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EDITORS

JAMES D. AND EDWARD S. DANA.

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[THIRD SERIES.]

Art. I.—*The Solar Corona, an instance of the Newtonian Potential Function in the case of Repulsion*; by Professor Frank H. Bigelow.

[Read before the National Academy of Sciences, Washington, April, 1891. Communicated to the Academy by Professor Simon Newcomb.]

The term Newtonian Potential Function, first employed by Neumann, is now generally accepted by writers on scientific subjects. It expresses the law of the attraction or the repulsion, as the case may be, of the action of all the material substance in the universe, the discrete parts acting mutually upon one another. The *approximate* value of the attraction between any two rigid bodies may be obtained by assuming that every particle of the one body attracts every particle of the other with a force directly proportional to the product of the masses of each pair of particles, and inversely proportional to the square of the distance between their centers. The *true* value is the limit approached as the bodies are subdivided indefinitely. From this case follows the whole subject treated as the attraction of gravitation. If we substitute in the definition the word repulsion we derive the expression of the second case, and many of the formulæ in the mathematical discussion can be interchanged between the two cases by a proper use of the plus and minus signs. Electricity and magnetism depend upon this function for their analysis.

The mystery underlying the physical condition of matter is as yet insoluble either by metaphysical speculation or by scientific investigation, but it is significant that this Newtonian Potential Function, using both algebraic signs, should reach to all the phenomena known to us up to this time. While I cannot justify the idea, the suspicion keeps forcing itself upon my mind that matter some how, that is to say by change of conditions or environment, can be made to pass from the positive to the negative form of the function and back again. We may yet discover that this is illustrated by the sun, when we get to the bottom of its mysterious nature. At present I am concerned simply with identifying the Solar Corona with the manifestation of the Newtonian Potential Function in the case of repulsion.

Whenever the particles of a body, not undergoing rotation, are free to move among themselves, the body assumes a spherical figure about a center. This figure is modified by the rotation of the body. If in connection with such a spherical body there be present other material conforming to the case of repulsion, the body is polarized along an axis, and the lines of force are parallel to the axis of polarization within the body, become discontinuous at the surface, and on leaving the surface form curves whose locus can be expressed by the formula

$$N = \frac{8\pi}{3} \cdot \frac{\sin^2\theta}{r},$$

where N is the given line $(r \,.\, \theta)$ the polar coördinates of points measured from the axis of polarization and the center. We are not now discussing either the interior or the surface conditions, and in the case of the potential outside the sun we may believe that we have a nearly ideal distribution, on account of the prevailing conditions of freedom of motion.

In the corona streamers, as displayed by the photographs, we must remember that the curves arising from the equation just given are modified by projection, and that therefore the measured curves must all be corrected for their distortion. At the outset we could not know the position of the axis of polarization or the center of reference, and as a first approximation we supposed that this axis passed through the center of the sun, and coincided with the plane perpendicular to the line of sight from the observer, which also passes through the center of the sun. Fortunately in the eclipse photographs of July 29, 1878, Jan. 1, 1889, and Dec. 22, 1889, which were studied, these conditions were not very erroneous in their assumption. These three coronas are so similar in their appearance that they are spoken of as the "American type," the fact being that at the epoch of the eclipse, the pole of the corona in its rotation with the sun happened to be near the plane of reference just defined, so that the coronas were observed in their most symmetrical position relatively to the earth. The amount of this angular divergence between the axis of polarization and its trace on the plane of the disk was less than two degrees, and this had but little influence upon the traces of the curves themselves. The second point, namely, that the center of polarization coincided with the center of the sun was more inaccurate, and this was shown by the fact that in computing the angle through which the plane containing a given ray must be turned about the axis of polarization to produce the curve as it appeared on the photograph, it was found that this angle progressed in value for points of the curve, as we passed from the surface of the sun to its extremity. This angle was however checked at the following step in the computation, by which each measured point on the ray gives the polar distance θ_0 at which the ray under discussion springs from the surface of the sun. We propose to rediscuss this question, in a second approximation, at some future time. The upshot of the whole matter is that of all the curves that theoretically exist in space, as surrounding a polarized sphere, only such occur in the corona as spring from a belt lying generally between the parallels of coronal polar distance 25° to 40° in each hemisphere of the sun. I subjoin a summary of my result for the three coronas. Each value of θ_0, the polar distance of the base of the ray on the solar photosphere, is the mean of generally three, sometimes four or five points measured on the ray. The mutual agreement is substantial and convincing.

ANGULAR DISTANCE FROM THE CORONAL POLE OF THE BASE OF THE RAYS.

Corona of July 29, 1878.

Ray.	N. E.	N. W.	S. W.	S. E.	
1	29° 42′	31° 8′	32° 41′	31° 31′	
2	28 32	27 18	30 30	31 31	
3	30 52	34 40	32 25	33 44	
4	31 45	33 36	30 38	33 8	
5	32 50	33 37	34 21	33 55	
6	33 46	41 34	36 16	34 8	
7	35 53	-- --	38 58	35 11	
8	41 41	-- --	40 54	38 18	
					Mean
	33 7	33 39	34 35	33 56	33 49

Corona of Jan. 1, 1889.

Ray.	N. E.	N. W.	S. W.	S. E.	
1	34° 54′	30° 33′	31° 50′	31° 52′	
2	28 27	29 31	29 49	27 23	
3	24 39	32 5	31 33	30 00	
4	18 1	32 18	30 11	32 16	
5	31 13	33 12	34 21	33 21	
6	37 49	32 45	29 20	33 48	
7	42 51	-- --	36 43	34 26	
8	-- --	-- --	-- --	36 52	
					Mean
	31 8	31 44	31 41	32 30	31 46

Corona of Dec. 22, 1889.

Ray.	N. E.	N. W.	S. W.	S. E.	
1	30° 25′	28° 51′	31° 15′	31° 30′	
2	25 33	25 11	27 19	31 56	
3	30 33	29 0	28 14	31 41	
4	27 13	26 1	26 59	31 14	
5	30 15	33 56	29 10	32 14	
6	30 17	34 8	34 25	32 20	
7	31 19	34 17	36 37	33 22	
8	28 43	38 17	36 15	-- --	
9	35 55	39 17	-- --	-- --	
10	38 1	-- --	-- --	-- --	
					Mean
	30 49	32 6	31 24	32 2	31 35

From this we proceed to the location of the coronal poles, or the points on the surface of the sun at which the axis of polarization pierces it.

The results are independent of each other as regards different coronas, and the two hemispheres are also independent for the same corona.

	North Pole.		South Pole.	
	Long.	Lat.	Long.	Lat.
July 29, 1878,	83° 18′	85° 12′	185° 4′	83° 49′
Jan. 1, 1889,	73 26	84 25	174 29	86 22
Dec. 22, 1889,	36 19	87 0	134 52	86 2
Mean latitude,		85 32		85 24

	Difference in Longitude.
July 29, 1878,	101° 46′
Jan. 1, 1889,	100 53
Dec. 22, 1889,	98 33
Mean difference,	100 24

The axis of polarization is therefore at the surface of the sun about $4\frac{1}{2}°$ degrees from the axis of rotation, and the southern end of it precedes by about 100 degrees in longitude. These coördinates of latitude and longitude are always referred to the plane of the sun's equator, considered as celestial, and from the ascending node of the sun's equator on the ecliptic, that is from the point whose longitude is 74° from the vernal equinox on the plane of the ecliptic. These coördinates are therefore celestial and, being independent of solar conditions, indicate the position of the axis of polarization without any complications. A computation of the distance apart in a great circle, from the center of the sun, of the north and the south coronal poles gives us for our three coronas:

172°	59′
173	56
175	23
Mean, 174°	6′

This will enable us to compute the position of the center of polarization of the sun, which is seen to be considerably eccentric, and from this our second approximation begins. It should be mentioned that although the existing photographs have served our purpose, and given results more satisfactory than was anticipated, yet no pains should be spared at approaching eclipses to produce pictures of much greater power than those we now possess. For this subject already opens up a vista of great interest in studying the physical nature of the sun.*

From the results that have been quoted we may draw the conclusion that the axis of polarization seems to be fixed in the body of the sun, the difference in longitude and the distance measured on a great circle being constant, within the errors arising from the measures, for epochs extending over nearly eleven years. Since the coördinates of position of the poles are celestial, we have only to compute the periodic time in order to know the period of the rotation of the sun at a distance of 4½ degrees from the axis of figure. It is desirable that this should be done, because the sun-spots, from which such a period is obtained for the equatorial regions, are confined to about 35° in latitude, and we shall thus be able to pass over the intervening 50° to the neighborhood of the solar poles. I have obtained the following results:

For the period from July 29, 1878 to Jan. 1, 1889, 138 revolutions +194°·69; the mean daily motion is 13°·1353 in longitude.

For the period from July 29, 1878 to Dec. 22, 1889, 151 revolutions +166°·68; the mean daily motion is 13°·1312 in longitude.

For the period from Jan. 1, 1889 to Dec. 22, 1889, 12 revolutions +331°·99; the mean daily motion is 13°·0876 in longitude.

As my conditions are of equal weight for each eclipse, a least square solution gives me for mean daily motion in longitude 13°·13307=788′, at latitude 85°·5.

This gives for the

$$\text{Siderial Period,} \quad 27^{d}{\cdot}41171 = 27^{days}\,9^{h}\,52^{m}\,52^{s},$$
$$\text{Synodic Period,} \quad 29^{d}{\cdot}63580 = 29^{days}\,15^{h}\,15^{m}\,33^{s},$$

in mean solar time. I propose the following formula for the rotation period of the solar surface at different latitudes, as

* A paper containing the details of the work by which these results were obtained, will be found in the Proceedings of the Astronomical Society of the Pacific, No. 17.

derived from the mean daily motion in longitude given by observations of the sun-spots and by computation at the coronal pole.

$X = 862' - 76' \sin l$, where X is the mean daily motion in minutes and l is the solar latitude.

Other formula have been given:

Faye, $X = 862 - 186 \sin^2 l$.
Tisserand, $= 857{\cdot}6 - 157{\cdot}3 \sin^2 l$.
Spoerer, $= 1011 - 203 \sin (41^{b} + l)$.

Latitude.	Faye.	Tisserand.	Spoerer.	Bigelow.	Siderial Period in days.
0°	863′	858′	878	862·0	25·0577
10	857	853	853	848·8	25·4470
20	841	839	833	836·0	25·8370
30	816	818	819	824·0	26·2131
40	786	793	810	813·2	26·5613
50	754	765	808	803·8	26·8729
60	723	740	812	796·2	27·1288
70	699	719	821	790·6	27·3206
80	683	705	837	787·2	27·4386
90	677	700	858	786·0	27·4806

If we compute back to the epoch 1878·0 we find the residuals in longitude for the three coronas,

	North Pole.	South Pole.
July 29, 1878,	−0°·9	+0°·5
Jan. 1, 1889,	+7 ·9	+8 ·4
Dec. 22, 1889,	−7 ·0	−8 ·9

I adopt as the longitude for 1878·0,

North Pole, 201°·2.
South Pole, 301°·6.

Siderial Period, 27·41171 days.

We can now readily locate the position of the coronal poles at any epoch, and I have done so for several past eclipses in order that comparison may be made between a model and the pictures obtained during the totalities of the eclipses. The model was constructed in the following manner. The body of the sun is represented by a five-inch globe. In the region of the coronal zones three parallels of coronal polar distance are taken, 29°, 34°, 39°, and on these somewhat at random, are inserted wires having the proper form. Their curvature and their inclination to the normals of the sphere were calculated from the formulæ, a graphic representation of the locus of the curves made for a pattern, and the wires bent accordingly.

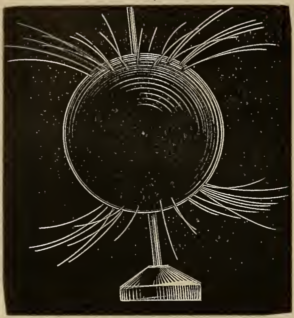
For giving the proper position to the model for any eclipse this simple device is adopted. The circular stand is placed on a sheet of card board and two concentric circles are drawn upon it surrounding the base of the stand. On the inner one the figures represent the direction from the center towards the earth, equal to the sun's longitude of date + 180°. A mark on the stand, drawn by regarding the inclination of the axis at 7° 15′, and representing the position of the node, is placed at the reading 74° on the circle just described. For any eclipse turn the card board with the stand upon it about so that the reading (☉ + 180°) is between the observer and the center. Furthermore adopting the data given above for the epoch 1878·0 as the elements of predicting the position of the poles of the corona, a table has been constructed for a series of coronas from 1857 to 1893. On the second circle the 0° reading begins at 74° of the first circle, and it is necessary to rotate the ball so that the North pole of the corona shall point to the reading that was computed. The observer will then see the model in the position of the corona of the sun, if the eye is placed on the same level plane as that passing through the center of the ball. The following table gives the two readings necessary for setting the model. They are computed for the Greenwich mean time of conjunction of the Sun and Moon for the several eclipses as given by the Nautical Almanac. Observations made at any other time can be readily corrected.

Table of Coördinates for setting the Model of the Corona.

Date of Eclipse.	Long. Earth.	Long. Corona.	Date of Eclipse.	Long. Earth.	Long. Corona.
1857·23254 G. M. T.	185°	294·4°	1876·71441 G. M. T.	355°	147·7°
1858·68616 "	344	67·3	1878 57741 "	306	84·4
1860 54647 "	295	351·1	1880·02999 "	111	212·4
1862·00094 "	99	128·2	1882·37597 "	236	305·9
1864·34503 "	225	248·6	1883·34747 "	226	286·1
1865·31645 "	215	192·5	1885·68965 "	346	1·4
1867·66140 "	336	281·0	1886·66132 "	336	342·4
1868·63032 "	325	248·8	1887·59106 "	311	122·4
1869 60209 "	315	230·4	1889·00517 "	101	65·7
1871·94778 "	80	322·5	1889·97616 "	91	43·5
1874·29174 "	206	46·3	1892 32003 "	216	126 9
1875·26358 "	196	30·2	1893·29187 "	207	108 8

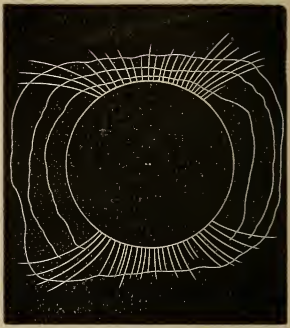
Three cases are presented for comparison. Figures 1, 3, 5, show the model placed in three positions, corresponding to the eclipses of Jan. 1, 1889, August 29, 1886, and July 29, 1878. Figures 2, 4, 6, represent these coronas, as drawn from the photographs.

1.



1889A.

2.



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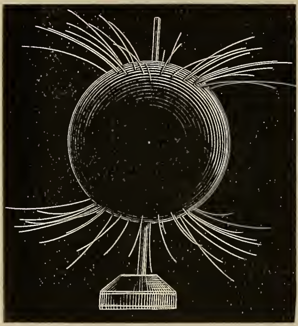
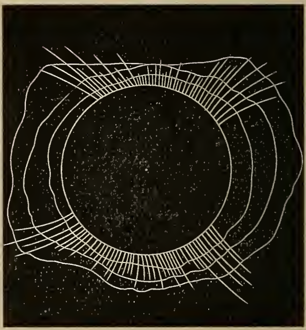
3.



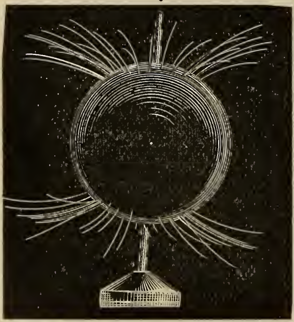
1886.

4.



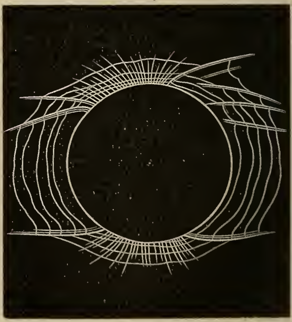
1886.

5.



1878.

6.



1878.

In making the comparison, it is proper to bear in mind a few obvious considerations. The wires that make the rays on the model properly represent only stream lines, or portions of the streamers of the corona. The curve is true for that part of the streamer which springs from the sun at the latitude corresponding to the axis of the wire. Inasmuch as the coronal streamer is large at its base the curvature of the ray must agree in all its parts with the lines springing from this region. The consequence is that each ray spreads out, as it recedes from the sun, to fill all the space occupied by the bounding curves, and we see as a result the curious forms of the curves of the corona, which are definite and conform to this law. I would propose this as a sufficient proof of the truth of the theory, even taking it by itself. The rays set into the model do not pretend to represent the lines measured for any particular eclipse, because it is designed to illustrate the subject only in a general way. One ought properly to construct a model for each eclipse using the computed $(\alpha . \theta)$, the coördinates of the base of the ray. Then photographing this, a comparison could be made between the individual lines. The model does not show the nebulous, structureless mass of material, which was probably thrown up along these coronal lines, and is going through other transformations in its return to the sun. We miss also the radiant light which passes through this coronal matter and illuminates it, for the most part in radial lines up to the region of the streamers, where it is in a sense shut off, thus producing the effect of great equatorial extension. Coronal material may accumulate along the equatorial regions for immense distances, and then the radiant light streaming through it would produce the wings of the corona. It is evident that the quadrilateral forms are made by the perspective thickening of the coronal belt as it passes round the side of the sun. The polar rays are the individual streamers seen in projection.

The reproduction of the eclipse photographs is necessarily such as to diminish very much their availability as objects of comparison. This should in fact be made with the glass negatives. Still it is easy to infer that there is an agreement in the following respects: (1) as to the general inclination of the corona as a whole to the plane of the ecliptic; (2) as to the general distribution of the larger and the smaller sides, supposing that the nebulous matter is supplied to the model by the imagination; (3) as to the trend of the stream lines wherever they are seen. We do not pretend to show all the individual lines, nor all the special solar outbursts in loco, nor do we pretend to account for all the imperfections of the photographs or drawings. Those which are composite, or which are halated, or which are inadequate, must take their chances.

This comparison shows, however, that it is not the equatorial extensions which are interesting in this connection, but chiefly the individual stream lines which can be subjected to measures.

Up to this point we have not been dealing in speculations, but in legitimate scientific data and their results. There are, however, two probable conclusions so apparent that I will not abstain from mentioning them.

If we regard these coronal streamers as the paths along which the sun is throwing off a portion of its energy, and consequently along which its material substances are being transported, whatever may be their physical conditions, we have only to suppose that near the extremity of these extremes these conditions change by loss of energy, cooling, condensation, and so on, so that the repulsive power is lost and the gravitation of the sun sets in to take its place. What becomes of this material that has been ejected from high latitudes at the surface of the sun into high altitudes above the equatorial belts? Obviously it must descend again; the heavier or denser vertically, and as the model shows, this will fall directly over the sun-spot regions; the lighter or more finely subdivided in the ceaseless nebulous equatorial rain, which by its increase of angular velocity accelerates the mean daily motion of the surface of the sun itself, at the time of its impact with it. It is a great solar whipping top. Much more might be said to illustrate these statements, and yet but little can be added to the model itself in enforcing this conclusion. There is some evidence shown in the table of the angle θ_0, giving the polar distances of the base of the streamers for the three eclipses, that the coronal belt has a motion in latitude on the surface of the sun, those of 1889 being more than a degree nearer the poles than that of 1878. This movement in latitude is illustrated by the motion of the maximum zones of the terrestrial aurora in latitude, and might be expected in view of the periodic nature of the activity of the sun, especially in the 11-year period. This fact would point to a more considerable motion in latitude of the ends of the streamers, by reason of the curvatures, and hence of the sun spots themselves, in case they are due to material coming from such a source.

It is not unlikely that we shall sometime be able to penetrate yet deeper into the mysterious nature that is implied in this most wonderful mechanism of the sun. We may well believe that it expresses the type of the common history through which all celestial bodies have to pass, in the process of construction and cooling. The aurora is an indication of this system on the earth, the residual being the permanent terrestrial magnetism. Now that we see more clearly the elements of the problem, it will be easy to construct a rigorous solution, including the eccentricity of the center of polarization, the inclination of the axis of polarization to the plane of reference, besides such corrections as may arise from refraction, or diffraction or photography. The importance of the problem will certainly justify us in trying to take good photographs of the streamers at the future eclipses.

ART. II.—*Newtonite and Rectorite—two new minerals of the Kaolinite Group;* by R. N. BRACKETT and J. FRANCIS WILLIAMS.

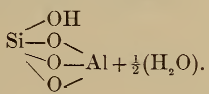
[Published by permission of the State Geologist of Arkansas.]

THE object of the following paper is to briefly describe two hydrous silicates of alumina, which we have every reason to believe have not before been observed, and to call attention to the relation of these new compounds to other members of the group.

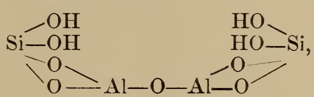
As is well known and generally admitted the commonest substance of this class, kaolin, or when crystallized called kaolinite, approaches the composition represented by the formula $Al_2O_3 . 2SiO_2 . 2H_2O$, and has the percentage composition:

SiO_2 46·50 Al_2O_3 39·57 H_2O 13·93 = 100.

Considering half of the water basic or as water of constitution and dividing the formula by two, the constitution of kaolinite may be represented as follows:*



As there is reason to think that all the water represented in the original formula should be regarded as water of constitution, the formula would become:



or writing this in the form suggested by F. W. Clarke in his paper on the Structure of the Natural Silicates,† the following formula is obtained:

* Kaolinite is thus regarded as a derivative of normal silicic acid $Si(OH)_4$, analogous to a similar compound $Al_2O_3 . 2SiO_2 . 3H_2O$ mentioned by Remsen. Inorganic Chemistry by Ira Remsen. American Science Series—Advanced Course. New York: Henry Holt & Company, 1889, p. 576.

† Bulletin of the U. S. Geological Survey, No. 60, Washington, 1890, p. 16.

$$\mathrm{Al}\begin{cases}\mathrm{OH} \\ \mathrm{SiO_4{\equiv}H_3} \\ \mathrm{SiO_4{\equiv}Al.}\end{cases}$$

Either of these formulas suggests the possibility of the existence of other hydrous silicates of alumina closely related to kaolinite, and indeed differing from it only in the presence of a larger or smaller proportion of water, while the relation of the silica to the alumina remains constant.

It is readily seen that three other hydrous silicates of alumina may be derived by eliminating one molecule, or introducing respectively one and two molecules of water into the formula, and that thus the following series would be formed :

Formulas.	Percentage composition.		
	Al_2O_3	SiO_2	H_2O
(1) $Al_2O_3 . 2SiO_2 . H_2O$	42·52	49·99	7·49
(2) $Al_2O_3 . 2SiO_2 . 2H_2O$	39·57	46·50	13·93
(3) $Al_2O_3 . 2SiO_2 . 3H_2O$	36·98	43·47	19·55
(4) $Al_2O_3 . 2SiO_2 . 4H_2O$	34·72	40·82	24·46

Of this series of four theoretically possible hydrous silicates of alumina only one, No. 2 of the series, ordinary kaolin, has been described, so far as we have been able to find in the literature at our command. From many of the published analyses of halloysite, this mineral might be supposed to correspond with No. 4 of the series, but, as will be shown below, this correspondence is only apparent.

