arrive at a clear understanding as to the minute structure of the indifferently preserved specimens. Obviously just those portions have caused the most trouble which were the worst preserved, or only came to hand in small fragments.

Fig. 161.—*Poliopogon amadou*, Wyv. Thoms., a representative of the Hyalonematidæ. One-third the natural size. Attached to branches of *Corallium* (see p. 125).

" As a rule small pieces selected from various regions of the sponge were first soaked for some time in concentrated hydrochloric acid and then boiled in it for a few minutes, washed out with water and alcohol, dehydrated by alcohol of increasing strength, cleared by oil of cloves, and finally after teasing and careful spreading out mounted in Canada balsam. In this manner the isolated siliceous spicules and the small fragments of continuous skeletons were perfectly cleaned and exposed to view; also pieces from different parts of the sponge were, after short treatment with hydrochloric acid and subsequent washing with water and alcohol, dehydrated *en masse,* soaked in spirit of turpentine or xylol, embedded in paraffin and cut into sections by means of the microtome in

FIG. 162.—*Pheronema carpenteri* (Wyv. Thoms.), a representative of the Hyaloneinatidæ.

various directions, but principally perpendicular to the surface. Such sections, in which all parts of the skeleton stood out clearly in the perfectly transparent soft parts, served principally for ascertaining the situation and distribution of the separate siliceous portions as well as for deciding whether the spicules which would have become separated in complete maceration were in their normal situation.

"Finally the exceedingly delicate soft parts were successfully examined, both with respect to their most minute characters as well as with reference to their relation to the skeletal structures. In addition to the usual methods of teasing and cutting into sections, it has been found advantageous to stain the specimen with some colouring matter, especially with picrocarmine, alum-carmine, and hæmatoxylin. For this purpose portions, about the size of peas or beans, were stained whole, then thoroughly washed out with alcohol of gradually increasing strength, and finally dehydrated with turpentine or xylol, embedded in paraffin and cut into sections of varying thickness with the microtome.

Fig. 163.—*Hyalonema lusitanicum*, Bocage, a representative of the Hyalonematidæ.

"In some cases it was desirable to obtain in the section not only the delicate soft-tissues but also the hard and brittle flinty skeleton as a complete network; but the well-known curling up of the thin sections was a serious hindrance, inasmuch as although the delicate, yet elastic, soft tissues were easily retained in connection, the brittle siliceous web was always obtained in fragments. I sought to discover a means by which this detrimental curling of the sections might be prevented, and after many attempts constructed that small accessory to the microtome which I have described and figured under the name of 'Schnittstrecker';[1] by means of this simple instrument it was possible to obtain sections, not only of very firm and compact pieces, but also of more delicate and brittle objects, such as the tubes of the genus *Farrea*, in which not only the soft parts but also the brittle siliceous trabeculæ were retained in their normal positions. The sections prepared in this manner proved of assistance in

[1] *Zool. Anzeiger.*, Jahrg. vi. p. 108, 1883.

the comprehension of the plan of organisation and the structural relations, but they were less applicable to the study of minute histological details, which undergo alteration by treatment of the object with turpentine and embedding in paraffin. For this purpose therefore other preparations were used, which were simply teased out or cut by hand after being stained and then mounted in glycerin.

Fig. 164.—*Crateromorpha murrayi*, n. sp., a representative of the Rossellidæ.

"The glycerin has the advantage over balsam not only in that the delicate outlines of the cells may be more easily recognised, but also because, in consequence of its refractive index agreeing very closely with that of the siliceous skeleton, this latter becomes almost invisible, and thus the soft tissues stand out much more prominently.

"As one of the most important results of the carrying out of these detailed investigations, the fact has been established that the Hexactinellida, which were first clearly marked off and characterised by Oscar Schmidt in 1870, form a division of the siliceous sponges, definitely bounded on all sides, whose members are intimately united by a common plan of structure. The subclass Hexactinellida is, however, principally charactèrised by the triaxial or six-rayed type, which underlies the forms of its spicules, and also by the close agreement of the organisation of its soft parts. In no single instance was I ever in doubt whether I had before me a Hexactinellid or not; for even when many isolated spicules and the several parts of a connected trabecular skeleton did not show the typical Hexactinellid structure without further investigation, yet on careful examination this could be demonstrated, and spicules were found showing either the usual six-rayed form or an easily recognisable derivative from it. As Oscar Schmidt was the first to point out, the determination of the axial-relations of the central canal is of special importance; by means of studying it in every connected trabecular skeleton the individual six-rayed spicules, already partially united, are always easily recognised; even in the case of many highly modified isolated needles, the central canal gives a clue to the derivation from the typical six-rayed form. However great the number of forms of the spicules in the Hexactinellida may be, yet there are fundamentally but few principles of modification which have been carried out. These are—(1) unequal elongation of the individual rays, in which may be found all degrees of shortening, even to complete atrophy of one or more rays; (2) division of the rays into two or more branches; (3) flexion of the rays or their branches; (4) unequal thickening of the rays or their branches, which may lead to the development of swellings of various forms, hooks, teeth, or the not infrequent terminal knobs or toothed plates.

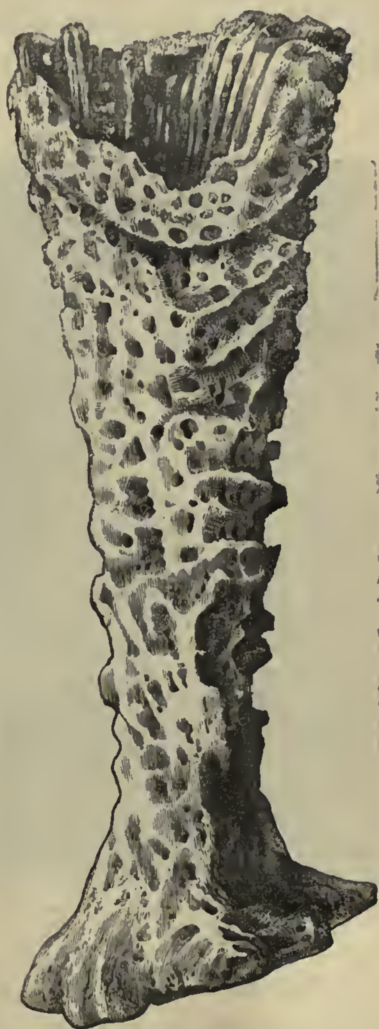


Fig. 165.—*Lefroyella decora*, Wyv. Thoms. (natural size), a representative of the Euretidæ.

"As in the case of the skeleton, so also in the general structure of the soft parts, a predominant principle might be recognised. In all Hexactinellids, that surface (usually the outer) which serves for the ingress of water, is covered by a thin perforated skin or membrane (which is supported by a special system of regularly arranged spicules), according to the form of the latter either a flat surface or one covered with numerous conical elevations is formed. A similar and similarly perforated membrane is found also on the opposed surface of the body-wall, the surface of egress, which indeed generally encloses an internal gastric cavity, but may also, as in the case of many flattened or mushroom-shaped sponges, be quite free and form an upper or lateral surface.

"Between these two perforated boundary-surfaces there extends the simple strongly folded layer of the ciliated cavities, which usually manifest a saccular shape, as I have already described in *Euplectella aspergillum*,[1] but in some cases, as in the family Hyalonematidæ, diverge to some extent from this. The delicate wall of the cavities allows the square lattice-marking to be perceived as in *Euplectella*, and is also more or less thickly but irregularly perforated by round pores. This system of ciliated cavities is connected with the two boundary-surfaces by means of a wide-meshed tissue of delicate anastomosing trabeculæ, which are suspended and stretched between them. Since, then, all the chambers are in direct communication, and since their convex surfaces are always turned towards the entering water, this latter must flow through them in such a manner that it enters through the pores and passes out through the wide oral opening.

FIG. 166.—*Melittiaulus ramosus*, n. gen. et sp., a representative of the Uncinataria.

"On account of the great uniformity in the structure of the soft parts, I have only been able to use these for systematic purposes in a few cases, such as in the definition of the Hyalonematidæ. For such purposes the form and arrangement of the siliceous skeleton, which has hitherto been almost exclusively applied by all spongiologists, is most significant.

"The two primary divisions of the Hexactinellida, LYSSACINA and DICTYONINA, which Zittel founded some years ago in his important work on fossil sponges, I retain with the same significance, but in consequence of my investigations I have been obliged to modify his original definitions to some extent.

"Zittel regards as LYSSACINA those Hexactinellida in which the whole skeleton consists of spicules which are only connected by means of the sarcode (exceptionally, however, irregularly by means of flattened siliceous bodies), and in which the spicules of the soft parts are for the most part very plentiful and highly differentiated.

"The DICTYONINA he defined as those Hexactinellida whose spicules are so united that

[1] *Trans. Roy. Soc. Edin.*, vol. xxix. pp. 661–673, 1881.

each arm of a six-rayed spicule is applied to the corresponding arm of a neighbouring spicule, both spicules thus becoming enclosed by a common siliceous covering. The connected skeletons of the DICTYONINA consist of a lattice-work with irregularly cubic meshes. Spicules belonging to the soft parts may be present or absent.

"In many sponges which, according to the rest of their organisation, belong without doubt to Zittel's 'Dictyoninen,' I have failed to observe that union of neighbouring spicules by the enclosure of the corresponding approximated branches in a common siliceous coating, which he mentions; on the contrary I found in these cases the spicules

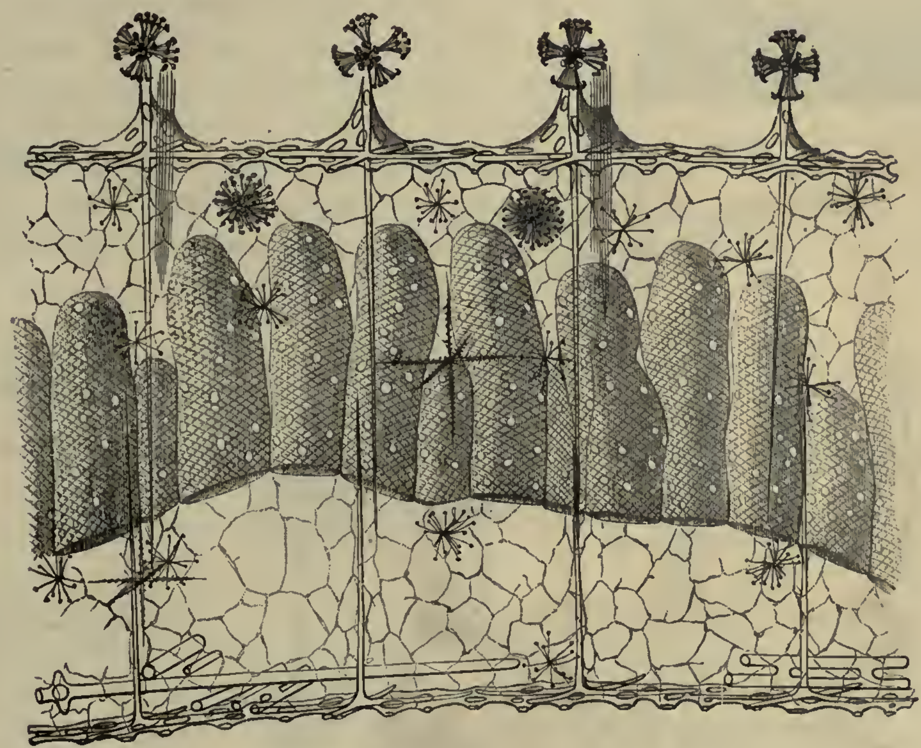


FIG. 167.—Section of the wall of *Walteria flemmingii*, n. gen. et sp., a representative of the Euplectellidæ $\left(\frac{70}{1}\right)$.

either united crossing each other quite irregularly or disposed in a different manner, which also has been already observed by Oscar Schmidt and Zittel; that is to say, the rays of the spicules were fused with other spicules in the angles between their rays, and thus united into a firm skeleton.

"On the other hand, in not a few LYSSACINA, I have, like Oscar Schmidt, met with a firm union of spicules of a particular kind, sometimes in a very irregular disposition, sometimes by lateral soldering, sometimes of closely approximated parallel spicules connected by transverse pieces (synapticulæ); this may take place only in the basal portion or throughout the whole body, as in *Euplectella aspergillum*, in its mature condition. I can, therefore, regard neither the union of spicules into a continuous trabecular skeleton, nor that particular mode of their union by means of the opposition of the corresponding branches of spicules and covering with a common envelope, as a sufficiently constant character for the diagnosis of the DICTYONINA, and for the division of the Hexactinellida into two primary classes, although I do not wish to deny that there are certain differences in the mode of union of the rays of the spicules between the DICTYONINA on the one hand, and the LYSSACINA, which are provided with a firmly united skeleton, on the other.

FIG. 168.—*Myliusia callocyathus*, Gray, a representative of the Inermia.

"On the contrary I find the chief difference between the above mentioned divisions of the Hexactinellida to be this—that in the DICTYONINA the skeleton is already deposited during the formation and growth of all the parts of the body, and hence typically and necessarily by the

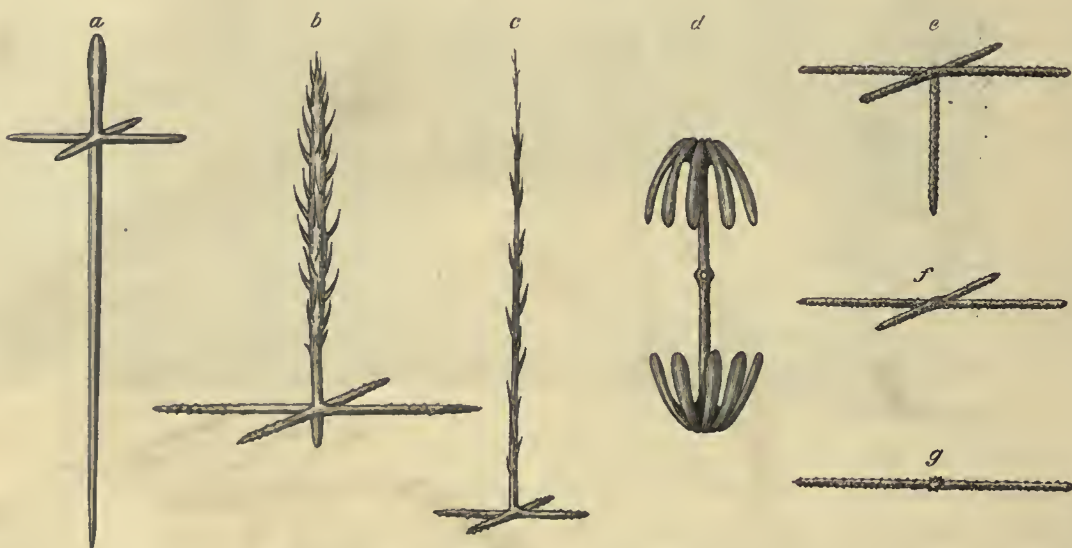


FIG. 169.—Characteristic forms of the dermal spicules of the four families of Lyssacina.
a, dagger-shaped spicule of *Walteria flemmingii*, n. gen. et sp. (a Euplectellid); *b*, "Pinulus," fir-tree shaped spicule of *Sympagella nux*, O. Sch. (an Asconematid); *c*, "Pinulus," and *d*, "Amphidisk" of the external surface of *Hyalonema sieboldi*, Gray (a Hyalonematid); *e*, *f*, *g*, dermal spicules of *Rossella antarctica*, Carter (a Rossellid).

union of certain spicules in more or less regular arrangement, whilst in the LYSSACINA either a continuous trabecular skeleton is entirely wanting or only formed at a later stage, partly by the enclosing of irregularly disposed spicules at their points of crossing or of contact, partly by transverse connecting trabeculæ (synapticulæ) between closely approximated parallel spicules; so that the adhesive process commences at one portion of the sponge, and is gradually continued to a greater or less extent.

"The order Lyssacina may be divided into four families—(1) Euplectellidæ, (2) Asconematidæ, (3) Hyalonematidæ, (4) Rossellidæ—which, apart from numerous other characters, may be easily distinguished as follows by the radially or tangentially directed spicules of the external membrane.

"The Euplectellidæ possess in the external membrane dagger-shaped six-rayed spicules with an elongated proximal ray.

"The Asconematidæ have 'pinuli,' that is six- or five-rayed spicules, whose strongly developed distal ray is in the form of a pine-tree, while the proximal ray is either entirely wanting or only feebly developed; 'amphidisks' are entirely wanting in this group.

"The Hyalonematidæ possess both pinuli and amphidisks.

"The Rossellidæ bear spicules in which the distal ray is either entirely wanting or much reduced, while the proximal ray is either strongly developed or also wanting;

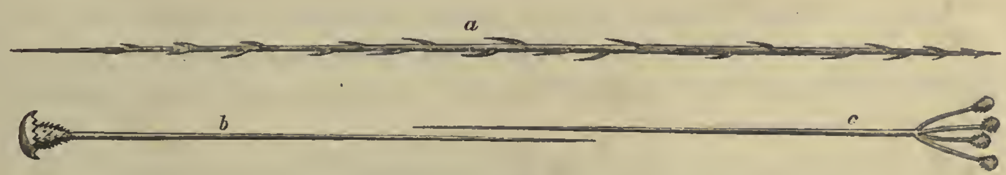


Fig. 170.—Characteristic spicules of the Uncinataria.
a, "Uncinatum," b, "Clavula" of *Farrea haeckelii*, n. sp.; c, "Scopula" of *Eurete carteri*, n. sp.

indeed two rays belonging to the same tangential axis may both be wanting, so that only simple tangentially directed rods remain.

"The Dictyonina may be divided into two suborders, Uncinataria and Inermia. The former are characterised by the possession of sharply pointed rods, 'uncinata,' which are abundantly provided with proximally directed recurved hooks; the latter are devoid of such 'uncinata.'

"In the first family of Uncinataria, the tubular or calyciform Farreidæ, there are found in the external membrane radially disposed acicular rods, the 'clavulæ,' while the five remaining families, instead of such 'clavulæ,' possess 'scopulæ,' that is radially directed structures formed like brooms or forks, with from two to eight prongs, the latter are termed Scopularia, whilst the former are called Clavularia.

"To the Scopularia belong—

"1. Euretidæ, in the form of a branched anastomosing tubular structure, or of a goblet with lateral outlets.

"2. Melittionidæ, of goblet or tubular form, with honeycomb-like walls, "3. Chonelasmatidæ, flat or beaker-shaped, with straight funnel-shaped canals which perforate the walls perpendicularly and open alternately on either side.

"4. Volvulinidæ, tubular, goblet-shaped, or massive, with crooked canals, more or less irregular in their course.

"5. Sclerothamnidæ, whose arborescent body is perforated at the ends and sides of the branches by round narrow radiating canals.

"The Inermia, which are devoid of either uncinata, clavulæ, or scopulæ, are divided into the following four families:—

"1. Myliusidæ, in form of low wide beakers, whose wall is complexly folded and forms lateral exhalent tubes.

"2. Dactylocalycidæ, of goblet or flat saucer shape, with thick wall, consisting of numerous parallel anastomosing tubes of equal breadth, which end on the same level without and within.

"3. Euryplegmatidæ, in the form of goblets or ear-shaped saucers, in whose walls there run parallel to the surface a number of dichotomously branching canals or partially covered-in grooves, which are due to a deep longitudinal folding.

"4. Aulocystidæ, of massive rounded form, consisting of a system of anastomosing tubes, which pass outwards from the sides of an axial cavity, and have intercanals between them. These latter, as well as the lateral terminal apertures of the tubes, are covered by a thin membrane which is provided with slit-like openings over the lamina of the tubes, and thus assumes a sieve-like character.

"A critical examination of all recent Hexactinellida, hitherto described, has led me to the conclusion that forty-two species have been sufficiently accurately defined for recognition, those being excepted which were described by Professor Wyville Thomson in preliminary communications from the Challenger Expedition; whilst in the rich material which was brought home by this Expedition I have been able to distinguish seventy-nine species, of which nineteen had been already described, while the remaining sixty are new. It is seen therefore that the investigations of the Challenger have raised the number of known species of Hexactinellida from forty-two to one hundred and two.

"The forty-two species previously known belonged to thirty genera, so that there were on an average 1·5 species to each genus; the sixty species which I have constituted are distributed in thirty genera, allowing on an average two species to each genus, whilst the total number of one hundred and two species, at present known, belong to fifty-three genera. Hence, as the result of the Challenger Expedition, the ratio between the numbers of the genera and species has been diminished from 3:4 to almost 1:2.

"This is readily understood when we consider that the first forms of a large and hitherto unknown group of animals which chance to be obtained, will as a rule belong to different divisions of the group; whilst the more this group becomes known the greater is the probability that the newly acquired species will be closely allied to forms which are already known, that is, the average number of species in each given genus will increase.

"Since the Challenger made an investigation of the great depths of all the important oceans, except the Arctic Ocean and the northern part of the Indian Ocean, a general view of the results obtained with respect to the geographical and bathymetrical distribution of the Hexactinellida will be of special value.

"I will therefore proceed to summarise the distribution of the Hexactinellida so far as the results of the Challenger dredgings permit. The number of dredging and trawling stations amounted altogether to about two hundred and eighty, of which fifty-three, that is about one-fifth, yielded specimens of Hexactinellida.[1] In many cases only one or two specimens were taken at each Station, but sometimes as many as fifty or more were obtained. If, however, not the number of specimens but (what is more important) the number of species found at each Station be reckoned, then a careful enumeration shows that of the fifty-three Stations—

32	gave each	1	species.
11	,,	2	,,
3	,,	3	,,
3	,,	4	,,
1	,,	5	,,
2	,,	6	,,
1	,,	18	,,

This last Station, rich both in individuals and in species, is Station 192, near the Ki Islands, southwest of New Guinea.

"The fifty-three Stations are distributed among the three principal oceans, so that

17	belong to the	Atlantic	Ocean.
27	,,	Pacific	,,
9	,,	Southern	,,

"From an examination of these Stations it appears that species of Hexactinellida are most numerous in the Southern Ocean, least so in the Atlantic; but on the other hand the number of species at particular places is greatest in the Pacific.

"The fact, which has been remarked in many other classes of animals, repeats itself here, namely, that the number of forms which live together in any given place is in general greatest in the tropics; the tropical zone of the Pacific being most remarkable

[1] It must be observed that in some cases (*e.g.*, Stations 149, 164) one number includes several dredgings which ought, perhaps, to be reckoned as so many different Stations; I have, however, reckoned each number as one Station.

in this respect. It is very probable, however, that the tropical zone of the Indian Ocean, which has not hitherto been investigated, will prove to be richer in species than that of the Pacific, since in its south temperate zone, which at present is alone available for comparison, it has shown itself to be richer. Hence we may anticipate that an investigation of the tropical region of the Indian Ocean would yield specially rich material as regards the Hexactinellida.

"Finally I will give the principal results of an inquiry undertaken to find out the dependence of the Hexactinellida upon the nature of the sea-bottom. For this purpose the Stations were classed according to the nature of the deposit found at each.

"When the different groups of Stations were examined it appeared that the Diatom ooze was specially favourable to the Hexactinellida, and also that Radiolarian ooze and blue mud were more or less adapted to their existence; while they appeared to be entirely wanting upon bottoms of sand and gravel, which is perhaps owing to the fact that deposits of this kind usually occur at depths of less than 100 fathoms, which are too shallow for these animals.

"It is also worthy of remark that several Hexactinellida, which came from great depths, were filled with Diatoms and Radiolarians, although the bottom at these Stations was not a Diatom or Radiolarian ooze."

The following is a list of the genera contained in the above mentioned families and subfamilies.

Type **CŒLENTERATA.**

Subtype **Spongiæ.**

Class Silicispongiæ. Subclass *Hexactinellida*.

Order I. LYSSACINA, Zittel.

Family I. Euplectellidæ.

Subfamily 1. Euplectellinæ.
- (1) *Euplectella*, Owen.
- (2) *Regadrella*, Osc. Schmidt.

Subfamily 2. Holascinæ.
- (1) *Holascus*, n.
- (2) *Malacosaccus*, n.