This series will be designated as the *Kaolinite Series*,* and will include the *Kaolinite Group*, which was first established by J. D. Dana in 1858 † under the name of the *Halloysite Group*, but was afterwards called the Kaolinite Group by the same author.‡ The object of forming such a series is to classify if possible the already existing members of the kaolinite group, most, if not all of which will be found to fall under kaolinite ; and at the same time to have a definite place into which to put any new minerals of this class which, like rectorite and newtonite, may from time to time be found, and which would at present hardly be classed under kaolinite itself if their water of constitution was properly determined. It is the hope of the authors to be able in a future paper to show the true chemical composition and microscopic structure of many minerals now existing as members of the kaolinite group ; and to assign them to their proper place in the above-mentioned series, by rede-

* The word *series* is not used here in the sense in which it is generally applied in the natural sciences, but as it is employed in mathematics to describe a sequence of similar terms which bear some definite relation to each other.

† This Journal, II, vol. xxvi, p. 361, 1858.

‡ System of Mineralogy, J. D. Dana, 5th edition, 1868.

termining their water of constitution under the conditions mentioned below.

Since kaolin approaches the composition represented by the formula ascribed to it only when it has been dried at about 110° C., and from the facts mentioned below regarding halloysite, we propose to consider the whole series as based upon analyses of material dried at 110° C. or thereabouts.

Considering the series in this way, at least one and probably two hydrous silicates of alumina lately analyzed in the laboratory of the Geological Survey of Arkansas fall into this series. One of these corresponds to No. 4 and the other possibly to No. 1 of the series.

Newtonite.

The first compound which will be described, and that which suggested the series given above, is found on Sneed's Creek in the northern part of Newton county (16 N., 23 W., section 1), in the State of Arkansas. At this place a mineral claim was laid and a shaft opened in 1889 by Mr. W. S. Allen of Harrison, Ark. The rocks of the region are for the most part sandstones and shales of the Barren Coal Measures, while the opening itself seems to penetrate some of the limestones of the Lower Carboniferous series. At a depth of eight feet this form of kaolin was found imbedded in a dark gray clay, through which it is scattered in lumps which vary from a few ounces to forty pounds in weight. Iron and a little manganese are also said to occur in the opening. Samples of the material were kindly furnished the Geological Survey of Arkansas by Mr. Allen, the proprietor of the claim.

On account of its occurrence in Newton county we propose the name *Newtonite* for this, the fourth member of the Kaolinite Series.

Newtonite is a pure white, soft, compact, homogeneous substance, and both chemical analysis and microscopic examination show it to be a remarkably pure substance. It is infusible before the blowpipe, and when in the form of a powder it has a specific gravity of 2·37. It is only slightly attacked by boiling concentrated hydrochloric acid, but boiling concentrated sulphuric acid decomposes it almost completely, with a separation of silica. It is also decomposed by a boiling saturated solution of caustic potash with the formation of a compound insoluble in water but easily soluble in cold dilute hydrochloric acid. (See below.)

Quantitative chemical analyses of newtonite gave the following results:

	I.	II.
SiO_2	38·86	40·22
Al_2O_3	35·20	35·27
Loss on ignition	23·69	22·89
Fe_2O_3	0·21	0.21
CaO	0·31	0·54
MgO	trace	trace
K_2O	1·73*	0·99
Na_2O		0·73
	100·00	100·85
Water at 110°–115° C.	5·53	5·44

If the impurities be disregarded and the silica, alumina and loss on ignition in analysis I be recalculated to 100 per cent, and the same be done in analysis II, after first bringing the whole to 100 per cent, the following figures are obtained:

	Ia.	IIa.	Theory for $Al_2O_3.2SiO_2.4H_2O$.
SiO_2	39·76	40·88	40·82
Al_2O_3	36·01	35·85	34·72
Loss on ignition	24·23	23·27	24·46
	100·00	100·00	100·00

Although this compound closely resembles ordinary kaolin in its chemical properties, it shows thus a marked difference in composition, by containing for the same amount of silica and alumina double the quantity of water usually found in kaolin.

That an apparent similarity exists between newtonite and halloysite when a comparison is instituted between the analysis of newtonite calculated on the material dried at 110° and the published analyses of halloysite where it is not stated whether the calculations are made on the air-dried material or that dried at the above-mentioned temperature, is shown in the following table:

	Newtonite.		Halloysite (Indianaite.)	
	Ia.	IIa.	III.	IV.
SiO_2	39·76	40·882	39·35	38·90
Al_2O_3	36·01	35·851	36·35	37·40
Loss on ignition	24·23	23·267	22·90	23·60
	100.00	100.00	98·60	99·90
			·40 CaO	
			99·00	

Analysis III is of a soft and IV of a hard, white variety of halloysite called indianaite.† H. Pemberton, Jr., who made

* Alkalies by difference.

† Report of the Geological Survey of Indiana, 8th, 9th and 10th Annual Reports (1876–1878), p. 156. See also Sixth Annual Report (1874), p. 15.

these analyses, kindly furnished the information that the calculations are made on the *air-dried material*, and that in analysis III, 8·68 per cent of the loss on ignition is given off at about 110° C.

If analyses Ia and IIa be calculated to the air-dried material the difference between them and the published analyses of halloysite is clearly shown, as is evident from a consideration of the following table:

	Ib.	IIb.	Halloysite.
SiO_2	36·83	37·96	39·35
Al_2O_3	33·42	33·34	36·35
Loss on ignition	24·22	23·26	14·22
Water at 110°–115° C.	5·53	5·44	8·68 (at 100° C.)
	100·00	100·00	98·60

If it be assumed that the 8·68 per cent of water in halloysite is partly hygroscopic and partly water of crystallization, this mineral would have the composition of kaolinite containing one molecule of water of crystallization. Judging from the newtonite analyses Ib and IIb, this substance would, under like circumstances, have one molecule of water of crystallization, but would be represented by the formula $Al_2O_3 \cdot 2SiO_2 \cdot 4H_2O + aq$, while the composition of halloysite would be expressed by the formula $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O + aq$.

Ordinary kaolin usually contains less than one per cent of loosely combined water. Hydrous silicates of alumina have, however, been analyzed in this laboratory, which have given off as much as five per cent of water at 110° C., but which differ from ordinary kaolin in no other respect, and it is probable that differences in origin and occurrence will account for these varying amounts of *loosely combined* water.

A thin section of newtonite under the microscope when viewed only with low powers appears as a perfectly amorphous substance but when magnified to four or five hundred diameters it shows that it is entirely made up of minute rhombs or squares. The largest of these are not more than $0·005^{mm}$ ($\frac{1}{5000}$ of an inch) on an edge, while the smallest appear to be about half that size. Sometimes they seem to form perfect squares but in the majority of cases the acute angles have values ranging from 88° to 89°, as nearly as could be measured. There appear between these minute figures blank spaces where nothing can at first be seen, but by sinking the microscope tube somewhat, so as to focus a little lower down, an entirely new set of rhombs is discovered, while those above go out of focus. At first sight all the rhombs appear as squares and show small indistinct lines running from their corners toward the center, giving the appearance of the hopper-shaped crystals of salt.

In addition to this there is a white rim about the edges which gives them the appearance of being higher than the rest of the surface. The cause of this is, however, not due to any marking or relief on the surface but probably to internal reflections whose origin it is hard to detect.

In polarized light the rhombs extinguish sharply parallel to their diagonals, thus showing that they are faces of some anisotropic material and not, as might be supposed, sections of cubes which had been cut more or less obliquely.

If these rhombs and squares are sections of rhombohedrons then one would expect to find also plane triangles corresponding to sections perpendicular to the principal axis. This, however, is not the case and only in a very few instances have any triangular forms been found and even then they are very indistinct and appear to be not in the upper surface of the plate but somewhat lower down. It is probable that in making sections of this material the individual crystals are not cut, but are either rubbed away entirely, or are left undisturbed, so that what are seen under the microscope are not sections but crystal faces. By means of a selenite plate the positions of the axes of greatest and least elasticity were determined, and were found to lie respectively parallel to the shorter and longer diagonals of the rhomb.

By powdering some of the material and allowing it to settle out from water, similar rhombohedral crystals were obtained.

Rectorite.

The second hydrous silicate of alumina, which is also to be regarded as new, is found in the Blue Mountain mining district in Marble Township, Garland county, 2 North, 19 West, section 27, about 24 miles nearly north of Hot Springs. It occurs in deposits which are very narrow near the surface but increase to the thickness of a foot or more in descending nine feet. Several such deposits have been found. The wall rock is sandstone probably of Lower Silurian age. Specimens of this mineral have been furnished by Messrs. Ware and Arnold of Hot Springs, who are interested in developing the deposit.

We propose the name *Rectorite* for this, the first member of the Kaolinite Series, in honor of Hon. E. W. Rector, of Hot Springs, Ark., who originated and has so unceasingly supported in the State Legislature the bills providing for the Geological Survey of Arkansas.

Rectorite, when pure, is a soft, white mineral occurring in large leaves or plates and resembling very closely in form that variety of asbestos known as "mountain leather," and at the same time having somewhat the soapy appearance of steatite. Parts of it are often pure white, while other portions are stained with hydrous oxide of iron and present a reddish-brown appearance. The sheets tear apart easily and are very flexible and perfectly non-elastic. Some specimens of this mineral have been obtained through the kindness of Mr. Charles F. Brown, of Hot Springs, in which fine doubly terminated quartz crystals are imbedded. Some of the latter are at least one and a half inches in length and when surrounded by the rectorite form very beautiful and striking specimens. The hardness of rectorite is less than that of talc—say 0·5—although this is difficult to estimate exactly. When heated in the flame of a Bunsen burner it loses water and becomes brittle. It is infusible before the blowpipe. Its behavior when treated with sulphuric acid and caustic potash will be explained below.

Two quantitative chemical analyses gave the following percentage composition calculated on the material dried at 110° C.:

	V.	VI.
SiO_2	52·72	52·88
Al_2O_3	36·60	35·51
Fe_2O_3 } once determined	0·25	0·25
CaO } once determined	0·45	0·45
MgO } once determined	0·51	0·51
K_2O } once determined	0·26	0·26
Na_2O } once determined	2·83	2·83
Loss on ignition	7·76	7·72
Total	101·38	100·41
Water at 110° C.	8·78	8·33

If these analyses be brought to 100 per cent, then all save silica, alumina, and loss on ignition be disregarded and the analyses again calculated to 100 per cent, the following figures result:

	Va.	VIa.	Theoretical for $Al_2O_3 . 2SiO_2 . H_2O$.
SiO_2	54·32	55·01	49·99
Al_2O_3	37·69	36·96	42·52
Loss on ignition	7·99	8·03	7·49
	100·00	100·00	100·00

If the calculations be made on the air-dried material the following figures are obtained:

	VIb.
SiO_2	50·18
Al_2O_3	33·72
Loss on ignition	7·32
Water at 110°–115° C.	8·78
	100·00

If the water given off at 110°–115° C. be regarded mainly as water of crystallization it is evident that it corresponds to one molecule, and the compound would have the formula, $Al_2O_3 . 2SiO_2 . H_2O + aq$.

Under the microscope a cleavage plate usually shows a few spots where it is evident that only one plate is included in the thickness, while the most of the section is made up of two or more plates lying one over another. In the single plate there is one comparatively distinct system of parallel lines in the direction of which a sharp extinction takes place. There is usually also a much less distinct system of lines which lie at nearly right angles to the first.* In the thicker portions of the plate two or more such pairs of line systems are often found superimposed one upon the other. In such cases the extinction parallel to either system is very indistinct.

The index of refraction is low—lower than that of Canada balsam—and the peculiar structure of the plates gives to the thin section, especially when viewed without the microscope, a peculiar undulating and glistening appearance.

In convergent polarized light, the simple plates show a strong double refraction, and give very beautiful biaxial interference figures. The acute bisectrix appears to stand perpendicular to the cleavage plane.† The angle between the hyperbolas varies much in size, in some cases being not more than 5°, and in others approaching nearer to 15° or 20°. The rings about the axes join each other forming ellipses so that the determination of the dispersion of the axes and bisectrix is uncertain. It appears, however, as if the angle for red were greater than that for blue, $\rho > \upsilon$. Dispersion of the bisectrix appears to be wanting. The fact that in many cases two plates lie one over the other gives rise to apparent optical anomalies which are, however, only caused by this superimposition. Thus in some cases beautiful examples of what is known as the "optical spectacles" (Optische Brillen) may be observed.

Among the inclusions of foreign material which appear in this substance may be mentioned the following: The hydrous oxide of iron, which has already been noted, appears in small round masses or globules, which are for the most part deposited between the individual plates of which the mass is made up. Some member of the pyroxene or amphibole group has also been observed lying in the cleavage planes.

These impurities occur in sufficiently large quantities to exert a decided influence over the results of the chemical

* 86° and 88° have been measured.

† A plate cut at right angles to the cleavage plane seemed to show extinction parallel and perpendicular to that plane, but owing to the wavy form of the plate it was impossible to determine it accurately.

analyses so that the discrepancy between them and the calculated formula may well be ascribed to this cause. There was, however, no mineral detected which would account for the relatively large amount of alkali shown by the analysis, and it is possible that the soda should be considered as replacing some of the water and be brought into the formula. Further investigation will probably throw some light on this point.

In view of the relatively large quantities of quartz of both macroscopic and microscopic dimensions, which have been observed intermixed with the rectorite, it may be allowable to consider the excess of silica found in the analyses as due principally to this cause. By recalculating the analysis after deducting just enough silica to bring that constituent down to the theoretical amount, the following percentages are obtained:

	Vc.	VIc.	Theoretical for $Al_2O_3 . 2SiO_2 . H_2O$.
SiO_2	49·99	49·99	49·99
Al_2O_3	41·26	41·08	42·52
H_2O	8·75	8·93	7·49
Total	100·00	100·00	100·00

In order to determine whether or not the soda found in the analyses really belonged to the rectorite, the following experiment was made. The mineral, in small flakes, was digested with concentrated hydrochloric acid for two hours on a sand bath. It was then washed and filtered, and the residue was boiled with sodic carbonate in order to remove any separated silica. The remaining substance was then washed with water, hydrochloric acid, and again with water, and was finally heated before the blast lamp. A portion of this dried and purified material was then analyzed with the following result:

	VII.
SiO_2	57·10
Al_2O_3	40·53
Sum	97·63
Impurities (undetermined)	2·37
Total	100·00

It appears from this that about half of the alkaline impurities were removed, but that the silica and alumina had approximately the same relative values as before. If the theoretical amount of water be introduced into this analysis, and the silica be diminished as in the preceding case, the analysis then expresses very nearly the theoretical composition.

Many points of similarity appear between rectorite and kaolinite, but in view of the peculiarity of the form which it assumes, and on account of its chemical composition, it is probable that it should be considered as a separate mineral.

In confirmation of the above opinion the statements of two manufacturers of ceramics to whom specimens of rectorite were sent for firing may be quoted.

Homer Laughlin, Esq., of East Liverpool, Ohio, writes: "The sample of what you call kaolinite, sent me, was duly received, and carefully examined and tested under fire. The mineral is neither kaolin nor kaolinite, but just what it should be called I am unable to say, never in all my experience having seen any mineral of its kind. Unlike kaolin it will not dissolve* in water. It burns a white color and becomes very vitreous and strong. It cannot be finished with a smooth face or skin, but roughs up like a blotting pad. It is certainly a very interesting and curious mineral, but I can think of no use for it in ceramic manufacture unless it could, after careful experiments, be made into novel ornaments."

Messrs. Oliphant & Company of the Delaware Pottery, Trenton, New Jersey, write: "Your sample of kaolinite came out of the kiln to-day, and would say that we are unable to make any report upon it. We do not know just what it is, therefore cannot say anything about its quality or market value."

It appears therefore from the above that its physical properties when subjected to heat do not correspond to those of kaolin.

Experiments were made in the laboratory on the relative solubility of newtonite and rectorite, and at the same time upon some specimens of true kaolin in the following manner:

The fine powder of the various substances was boiled with 10^{cc} of concentrated sulphuric acid for five minutes, after having been digested with it for three hours on a sand bath. It was then diluted, decanted, treated with a strong solution of potassium carbonate, washed with water and hydrochloric acid, filtered and weighed. In all the cases, the results were very similar, so much so in fact that no characteristic differences could be detected.

When treated with caustic potash the results were somewhat different in the different cases. Powder from each specimen was boiled with 10^{cc} of a saturated solution of caustic potash for 20 minutes, diluted, filtered, washed and treated with dilute hydrochloric acid. The white flocculent residue which remained after the treatment of the powder with caustic potash

* Mr. Laughlin does not mean dissolve in the chemical sense of the word, but disintegrate into a fine powder which remains partly in suspension.

dissolved readily in cold dilute hydrochloric acid in all cases except that of rectorite. In order to dissolve the residue from the latter it was necessary to use much stronger acid and even then the solution was not complete. The composition of this residue has not yet been determined.

From the foregoing facts and considerations, it is probable that three members out of the possible four, making up the above described series, are known, and the present status of the Kaolinite Series may therefore be concisely stated as follows:

KAOLINITE SERIES

1. Rectorite	$Al_2O_32SiO_2H_2O$ + aq.	Monoclinic (?).
2. Kaolinite and members	$Al_2O_32SiO_22H_2O$	Monoclinic or 0.
of the Kaolinite Group	$Al_2O_32SiO_22H_2O$ + aq.	0.
3.	$Al_2O_32SiO_23H_2O$.	
4. Newtonite	$Al_2O_32SiO_24H_2O$ + aq.	Rhombohedral.

In the case of other hydrous silicates of alumina, as well as of magnesia and other bases, similar homologous series could be formed, which would tend toward a more systematic arrangement of the species than now exists.

Chem. and Petrog. Laboratory of the Geol. Survey of Arkansas, Dec., 1890.

ART. III.—*On the Intensity of Sound.—II. The Energy used by Organ Pipes*; by CHARLES K. WEAD.

[Read in abstract at the Philadelphia meeting of the American Association, 1884.]

IN a former paper* the case of a vibrating tuning fork has been considered as an important example of sounding bodies that gradually expend the store of energy originally imparted to them. We have now to consider one of the class that can store up little or no energy, viz: an organ pipe; and have therefore to determine, not the rate of loss as with the fork and piano string, but the rate at which energy is supplied to the system from without. The experimental problem is very simple, and it seems strange that it has not been completely worked out.

The literature of the subject is very slight. Lord Rayleigh,† in an oft-quoted experiment, measured the pressure and volume of air supplied to a whistle of 2740 d. v., and so found the rate of consumption of energy. Several years earlier Mr. Bosanquet in a very interesting and valuable paper‡ discussed the relative amount of energy supplied to the several pipes of an

* This Journal, xxvi, 177, Sept., 1883.
† Proc. Roy. Soc., xxvi, 248.
‡ Phil. Mag., xliv, 1872.

Open Diapason stop in an organ, but gave no absolute amount. He assumes as a matter of general knowledge that an organ builder furnishes a series of pipes of sensibly equal loudness (and quality) throughout the scale; he quotes what he calls Töpfer's law, that the consumption of wind by pipes belonging to the same stop varies directly as the length of the pipe, and confirms it approximately by experiments; and so he concludes that the amount of energy per second necessary to produce sounds of equal loudness under similar conditions varies inversely as the vibration-frequency. On the other hand M. Allard* makes the assumption that the energy per second needed to maintain a sound just audible at a given distance varies directly as the vibration-frequency, and finds a satisfactory confirmation of his views in the experiments on the range of fog-horns made by various lighthouse boards. But the condition of the observer will be very different in the two cases; so they are scarcely comparable.

The experiments now to be detailed and discussed are sufficiently numerous and exact to disprove this alleged law of Töpfer's, so far at least as one organ is a fair sample of all. They were performed on a Hook and Hastings No. 11 Organ in the Congregational Church of Ann Arbor, Mich.; this instrument has two manuals of 58 keys each from C to a''', the great organ having 9 stops—the seven to be named in table I, a $2\frac{2}{3}'$ twelfth and a 3 rank mixture. The pressure of wind was very exactly 3 inches of water, and the total capacity of the bellows about 35 cubic feet; this quantity of wind would leak out in about 3 minutes.

The only method of experiment available, unless one has a very large gas-meter at his disposal, is to fill the bellows and determine the time needed for the whole or any definite part of its contents to leak out; then determine similarly the time when one or more pipes are sounding. For example, 12 cu. ft. ($=A$) of air are used; if this leaks out in 60 seconds the leakage is $A \div 60 = \cdot 20$ cu. ft. per sec.; if when a pipe is sounding the time is 24 sec., the flow is then $A \div 24 = \cdot 50$ cu. ft. per sec., and the pipe consumes the difference, that is 0·30 cu. ft. per second; if this is supplied under a pressure of 3 inches of water $= 15\cdot 6$ lbs. per sq. ft., the energy used by the pipe $= \cdot 30 \times 15\cdot 6 = 4\cdot 7$ ft. lbs. per sec. In this way the computations have been made for the tables.

Mr. Bosanquet limited his work to observing the times, and finding the difference of their reciprocals, thus getting the desired relative values. He used a string pendulum, finding the time needed for the bellows to empty itself, the "feel" of the blowing lever indicating when the bellows is full or empty.

* Comptes Rendus, xcv, 1062.

But the numbers he gives, especially for leakage, show such wide variations as to throw great doubt on the accuracy of the method. Therefore two modifications were made: first, a stop-watch indicating eighths of a second was used; and second, the movement of the wind-indicator above the key-board was observed through a space of 50^{mm}; to be sure only about one-third of the wind was used, but it is absolutely necessary to allow 10 to 20 seconds to elapse for the subsidence of the strong vibrations set up in the top of the bellows by the act of pumping. It was sometimes found that though no key was pressed the leakage was different according as the stop was drawn or closed, especially with one of the pedal stops.

One further modification of method was made: since the leakage is more than the amount of wind consumed by any single pipe, except a few of the largest, the influence of errors of observation was diminished by combining several pipes so that they might all sound at once; two ways of doing this were tried:

1. A single stop was drawn, and several consecutive white keys, usually eight, were held down by a loaded block; thus we find the relative consumption of wind by different stops, or by pipes of the same stop in different parts of the scale. See table I.

2. Several stops were drawn as in ordinary playing, and a single key held down by a wedge. In this case each pipe receives less wind than when no unison pipe is near, a fact long known and further established by these experiments; but we may still find the relative wind-supply in different parts of the scales. See table II and part of III.

Most of the results of the work can be given best in tabular form. In the tables the names of the stops need no explanation; where 9 stops were drawn they comprise all the stops drawn by the *forte* composition pedal, including the 7 named separately, a twelfth and a 3-rank mixture. The notation of the keys is used consistently always referring to the key, not the pitch, c' corresponding to middle c(=268 d. v.) when an 8′ stop is drawn; it will therefore be seen that the absolute pitch of all the notes in the lower part of table I is the same; while in the next table pipes of five different lengths, besides the mixtures will respond to a single key. L of course means leakage. The time given is the mean of from 3 to 8 observations: these agreed so well that the probable error of the mean is very rarely 1 per cent: take two examples at random;

Table III C $22\frac{4}{8}$, $22\frac{6}{8}$, $22\frac{6}{8}$, $22\frac{5}{8}$; mean 22·66 sec.

C–*c* $6\frac{3}{8}$, $6\frac{3}{8}$, $6\frac{5}{8}$, $6\frac{2}{8}$, $6\frac{2}{8}$; mean 6·375 sec.

The following columns contain respectively $1 \div t$, and this quantity diminished by the leakage: this remainder represents

TABLE I.—ONE STOP DRAWN; SEVERAL KEYS DEPRESSED.

1. Stop Drawn.	2. No. Keys.	3. Highest. Lowest.	4. t.	5. $1 \div t$.	6. V.	7. Ratio.	8. V'.	9. (6–8)÷8.	10. V''.	11. (6–10)÷10.	12. Energy.
			sec.		c c. $3{\cdot}4 \times 10^5 \times$		$3{\cdot}4 \times 10^5 \times$	per cent.	$3{\cdot}4 \times 10^5 \times$	per cent.	ergs. sec. $10^6 \times$
Leakage	0	----	56·2	·0178		----	----	----	----	----	----
8′ Open Diapason	8	C–c	5 44	·1838	·1660	----	·1635	+1·5	·1741	−4·7	415
″	8	c–c′	8·73	·1145	·0967	·569	·1014	−4·6	·1035	−6·5	242
″	8	c′–c″	11 94	·0838	·0660	·683	0628	+5·1	·0615	+7·3	165
″	8	c″–c‴	17·83	·0561	·0383	·580	·0389	−1·6	·0366	+4·6	96
″	8	a″–a‴	21·04	·0475	·0297	----	----	----	----	----	74
8′ Open Diapason	0	----	65·0	·0154	----	----	----	----	----	----	----
″	8	C–c	5·10	·1961	·1807	----	----	----	----	----	452
″	4	C–F	8·60	·1163	·1009	----	----	----	----	----	252
″	4	G–c	11·0	·0909	·0755	----	----	----	----	----	189
8′ Trumpet	8	C–c	10·25	·0976	·0822	----	·0766	+ 7·	----	----	206
″	8	c–c′	16·00	·0625	·0471	·573	·0549	−14·	----	----	118
″	8	c′–c″	18·21	·0549	·0395	·839	·0377	+ 5·	----	----	99
″	8	c″–c‴	23·71	·0421	·0267	·660	·0264	− 1·	----	----	67
2′ Fifteenth	8	C–c	9·75	·1026	·0872	----	·0815	+ 7·	·0896	− 2·7	218
″	8	c–c′	16·16	·0619	·0465	·533	·0533	−13·	·0533	−13·	116
″	8	c′–c″	18·96	·0527	·0373	·802	·0365	+ 2·	·0317	+18·	93
16′ Bourdon	8	c′–c″	12·54	·0797	·0643	----	----	----	----	----	161
″	8	c″–c‴	16·29	·0614	·0460	·71	----	----	----	----	115
16′ Bourdon	8	c″–c‴	16·29	·0614	·0460	----	----	----	----	----	115
8′ Open Diapason	8	c′–c″	11·06	·0904	·0750	----	----	----	----	----	188
8′ Melodia	8	″	14·50	·0690	·0536	----	----	----	----	----	134
8′ Dulciana	8	″	17·83	·0561	·0407	----	----	----	----	----	102
8′ Trumpet	8	″	18·06	·0554	·0400	----	----	----	----	----	100
4′ Octave	8	c–c′	14·28	·0700	·0546	----	----	----	----	----	137
2′ Fifteenth	8	C–c	9·75	·1026	·0872	----	----	----	----	----	218

that fraction of the total volume of wind which goes to the pipe: the total volume was found by measuring the bellows and the distance it fell while the indicator moved 50 mm.; this was 11·9 cu. ft. = 337000 cc. (say $3·4 \times 10^5$cc.) with an uncertainty of 1 or 2 per cent on account of the folds: this uncertainty, however, does not affect the relative values given in the tables, for it is an uncertainty in our knowledge, not in the action of the bellows.

Table II.—Nine Stops Drawn; One Key Depressed.

July 21.

1. Key.	2. *t.*	3. 1÷*t.*	4. V.	5. Comp. *V.*	6. 4÷5.	7. 6÷5.	8. Energy.
	sec.		c. c. $3·4 \times 10^5 \times$	$3·4 \times 10^5 \times$	$3·4 \times 10^5 \times$	per cent.	ergs. sec. $10^6 \times$
L	67·37	·0148	----	----	----	----	----
C	12·35	·0810	·0662	·0652	+·0010	+1·5	165
C ♯	12·94	·0773	·0625	·0625	0	0	156
D	13·32	·0751	·0603	·0598	+ 5	+ ·8	151
D ♯	13·03	·0767	·0619	·0573	+ 46	+8·0	155
E	15·25	·0656	·0508	·0549	— 41	—7·6	127
F	14·56	·0687	·0539	·0526	+ 13	+2·5	135
F ♯	15·69	·0637	·0489	·0504	— 15	—3·0	122
G	16·00	·0625	·0477	·0483	— 6	—1·3	119
G	16·79	·0596	·0448	·0463	— 15	—3·2	112
A	17·08	·0586	·0438	·0443	— 5	—1·1	110
A ♯	17·21	·0581	·0433	·0424	+ 9	+2·1	108
B	18·65	·0536	·0388	·0407	— 19	—4·7	97
c	17·58	·0569	·0421	·0390	+ 31	+8·0	105
L	67·43			Mean		±3·4	----

July 28.

1. Key.	2. *t.*	3. 1÷*t.*	4. V.	8. Energy.	1. Key.	2. *t.*	3. 1÷*t.*	4. V.	8. Energy.
			c. c. $3·4 \times 10^5 \times$	ergs. sec. $10^6 \times$				c. c. $3·4 \times 10^5 \times$	ergs. sec. $10^6 \times$
L	77·37	·0129	----	----	*g*	24·29	·0412	·0286	71
c	17·87	·0560	·0431	108	*g* ♯	24·37	·0410	·0285	71
c ♯	18·69	·0535	·0407	102	*a*	26 04	·0384	·0259	65
d	20·54	·0487	·0359	90	*a* ♯	22·83	·0438	·0313	78
d ♯	21·21	·0471	·0344	86	*b*	27·33	·0366	·0242	60
e	23·25	·0430	·0303	76	*c′*	26·79	·0373	·0249	62
f	24·21	·0413	·0286	71	L	80·81	·0124	----	----
f ♯	24·10	·0415	·0289	72					

The energy is found by multiplying the volume by the pressure, which was 15·6 lbs. per sq. ft. or 7·6 gms. per sq. cm.

∴ Total energy = $11·9 \times 15·6 = 186$ ft. lbs. $= 2·5 \times 10^9$ ergs.

By this multiply the fractions in columns headed V, as col. 6 table I.

The numbers in the column ratio (except in table I-V) are found by dividing the number against which they are placed by the preceding one; if Töpfer's law were true these ratios would be for the octave everywhere ·500.

TABLE III.—MISCELLANEOUS.

1. Stops drawn.	2. Key.	3. t.	4. $1 \div t$.	5. V.	6. Ratio.	7. Energy.
		sec.		c. c. $3{\cdot}4 \times 10^5 \times$		ergs. sec. $10^6 \times$
16′ Bourdon	L	69·44	0144		----	
	C	22 66	·0441	·0297	----	74
	D	28·59	·0350	·0206	----	52
	E	33·22	.0301	·0157	----	39
	F	33·50	·0299	·0155	----	39
	C	35·59	·0281	·0137	----	34
	A	38·04	·0263	·0119	----	30
	B	39·58	·0253	·0109	----	27
	C	32·37	·0309	·0165	----	41
	C–*c*	6·375	·1569	·1425	----	356
8′ Open Diapason, Melodia, Dulciana	L	69·62	·0144	----	----	----
	C	18·21	·0549	·0405	----	101
	c	26·62	·0376	·0232	·572	58
	c′	35·25	·0284	·0140	·603	35
	c″	43·69	·0229	·0085	·608	21
9 stops	L	70·6	·0142	----	----	----
	C	12·37	·0808	·0667	----	167
	c	17·96	·0557	·0415	·632	104
	c′	26·00	·0385	·0243	·586	61
	c″	34·25	·0292	·0150	·619	38
	c‴	44·62	·0224	·0083	·550	21
9 stops	L	80·62	·0124	----	For 17th.	----
	C	12·42	·0805	·0681	----	170
	e	23·25	·0430	·0306	·449	77
	g′♯	37·46	·0267	·0143	·467	36
	c‴	47·92	·0209	·0085	·592	21

In several cases the results have been discussed mathematically and thus a computed value of V' is found (T. I, col. 8; T. II, col. 5): in these cases an exponential formula was assumed similar to that for the vibration-frequency of the tones in a tempered scale, and the logarithmic formulæ derived from it were combined by the method of least squares; thus

$$yr^n = V$$

$$\log y + n \log r - \log V = 0$$

Whence $$(n+1) \log y + \Sigma(n) \log r - \Sigma(\log V) = 0$$

$$\Sigma(n) \log y + \Sigma(n^2) \log r - \Sigma(n \log V) = 0$$

The values of r thus found are collected in table IV. The difference between the computed and observed values of V is divided by the former and the quotient, as a per cent, is placed in a following column. To obtain V'' in cols. 10 and 11, table I, the ratio was assumed as $\sqrt[4]{\frac{1}{8}}$.

Observations of the same quantity on different days agree to within a few per cent (e. g. key C with 9 stops, ·0662, ·0667, ·0681) but since they differ more than the probable error of a single day's observations the results in the different tables should not be combined if accurate relative values are desired, nor should results in the same table be combined unless they are based on the same value of L. The data for table I were obtained in April and May, 1883, and are not quite as accurate as the data obtained in July, 1884, for the later tables.

Conclusions.—The results of experiments with *different stops* are shown in table I It is very clear from them that no exact or important conclusions can be drawn from the loudness of the sound as to the relative quantity of wind required to blow pipes of different construction: thus, the soft Dulciana takes more than half as much wind as the comparatively loud Open Diapason (102÷188). Again, the Trumpet stop in this organ is voiced very loud, yet its pipes require absolutely less energy than any others that sound the same note: this is a conclusive proof that a reed-pipe has a much higher efficiency as a wave-producing mechanism than a flue pipe.

The results on *different pipes* of the same stop or of the same combination of stops are shown in all the tables; in table I for the eight notes of an octave taken together in various parts of the scale, a single stop being drawn; in table II for each of the twenty-five notes in a range of two octaves, nine stops being drawn; in table III for various combinations of stops. Some of the conclusions from these are very clear, and some curious. We must assume with Mr. Bosanquet that a set of pipes gives us a series of sounds of the same quality and of nearly the same loudness as judged by the ear of an expert, and also assume that all pipes of the same stop are equally efficient sound-producers. Now if we recall Töpfer's law, that the consumption of wind varies inversely as the length of the pipe, we should expect to find for the octave approximately the ratio ·500, or a little less, since the higher pipes are relatively larger than the lower ones and so must be relatively shorter. But not a single ratio can be found in the tables to confirm this view; everywhere the ratio is considerably greater than ·5. The tables give the values in a dozen cases (not including the Trumpet stop) and from table II a dozen more values can readily be found.

To some of the observations it seemed worth while to apply the method of least squares as already said; the several ratios found for the octave are given in table IV.

If a smooth exponential curve be drawn with these ratios for the experiments of table I, where eight keys were depressed at once, it will be found to fall below the experimental curve in the first and third octaves, and above it in the second and fourth octaves in every case examined; the magnitude of the difference is shown in column 9; but this alternating deviation is not great, and is probably not of importance; it does not appear in table III, where several stops are combined.

TABLE IV.

Table.	Stop drawn.	No. keys.	Range, Octaves.	Number equations.	Ratio.	Av. Difference per cent.
I	Trumpet.	8	4	4	·701	± 7
I	Open Diapason.	8	4	4	·620	± 3·2
I	Fifteenth.	8	3	2	·654	±10
I	Bourdon.	8	2	--	·71	--
III	Three stops.	1	3	4	·595	±1·4
III	Nine stops.	1	4	5	·595	±2·4
III	"	1	4	4	·591	±7
II	"	1	1	13	·5975	±3·4

The latter half of table IV shows that when the stops were combined as in ordinary playing, but a single key being pressed, there is a remarkable constancy in the value of the ratio for the octave however it is determined, and its value for the Open Diapason differs little from these latter values. This constancy demands an explanation. According to Töpfer's law we should have $\cdot 50 = \sqrt[3]{\frac{1}{8}}$; we do have very nearly $\sqrt[4]{\frac{1}{8}} = \cdot 5946 = 1 \div 1\cdot 682$. This I believe to be an excellent illustration of the unconscious recognition by the artist of the physical or mathematical laws underlying his art. At present we cannot explain the law, any more than the laws of the scale could be explained before the subject of harmonic overtones was understood; we can only correlate this with the following fact relating to organ-pipes—to their diameter, or "scale" as organ-builders call it. It is a matter of experience that to produce the proper loudness of sound it is necessary to increase the ratio of the diameter to the length as the pipe becomes shorter, so when the pitch rises an octave and the theoretical length becomes one-half that of the fundamental the diameter is greater than half that of the fundamental; usually we must go to the seventeenth pipe, as from C to *e*, to find the one of half the diameter. This is equivalent to saying that in rising 4 octaves the theoretical length becomes $(\frac{1}{2})^4$, but the diameter $(\frac{1}{2})^3$; if we assume an exponential series all the way up the ratio of diameters of pipes an octave apart is therefore $(\frac{1}{2})^{\frac{3}{4}}$ or $\sqrt[4]{\frac{1}{8}}$,—the ratio already found; the corresponding ratio for the semitone is of course $(\frac{1}{2})^{\frac{1}{16}} = \cdot 9576$. This ratio for the diameters is only a mathematical expression of a mechanical *fact*, there is no theory about it. Such a "scale" gives convenient rules in practice for laying out the pipes, and satisfies the ear, or it would not have found such general adoption. In this organ Open Diapason c' has an internal diameter of 57 mm., the e'' of $29\frac{1}{2}$; the Dulciana c' of 31, the e'' of $15\frac{1}{2}$*. It is not for a moment to be assumed that the amount of wind required is directly determined by the diameter of the pipe; for the organ builder would point out that the shape of the mouth is an important factor, and that the voicer or finisher varies the amount of wind by plugging the holes through the feet of wood pipes, cutting out or closing the feet of metal pipes, varying the width of the slit for the wind, etc., till his ear is satisfied with the loudness and quality of the sound. But in the light of these experiments we must conclude that for similar pipes the volume of air used per second, and therefore the energy expended per second, varies as the $\frac{3}{4}$-power of the wave-length of the note, or inversely as the $\frac{3}{4}$-power of the vibration-ratio; and further conclude that the voicer unconsciously strives to secure this ratio just as the tuner unconsciously strives to get the familiar vibration-ratios in the tuning of any instrument. It is to be remembered that we cannot recognize small differences of intensity with much accuracy. Volkman could always detect a difference of 25 per cent; Renz & Wolf† one of 28 per cent; the latter experimenters

*In Clarke's little book on "The Pipe Organ" a simple construction is given for finding the diameters of intermediate pipes when the diameters are given for two pipes 16, 8, 4, &c. semitones apart. At the ends of any convenient base line AB erect perpendiculars AC, BD proportional to the given diameters and join the ends C, D: Draw the two diagonals of the trapezoid thus formed and erect through their point of intersection a perpendicular to the base line. The part of this perpendicular between AB and CD is proportional to the diameter of the pipe midway between the given extremes. By continuing the construction the diameters of the other pipes will be obtained.

A little calculation shows that this gives a harmonic series, and if the first diameter be 2, and the seventeenth 1, the series is 32 ÷ 16, 17, 18 . . . 31, 32. All of the intermediate quotients are slightly less than the numbers derived from the exponential series whose ratio is the 16th root of $\frac{1}{2}$, the value for the 8ve being $\frac{16}{28} = \cdot 571$ instead of $\cdot 5946$. The maximum difference is about 5 per cent—a quantity entirely negligible to ordinary ears.

If a series of pipes were made on this harmonic scale and the quantities of wind could be accurately adjusted in the ratio of the diameters, an exponential curve deduced from experiments on them would show an "alternating deviation" similar to that referred to above. The sign of the deviation in a given 8ve would depend on where the starting point of the harmonic scale was taken.

The sum of 8 terms of the harmonic series corresponding to the key of C, the lowest term being 1, is 5·95; of the same terms of the exponential series 6·19; of 13 terms in the exponential series 9·4 Therefore to find the amount of wind (or of energy) used by the lowest pipe of any group of eight in the tables divide by 6 the amount given for the group.

† Pogg. Ann., xcviii, 595, 1856.

were correct in their judgments about the loudness of sound of a watch when held at different distances in only 55 per cent of their trials if the ratio of loudness in the two cases (computed from the law of inverse squares) was 100 : 92. In the light of such experiments the numbers headed per cent of difference in our tables are strikingly small in nearly every case—partly of course because of the method of averages we have followed, a number of pipes sounding at once in most cases.

It is interesting to compare the energy used here with that of a tuning fork. From table IV of my former paper (p. 186) it appears that the maximum energy I could give by bowing to König's forks of the middle octave mounted on their cases was considerably less than $0{\cdot}5 \times 10^6$ ergs.; and the maximum rate at which energy was lost was about $0{\cdot}1 \times 10^6$ ergs. per sec. But the Open Diapason pipes of this range ($c'-c''$) used each from 18 to 30×10^6 ergs. per sec., some 250 times as much as the fork giving its maximum sound, or from 1,000 to 6,000 times as much as the fork when giving an ordinary sound. About one-millionth of one horse-power would maintain in ordinary vibration one of these forks; and a tenth of this amount gave a sound loud enough to be heard 200 feet in the open air.

There remains one question of some interest: Do all parts of the scale *seem to the ear* to be of equal loudness, especially the scale of an organ for which we have found the relative intensity of vibration. I find few musicians who have any definite impression on the subject; the question is certainly difficult, and is perhaps indefinite. If, for example, we call that sound the louder which can be heard at the greater distance and then compute the energy passing through the unit of surface at the limit of hearing, we make the violent assumption that the efficiency of the two sound-producers is the same. If we place the two bodies at the same distance Mayer* has shown that the sensation of one sound may be obliterated by a lower one that could not be heard as far off as the first. And there are other physiological difficulties. In fact the problem before us is analogous to the long-standing one of the comparison of two lights of different colors. The problem must, therefore, be left as insoluble with our present knowledge; but two statements of musicians are of interest in this connection. One organist points out that if a piece of music is played on a two or three manual organ, the left hand on the swell keyboard, while the melody is played by the right hand on the great, and the swell-boards are opened to give a proper balance

* Phil. Mag., ii, 500.

of tone, the boards will be found to be too widely opened when the left hand plays the melody on the great key-board and the right on the swell, the stops remaining unchanged. Another points out that if, with a single stop or combination of stops, one runs over the key-board ascending the effect is of a *crescendo.* This would indicate that the organ-builder intentionally makes the higher pipes louder instead of keeping them of equal loudness as assumed previously, and also shows that the ear is more sensitive to high notes than to low ones under the conditions in which music is heard, whatever the case may be with foghorns heard at sea and reported by Allard.

Some time after the preceding experiments had been discussed and reported on Mr. F. H. Hastings kindly furnished the writer with a copy of Töpfer's great work,* and a summary of his views may fitly be connected with this paper. Through many hundred pages the author discusses the theory of organ pipes and gives formulæ for their dimensions, and for the quantity of wind they require. He determined this last experimentally by the method already described, using a bellows of 63 cubic feet capacity; 9 min. 57 sec. were required for this volume of air to leak out under a pressure of 3·2 Weimar inches of water (= 76^{mm}), (II, 95). The experiments must have been very tedious with so large a bellows; they are open to the criticism that the leakage is greater than the wind-consumption of any pipe, except a few of the largest ones; so errors of observation make large errors in the final result, as previously pointed out.

The author's theory on the subject is curious. He says (II, 65) pipes of equal length consume volumes of wind proportioned to the squares of their diameter, and those of the same diameter quantities inversely proportional to the square root of their length, [or directly proportional to the square root of the vibration frequency].

Therefore $$Q = K \frac{D}{\sqrt{L}}$$

$Q\sqrt{L} \div D^2 = K' =$ coefficient which measures "intensity of vibration."

$Q\sqrt{L} \div$ area of mouth $= K'' =$ coefficient which measures "sharpness of tone."

Q is expressed in Weimar cu. in. per sec.

K' is found to range from 68 to 110, average 85:

K'' from 394 to 536, average 450.

* J. G. Töpfer: Lehrbuch der Orgelbaukunst. Weimar, 1855. About 1,800 pages and 130 plates folio. Mr. Hastings calls it "by far the most complete book on organ building."

For all the pipes of any given stop K′ and K″ should remain constant (pp. 99, 112). This assumption underlies his elaborate table of "normal scales." But his experiments do not seem to establish this constancy. Thus, for the 16 ft. Principal:

	Length.	Q.	K′.	K″.	
e′	20″	61·5	91·7	496	
e°	40″3‴	99	72·5	408	
E°	82·6	177	58	352	
E′	100·4	162	25·6	165	tone dull.

In other cases the values of K′ and K″ vary considerably without showing any regular increase.

The second constant, K″, appears to be in some sense a measure of the quality of the note, the note being duller as K″ is smaller. For pipes of the same length obviously K′ is proportioned to the mass of air used per unit section of the pipe, and so to the energy of vibration at any point *within* the pipe, if we make the violent assumption of equal efficiency for pipes of all diameters. In the same way K″ is proportioned to the energy of vibration at the mouth. But we are not concerned with the intensity of vibration *in* the pipe; we want the external effect due to the total cross-section.

The introduction of the square root of the length has no physical meaning or justification that I can discover; but it is needed to make all parts of Töpfer's theory hang together. This may be shown as follows: Assuming equal temperament and that diameters double at the 17th pipe, and putting a for the diameter of any pipe, the diameter of the nth pipe above becomes:

$$D = a\,(\tfrac{1}{2})^{\frac{n}{16}}$$

Similarly for length

$$L = b\,(\tfrac{1}{2})^{\frac{n}{12}}$$

And for quantities of wind on Töpfer's assumption

$$Q = c\,(\tfrac{1}{2})^{\frac{n}{12}}$$

$$\therefore\ Q \div D^2 = (\tfrac{1}{2})^{-\frac{n}{24}}\,c/a^2. \quad QL^{\frac{1}{2}} \div D^2 = c\,b^{\frac{1}{2}}/a^2 = K'.$$

Evidently it is necessary to introduce $L^{\frac{1}{2}}$ to obtain a constant factor.

Töpfer then goes on to establish a "scale" or series of diameters for a set of pipes. He has found in tables published by Dom Bedos in 1766, on whose work his own treatise is largely based, that the ratio of sections of pipes differing an 8ve in pitch ranges between 1:4 and 1:2; experience shows that these are extreme; so it is safe to take their mean 1: $\sqrt{8}$.

Again, it is found he tells us (p. 153–4) that in practice the quantities of wind used are nearly as 1 : 2 for the 8ve, sometimes less, and fortifies himself by a quotation from Chladni (Akustik, p. 233): that if two tones of different pitch are to have equal effect the forces which each vibration exerts must be inversely as its vibration-frequency; but this force is proportional to the mass of air used; therefore Q varies inversely as n.

By the proceeding formula

$$Q = K'D^2L^{-\frac{1}{2}}; \quad q = K'd^2l^{-\frac{1}{2}}$$

If the pipes are an 8ve apart $L = 2l$ and $Q = 2q$:

Then $$\frac{Q}{q} = \frac{D^2}{d^2}\sqrt{\frac{l}{L}} = 2 = \frac{D^2}{d^2}\sqrt{\frac{1}{2}}$$

$$\therefore D^2 = d^2\sqrt{8} = 2{\cdot}83d^2; \quad D = d\sqrt[4]{8} = d \times 2^{\frac{3}{4}}$$

This proof is clearly very unsatisfactory; but the "scale" thus determined, and published by Töpfer in 1832, has been largely used by organ builders. By it pipes 4 8ves, 48 semitones apart, have diameters in the ratio of 1 : 8, or pipes 16 semitones apart, a major 10th, are in the ratio of 1 : 2.