Subfamily 3. Tægerinæ.
- (1) *Tægeria*, n.
- (2) *Walteria*, n.
- (3) *Habrodictyum*, Wyv. Thoms.
- (4) *Eudictyum*, Marshall.
- (5) *Dictyocalyx*, n.
- (6) *Rhabdodictyum*, Osc. Schmidt.
- (7) *Rhabdopectella*, Osc. Schmidt.
- (8) *Hertwigia*, Osc. Schmidt.

Family II. Asconematidæ.

Subfamily 1. Asconematinæ.
- (1) *Asconema*, Sav. Kent.
- (2) *Aulascus*, n.

Subfamily 2. Sympagellinæ.
- (1) *Sympagella*, Osc. Schmidt.

Subfamily 3. Caulophacinæ.
- (1) *Caulophacus*, n.
- (2) *Trachycaulus*, n.

Family III. Hyalonematidæ.

Subfamily 1. Hyalonematinæ.
- (1) *Hyalonema*, Gray.
- (2) *Dictyosphæra*, n.
- (3) *Pheronema*, Leidy.
- (4) *Poliopogon*, Wyv. Thoms.

Subfamily 2. Semperellinæ.
- (1) *Semperella*, Gray.

Family IV. Rossellidæ.

Subfamily 1. Rossellinæ.

(1) *Lanuginella*, Osc. Schmidt.
(2) *Polylophus*, n.
(3) *Rossella*, Carter.
(4) *Acanthascus*, n.
(5) *Bathydorus*, n.

Subfamily 2. Crateromorphinæ.

(1) *Crateromorpha*, Gray.
(2) *Rhabdocalyptus*, n.

Subfamily 3. Aulochoninæ.

(1) *Aulochonen*, n.

Appendix.

Hyalostylus, n.
Aulocalyx, n.

Order II. DICTYONINA, Zittel.

Suborder 1. Uncinataria.

Tribe I. Clavularia.

Family I. Farreidæ.

(1) *Farrea*, Bowerbank.

Tribe II. Scopularia.

Family I. Euretidæ.

(1) *Eurete*, Semper.
(2) *Periphragella*, Marshall.
(3) *Lefroyella*, Wyv. Thoms.

Family II. Melittionidæ.

(1) *Aphrocallistes*, Gray.
(2) *Melittiaulus*, n.

Family III. Chonelasmatidæ.

(1) *Chonelasma*, n.

Family IV. Volvulinidæ.

(1) *Volvulina*, Osc. Schmidt.
(2) *Tretodictyum*, n.
(3) *Fieldingia*, Sav. Kent.

Family V. Sclerothamnidæ.

(1) *Sclerothamnus*, Marshall.

Suborder 2. Inermia.

Family I. Myliusidæ.

(1) *Myliusia*, Gray.

Family II. Dactylocalycidæ.

(1) *Dathylocalyx*, Gray.
(2) *Scleroplegma*, Osc. Schmidt.
?(3) *Margaritella*, Osc. Schmidt.

Family III. Euryplegmatidæ.

(1) *Euryplegma*, n.
?(2) *Joannella*, Osc. Schmidt.

Family IV. Aulocystidæ.

(1) *Aulocystis*, n.
(2) *Cystispongia*, Rœmer.

The Tetractinellida.—Professor W. J. Sollas, who is preparing a Report on the Tetractinellid Sponges collected by the Expedition, writes as follows:—"Although my investigation of the Tetractinellida of the Challenger Expedition is by no means yet complete, it is sufficiently advanced to show that considerable additions have been made to our knowledge of this group. The excellent state of preservation in which the spirit specimens have been brought home has afforded me an opportunity of ascertaining the anatomy and histology of most of the recognised genera of the group. This is especially fortunate in the case of the Lithistidæ, of the soft parts of which next to nothing was hitherto known. These sponges conform in all essential characters of the canal system to the complicated racemose type which occurs in the majority of sponges, and neither in the characters of the pores, subdermal cavities, nor of the flagellated chambers, offer anything markedly distinguishing the group from the non-cortical Choristid Tetractinellids.

"The Choristidæ have not only afforded rich material for working out the relations of the genera of the group, but furnish also some new forms of considerable interest on account of the reduction and other modifications presented by the Tetractinellid spicules characteristic of the order.

"It would be premature to discuss questions of distribution before the practical study of the collection is concluded; so far I will content myself with stating that the majority of the Tetractinellid Sponges are not usually inhabitants of very deep water, they rather affect shallow water, say from 10 to 50 fathoms, but occasionally extend to greater depths, such as 1000 fathoms. There is only one characteristic exception to the rule, viz., in the case of the genus *Thenea*, which is usually found at depths of from 1000 to 1800 fathoms, but sometimes enters shallower water; in one case it was obtained from the comparatively shallow depth of 95 fathoms.

"Tetractinellid genera appear to be of world-wide distribution, but certain subgeneric groups of species appear to be restricted to particular areas. Thus, such a group as the Stellettina, characterised by a particular form of minute spicule, occurs along the track of the Challenger at various points between Australia and Japan. Another group appears to be confined to Southern Australia.

"Although I expect to add much on distributional questions when I have completed my study of the collection, I consider that the chief additions to our knowledge will be found to bear on problems of histology and minute anatomy."

CHAPTER XII.

Melbourne to Sydney—Sydney—Excursion to Queensland—The Marsupialia—Sydney to Wellington—Procalistes—Wellington to the Kermadec and Friendly Islands—Tongatabu, Friendly Islands to the Fiji Islands—The Fiji Islands.

Melbourne to Sydney.

The Expedition remained at Melbourne until the 1st April, refitting the ship and obtaining magnetic and other observations on shore, and the stay was greatly enlivened by the receptions and excursions arranged for the members of the Expedition by the inhabitants of Victoria.

The German frigate "Arcona," Captain von Reibnitz, which had also recently visited Kerguelen and Heard Islands to ascertain their fitness as a Station for observing the transit of Venus, was anchored off Melbourne at the same time. The "Arcona" had passed round the south end of Heard Island, so, from the information received from her officers, it was possible to add somewhat to the Challenger's plan of that island. The relations between the officers of the Challenger and those of the "Arcona" were most cordial; visits were frequently interchanged, and several pleasant reunions held on both vessels.

On the 1st April, at 6 A.M., the vessel left Port Philip for Sydney, passing the heads at 2 P.M. When outside a few trawlings were obtained, and at 5.30 P.M. a course was shaped for Rodondo Island.

On the 2nd April, at 5.30 A.M., the Glennie Islands and the land about Wilson Promontory were seen, and the ship was steered to the southward of Rodondo Island, which was passed at 8.30 A.M. During the forenoon an exploring party was landed on East Moncœur Island,[1] and dredgings and trawlings were obtained off the island in 38 to 40 fathoms (Station 162; see Sheet 25), after which the ship proceeded to the northeastward. West Moncœur Island has two small rocky islets off its southern end, instead of one as marked on the chart, and the eastern island has a rock separated from it by a narrow channel both at the northwest and southwest points. The weather in the forenoon was gloomy, with rain, but shortly after noon a southwest breeze sprang up, the rain gradually cleared off, and the weather became finer.

On the 3rd April the land about Mount Everard was observed at 11.30 A.M., and the ship was steered to pass Gabo Island at a distance of 3 or 4 miles, fixing with Mount Everard, Rame Head, Genoa Peak, and Howe Hill, which objects were easily recognised. At 5.30 P.M. Gabo Island was passed, and a course shaped to get outside the edge of the 100-fathom bank of soundings to ascertain the depth and temperature the

[1] The rock specimens collected were typical granite.

next day. At 6 and 8 P.M., when close to the land, the temperature of the surface water fell to 60°, having previously been 66°; as the distance from the shore increased it again rose to 66°.

On the 4th April, at 9 A.M., being then about 10 miles east of the 100-fathom contour line, a sounding was taken in 2200 fathoms, the bottom temperature being 34°·5. The current was found to be running to the southward at the rate of $1\frac{1}{2}$ miles per hour, the surface temperature being 71°. Serial temperatures were taken to 300 fathoms, by which it appeared that the temperature of 71° was very superficial, as at 50 fathoms the thermometers registered 65°·2. The position of the sounding was fixed by angles to objects on shore, the angles being Mount Imlay 27° Mount Massey 48° 40′ Mount Dromedary. After completing the observations the ship steamed towards the shore, and trawlings were obtained, in 120 to 150 fathoms, many Invertebrates and Teleosteans being procured, among which were a quantity of Grey Mullet (*Percis allporti*, Günther) sufficient to provide the officers' mess with fish for dinner. At 6.30 P.M. a course was shaped to the northward towards Montague Island, the ship being first swung to ascertain the errors of the compass. The temperature of the surface water rose to 71° at 4 A.M., and remained nearly the same throughout the day, being considerably higher than the temperature of the air.

On the 5th April, at 6 A.M., when abreast of Montague Island, the vessel proceeded inshore, and was then swung to ascertain the errors of the dipping needle. This occupied until 2 P.M., when a course was again shaped to the northward. During the previous night a current of two miles per hour was experienced running to the southward. During the operation of swinging the current was only one mile per hour, but the approach of the flood tide, which in this part of the Australian coast comes from the southward, may have caused a retardation of the current; whilst the ship was close inshore from Montague Island little or no current was experienced until midnight, at which time the ship was abreast of Jervis Bay, the temperature of the surface water having fallen to 68°·5.

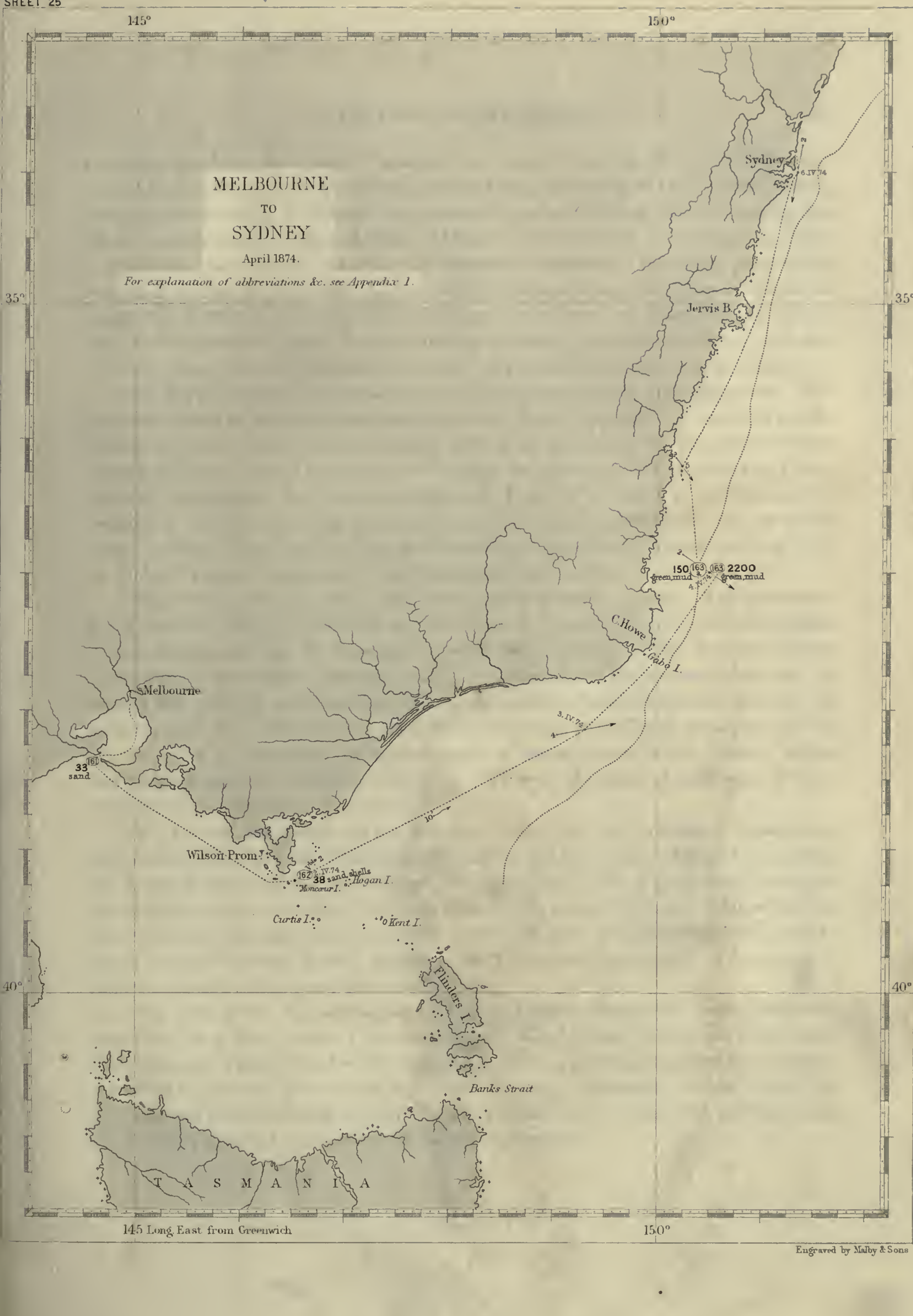
On the 6th April, at 6 A.M., the surface temperature again rose to 71°, the position of the ship being Mount Berry 20° 20′ Broughton Head 74° Mount Kiera. From here to Port Jackson Head a current was experienced running south $1\frac{1}{2}$ miles per hour. At 2 P.M. the vessel entered Port Jackson, and at 3 P.M. was moored in Farm Cove.

SYDNEY.

Sir Wyville Thomson gives the following account of an excursion to Queensland during the stay at Sydney :—

"There seemed to us, from what we heard at Sydney, to be a chance of making valuable additions to the knowledge of the natural history of northeast Australia, by

SHEET 25



Engraved by Malby & Sons

examining carefully the faunæ of some of the rivers. Those in which *Ceratodus* had lately been discovered had the greatest interest for us, for we hoped that, besides getting a number of specimens of *Ceratodus* in various stages, we might by effective netting and other means find some additional forms of Dipnoi. Accordingly a little party, consisting of Lieutenant, now Captain, Aldrich (who afterwards commanded the sledge party which proceeded westwards from the 'Alert's' winter quarters along the coast of Grinnell's Land), Mr. Murray and myself, with Mr. Pearcey and a couple of blue-jackets in attendance, was organised to go to Brisbane during the stay of the ship at Sydney, with the view of pushing on, if time permitted, to the upper reaches of the Mary or the Burnet.

"We got information and introductions from Dr. Bennett, Mr. Hill, and others. We prepared a stock of trammel nets, lines, and other fishing appliances, a box of dynamite cartridges, fowling pieces, and collecting gear of all kinds, and we arranged to leave Sydney by the 'City of Brisbane' on Tuesday the 29th April 1874; the vessel was, however, detained by bad weather till the 4th May. We arrived at Brisbane on the morning of the 7th. An intimation of our intended trip had preceded us, and we found a kind invitation from the Marquis of Normanby to Government House awaiting us at the club, of which we had already been made honorary members.

"We stayed a few days at Brisbane seeing all that was to be seen. The Governor's A.D.C. tried to make arrangements to send us on to Gympie in carriages, but we found it more convenient to go by a coasting steamer to Maryburgh. The departure of the 'Lady Bowen,' the regular trading packet, was hurried to give us more time, and on Sunday the 10th we were steaming past a monotonous undulating coast line, the low hills crowned with dusky woods of sombre gum-trees, past Fraser Island, one of the districts given up entirely to the natives, many of whom we saw in the distance, with a fine walk and gait, but absolutely unclothed. We were disappointed that none of them swam off to the steamer as they often do.

"We reached Maryburgh on the morning of the 11th, and introduced ourselves to Mr. Sheridan, the Collector of Customs, to whom we had been referred by Lord Normanby. We found Mr. Sheridan a most pleasant companion, and a man of great intelligence and considerable special knowledge of natural science. He most kindly placed himself at our disposal during our stay, and afterwards took the trouble to collect and send home to us a valuable collection of such species as we had not an opportunity of procuring in sufficient quantity during our short visit.

"We went on in the evening in a couple of buggies through the bush of scattered gum-trees, to a little group of wooden shanties called 'Tiaro,' about 20 miles above Maryburgh, on a pretty bend of the river Mary, with a good long stretch of open stream, succeeded by some irregular rapids and deep pools, and overhanging woods farther up. The influence of the tide was slightly felt for a considerable distance beyond Tiaro, and some of the fishes had consequently an estuarine character.

"We got the loan of a boat from a contractor who was deepening the river a little below Tiaro for the Queensland Government, and on the following day were joined by Mr. Sheridan with his boat and servant. It was reported on all hands that the Barramunda (the native name for *Ceratodus*) was to be found occasionally in the neighbourhood, and we determined to spend the short time at our disposal in exploring the fauna of the river for a few miles up stream.

"Lieutenant Aldrich and Mr. Murray, with our escort and one or two natives whose services we had secured, camped a little way up the river, and Mr. Sheridan and I, as the seniors of the party, slept at Tiaro, rowing up the river in the morning, and usually reaching the camping-ground in time to supply the materials of stew for luncheon, in the shape of cockatoos, wallaby, ducks, &c., which we had shot by the way. For about ten days the river was fished day and night with net and rod, and fishes of several species were taken in large numbers, but we found no trace of *Ceratodus* or of any allied form. We had taken with us a number of powerful dynamite cartridges, and these were thrown, with a few feet of Bickford's fuse attached, into the deeper pools, and in a minute or so a shock like a blow from a heavy wooden mallet was felt on the bottom of the boat, one could see a slight rise on the surface of the water, and perhaps a hundred fishes of different sorts and sizes rose to the surface and floated on their backs or sides. Those we required were taken into the boat with a landing net, and the rest recovered from their shock in a few minutes and swam away. The number of individual fishes taken in this way was very large, but it is somewhat singular that *Ceratodus* never occurred among them. At the end of about ten days, however, three specimens were taken, one by Lieutenant Aldrich with hook and bait, one in the trammel net, and one by the natives.

"As our leave of absence was nearly exhausted, we now returned to Maryburgh, and after waiting for a few days to catch a return steamer, rejoined the Challenger at Sydney."

Two crania and a skeleton[1] of the aborigines were obtained in the Queensland district, and a number of Marsupials were collected during the trip above described, as well as during other excursions in different parts of Australia. The latter, together with two specimens of *Thylacinus cynocephalus*, which were sent to the Expedition from Tasmania by the Governor of that colony, were on the return of the Expedition handed to Professor D. J. Cunningham for anatomical examination, and a Report giving the result of his investigations appears in the Zoological Series of Reports.[2]

The Marsupialia.—This Report deals with the myology, the arrangement of the spinal nerves, and the visceral anatomy of the Marsupial animals brought home. Two

[1] Described in the Report on the Human Skeletons, The Crania, by Prof. Turner, F.R.S., Zool. Chall. Exp., part xxix., 1884.

[2] Report on some points in the Anatomy of the Thylacine (*Thylacincus cynocephalus*), Cuscus (*Phalangista maculata*), and Phascogale (*Phascogale calura*); with an account of Comparative Anatomy of the Intrinsic Muscles and the Nerves of the Mammalian Pes, by Prof. D. J. Cunningham, M.D., Zool. Chall. Exp., part xvi., 1882.

plates also are devoted to the osteology of *Thylacinus cynocephalus.* Owing to the prevalent belief that the genus, of which this animal is the sole member, is rapidly becoming extinct, special care has been taken in recording its anatomical peculiarities.

The chief interest of the Report, however, is centred in the fact that it contains the results of an investigation into the comparative anatomy and homologies of the intrinsic muscles and nerves of the Mammalian foot. The author was induced to engage in this research from conditions which he found in the Marsupial foot, and special opportunities were afforded him for carrying on the work by the many valuable specimens of Mammalia collected during the voyage, which were also placed at his disposal.

The conclusions arrived at may be briefly stated to be the following:—That the typical arrrangement of the intrinsic muscles of the Mammalian pes is seen to best advantage in the feet of certain of the Marsupialia. In these animals the muscles are disposed in

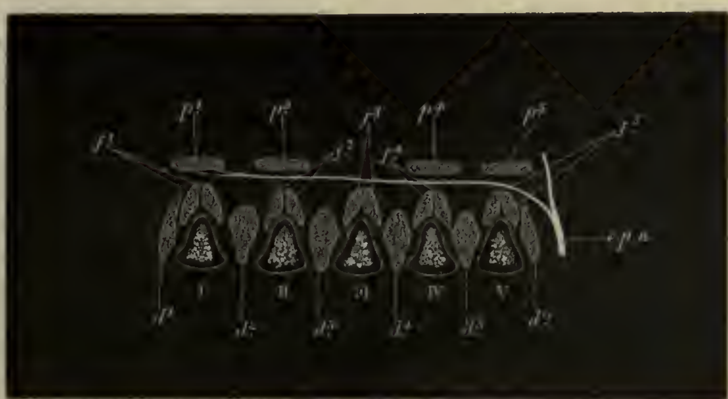


Fig. 171.—Schematic view of a section through the metatarsus of a typical mammalian foot.
I.-V. Metatarsals; p^1-p^5, adductores; f^1-f^5, flexores breves; d^1-d^6, abductores; *e.p.n.*, external plantar nerve.

three layers, viz., (1) a plantar layer of adductores, (2) an intermediate layer of flexores breves, and (3) a dorsal layer of abductores.

Deviations from this typical trilaminar disposition may take place—(*a*) by subdivision of certain of the members of one or other of the layers, (*b*) by fusion of certain of the elements of the different strata, or (*c*) by suppression or non-development of some of the muscles.

The first of these deviations is to be found in a few Marsupial animals (*e.g.*, *Cuscus*) in which a tendency is exhibited to the development of a fourth layer by the splitting of the dorsal interossei. Fusion of the constituents of the intermediate and dorsal layers is extremely common, whilst fusion between the plantar and intermediate muscles is a very rare occurrence. Suppression of certain of the muscles may take place in two ways; it may either be complete—not a trace of the lost muscle being left—or partial, in which case the place of the missing muscular belly is taken by a ligamentous structure, having the same connections, and probably a distinct function to play in the mechanism of the foot.

The *plantar layer* constitutes a very constant part of the intrinsic muscle apparatus of the Mammalian foot. In the feet of forty-six different species possessed of three or more toes, it was absent entirely in three cases only. In the monodactylous and didactylous feet of Solipeds and Ruminants not a trace of adducting muscles is to be found. The original number of these muscles is five, one for each toe, but they exhibit a distinct tendency to disappear from the centre of the foot towards the margins, and this disappearance takes place in a more marked degree outwards towards the minimus than in an inward direction towards the hallux. The central adductor (*i.e.*, adductor medii) was only found in three specimens. The sudden disappearance of this adductor is probably due to the tendency which these muscles have to arrange themselves so as to act with reference to the middle toe.

Fig. 172.—Schematic view of a transverse section through the metatarsus showing the intrinsic muscles of the left human foot.

I.–V. Metatarsals; f^1, flexor brevis hallucis; f^3t, tibial head of flexor brevis medii (1st plantar interosseous); f^4t, tibial head of flexor brevis annularis (2nd plantar interosseous); f^5t, tibial head of flexor brevis minimi digiti (3rd plantar interosseous); f^5f, fibular head of flexor brevis minimi digiti; p^1, adductor obliquus hallucis; d^1, abductor hallucis; d^6, abductor minimi digiti; d^2–d^5, dorsal interossei; *e.p.n.*, external plantar nerve.

The *intermediate group* of flexores breves is the most constant layer, and is closely associated with the *dorsal layer*, which is the least constant and most variable. It is quite possible that the latter (*i.e.*, dorsal interossei, abductor hallucis, and the abductor of the minimus) may have originally been derived from the former. Ruge's [1] investigations into the development of the muscles of the human foot favour this view.

If the human foot be studied in the light of these results, it will be seen that the *dorsal layer* is the most fully represented. It consists of (1) the abductor hallucis, (2) the abductor minimi digiti, and (3) the four dorsal interossei.

The *plantar layer* is represented by the adductor hallucis and the transversalis pedis,

[1] Zur vergleichenden Anatomie der tiefen Muskeln in der Fusssohle, *Morphol. Jahrb.*, Bd. iv. pp. 644–660, 1878.

whilst the *intermediate layer* is composed of the flexor brevis hallucis, flexor brevis minimi digiti, and the three plantar interosseous muscles.

The hypothesis that the relationship between "nerve supply" and "muscle-homology" is invariable and immutable has also been tested in this Report. The author maintains that the nerve of supply is not an infallible guide to the homology of a muscle; at the same time he is inclined to consider it in many cases the most important factor to be taken into account in determining this point.

During the stay at Sydney Mr. Moseley made two excursions to Browera Creek, one of the many branches of the main estuary, or rather inlet, into which the Hawkesbury River runs, and is a place full of interest to the naturalist. Suddenly, after traversing a high plateau of the horizontal sandstone, the traveller meets with a deep chasm about 1000 feet in depth, but not more than a quarter of a mile wide. This chasm or channel has precipitous rocky walls on either side, with more or less sloping talus, and at the bottom runs the river, a small stream over which one can easily jerk a pebble when standing at its brink. The chasm or creek takes a winding course, so that only short sweeps of it can be seen at a time, and as it widens out and turns sharply or again contracts, one seems, when in a boat on its waters, to pass through a succession of long narrow lakes. The river, or rather stream, at the place where the creek was approached, is tidal. It is impossible to say where the river ends and the sea begins. The main part of the creek is a long tortuous arm of the sea, 10 to 15 miles in length, and is itself provided with numerous branches and bays, which are perfectly bewildering to a man not accustomed to row on them every day in his life; the whole is, in fact, like a maze. The side walls of the creek are covered with a luxuriant vegetation, with huge masses of Stagshorn Fern (*Platycerium*) and "Rock Lilies" (*Orchids*), and a variety of timbers, whilst there are Tree-ferns and small Palms in the lateral shady gullies. As an example of denudation, the creek appears to correspond exactly to what is seen at a much higher level in the Blue Mountains. The extraordinary proximity into which animals found usually only in the open sea, are here brought with those only occurring inland, is of great interest from a geological point of view; it recalls at once to the mind such mixtures of marine and terrestrial animal remains as those occurring in geological deposits, such as the Stonesfield beds. Here is a narrow strip of sea water, 20 miles distant from the open sea; on a sandy shallow flat close to its head are to be seen basking in the sun numbers of Sting-rays (*Trygon*), a kind of Skate provided with a sharp saw-edged bony weapon (the sting), at the base of its tail. All over these flats, and throughout the whole stretch of the creek, shoals of Grey Mullet are to be met with; numerous other marine fish inhabit the creek, some growing to 150 lbs. in weight, and often caught weighing as much as 60 or 80 lbs. A *Diodon* or Trunk-fish occurs amongst the fishes. Porpoises chase the Mullet right up to the commencement of the sand-flat. At the shores of the creek the rocks are covered with masses of excellent Oysters and Mussels, and other shell-bearing molluscs are abundant, whilst a small Crab is to be found in numbers in every crevice. On the other hand the water is overhung by numerous species of forest trees, by Orchids and Ferns, and other vegetation of all kinds; Mangroves grow only in the shallow bays. The Gum-trees lean over the water in which swim the *Trygon* and Mullet, just as willows hang over a pond full of Carp. The sandy bottom is full of branches and stems of trees, and is covered in patches here and there by their leaves. Insects constantly fall on the water, and are devoured by the Mullet. Land birds of all kinds fly to and fro across the creek, and when wounded may easily be drowned in it. Wallabies swim across occasionally, and may add their bones to the débris at the bottom. Hence here is being formed a sandy deposit, in which may be found Cetacean, Marsupial, bird, fish, and insect remains, together with land and sea shells, and fragments of a vast land flora; yet how restricted is the area occupied by this deposit, and how easily might surviving fragments of such a record be missed by a future geological explorer! The area occupied by the deposit will be sinuous and ramified like that of an ancient river-bed. The inlet being so extremely long and narrow, although the rise of the tide is two feet or more at the head of the creek, the interchange of water with the ocean is very small; the water in the upper parts of the creek is merely forced back to a higher level by the tide below at flood-tide, and similarly lowered again at ebb. Hence, after heavy rain, the surface water in all the upper parts of the creek is so diluted by the torrent of fresh water from the stream, that it becomes almost fresh; indeed, at the time of the visit, it was for three or four miles down, as far as explored, so slightly brackish as to be drinkable. At a little depth, no doubt, the water was salt. Here are the most favourable conditions possible for turning marine animals into fresh water animals; in fact the change of mode of life presents no difficulty. Below, no doubt the water is always salt, but the fish find a fluid gradually less and less salt as they rise to the surface. Grey Mullet are caught here in almost fresh water, and Oysters flourish in the same water, and with them Mussels and Crabs; abundance of Medusæ were swimming in the creek above the sand-flats, where there is scarcely any salt at all in the water, yet evidently in most perfect health. Occasionally in times of long drought the water becomes as salt as the sea. A fisherman said that after sudden very heavy freshes of water from the river, some of the shell-fish sickened and died. He accounted for the presence of numerous dead cockle shells (*Cardium*) in the bed of the creek, since he had never found the animals there alive, by supposing that they had all been killed off by some unusual influx of fresh water many years before.

But beyond all that has been described, and beyond the extreme beauty of its wild and rocky scenery, the Browera Creek has yet another interest; it was in old times the haunt of numerous aborigines, who lived on its banks in order to eat the Oysters, Mussels, and Fish. On every point or projection, formed where a side branch is given off by the main creek, is to be seen a vast kitchen midden or shell mound. So numerous are these heaps of refuse, and so extensive, that it has been a regular trade at which white men have worked all their lives to turn over these heaps and sift out the undecomposed shells for making lime by burning them; unfortunately the numerous weapons thus found in the heaps have mostly been thrown away. There is now not a single black on the creek. Many of the mounds are very ancient, and it must have taken hundreds of years for such heaps to accumulate. Stone hatchet blades are still to be picked up in considerable numbers, and several were obtained. The softer layers weathering out from under the harder slabs of the horizontally bedded sandstones, form numerous shelters and low-roofed caves along the creek banks. It was in these caves or "gunyas" that the blacks used to camp, and in front of all of them a mass of shells slopes down towards the creek just as at the Cape of Good Hope. One of the heaps was dug into; places were found where fires had been made, and there were numerous bits of burnt stick and charcoal, a piece of wallaby bone charred by the fire, and the thigh bone of a black woman. This latter was found without any of the remaining bones, the woman having been perhaps eaten piecemeal. These relics were buried in a mass of cockle, oyster, and mussel shells mingled with much black powdery matter composed of decayed shells and other débris.

The walls and roofs of the caves are covered all over with drawings executed by the blacks in charcoal on the rock. These are interesting from their rude character. They represent Opossums, Fish, Sharks, and white men. Near one of the caves, on a flat slab of stone standing naturally erect, is a figure of a Kangaroo cut out in the stone itself; the figure is 5 feet in height, and is marked out by means of an incised groove, an inch and a half in depth. The figure is shaded, or rather rendered more conspicuous by the chipping of irregular small holes all over the area representing the body, and also, as in the charcoal drawings of Opossums, by means of lines. The fore-legs of the Kangaroo seem not to have been finished, or the artist has been especially unsuccessful in his attempts to represent them, and perhaps has tried to correct them, as appears possible from the number of lines. The contour line of the body is carried across the root of the tail. Similar drawings executed by cutting grooves in stone are common about Sydney.

Besides the drawings, in almost every cave were hand marks. These marks have been the subject of much discussion, and various speculations have been made as to some important meaning of the "Red Hand of Australia." They have been made by placing a hand against the flat stone, and then squirting a mixture of whitish clay and water from the mouth all around. The hand being removed, a tracing of it stands out in relief, and where the sandstone is red, appears red on a whitish ground. The hand marks have evidently been made haphazard, like the drawings.

They are now often out of easy reach, the former floors of the caves having slipped away. They are grouped in all sorts of ways, and amongst them one was seen in which a finger was missing, the native having possibly had a finger cut off as a matter of ceremony. The figure of a whole man is said to exist thus executed, in Cowan Creek, close by. Exactly similar hand marks, made in the same way by the Pueblo Indians, occur in New Mexico in caves in the neighbourhood of the town of Zũni.

The steam pinnace was frequently engaged in dredging and trawling in Sydney Harbour, and the tow-nets were extensively used. Annelid and Ascidian larvæ were especially abundant on the surface, and large collections of Invertebrates were made from the bottom. Of the numerous forms here obtained none were more interesting to the naturalists than *Trigonia* (*Trigonia lamarckii*), a genus of which over a hundred fossil species from Secondary formations of Europe, the United States, parts of South America, Africa, India, &c., are already known. The genus was supposed to be extinct until discovered living in Bass Strait by Quoy and Gaimard, by whom the soft parts were first described. Huxley subsequently gave further details of the anatomy, and Selenka has still more recently published a memoir on this subject. Von Willemoes Suhm, who examined all the recent species known, at the time of his death, thought they might be reduced to four—*Trigonia lamarckii* and *Trigonia strangii* from Port Jackson and Botany Bay, *Trigonia uniophora* from the region of Torres Strait, and *Trigonia margaritacea* (=*Trigonia pectinata*) from Bass Strait and Southeast Australia. Besides these there is in the Sydney Museum (in single valves) a *Trigonia* showing very large tubercles on the radiating ribs like some of the fossil forms, which appears to be undescribed. Since von Willemoes Suhm made the above notes another species (*Trigonia acuticostata*), which was previously only known as a Miocene fossil, has been dredged alive in Bass Strait.

Several specimens of the Port Jackson Shark (*Cestracion philippi*) were also procured, and it is interesting to note that the remains of a closely allied Plagiostomous fish have been found in Secondary deposits along with *Trigonia*.

Von Willemoes Suhm says :—"The Phyllopods got at Sydney belong to the genera *Limnetis* and *Limnadia*, and are especially interesting because of *Limnadia*, found in some places in Europe, is constantly parthenogenetic, the male being known only from the Australian species, as described by Claus. Kreeft says that males and females are constantly found together here, except in the wet season, as now, when no living animals but only some shells, could be got."[1]

The Challenger remained at Sydney from the 6th April to the 8th June, as the ship required docking and a general overhaul, and during this time the members of the

[1] A Dipterous insect was obtained by von Willemoes Suhm, which has been made the type of a new species, *Dasypogon diversipes*, Kirby (*Ann. and Mag. Nat. Hist.*, ser. 5, vol. xiii. p. 458, 1884).

SHEET 26

SOUNDINGS AND STATIONS

in the vicinity of

SYDNEY, N.S.W.

For explanation of abbreviations &c. see Appendix 1.

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Expedition met with great hospitality from the Governor, Sir Hercules Robinson, and the inhabitants of New South Wales. The collections made during the Antarctic cruise were carefully packed and catalogued, and despatched to England in sixty-five large boxes and ten casks.

On the 8th June, at 4 P.M., the Expedition left Sydney for Wellington, New Zealand. At 5.30 P.M., when well outside the heads, sail was made and the ship lay to for the night, ready to sound and dredge the next day, but towards midnight the wind freshened considerably, and the morning of the 9th was so stormy and the sea so short and confused that being unable to get satisfactory soundings, the vessel returned to Port Jackson and anchored in Watson's Bay at 4.30 P.M. until the weather should improve.

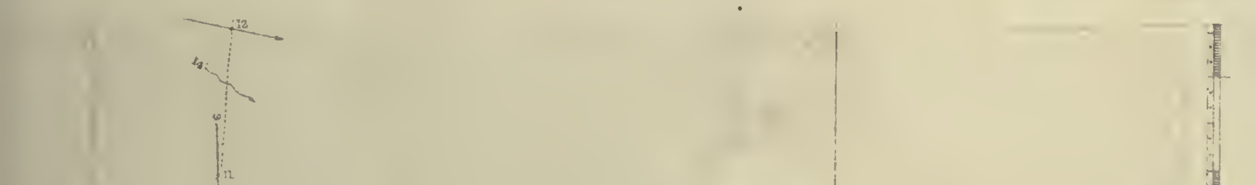
Sydney to Wellington.

Rough weather detained the ship in Watson's Bay until 7.30 A.M. on the 12th, when the Expedition again left for Wellington. When outside the heads a course was shaped to the eastward to get a line of soundings into ocean depths, in order to ascertain the nature of the slope from the land for the submarine cable to connect Australia with New Zealand. At 11 A.M. a sounding of 85 fathoms was obtained in lat. 33° 55′ S., long. 151° 35′ E. (see Sheet 26), the position of the ship being fixed by angles to objects on shore, but after this hour the rain squalls hanging over the land prevented the points on shore being seen, so that it was necessary to trust to astronomical observations in ascertaining the position of the other soundings. Proceeding eastward, depths of 120, 290, 650, and 950 fathoms were successively obtained, as shown on Sheet 26. The last sounding, at 5.30 P.M., was fixed by satisfactory observations of Jupiter, Sirius, and Canopus; and observations of the sun for longitude were obtained when the other soundings were taken. The current was found running to the southward at the rate of 2 miles per hour from 0.30 P.M., at which time the surface temperature had risen to 69°·5. After the line was hove in the ship made sail to double-reefed topsails and stood to the northward to stem the current, in order to retain as nearly as possible the same position during the night, so that sounding operations might be resumed early next day.

On the 13th June, at 6 A.M., the position of the ship as ascertained by observations of Saturn, Canopus, and Rigel showed a current of $1\frac{1}{3}$ miles per hour to the southward during the night, the surface temperature continuing steady at about 70°. At 7 A.M. a sounding was obtained in 1200 fathoms, the surface current running to the southward at the rate of $1\frac{1}{2}$ miles per hour. The ship then stood in towards the land to dredge. At 11 A.M. a sounding was obtained in 410 fathoms (see Sheet 26), and the trawl then put over. From this Station (164B) the land was distinctly visible from the deck, but Mount Kembla was the only conspicuous object. The current still continued strong to the southward, and the temperature of the surface water was 69°. At 2 P.M. the trawl was hove up and the dredge put over, another sounding being obtained in 400 fathoms (Station 164C, see Sheet 26). The difference in position between this sounding and that of 410 fathoms is due partly to the drift of the ship whilst trawling, owing to the southerly current. At Station 164C there was very little current, and the temperature of the surface water fell to 67°. Serial observations showed that this temperature extended to the depth of 40 fathoms, after which a gradual decrease took place to the bottom. At 5 P.M. the dredge was hove up, and sail was made to the northward under double-reefed topsails and courses. At 6 P.M. the temperature of the surface water again rose to 69°·7, and continued above 69° during the night.

On the 14th June, at 6.15 A.M., the ship's position was ascertained by observations of α Andromedæ and α Aquilæ, showing a current of 25 miles in a S. 17° E. direction (true) since 6 P.M. yesterday, or 2 miles per hour. After altering the course to get into a convenient position for sounding, the temperature of the surface water fell to 67° at 10 A.M. At 11 A.M. a sounding was obtained in 2100 fathoms at Station 164D (see Sheet 26), and here no current was experienced. At noon sail was made to triple-reefed topsails, and a course shaped to the eastward. A fresh southwesterly gale prevented temperatures being obtained.

The Challenger observations on the current off Sydney, New South Wales, showed that in June 1874 the surface temperature, which was 62° in Port Jackson, and 66°·5 just outside the heads, rose to 69° at a distance of 20 miles from the land, and continued at, or above, that temperature for 30 miles, when it again fell, at 50 miles from the shore, to 67°, and gradually decreased to 63°. When the temperature of the surface water was at, or above, 69°, it was found both by astronomical observations and from observations whilst sounding, that the current was running to the southward at an average rate of 1½ miles per hour; but directly the temperature of the surface fell to 67°, little, if any, current was experienced. The highest temperature registered in the heart of the stream was 70°·7. The impossibility of mooring a boat by the dredge or trawl rope, in order to obtain a good observation of the speed of the current in the centre of the stream, was much regretted, but the weather was very unfavourable, there being strong breezes with a considerable swell, so that the rate could only be estimated whilst sounding, and calculated from the differences between the position of the ship by D.R. and observation. In April, when steaming along the land from Montague Island to Sydney, the stream was found close in shore (from Jervis Bay to Port Jackson); in June, after a continuance of westerly winds, its inner edge was 20 miles from the coast. This seems to indicate that the wind has much to do with the distance of this stream from the shore. The temperature of the stream in April was 72°, and in June 69°, showing a diminution of 3°. The mean temperature of the air at Sydney in April is 65°, and in June 54°·6.



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On the 15th June, at 2.30 A.M., the force of the wind was 10, and as there was a considerable sea on, the waves lifted the lee cutter inboard, and the ship had to bear up to secure it. At 3.20 A.M. the ship was again brought to the wind until the weather moderated sufficiently to allow of sounding. At 6 A.M. star observations showed that a N. 30° E. current of 15 miles had been experienced since noon of the previous day. At 8.30 P.M. the wind began to moderate, and a reef being shaken out of the topsails, the ship wore and stood to the southwestward. The swell was heavy all day, the waves being at least 20 feet from trough to summit.

On the 16th, the weather being favourable, a sounding was taken at noon in 2550 fathoms at Station 164E (see Sheet 27). Unfortunately, the line parted when heaving in, owing to two strands having been cut, probably on its passage out from England, and the circumstance is of special interest since this was the last sounding line lost during the commission. Having obtained temperatures down to 1500 fathoms, at 4 P.M. sail was made towards Cook Strait, but the wind being foul, and falling light, at 8 P.M. the ship proceeded under steam. The surface current was again southerly, its average rate being one mile per hour, the temperature fairly steady at 63°·5.

On the 17th a sounding and dredging were obtained in 2600 fathoms at Station 165 (see Sheet 27); but the dredge came up empty at 4 P.M., when, the weather being fine, with a moderate southerly breeze, sail was made. From observations at 6 A.M. and noon it appeared that during the past twenty-four hours the current had run 23 miles N. 65° W. (true), and whilst sounding the direction and speed were found to be the same, the rate being estimated at about one mile per hour.

On the 18th, the wind being light and variable, the vessel proceeded under steam. The current still running steadily to the northward; by star and sun observations its direction and rate for the last twenty-four hours were found to be N. 15° W. 16 miles, and the surface temperature 64°.

On the 19th, at 2 P.M., a sounding and serial temperatures were obtained in 2600 fathoms, at Station 165A (see Sheet 27), the bottom temperature 34°·4. No current was experienced whilst sounding, but star observations at 6 A.M., confirmed by those at noon, showed a set of S. 60° E., 0·6 mile per hour. The temperature of the surface water fell gradually during the day from 64° to 62°.

On the 20th no current was experienced, thus confirming the observation whilst sounding at 2 P.M. on the 19th; the surface temperature gradually fell to 59°·5.

On the 21st, at 6.30 A.M., a sounding, with serial temperatures, was obtained in 1975 fathoms, bottom temperature 34°·7, at Station 165B (see Sheet 27). The current was S. 23° W., three quarters of a mile per hour, and the surface temperature 59°·5. During the day a fresh northerly breeze was experienced, which at midnight amounted to a gale.

On the 22nd, at 0.20 A.M., the ship was brought to the wind under close-reefed topsails, a fresh gale blowing with dirty rainy weather. At 3 A.M. the wind suddenly subsided, and at 6 A.M. the weather was quite fine and bright, and the vessel again proceeded on her course. At 1.15 P.M. a sounding and serial temperatures were obtained in 1100 fathoms at Station 165C (see Sheet 27), and then the course was resumed towards Cook Strait. At 6 A.M. star observations proved that a current of 28 miles, S. 39° W., had been experienced since noon of yesterday, but between 6 A.M. and noon there was no current; the temperature of the surface water was 58°·5.

On the 23rd June, at 6.30 A.M., a sounding and trawling were obtained in 275 fathoms, at Station 166 (see Sheet 27). Star observations showed no current at 6 A.M., but between that time and noon a current of 8 miles, S. 56° E., was experienced. Part of this was no doubt due to the drift of the ship whilst trawling in shallow water. At 1.30 P.M. sail was made and the vessel proceeded towards the centre of an imaginary line, joining Mount Egmont and Cape Farewell. At 5.30 P.M. a sounding was obtained in 350 fathoms (Station 166A, see Sheet 27), and star observations showed a current of 7 miles, N. 53° E. since noon, or nearly the same rate, though not the same direction, as in the forenoon. At 10 P.M. a sounding was obtained in 400 fathoms, at Station 166B (see Sheet 27). From these soundings it is evident that a bank extends some 200 miles west of Mount Egmont, and may possibly reach as far as Lord Howe Island.

On the 24th, at 4 A.M., bottom was obtained in 400 fathoms, Station 166C (see Sheet 27). At 6 A.M. star observations showed a current of 9 miles, or three-quarters of a mile per hour, to the eastward since 5.30 P.M. on the previous day. At 7.30 A.M. a sounding and trawling were obtained in 150 fathoms at Station 167 (see Sheet 27). At noon all sail was made for Wellington, no current having been experienced since 6 A.M. At 6 P.M. star observations showed a slight E.S.E. set of half a mile per hour. At 9 P.M. the wind increased and became squally, with rain, which necessitated working to the eastward under steam and fore and aft sails. The temperature of the surface water was 58°.

On the 25th June, at 8.30 A.M., the land about Separation Point was observed, and at 9.30 A.M. the position of the ship was fixed by angles to objects on the shore, showing a westerly current of 16 miles since 5.30 P.M. on the 24th, or of one mile per hour. Passing along the land a remarkable yellow patch was observed at Cape Farewell, which is most probably Sandstone Island, but it is not mentioned in the sailing directions. At 10.30 A.M. the lighthouse on Farewell Spit was seen, and the ship steered for Port Hardy, anchoring there at 5 P.M. in 15 fathoms, off the Squadron Rocks. The vessel remained there until 4 A.M. on the 27th June, when the wind moderated, and at 6 A.M. Stephen Island was rounded, and the ship worked to windward under steam and fore and aft sails; but, finding at noon that Port Nicholson could not be reached that day, the vessel was anchored in Queen Charlotte Sound at 1.30 P.M., between Long and Motu Ara Islands.