Another scale may be had by letting the 16th pipe (15 semitones) have the double diameter; the ratio for the 8ve is then 1 : 3, or more accurately $1 : \sqrt[5]{16} = 1 : 3{\cdot}032$. But the bass pipes have too little wind.

If, on the other hand, the 18th pipe (17 semitones) have the double (or half) diameter, the ratio is $1 : 4^{\frac{12}{17}}$ or 1 : 2·661; the higher pipes are relatively "sharper." This defect may be corrected by cutting their mouths lower, and conversely for the low pipes, remembering that for "gleiche Klangstärke" the quantity of wind and therefore the area of mouth must be in the ratio of $1 : \sqrt{8}$ for the 8ve (p. 244). If, in the last case, the ratio of height of mouth to breadth be for c' 0·25, it will be for c^6 0·23, for C^2 0·41.

Another scale might be formed doubling the diameter at the 19th pipe; the same correction is to be made but its execution is doubtful. A uniform quality is the first condition in a stop (p. 295).

The author then goes on to apply his theories to the laying down of several "normal scales;" these all have 121 pipes, 60 each way from No. 61 assumed 27‴ (53^{mm}) diameter. In these tables we find, for example, with the ratio of sections:

$1 : \sqrt{8} = 1 : 2{\cdot}83$, diam. No. 1, 363·2‴;	No. 61, 27‴;	No. 121, 2‴
$1 : 8/3 = 1 : 2{\cdot}67$	311·8	27	2·3
$1 : 5/2 = 1 : 2{\cdot}5$	272·1	27	2·7

From these 121 theoretical diameters for each scale a consecutive series to be chosen for each stop. He finds in practice that for a large number of stops the first ratio is suitable; for an ordinary Principal c' should have the diameter of No. 62; for a Wide Principal, No. 58 is suitable. But for many stops this ratio is not satisfactory; the tone must be fuller in the upper parts; for a given list of stops the ratio 1 : 2·67 is better; the diameter of c' ranges between No. 55 for the Wide Principal Bass, and No. 77 for the Viola d'Amour. For the Pedal stops and some others he advises the ratio 1 : 2·5.

This is a very brief summary of the portions of Töpfer's voluminous work that relate to the physical side of organ building. It does not appear that the questions involved have been thought out from the standpoint of the physicist, or that the author's views are entirely consistent. Mr. Bosanquet credits to Töpfer the law that the quantities of wind belonging to the same stop vary as the lengths of the pipes. I have not been able to find any statement to this effect more definite than the one already quoted from p. 153–4, that the quantities of wind used are nearly as 1 : 2 for the 8ve, sometimes more, sometimes less; but on p. 200 he gives the theoretical quantities for the successive C's through 9 octaves, and the ratio for the 8ve I find to be 1 : 1·99. But on the other hand he states positively, as already quoted, that the quantity of wind must be as $1 : \sqrt{8}$ for the 8ve; that is, as the sections of the pipes in his first "normal scale." In other words, his most definite statement makes the quantities for the 8ve as $1 : \sqrt{8}$; his alleged law and Mr. Bosanquet's experiments give the ratio $1 : \sqrt[3]{8}$, and my experiments give the ratio $1 : \sqrt[4]{8}$; these ratios are as $1 : \sqrt[4]{64}$, $\sqrt[4]{16}$, $\sqrt[4]{8}$. While it is unsafe to dogmatize on a matter that must vary according to the circumstances of the case, the character of the stop, the location of the pipes, the size of the hall where they are to sound, the judgment of the finisher, etc., etc., I have no hesitation in expressing my belief that the last ratio, or one still nearer unity, will usually be found nearer the truth than either of the others.

Feb., 1891.

Art. IV.—*New Analyses of Astrophyllite and Tscheffkinite;* by L. G. Eakins.

I. *Astrophyllite.*

Near the noted cryolite locality at St. Peters dome in the Pike's Peak region of Colorado, there was found some years ago an unusually fine lot of astrophyllite, and in such a pure condition that it was thought a new analysis would be not without interest notwithstanding the fact that material from the same region had already been analyzed by König.*

This astrophyllite occurs in large, brittle, micaceous blades, golden to brownish yellow in color, and perfectly free from admixed minerals, such as zircon; the only foreign matter being on the ends or sides of the blades which were in contact with the containing rock; so that pure material for analysis was readily obtained. In this analysis the zirconia was separated by a modification of the hydrogen peroxide method and weighed directly, being subsequently identified qualitatively. For comparison with this analysis, those made by König and by Bäckström† are added in the table below. König's being the one previously referred to, of material from the same region, and Bäckström's of the Eikaholmen mineral.

	Eakins.		König.		Bäckström.	
	Analysis.	Molecular ratio.	Analysis.	Molecular ratio.	Analysis.	Molecular ratio.
Ta_2O_5	0·34	·001	0·80	·002		
SiO_2	35·23	·587	34·68	·578	33·02	·550
TiO_2	11·40	·143	13·58	·170	11·11	·139
ZrO_2	1·21	·010	2·20	·018	3.65	·030
Fe_2O_3	3·73	·024	6·56	·041	2·53	·016
Al_2O_3	*tr.*		0·70	·007	0·98	·009
FeO	29·02	·403	26·10	·362	21·76	·302
MnO	5·52	·078	3·48	·049	11·96	·169
CaO	0·22	·004			1·26	·023
MgO	0·13	·003	0·30	·008	0·92	·023
K_2O	5·42	·058	5·01	·053	5·78	·062
Na_2O	3·63	·059	2·54	·041	2·77	·045
H_2O	4·18	·232	3·54	·197	3·47	·193
			CuO ·42	·006	F 0·97	·051
	100·03		99·91		100·18	

From a discussion of these analyses of Bäckström and König, Brögger deduces the general formula: $R''_4R'_4Si(SiO_4)_4$ for astrophyllite. It will be seen that my analysis closely confirms this formula, agreeing with it better in fact than those from which it was derived. Calculating the small amount of ferric oxide present in with the R'' group, the molecular ratios of my analysis give the following elementary proportions:

$$Si_{587}O_{2389}Ti(Zr)_{153}R''_{536}R'_{234}H_{464}$$

this reduces to:

* Proc. Am. Phil. Soc. Philada., xvi, 509, 1877.

† Given by Brögger in:—Groth's Zeitschrift, vol. xvi. W. C. Brögger, Die Mineralien der Syenitpegmatitgänge, etc.

$$Si_4O_{16\cdot3}Ti_{1\cdot04}R''_{3\cdot65}\underbrace{R'_{1\cdot6}H_{3\cdot1}}_{4\cdot7}$$

which is quite close to $R''_4R'_4Ti(SiO_4)_4$, the excess of the R′ group is presumably due to the percentage of water being somewhat too large, this may result from incipient alteration of the mineral, which may also be the cause of the variation in color.

II. *Tscheffkinite.*

A fragment of this rare mineral was last year sent to the National Museum by Mr. Horace M. Engle, of Roanoke, Va. And upon its identification he very kindly presented all at his disposal for the purpose of investigation; in addition to some small fragments there was one large mass, which before breaking weighed over three and one-half kilograms, most of it now being in the museum collection. It was found in Bedford Co., Va., a point considerably farther south than the locality of the material analyzed by Price.* The various pieces of this tscheffkinite when found were all more or less rounded nodules, with a superficial brownish yellow ochreous coating, evidently an alteration product, which at some later date may be made the subject of investigation to endeavor to determine the method of alteration. The beginning of this alteration was also seen in the numerous fissure planes developed in breaking up these nodules. Examination of a fresh surface showed a distinctly banded structure of lustrous black and dull black material, the bands varying from mere lines to over five millimeters in width. As well as could be these two differently appearing substances were separated and each analyzed by itself, such separation however was only approximate, as under a magnifying glass it was seen that each band contained veins of the other. Analysis I is that of the lustrous part, and II that of the dull.

Duplicate determinations confirmed these specific gravities, the seemingly more altered one being the higher. The action of acids on the powdered materials shows a marked difference, the lustrous portion being completely decomposed in a few minutes by warm and moderately strong hydrochloric, sulphuric or nitric acids, while an hour or more was necessary to decompose the dull portion under similar conditions. A fire assay of a fragment of this tscheffkinite was made by Mr. E. L. Howard, of the U. S. Geological Survey and gave 0·74 oz. of silver per ton.

These analyses show that the two bands are practically identical in composition, the dull being somewhat more hydrated. The molecular ratios seem to lead to no definite or satisfactory

* R. C. Price, Am. Chem. Journal, Jan., 1888.

formula, a result quite in accordance with the evidence furnished by the microscopical examination of sections. For this purpose chips were taken showing both bands, but as in the case of the chemical analysis, they were seen to be practically the same.

	I. Analysis.	I. Molecular ratio.	II. Analysis.	II. Molecular ratio.
Ta_2O_5	0·08		0·08	
SiO_2	20·21	·337	21·49	·358
TiO_2	18·78	·235	18·99	·237
ZrO_2	*tr.*(?)		*tr.*(?)	
ThO_2	0·85	·003	0·75	·003
$(Y, Er)_2O_3$	1·82*	·006	1·64†	·005
$(La, Di)_2O_3$	19·72	·059	17·16	·052
Ce_2O_3	20·05	·061	19·08	·058
Al_2O_3	3·60	·035	3·65	·036
Fe_2O_3	1·88	·012	2·89	·018
FeO	6·91	·096	5·92	·082
CaO	4·05	·072	5·24	·094
MgO	0·55	·014	0 48	·012
Na_2O	0·06	·001	0·04	·001
H_2O	0·94	·052	2·06	·114
	99·50		99·47	

Specific gravity, 4·33 at 27°. Specific gravity, 4·38 at 22°·2.

I am indebted to Mr. Whitman Cross, of the U. S. Geological Survey, for the following notes on the thin sections: "The sections consist mainly of reddish and yellowish brown transparent amorphous substance, apparently the original material, this is traversed in all directions by cracks from which there has proceeded a decomposition producing a reddish brown opaque ochreous matter which fills the cracks and replaces the original material so that in certain spots there is now merely a network of the two substances. In each section there are two parallel bands of secondary minerals nothing corresponding to which was detected in the chips before the sections were made. These bands consist chiefly of two colorless minerals, the more abundant occurring in irregular grains closely resembling calcite in strength of refraction and double refraction ; the other occurs in rounded grains and is probably sphene. In addition to the two colorless minerals in these bands, there also appear two brownish substances, one of which has distinct prisms without terminal planes, shows strong pleochroism and its absorption parallel to the vertical axis is so strong as to make it opaque, while at right angles to this axis it is yellow-brown. More abundant than this prismatic mineral is one occurring in apparent flakes

* Molecular weight=308. † Molecular weight=312.

of reddish-brown color, it is doubly refracting, but not strongly pleochroic, and cannot be identified with any of the substances already mentioned. Adjacent to these bands, and replacing the amorphous material to varying distances is still another substance, in general appearance similar to the prismatic mineral, but evidently different as it shows no very marked absorption. This mineral is also strongly pleochroic, varying from yellow-brown to chestnut-brown. All of it in the sections seems to have a uniform crystallographic orientation, the cause of this uniformity not being apparent. Its relations to the amorphous substance are similar to those which I have observed in several instances between crystalline allanite and the amorphous variety."

The microscopical examination having shown this tscheffkinite to be such a mixture, it became desirable to examine others in the same way.

The only one available for this purpose was that analyzed by Price, a specimen of which is in the National Museum collection. This specimen has the same general appearance and banded structure as my own. Chips were taken from it for sections which Mr. Cross examined and found to be in every respect similar to the other, about the only noticeable difference being in Price's material a somewhat greater development of the opaque ochreous decomposition product of the transparent amorphous substance than in mine, and a lesser development of the colorless minerals.

Taking into consideration the results of this work, and the manifest contradictions of most of the earlier analyses, it seems reasonable to conclude that, unless one of the earlier analyses can be shown to have been made on pure material, the so-called tscheffkinite is not a mineral in any strict construction of the word, but merely a mixture; the structure of the chemically complex body or bodies evidently its basis being a problem to be elucidated in the future when purer material may be found.

Laboratory, U. S. Geological Survey,
Washington, D. C., March, 1891.

ART. V.—*The Minerals in hollow Spherulites of Rhyolite from Glade Creek, Wyoming;* by J. P. IDDINGS and S. L. PENFIELD.

THE occurrence of fayalite with quartz, tridymite and soda-orthoclase or sanidine in the lithophysæ and hollow spherulites of the obsidian at Obsidian Cliff, Yellowstone National Park,* has been described by one of the writers of the present paper, the mineralogical investigation of the fayalite and sanidine having been carried on by the other writer. Recently we have had occasion to call attention to the occurrence of fayalite in obsidian at Lipari and Vulcano in the Mediterranean,† and have observed that the modes of occurrence are alike in both regions, and that the causes leading to the crystallization of fayalite in these magmas must have been the same, namely: the action of superheated vapors, presumably of water, upon the magmas before their final consolidation and cooling.

In the present paper we wish to contribute further to the knowledge of these aqueo-igneous products in siliceous lavas, by describing a somewhat different development of hollow spherulites in rhyolite at the forks of Glade Creek, a tributary of the Snake River, just south of the boundary of the Yellowstone National Park. This locality was visited by us in the summer of 1886. The rhyolite forms a high bluff of massive rock, exhibiting great contortion of banding or planes of flow. The spur between the two branches of the stream rises some 1200 feet above the valley, and presents a section of the great rhyolite sheet which forms the mass of Pitchstone Plateau, lying to the north.

The rock at the forks of Glade Creek is dark gray, dull, lusterless and lithoidal, with a rough hackly fracture. It carries many phenocrysts of a white plagioclase, less numerous glassy sanidines and quartzes, and many rusted crystals, which prove to be more or less altered augites. Through this mass are scattered cavities with light gray or white walls, which are partially filled with crystals. The cavities vary in size from that of a walnut to almost nothing. They are irregular in shape, but the spherical form of the light colored walls suggests at once that they are the cavities of very hollow spherulites. They are, in fact, wide-gaping spherulites like some of those found at Obsidian Cliff.‡ Occasionally there are

*J. P. Iddings, Obsidian Cliff, Yellowstone National Park, Seventh Annual Report of the Director of the U. S. Geological Survey, Washington, 1888.

† Iddings and Penfield, Fayalite in the obsidian of Lipari. This Journal, vol. xl, July, 1890.

‡ l. c. p. 264, and Plate XII, figs. 1 and 5.

indications of spherical zones near the outer margin of the shell, but no radial fibration can be observed macroscopically. There is nothing in the arrangement of the comparatively large crystals within the cavity which suggests either a radiation from the center, or the concentric shelly structure of lithophysæ.

An examination with the microscope proves that there is a radial fibration in the outer shell of these spherulites. And since certain of the minerals which are characteristic of the central portion are found in the shell also, it is evident that the formation of the outer and inner parts of these spherulites was contemporaneous. There are also small irregular cavities containing the same well-developed crystals, which have no definite spherulitic walls, but are surrounded by white crystalline margins, which extend irregularly into the surrounding rock. The same thing also occurs in small crystalline patches and streaks in the ground-mass of the rock, like the more crystalline portions of the laminated lithoidite at Obsidian Cliff.* The massive rhyolite at Glade Creek also passes to the westward into laminated lithoidal rhyolite with open layers filled with the same minerals as those in the hollow spherulites.

The light colored crystalline portions just mentioned, when examined with a lens, are found to be dotted with minute round pits about as large as the point of a pin. At first sight they appear to be small colorless grains of some mineral like quartz, but closer investigation shows them to be hollow. Their relation to the crystalline material about them is revealed by a microscopical study of the rock.

Thin sections of the rock show it to be a rhyolite similar to much of the lithoidal rhyolite of the neighboring region, except for a greater amount of augite phenocrysts. The porphyritical quartz, sanidine and plagioclase need no special mention, being like those of most rhyolites. Magnetite forms quite large grains, associated with the augite, often having zircon crystals attached to them. The augite is light greenish yellow, and is somewhat rounded. It is partly altered to brown iron oxide, which penetrates cracks in the crystals. In some instances it is entirely decomposed, leaving a pseudomorph of brown iron oxide.

The ground-mass of the rock is spherulitic throughout, with here and there spaces between groups of spherulites which are composed of crystals of feldspar with tridymite or quartz. Short opaque trichites and sharply defined crystals of magnetite are scattered uniformly through the mass, or are arranged in lines which mark the flow structure. The microscopic spheru-

* L. c., p. 264.

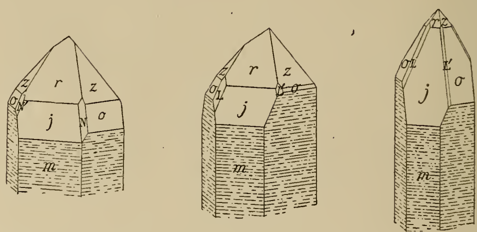
lites are distinctly radially fibrous, the rays being relatively coarse or prismatic. The outline of the spherules is not evenly circular, but irregularly jagged, especially when they adjoin areas of tridymite and quartz. Here the rays of the spherules develop into definite prismatic crystals, and have the optical characters of orthoclase in prisms elongated parallel to the inclined axis, *ȧ*. They have a slight extinction angle, reaching 10°, and have the axis of greatest elasticity parallel to the length of the prism. The spherulites, therefore, behave as though made up of optically negative prisms. In one rock section they appear to have more of a granophyric structure, with a feather-like texture within the feldspar prisms. The fine fibers producing this effect do not reach the end of the best developed prisms, leaving them terminated by clear feldspar substances, as in the case of the granophyric phenocryst in the rhyolite of Eureka, Nevada, described in the article on Obsidian Cliff already referred to.* In these spherulites the presence of quartz within the feldspar is indicated by this micro-structure, but in the first mentioned spherulites there is nothing to suggest its presence, except the highly siliceous nature of the rock. Since it is only the marginal terminations of the feldspar prisms which are determinable as such, the central portion of the spherulites may be more complex without its being recognized, for a small amount of quartz would not materially affect the optical character of the feldspar. The light colored, crystalline portions of the rock with the minute pits are seen under the microscope to be more highly crystallized parts of the groundmass. They combine the spherulitic structure with a more or less granular one. The little cavities are found to be hollows at the centre of small feldspar spherulites, which are made up of feldspar prisms whose ends project irregularly inward into the cavities and outward into the adjoining minerals. The cavities appear to be minute spots once occupied by vapor or some liquid, around which feldspar crystallized in prisms radiating outward. In the crystalline patches the tridymite lies in various orientations, and through it in all directions run what look like transparent needles, which in some cases also radiate out from the coarser micro-spherulites. They are dull between crossed nicols, and might easily be mistaken for apatite, but their optical characters are also those of sanidine prisms that have developed parallel to the axis of greatest elasticity. This is shown to be the case in a thin section of another rhyolite in which the same structure has been developed on a somewhat larger scale. In the rhyolite from Glade Creek, quartz some-

* L. c., p. 275, Plate XV, fig. 5.

times occupies the place of tridymite between the feldspar crystals.

The mineral which is most abundant in the hollow spherulites is quartz, occurring in stout crystals, seldom over 2^{mm} in diameter (in one instance 5^{mm}), very transparent and with a pale smoky color; also in slender white prisms, 10^{mm} long. The latter are sometimes clear and transparent in part, but are mostly full of cracks, and many of them are covered with a crust of hyalite. The hyalite is isotropic, and has minute microlites of feldspar scattered through it. Both the stout, clear quartz crystals, and the slender white prisms occur together in the same spherulite, and in a number of instances it was observed that the clear crystals are deposited on a nearly flat side of the cavity, while the white prisms, intersecting in all directions, make up a sort of net work which rises above it in a dome-shaped mass. The first impression is that the transparent quartz crystallized in a shallow basin in a liquid while the upper portion crystallized in a vapor. This hypothesis is, however, untenable, since in some cases, the transparent crystals in the hollows of one rock specimen,

1. 2. 3.



coat walls which are not symmetrically disposed to one another and hence could not represent the same water level. Transparent, stout, quartz crystals are attached to the walls of the cavity so that only one termination or one side of the prism is free; in the net work of slender white prisms, however, doubly terminated crystals occur. These quartz crystals proved on examination to be very interesting. They are not highly modified, but possess some faces with very simple indices which are exceedingly rare, even on highly modified quartz crystals, giving therefore a type of crystallization which, to our knowledge, is altogether new for this common mineral. They all show, in addition to the common quartz forms (prism *m*, $10\bar{1}0$, I, always horizontally striated, and the rhombohedrons *r*, $10\bar{1}1$, 1 and *z*, $01\bar{1}1$, -1) steep rhombohedrons *j*, $30\bar{3}2$, $\frac{3}{2}$ and *σ*, $03\bar{3}2$, $-\frac{3}{2}$ and narrow trapezohedral faces N and L $\pm \frac{3}{2}-\frac{3}{2}$, which lie in the zone between *j* and *σ* and also in the zone *z*, *r* and *m*. The rhombohedrons *j* and *σ* are not mentioned by G. Rose* in his classical paper on quartz. Des Cloizeaux,† in his very extensive monograph on the crystallization of quartz was the first to observe these forms. During his investigation he added twenty-one new positive rhombohedrons to the seven which were already known. Of the $+\frac{3}{2}$ rhombohedron *j* he says: "this has been found on two crystals from Traversella, on a large crystal from Brazil, and upon a little crystal from Ala. Its measurement is a little uncertain as it always presents rounded faces. Among the considerations which favor the acceptance of this rhombohedron is the occurrence of the negative $\frac{3}{2}$ form." He also added twenty-five new negative rhombohedrons to the five which were already known. Of the $-\frac{3}{2}$ rhombohedron *σ* he says: "this rhombohedron has been observed upon twenty-three crystals from Traversella, and upon many crystals from Valais. The mean of fifty-four measurements, in spite of a slight rounding of the faces, leaves no doubt of its symbol." On the crystals from Glade Creek both *j* and *σ* are perfect as regards luster and freedom from striations. They may be detected on nearly all crystals and sometimes they are largely developed. Figures 1 and 2 represent the relative size and development of these faces on two of the transparent stout crystals which were detached for measurement, and figure 3, the greater development of them at one end of a slender white prism. In the majority of cases, the edges between *j* and *σ* are replaced by trapezohedral faces having the simple parameter relation $\frac{3}{2}-\frac{3}{2}$; moreover all of the four possible trapezohedral forms with the above parameter relation were observed. On the right-handed crystal represented in fig. 1, N, $21\bar{3}2$, $+r$ $\frac{3}{2}-\frac{3}{2}$, and N′, $3\bar{2}\bar{1}2$, $-r$ $\frac{3}{2}-\frac{3}{2}$ occur, while on the left-handed crystals represented in figs. 2 and 3, L, $3\bar{1}\bar{2}2$, $+l$ $\frac{3}{2}-\frac{3}{2}$ and L′, $12\bar{3}2$, $-l$ $\frac{3}{2}-\frac{3}{2}$ occur. DesCloizeaux also observed these forms and says of N $+\frac{3}{2}-\frac{3}{2}$ "this very rare form has been observed only upon the very remarkable crystal from Brazil. As it is very narrow and a little rounded its measurement could not be made very exactly; however its angle upon *r*, calculated for the symbol here adopted, differs very little from the mean of the observation and its very simple symbol, being the inverse of the probable face L, $-\frac{3}{2}-\frac{3}{2}$, point to its existence." Of L, $-\frac{3}{2}-\frac{3}{2}$, indicated by DesCloizeaux with (?) as a probable but not certain form, he says: "this very simple symbol can be applied to a face observed upon many

* Abh. Akad. Berlin, 1844, p. 217. † Ann. Ch. Phys., 1855, p. 129.

crystals from Traversella. This face is always brilliant but so much rounded that upon measuring upon *z* one can indifferently arrive at a number of approximations according as one stops at the upper, central or lower part of the broad reflection which it furnishes." On the crystals from Glade Creek, N and N′ and L and L′ are faultless as regards luster and absence of striations and rounding. An idea of the prominence of these faces may be obtained from figs. 1, 2 and 3 where their relative size and development on three of the measured crystals has been presei ved as far as possible. They undoubtedly occur both as positive *r* and negative *r*, and as positive *l* and negative *l*; their persistency in replacing all of the edges between *j* and *σ* would indicate this as well as the results of an experiment in etching one of the crystals with hydrofluoric acid. The crystal represented in fig. 1, was thus proved to be a right-handed twin. The greater part of *r* and *j* in front, and all of N were positive, as was also the greater portion of the faces lettered *z* and *σ*, the twinning boundaries running very unequally over these faces; while the face lettered N′ was both positive and negative, the positive part being deeply etched while the acid had almost no action on the negative portion. Left-handed crystals were not etched, but it is safe to infer from the development of L and L′, that they are both positive and negative. Right and left forms were not observed in the same crystal. On the goniometer the reflections from all of the faces except *m* were very perfect, and the following measurements were made.