The ship left Queen Charlotte Sound at 8 A.M. on the 28th, and worked to windward under steam and fore and aft sails through Cook Strait for Port Nicholson, against a strong southeast wind, which raised a short heavy sea, so much so that the leadsman

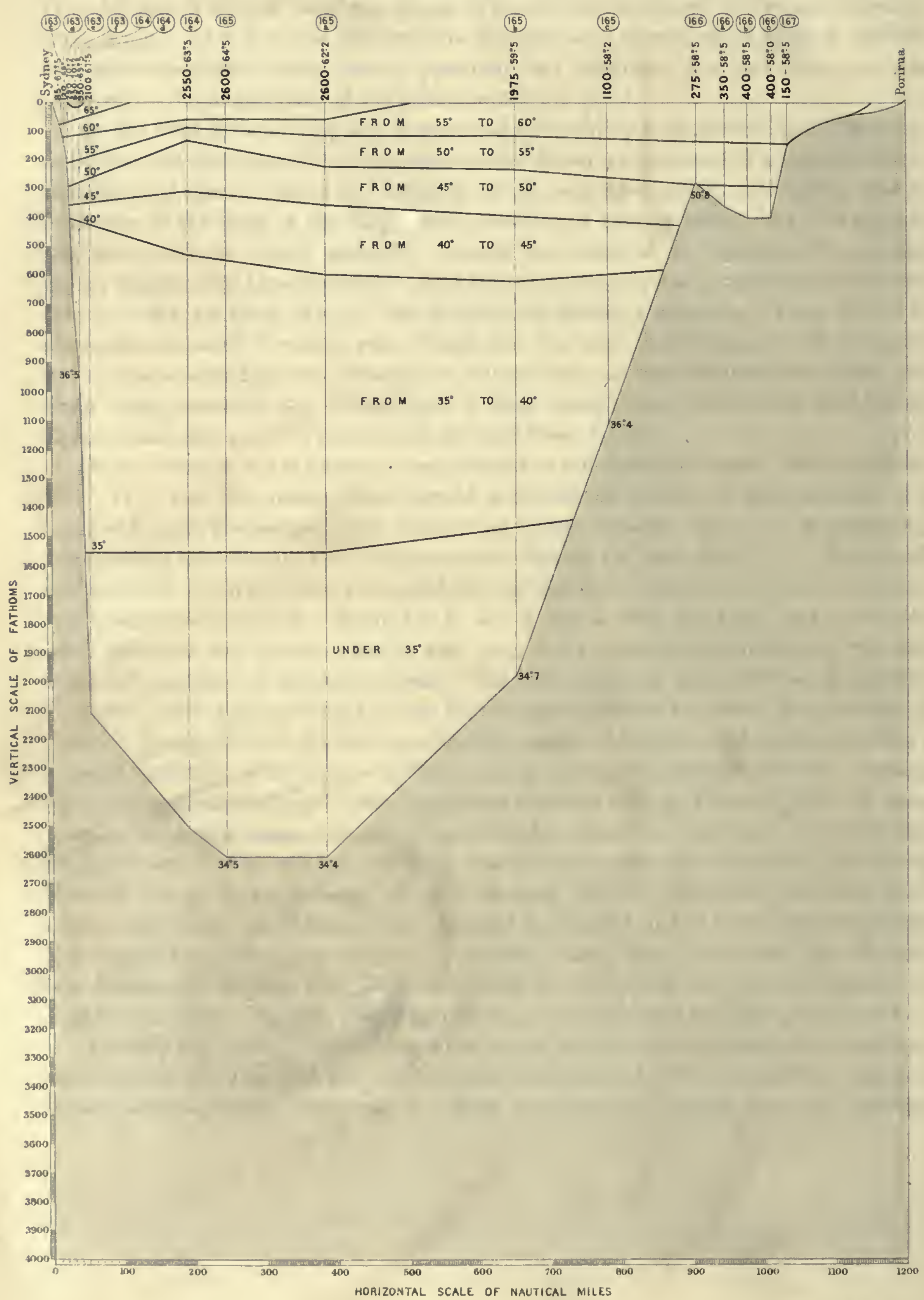
DIAGRAM II

PACIFIC OCEAN

Longitudinal Temperature Section

Sydney, New South Wales, to Porirua, Cook strait, New Zealand.

For explanation of Symbols see Appendix 1.



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was washed out of the chains just after noon; he must have sunk immediately, for although the vessel was stopped for about an hour, no sign of him could be seen. At 4 P.M. the ship entered Port Nicholson, and at 5 P.M. anchored in 9 fathoms off the town. In passing through Cook Strait the surface temperature was found to be 9° higher at the western entrance than in Port Nicholson.

The section from Sydney to Cook Strait shows that on the Australian coast the incline of the bottom from the 100 fathom line (which was 17 miles from the shore), to a depth of 2100 fathoms 57 miles from the land, was about 1 in 20, which is less abrupt than had been previously found to be the case farther to the southward off Twofold Bay, where it was about 1 in 6. From Station 164D, 2100 fathoms, the bottom slopes gradually to 2600 fathoms, at a distance of 240 miles from the coast, and continues at that depth for 140 miles, when it rises with a gentle incline to 1100 fathoms, 780 miles from Sydney, and 335 miles from the entrance to Cook Strait, after which comparatively shallow soundings were obtained (under 400 fathoms) to the entrance of Cook Strait. The most westerly of these shallow soundings was one of 275 fathoms, 200 miles from the land, and 125 miles east of the 1100 fathoms sounding. The bottom on this bank was extremely hard, so much so that but a small quantity was brought up by the sounding rods; but as both the trawl and dredge dragged freely along, without catching in any irregularities, it seems to be smooth on the surface. A reference to the general chart seems to indicate that a bank of soundings, of less than 500 fathoms, extends a considerable distance west of the North Cape of New Zealand. Such being the case, the bank is probably continuous all along the western side of the North Island.

The bottom temperature in this section at depths exceeding 2000 fathoms was 34°·5, in less than 2000 fathoms the temperature increased gradually to the surface.

The surface temperature increased from 62° at Sydney to 69° twenty miles from Port Jackson, remaining at or above that for 30 miles, and then decreased gradually for the next 50 miles to between 63° and 64°, which temperature was retained for 300 miles, after which it gradually fell to 58° at the entrance of Cook Strait.

The serial temperatures show that immediately adjacent to the Australian coast, the warm southerly current appears to affect considerably the position of the isotherms above 45°; the isotherms of 40°, 45°, 50°, and 55° are found at greater depths on the New Zealand side of the section than on the Australian side (see Diagram 11).

The deposits in depths of from 290 to 1200 fathoms off the Australian coast were green muds, containing a considerable quantity of glauconite, and resembling in many respects the deposits at similar depths off the south coast of Africa. The carbonate of lime ranged from 44 to 48 per cent., and consisted of the shells of *Globigerina*, *Orbulina*, *Pulvinulina*, *Pullenia*, *Miliola*, *Textularia*, *Discorbina*, *Cristellaria*, and other Foraminifera; Coccospheres and Rhabdoliths; fragments of Pteropods, and other pelagic Molluscs; Ostracode valves, fragments of Echinoderms, Polyzoa, and other calcareous organisms. The mineral particles in these green muds were about 0·2 mm. in diameter, and consisted of rounded fragments of quartz, felspars, hornblende, magnetite, mica, volcanic glass, in addition to glauconite. There were a few Radiolarians and Sponge spicules. A quantity of the glauconitic grains and casts were carefully collected, after the removal of the calcareous organisms by dilute acid, and a careful analysis of these was made by Dr. Sipöcz. A microscopic examination of the substance analysed showed it to be, by estimation, made up of about 10 per cent. of white, pale grey, and yellow casts, about 25 per cent. of pale green casts, about 60 per cent. of dark green ones, and about 5 per cent. of mineral particles and siliceous organisms. In practice it was found impossible to separate the siliceous organisms and small mineral particles from the casts.

Analyses of Glauconitic Grains and Casts.

	I.	II.	III.	
Silica (SiO_2), . . .	51·80	...	...	51·80
Ferric Oxide (Fe_2O_3), . .	24·21	...	...	24·21
Alumina (Al_2O_3), . .	8·67	...	...	8·67
Ferrous Oxide (FeO), . .	...	...	1·54	1·54
Lime (CaO), . . .	1·27	...	...	1·27
Magnesia (MgO), . .	3·04	...	...	3·04
Potash (K_2O), . . .	...	3·86	...	3·86
Soda (Na_2O), . . .	...	0·25	...	0·25
Water (H_2O), . . .	5·68	...	...	5·68
Manganese Peroxide (MnO_2), .	traces	...	...	traces
				100·32

I. 0·7312 gramme of the substance fused with double carbonate of soda and potash gave 0·0416 grm. water (H_2O), 0·3788 grm. silica (SiO_2), 0·1896 grm. ferric oxide (Fe_2O_3), 0·0634 grm. alumina (Al_2O_3), traces of manganese, 0·0093 grm. lime (CaO), and 0·0618 grm. magnesium pyrophosphate ($Mg_2P_2O_7$), equivalent to 0·02227 grm. magnesia (MgO).

II. 0·6827 gramme of the substance treated with hydrofluoric and sulphuric acids gave 0·0450 grm. potassium chloride (KCl) and sodium chloride (NaCl), which gave 0·1367 grm. potassium platinochloride (K_2PtCl_6), equivalent to 0·0417 grm. potassium chloride (KCl), corresponding to 0·02634 grm. potassium oxide (K_2O), and 0·0033 grm. sodium chloride (NaCl), corresponding to 0·00175 grm. sodium oxide (Na_2O).

III. 0·3205 gramme of the substance treated with hydrofluoric and sulphuric acids required for oxidation, 0·85 c.c. permanganate of potassium corresponding to 0·00496 grm. ferrous oxide (FeO) [1 c.c. permanganate of potassium = 0·0058355 grm. of ferrous oxide (FeO)].

The two soundings in 2600 fathoms contained respectively 7 and 19 per cent. of carbonate of lime. In 1975 fathoms there was 77 per cent., in 1100 fathoms 84 per cent., and in 275 fathoms 88 per cent. The carbonate of lime in all these consisted essentially of the shells of pelagic Foraminifera, with Coccoliths, Coccospheres, and Rhabdoliths. It will be noticed that the amount of lime was less the greater the depth from which the deposits came, and this was due to the gradual removal of the more delicate and smaller shells. While these small shells and Coccospheres made up most of the deposit at 275 and 400 fathoms, they were very rare at a depth of 2600 fathoms; these organisms appeared to be quite as abundant at the surface over the one locality as the other. The mineral particles were very minute in these soundings, and consisted chiefly of felspars and glassy fragments. As the entrance of Cook Strait was approached, the mineral particles derived from the coast of New Zealand increased both in number and size, and the pelagic shells diminished, while glauconite, which was absent in the soundings from the middle of the section, again made its appearance.

The dredgings along the Australian coast were very successful, and yielded a large number of specimens belonging to characteristic species. In 950 fathoms there were two specimens of *Lætmogone violacea*, Théel, one of the Elasipodous Holothurians. The only other known specimens of this species were subsequently obtained by Mr. Murray at a depth of 555 fathoms in the Færöe Channel, when over three hundred specimens were taken in one haul.[1] Dr. Théel says "it is impossible to discover any characteristic by which these almost antipodal specimens may be distinguished from each other." From 2600 fathoms several Polyzoa, a siliceous Sponge, and some worm tubes were obtained.

The surface nets were continually in use, and the naturalists on several occasions went out in boats to observe the surface life. *Pulvinulina micheliniana* was more abundant than had been previously observed, the best hauls being got when the net was dragged as nearly as possible at 80 fathoms. In the majority of the specimens the brownish-yellow sarcode enveloped the shell, and on two occasions the sarcode was observed thrown out in bubble-like expansions, apparently serving the purpose of a float, similar to what was afterwards observed in *Hastigerina*. Coccospheres were especially

[1] *Proc. Roy. Soc. Edin.*, vol. xi. p. 694, 1882.

abundant on the surface. Minute, quite transparent, masses of jelly were frequently picked up on the surface, which when examined under the microscope were found to enclose great numbers of Coccospheres, and occasionally Rhabdospheres and other foreign particles. These masses of jelly at once recalled the *Myxobrachia* of Haeckel, but it

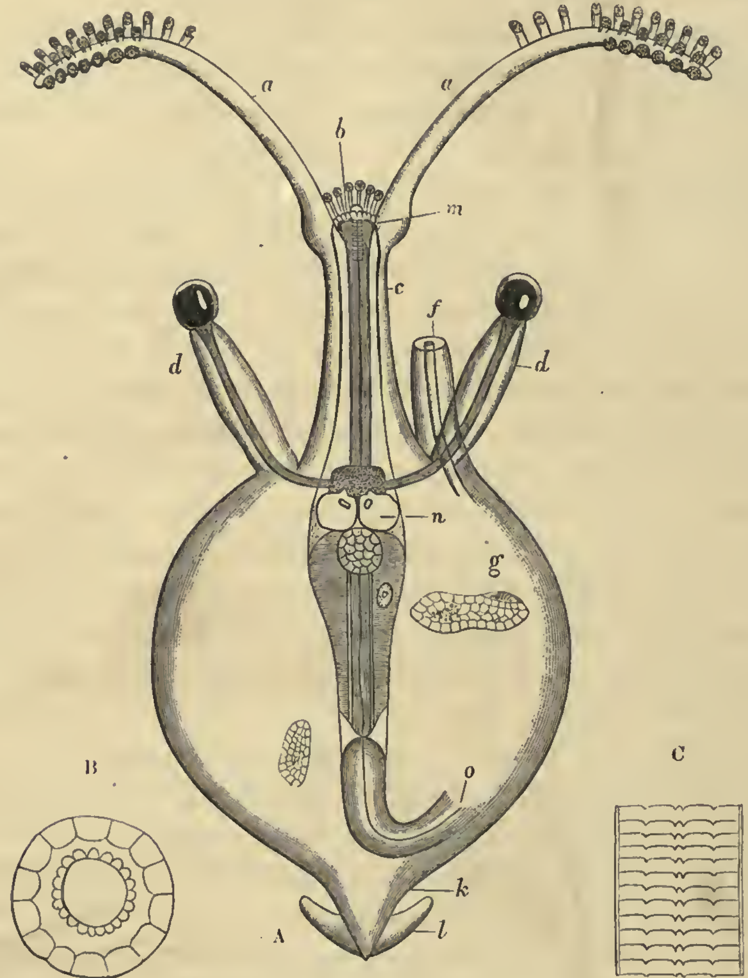


FIG. 173.—(*Procalistes*) *Taonius suhmii*, Lankester.

A. Youngest specimen of (*Procalistes*) *Taonius suhmii*, Lankester, drawn by R. von Willemoes Suhm from a living specimen; magnified 25 diameters. *a*, The long "arms" or processes of the fore-foot; *b*, the six small suckers, representing the eight short processes of the fore-foot of a typical Decapod; *c*, the elongated neck; *d*, the pedunculated eyes; *f*, the funnel or siphon; *g*, the anal process seen through the transparent mantle; *k*, the median posterior process of the body; *l*, the lateral fins attached to the same; *m*, the buccal apparatus; *n*, the oto-cysts; o, the intestine.
B. One of the suckers of the long arms, more highly magnified.
C. A portion of the lingual ribbon, more highly magnified.

was impossible to make out in them the structures which that naturalist has described. R. Hertwig has since shown that the various supposed species of *Myxobrachia* are in reality curious malformations of *Thalassicolla sanguinolenta.*[1]

[1] Hertwig, R., Der Organismus der Radiolarien, *Jenaische Denkschriften*, Bd. ii., p. 129, 1879.

Procalistes.—On June 16th, Dr. von Willemoes Suhm found among the surface animals an interesting form, concerning which he wrote in his journal as follows:—"Among the surface gatherings there is a transparent and very interesting Pteropod, with large eyes on the tentacles and without any 'ptera' or foot. Having obtained three more or less

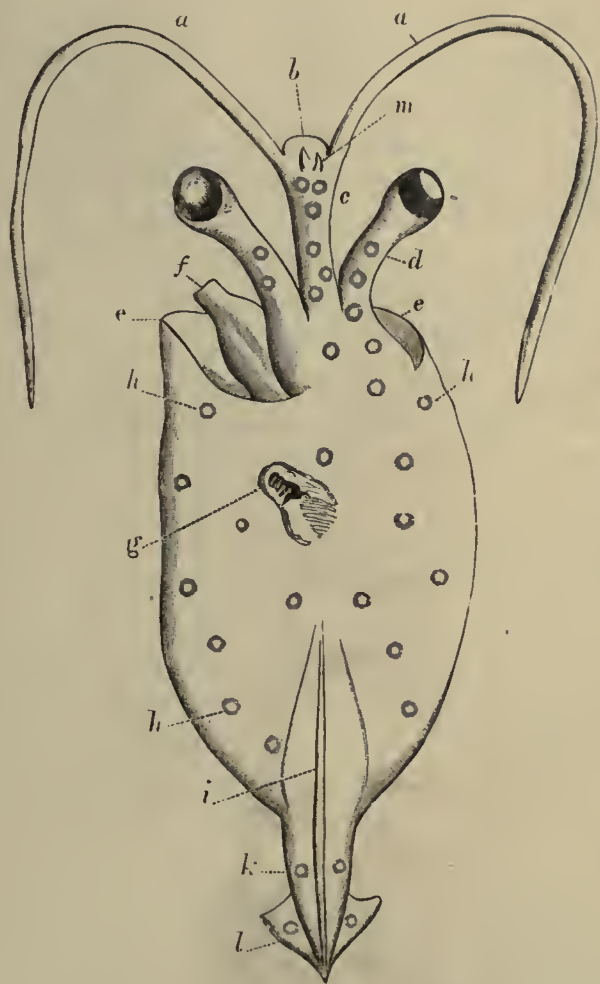


FIG. 174.—A somewhat older specimen of (*Procalistes*) *Taonius suhmii*, Lankester, drawn by Professor E. Ray Lankester, F.R.S., from a specimen mounted on a glass slide in balsam by R. von Willemoes Suhm; magnified 20 diameters.

a, The long "arms" or processes of the fore-foot; *b*, the smooth buccal margin devoid of processes; *c*, the elongated neck; *d*, the pedunculated eyes; *e*, the edge of the mantle flap, separated from its attachment to the head and funnel by pressure; *f*, the funnel or siphon; *g*, the anal process seen through the transparent mantle, and showing a spiral band of black pigment lying in the ink-bag; *h*, chromatophores; *i*, the pen; *k*, the median posterior process of the body; *l*, the lateral fins attached to the same; *m*, the two horny beaks of the buccal apparatus.

damaged specimens from which I could not complete its anatomy, I shall have to defer giving a proper account of it. The animal belongs to the Clionidæ, and is probably allied to *Pelagia*, Quoy and Gaimard."

He also made a drawing of the animal to which are appended the following notes :—"Clionid Pteropod: June 16–18, 1874. In the warm East Australian current coming from the north (surface temperature 70°), together with *Calcarella* on the voyage from Sydney to Wellington. In all only three specimens, of which the largest alone showed the eyes well. It measured 13 mm. long; tentacles 6–7 mm. long; eye-peduncles 2 mm. long. Neither of the smaller specimens showed any thing new. Tentacles with suckers, of which one is strongly magnified below (woodcut, fig. 173B). Mouth with six suckers, two teeth, and radula; the latter, as far as I could make it out without injury to the animal, is drawn below to the right hand side (woodcut, fig. 173C). The mouth leads into an œsophagus; this into a muscular stomach, in the muscular wall of which is a unicellular gland *à la nematode*. Sharply defined intestine which I could not follow out to the anus on the process to the right (woodcut, fig. 173, *f*). Ganglion superius sends out the nerves to the eyes; between it and the ganglion inferius are the two otolithic vesicles. On the right side the generative gland is seen with reddish oil specks, and in the corner black pigment; to the left is a cellular body, probably an excretory organ. Subsequently it seemed to me as though there were a calamus in the hindermost portion of the animal; this must, however, have been a mistake. Heart not seen."

Professor Lankester, after an examination of the drawing and the specimens, showed the animal to be a Dibranchiate Cephalopod, and erected it into a new genus *Procalistes*, one of the characters of which was the absence of suckers[1] (fig. 174). Mr. W. E. Hoyle has since had the opportunity of examining several other specimens in the Challenger collection, and of comparing them with those of the genus *Taonius*, Stp., in the Copenhagen Museum, and believes that the form in question is a new species of that genus; the reasons for this view will be given at length in the Report on the Cephalopoda.

Wellington.

The former observing position at Port Nicholson was Pipitea Point, but owing to the New Zealand Government reclaiming the ground off the Point, and from it to the southward, and to the fact that a railway runs into Wellington past the old observing station, satisfactory observations could not be obtained there, consequently it was necessary to select another position, and the Protestant Cathedral was chosen for the purpose, which is 5″ S. and 13″ W. of the former observing station.

The coast hills in this part of New Zealand, as seen from the sea, recalled Kerguelen Island in the general appearance and colour of their vegetation, especially the shores about D'Urville Island, but all the valleys and inland slopes are covered with a dense

[1] Lankester, On Procalistes, a young Cephalopod with pedunculate eyes, taken by the Challenger Expedition, *Quart. Journ. Micr. Sci.*, N. S., vol. xxiv., pp. 311-318, 1884.

forest and almost impenetrable bush. The trees are covered with epiphytic ferns, Astelias, and Liliaceous epiphytes, which, perched in the forks of the branches, remind one in their habit and appearance of the Bromeliaceous epiphytes of Tropical America. One of the most remarkable trees, as pointed out by Mr. T. Kirk, F.L.S., is the Rata (*Metrosideros robusta*).[1] This, though a Myrtaceous plant, has all the habits of the Indian Figs, simulating them in the closest manner. It starts from a seed dropped in the fork of a tree, and grows downward to reach the ground; then having taken root there, and gained strength, chokes the supporting tree and entirely destroys it, forming a large trunk by the fusion of its many stems. Nevertheless, it occasionally grows directly from the soil, and then forms a trunk more regular in form. Another species of Rata (*Metrosideros florida*) is a true climbing plant.

Few birds were seen. The Gull of Kerguelen Island (*Larus dominicanus*) was common in the harbour. On the telegraph wires along the shore sat a Kingfisher (*Halcyon sanctus*) in abundance, and dashed down from thence on its prey into the shallow water of the harbour. It was interesting as being the first Kingfisher met with on the voyage leading a littoral existence and feeding on sea fish. Afterwards Kingfishers similarly inhabiting the sea shores became familiar in the Strait of Magellan. In the poulterers' shops the curious parrot, or Kaka (*Nestor meridionalis*), was hung up for sale. Mr. T. H. Potts[2] describes this bird as tearing away the dead wood of trees in search of insects, and appearing by its habits to replace to some extent the woodpecker, which is totally absent in New Zealand.

The New Zealand *Peripatus* (*Peripatus novæ zealandiæ*)[3] is abundant near Wellington amongst dead wood, and forty or fifty specimens were brought to the ship as the result of a day's search in the Hutt Valley. As in the case of the species from the Cape of Good Hope (*Peripatus capensis*), the males are much less abundant than the females. In essential structure and habits the animal closely resembles the South African species, but is distinguished by having fewer pairs of feet, viz., fifteen instead of seventeen. The females all contained young, although it was mid-winter (see p. 284).

Land Planarian worms are also pretty common near Wellington. In their anatomical structure, the New Zealand species are more nearly allied to South American forms of the genus *Geoplana* than to the Australian Land Planarians. These latter belong to a special genus (*Cœnoplana*), which has affinities with the genus *Rhynchodemus* of India and the Cape of Good Hope.

Mr. W. T. Travers, F.L.S., to whom the Expedition was indebted for much kindness and scientific information during the stay at Wellington, brought on board specimens of *Peripatus novæ zealandiæ* and also of Land Planarians, together with the egg capsules

[1] T. Kirk, F.L.S., On the Habit of the Rata, Metrosideros robusta, *Trans. New Zealand Inst.*, vol. iv. p. 267, 1871.
[2] *Trans. New Zealand Inst.*, vol. iii. p. 82, 1870.
[3] H. N. Moseley, *Ann. and Mag. Nat. Hist.*, ser. 4, vol. xix. pp. 85–91, 1877.

of the latter, which were hitherto unknown. They are spherical in form, of about the size of sweet-pea seeds and of a dark brown colour. The capsules have a tough chitinous wall, and each contains four or five young Planarians.[1] Mr. Travers also presented a Maori skull; and other Maori crania, together with some crania of the Chatham Islanders, were given by the authorities of the Colonial Museum.[2] From the same Museum also some bones of Cetacea were obtained, which have been described by Professor Turner in his Report on the Bones of Cetacea collected by the Expedition.[3]

The Governor of the colony, Sir James Fergusson, and many of the inhabitants gave entertainments in honour of the Expedition.

Wellington to the Kermadec Islands and Tongatabu.

On the 6th July, at 4 p.m., the Expedition left Lambert Harbour, Port Nicholson; but when passing Gordon Point the weather became so thick that it was not considered advisable to proceed; the ship was therefore anchored for the night in Worser Bay, and finally left Port Nicholson at 6.40 a.m. on the 7th, rounding Cape Palliser at 11.20 a.m., and then a course was shaped to the northward along the coast as the wind permitted. Some difficulty was experienced in distinguishing the hills north of Cape Palliser, owing principally to the fact that their heights had not been determined. On leaving Port Nicholson the temperature of the surface water rose from 47° to 52°, or 5° less than at the western entrance of the Strait.

On the 8th July, at 10 a.m., a sounding was obtained in 1100 fathoms, and afterwards a trawling and serial temperatures. The surface temperature rose at 1 a.m. to 57°, or nearly the same as on the other side of the island, showing that the cold surface water is almost entirely confined to Cook Strait, and is probably caused by tidal action over a shallow bottom. Whilst sounding the surface current was running slowly to the northward, but the observations showed a total drift of 19 miles, S. 39° E., since noon of the previous day. The weather being calm and fine steam was used until 1 a.m. on the 9th, when a breeze sprang up from the southwestward, which enabled the ship to proceed under sail. In the evening there was a most wonderful display of phosphorescent light on the surface, caused by *Pyrosoma*, the ship passing through several "banks" of them.