	Calculated.	Measured.			
$z \wedge r$	46° 15′ 52″	46° 15′			
$r \wedge$ (N or L)	17° 22′ 43″	17° 24′			
$j \wedge \sigma$	52° 33′ 20″	52° 32′	52° 33′	52° 32½′	52° 35′
$j \wedge$ (N or L)	16° 56′	16° 55½′	16° 57′	16° 57′	
$r \wedge j$ or $z \wedge \sigma$	10° 31′	10° 33′	10° 32′		

We have also examined the quartz crystals in the lithophysæ of Obsidian Cliff, Yellowstone National Park, and find that they too have the habit which we have just described. They are always very small, seldom over $\frac{1}{8}^{mm}$ in diameter, but some were found which were so perfect that they gave excellent reflections and could be accurately measured on the goniometer. They generally have the habit represented in figs. 1 and 2, although sometimes *j* and *σ* were as fully developed as in fig. 3. The N and L faces seldom failed. The crystals were so small that the positive and negative character of the rhombohedrons could not well be distinguished. In most cases however a $\frac{3}{2}$ rhombohedron was observed between the unit rhombohedron and prism. Measurements were mostly made in the vertical zone *m*, *j*, *r*, over the apex of the crystal on *z*, *σ*, *m*. The prism faces were always so much striated that no satisfactory measurements could be made from them. The measurements are as follows:

	Calculated.	Measured.						
$r \wedge z$ over base,	103° 34′	103° 35½	103° 33′	103° 34′	103° 35	103° 35′		
$r \wedge j$ or $z \wedge \sigma$,	10 31	10 42	10 47	10 35	10 29	10 45	10° 35′	10° 19′
$r \wedge z$ adjoining,	46 16	46 17						
$r \wedge$ N,	17 23	17 19						

On several crystals a second rhombohedron having the symbol $\frac{10}{7}$, (10·0. $\bar{1}$0·7) was observed, occurring either alone with *r*, *z* and *m*, or between *j* and *r* and *σ* and *z*. It had a relatively large size and gave distinct reflections; its measurement on to *r* and *z*, is as follows:

Calculated.	Measured.				
9° 21′	9° 45′,	9° 25′,	9° 38′	9° 52′,	9° 43′.

The occurrence in the hollow spherulites of this very unusual development of quartz, as well as its association with the rare mineral fayalite, may be taken to indicate that the crystals were formed under conditions which do not usually prevail. On the highly modified quartz crystals from Alexander Co., N. C., *j*, *σ* and L were frequently observed by vom Rath,* but the crystals from Glade Creek, and Obsidian Cliff, are very different in showing these rare forms well-developed on otherwise very simple crystals.

Tridymite is present in some of the cavities in characteristic crossed twins, and is abundant in thin sections of the rock.

The most noticeable mineral next to quartz is fayalite. It forms stout crystals about 1^{mm} long with very much the same habit as those represented by fig. 2, in our paper "On the occurrence of Fayalite in the lithophysæ of obsidian and rhyolite in the Yellowstone National Park,"† or by fig. 54 in the paper on Obsidian Cliff already cited.‡ They have undergone more or less alteration to iron oxide and are now opaque and black. Some are still transparent at the centre. When tested chemically they give decided reactions for both iron and magnesium. This may indicate that the unaltered fayalite is rich in magnesium. There is not sufficient unaltered material at hand to undertake a complete chemical analysis. The occurrence of the fayalite at Glade Creek is quite the same as that in other hollow spherulites in the rhyolites at various localities in the Yellowstone National Park.

* Zeitschr. Kryst., x. p. 156.

† This Journal, vol. xxx, July, 1885, p. 59.

‡ L. c. p. 271.

In some of the more irregular cavities of the rock, at Glade Creek, there are accumulations of sanidine crystals of very small size. Occasionally they exhibit a blue iridescence, and when magnified are seen to have the same crystal habit as those in the lithoidite of Obsidian Cliff,* that is, they are thin tablets parallel to the basal plane, with the clinopinacoid, prism and two orthodomes less highly developed. The chemical analysis of these uncommon sanidines from Obsidian Cliff showed the presence of one molecule of soda to one of potash. In some of the hollow spherulites there are very small crystals of hornblende about $\frac{1}{2}^{mm}$ long. They form stout prisms with brilliant faces, and appear to be terminated by the basal plane and unit pyramid. In thin section they are brown. They are not found in most of the cavities. Biotite is also observed, in a few cases, in very small particles built up of thin hexagonal crystals with parallel orientation. They yield an almost uniaxial negative interference figure between crossed nicols. Both the hornblende and biotite occur sparingly in small crystals within the groundmass of the rock. These minerals are not found in the same cavities with fayalite.

In conclusion, we find that in the rhyolite of Glade Creek, as in the obsidian of Obsidian Cliff, fayalite occurs in association with abundant quartz, as the result of the mineralizing action of vapors in the cooling acid lava. The quartz in both localities has a peculiar development, remarkable alike for its simplicity, rarity and perfection. These minerals are accompanied by an uncommon form of sanidine, and by tridymite. Moreover in certain hollow spherulites the fayalite is wanting, and in its place are hornblende and biotite.

ART. VI.—*Bernardinite: Is it a Mineral or a Fungus?*† by JOSEPH STANLEY-BROWN.

TWELVE years ago Prof. J. M. Stillman announced through this Journal‡ his discovery of "a new mineral resin from San Bernardino Co., Cal.," and proposed for it the name "Bernardinite." The specimens were sent to him by farmers who, finding them among rocks, supposed them to be derived from veins.

While engaged in geological work in northeastern California during the summer and fall of 1890, Mr. A. B. Frost, of Susanville, called my attention to the occurrence of bernardinite near Eagle Lake. Search for the mineral was unrewarded for the

* L. c. p. 267, figs. 51 and 52.

† Abstract of a paper read before the Washington Phil. Soc., Mar. 14, 1890, and now printed by permission of the Director of the U. S. Geol. Survey.

‡ This Jour., vol. xviii, page 57.

reason that it is more likely to be found on tree trunks than in veins. During the winter the excellent specimen used in the preparation of the accompanying illustration was forwarded by Mr. Frost, who stated that it was cut from a live pine tree near Eagle Lake. Bits of adhering bark can be seen in figure 1, which is a little less than half size. Professor Stillman generously placed at my disposal a piece of the original material and their comparison and study were taken up.

As the description of the "mineral resin" answers equally well for the recently obtained specimen it is quoted here. "It presents a nearly white mass, friable, light and porous, containing much enclosed air so that it floats on water like cork. On fracture it presents a slightly fibrous structure. Under the microscope it exhibits a two-fold structure—a quantity of very fine irregular fibers permeating a mass of a brittle, amorphous, structureless substance." Nothing more need be added, save to call attention to the concentric form of growth and to the remnants of tubes.

Macroscopically and chemically the two specimens appear to be identical. No improvement of Professor Stillman's careful analysis was attempted, and its duplication was only carried to the point of identification. Both substances agree in melting imperfectly at 140° and in softening at temperatures below 100; they are insoluble in water; 86 to 90 per cent dissolves in alcohol—the solutions being of a slightly yellow color, marked bitter taste and acid reaction; residues from solution are white and amorphous; the alcoholic extracts burn with smoky flame leaving a trace of ash; they are much less soluble in ether than in alcohol. Professor Stillman found further that his material was soluble in caustic potash, and from such solutions a purified tasteless mass could be precipitated by hydrochloric acid, also that the filtrate evaporated to dryness yielded a "waxy substance" of intensely bitter taste. Taking into account hygroscopic moisture and ash, his analysis gave:

Carbon	64·46
Hydrogen (not in water)	8·75
Oxygen " "	22·80
H_2O	3·87
Ash	0·12
	100·00

Dr. H. N. Stokes, of the Chemical Division of the Geological Survey, gave it such consideration as pressure of work would permit, and says in regard to it: "In continuous extraction with alcohol the 'bernardinite' left a residue of 7·56 per cent, and your specimen a residue of 6·08 per cent. The appearance of the residue under the microscope is the same in

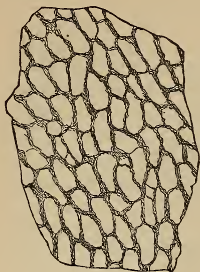


Fig. 4.

Fig. 1.

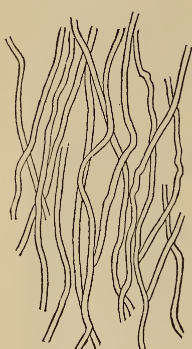


Fig. 5.

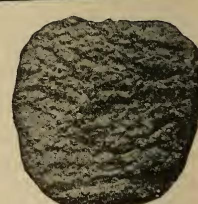


Fig. 3.

Fig. 2.

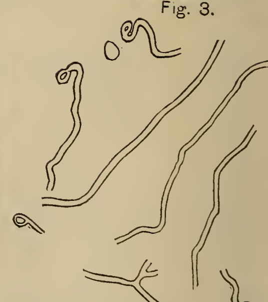


Fig. 6.

each case, consisting of fine fibers, mixed with some granules. I have not had time to prove that the substance [fiber] is cellulose, but it appears to be, being insoluble in all neutral solvents and unacted upon by bromine water. The alcoholic solutions being evaporated to dryness, left a crystalline residue. The mass of the residue is crystalline—the crystals being imbedded in some amorphous substance. The crystalline substance is a mixture of crystalline acids, which form soluble crystalline salts. The appearance in each case is the same, and I therefore do not hesitate to pronounce the two specimens identical."

My petrographic microscope showed clearly the structural similarity of the substances and suggested a fungous origin, and a botanical authority was sought in Mr. F. H. Knowlton whose examination of a fragment of each piece, with a biological microscope, not only confirmed previous testimony as to identity, but indicated their fungous character with certainty.

Assuming that the sameness of the specimens has been established, a brief reference to the nature, origin and structure of the substance may be given.

Professor Stillman expressed the belief* that it was a resinous secretion which, having fallen from some species of conifer, was covered with debris, lost all traces of volatile and soluble matter, became permeated and splintered by a fungous growth and being mixed with surface soil, would easily be mistaken by untrained observers for material *in situ.* Considering the fact that Professor Stillman did not see the bernardinite (?) in place and that the specimens available for his guidance were fragmental, stained and weathered, it is remarkable he should have been able to give so plain a hint as to its character and source. But the truth of the matter probably is, that the fungous growth is responsible for the presence of the resin and not the resin for the fungus growth. Through the kindness of Professor Gallaway of the Agricultural Department, the large specimen was referred to Mr. J. B. Ellis, of Plainfield, N. J., an authority on fungi, and it was by him recognized as the fungus "*Polyporous officinalis* Fries." As already noted its home is on the pine tree and it probably occurs over a wide area, for it is found on *Pinus strobus* of Michigan, and a specimen has just been sent to the National Museum from Wyoming. A glance at figure 2, which is about half the natural size, shows clearly the ring-like growth and the remains of tubes. Figure 3 is from a photograph of a small piece of Professor Stillman's original material and is full size.

A microscopical examination of a thin section shows the features represented in figure 4. A somewhat regular arrangement of granules is seen (indicated by the lighter color), which

* This Jour., vol. xx, page 93.

are apparently enclosed in a network of fibers. The granules are about a millimeter in width and vary from two to three milimeters in length, and when carefully removed and fractured they break up into transparent irregular particles. If the granules are dissolved in alcohol there remains a mass of microscopic mycelial threads indicated by the hair lines in figure 4, and more clearly shown in figure 5. Miss Southworth,* of the Agricultural Department, after studying both specimens, declared them to be identical, and found that these microscopic fibers are arranged in a more or less parallel manner, and sometimes great numbers are closely bound together or wound around each other, forming a distinct branching cord up to half a millimeter in diameter. The fibers are also branching, wavy in outline, with thick colorless wall, narrow thread-like lumen, and occasional swellings. They are often terminated by forms such as are seen in figure 6, and there are other features which must, however, be left to the mycologist to investigate.

Just what function this resinous material plays in the life of the plant is not now known. Its presence can hardly be accidental, for its association with the fungus is persistent over a wide area. It is difficult to conceive of a fungus penetrating a mass of resin with such regularity. It would seem more probable that the irritation of its presence caused an exudation from the tree which was appropriated by the fungus either for its nourishment or its preservation from destruction.

A final word concerning the supposed medicinal and historical character of the fungus may be interesting.

Mr. W. W. Calkins of Chicago, who has described a specimen obtained from Michigan, asserts that this substance is employed by lumbermen, and was used by soldiers during the war, as a substitute for quinine, and that its tonic effect is undoubted. Attention was called by Mr. Ellis to the statement by Fries that the old Greek botanist Dioscorides was acquainted with this fungus and its medicinal qualities and that it is mentioned in his "Materia Medica," published during the reign of Nero. Those engaged in therapeutic research may find the study of the intensely bitter "waxy substance" obtained by Professor Stillman interesting.

If there has been an accurate determination and presentation of the facts involved, there only remains the question: Can the substance confined within the meshes of this fungus be properly considered a new or even a true mineral resin? Should not bernardinite disappear from mineralogic literature and be found only in the future in that referring to the venerable *Polyporous officinalis?*

Washington, D. C., March, 1891.

* Miss Southworth made drawings 5 and 6.

ART. VII. — *Development of Bilobites;* by CHARLES E. BEECHER, PH.D. (With Plate I.)

THE Linnean species so well known under the name of *Orthis biloba*, and so widely distributed in the Silurian rocks of the world, represents one of the very distinct members into which the Orthis group is now divided. It is much removed from ordinary Orthis in general external features, and only by means of developmental characters is it possible to arrive at any idea of its genetic history.

After having been referred to various genera, including Anomia, Terebratula, Delthyris, and Spirifer, by different authors prior to 1848, Davidson* first showed conclusively, from a study of the internal characters, that the true relations were with the genus Orthis. Its position has since remained unchallenged, and subsequent investigation has not brought forth any new characters, nor invalidated the results obtained by Davidson. The additional observations here made concerning the development of the shell, while adding to our knowledge of the species, merely serve to bind more closely this form to the group having the broad designation of Orthis. Prof. King in 1850† proposed the genus *Dicœlosia* for this species, on account of its characteristic form, and authors disposed to divide Orthis have recognized this name. Since then, it has been shown that Linné gave the generic term *Bilobites* to the type species of King's genus, and this name is now generally adopted with the rank of a subgenus. The validity of the specific names applied to variations from the typical form is not of much moment in this place, although the geologic history and interpretation of these differences are of considerable interest. Two well-defined varieties or species are recognized in Sweden, and are represented in outline by figures 2 and 28, Plate I. The prevailing form in the Wenlock shales at Dudley, England, agrees with figure 28, and also represents the ordinary form from the Niagara Group of Indiana and New York. Each locality, however, presents minor differences, mainly of local interest, and seldom of varietal importance. In Western New York, besides the ordinary form with both valves convex there is found an arcuate, deeply bilobed variety, agreeing with the extreme of the Swedish *B. bilobus*, var. *Verneuilianus* Lm., represented in figure 2. The lobes of the New York variety are commonly more divergent, as shown

* Bull. Soc. Géol. France, 2d ser., vol. v, p. 321, t. 3, fig. 18, 1848.
† Monograph Permian fossils, page 106, 1850.

in the outline, figure 1. This form was recently described by Ringueberg, as *Orthis acutiloba.**

The Lower Helderberg species known as *B. varicus* Conrad, sp., presents an amount of departure from typical *B. bilobus*, as would be anticipated from the change in the chronological and physical conditions of the species, combined with its extremely prolific development at this time. The abundance and comparatively large size of individuals clearly indicate most favorable conditions for their existence and multiplication, and, also, for the assumption and transmission of any varietal forms in harmony with the environment.

Mature individuals from Dudley, England, and Gotland, Sweden, represented by figure 28, correspond in all characters with specimens of *B. varicus* which are about half or two-thirds grown. After reaching the adult *bilobus* stage, *B. varicus* continues its growth, but this subsequent increment is geratologic in its nature, although such senile features are here the conditions of simple maturity or the completed ephebolic stage. Evidences of this are seen in the gradual obsolescence of the pronounced lobation of the shell and the cessation of areal growth in the nealogic period. The form known as *B. bilobus*, var. *Verneuilianus*, Lm., from Gotland, shows a tendency to develop in the opposite direction, as the lobation becomes more and more pronounced with growth, and the shell exceeds in size the normal species. The decrease in the lobation of *B. varicus* is a degeneration towards an embryonic character, while the arrested areal development produces a condition of partial isomorphism resembling one of the higher groups of Orthis, such as Rhipidomella (*R. Michelini* Lév).

From what has been stated, it seems evident, that the form typified by *B. bilobus* from the Niagara was, at that time, not a very plastic type, and capable of only slight degrees of variation or departure from the normal form. Naturally, all the modifications which occur containing a differentiation of the essential idea of the genus appear in the early history of the group, and are found previous to the Lower Helderberg form. The latter species while losing, in a manner, its *bilobus* expression at maturity, degenerates into forms resembling ancestral and other groups.

The material for the basis of this paper was collected by the writer from the lower members of the Shaly Limestone of the Lower Helderberg group, along the top of the main escarpment of the Helderberg Mountains, between Clarksville and the Indian Ladder, Albany County, New York. Half-

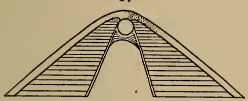
* Proceedings of the Academy of Natural Sciences, Philadelphia, p. 134, 1888.

grown and fully developed specimens of *Bilobites varicus*, Conrad, sp., can still be picked up in considerable numbers in the soil formed of the decomposed limestones. The species, however, is not so abundant as formerly. Professor James Hall is authority for the statement (Pal. N. Y., vol. iii, p. 493), that forty thousand individuals were collected between 1843 and 1853, and about four thousand in the four following years. The young specimens have been obtained only by carefully examining the decomposed surfaces of the limestones, and by treating with hydrochloric acid slabs of rock in which the fossils are replaced by silica. After considerable labor and search, about a thousand individuals have been obtained. From this number, it has been possible to select a series of over forty specimens, showing stages of growth ranging from shells a little less than one-half a millimeter in length to a length of nine millimeters; thus representing the development between these limits by almost insensible gradations.

Developmental Changes in Bilobites varicus.

In the youngest specimens yet detected, measuring ·49^{mm} in length, and semi-elliptical in outline, the dorsal valve is longer than the ventral; the hinge is equal to the greatest width of the shell; both areas are high, subequal, and perforate by a triangular fissure in each valve. In rare instances, the pedicle covering, or pseudo-deltidium, is retained in young shells. Figure 1 of the ventral area, shows the fissure and pedicle covering, with the foramen at the apex of the beak. The covering is soon absorbed or abraded during subsequent growth, and the pedicle then emerged through the fissure below. None of these characters obtain in the nealogic or ephebolic stages, which are represented by a cordate, bilobed shell; dorsal valve shorter than the ventral; hinge line much shorter than the width of the shell, and an inconspicuous dorsal area without a fissure.

1.



B. varicus, ventral area. ×25.

The series of outlines, figures 11 to 26, drawn to the same scale, illustrate both the important changes which take place in the general form, and the corresponding increase in size from stage to stage. The rounded frontal margin of figures 11 and 12, becomes straight in figure 13, and in figure 14 a gentle sinus is apparent, which is pronounced in figure 15, and thereafter is the conspicuous character of the entire shell up to the ephebolic stage represented by figure 23. Figures 24 and 25 show that upon reaching maturity a geratologic tendency to obliterate the marginal sinus is initiated; thus degenerating to an embryonal condition of lobation similar to figure 14.

The length of the hinge line from an initial dimension equal to the greatest width of the shell becomes equal to but one-half the width of the shell in a specimen 3·5^{mm} wide; and in a full grown individual, as represented by figure 25, the hinge is not more than one-quarter the width of the shell. From having subequal areas, the change is rapid, so that in a very early stage, but two or three removes from the initial one of the series, the ventral area is the larger and the fissure higher. This ratio progressively increases, and after the shell reaches a length of 1·5^{mm}, the dorsal area ceases to be a conspicuous feature. All areal growth and hinge extension end in the middle nealogic period, and to this cause is due the great disparity between the length of the hinge and the width of the shell in ephebolic individuals. The nepionic shells show some extension of the cardinal angles, but the auriculation does not become apparent until the lobation of the valves is initiated.

On account of the greater length of the incipient dorsal valve and consequent obliquity of the area, the fissure and area of that valve may be seen when the shell is viewed from the ventral side, as in figure 10, and, consequently, the ventral area is concealed from the dorsal aspect, as shown in figures 3–9, and 11–15. This is a remarkable reversion of characters, and one which appears to be of considerable significance from a phylogenetic standpoint.

The radiating striæ first appear on the lower half of the initial shell of the series, indicating that in an earlier condition, the shell was smooth. The striæ appear in pairs. The first two striæ extend to the antero-lateral borders. An additional intercalated pair is next introduced, together with a single one on each side between the primary radii and the cardinal border. The number after this stage is more rapidly increased by increment in the cardinal lateral areas than in the median region.

Observations.—As shown in the ontogeny of *B. varicus*, the generic stock was derived from a radicle having, in many respects, the characters of the group represented by *Platystrophia biforata.* The general proportions of the nepionic shell in *B. varicus* resemble it very closely. The length of the hinge at this period, the high hinge areas in both valves, with subequal triangular fissures, and the extent of the dorsal and ventral beaks, are characters very much the same as in *Platystrophia biforata.*

These features are maintained until the nealogic stage represented by figure 15, after which arrested hinge extension and increasing areal growth in the ventral valve rapidly obliterate the early characters, and in addition, the growing lobation of the valves emphasizes the expression of Bilobites.