On the 10th, at 6 a.m., a sounding, trawling, and temperatures were obtained in 700 fathoms (see Sheet 27), 40 miles east of East Cape. On the 12th and 13th a strong easterly current was experienced, which continued regularly up to 6 p.m. on the 13th, as was seen from both star and sun observations. At 10 p.m. on the 13th Macauley Island,

[1] H. N. Moseley, On the Anatomy and Histology of the Land Planarians of Ceylon, *Phil. Trans.*, vol. clxiv. pp. 105–171, pls. x.–xv., 1874. Also Notes on the Structure of Several Forms of Land Planarians, *Quart. Journ. Micr. Sci.*, N. S., vol. xvii. p. 275, 1877.

[2] Zool. Chall. Exp., part xxix., 1884.

[3] Zool Chall. Exp., part iv., 1880.

one of the Kermadec group, was sighted, and the ship passed between it and Raoul or Sunday Island.

At 6 A.M. on the 14th star observations showed a strong northerly current. At 7 A.M. a sounding and trawling were obtained in 520 fathoms at Station 170 (see Sheet 27). Raoul and Macauley Islands both being in sight, and the former having been surveyed and fixed by Captain Denham, it was possible to determine the height of Macauley Island, which proved to be 800 feet. From the northward Macauley Island appeared to be wedge-shaped, but from the eastward it looked round-backed. At noon another sounding and trawling and serial temperatures were taken in 630 fathoms (Station 170A, see Sheet 27), and at 4.30 P.M. the ship proceeded to the northward under steam, passing west of Raoul Island.

Kermadec Islands.—The Kermadec group of islands, which are all very small, forms with New Zealand, Macquarie Island, and the Tonga group, a direct line of volcanic action, stretching in a northeasterly direction, and thus nearly at right angles to the northwest lines, which are followed by many of the remaining Pacific groups, such for example as the Fijis.

The flora of Raoul Island was described by Sir J. D. Hooker[1] from collections made by Mr. Macgillivray of H.M.S. "Herald." Forty-two vascular plants are known from the islands, of which five are endemic species. Half the number are New Zealand ferns; the large proportion of ferns in the flora is most remarkable, and also their New Zealand character. The group lies just at the northern limit of the zone of westerly winds, and within that of calms and changeable winds, but so close to the limit that the winds may well have transported many of the plants, and the preponderance of ferns may possibly be due to the fact, that the winds have been the main agents in transporting vegetation to the islands, and have sufficed to carry the minute fern spores, whilst heavier seeds have seldom reached the island, by other means of transit. If fern spores be diffused mainly by wind, it should be especially difficult for them to cross the zones of constant rains, and there ought to be a marked separation of fern forms in distribution about those lines. There is no connection between the flora of the Kermadecs and that of Norfolk Island, although on all considerations such would have been expected to occur, as is also pointed out by Sir J. D. Hooker. The soundings of the "Gazelle" and "Tuscarora" have proved that a channel of more than 1000 fathoms in depth passes up between New Zealand and the Kermadec Islands, hence an ancient land connection cannot be looked to as an explanation of the New Zealand affinities of the Kermadec flora.

On the 15th July, at 6.30 A.M., a sounding and trawling were obtained in 600 fathoms, in lat. 28° 33′ S., long. 177° 50′ W. From this position Raoul Island was just visible,

[1] Sir J. D. Hooker, Botany of Raoul Island, *Journ. Linn. Soc., Lond.* (Bot.), vol. i. p. 125, 1857.

bearing S. ¼ E. After trawling, sail was made at 10 A.M. towards the Friendly Islands. It was intended at first to try to pass over the La Rance Banks, but on due consideration it was thought more advisable to avoid them, as from the description given they appear to be merely the shoal parts on the outside of a large coral bank, which would require more time to survey than could be spared for the purpose.

On the 17th, at 9 A.M., a sounding and serial temperatures were taken in 2900 fathoms, at Station 171A (see Sheet 27), the bottom temperature being 34°·3, slightly colder than that between Australia and New Zealand, after which the ship again proceeded towards the Friendly Islands. During the past forty-eight hours a strong easterly current was experienced, running more than a mile per hour.

After leaving the Kermadecs, no Cape Pigeons, Albatrosses, Prions, nor any other of the southern birds, which had been constant attendants on the ship while in the Southern Ocean, were noticed. For several days between the latitudes of 25° and 28° S., no birds were noticed from the deck of the ship. The night before arriving at Tongatabu a *Phaëthon flavirostris* came on board; it flew straight at the quartermaster's light near the wheel, and nearly knocked it over.

On the 19th, at 3 A.M., having run within 15 miles of the island of Eooa, the vessel was hove to until daylight, the weather being dark and misty. At 6 A.M. sail was made for Tongatabu, the low land of which and of Euaigee Island were seen at 7 A.M., and at 9 A.M. the ship proceeded under steam through the east channel for the anchorage.

Between Wellington, New Zealand, and Tongatabu the Stations were few, and at too irregular distances to admit of a section being constructed; the deepest water obtained was 2900 fathoms, where the bottom temperature, as stated above, was nearly the same as that between Australia and New Zealand, but sufficient observations were obtained to allow a temperature section being drawn between New Zealand and the Fiji Islands, from which it will be seen that the isotherms all close together as the latitude decreases, or in other words that whilst the surface temperature gradually increased from 57° to 78°, the isotherm of 40°, which at New Zealand was at the depth of 800 fathoms, was found to be only 490 fathoms from the surface at the Fiji Islands (see Diagram 12).

The deposits off the east coast of New Zealand in 1100 and 700 fathoms were blue muds, with a thin characteristic layer of a reddish colour on the surface. They contained only from 4 to 9 per cent. of carbonate of lime, the chief part of the deposit consisting of continental débris derived from the neighbouring land. The dredgings were rich in *Pourtalesia laguncula*, Agass., *Serolis bromleyana*, Suhm, *Protocaulon molle*, Köll., and *Leptoptilum gracile*, Köll., and contained a very large number of other deep-sea species in addition.

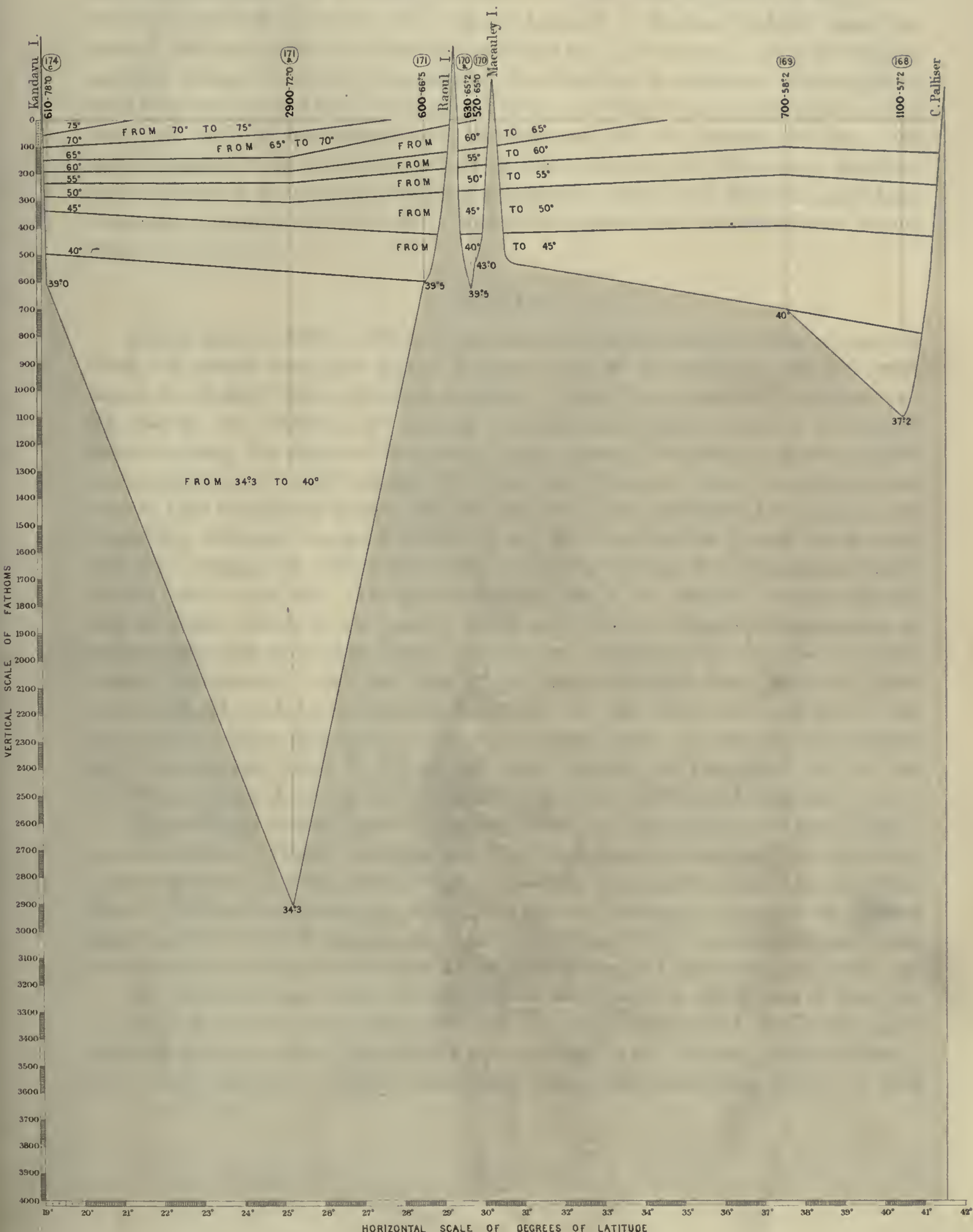
The deposits off the Kermadec Islands in 520, 630, and 600 fathoms were volcanic muds, containing very many large blocks of pumice. The dredgings here also yielded

DIAGRAM 12

PACIFIC OCEAN

Meridional Temperature Section. Kandavu I. to C. Palliser, New Zealand.

For explanation of Symbols see Appendix 1.



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many deep-sea forms. A very large fragment of a huge new Hexactinellid Sponge was brought up from 630 fathoms. This will be described by Professor Schulze under the name of *Poliopogon gigas;* it measured about 2 feet by 3 feet 6 inches. Many of the deep-sea forms obtained here were identical with those found in the Atlantic. The deposit at 2900 fathoms was a red clay, which showed only a very slight trace of effervescence with weak acid, and did not contain more than one per cent. of carbonate of lime. The mineral particles were very small, the bulk of them being less than 0·05 mm. in diameter, and consisted of felspar, magnetite, and hornblende; there were, however, some large fragments of pumice, while the great bulk of the deposit was composed of very minute fragments of pumice.

Tongatabu.

Euaigee Island is higher than the other islets, and can be seen farther than Tongatabu itself. A narrow coral reef fringes its shore, and off its southeast end is a small detached reef, about half a mile from the island. From the east point of Tongatabu along the coast to the southward, the fringing coral reef does not extend above a few yards from the shore; but from the east point to the westward it gradually extends until it reaches a distance of about a quarter of a mile from the land. From the point opposite Onevah Islet to Makkaha Island, the coral patches on the south side of the channel into Tongatabu anchorage are much broken up and ill-defined, whilst the reef on the north side of the channel has a sharp edge with no outlying knobs. It is therefore preferable to sail near to this side. The quarter fathom rock in the channel between Makkaha and Monuafai Islands is not exactly in the centre of the channel, the passage on its western side being wider than that on the eastern. On a dull day this rock cannot be readily distinguished; but the edge of the reef extending from Makkaha Island is well-defined, and by keeping close towards it, the rock will be avoided. The church on the hill at Nukalofa is a most conspicuous object. At noon the ship anchored off it, with Faffao Island N. 31° E., the right extremity of Pangimodu, in line with the left extremity of Onevah N. 81° E., King's House S. 16° W., in 13 fathoms.

Three whaling vessels were at Tongatabu when the ship arrived, and from them it was ascertained that Raoul or Sunday Island of the Kermadec group, had been abandoned, in consequence of a sudden eruption of the volcano, by an American family who had settled there. The island was certainly quite quiet when the Challenger passed, not the slightest sign of smoke issuing from any part, but the whalers said that this state of things was exceptional, and they reported also that a rock or shoal rose, and again sunk, in its west bay.

The whaling season at the Friendly Islands commences in the middle of June, and continues to the end of October; during this time the Humpbacked Whale (*Megaptera lalandi*) frequents the neighbourhood of these islands for breeding purposes, and is then easily captured. Several whales were passed just outside the reefs. A small

German vessel, belonging to the firm of Godeffroy Brothers, the famous collectors of South Sea Island productions, was also at anchor in the harbour.

The sky was dull, covered with grey clouds, and the air even somewhat chilly as the islands were approached, and they did not look bright and sunny, as might have been expected of the first South Sea Islands met with on the voyage. As the small island of Eooa was passed, the surf in places raised jets of spray at its base, looking from a distance like thin white smoke.

Tongatabu was seen 7 miles distant from Eooa, stretching along the horizon as a long narrow neutral tint band, with an indented upper margin; towards the northern end the band thinned out into isolated rows and groups of palm trees, which looked like dots on the watery horizon. As the vessel approached nearer, the forms of the cocoanut trees became more and more distinct. At length sail was shortened and the Challenger steamed through the reefs with a long stretch of palm-covered land on the one hand, and numerous islets on the other, some bearing many cocoanut palms, others few.

The main island is exceedingly flat and low, its highest point being only 60 feet above the sea level. It thus stretched itself before the view as a green horizontal streak of uniform width, the width being due merely to the height of the vegetation; here and there at the water's edge were seen small inlets and stretches of white sandy beach, or low honeycombed and weathered clifflets of coral rock. Above these appeared a band of dark foliaged shrubs, and shrubby trees with shore-loving plants growing in the sand at their feet; and as a background behind, rose a mass of cocoanut trees of various heights, but densely packed together, and thus forming with their crowns a tolerably even line; no palms other than cocoanuts were to be seen in the mass. On the small scattered islets which were near at hand, Screw Pines (*Pandanus*) were conspicuous, their stems surrounded with prop-like aerial roots, whilst on the main island these trees, which are numerous along the shore, were almost lost to view against the general background of dark foliage.

As the vessel steamed on, there came into view beneath the cocoanut trees on the shores, the villages of the islanders, composed of small houses of palm mats and grass thatch, and as the news spread, the villagers assembled on the beach in their conspicuous white or red clothing, to gaze at the ship. Not until the ship had passed the most difficult twist in the passage into the harbour, did the pilot come out, in a small English-built whale-boat belonging to the king, manned by four sturdy Tongans. These were naked, except that they had a cloth round the waist, and one of them a further girdle of green Screw Pine leaves; they had all, however, linen shirts with them, which they put on as they became cool; and the coxswain, formerly a Mataboolo, or lord amongst the Tongans, had on a pea jacket also. As is always the case, the men being so little clothed, appeared bigger than they really were. They were, however, remarkably finely made men, with all their muscles well developed, and all of them were extremely

SHEET 28

SOUNDINGS AND STATIONS

in the vicinity of

TONGA-TABU I^S.

For explanation of abbreviations &c. see Appendix 1.

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well nourished. The Tongans have large broad foreheads and faces, the lower jaw being wide at the articulation, the chin narrowing off rather abruptly from the face. The nose is flattened, but not very much; the eyebrows straight; and the lips neither large nor protuberant. The colour of the skin is a light brownish yellow with a tinge of red (see Pl. E. fig. 5). Their hair forms the most remarkable feature in their appearance, being worn in a sort of mop sticking straight up from the head, and composed of a mass of small curls; naturally it is black, as are the eyebrows, beard, and moustache, which latter are, however, scanty as a rule; but it is altered to a rusty colour by the application of coral lime, which is usually only applied partially, so as to give variety from the contrast between the black and red locks. With some the centre of the head is left black, and a marginal zone coloured red; with others isolated locks all over the head are reddened so as to show a black mop variegated with red, and various other fashions are adopted. The Tongans often sit on their heels like Indian races, but more usually cross-legged in the posture in which Buddha is ordinarily represented.

To those who had read Mr. Darwin's work On the Expression of the Emotions, the unusually marked development of facial expression exhibited by the men conversing in the boat with one another was very striking. The muscles of the forehead during animated conversation are contracted and relaxed incessantly, and in a most varied manner; the brow is strongly wrinkled, and the eyebrows are jerked up to such an extent as to remind the observer at once of the jerking up of the eyebrows in monkeys. Mr. Moseley made as careful a study as time would permit of the various expressions of the emotions; all of them appear to coincide in their intimate character with those of Europeans, and this holds good also in the case of the expressions of children, but the movements made use of are much more strongly marked in the Tongans than in Europeans: thus, for example, in the expression of astonishment the eyebrows are thrown up with a succession of strong jerks, not merely raised once as with Europeans. The use of the forehead muscles is very peculiar, and indeed seems to be the most characteristic feature in a Tongan. No similar exaggerated facial expression was observed amongst Hawaiians or Tahitians, nor was there anything of special interest noticed about their means of expression; probably they have copied European modes to a large extent. In some of their gestures the Tongans differ remarkably from Englishmen; in beckoning a person, they use, like the Malays and others, the hand with its back turned towards their bodies, and the palm directed towards the person called; the hand is moved downwards and inwards, instead of upwards and inwards as by Europeans. In affirmation the head is jerked slightly upwards, the eyebrows being raised a little at the same time. One of the missionaries who visited the ship was asked about this matter, and to test it he pronounced the word for "yes," and involuntarily threw up his head. The gestures accompanying the language are necessary to its perfect use, and to speak without them would be like speaking a European language with a false accent. In negation, the head is sometimes moved slowly from side to side, but never shaken. In pointing out the way to a place, the lips are pouted in order to indicate direction at the same time that the hand is used to point with in the ordinary manner. The use of the arms and head in gesture language is very remarkable, and conversations are carried on thus in an extremely animated manner with the help of very few actual words.

As has been said, the coxswain of the pilot's boat, the ex-member of the nobility, wore a pea-jacket; when a photograph was taken of the boat's crew, it was impossible to persuade him to take it off in order to make the group uniform; he would only promise that if he were photographed in the group with the jacket on, he would allow himself to be taken separately afterwards without it. The jacket was a thick garment of the usual pilot cloth, fit only for an English winter, but the man evidently regarded it as a decoration and mark of distinction, and a proof that he was coxswain.

Much difficulty was experienced in getting a lock of hair from one of the boat's crew, and success was attained only by the help of a missionary, who explained that it was not wanted for purposes of witchcraft. The man also evidently was loth to part with even a single lock of what was his chief pride.

The Friendly Islands were, at the time of the Expedition's visit, treated as an independent power; they had a national flag (white cross quartered on red), a King, taxes, and other accompaniments of national life. A poll tax of seven dollars a year was levied on each adult, a duty of one dollar per gallon on wine, two dollars per gallon on spirit, and one shilling on each bottle of beer, and there was a charge of £100 for a licence to sell intoxicating drinks. In consequence of these prohibitory duties no liquor was sold at any of the islands, and to protect the morals of the natives, seamen were fined if they remained on shore after 9 P.M.

The most prominent feature in the town of Nukalofa (see fig. 175), as the principal place in the island is called, is the small white church which stands on the summit of a rounded hill about 40 feet in height. Conspicuous also is the King's House, a respectable looking small one-storied wooden building with a verandah. There is, further, the Government Building, a neat wooden structure with a tower in the centre and a wing on either side, each containing a single office. Here the revenue of the Friendly Island group, which amounts to about £7000 or £8000, is dispensed, and the King's seal attached to documents. At a small printing office close by an almanac, a magazine, bibles, and a few books are printed in the native language. The remainder of the town consists almost entirely of native houses. The houses of the Tongans are small and oblong in shape, about 20 feet by 10 feet in dimension; the walls are of reed mats or plaited cocoanut leaves, and the thatch of reeds; the posts and beams, often of cocoanut stems, are lashed together with plaited cocoanut fibre; the ground within is simply covered with *Pandanus* mats. There are usually two doors or openings opposite one another in the middle of each side of the house, which are closed with a mat only, and in most houses a sleeping chamber is partitioned off at one end by means of mats. The only furniture to be seen within is the kaava bowl and the pillows, wooden rods supported on four legs, on which the neck is rested in sleep in order that the elaborately dressed hair may not be disarranged. Most Polynesians, and various other races, such as the modern Japanese, use similar pillows, and they were also used by the ancient Egyptians. Long practice is required to allow of their use. Near the houses are small sheds, underneath which a hole in the ground serves as an oven for cooking. The houses at Nukalofa are clustered under the cocoanut trees, with three or four open roadways between them.

The people are remarkably hospitable, and delighted to get a strange visitor into their

Fig. 175.—Nukalofa, Tongatabu.

houses to sit and communicate what little can be managed in this way between persons knowing almost nothing of each other's language. They offer kaava or cocoanuts as refreshment. The women are large, have fine figures, and are, most of them, handsome. They wear a cotton cloth round the loins reaching down below the knees, or often, and especially on week-days, a "tappa" or native cloth made from the bark of the paper mulberry. The missionaries have compelled them to cover their breasts, which is done with a flap of cloth thrown up in front, and a fine is imposed on any woman seen abroad without this additional covering. The women, however, evidently have little idea of shame in the matter, and often the cloth is put on so loosely that it affords no cover at all. The hair of the women was formerly cut short as amongst so many savages where the men keep to themselves the right of cultivating and decorating the hair, but now it is often allowed to grow long and fall down the back; it is oiled and powdered with sandal-wood dust as a perfume. On Sundays a few women appear in complete European dress, wearing muslin gowns, and hats profusely decorated with gaudy artificial flowers. The girls are most accomplished coquettes. The missionaries have prohibited dancing, and also the chewing of the kaava root, which is now grated instead. The chewing method was believed to spread disease. The people are diminishing notwithstanding all the efforts of the missionaries, there being now only about 8000 islanders in the whole group.

The Tongans are a fine manly race, and delighted everybody, and a longer stay in their island would have been appreciated by the Members of the Expedition. They are extremely merry, fond of practical jokes, and when a crew of them was rowing anyone on shore, they kept playing all kinds of pranks on one another between the strokes of the oars, such as bending over and catching at each other's legs, and were full of laughter the whole time.

Some difficulty was experienced in persuading one of the natives to get fire by friction of wood. Matches are now so common in Tonga that the natives do not care to undergo the labour necessary for getting fire by the old method, except when driven by necessity. No doubt the younger generation will lose the knack of getting fire by friction altogether. The method adopted in Tonga is the usual Polynesian one of the stick and groove. The wood of the "Vau" (*Hibiscus tiliaceus*), which when dried is extremely light, is used for this purpose. In order to procure fire, a stick or stout splinter of very dry wood about a foot in length is cut at one end so that it has a sharp edge bounded by two sloping surfaces on one side of the end. The side of the tip is thus in the form of a wedge with a sharp edge. This stick is held in a slanting position between the two thumbs crossed behind it, and the fingers of the two hands crossed in front of it. The sharp edge of the wedge is applied to the surface of a large billet or stem of the same dry wood, and the stick is rubbed backwards and forwards, a certain amount of pressure being exerted. A V-shaped groove is thus cut into the billet about four or five inches in length. If the piece of wood to be grooved is rounded and smooth, a slight score is sometimes made upon it with a knife beforehand in order to prevent the stick from slipping. Of course everything depends on the larger billet being kept absolutely immovable during the process; sometimes the operator holds it with his own feet, or often gets some one else to stand on it for this purpose. The stick is rubbed backwards and forwards slowly at first. It must not be pressed too hard or the rubbing surfaces become polished, nor too softly or no heating results. A great deal of the knack of getting fire readily, no doubt, depends upon applying the exact amount of pressure. If the operation is proceeding well, there should be a constant feeling of slightly grating friction to the operator as he rubs, and a fine powder should be rubbed off from the surface of the groove, and pushed along by the end of the stick, so that it accumulates at the far end of the groove in a small heap. Great care must be taken that this small heap of powder is not shaken or blown away. The friction being kept up slowly and steadily, the sides of the groove begin to blacken and soon to smoke. Rapid strokes are now resorted to, the fine dust rubbed off becomes black like soot, and at last ignites at the end of the stroke just as it is pushed into the small accumulated heap, which acts as tinder. A tiny wreath of smoke ascending from the heap shows that the operation has been successful. A gentle blowing soon sets the whole heap aglow. The operation is excessively tiring to the wrists, since it has to be prolonged for a considerable time, but the greater the practice the less the waste of force. Very few Europeans have been able to get fire by friction in this way with their hands unassisted by mechanical appliances, though Mr. Darwin succeeded at Tahiti, and Dr. Goode, R.N., frequently lighted a candle in this way to show the process on board H.M.S. "Dido" at Fiji. It is easy enough to get smoke and char the wood a little, but very difficult to get the actual fire. The slightest halt during the friction is fatal.