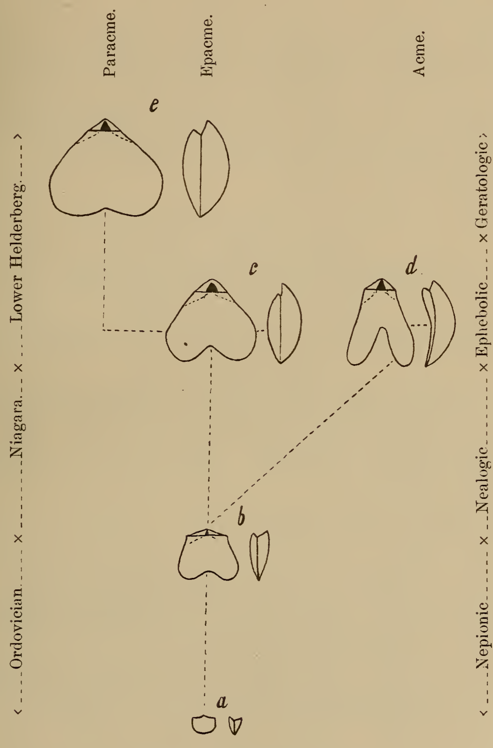


FIGURE 2.—Genesis of Bilobites.

a, nepionic stage (× 4). Ordovician type like *Platystrophia biforata*.
b, nealogic period (× 4) at which divergence begins.
c, *Bilobites bilobus* (× 2). Epacmic form, Niagara horizon.
d, *Bilobites Vearneuilianus* (× 2). Acmic form, Niagara horizon.
e, *Bilobites varicus* (× 2). Paracmic form, Lower Helderberg horizon.

The genesis of the species is represented in the accompanying illustrations, in which it is shown, that all these species are alike in their development up to an early nealogic period, figure *b*. *B. Verneuilianus*, figure *d*, diverges at this point, progressively increasing its variation from the normal direct growth, as exemplified in *B. bilobus*, figure *c*. *B. varicus*, figure *e*, passes through all the *bilobus* stages, and culminates in larger individuals, with less pronounced lobation of the shell.

The direct line of development, or the epacme, is represented by *B. bilobus*, and it is significant that this form also has the greatest geological and geographical distribution. Next, the divergent and indirect line, or acmic group, typified by *B. Verneuilianus* and *B. acutilobus*, is also widely distributed, but less so than the first. Finally, the paracmic, or geratologous form, *B. varicus*, culminated and disappeared within very narrow time and regional limits.

Yale Museum, New Haven, Conn.

EXPLANATION OF PLATE I.

Bilobites acutilobus, Ringueberg.

FIGURE 1.—Outline of specimen from Niagara Group, *Lockport, N. Y.* ×4.

Bilobites Verneuilianus, Lindstrom.

FIGURE 2.—Common elongate form from Upper Silurian, *Gotland, Sweden.* ×4.

Bilobites varicus, Conrad.

FIGURE 3.—Dorsal view of youngest individual observed; showing inception of radiating striæ and concealment of hinge areas. ×18.
FIGURE 4.—Profile of same; showing depth and extent of both valves. ×18.
FIGURE 5.—Hinge view of preceding. ×18.
FIGURE 6.—Dorsal side of specimen; showing beginning of anterior marginal sinus. ×18.
FIGURE 7.—Profile of same. ×18.
FIGURE 8.—Posterior view of same. ×18.
FIGURE 9.—Dorsal view of specimen, figure 15, showing concealment of ventral area. ×9.
FIGURE 10.—Ventral view of same; showing dorsal area ×9. Compare this with dorsal view of larger specimen, figure 21, in series.
FIGURES 11–26.—Series of specimens; seen from dorsal side; exhibiting observed stages of growth, variation and development of hinge, hinge area, and marginal sinus. ×4.
FIGURE 27.—Interior of ventral valve; showing teeth, muscular impressions, minute concave plate in apex of fissure, and arrangement of punctæ between nodes and ribs. ×6. Lower Helderberg group. *Albany County, N. Y.*

Bilobites bilobus, Linne.

FIGURE 28.—Outline; showing characteristic form of this species as occurring in Upper Silurian of *Gotland, Sweden.*

ART. VIII.—*Gmelinite from Nova Scotia;* by LOUIS V. PIRSSON.

THE zeolites of Nova Scotia have long been noted for the size and perfection of their crystals, and among them gmelinite has held a prominent place. Originally described by Jackson* under the name of ledererite, it was first proved to be identical with the gmelinite of European localities by Des Cloizeaux,† from crystallographic measurements. This was subsequently confirmed by analyses published by Marsh.‡ Analyses have also been published by A. B. Howe, referred to later. Beyond these observations there seems to have been no investigation of the crystal form and physical properties of the mineral from American localities. This has been undertaken chiefly upon material collected during the past summer at Pinnacle Island, one of the "Five Islands" in the Basin of Minas, Nova Scotia. An analysis, which was made to control the results of the investigation, having brought out some interesting facts, a discussion of the chemical composition has also been added. And since gmelinite has been referred by some authors, especially Tamnau§ and Streng,‖ to chabazite, all points bearing on this question have been kept in mind and are here presented.

The gmelinite from Five Islands occurs in seams implanted in a greatly decomposed trap. The crystals, often of large size, vary in color from a very pale flesh-red to a strong reddish-brown. In thin section they are seen to be composed of a colorless outer shell or zone, inclosing a colored inner nucleus. In grinding the sections it was noticed that the outer shell was hard and tough, preserving the crystal boundaries, while the inner portion was spongy, cellular, somewhat friable and readily crumbled away. In large crystals the separation into parts of the colorless outer shell and the colored nucleus can be readily seen with the eye at a trihedral angle. There were no inclusions seen in thin section, only a slight discoloration along the cleavage cracks and occasionally elsewhere. The crystals from Two Islands, Nova Scotia, and Bergen Hill, N. J., studied in connection with these are white, often with a pink tinge, translucent and apparently entirely homogeneous. Some in Professor Brush's collection labeled Parsborough, Nova Scotia, are similar to those from Five Islands and may indeed have come from that locality.

* This Jour., xxv, pp. 78, 1834.

† Man. de Min., pp. 398, 1862.

‡ This Jour., xliv, pp. 362, 1867.

§ Jahrb. f. Min., pp. 633, 1836.

‖ Ber. d. Oberhess. Ges. f. Natur u. Heilkunde, xvi, pp. 74, 1877; also full abstract in Zeitschr. f. Kryst., pp. 519, vol. i, 1877.

The following table shows the forms which have been observed on these crystals, several of which are new. In the first column the symbols are those of gmelinite as a distinct species, in the second the same are referred to the axes of chabazite.

As gmelinite.	As chabazite.	As gmelinite.	As chabazite.
c, *O*, 0001	*O*, 0001	*r*, *R*, $10\bar{1}1$	$\frac{2}{3}$, $20\bar{2}3$
m, *I*, $10\bar{1}0$	*I*, $10\bar{1}0$	*ρ*, −1, $01\bar{1}1$	$-\frac{2}{3}$, $02\bar{2}3$
a, *i*-2, $11\bar{2}0$	*i*-2, $11\bar{2}0$	*q*, $\frac{3}{2}$, $30\bar{3}2$	*R*, $10\bar{1}1$
l, *i*-$\frac{7}{5}$, $52\bar{7}0$	*i*-$\frac{7}{5}$, $52\bar{7}0$	*φ*, $\frac{1}{7}^{7}$, $43\bar{7}7$	$-\frac{2}{21}^{7}$, $8\ 6\ \bar{14}\ 21$

Of these forms *c*, *a*, *l* and *q* are rare, the others occur on all crystals, almost without exception, from American localities. The basal plane *c* occurs only on a few crystals from Two Islands and on a number of those from Bergen Hill. As noted by others, the face *ρ* is generally characterized by the vicinal development of a pair of low scalenohedrons. The prism *m* is not generally striated in a horizontal direction, as observed on European forms. The scalenohedron *φ* is invariably striated, oscillating with both the plus and minus rhombohedrons and in some cases, possibly, with a pyramid of the second order and a minus form of the same scalenohedron. Many crystals show on the goniometer, by revolving in the zone *r*–*ρ*, a continuous band of light with the signals of these faces standing out. The scalenohedron mentioned is, however, most prominent. The presence of this striated scalenohedron *φ* is the most characteristic feature of the American forms, it is almost never lacking on any of the large number of specimens examined. A common appearance of one corner of the Pinnacle Island crystals, where it oscillates with the rhombohedrons, is shown in fig. 3.

While in general the crystal planes gave poor reflections of the signal, a number from Pinnacle Island were well suited, by the brilliancy and luster of the unit rhombohedron, for measuring the polar angle $r \wedge r$. This was done on a series of ten carefully selected crystals and the results are given in the following table. Each measurement is the mean of five determinations and the greatest variation between the mean and any one determination is given in the second column.

68° 0′ 42″	0° 0′ 48″	68° 8′ 0″	0° 0′ 0″
68 10 24	0 0 36	67 56 54	0 0 54
68 6 12	0 0 18	68 77 24	0 0 36
68 3 40	0 0 40	68 0 18	0 1 12
68 4 18	0 0 18	68 0 45	0 0 55
	Average	68 3 51	

The table shows the degree of accuracy with which the angle could be measured. Of the above, that which gave 68° 08′ was selected as a fundamental. The reflections of the signal were extremely good and it is not far from the average of them all. From this we derive the axial ratio:

$$a : c :: 1 : 0·734486$$

If we refer gmelinite to the axial ratio of chabazite, commonly accepted where $r \wedge r = 85° \ 14'$ and

$$a : c :: 1 : 1·0860$$

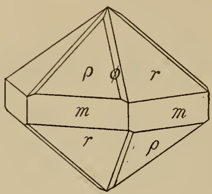
the prominent rhombohedron of gmelinite becomes $\frac{2}{3}$, $20\bar{2}3$, and this requires a length on the vertical axis of chabazite of ·7240 and a polar angle of 67° 28′. These Pinnacle Island crystals would not permit of so great an error in the determination, if they were referable to the axis of chabazite. The discussion of this point will be referred to later. The following table gives the calculated and measured angles which show the identification of the forms. The first column of figures gives the theoretical angles calculated for this species, the second gives the theoretical ones calculated by DesCloizeaux, and the third those calculated from the axes of chabazite:

Forms.		Calc.	Dx.	Chab.	Meas.
$r \wedge r$	$10\bar{1}1 \wedge \bar{1}101$	*68°08′	67°34′	67°28′	See above.
$r \wedge m$	$10\bar{1}1 \wedge 10\bar{1}0$	49 42	*50 03	50 06$\frac{1}{3}$	49°40′–50°02′ av. of 8=49°46′
$r \wedge \rho$	$10\bar{1}1 \wedge 01\bar{1}1$	37 44$\frac{1}{3}$	37 27	37 24$\frac{1}{2}$	37 30 –37 51 av. of 7=37 39
$m \wedge q$	$10\bar{1}0 \wedge 30\bar{3}2$	38 10	----	38 34$\frac{1}{4}$	38 48
$\phi \wedge \phi$	$43\bar{7}7 \wedge 7\bar{3}\bar{4}7$	29 21$\frac{1}{2}$	----	29 04$\frac{3}{4}$	29 33 29 58
$r \wedge \phi$	$10\bar{1}1 \wedge 43\bar{7}7$	16 04$\frac{1}{2}$	----	15 56$\frac{1}{4}$	16 14 16 00
$m \wedge a$	$10\bar{1}0 \wedge 11\bar{2}0$	30	----	----	29 56
$m \wedge l$	$10\bar{1}0 \wedge 52\bar{7}0$	16 06	----	----	16 30

For reasons stated before, none of these angles could be measured with great accuracy, yet the averages agree better with the theory presented for these crystals than that given by Des Cloizeaux. The angles of the scalenohedron, as given above, was measured on a crystal from Two Islands where it was present almost without striations. This crystal is shown in fig. 1. In all of the figures the crystals are shown revolved 60° into the position of a minus rhombohedron, it having been found that this gave a better view of them. With the exception noted, all the measurements given in the foregoing are upon crystals from Five Islands.

Twinning.—The twinning of gmelinite has never to our knowledge been observed, beyond a brief note as to its possibility in an article by Howe, mentioned later. In examining a series of specimens I have discovered, however, numerous instances of a twinning on the basal plane. All that have been observed were penetration twins. They are often shown by the growth of the scalenohedron φ and small ρ face, as presented in fig. 3, directly out from the plane of the positive rhombohedron. This method of twinning is shown in fig. 2, an example which did not have the centers of the two individuals coincident. Further, the figure shows a common habit in the development of the forms. The second method of twinning is that in which the $\frac{3}{2}$ rhombohedron becomes the twinning plane.

1.



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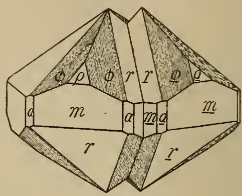

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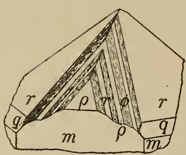

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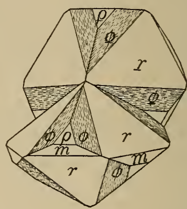

This was first seen on a specimen from Parsborough, which presented a number of examples; it was afterwards observed on a number of other specimens. In all of these the twins were large sized crystals. An example of this method of twinning is shown in fig. 4, as well as another modification of the habit. The angle $r \wedge r$ was measured over the twinning plane in eight cases with the following results:

26° 04′, 26° 05′, 25° 58′, 25° 59′, 25° 48′, 25° 42′, 25° 45′, 25° 33′

the average of which would give an angle of r on the twinning plane of 77° 0′, and this shows the latter to be the $\frac{3}{2}$ rhombohedron. If we use the elements already given (and the angle $r \wedge r$ was measured on one of the best of these crystals as 68° 09′ agreeing closely with that given as theoretical) the angles given above would be in theory 25° 04′. If, however, we use the elements of chabazite and consider the prominent rhombohedron on the gmelinite as $\frac{2}{3}$, our twinning plane becomes the unit rhombohedron of chabazite and the theoretical re-entrant angle between the $\frac{2}{3}$ rhombohedrons twinning on this plane would be 26° 18¾′. The last three measured angles, which were the best, are then about half-way between these two calculated angles. In like manner $\rho \wedge \rho$ was measured over the twinning plane in two cases and found to be 2° 21′ and 2° 55′, while theory would demand from our gmelinite ratios 4° 16′ and for the chabazite 2° 39′. It should be stated, however, that the two ρ faces on each pair of the measured twins showed the low vicinal scalenohedron, characteristic of this face, and this of course tended to diminish the measured angles.

Indices of refraction.—Three prisms were cut from different crystals, by using the plane *m* for one face of the prism and grinding another in the prismatic zone. In the first one only was any well defined double refraction detected by the eye; in the other two the image of the slit was measured by holding the analyzer in front with the shorter diagonal vertical and horizontal. The three gave:

ωNa	1·4760	1·4646	1·4770
εNa	1·4674	1·4637	1·4765

There is therefore a very weak negative double refraction which varies in different crystals, the averge was ωNa − εNa for the above = ·0033, while Negri* found ωNa−εNa = ·0018 in crystals from Montecchio Maggiore.

Optical characters.—In a section cut normal to the vertical axis it is seen under the microscope, between crossed nicols, that the section is not uniformly dark, but that slight optical anomalies present themselves, somewhat as in leucite. There does not seem to be any definite separation into parts, which would show the crystal composed of several individuals. In strongly convergent light the uniaxial interference figure is seen, and at some places, in revolving, this generally opens a trifle, with the arms of the cross assuming the position of hyperbolas. This is most marked in the hard outer shell, mentioned before, where a small but distinct separation can be seen. These characters explain very clearly the variation in the indices of refraction in different crystals noted above.

Cleavage.—The prismatic cleavage, first noted by Rose, is easily produced but is never very perfect. In a basal section, under the microscope, it is seen as a series of cracks parallel to the prism edges. An endeavor to determine whether a rhombohedral cleavage existed, or not, met with only partial success. A series of fragments, with the faces of the prism and unit rhombohedron upon them for orientation, were placed on the goniometer. Upon revolving, the prismatic cleavage always gave a reflection and in a number of cases there were reflected faint but distinct signals in the zone, from small faces, which gave measurements from the prismatic cleavage, as follows:

49° 42′, 49° 36′, 49° 50′, 49° 43′, 49° 55′, 50° 06′, 49° 02′

* Zeitschr. f. Kryst., xiv, p. 584, 1888.

Our theory demands for $m \wedge r$, $10\bar{1}0 \wedge 10\bar{1}1$, of gmelinite 49° 42′. In two cases the above were measured both as positive and negative rhombohedron on the same fragment. This latter and the fact that the crystals are more or less cellular internally, renders it probable that these reflections came from minute interior faces.

Chemical composition.—In order to obtain a control over the crystallographic work on the Five Islands gmelinite, two analyses A and B have been made. In A, the outer shell mentioned before, was analyzed, and in B the inner nucleus. The material was easily obtained by taking fine crystals and splitting off the shell by pressure. The fragments thus obtained were perfectly colorless, the inner portion had the usual flesh color. Both ground to a pure white powder. The analyses on the air-dried material were as follows:

	A	B
SiO_2	50·35	50·67
Al_2O_3	18·33	18·50
Fe_2O_3	0·26	0·15
CaO	1·01	1·05
K_2O	0·15	0·16
Na_2O	9·76	9·88
H_2O	20·23	20·15
	100·09	100·56

It will be observed that the analyses show no difference between the two portions. Also the specific gravity carefully taken with the heavy solution was found to be 2·037, the same for both. The most marked result of the analyses is the very small amount of lime and large amount of soda indicated.

Analyses of American gmelinite, on material from Two Islands, Five Islands and Bergen Hill have been made by A. B. Howe.* It will be observed that the one on Five Islands' material is almost exactly like those just given.

	Two Islands $\frac{2}{3}$.	Theory.	Bergen Hills $\frac{1}{1}$.	Theory.	Five Islands $\frac{2}{3}$.	Theory.
SiO_2	51·36	51·18	48·67	48·79	50·45	49·74
Al_2O_3	17·81	17·42	18·72	18·84	18·27	18·12
Fe_2O_3	0·15	----	0·10	----	0·17	----
CaO	5·68	6·04	2·60	2·40	1·12	1·12
K_2O	0·23	----	trace	----	0·20	----
Na_2O	3·92	3·89	9·14	8·69	9·79	9·75
H_2O	20·96	21·47	21·35	21·28	20·71	21·27
	100·11	100·00	100·58	100·00	100·71	100·00

In the article previously quoted Streng has shown that chabazite may be considered a mixture of two isomorphous hydrated molecules, similar to the feldspars. If we consider gmelinite as a soda chabazite, we then have for these molecules:

$$x = NaAlSi_3O_8 \,.\, 4H_2O \quad y = Na_2Al_2Si_2O_8 \,.\, 4H_2O$$

* This Jour., vol. xii, pp. 270, 1876.

the first a hydrated albite molecule, the second a hydrated soda anorthite. If, according to this, we deduce the composition indicated by the analyses of the three gmelinites, replacing soda by lime to the extent observed, we have

Two Islands	$=6x+y$	in which	Na : Ca : : 2 : 3
Bergen Hill	$=3x+y$	"	Na : Ca : : 3·2 : 1
Five Islands	$=4x+y$	"	Na : Ca : : 8 : 1

The theoretical composition for these formulas is given, for convenience, in the table after each analysis. The very close agreement of the theory, calculated for these simple relations, with the analyses themselves is very striking and a strong proof of the correctness of Streng's theory. In chemical composition we may consider typical gmelinite as a soda chabazite, whose relation to the normal lime chabazite is the same as that for instance of lithiophilite to triphylite.

Conclusion.—In considering the bearing of the foregoing facts upon the identity of this mineral with chabazite there is an apparent discordance. The result of the crystallographic work, points to a distinct difference in axial ratios and there is also a different habit and cleavage. On the other hand the twinning and the chemical constitution, both following that of chabazite present the strongest possible arguments for the identity of the species. To explain these apparent discrepancies the following hypothesis is offered. The analyses of chabazite and gmelinite, made by various chemists, show that soda and lime may replace each other to any extent, but that in gmelinite the soda is in excess, while in chabazite the reverse is true. If we consider then that the effect of the soda is to lengthen somewhat the vertical axis, the difference in angles and ratios would be accounted for and we might expect it to change also the habit and cleavage. While this cannot be considered otherwise than a hypothesis, the fact that in the Five Island material under examination these differences are greater than noted by any former observer, while at the same time the percentage of soda is also greater, points distinctly towards it. According to this view gmelinite would bear much the same relation to chabazite that enstatite does to hypersthene, whether it should be considered a distinct species would be largely a matter of choice or convenience.

In closing the author desires to express his thanks for the liberal use of valuable material to Professor G. J. Brush and to Professor S. L. Penfield, to the latter also for valuable advice during the progress of this examination.

Mineralogical Laboratory, Sheffield Scientific School,
New Haven, Feb., 1891.

Art. IX.—*Analyses of Kamacite, Tænite and Plessite from the Welland Meteoric Iron;** by John M. Davison.

The siderolite, which forms the subject of this paper, is described by Edwin E. Howell on pages 86–87 of the Proceedings of the Rochester Academy of Science for 1890. Its analysis gave Fe 91·17 and Ni 8·54. It is singularly free from troilite and schreibersite and thus offered an unusually good opportunity for the analysis of its separated nickel-iron alloys. On sawing the meteorite, the outside was found much decomposed; but between this and the compact center was a zone in which the oxidation was superficial and confined for the most part to planes of contact of the different nickel-iron alloys that form the Widmanstätten figures. It thus became possible to separate the kamacite and the tænite in quantities sufficient for analysis. The quantity of kamacite used for analysis was gm. 0·934, of tænite gm. 0·4522.

The physical characters of these alloys differ widely. The kamacite is brittle, breaking with a subconchoidal fracture, and is of the color of cast iron. It was coated with a thin film of black oxide which had often a resinous luster as if covered with lacquer, particularly where the tænite had been freshly stripped off. This oxide is attracted by the magnet, and is probably the magnetic oxide Fe_3O_4. Some pieces of kamacite of a millimeter or two in thickness were entirely altered to this oxide. The kamacite shows, in places, a corrugated surface, in some specimens resembling bundles of rods, like the columnar structure of hematite. Figures 1 and 2 show this columnar structure. In the latter the tænite which closely followed the form of the kamacite is laid back, but not detached.

The tænite has a silvery luster with, when slightly oxidized, a tinge of bronze. It is flexible and elastic and fuses on the edges in the oxidizing flame of the blowpipe, turning dark. Its fusibility seems to be about 5. It resists oxidation better than the kamacite; the contrast between its comparatively fresh appearance and the dark film covering the other was marked, and facilitated their separation.

Both kamacite and tænite were magnetic and exhibited a weak polarity which was more marked in the latter. Pieces of tænite floated directly on water, and of kamacite buoyed on a cork, arranged themselves in the magnetic meridian; the tænite promptly, the kamacite after being left for some time protected from air currents under a bell glass. The meteorite as a mass also showed polarity. The tænite is found separating the plates

* Read before the Rochester Academy of Sciences and published in the Proceedings for 1891, where it is accompanied by a plate, not reproduced here.

of kamacite and enveloping the crystals of plessite. Figures 3 and 4 show plates of kamacite which were in close contact, and when separated were found to have been joined by a little triangular prism of the same substance.

It was, at first, intended to analyze the plessite as a whole; but on examination its fine layers were so suggestive of kamacite and tænite that the attempt was made to separate them, and to analyze each separately. It was found that one was brittle, the other flexible and elastic; one dark with superficial oxidation, the other showing the tænite luster. Physically their correspondence, the one with kamacite, the other with tænite was exact, and in the kamacite-like part the columnar structure was shown on a diminutive scale, the diameter of the rods being from $\frac{1}{6}$–$\frac{1}{3}$ mm.