The old stone implements have entirely gone out of use in Tonga, and they are not plentiful. Several were bought from natives who had them put away in their houses. They call them "toki Tonga," Tongan axe, or adze, in distinction to foreign axes, whereas the Sandwich Islanders speak of their adzes as stone adzes "pohaku koi." All the stone adzes seen were unmounted; no doubt the handles had been used long ago, when iron was introduced, to fasten hoop iron blades to in place of the discarded stone ones. The manners and customs of the ancient Tongans are probably better understood than those of any other Polynesian Islanders, because of the existence of Mariner's well-known account of them.[1]

The island of Tonga is about 27 miles in extreme length and 10 in extreme breadth, and is entirely composed of coral reef rock, without, as far as is known, any blown sand formation. The sand on the beaches is scanty. The presence of blown sand rock on coral islands must depend on the freedom of some part of the coast from breakwaters of coral, in order that a heavy surf may form sand in abundance. In Bermuda the sand is derived from the unsheltered side of the island. In some rock about 30 feet above sea level were seen, as Dana describes, some Brain Corals imbedded in the position in which they had grown. About the reefs are to be seen curious cylindrical blocks of coral standing on end, and often hollowed out at the top. These arise from the growth of a mass of ordinarily rounded coral until the top reaches the surface of the water or an insufficient depth to allow of further growth. The top of the mass then dies, whilst growth goes on round the sides, and the dead core is hollowed out by decay, and by the subsequent solution of lime by the water. The surface of the rock in Tonga is covered with a reddish soil like that of Bermuda. It is so hidden with soil and vege-

[1] An Account of the Natives of the Tonga Islands, compiled from communications by Mr. W. Mariner, several years resident in those islands, by John Martin, M.D., London, 1817.

tation that it is very difficult to observe the rock structure. The wells, which are round holes sunk to a depth of four or five feet close to the shore, show a mere continuation of the reef-structure of the shore covered by about a foot of soil.

It was interesting to recognise amongst the littoral plants of Tonga many forms which had been gathered on the shores of the far-distant Bermuda; these were cosmopolitan tropical plants, and became familiar objects on nearly all the tropical shores visited subsequently. One plant (*Nitella flexilis*) which grows in Tonga is almost identical with one occurring in Kerguelen Island (*Nitella antarctica*), but it again is cosmopolitan and a water weed. The *Casuarina* trees in Tonga remind one of Australia, but they are nowhere abundant. In every direction there are large tracts of land which have been under cultivation, but are now overrun with a wild growth of a dense low tangle of several species of *Convolvulus* and a trailing bean, affording plain evidence of the reduction of the population (see Pl. XVIII.). The position of the more recent clearings is marked in the distance by the projection from the main mass of dark foliage of the dead branches of trees that have had their bark ringed.

Bats are the only indigenous mammals in Tonga. A large Fruit Bat, probably *Pteropus keraudrenii*, which occurs in Fiji and Samoa and also in the Caroline Islands,[1] is very abundant. These Fruit Bats appear on the wing in the early afternoon in full sunlight, and at the time of the visit were feeding on the bright red flowers of one of the indigenous trees. Flowers form a large proportion of the food of the Fruit Bats. At Botany Bay, New South Wales, in May, numbers of Fruit Bats were to be seen feeding on the flowers of the gum trees. The bats probably often act as fertilizers, by carrying pollen from tree to tree, adherent to their fur. As dusk comes on, the Fruit Bats on the wing become more and more plentiful, and it is probably only those specially driven by hunger that come out before dusk. Besides these large bats, there are small insectivorous bats in Tonga, which dart about amongst the cocoanut trees, but no specimens were obtained. The heavy flapping of *Pteropus* is as strongly contrasted with the rapid motion of the true bats as is the flight of a goose with that of a swallow. There are plenty of horses and cattle in Tonga, and the high ground of Eooa is occupied as a sheep run.

A small Heron (*Demiegretta sacra*) wades about on the coral reefs at Tonga, and catches small fish, and is also to be seen frequently inland all over the island. This bird changes its plumage from pure white to uniform grey, and all stages of particoloured plumage were to be seen during the visit; contrary to the usual rule, the bird is white when young, and dark in the mature state, hence it is probable that the ancestors were white, and the race is assuming a darker plumage for protection. In the groves, the most abundant bird is one about the size of a sparrow, brown with yellow wattles (*Ptilotis carunculata*), which has a sweet and very loud song, and fills the

[1] Die Carolinen Insel Yap oder Guap, *Journal des Museum Godeffroy*, Heft. ii., 1873.

Plate XVIII.

Horsburgh, Edinburgh. Permanent Phototype.

WOOD SCENERY, TONGA.

woods with its melody. A Kingfisher (*Halcyon sacra*) is constantly to be seen sitting on dead twigs, ready to dart on its prey. Amongst the cocoanut trees a beautiful little Swift (*Collocalia spodiopygia*) skims about with a constant twittering. It belongs to the same genus as the species by which the edible birds' nests, the well known Chinese luxury, are made, which, however, is a Swift and not a Swallow as it is commonly called. These Tree-swifts are especially abundant about the villages, though they nest in the crowns of the cocoanut palms.[1] In the thickest masses of foliage, a most beautiful small Fruit Pigeon (*Ptilinopus porphyraceus*), of a bright green colour, with a patch of the purest purple on its head, is to be heard cooing gently, and the Great Fruit Pigeon (*Carpophaga pacifica*), the note of which is harsh and drawling, but still derivable from a coo, is to be shot with ease by creeping up to the trees on the berries of which it feeds at this season. There are two parrots known from Tonga, but they are very scarce. One of them (*Platycercus tabuensis*) is found only in Tonga and in the neighbouring island of Eooa, and is called the Pompadour Parrot, from the peculiar purple red of its head and neck; the natives procure it alive from Eooa, where it is abundant, and one was bought for a shilling in the port during the stay. The other is a Parroquet (*Coriphilus fringillaceus*); neither of the parrots was seen in the wild condition.

Lizards are abundant, but there are only two or three species. One of them is *Mabouya cyanura*, while *Otosaurus microlepis*, one of the Scincidæ, is peculiar to the group. On the reefs occurs an Eel (*Muræna*), of a whitish yellow colour spotted with brown. It is very snake-like in its movements, and it may easily be mistaken, when encountered in the water, for the true Sea-snake (*Pelamys bicolor*), which also occurs here. Eight species of land shells were collected, none of them, however, being new to science; *Nanina tongana* is peculiar to these islands.[2] Rev. O. P. Cambridge writes that the Arachnida collected at Tongatabu included *Epeira mangareva*, Walck., *Meta tuberculata*, Keys, *Nephila victorialis*, L. Koch, *Nephila nigritarsis*, L. Koch, *Argyrodes* sp.?, *Diæa septempunctata*, L. Koch, and immature examples of *Tetragnatha*, *Dolomedes*, and *Icius*.

Among the insects collected by the Expedition, the following have been made types of new species, viz., Neuroptera,[3] *Diplax pacificus*, Kirby; Lepidoptera,[4] *Hypolimnas thomsoni*, Butler, *Hypolimnas moseleyi*, Butler, *Hypolimnas naresi*, Butler, *Terias aprica*, Butler; Hymenoptera,[5] *Schizaspidia murrayi*, Kirby.

A large Foraminifer (*Orbitolites*) is very common on the reefs. The specimens collected were handed to Dr. W. B. Carpenter, C.B., F.R.S., who has written a special memoir on the genus.[6]

[1] For an account of the nesting of *Collocalia*, see Bernstein On the genus Collocalia, *Acta Societatis Scientiarum Indo-Nederlandicæ*, vol. ii. For the nesting of the closely allied "Tree-swift," *Dendrochelidon*, see Bernstein, Habits of Javan Birds, *Ibid.*, vol. iii.

[2] E. A. Smith, *Proc. Zool. Soc. Lond.*, p. 271, 1883.

[3] Kirby, W. F., *Ann. and Mag. Nat. Hist.*, ser. 5, vol. xiii. p. 455, 1884.

[4] Butler, A. G., *Ibid.*, vol. xi. p. 402.

[5] Kirby, W. F., *Ibid.*, vol. xiii. p. 403.

[6] Zool. Chall. Exp., part xxi., 1883.

A meteorological register had been kept for some time at the college, under the superintendence of Mr. Baker, the Wesleyan missionary; he was kind enough to supply a copy of it, and as it may be useful, the chief results are appended.

METEOROLOGICAL TABLE compiled from observations made during the years 1872–74, by the Rev. J. Baker, at the Mission House, Nukalofa, Tongatabu.

Barometer readings reduced to 32° and sea level.

MONTH.	Barometer. Mean Height.	Barometer. Ext. Range.	Mean Temp. in shade.	Mean daily Range of Temp.	Max. Temp. in shade registered.	Min. Temp. in shade registered.	Clouds—0 to 10 Mean Amount.	Rain. Total Fall.	Rain. No. of days.	Wind. Av. Hourly velocity.	No. of days from N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.	C'lm	No. of days Gales.	No. of days Fogs.
	in.	in.	°	°	°	°		in.		miles											
JANUARY,	29·830	·33	77·6	15·4	90·0	51·7		9·16	10	4·0	10	12	2	2	2	1	0	2	0		
FEBRUARY,	29·750	·37	79·0	15·1	98·0	51·0		6·83	11	3·5	7	8	3	2	3	1	1	3	0		
MARCH,	29·890	·34	77·1	16 8	89·2	51·0		6·36	8	4·2	4	8	9	3	2	1	2	2	0		
APRIL,	29·890	·49	75·5	14·8	89·7	57·0		10·35	11	1·8	7	7	5	2	3	1	1	4	0		
MAY,	29 950	·37	72·7	15·0	89·7	50·5		8·20	9	2·7	7	9	7	4	2	0	1	1	0		
JUNE,	30·020	·37	70·3	17·4	90·5	50·0		8·10	9	2·3	1	5	4	9	6	1	1	3	0		
JULY,	29·930	·44	69·2	18·4	90·0	50·2		1·66	3	2·4	6	3	10	4	5	1	1	1	0		
AUGUST,	29·970	·42	68·5	15·4	82·7	51 2		3·66	6	3·4	4	4	4	4	9	0	1	1	4		
SEPTEMBER,	29·990	·37	68·6	15·8	82·7	51·2		7·07	8	4·2	6	1	11	5	5	2	0	0	0		
OCTOBER,	29·930	·23	71·7	14·4	88·2	52·2		7 18	5	3·8	4	7	13	4	1	0	0	2	0		
NOVEMBER,	29·940	·43	72 7	15·7	88·0	56·2		3·57	7	3·5	1	12	11	2	2	0	0	0	2		
DECEMBER,	29·890	·21	74·7	15·1	88·7	54·0		4·45	10	3·8	6	12	7	4	1	0	1	0	0		
MEANS AND TOTALS,	29·915	·49	73·1	15·7	98·0	50·0		77·59	97	3·3	63	88	86	45	41	8	9	19	6		

The water on Tongatabu is scanty and not good, owing to the flatness of the land and the absence of streams. The water in all the wells which have been dug is brackish, owing to the percolation of the sea water through the coral reefs.

The landing place is between the King's House and the Church on the hill; at high water a gig can reach the shore through a narrow channel cut in the reef, but at low water this is impracticable. A "hard" of loose stone has, however, been constructed from the beach to the outer edge of the reef to facilitate communication at low water.

The observing station chosen by the Expedition was the church on the hill at Nukalofa, as the observers were there less disturbed than elsewhere. It may be as well to mention that at Tongatabu the day is the same as in Australia, that is, that although the island is in west longitude, and the inhabitants should, properly speaking, reckon time as slow on Greenwich, they reckon it fast on Greenwich, or for the longitude of $184\frac{1}{2}$° E.

At the time of the ship's visit a schooner ran between Tongatabu and Sydney about every two months.

Engraved by Malby & Sons

Tongatabu to the Fiji Islands.

On the 22nd July, at 8 A.M., the Challenger left Tongatabu for the Fiji Islands, passing out to the northward between Mallenoah and Atataa Islands. Nothing was seen of the Juno Shoal, or of any belt of shallow water, the shallowest sounding being 9 fathoms. This northern route appeared to be a better channel into and out of the harbour than the eastern, for, although the water is not so deep, the channel is wider. Cook on his first visit used it, but ran on shore two or three times, and left by the east channel, out of which he had to beat against a fresh trade wind. The water appears to have deepened since his time, at any rate the shoals are fairly known, and can be avoided, and no one would now think of working out through the narrow east channel, when he could proceed through the northern with a leading wind. When outside a line joining Mallenoah and Atataa Islands dredgings were obtained, first in 18 fathoms (Station 172), and then in 240 fathoms (Station 172A, see Sheet 28). The deposit at both these depths was a coral mud containing 90 per cent. of carbonate of lime, and composed of fragments of Coral, calcareous Algæ, *Orbitolites* and many other Foraminifera, fragments of Polyzoa, Echinoderms, and Molluscs. At the greater depth farther from the reef, the fragments were smaller and the pelagic shells more abundant than in the depth of 18 fathoms nearer the reef. At 0.30 P.M. the ship proceeded to the westward towards Turtle Island, which was sighted at 11 A.M. on the 23rd. At 2 P.M. on that day the northern extremity of the detached reef off Turtle Island was passed, and a course shaped towards Matuku Island, the weather being rainy and cloudy.

On the 24th July, at 6 A.M., Matuku Island was sighted, and the vessel having proceeded to the lee side, a party was landed and remained on the island for two or three hours. During this time the ship was engaged in dredging off the mouth of the harbour in 310 and 315 fathoms (Stations 173 and 173A, see Sheet 29).

The Fiji Islands.

Matuku Island.—Matuku Island (see fig. 141), one of the Fiji group, lying about 70 miles east of Kandavu, is volcanic, and surrounded by a barrier reef which is about 16 miles in circumference. The highest peak is about 1200 feet in height. From its summit the island was seen to consist of a single crater, the edge of which had been denuded and cut into a series of fantastic peaks, with intervening steep-sided gullies. The ancient crater itself now forms the harbour, the inlet to which is through an opening in the girdling reef, at a spot where the border of the crater has been broken down. The surfaces of the irregular hills showed the peculiar sharp-angled ridges so characteristic of volcanic cones denuded by pluvial action. The windward side of the main peak was precipitous, and covered with thick vegetation, whilst the leeward side was open, covered only with grass and *Pandanus* trees. It seemed uncertain whether this condition was due partly to clearing by the natives or entirely to the greater access of moisture from the trade wind on the windward side. Seemann[1] describes a similar condition, produced by aspect, as common to all the Fiji Islands. There are also, however, dense patches of wood here and there on the leeward side of the crater in Matuku, and it may be that all the grass-covered area has been cleared at some time for cultivation, the island being too small and low to vary much in atmospheric conditions. At all events the most prominent feature in the appearance of the vegetation of Matuku is the contrast of the light green open grass slopes with the dark patches of wood. The grass is high and reedy, and very tiring to force one's way through, as are also the wooded tracts; through which latter a road had to be cleared with the knife. In some places the grass had been intentionally fired by the natives as a preliminary to cultivation.

FIG. 176.—The Island of Matuku, from the entrance through the Barrier Reef.

The view from the summit of the island was most interesting as well as beautiful. The exploring party stood on what is now the highest point of the edge of the weathered crater. On the one side a steep slope led down to a narrow tract of flat land bordering the sea. This was partly open and swampy, covered with sedges and ferns, and with *Pandanus* trees dotted about over it, and partly covered with groves of cocoa-nut trees. On the other side a vertical precipice, terminating in a similar steep slope, led down into the crater itself. The cliff and internal slope of the crater were covered with thick and tangled wood, amongst which grew, even close to the summit, a few cocoa-nut palms, and one or two of the palms called "Niu Sawa" by the natives (*Kentia exorhiza*).

All round the island, except for a very short interval at the entrance to the harbour, was a circling zone of white breakers, marking the position of the barrier reef. This zone

[1] *Journ. Geogr. Soc. Lond.*, vol. xxxii. p. 52, 1862.

was separated from the shore of the island by a band of water which had a slightly yellowish tinge, caused by its shallowness and the colour of the coral-built bottom. The lagoon channel was very shallow, and in many places it was possible to wade from the shore to the outer edge of the reef. The reef, in short, may be regarded as a transitional stage between a fringing and a barrier reef.

The vegetation of Matuku is very different from that of Tongatabu, though no doubt much like that of Eooa. Ferns are numerous instead of scanty, and amongst them a beautiful climbing species (*Lygodium reticulatum*) is abundant. At the time of the visit the most conspicuous trees, after the screw pines and cocoanut palms, were those of a species of *Erythrina*,[1] which was in full scarlet blossom. On the honey of the flowers of this tree a most beautiful Lory (*Domicella solitaria*) was feeding, and with it some little Honey Birds (*Myzomela jugularis*). The Lory is one of the most beautiful little parrots existing, showing a splendid contrast of the richest colours, jet black, red, and green. It is peculiar to the Fiji Islands, and flies in flocks, and hence the term "*solitaria*" is apt to give an erroneous impression as to its habits. A Swallow (*Hirundo tahitica*) was flying about in considerable numbers at the summit of the peak. Several lizards were found at the Fijis, *Hemidactylus* sp., at Matuku, and *Gymnodactylus* sp., one of the Agamidæ, at Kandavu, and *Mabouya cyanura* at both islands.

Hopping about on the mud beneath the mangroves on the shore was the extraordinary little fish, *Periophthalmus*, which skips along with great rapidity on the surface of the water by a series of jumps, each being as much as a foot in length, and it prefers escaping in this way to swimming beneath the surface. It is very nimble on land, and difficult to catch, using its very muscular pectoral fins to spring with, and when resting on shore the fore part of its body is raised and supported on these. The eyes of the fish, which is one of the Gobies, are remarkably prominent, projecting directly upwards from the skull. In the mangrove swamps the fish often sits on the lower branches and roots. From what is known of its habits, it is probable that it would be drowned by long immersion in water. The Fijian species is *Periophthalmus koelreuteri*. Its prey is said to consist of terrestrial insects[2] and Crustaceans left by the receding tide; according to Semper it feeds also on *Onchidium*.[3]

Sixteen species of land shells were obtained at the Fiji Islands, among them one novelty, *Helix* (*Trochomorpha*) *latimarginata*, E. A. Smith.[4]

The Arachnida obtained by the Expedition at Matuku were *Meta tuberculata*, Keys, *Meta granulata*, Walck., *Nephilengys* sp. ?, *Nephila* sp. ?; from Kandavu were brought *Epeira moluccensis*, Dol., *Epeira mangareva*, Walck., *Meta tuberculata*, Keys, *Meta*

[1] *Erythrina indica*. The "Araba" flowers in August, the time to plant yams; hence the flowering of this tree is the basis of the Fijian calendar. Seemann, Flora Vitiensis, London, 1865–73.

[2] Dr. A. Günther, *Brit. Mus. Cat.*, Fishes, vol. iii. p. 97, 1861; Introd. Study of Fishes, p. 487, Edinburgh, 1880.

[3] Animal Life (Internat. Sci. Series), p. 189, London, 1881.

[4] *Proc. Zool. Soc. Lond.*, p. 270, 1884.

insularis, Keys, *Nephila victorialis*, L. Koch, *Pholcus ancoralis*, L. Koch, *Tetragnatha* and *Chiracanthium* (immature), *Heteropoda* sp. (immature), *Argyrodes* sp. ?, *Argiope* sp., and *Attus* sp.? The Lepidoptera included the following new species—*Xois fulvida*, *Hypolimnas murrayi*, *Hypolimnas thomsoni*, and *Astura fluminalis*.[1] The Hymenoptera included one new species, *Belenogaster bidentatus*.[2]

The natives of Matuku were mostly true Fijians, though there were some pure Tongans amongst them, immediately to be distinguished by their use of the frontal muscles in conversation. There is no doubt also mixed blood in the island. The houses of the people were miserably dirty, and built on filthy black muddy flats close to the sea. A boy was observed to make his way over a mangrove swamp, with remarkable rapidity, by crawling over the tops of the mangrove roots, and thus avoiding the mud below; just as the coast natives in parts of New Guinea are said to traverse the low swampy shore.

In dredging off Matuku Island, in 310 and 315 fathoms, on a coral bottom, some *Phorus*, *Turritella*, and a few other shells were brought up, as well as numerous specimens of the blind Crustacean, *Polycheles*, and other animals showing the fauna to be a true deep-water one.

A living specimen of the Pearly Nautilus (*Nautilus pompilius*), so rarely seen in the living condition by any naturalist, was captured here. This was the only specimen of this animal obtained by the dredge or trawl during the voyage. The animal was very lively, though probably not so lively as it would have been if it had been obtained from a less depth, the sudden change of pressure having no doubt very much disarranged its economy. However, it swam round and round a shallow tub in which it was placed, moving after the manner of all Cephalopods, backwards, that is with the shell foremost. It floated at the surface with a small portion of the top of the shell just out of the water, as observed by Rumphius.[3] The shell was maintained with its major plane in a vertical position, and its mouth directed upwards. The animal seemed unable to sink, and the floating of the shell, as described, was due no doubt to some expansion of gas in the interior, occasioned by diminished pressure. The animal moved backwards slowly by a succession of small jerks, the propelling spouts from the siphon being directed somewhat downwards, so that the shell was rotated a little at each stroke, upon its axis, and a slightly greater area of it raised above the surface of the water. Occasionally, when the animal was frightened or touched, it made a sort of dash, by squirting out the water from its siphon with more than usual violence, so as to cause a strong eddy on the surface of the water. On either side of the base of the membranous operculum-like headfold, which when the animal is retracted, entirely closes the mouth of the shell, the fold of the mantle closing the gill

[1] A. G. Butler, *Ann. and Mag. Nat. Hist.*, ser. 5, vol. xi. p. 402, 1883.
[2] W. F. Kirby, *Ibid.*, vol. xiii. p. 410, 1884.
[3] De Amboinsche Rariteitkamer, p. 61, Amsterdam, 1705.

cavity was to be seen rising and falling, with a regular pulsating motion, as the animal in breathing took in the water, which was afterwards expelled through the siphon. The tentacle-like arms contrast strongly with those of most other Cephalopods, because of their relatively extreme slightness and shortness, though they are not shorter proportionately than those of the living *Sepia*. They are held by the animal, whilst swimming, extended radially from the head, somewhat like the tentacles in a sea anemone; but each pair has its definite and different direction, which is constantly maintained. This direction of the many pairs of tentacles at constant but different angles from the head, is the most striking feature to be observed in the living Nautilus. Thus, one pair of tentacles was held pointing directly downwards; two other pairs, situated just before and behind the eyes, were held projecting obliquely outwards and forwards, and backwards respectively, as if to protect the organs of sight. In a somewhat corresponding manner, the tentacular arms of the common cuttle-fish whilst living are maintained in a marked and definite attitude, as may be observed in any aquarium. Another living Nautilus was brought to the Consul at Kandavu during the stay of the Challenger. The natives were said to frequently catch them alive, and to give them to their chiefs, who eat them.