Their separation then became simply a matter of patience, and with the aid of a watchmaker's glass, and a magnetized needle to pick up the grains and flakes, most of which were too small for even delicate forceps to handle, there was obtained for analysis, of the part resembling kamacite gm. 0·5261, of that resembling tænite gm. 0·1314. The thickness of the kamacite was from 1–2 mm., that of the tænite from $\frac{1}{15}$–$\frac{1}{30}$ mm. In the plessite the kamacite-like bands were from $\frac{17}{30}$–$\frac{1}{30}$ mm. thick; the tænite-like bands, as nearly as could be measured, from $\frac{1}{130}$–$\frac{1}{220}$ mm.

The method of analysis was the same in each case. The material was gone over repeatedly, piece by piece, with a watchmaker's glass and very carefully assorted and cleansed, the pieces of kamacite being scraped bright. It was not possible to do this to any extent with the kamacite-like part of plessite. It was dissolved in dilute hydrochloric acid by the aid of a weak galvanic current, at the positive pole of the battery. The carbon thus separated was collected on a Gooch filter and burned. The nickel and cobalt were separated from the iron by digestion in ammonium hydrate, the process being repeated four times. The iron was weighed, and the nickel and cobalt first determined together by electrolysis, then separated by potassium nitrite and each determined separately in the same manner. For comparison, the analyses of kamacite and tænite are given each next to its corresponding part of the plessite.

	Kamacite.	Plessite.		Tænite.
		Kamacite-like part.	Tænite-like part.	
Fe	93·09	92·81	72·98	74·78
Ni	6·69	6·97	25·87	24·32
Co	·25	·19	·83	·33
C	·02	·19	·91	·50
	100·05	100·16	100·59	99·93

These physical and chemical correspondences justify, I think, the conclusion that in the Welland siderolite there are but two distinct nickel-iron alloys, viz: kamacite and tænite; and that the so-called plessite is merely thin alternating lamellæ of kamacite and tænite.

It is unsafe to generalize on a single analysis, but an examination of the markings of other meteoric irons suggests the thought that in them also there may be but two distinct alloys. Such are the Descubridora, the Glorietta Mt. and notably the Kiowa Co. and the Augusta Co., Va. meteorites. In sections of the last two irons in Ward & Howell's collection every piece of the so-called plessite in the Augusta Co. iron shows its thin lamellæ, and in the Kiowa Co. pallasite the gradations of the markings are such, that in parts of the iron it would be difficult to say which should be called kamacite and which plessite.

In etching meteoric iron, the kamacite is attacked by acid more readily than the tænite richer in nickel. The tænite and plessite stand in relief. Where lamellæ do not show in plessite may not closely crowded tænite bands have protected neighboring kamacite layers from acid action, and might not more careful or prolonged etching develop lines in plessite that now appear homogeneous?

Reynolds Laboratory,
University of Rochester, April, 1891.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Speed of the Explosive wave in Solid and Liquid Bodies.*—Berthelot has studied the phenomena attending the production and transmission of the explosive wave in solid and liquid substances and finds that these phenomena do not have the regularity of progression observed in gases. In liquids the speed appears to be dependent upon the rigidity of the enclosing tubes, this speed being the greater the greater the resistance of the tubes to rupture. It is probably not possible, however, to prepare tubes which can bear without fracture the force of the explosion, since the volume of the high explosives is smaller as a rule than the volume of their decomposition products, even when these are compressed into the liquid condition. In methyl nitrate, the author finds that the explosion travels, when the liquid is contained in tubes of steel, with a speed of about 2100 meters per second.—*C. R.*, cxii, 16; *Ber. Berl. Chem. Ges.*, xxiv, (Ref.) 253, April, 1891. G. F. B.

2. *On the Relation between the Electrical Energy and the Chemical Energy in Voltaic cells.*—A series of experiments by Lévay has been made to ascertain the amount of heat gener-

ated by the current of certain voltaic cells, as compared with the amount generated by the chemical action going on in the cells; in order to determine the exact relation of these two quantities. The heat developed by the current was ascertained by means of a silver voltameter placed together with the cell, in a calorimeter. The heat evolved by the chemical action was determined by direct calorimetric means. The cells examined were of the Daniell and the De la Rue forms, three experiments being made with each. As a result the author finds that with the Daniell cell, the heat equivalent of the current is greater than that generated chemically; so that in the working of this cell, heat is absorbed. On the other hand the De la Rue cell shows a reverse effect, not all the heat proper to the chemical action going on appearing in the circuit. But in this case the author observed that the relative amount of electrical energy increases with the concentration of the solution in the cell. These results confirm substantially those of Jahn.—*Ann. Phys. Chem.*, II, xlvii, 103; *J. Chem. Soc.*, lx, 513, May, 1891. G. F. B.

3. *On the Action of Heat on Carbon Monoxide.*—BERTHELOT has observed that when carbon monoxide is heated in a glass tube to 500° or 550°, a minute quantity—three or four thousandths—of carbon dioxide is produced; and this without any simultaneous separation of carbon. If, however, the carbon monoxide be passed through a porcelain tube, and the temperature of this be raised to a dull or even a bright red heat, while approximately the same quantity of carbon dioxide is observed to be produced as before, there is at the same time a distinct separation of carbon. Hence the author concludes that in this experiment carbon monoxide is not simply dissociated, but is at the same polymerized; and that the product of this polymerization decomposes into carbon dioxide and carbon sub-oxide according to the equation $C_nO_n = C_{n-1}O_{n-2} + CO_2$; which sub-oxide at a higher temperature yields carbon monoxide and free carbon.—*C. R.*, cxii, 594 *Ber. Berl. Chem. Ges.*, xxiv, (Ref.) 348, May, 1891. G. F. B.

4. *On the Electro-metallurgy of Aluminum.*—MINET has contributed further details concerning the reduction of aluminum by electrolytic methods. The steel crucible is now made smaller and is provided with an internal lining of carbon which serves as the negative electrode. The difference of potential between the two electrodes is 4·55 volts and the yield is 31·9 grams of aluminum per horse power per hour, or 31·3 horse powers per hour for one kilogram of aluminum. The author believes that it will be possible to reduce the difference of potential to 4 volts and under these conditions there will be no electrolysis of the sodium chloride and the yield will reach 70 per cent of the theoretical quantity. The loss of 30 per cent is due to the action of the fused fluorides on the aluminum and does not occur when aluminum alloys are made, since in this case the electrolytic cell is composed of the other metal and the liberated aluminum at once combines with it.—*C. R.*, cxii, 231; *J. Chem. Soc.*, lx, 525, May, 1891.

G. F. B.

5. *On the Detection of metallic Mercury in cases of Poisoning.*—It is generally assumed that metallic mercury when treated with hydrochloric acid and potassium chlorate goes readily into solution. But LECCO has observed that in destroying the organic matter in toxicological cases with these reagents, metallic mercury if present is only very slowly attacked. A human stomach in which minute globules of mercury could be distinctly seen was treated in this way until the organic matter was destroyed and then examined as usual. Scarcely a trace of mercury could be detected in the solution, while in the residue minute globules of the metal were visible. Direct experiment showed that mercury itself is soluble with extreme difficulty under these conditions; and hence the author believes that in examination for poisons this fact should be borne in mind. He recommends that the process of treating with hydrochloric acid and potassium chlorate should be continued for some time after the organic matter disappears.—*Ber. Berl. Chem. Ges.*, xxiv, 928, April, 1891. G. F. B.

6. *On Tetrazotic acid and its Oxy- and Di-oxy derivatives.*—In consequence of the observation that by the action of acids upon benzenyl-amidine nitrite, an acid is produced having the formula $C_7H_6N_4O_2$ and therefore of the composition of a di-nitroso-benzenyl-amidine, W. LOSSEN undertook further researches in this direction and has obtained some noteworthy results. He finds (1) that similar compound acids are yielded by other amidines provided that in them the hydrogen in the group $C\genfrac{}{}{0pt}{}{\diagup NH}{\diagdown NH_2}$ is not replaced by alkyl radicals; (2) that the acids thus obtained $X . CN_4O_2H$, called dioxy-tetrazotic acids and of which the above benzenyl-dioxytetrazotic acid $C_6H_5 . CN_4O_2H$ is an example, are reduced by sodium amalgam to oxy-tetrazotic acids, $X . CN_4OH$, such as benzenyl-oxytetrazotic acid $C_6H_5 . CN_4OH$, and to tetrazotic acids $X . CN_4H$, as for example $C_6H_5 . CN_4H$ benzenyl-tetrazotic acid; (3) the dioxytetrazotic acids decompose spontaneously when set free from their salts, and their metallic salts when dry are extraordinarily explosive; (4) the oxytetrazotic acids, in regard to their permanence are intermediate between the unstable dioxytetrazotic acids and the quiet permanent tetrazotic acids, although the latter and also its salts are explosive; (5) by Raoult's method the molecular formulas of benzenyl-tetrazotic and benzenyl-oxytetrazotic acids were found to be $C_7H_6N_4$ and $C_7H_6N_4O$ respectively; (6) with reference to the constitution of these acids, the author states (a) that the hypothetical free benzenyl-dioxytetrazotic acid has apparently the formula $C_6H_5 . C\genfrac{}{}{0pt}{}{\diagup N . NO}{\diagdown N . NOH}$, since it gives Liebermann's nitroso-reaction and decomposes into benzonitrile, nitrogen and nitrogen dioxide; (b) that benzenyl-tetrazotic acid, by the action of concentrated hydrochloric acid, decomposes according to the equation

$$C_7H_6N_4 + (H_2O)_2 = C_6H_5 . NH_2 + CO_2 + N_2 + NH_3$$

though possibly an intermediate stage occurs as follows:

$$C_6H_5C{\lt}{N \atop N}{\gt}N_2H + (H_2O)_2 = C_6H_5C{\lt}{NOH \atop OH} + N_2 + NH_3$$

the benzhydroxamic acid splitting into aniline and carbon dioxide; benzenyl-tetrazotic acid may be considered either as a phenyl-tetrazol $C_6H_5.C{\lt}{N - N \atop NH - N}$ ||, analogous to the isomeric compound discovered by Bladin $CH{\lt}{N \text{———} N \atop N(C_6H_5).N}$ ||, or as an imido compound corresponding to the benzoyl-azoimide of Curtius $C_6H_5.CO.N{\lt}{N \atop N}$ ||, in the latter case having the formula $C_6H_5C(NH).N{\lt}{N \atop N}$ ||; (*c*) since benzenyl-oxytetrazotic acid does not give Liebermann's reaction, it is not a nitro-compound. According to C. Lossen, benzenyl-oxytetrazotic acid crystallizes from boiling water in rhombic needles which fuse with decomposition at 175°. With one molecule of crystal water the acid is permanent, but when deprived of this water at 105°, it readily decomposes evolving nitrous vapors. Its salts with potassium, barium and silver are described. Benzenyl-tetrazotic acid crystallizes from hot water, better from alcohol in rhombic hemimorphic colorless needles, fusing at 212° to 213° with decomposition. By slowly heating it, a beautiful red mass is obtained; while on rapid heating a violent decomposition results, often with ignition, a dark green tenacious residue being left in the test-tube, whose vapor is red or violet. The dioxytetrazotic acid affords a meta-nitro-derivative m-nitrobenzenyl-dioxytetrazotic acid.—*Liebig's Annalen*, cclxiii, 73; *Ber. Berl. Chem. Ges.*, xxiv, 392, May, 1891. G. F. B.

7. *Polar light and Cosmic dust.*—LIVEING and DEWAR obtained metallic dust by means of electrical discharges between terminals of different metals inserted in a glass receptacle—from this the dust was conveyed by means of a stream of hydrogen into an end-on-tube, through which electrical discharges were passed. The spectrum of these discharges showed no trace of the lines of the finely divided metals although the finely divided dust was present in great abundance. They therefore conclude that if the northern lights are due to great electric discharges through rarified air filled with cosmic dust, conditions must exist which are different from those in the experiment devised by them.—*Proc. Roy. Soc.*, xlviii, p. 437–440, 1891. J. T.

8. *Phosphorescence.*—E. WIEDERMANN has investigated the character of the light given out by Balmain's paint under different conditions of exposure. He expresses his belief that a source of light which sends forth proportionally more light waves than heat waves, as Langley maintains is the case with the fire fly, is not

necessarily the cheapest source of light. In order to estimate the cheapness of a light account must be taken of the entire transformation of the energy of the light in the process of vision."—*Beiblätter zu den Annalen der Physik*, No. 4, 1891, p. 281. J. T.

9. *Reflection and Refraction of light by thin surface layers.*—P. DRUDE examines mathematically the conditions which must hold for the reflection and refraction of light by thin layers of metals such as Professor Kundt has experimented with in obtaining indices of refraction of metals. The paper is long and exhaustive; but is not supported by experimental results. The author hopes to obtain suitable surfaces to verify his theoretical conclusions. These are as follows:

(1.) In the expression for the absolute amplitude, ratios and difference of phase of the reflected and the transmitted light—three constants depending upon the nature of the layer enter. In Cauchy's formula but one constant depending upon the boundary enters.

(2.) For refraction and ordinary reflection the formulas are identical with those of Cauchy.

(3.) A lower limit for the thickness of the layer transmitting light is given by elliptical polarization.

(4.) No ellipticity is shown if the layer is contained between the media of the same index of refraction. If the plate is wedge-shaped of small angle; in reflected light the bright bands have the normal polarization angle. The dark bands deviate from this, and a conclusion can thus be drawn in regard to the index of refraction of the layer in case the layer is homogeneous.

(5.) In the dark band the reflected light is linear polarized—the transmitted light elliptically polarized. In the bright bands the reflected as well as the transmitted light is elliptically polarized.

(6.) From observation upon the light transmitted by thin metallic layers and on light reflected the true optical constants of the metals can be computed.—*Ann. der Physik und Chemie*, No. 5, 1891, pp. 126–157. J. T.

II. GEOLOGY AND MINERALOGY.

1. *Annual Report of the State Geologist of New Jersey* for the year 1890. 305 pp. 8vo. 1891.—Since the death of Prof. Cook, Prof. G. C. Smock has been appointed the State Geologist of New Jersey with F. L. Nason and C. W. Coman as assistant geologists. This report contains an article on the age of the Sussex Co. crystalline limestones by Mr. Nason; an account of geological work in the southern part of the State by C. W. Coman, treating especially of the strata overlying the upper marl bed, and a report on the water-power and water-supply of the State by C. C. Vermeule.

Mr. Nason's paper contains the important announcement that the bluish, semi-crystalline limestone of Sussex Co. and the associated sandstone, have afforded Dr. C. E. Beecher Lower Cambrian fossils ; and that in one case the sandstone contained, near by, the mineral graphite. The main purpose of the article is to give the evidence obtained by the author in favor of the conclusion that the white crystalline limestone of the county, containing chondrodite and other minerals, which has been supposed to be Archæan, is really of the age of the blue limestone. The evidence given is, briefly, the occurrence of graphite in both the white and blue limestones ; the passage of one into the other at some localities ; and the inference that the white limestone owes its crystallization to contact with eruptive rocks, (granite, etc.), and exhibits various contact phenomena. The Franklinite iron ore-bed of the county is associated with the white limestone, and is made therefore of the same age. The conclusion is a wide-reaching one, and the facts should have full investigation before it is adopted. The evidence drawn from the graphite is of uncertain value as the mineral occurs in rocks of much later time. Prof. Cook regarded the iron ore beds and the limestones as part of the gneissic formation of the region, the gneiss being not in his view foliated granite ; and the writer's examinations of the rocks associated with these ores have led him to the same conclusion. Moreover, it is an impossibility that the crystallization of the white limestone formation should have been produced by contact with the dikes of igneous rocks, or even with protruded granite ; for the rock of a dike cools outside too rapidly for such a result. The trap dikes of New Jersey illustrate this point abundantly. Melted granite injected through a cold rock would not be true crystalline granite against the walls or make the limestone adjoining coarsely crystalline, like the white limestone, even for a hundred feet. Again dikes of a hornblendic scapolite rock are described. But it is impossible that melted scapolite injected into cold rocks in fissures four to six feet wide or wider than this, should become on cooling crystallized scapolite, even of a granular form, alike from wall to wall, with "perfect foliation" parallel to the walls, so that it has been mistaken for gneiss. For such crystallization the enclosing limestone should be hot enough for its own crystallization—the condition attending metamorphism.

The actual passage of the blue limestone into the white has weight, if the observation is beyond question. The writer doubts the conclusion as to actual passage because he has observed in East Lee, Massachusetts, an apparent passage of the kind between the Stockbridge limestone and another which is chondroditic, and saved himself from inferring their identity by finding the latter associated in a part of the area with a very different class of crystalline schists. In other cases over eastern Berkshire chondroditic limestone was met with ; and in each it was associated with rocks that were in part so unlike the schists of the Stockbridge limestone or Taconic belt, viewing them through its whole course, from Vermont, Massachusetts, and

Connecticut to New York island, that it was accepted as evidence of Archæan age. Superposition of the later limestone on the earlier and subsequent changes may account for the cases of apparent passage. Limestone belts have determined the positions of the chief valleys of Berkshire; and in some cases Archæan limestone was first in the work.

One of the most comprehensive facts in the geology of Eastern America is the general identity of strike and dip, in associated metamorphic or crystalline rocks of Archæan and later time. In eastern Berkshire the writer failed to detect the limit between the Taconic schists and the Archæan, after several trials; and the same was true for the ridge southwest of Cornwall, Conn., where chondroditic limestone occurs; and also in Putnam County, N. Y., where there are Archæan iron ores. In each case the quartzyte of the Taconic series was followed by gneiss of like dip and this by other gneisses, and the Archæan limit was not discovered. The question was left for a later and more thorough investigation, which has not been made. It is now in other hands, with a promise of success. Taking the evidence which strike and dip afford as of itself conclusive, it is probable that nearly all the so-called Archæan rocks of the Appalachian Protaxis could be proved to be Paleozoic. The problem which Mr. Nason has investigated in Northern New Jersey is one of great importance and difficulty. It is a part of a wider problem—that embracing all the Archæan schists and ore-beds of New Jersey.

J. D. D.

2. *Two belts of fossiliferous black shale in the Triassic formation of Connecticut*, by W. M. Davis and S. Ward Loper. 16 pp. 8vo. (Bull. Geol. Soc. America, vol. ii, April, 1891.)—Professor Davis commences his paper with a summary of his conclusions respecting the Triassic formation in the vicinity of Meriden, Conn., and its associated trap. His list of papers mentions five subsequent to the one published in this Journal in 1886, with the title "Triassic formation of the Connecticut Valley." Under the same title, he published a fuller paper in the Report of the U. S. Geological Survey for 1888. Since then the following have appeared: "The ash-bed at Meriden and its structural relations," in the Proceedings of the Meriden Scientific Association for 1889; "On the Topographic development of the Triassic formation of the Connecticut Valley," in vol. xxxvii of this Journal, 1889; "On the faults near Meriden, and on the intrusive and extrusive trap sheets of the Connecticut Valley," in the Bulletin of the Museum of Comparative Zoology for 1889. In the present paper the following general conclusions are stated.

Three overflow trap-sheets in the vicinity of Meriden are now well made out; the first, thin and amygdaloidal, the second, thick and massive and sometimes a double flow, the third, thin like the first. Beside these overflows one great intrusive sheet, exists, and apparently several smaller ones. The great sheet, as implied in a note, is that of West Rock, of the New Haven region. The east-and-west ridge called Mt. Carmel, situated about half way between New Haven and the Meriden trap ridges is a "great mass of dikes," which "may be regarded as the locus of the volcanic pipes up through which rose the lavas now seen in the extrusive and intrusive sheets." The existence of these volcanoes is spoken of as without direct evidence, but probable. In the two figures of the paper these volcanoes are represented as buried in the sandstone formation and are entitled "the Group of buried volcanoes," "The lost volcanoes." The tilting of the sandstone with the intercalated sheet of trap, giving the formation its eastward dip throughout the region, probably followed the time of deposition and eruption. Even the intrusive dike, West Rock, is probably "of earlier date than the tilting and faulting of the formation, and hence of roughly synchronous date with the overflows." The faulting of the sandstone accompanying the uplifts was probably guided in direction by the planes of foliation in the underlying schists.

The two belts of black shale contain fossil fishes and plants. One of them is that of the well-known Durham locality and others of the same belt. The second occurs in a small brook north of the village of Westfield, Conn., and has been opened also at four other places along a line of about fifty miles. The latter, Mr. Loper states, has afforded one species of fish, *Ischypterus gigas*, not found in the Durham line, and two species of plants also absent from it, *Equisetum Rogersi* Sch., and *Ctenophyllum Braunianum* Sch.

3. *Illustrations of the Fauna of the St. John Group*, No. V.; by G. F. MATTHEW.—Mr. G. F. Matthew's paper under the above title, though read before the Royal Society of Canada in May, 1890, has only recently been distributed. The author has made a study of the fauna of the lower rocks of New Brunswick, especially near the city of St. John, and has given the results of his labors in numerous papers of interest. In the present one after discussing the structure of the St. John Basin, and various sections of the strata, he describes several new species of fossils and presents remarks upon some old ones, especially upon trilobites. This section is followed by a third treating mainly of tracks and markings, and upon this we offer some remarks and criticisms.

He gives, in the first place, a short sketch of Nathorst's observations upon Medusæ, quoting the descriptions of *Medusites princeps* Torell (sp.) (= *M. favosa* of Nathorst), *M. radiata* Linrs., (sp.) and *M. costata* Torell (sp.) (= *M. Lindstromi* of Nathorst). All these forms were described from beds of Cambrian age in Sweden, and Mr. Matthew says that in the St. John group indications are found of some of these "medusa-like forms as Nathorst considers them." He then proceeds to describe a new genus *Medusichnites*, founded for the reception of certain trails or tracks "which appear to have been produced by such creatures." Not that there is any indication they were positively made by *Medusæ*, "but rather that they are probably due to those Radiate animals which Nathorst has referred to *Medusites*." The name *Taonichnites* had been previously suggested by him for some similar form, but he now advocates discarding the old name and substituting a new one. Why the new forms should not have been included with the old one we are unable to understand. Fortunately no specific names are given to the series of markings referred to this genus. The author prefers, instead, to designate them as "forms," and of these he describes and illustrates five.

In these descriptions we no longer find any doubt expressed as to the manner in which the tracks were made or the kind of animals which made them. One is "the imprint of tentacles resting on the bottom." Another, from the Animikie group of the Lake Superior region, and the original of *Taonichnites*, he says "is a good illustration of certain impressions which have been mistaken for rill markings, but which are really of organic origin. It has been made by a Medusite swept along by a current above the surface of a bed of very fine sandy mud." It is interesting to know that the same genus ranged from the Animikie into the Middle Cambrian.

Another new genus proposed is *Eoichnites*, the name being a substitute for *Eophyton*. Mr. Matthew gives an account of *Eophyton* and of its supposed nature by the original discoverer, Torell, and figures what he calls *Eoichnites Linnæanus* Torell (sp.), from the St. John group. These figures, while they bear little resemblance to the typical *Eophyton Linnæanum*, are very much like some of the figures of *Medusichnites*, and should be placed there if that genus be a good one.