Ngaloa.—The ship left Matuku at 4 P.M. on the 24th July, and on the following morning at daylight the whole of the Kandavu group was well in sight, and the ship was steered for Ngaloa Harbour, which it was proposed to survey in consequence of its having been made a port of call for the mail steamers running between Sydney and San Francisco. No difficulty was experienced in entering the harbour under sail, for the reefs and dangers can all be readily distinguished from aloft. At 11 A.M. the vessel "came to" on the south side of Ngaloa Island, in 15 fathoms, and in the afternoon a tide pole was put up and other preliminary operations performed so that the survey might be commenced at once.

The survey was continued, and astronomical observations obtained on the 26th; on the 27th the ship left Kandavu for the capital of the Fiji group, to connect the island with Captain Denham's position at Levuka, and to complete the stock of coals and other necessaries. At 6 P.M. on the 27th, when to the southward of Kandavu, the light cast by the moon on the water ahead, appeared exactly like a reef, and for a short time it was thought to be one; and once again, shortly afterwards, the same deceptive appearance caused the officers of the watch to stop and go full speed astern. Such phenomena are frequently reported as reefs, and had it not been ascertained that this appearance was merely caused by a break in the clouds, through which the moon cast a peculiar reflection on the water, it might have been inferred that a shoal existed. At 10.30 P.M., after the vessel rounded the eastern end of Kandavu Island, the fires were put out and sail was made for Levuka.

At daybreak on the 28th the vessel was close to the position of a recently reported reef, Meteore, but nothing was seen of it; the traders at Kandavu knew nothing of it, and doubted its existence. Steering for Levuka Harbour, with the islands of Angau, Nairai, Mbatiki, Wakaya, Makogai, and Ovalau in sight, no difficulty was experienced in ascertaining the position of the ship. At 1.30 P.M. the leading marks through the reefs into Levuka were seen, and the vessel sailed into the harbour, anchoring at 2 P.M off the town.

The two beacon-houses, or light-boxes, were very indistinctly seen from seaward, and the old mission house, used for Government purposes, could not be distinguished from the surrounding buildings until close to the shore.

Levuka.—The Expedition remained at Levuka until the evening of August 1st, obtaining sights at the old observing position of Captain Denham, at the mission house, and completing the store of coals from a vessel which had been freighted from Sydney for the purpose.

On the 31st July, a party of officers and naturalists left Levuka in the barge for a trip to Mbau and Rewa, thence to sail across to Kandavu Island. The following is an account of this excursion from Mr. Moseley's Journal:—

"At 6 A.M. on July 31st, I started on a cruise in one of the ship's boats, called the barge, to the island of Mbau, and the Wai Levu, with a party which was to join the ship again at Kandavu. There being little wind all day, we failed in reaching Mbau on the first day, but arriving in its neighbourhood about dusk, we mistook a projecting headland of Viti Levu,[1] some miles north of Mbau, for the island of Viwa, and a small island lying off this headland for Mbau. It was impossible to distinguish in the gloom what were islands and what promontories, against the dark background of the Viti Levu coast. All around Mbau, Viwa, and the neighbouring coast are extensive shallow coral and mud flats, the mud being brought down by one of the mouths of the river Wai Levu, which opens in the direction of Mbau. After making several attempts to reach the island which we supposed to be Mbau, and constantly grounding on the coral, we anchored in a deep channel between the coral flats for the night. In the early morning we made out Mbau, conspicuous from the white house of the missionary upon its summit, and soon reached it.

"Mbau is a very small island, not more than half a mile in circumference, and consists of a central hill, of about 50 feet elevation, with a flat area at its top, and bounded by steep grass-covered slopes, surrounded by a tract of flat ground. The central mass is composed of a friable stratified rock, of a greyish or reddish colour. An exactly similar rock composes the mainland immediately opposite the island, and the strata there correspond in inclination with those of Mbau. The central mass of the island is thus a small detached fragment left standing by the denuding waves. The passage between the mainland and Mbau is so shallow as to be fordable at high water, and is nearly dry at low water. The flat lower part of Mbau, which is raised only a few feet above the sea, con-

[1] Viti Levu (pronounced Veetee lāyvoo). Levu means "great." Settlers often clip the u, and talk of "Viti lib."

sists of made ground, built up of blocks of coral and mud and stones collected from the vicinity at low water, and secured all around against the action of the sea, by means of large slabs of a stratified tufa which have been brought in canoes from the main island, a distance of several miles. These stone slabs are set up on end, so as to form a parapet, and keep the earth from being washed down; they project far above the level of the land surface, and thus form at the same time a sort of fence or wall. At intervals, openings are left in the parapet, through which the water flows up short channels into the area of made ground, and forms as it were small harbours into which canoes can be put at high water. The top of the hill was formerly used as a general refuse heap by the natives, but it is now occupied by the house of the missionary. The native houses all lie on the low flat tract close to the sea. Mbau has long been a native fortress of great strength and hence the immense labour which has been spent on its formation. It is now the residence of King Thackombau, and almost every one in the island is a chief or of high family. The surface of the island, including the hill-ground, is covered almost everywhere with a thick kitchen-midden deposit of black soil, full of the shells of a large *Trochus* and Cockles (*Cardium*), which abound on the mud flats all around. Mingled with these are quantities of human bones, Mbau having been one of the places in Fiji at which cannibalism was most largely practised. There are very few trees growing on Mbau, and the food, such as taro and yams, is all brought from the mainland, where there are extensive plantations.

"One of the most interesting features in Mbau is perhaps the stone against which the heads of the human victims destined for the oven were dashed, in the ceremony of presenting them to the god Denge. This stone stands close to one corner of the remains of the foundations of the ancient temple of Denge, the 'Na Vatani Tawake.' The temple itself was destroyed when the Mbauans became Christians, but the mound on which it stood remains, and is of great interest. It is a large oblong tumulus of earth, supported by two series of vertically placed slabs of stone, exactly similar to those used for the sea parapet. The slabs of the lower series are much larger than those of the upper, and the latter being placed farther inwards, a sort of step is thus formed in the tumulus all round. The mound must be about 12 feet high, and some of the stones of the lower series are more than 6 feet in height. Opposite the centre of one side is set up a large column of basalt, and there is another opposite the strangers' house. These columns are said to have been taken in war, from some enemies on Viti Levu, and were intended to be used as posts for the king's house. The columns are said by Dana,[1] however, to have been brought by a Mbau chief from a small island in the harbour of Kandavu, which is composed of them, and where they were long desperately defended by the inhabitants,

[1] Dana, U.S. Expl. Exped., Geology, p. 348, Philadelphia, 1849. The columns at Mbau are referred to by Capt. Erskine, Islands of the Western Pacific, p. 193, London, 1853, who, however, did not recognise them as of unartificial formation.

who held them sacred. The whole mound most strikingly reminds one of ancient stone circles and similar erections at home. Were the earth of the mound washed away, numbers of the stone slabs might remain standing on end. Its condition before its destruction is to be seen in a book on Fiji, by Thos. Williams.[1] The tumulus supported a large 'Mburė' or temple, with the usual high-peaked roof and long projecting decorated ridge pole. Now the mound is falling into decay and covered with grass, and a small pony (there are very few horses in Fiji, and of course only room for this one in Mbau) belonging to Ratu David, the king's eldest son, found the top of it a pleasant place to graze on. The pony led a quiet life, for Ratu David having been kicked off on his first attempt at riding, had not tried again. The sacrificial stone against which the heads of the victims were dashed, is an insignificant looking one, in no way different from the other slabs, except that it is smaller and stands by itself a little in front of them, near one corner of the mound. In old time, bodies have been heaped up in front of it till they formed a pile 10 feet high. Whilst I was sketching the mound and its stones, a very pretty daughter of one of the chiefs came and looked on, and at my request wrote her name and the Fijian name of the mound in my sketch-book, in a very good round hand. There are several similar slab-built foundations of temples about the open space near the site of the Na Vatani Tawake, but except in the case of one small one, they are not in such good preservation. The slabs from one of these are now being used to construct the foundations for a Wesleyan church. Conspicuous amongst the buildings close by is the large 'visitors' house,' where guests were formerly entertained, and if of distinction, always provided with human flesh, at least once, by their hosts. Beside the building, a slight depression in the turf is the remains of one of the ovens used for cooking the 'long pig,' which is the actual name by which human flesh always went in the Fijian language; I always thought it a joke, until I was told by the interpreter. On a tree overhanging the ovens are to be seen notches, cut in the trunk from its base to its summit, an old score of the number of victims cooked beneath. There is another stone not far from Thackombau's house, which is smooth, and somewhat like a millstone in appearance. The ground around this is paved with slabs of coral rock, which had been perforated with holes by boring molluscs and worms before it was taken from the water. So many heads have been dashed against this stone, that it has happened that human teeth have fallen into almost all the holes in the slabs, and have become jammed there. The slabs were quite full of them. This second stone was seen by Captain Wilkes' officers, and is mentioned by Brenchley. We were told by the people that a second ceremony was performed at it, the heads of bodies being a second time pounded to pieces here, in honour of the slayer, who drank kaava from some grooves which are to be seen in the slab in front. The grooves are, however, very irregular, and look much rather as if they had been made in sharpening stone axes. I think this second stone must have been used by a separate tribe,

[1] Williams, T., Fiji and the Fijians, London, 1870.

occupying this quarter of Mbau, for even on this small island the people were often much divided. On going up the hill we came suddenly upon two old women bathing in a fresh water pool; they made for deep water in a hurry, but I saw that they were tattooed of a uniform indigo blue colour, from the hips to near the knees, just like the Samoan men.

"King Thackombau was visited in the morning by two of our party, who took him by surprise; he was found lying on his stomach, reading his Bible. I went with a party afterwards and we were regularly announced. The King, who was dressed in a flannel shirt, and a waist cloth reaching to his knees, rose to receive us, and came forward and shook hands. He is a very fine looking man, 6 feet high, with his dark face set off by an abundance of grey hair; his eyes are bright and intelligent, and his face full of expression, in this respect very different from that of the ordinary Fijian of lower rank. Three chairs were produced, this being the whole stock in the house, and those of our party without chairs sat on the matted floor. The King reclined on his stomach as before, on his own peculiar mat, at the head of our circle, with his Bible and Prayer Book neatly piled on the right hand front corner of the mat. We said, through our interpreter, that we were glad to see His Majesty looking so well, and explained the nature of the voyage we were making in the Challenger. I was then deputed to give an account of the wonders of the deep sea. In this subject Thackombau took the liveliest interest, inquiring about what kinds of animals existed in the deep water, evidently knowing the shallow water ones well. He was very much interested in the fact that they are so often blind. He said he could not understand the depth in miles, but comprehended it perfectly in fathoms. He then inquired the strength of the various navies, asking after that of England, Germany, France, Russia, and America, and wanting to know even the numbers of wooden and iron ships. The information we gave him drew from him the remark that the English were a wonderful people, far greater than the Fijians. The house was a large barn-like one of ordinary Fijian structure, with tall open roof, and a sleeping place separated off at one end with a 'tappa' curtain. There was the usual square hearth, with its edging of stone. Overhead were stored the heads of canoe masts. A European chest of drawers, a table, a lamp, and two tin coffee-pots, were the only visible articles of luxury. Against the door-post hung a fine club, freshly painted blue, belonging to the king's youngest son. We asked the king for a pilot to take us up the mouth of the Wai Levu, the great river which opens nearly opposite Mbau. He sent out at once to order one for us, and we took our leave of this knowing old Christian, who is currently reported to have partaken of two thousand human bodies, and is certainly known to have cut out, cooked, and eaten a man's tongue, in the man's sight, as a preparation to putting the rest of him in the oven, and that merely to spite the man because he begged hard not to be tortured, but clubbed at once. The contrast between Thackombau and King George of Tonga was very striking, at least as far as concerns their behaviour before visitors: Thackombau took the liveliest interest in everything, and put question after question, whereas it seemed impossible to interest King George in any subject; he said nothing at all during our interview. Both are warriors of renown, and have fought their way to their positions. Ratu David, the eldest son of Thackombau, was very hospitable, and invited us to drink kaava with him in the evening, when he produced a bottle of brandy also. We wished to see a dance, but this was impossible, because it was Saturday evening, which is by order of the missionaries kept in a certain way sacred, as a preparation for Sunday. For the same reason Ratu David dared not allow his retinue to sing a chant used during kaava drinking, which we were anxious to hear.

"We pitched a sort of tent on a very small islet about forty yards off Mbau, and slept there. Ratu David sent us off a young pig and a couple of fowls all alive, a most welcome present. They were killed and consumed within an hour of their arrival. The islet on which we slept is made up of blocks of coral, weathered and bored by various animals, piled up by the waves. The blocks near tide mark are so blackened by exposure, that I took them at first for vesicular lava.

"Around Mbau are extensive shallow mud flats, the mud being brought down by the Wai Levu. Across these flats we sailed next morning, with scarcely a breath of wind, though our pilot, whom we christened 'Joe,' kept constantly calling for a breeze, using an old Fijian pilot's chant, 'Come down, come down, my friend, from the mountains.' As we drifted slowly away over the glassy water, the view behind us was beautiful. Far away, blue in the distance, was a long range of the lofty peaked mountains of Viti Levu, the abode of the Kaivolos, who are a long-haired race of mountaineers, and still cannibals. Nearer lay a streak of dark green, undulating, low country, bounded seawards by low cliffs, and showing near the coast the numerous cultivated clearings of the natives. Just off the cliffs of Vitu Levu lay the small island of Viwa. In the foreground was the island of Mbau, with its crowded reed houses, its strange stone parapets, and its green hill topped by the missionaries' white house. From the centre of the village came the sound of what was the old cannibal death drum, beating now for morning prayers. There were two of these drums in front of the strangers' house; they are simply logs of wood, hollowed out above into troughs, and supported horizontally on posts about 3 feet above the ground, looking like horse-troughs. One was larger than the other, and they were beaten with two wooden billets alternately, and gave out different low bass booming notes. Very similar drums are used amongst the Melanesians, as at Efate in the New Hebrides,[1] and at the Admiralty Islands, where, however, they are stuck upright in the ground, and the mouths of the trough-like cavities are contracted to narrow slit-openings, the trunks being hollowed out through these. The Japanese wooden bell, or narrow-mouthed wooden drum, seems to be merely a more perfect development of these drums, and no doubt the actual bell was derived from the copying of some such wooden

[1] F. A. Campbell, A Year in the New Hebrides, p. 111, Melbourne, 1873.

instrument in metal. The addition of a clapper to a bell is a late improvement; Japanese bells still have none, but are sounded by means of a beam of wood swung against them from outside. The term 'drum' should perhaps be restricted to instruments with a tense membrane. As a musical instrument, our ordinary English chapel bell is much on a par with the Fijian drum, and makes an equally uncultivated and unpleasant noise.

"We ascended by the northernmost of the several mouths by which the great river, the Rewa River, or Wai Levu (great water), opens into the sea. About the mouth of the river the land is flat and alluvial, and the river is bordered on either hand by a thick growth of mangroves. Below these trees, slimy mud slopes are left bare at low tide, on which a *Periophthalmus* hops about like a frog. Close to the sea the mud is covered with a Sea Grass (*Halophila*), and hence looks greenish when left uncovered. Ducks (*Anas superciliosa*) are common on the mud at the river's brink, as is also a Heron (*Ardea sacra*), which pitches often in the mangroves, where also the *Ptilotis* sings and the Parrot (*Platycercus splendens*) screams.

"After a stay at Novaloa, where there is a mission college for training native teachers, in which Fijians even learn rudimentary algebra, we drifted up with the rising tide, grounding once and having to wait an hour to float off again. We passed many villages, and several canoes full of people. We slept at Nadawa, where a small paddle steamer, the property of a resident trader, Mr. Page, and built by him there, was under repairs and waiting for new engines from Sydney. Here also was a sort of hotel kept by two Englishmen. Mr. Page, who was extremely hospitable, gave me a bed. In the morning we had to beat against the land breeze up the main river, which we had entered just below Nadawa. The Wai Levu is a fine large river, in some reaches 300 yards across, and occasionally in flood time pouring so much fresh water into the sea that ships at anchor three miles off its entrance are able to take in their store for drinking from the water alongside them. Dana[1] calculates the volume of water poured into Rewa Harbour at 500,000 cubic feet per minute, and that discharged by all the mouths of the river together at 1,500,000 cubic feet; the area of the delta is 60 square miles. The mangrove thickets had ceased before the main river was reached, and here above Navusa the low banks on either hand were hidden by a dense mass of a tall grass, a species of *Saccharum*, or Wild Sugar Cane. For the first 12 miles or so of its lower course, the river flows through its delta, and hence the banks are low and the country flat. Some few miles above Navusa the banks become steeper, and low hills commence. These gradually become more frequent as the ascent is continued, until steep slopes with intervening stretches of flat land are of constant occurrence on either hand. The view up the river now shows a succession of ridges, one behind the other, rising gradually in the distance, and terminating in a line of distant blue mountains. The steep slopes

[1] Dana, U.S. Expl. Exped., Geology, p. 348, Philadelphia, 1849.

are covered with a thickly interwoven vegetation, the large trees being covered with epiphytes, ferns, lycopods, and climbing aroids, and festooned with creepers, which form in places a continuous sheet of bright green, falling in gracefully curved steps from the top of the slopes to the bottom, and almost entirely concealing their supports. Here and there tall tree-ferns rear their heads amongst the tangled mass, and palms (two species of *Kentia*) form a conspicuous feature amongst the foliage. We were forced to anchor in the evening to await the turn of the tide. As it became dusk numbers of Fruit Bats flew overhead, whilst in the beds of reeds a constant cry was kept up by the coots and water rails. On the tide turning we had to take spells of an hour each at the oars as our time was short, and by paddling on gently all night we reached before daylight a spot, about 35 miles from the mouth of the river, called 'Viti.'

"Mr. Storck, a German, and his wife live at Viti. He was the assistant of Mr. Seemann during his investigation of the plants of Fiji, and was extremely hospitable. He had taken to growing sugar, as cotton had failed, and had a splendid crop, which he calculated to weigh 62 tons of cane to the acre. Mills were about to be erected, and there seemed every prospect of sugar paying well. There were already twenty plantations of sugar on the Rewa River. It was curious to see a man from the New Hebrides Islands, so notorious for the murders of white men committed in them, acting as nurse to one of Mrs. Storck's children, and hushing the baby tenderly to sleep in his arms; he was one of the imported labourers, concerning whom so much has been written. About Viti there are abundance of large Fruit Pigeons and of the pigeons with purple heads, identical with those of Tongatabu (*Ptilinopus porphyraceus*); also of the 'Kula' (*Domicella solitaria*), and the 'Kaka' (*Platycercus splendens*). The Kaka attacks the sugar canes, and does considerable damage. There are some huge fig-trees at Viti, with the typical plank-like roots and compound stems. Here also grow one or two cocoanut trees, which are rarities so far up the river, for at the inland villages along the river there are no cocoanut trees, and a regular trade is carried on by the natives in bringing the nuts up the river from the coast in canoes, to barter them with the inland people. The black rat and Norway rat are abundant at Viti, and, according to Mr. Storck, there is also a native field mouse, but I could not procure one in the short time available. I do not know whether a field mouse is known from Fiji. A large fresh water prawn is common, and is caught for eating by the Fijian women, and in their baskets I saw also an Eel (*Muræna*). A red stratified tufa, with a slight inclination of its strata, is exposed in section opposite Mr. Storck's house; it is said to contain no fossils. An exactly similar rock is exposed at various spots for several miles down the river.

"On the way down the river, the barge constantly grounded on shoals, our pilot, Joe, knowing nothing of the upper part of the river. We had to strip our clothes off constantly and jump overboard to shove the boat over the shallows, and at last stuck fast and had to remain in that condition till the tide came up and turned again. Joe cautioned us against jumping over into the water, as he said there were sharks. A shark about 3 feet long is common as far up as Mr. Storck's plantation, and large ones are believed to be common in the lower parts of the stream, and are mentioned in Jackson's Narrative, in the appendix to Capt. Erskine's Islands of the Western Pacific, as often taking down natives in the neighbourhood of Rewa. At Nadawa, however, Mr. Page had never seen one, and I saw women there constantly standing up to their necks in the water, collecting fresh water Mussels (*Unio*), evidently without fear. The Shark of the Wai Levu is *Carcharias gangeticus*, found also in the Tigris at Bagdad, 350 miles distant in a straight line from the sea, where it attains a length of 2½ feet, and is common in large rivers in India. It breeds in fresh water in Viti Levu, inhabiting a lake shut off from the sea by a cataract.[1] There are sharks inhabiting fresh water in other parts of the world, as in South America, in the Lake of Nicaragua;[2] and in a fresh water lake in the Philippines there lives permanently a 'ray,' a species of saw fish. A peculiar genus of Mugilidæ occurs in the Wai Levu, *Gonostomyxus* ('sa loa,' Fijian), which has been described by Dr. Macdonald.[3]

"Joe was, I suppose, about thirty-five years old. He had no notion of his age, but said, when asked by the interpreter in his own language, for he knew no English at all, that he was five years old. When asked if he had eaten human flesh, he said 'No,' that he had killed four men, but had never been allowed a taste by the chiefs; he evidently thought himself in this respect an injured man. He had had four wives. He suffered much from cold on the river in the early morning; but, dressed up in a blanket suit by the blue-jackets, who were very kind to him, he managed to keep alive, and seemed to enjoy himself pretty well, especially at meal times.

"We passed a hill, opposite which the water of the river is supposed to have the effect of making the whiskers and beard grow, and the spot is resorted to by young Fijians, in order to force their hair. Joe said that he had been and bathed there when young. We passed numerous villages on the river side, and landed at some to buy clubs, spears, kaava bowls, and other implements, and the river was lively with canoes laden with yams and cocoanuts. In most places the people crowded to the banks to stare at us, and the girls and boys shouted as we passed. On the upper part of the river I heard a call used which reminded me somewhat of a European mountaineer's 'Jodel'; it sounded like 'Hē, Hāh, hŏ, hŏ, hŏ.' Our guides to the top of the mountain in Matuku used the same call when at the summit. Mountaineers in all parts of the world seem to have a similar cry; the echo no doubt provokes it.

"One village, Navusa, some few miles above Nadawa, interested me, as having its

[1] *Ann. and Mag. Nat. Hist.*, ser. 4, vol. iv. p. 36, 1874.
[2] Thos. Belt, The Naturalist in Nicaragua, p. 45, London, 1874.
[3] J. D. Macdonald, *Proc. Zool. Soc. Lond.*, p. 38 1869.

fortifications still perfect. It occupies an oblong rectangular area, two sides of which are protected by a natural water defence. On the other two a deep ditch is dug and the earth has been thrown up inwards to form a bank, on the summit of which is set a strong palisade, which extends around the whole area. Three narrow openings, only wide enough to admit one man at a time, give means of access. The openings are guarded by a sort of stile, over which a slab with notches for the foot leads up on one side, a similar one leading down the other. The whole site of the village has been levelled and raised. Nearly all the houses rest upon raised platforms of earth, a foot or six inches in height, the chief's house being especially elevated. Around all the houses were immense heaps of the shells of the fresh water Mussel (*Unio*), which is very common in the river. The site of the old village on Mr. Storck's estate was made up of beds of these mussel shells. We saw canoe-building going on at Navusa. For an adze, a broad chisel was used, fixed into what had been the handle of an old stone adze, just as the Admiralty Islanders fix blades of hoop iron into the old handles of their shell adzes. A chisel of hard wood was used for caulking, shaped just like our own caulking irons.

"Near Nadawa on the road to Nakello is the village of Tongadrava, which has also been strongly fortified. It is of an oval form, with two deep broad ditches encircling it, a zone of flat ground intervening between them; narrow cross banks on opposite sides of the village lead across the ditches. Formerly all Fijian towns were fortified; those in the Rewa district appear to have been remarkable for their strength,[1] especially a town called Tokotoko, where there was a perfect labyrinth of moats and ditches.

"The people of Nakello, a large village, about two miles from Nadawa, according to Jackson's Narrative, were peculiar amongst the Fijians for not eating human flesh, it being forbidden 'tambu' with them. In the centre of Nakello are the tombs of two chiefs, consisting of two large tumuli of earth, adjoining one another, one being older than the other. The older tumulus is oval in form, about 20 yards in diameter at the base, with sloping sides, and about 10 feet in height. At the top is a flat circular space, which is enclosed by a wall formed of slabs of coral and coral rock, set on edge, none of the slabs being very large. Another line of slabs surrounds the mound about half-way up, and here there is a sort of step on the side of the mound. Within the upper circle of stones are some slabs of tree-fern stems set on end like the stones. The more recent mound has no circles of stones, and is oblong in form.

"Our object in visiting Nakello was to be present at a grand dancing performance, which happens in each district only once a year, and which we were lucky enough to arrive just at the right time to see. The dance takes place on the occasion of the collection of the contributions made to the Wesleyan Missionary Society by the natives. Such dancing performances used always to be held when the annual tribute was paid over to the chiefs, and dancing on their collection days has been encouraged by the missionaries.

[1] Capt. Erskine, Islands of Western Pacific, App. A, p. 459, London, 1853.

The policy of the Wesleyan Society pursued in Fiji is very different from that maintained by the missionaries in Tonga, where dancing is suppressed. The village was full of visitors, and everyone was dressed in his best. The dancing green in front of the chief's house was cleared, and a white tappa flag was stuck up in the centre. We called on the chief, and found him sitting on his mat in a fine large house, about 40 feet long by 20 broad, 10 feet in height to the slope of the roof, and 25 feet to the ridge pole, built of a wooden frame, the rafters and beams being secured with plaited cocoanut fibre or sennit. The walls were of reed, the roof a thatch of grass; the sleeping place at one end was on slightly raised ground, 6 inches above the rest of the floor, and divided off by a curtain of tappa suspended from a cord stretched across; the floor was merely the earth covered with mats. This description will suit any Fijian house except as to dimensions. The chief sat on his mat near the middle of the house, whilst four or five servants and a visitor sat at the far end. The chief's little boy was being polished up by his nurse for the festivities, and another woman was making girdles of jasmine twigs for the chief's little daughter, holding one end of the garlands between her toes, as she twined the twigs into the sennit with her fingers at the other. When the small boy was handed from one nurse to another, each, after passing him to the other, went through the usual ceremony of respect to a chief, sat still a moment and clapped her hands four times reverently, and did the same after handing the boy to his father. The clapping was not done so as to make a noise, the palms of the hands were merely brought together quietly four times. The women looked reverently on the floor whilst doing it, as if saying a prayer. It was not at all done as an act of ostentation—indeed the women's backs might be turned to the company at the time—but appeared much more like a ceremony of private devotion. The posture of the hands whilst being clapped together is the same as that of Europeans and Japanese and so many races during prayer. The chief dressed his son's head himself. The head dressing consisted in shaving off all the boy's wool, except a vertical ridge which was left intact at the back and looked somewhat like the crest of a Greek helmet, and in smearing the whole of the shaved part with a thick coating of a bright vermilion red.

"We drank kaava and tasted Fijian puddings, which are glutinous semi-fluid masses, made of taro and cocoanut, and flavoured with molasses. The puddings are kept done up in a bag of banana leaf, and are very nasty, though specially prepared as a luxury on this occasion. The chief showed us two clubs, family heirlooms, which had killed a large number of illustrious enemies; but since, as he told us, they are always kept very carefully oiled, just as we oil our cricket bats, there was no hair nor remains of blood or brains about them.

"It was past noon before the people began to assemble in numbers, and seat themselves on the banks and rising ground, commanding a view of the dancing place. The dancing was begun by the body of about eighty young men which I had before seen practising the same dance for this grand occasion at Bureta, in Ovalau. A party stood together in the centre and kept up a sort of chant, one of their number beating time with two sticks upon a small bar of light wood, which was held by the hands of another. The remainder danced round to the chorus in a ring, but every now and then, changes between members of the ring and chorus took place. One of the chants I took down as 'Rāihĭ vāl sāl sāte ă dūmm,' the last sound being uttered with a peculiar lingering humming sound. The words chanted usually have no meaniug, corresponding to our 'fal la la,' and similar sounds. The chant was commenced always as a solo, the chorus joining in after the first few notes. Combined with the music, with excellent effect at various stages of the dance, was the loud clapping of hands, which was done in most perfect time, the claps of all the dancers and chorus sounding as one. Two kinds of claps were used, one with the hands hollowed, and the other with them flat. The two sounds thus produced served further to diversify the effect, and there was also added a loud shrill cry used in some of the figures just before their conclusion and uttered by one performer only, and which came in very well. The dancing consisted in most varied motions of the head, arms, body, and legs, the same motions exactly being gone through by every member of the circle in most perfect time. At one time the head and shoulders were bent forward, and the hands swung clapping together, at the same time as short side steps were made, carrying the performers round in the circle. Then a half-squatting position was suddenly assumed and the head was thrown first on to one shoulder, then on to the other. Then the performers would move on again, and stretch their arms out with a fixed gaze, as if shooting with the bow. None of the motions were very quick, and none very fantastic. The men wore fringes of various kinds, hanging from round their waists, mostly a combination of the yellow and red *Pandanus* leaf strips and the black fibrous girdles of the Fungus (*Rhizomorpha*). Most of them had also fringes of *Rhizomorpha* just below the knee, often with beads strung upon them. All had their bodies well covered with cocoanut oil, and their hair trimmed with great care.

"By the time the first dance was over, there was a dense concourse of spectators round the green. The missionary arrived, a table was set out under a tree opposite the chief's house, and three native teachers, two of them Tongan men, sat behind it to receive the money. The inhabitants of the various villages and smaller districts now advanced in separate troops, walking up in single file to the table and throwing down, each man or woman, their contributions upon it, with as loud a rattle as possible. As each contribution fell, the three teachers and some of the members of a further large body of teachers from the college, who were squatting close by, shouted 'Vinaka, vinaka' (slowly), 'Vinaka, vinaka, vinaka' (quickly), which means 'good, good,' or 'hear, hear.' Many bystanders joined in the applause. The money consisted of all sorts of silver coins, and a very few copper ones, and over £100 must have been collected

W. Hanhart lith. Hanhart imp.

1, 2, 3 AND 4 VARIOUS DANCING COSTUMES WORN AT NAKELLO, FIJI. Nº 1 AND Nº 2 OF THE FISHERMAN TRIBE
Nº 5 A TONGAN TO SHOW THE COLOUR OF THE RACE

in coin. The people of the various villages, and the districts subject to the chiefs of these, prepare dances for this yearly festival for many months, and they vie with one another in the splendour and perfection of the performance. As each band came up and made its contribution, a part or the whole of it at once proceeded to perform the prepared dance, and when this was over another party approached the table, and so on.

"The people as they filed up to the table formed a wonderful spectacle. The girls were most of them without coverings to their breasts, but the upper parts of their bodies were literally running with cocoanut oil, and glistened in the sun. The men and boys were painted in all imaginable ways, with three colours, red, black, and blue (see Plate E, figs. 1, 2, 3, and 4). There were Wesleyans with face and body all red, others with them all blackened soot black, others with one half the face red, and the other black; some had the face red and the body black, and *vice versa*; some were spotted all over with red and black; some had black spectacles painted round the eyes; some had a black forehead and red chin; some were blue spotted, or striped on the face with blue, and so on in infinite variety. How amused would John Wesley have been if he could have seen his Fijian followers in such guise! For many of the dances the men were most elaborately dressed. They were covered with festoons of the finest gauzy white tappa, or cuticle of the shoot of the cocoanut tree. These hung in long folds from the backs of their heads, and were wrapped round their bodies as far up as the armpits, and hung from the waist down to the knees in such quantity as to stick out almost in crinoline fashion. Round the men's heads were turbans, or high cylindrical tubes or mitres of white tappa, whilst hanging on their breasts were pearl oyster shells (see Plate E, figs. 1, 2) set in whales' teeth, the most valuable ornament which a Fijian possesses, and which he is forbidden by the chiefs to sell. Some of the men had remarkable head-dresses. One of them for instance had, sticking out from the front of his head, and secured in his hair, a pair of light thin twigs of wood, which were a yard in length; they were slightly bent over in front of his face, and at their extremities were fastened plumes of red feathers (see fig. 177). The whole was elaborately decorated, and as he danced, the red plumes swayed and shook at each jerk of his head with great effect.

"The most interesting dances were a club dance and a fan dance, in each of which a large body of full-grown fighting men, some of them with grey beards, performed. In all the dances, except the first one already described, the chorus sat on the ground at a corner of the green, and usually contained a number of small girls and boys, and used in addition to the wooden drum, a number of long bamboo joints open at the upper end, which when held vertically and struck on the ground, give out a peculiar booming note. In each of the dances there was a leader, who gave the word of command for the changes in the figures, and his part was especially prominent in the club dance, in which all the attitudes of advance, retreat, and the striking of the blow were gone through with various manœuvres, such as the forming of single file and of column. Clubs are carefully decorated when used for dancing; some indeed seem to be kept for this purpose, and to correspond to our court swords in being merely decorative. There are flat spaces near the heads of the curved clubs, which on festive occasions are freshly smeared with red, blue, or white paint. Coloured strips of screw pine leaf are often wound round the clubs, and some are decked with beads strung on *Rhizomorpha* fibres. Thackombau's son's club was, as I have said, freshly painted blue near the top. The King himself on state occasions had a decorated club carried before him, just as at home the Vice Chancellor of Oxford, and even the President of the Royal Society, now have.

"In the fan dance all the dancers were provided with a fan of tappa stretched on a wooden frame. They divided themselves into two parties, forming into single file in the same line with one another, but with a considerable interval between the two parties.

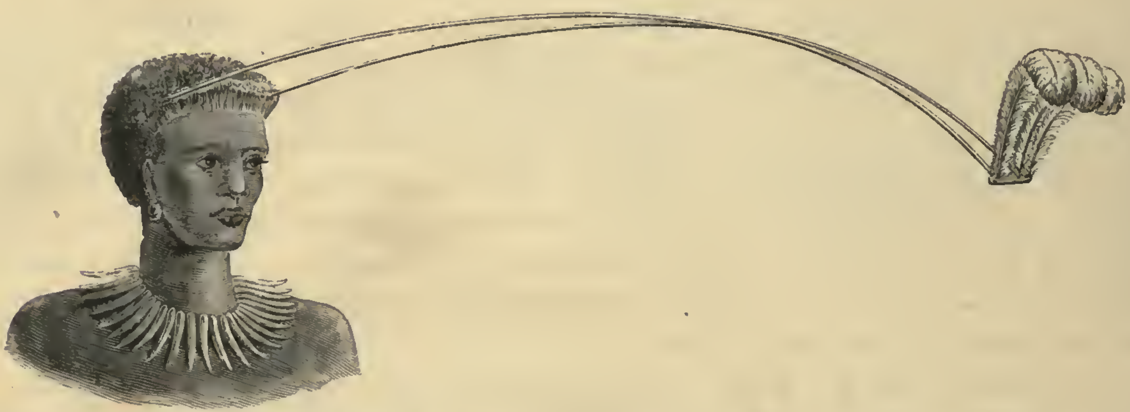

Fig. 177.—Fijian Native with remarkable head-dress, part of dancing costume. From a drawing by Lieut. Swire, R.N.

The two bands took up the chant and danced alternately, answering each other as it were. The fans were waved in various attitudes, and at the end of each movement thrown suddenly up over the head (still held in the hands), and a wild war-cry was uttered by the whole line simultaneously with the movement. The war-cry was a single prolonged high-pitched note, and sounded intensely savage. In another dance, performed by a large body of men, about one hundred and twenty I think, the dancers formed a sort of rectangular group, arranging themselves in eight rows, the leader being in the centre of the front row. Once or twice the leader came forward to the chorus, and addressed a few words in a dramatic manner partly to them, exhorting them to do their duty well, and partly to the spectators. A club dance by boys was one of the performances. In one figure of this the boys, standing in a line with their bodies bent forwards, jerked their hips with a most astonishing facility, first to one side and then to the other. The motion, especially in cases where the boys had a large quantity of tappa projecting behind as a sort of bustle, was most ludicrous, and the audience, instead of crying the oft repeated 'Vinaka, vinaka,' fairly shouted with laughter. A band of women of the district, headed by the Queen of Rewa and her daughter, who were both dressed in bright blue striped prints, marched slowly forwards across the green to deposit their offerings, singing a chant, descriptive of various incidents from the New Testament, the descriptive part being a solo, whilst the whole band joined in a constantly repeated chorus containing the words 'Allelujah, Amen.' This song was in lieu of a dance.


FIG. 178.—Queen of Rewa, from a Sketch by Lieut. Swire, R.N.

"The principal interest of the performances, however, lay in the obvious fact that here were to be observed in development the germs of the drama, of vocal and instrumental music, and of poetry in almost their most primitive condition. In these Fijian dances they are all still intimately connected together, and are seen to arise directly out of one another, not having as yet reached the stage of separation. The dance is evidently first invented by the savage, then rhythmical vocal sounds are used by the dancers to accompany it, and simple instruments of percussion are employed to keep time. As the dance becomes gradually more varied and complex, the accompanists are separated as an orchestra, the actual performers joining less and less in the vocal part, until, as here, they merely utter a single loud cry or note occasionally during the dance. The instrumental music of the orchestra remains long subordinate to the vocal and very simple, being represented at Fiji, as described, by the single small wooden drums and the bamboos. The orchestra continuing its performance in short intervals in the dancing, and commencing somewhat before the first figures, in order to allow the dancers to be ready to take up the measure, as was the case at Nakello, comes at length to perform solos; and hence the origin of music apart from dancing. The gradual complication of the music and improvement and multiplication of instruments follow, until vocal and instrumental music change places in importance and become also at length separated from one another. The dances being descriptive of victorious battles and such exploits, the chants, at first mere musical sounds and war-cries, become short descriptions of the fight, or praises of the warriors, and hence the origin of poetry. I could get no explanation of the meaning of the chants used at Nakello; as far as I could gather, they were without meaning, mere convenient sounds; but Fijian songs do exist, for Joe, our pilot, sang part of one, and explained that it related to the superiority of the Mbau men to the Rewa men. The origin of the drama is clearly seen in the stepping forward of the leader of the dance, as described, and dramatic enunciation by him of a short speech. A further step was to be seen in one of the other dances, when the leader, before his troop came on to the ground, rushed forward brandishing two spears in his hands, and gave a short harangue descriptive of what he was going to do. The separation of the dancers in the fan dance into two parties, performing alternately and responsively, is also interesting, and brought the Greek chorus and drama into one's thoughts. It was of course unnecessary to have recourse to Fiji in order to trace the origin of dancing, music, and the drama; this has been done fully long ago. But nowhere, I believe, is the primitive combination of these arts so forcibly brought before the view as a matter of present-day occurrence as in this group of islands.

"The most extraordinary feature in the Nakello performance was the extreme order and decorum of this concourse of three or four thousand people. It seemed astounding, whilst looking on at these blue, red, and black-painted Fijians flourishing their clubs and shouting their war-cries, to reflect that this was a Wesleyan Missionary meeting. The representative of the power which has tamed these savages was a little missionary with battered white tall hat and coat out at elbows, who stood beside us and who took no prominent part in the ceremonies, but yet had full sway over the whole, no dance having been prepared without his previous sanction. There could be no doubt as to the amount of good which had been done to these people, and it is sincerely to be hoped that the Wesleyan Missionaries will be left unmolested to continue the work in which they have been so successful, and which they have begun and carried out often at the risk, in some instances with the loss, of their lives.

"The men and children attending the meeting vied with one another in getting money to contribute, and were ready to sell almost anything they had for what we would give them. One boy pestered us to buy an old hen, and followed us about with the bird. Others sold us clubs and ornaments. The great wish was to have several pieces of silver to make a rattle on the table, and two sixpences were worth much more than a shilling, two shillings than half-a-crown. Immediately the ceremony was over, everything went up in value, and a good many articles pressed on us before were not now to be had at any price.

"Amongst the crowd was an Albino boy, who was perfectly white, his skin having a peculiar look, almost as if covered with a white powder, in places. His eyes, which he hid either from the light or because of shyness, appeared as if the iris were of a pale grey colour. His parents said he could see perfectly, but I could not examine him closely as he roared at the prospect. Albinos seemed unusually common amongst Melanesians, and are constantly mentioned by travellers; hence these savages, when first seeing whites, no doubt often took them for a race of Albinos. I saw several hunch-backed dwarfs amongst the crowd.

"We sailed from the Wai Levu, or Rewa River, to Kandavu, stopping at a small island on the way, to buy a pig and some fowls. A voyage in an open boat has many discomforts, especially when the boat is crowded. It was a difficult matter to sleep six together in the confined space of the stern-sheets of a ship's barge, especially

SHEET 30

SOUNDINGS AND STATIONS
in the vicinity of
NGALOA HARBOUR
Fiji islands.
For explanation of abbreviations &c. see Appendix 1.
178°
10'
20'
19°
Malatta
Reefs
Tomba ni Malatta
Tomba ni Tavuki
Hope Reef
John Wesley Bluffs
Tomba ni Richmondi
Yawi Reef
Dawson Reef
Uthuna Yawi
Tomba ni Soso
Tawandromu I.
North Bay
Anda Tavie
(165)
Ngaloa
Beacon
NGALOA HARBOUR
Barrier Reef
Soso Passage
(300 yards broad)
Esk R.
Pearl R.
210
coral mud
140
coral mud
160
coral mud
255
coral mud
610
coral mud
Full of Coral Patches
dry at L.W. Springs
Sea Reef
South I.
(79)
Uthuna Ya-uravu
Tomba Ya-uravu
(200 yards broad)
Breaks heavily
Matanuku I.
(370)
Boat Passage
in fine weather
Koro-e-Rangi
(520)
Barina
Ndavingeile
Mbardki
Levuka
Banyan Tree
Nasengai
Therai
Ya-uravu
Mt. Creak
1145
Vanua Levu
Wai Levu
Tavuki
Naku naku
Richmond
Missionary Ho.
Yawi
Tawapa
Ndongai
Tuladia
Sharp Pk.
1260
Sharp Pk.
1460
Solondamu
Mt. Mouleh
1414
Korobola Sarra
Malatta
Tavuki Isthmus
Mt. Hoskin
Asses Ears
1600
Mounduk
Nikorokoro
Mt. Chalmers
Na Koro
Yanua Kania
Ndravuwalu
Soso
Nabia I.
(70)
Village

as the available surface was rendered extremely irregular by the various articles necessarily stowed upon it, such as provision boxes and beer cases. We all slept with our shooting-boots on, to ensure mutual respect, as we lay packed like herrings in a barrel. On the whole the trip was pleasant enough, and the inconveniences were nothing compared with the interest of a visit to such places as Mbau and Viti Levu."

The ship left Levuka Harbour at dusk on the 1st August, steaming out of the passage between the reefs and then far enough to get an offing, when sail was made for Kandavu Island, to complete the survey of Ngaloa Harbour. The 2nd (Sunday) was calm nearly all day, so the vessel steamed during the night, and arriving off Ngaloa Harbour at 8 A.M. on the 3rd, despatched the boats to proceed with the survey, whilst the ship obtained some soundings and dredgings off the reef, anchoring in the evening in Ngaloa Harbour (see Sheet 30).

Kandavu.—Ngaloa Harbour, which at the time of the visit had already acquired some importance as a port of call for the mail steamers running between Sydney and San Francisco, is an indentation in the south coast of Kandavu Island, protected to seaward by a line of coral reefs rising to the surface, and forming a natural breakwater, through which is a deep narrow channel into the anchorage. The harbour is divided into two parts by Ngaloa Island, and the anchorage on the west side of the island is again divided by reefs, occupying a considerable area, into an inner and outer harbour, both of which are perfectly safe in all weathers. The anchorage ground on the east side of Ngaloa Island is named North Bay, and this also is well protected, and is capable of affording shelter to a large number of vessels. At the head of the harbour is a narrow isthmus named Tavukie, which separates Ngaloa from Malatta Bay, and on the west side a range of high hills, culminating in Koroh-to-Sarra, a conical peak covered with trees, 1643 feet above the level of the sea.

Inside the harbour, more particularly in the immediate vicinity of the barrier reef, are numerous coral knobs; they can, however, be readily seen by a look-out from aloft, and with the chart as a guide, no difficulty should be experienced in entering or leaving this port. During the survey of Ngaloa Harbour several marks on the shore were noticed which appeared to indicate that either the level of high water was different at other seasons of the year, or that the land is now more elevated than formerly. On the side of the small rocky islet, 15 feet high, in the passage between the North Bay and Inner Harbour, is a water mark 4 feet above high water, and other points showed these water marks, though not so distinctly as the small islet. These marks cannot be caused by the sea in bad weather, for the reef protects the harbour from any such swell.

The native chief at Kandavu on two occasions sent off a large Green Turtle as a present to Captain Nares, and the large double canoe which brought the present was photographed from the ship (see Plate XIX.). The supplies at the Fiji Islands were few and expensive; the beef was, however, good, better even than the Australian meat.

Whilst at Levuka the slope from the barrier reef was taken outside the north entrance to the harbour; 65 fathoms from the edge of the reef awash the depth was 21 fathoms, or a slope of 1 in 3; at 150 fathoms' distance the depth was 80 fathoms, or a slope of 1 in 1·4 from the last sounding; farther out the slope was fairly uniform at 1 in 2 to 300 fathoms. The reefs around Kandavu have generally the character of fringing reefs, and in other places are barrier reefs. Indeed, throughout the Fiji Islands the three varieties of barrier, atoll, and fringing reefs are distributed in such a manner as to render it difficult to understand how the two former have been formed by subsidence. It has already been stated that at Kandavu there were indications of recent elevation.

A new genus and species of Reef Corals (*Tichoseris obtusata*)[1] was obtained at these islands, and some rocks, collected at Kandavu, are referable to the type of amphibolic andesite, very often containing augite and biotite, with tufa of the same composition.

Having heard at Ovalau that there were a number of natives of the New Hebrides who had just completed their engagement and wished to return to their native island (Api), which would be passed on the way to Australia, they were received on board.

On the 10th August the ship left Ngaloa Harbour, steering to the westward along the land. Passing within a moderate distance of the edge of the coral reef off Kandavu Island, it was observed that the bay next west of Ngaloa Harbour (Tomba Ya-uravu) had apparently good anchorage and a clear channel into it through the reef. In the bay are four small islands, just eastward of the large island which forms its western boundary. This island, which is round-backed, was estimated to be 700 feet high; it is called Matanuku. West of Matanuku the land trends to the westward, and then projects in the form of a peninsula, which terminates in a bluff point with a knob on it, five miles from Matanuku Island. To the westward of the knob bluff (Koro-e-Rangi) is another bay, formed between the bluff and a hill joined to the mainland by a low narrow isthmus, which makes it appear like an island when first seen. Off this False Island there is only a small reef running out to the southward, but just east of it is a reef stretching to the southwestward from the knob bluff, on which the sea breaks very heavily. There is a passage between False Island and this reef to the shore, and probably anchorage, but there appeared to be some detached reefs inside, so that it must be approached with great caution. To the westward of False Island (Thickombia) the sea was seen breaking against the sandy beach joining it to the shore, and the land trended to the northwestward, forming a bay between it and a low point (the western extremity of Kandavu Island), off which is a flat island (Denham Island), from which a reef stretches to the southwestward. At Denham Island the reef apparently ended. The whole of Kandavu

[1] Quelch, *Ann. and Mag. Nat. Hist.*, ser. 5, vol. xiii. p. 296, 1884.

Plate XIX.

Horsburgh, Edinburgh. Permanent Phototype.

Fiji Canoe.

Island west of Ngaloa Harbour is high, culminating in Mount Washington at its western extremity, a fine flat-topped mountain with precipitous sides, about 2500 feet high. The exact height and position with reference to the coast could not be ascertained, as its summit was clouded the whole afternoon.

At 6.30 P.M. the ship was stopped to hoist in the barge, which had sailed round the north side of the island from Malatta Bay, and then "laid to" under fore and aft sails for the night. At this time Denham Island bore N. by W. and False Island N.E.