A third new genus established is *Ctenichnites*, adopted for markings which Mr. Matthew says Torell and Linnarsson confounded with *Eophyton*. We are told the markings resemble *Eoichnites* so far "that they might easily be supposed to have been produced by larger individuals of the kind which made the *Eoichnites*." This genus has one species, *C. ingens*, and it is described with considerable detail. A table is given of the chief varieties. Then the sort of animal supposed to have made them is discussed, the exposures yielding the following inferences to the author:

"1. That the animal lived in schools. 2. That it had a rapid, direct, darting motion. 3. That it had three or four flexible, fleshy arms. 4. That these arms were furnished with sharp (horny?) spines. 5. That it had an easy motion through the water so that sometimes the arms of one side touched the bottom, sometimes the other."

Then "having found reason to believe *Ctenichnites* to be of animal origin," Mr. Matthews concludes that it might have been a naked cephalopod. Then the habits of squids, and the nature of coprolites, and the armature of trilobites are examined in turn, and the final conclusion is that all the facts point to squids of some sort being the probable source of the *Ctenichnites* markings.

A comparison of the figures of *Ctenichnites ingens* with those of *Eoichnites* and some forms of *Medusichnites* induces the opinion that they are not to be separated even specifically. Some of the first have the lines wider apart than those of the second, and are less curved than the third, but the variability in all is so great that to draw a line anywhere between them is a task that few would dare undertake.

Under *Psammichnites* he refers to certain specimens found in St. John which seem to him probably "may have been made by by a *Psammichnites*." From this it would appear that Mr. Matthew considers *Psammichnites* to be an animal form of some sort. The general opinion is (Hancock, Haughton, Torell and Nathorst) that the forms described under that name are only tracks.

Under *Fræna* a new species, *F. ramosa*, is described, and under *Arenicolites* also, a new form, *A. brevis*, is given. Still a fourth genus, *Goniadnichnites*, with one species, *G. trichiformis*, is created, and on very slender grounds. Small, slender and thread-like, the name is given because of their resemblance to tracks made by recent *Goniada*. The figure bears some resemblance to certain branching forms of graptolites like *Dendrograptus tenuiramosus*, from the Utica Slate of New York.

Last of all the new species is an addition to Torrell's *Monocraterion*, under the name of *M. magnificum*. From the plate it is well named, for from a central cavity two inches in its longer diameter, and one and a quarter inches in its shorter, spread out filaments, called "tentacles," three inches in length: and this figure is reduced one-third. If this burrow were made by a worm, it must have been a gigantic creature.

In studying this paper of Mr. Matthew's we cannot but regret that he has made his many new genera and species upon such scanty material. As objects illustrating some phase of sedimentation, or the possibility of some sort of life having existed, these markings are of interest. But it is a useless burden upon science to give to them generic and specific names.

JOSEPH F. JAMES.

Washington, D. C., June 13, 1891.

4. *Études des gites minéraux de la France. Bassin Houiller et Permien d' Autun et d' Épinac. Fasc. II, Flore fossile, Première partie*, par R. ZEILLER. Pp. 1–304. Atlas, xxvii plates, 4°.—This fascicle begins the third of a series of valuable recent works on the flora of the Carboniferous epoch in France. Of these three, the first, on the flora of the Valenciennes basin, by M. R. Zeiller, dated 1888, is the most important work in French on the Paleozoic flora since the "Histoire" of Brongniart, with which it will take a place as a classic in paleobotanical literature. The first part of the second work, on the Commentry flora, in which the ferns are monographed by Zeiller, bears the same date; but the second part, under the joint authorship of MM. B. Renault and Zeiller was not finished until 1890. The present

work includes the flora of the Épinac and Molloy stages of the Upper Carboniferous and the Igornay-Lally, Cornaille-Chambois, and Millery stages of the Lower Permian. The Millery horizon, in the Autun basin, is celebrated as the source of the wonderfully preserved silicified plants that formed the basis of the many important works on the organization and fructification of the plants of the Paleozoic by Brongniart, Grand 'Eury, Renault, Bertrand, and Zeiller. In this fascicle Zeiller treats the ferns, prefacing their description with an illustrated résumé of the classification of the types represented in this flora according to their discovered fruiting forms. Considerable new and interesting material is here brought to light. About forty species, many of them new, are described from foliar and fruiting characters. The last 120 pages contain descriptions and illustrations of the trunks and petioles of the ferns, belonging to *Ptychopteris*, including *Caulopteris gigantea*, F. & W., to *Psaronius*, representing trunks of *Pecopteris* and *Scolecopteris*, and comprising an extinct tribe of the *Marattiaceæ*, and to *Myeloxylon*, including *Medullosa* (pars), *Myelopteris* and *Stenzelia*, which he regards as petioles and rachises of *Alethopteris*. *Odontopteris* and *Neuropteris*, representing a group, with pithed petioles and a centrifugally developed secondary woody zone, perhaps intermediate between the *Ophioglossaceæ* and the *Marattiaceæ*. The flora is interesting as showing many transition forms between the Upper Carboniferous and the Permian types. The second part of the work, dealing with the remaining groups, is in preparation by M. B. Renault. D. W.

5. *The Genus Sphenophyllum*, by J. S. Newberry. Journ. Cincinnati Soc. Nat. Hist., vol. xiii, 1891, pp. 212–217, pl. xix. —In this short paper Dr. Newberry reiterates the view proposed first by himself in 1853, and afterwards independently by Coemans and Kickx, that in certain species of *Sphenophyllum* in which the leaves are normally wedge-shaped and dentate or serrate, the deeply dissected, fimbriate, or capillary forms, simulating *Asterophyllites*, belonging to the same species, represent only portions of the same plant that were submerged. Several figures illustrate different parts of *S. erosum*, including the forms known as *S. saxifragæfolium*. The author also gives a few of the characters of six species of this genus with which he is familiar in this country. Dr. Newberry regards *Sphenophyllum*, whose affinities have for over fifty years been the subject of controversial discussions, as representing a peculiar and extinct family whose nearest living relative is *Equisetum*. D. W.

6. *Annuaire Géologique Universel, Année* 1889, Tome VI. Paris 1890.—This geological Annual, founded by Dr. Dagincourt, is now under the direction of Dr. L. Carez for Geology, and M. H. Douvillé for Paleontology; and besides, it has many able co-workers from among the geologists of France and other countries. The Annual for 1889 is a closely printed large-octavo volume of 1200 pages. The first 120 pages are occupied with lists of the

geological and paleontological papers, memoirs, maps, etc., of the year, arranged according to subjects and countries; and after a catalogue of the authors in the lists, the following 1000 pages of the volume contain quite full abstracts of very many of these publications. Not only the names of new species are given in the Paleontological part, but, to a large extent, descriptions of genera, and among the Vertebrata of many of the species, besides a review of new deductions and opinions. The Annual is essential to the geologist who would know about the yearly progress of the science over the world, and keep himself informed of discoveries bearing on his own work.

7. *Tables for the Determination of Minerals* by physical properties ascertainable with the aid of a few field instruments, based on the system of Professor Dr. Albin Weisbach by PERSIFOR FRAZER. Third edition, entirely re-written, 113 pp. Philadelphia, 1891 (J. B. Lippincott Company).—Professor Frazer's tables have already been found of much practical value by many workers, and in their present revised and improved form, their sphere of usefulness should be widely extended.

8. *Materialien zur Mineralogie Russlands*, von N. v. KOKSCHAROW. Vol. x, pp. 225–351. St. Petersburg, 1891.—The part now issued forms the conclusion of volume x. It includes descriptions of jeremejewite, eichwaldite, columbite, also supplementary notes on enclase, zircon, topaz and other species.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Volcano of Kilauea.*—In a letter of May 9th, Rev. E. P. Baker reports that after the eruption of March 6 the lava first appeared in the bottom of the empty basin of Halemaumau on the 10th of April. He visited the crater on the 29th of April and found the lake of liquid lava within it 100 or 200 feet across, and a blowing cone by the side of it which was throwing up globules of lava. The lake had a thin scum-like crust over it. While looking at the lake from the edge of the basin, 300 feet perhaps above the lake, the lava began to run off through an orifice beside the cone until the basin was nearly empty. The next day the lava had wholly disappeared. Again on the 6th of May Mr. Baker was down in the crater and found no liquid lava in the basin; but from the cooled lava on its sides it appeared that the lava had in the interval risen to a higher level than on April 30th. It thus seemed that the lake was rising and falling—rising through the accession of new lavas from below, and falling through discharges. The cone continued to throw up occasionally globules of lava.

2. *American Geological Society.*—The summer meeting of the society is to be held Monday and Tuesday, August 24 and 25, in the Columbian University, Washington, D. C., and will doubtless be one of unusual interest. The meeting will be preceded August 19–22, by the meeting of the American Association for the Advancement of Science, and will be followed by the International

Geological Congress, which meets August 26, and remains in session one week. The three societies will meet in the same building. The foreign members of the International Geological Congress are to be invited to read papers before the Geological Society, and their papers will be given precedence on the program. A number of excursions will probably be arranged. The local arrangements are in the hands of a committee, Mr. G. K. Gilbert, chairman.

3. *International Congress of Geologists—5th Session, Washington*, 1891.—Circular of information, No. 11, has been recently issued by the Secretaries, H. S. Williams and S. F. Emmons, giving full information in regard to time and place of meeting (see above), program, transportation, excursions and hotel accommodations. Correspondence should be addressed to S. F. Emmons, 1330 F street, Washington.

4. *Physical Observatory at the Smithsonian Institution, Washington.*—Prof. S. P. Langley announces (in a letter to the Editors, dated June 1, 1891) that there has been established at Washington, as a department of the Smithsonian Institution, a Physical Observatory, which has been furnished with specially designed apparatus for the prosecution of investigations in radiant energy and other departments of telluric and astro-physics. The communication of new memoirs bearing in any way on such researches is requested, and for them it is hoped that proper return can be made in due time.

Prof. Langley also states that he has resigned the titular directorship of Allegheny Observatory.

OBITUARY.

Charles Arad Joy, for many years Professor of Chemistry in Columbia College, died May 29 at Stockbridge, Mass. He was born in Ludlowville, Tompkins County, N. Y., Oct. 8, 1823. He was graduated from Union College in 1844 and from the Harvard Law School in 1847. The same year he was appointed on the Geological Survey of the Lake Superior region under Josiah D. Whitney and Charles T. Jackson. Subsequently he went abroad and studied chemistry in Berlin, at Göttingen, and at the Sorbonne in Paris. On his return he was called to the Chair of Chemistry at Union College. He held this position until 1857, when he was made Professor of Chemistry at Columbia College, which position he held until 1877.

Professor Joy's labors were devoted to chemistry and allied branches, and he was the author of many papers especially of a popular character upon scientific subjects. When a student in Göttingen he carried on a series of researches on the combination of alcohol radicals with selenium and later he investigated the compounds of glucinum, the results of which were published in this Journal (1863). He also made contributions to the subject of mineral chemistry. Professor Joy was one of the jurors at the International World's Fairs of London, Paris, Vienna, and Philadelphia, and was a member of many scientific societies.

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SCIENTIFIC INTELLIGENCE.

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THIRD SERIES.

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WITH PLATES II–IX.

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[THIRD SERIES.]

Art. X. — *Some of the features of non-volcanic Igneous Ejections, as illustrated in the four "Rocks" of the New Haven Region, West Rock, Pine Rock, Mill Rock and East Rock;* by James D. Dana. With Plates II to VII.

The observations on the igneous ejections of the New Haven region here recorded and discussed were mostly completed during the years 1879 and 1880, shortly after the publication (in 1877) of a detailed topographical map of the region by the U. S. Coast and Geodetic Survey, made under the special direction of R. M. Bache. As this map is on the large scale of $\frac{1}{10000}$, or about $6\frac{1}{3}$ inches to the mile, and has 20-foot contour lines, it afforded a very convenient basis for the record of geological facts.

A reduction of a portion of this map to a scale of two miles to the inch, is presented on Plate II.* Excepting the hills in the southwestern corner of the map, its whole area, even that of the New Haven plain, is underlaid by the Jura-Trias Red-sandstone formation. (The excepted hills are part of the border of metamorphic schists that bounds the Jura-Trias region

* This map is a portion of Plate II in the writer's paper on the "Phenomena of the Glacial and Champlain Periods about the mouth of the Connecticut Valley, or the New Haven Region" (This Journal, xxvii, 113, Feb. 1884). The limit of the New Haven plain is marked by a dotted line at the base of the hills, and the contour-lines over it are omitted, the heights instead being given after a special survey. The small nearly circular depressions marked on the map represent "Kettle-holes." The New Haven plain was of river-flood origin and it is presented on the map with the outlines and height unaltered by the gradings for road-making, and by the making of mill-dams; and hence the map is a map of the region of New Haven before 1640, as stated in its title.

on the west.) The map shows the positions of the four trap ridges—more strictly trap-and-sandstone ridges—West Rock, Pine Rock, Mill Rock and East Rock, and gives their heights above mean tide. These rampart-like elevations are now two to three miles from New Haven Bay; but they bear evidence of having been for a time the headlands of a much larger bay.

The ridges are part of the Jura-Trias Mountain-range of the Connecticut Valley. (1) East Rock and West Rock are like the other north-and-south ridges of the range in their form, structure and direction, and West Rock ridge after a course of seventeen miles, dies out just where the higher trap ridges of the Mt. Tom line commence, showing an interlocking with the rest of the system. (2) They consist of Jura-Trias sandstone with an intercalated sheet of trap (as the igneous rock is popularly called). (3) The sheet of trap in the ridges has a rising inclination westward, or a dip eastward, like the associated beds of sandstone, the liquid rock having been extruded from a fissure or fissures situated somewhere to the eastward. (4) As a consequence of these common features, denudation by water and ice has given to the New Haven ridges the features typical of the range,* namely, a steep western front, consisting of sandstone below and the harder trap above, a top of bare trap, and eastern slopes of sandstone, that is of the overlying sandstone.

From such common features the inference as to a common method of origin is natural. Still, as Professor Davis claims, it needs also other support for acceptance.

We note also (4) that these Rocks are situated at the southern extremity of the Jura-Trias Mountain-range; for the Connecticut Valley and its Jura-Trias beds do not extend over Long Island. Instead of this, Long Island pertains to an east-and-west system of mountain-structure. Whether nearness in position to this east-and-west range has occasioned any of the features of the Rocks is an interesting question for consideration.

1. Summary of the principal facts and conclusions.

The facts.—The facts relate to the sandstone of the New Haven region as well as the trap; for the sandstone was broken through to give exit to the liquid trap, and it broke as such a sandstone would break.

(1) The sandstone, as the rock is comprehensively called, varies from fine-grained to coarse, and beyond this, to a fine

* In the writer's paper on the Geology of the New Haven region of 1869, (Trans. Conn. Acad. Sci., ii, 4. 1870), he observes that "the sandstone mass with its intersecting dikes of trap constituted the block out of which the future New Haven region was to be carved by various denuding agencies."

and coarse conglomerate, even cobble-stone-gravel conglomerate. When fine-grained and shaly it is not a firm laminated rock, but divides or crumbles readily to thin chips. The more massive kinds are usually traversed with fractures; and none has much firmness except where consolidated by heat from the trap-ejections, or the hot vapors produced thereby. Consequently, fissures made though the formation should have great irregularities, from irregular fracturing and the tumbling into them of masses of sandstone and large sections of their walls.

(2) The thickness of the sandstone intersected by the fissures over the center of the New Haven region was at least 3000 feet, as proved by borings at a point half way between the bay and the west end of Mill Rock. Along the West Rock line the depth was probably less, as this ridge is within a mile and a half of the western metamorphic limit of the Connecticut Valley of Triassic time. Beneath the sandstone the fissures came up through underlying crystalline rocks, in which they would probably have great regularity in course, width and continuity.

(3) When the heat from the trap, or the hot vapors generated by it, consolidated the sandstone, it generally made hard, durable rock of the coarser kind, but left the finer beds, alternating with the coarse, fragile and chip-making; and this was so, apparently, because hot vapor penetrates most easily the coarser beds for the cementing work. The heat, through the penetrating vapors, generally discharged more or less completely the color of the beds it consolidated, producing an ash-gray and brownish shade; made in them steam tubes with blanched walls; produced blotches of impure chlorite, or epidote, and crystallizations of hematite and epidote, and less commonly garnet. But the finer beds that alternate with the coarse commonly retain, except perhaps for a few inches, their red color, and even have it deepened to a dark purplish red—as if by the reduction of some of the red coloring matter (oxide of iron) to magnetite. Moreover, the sandstone often loses all the old bedding. These varying effects from the heat have added much to the original irregularities of the beds.

(1) Of the four Rocks, East and West belong to the prevailing north-and-south system, as already stated; the other two, Pine Rock and Mill Rock, to a transverse system.

(2) In East Rock and West Rock the sheet of trap made by outflow from the opened fissure or fissures has a length westward of 100 to 500 yards.

(3) The supply fissure, or its filling, the dike, descends beneath the eastern slope with a large eastward pitch: the angle of pitch in the case of East Rock being about 50°.

(4) In Pine Rock and Mill Rock, the trap is in *dikes*, there being no evidence of any outflow. Yet these dikes have in some of the outlets the great breadth of 150 to 300 or more feet.

(5) The pitch of these dikes is to the northward ; and its angle 18° to 40°—both characters of unusual interest.

(6) Although neither East Rock, Mill Rock nor Pine Rock has a length exceeding a mile and a half, each has three or four distinct outlets of trap, separated by intervening sandstone ; moreover, there is wide diversity between the Rocks in the form and arrangement of these areas of extruded trap, as the map illustrates.

(7) The trap of the several ridges, according to examinations by E. S. Dana, is true doleryte, free, or nearly so, from chlorite and other evidences of interior alteration, and not at all vesicular.

(8). Columnar fractures give the rock a rudely columnar structure, in which the half-defined columns are four to eight feet in diameter. In the west fronts of the north and south ridges the rude columns have usually an inclination nearly at right angles to the mean dip of the associated sandstone—according thus with the usual rule : perpendicular to the cooling surfaces. But among the columnar fractures, whatever the inclination of the columns, that plane of fracture or joint which is transverse to the sides of the dike or trap-mass and nearly vertical is the most strongly developed, and consequently the trap often cleaves into nearly vertical plates or laminæ of great extent, much like a laminated rock. There usually is also a second easy cleavage-direction, nearly at right angles to the former so that rectangular columns sometimes come out with great prominence.

(9). The outflows of trap have a floor either of an inclined layer of the sandstone or of edges of the upturned layers.

The principal conclusions.—(1). The igneous eruptions of the New Haven region took place after the sandstone had been upturned ; that is, after the evolution of the Connecticut-valley mountain-range in this part of the valley had made great progress.

(2). None of them were volcanic eruptions, for there was no center of action, no pericentric discharge of volcanic materials.

(3). In the outflows from the fissures (those of East and West Rock) the liquid trap did not escape into the open air and spread over the surface, but entered between layers of the sandstone.

(4). Moreover the flow was not by gravity into spaces that had been previously made, but a forced flow that opened spaces or chambers for its occupation, the liquid rock thus lifting the overlying sandstone as long as the discharge was continued. By such means the sheets of liquid trap attained, in some cases, a thickness of 300 or more feet. This forcible opening and filling of a chamber in the sandstone by the up-thrust lavas, is a *laccolithic* process, it according with that of the typical laccoliths ably studied out and described by Gilbert.*

(5). The intrusion of the flowing rock between the sandstone layers took place at comparatively shallow depths, where the pressure of the rock was not too great to prevent it.

(6). It was favored, in each case, by the fact that the oblique fissure supplying the lava was inclined in the same direction with the layers of the uplifted sandstone—both inclining westward, the dip being eastward.

(7). The termination of a fissure in several outlets, exemplified in three of the Rocks, was largely due to the great inclination and depth of the fissures opened through the weak upturned and faulted sandstone, and thence to great downfalls of the hanging wall. The same cause led to irregularities in the width and forms of dikes, and influenced the outlines and surface-features of outflows.

(8). The course and dip of supply-fissures was not determined by the foliation or bedding of the schists underneath the sandstone.

2. Special facts from the several Rocks illustrating the above conclusions.

The ridges, Pine Rock and Mill Rock, containing simple dikes are first considered, and then East Rock and West Rock, which include dikes and outflows from them.†

1. PINE ROCK.

The general form of Pine Rock is shown on Plate II, and still better on the following larger map.‡ It is only three-fourths of a mile long and trends N. 67° E., or east-northeast. This small ridge has three, perhaps four, independent outlets of trap, A, BB′, CC′ and D. The first, at the west end, is a small dike 15 to 20 feet wide, trending north 20° west, and traceable for 220 feet. It dips eastward 25°, and thus proves

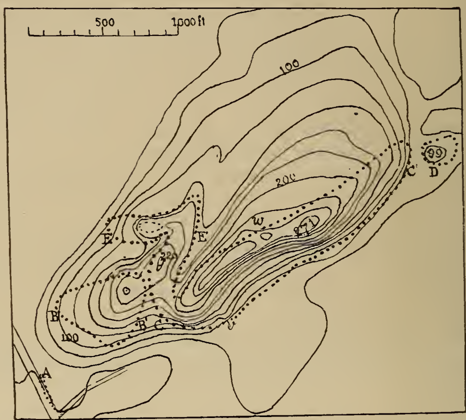
* Geology of the Henry Mountains by G. K. Gilbert, 4to, 1877.

† In justice to Percival, the author of the Report on the Geology of Connecticut of 1842, it should be here stated that there is scarcely an outlet or area of trap mentioned beyond which is not recorded on his map or described in his Report.

‡ The contour lines on this map, and also those on that of Mill Rock on page 87, are copied from the Bache Coast Survey map.

that it is not an outlier of West Rock, but part of the Pine Rock group. The other three are, more evidently, outlets from one great fissure. The width of the larger mass, CC′, is about 300 feet; and it is therefore one of the widest of dikes. The dip of the dike is 50° to 55° northwestward. This inclined

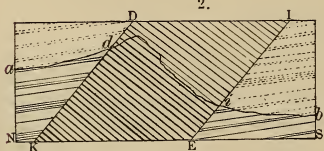
1.



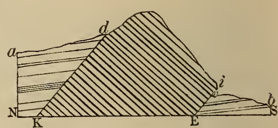
Map of Pine Rock. Heights reckoned from high-tide level. Areas of trap with dotted outline.

position (35° to 40° from a vertical) is given the dike in fig. 2, in which D I K E represents a section of it between its sandstone walls before denudation, and *d i* K E, the same through the

2.



3.



highest point of the Rock as it now is—or was before recent quarrying. The cross-lining gives the direction of the columnar fractures. The other figure, fig. 3, is a section through *v* on the map, where the removal of the sandstone of the southern wall (*v*, in the section) has left a depression called the *Cave*. (The sandstone of these sections is now concealed by the debris, and outside of this by the Terrace formation.)

The southern wall of the dike is the roof of the cave; the rock has the fine texture and fissured surface usual where it cooled in contact with the sandstone. Just above the cave,

4.

Inclined columns of Pine Rock, above the "Cave."

where the exterior is removed, the surface is made up of the ends of rude columns. A profile view of these inclined columns from a point just south is shown in fig. 4.*

At *w*, (see the preceding map) the *north* wall of the inclined dike is uncovered for a height of 50 feet, the sandstone having been carried off by the glacier.†

At the eastern extremity of Pine Rock (near C′), the trap of the north wall may be seen in contact with hard-baked sandstone. In the large quarry just south, the rock exhibits finely the transverse lamination crossing the dike—referred to on page 82. The laminæ incline 10° to 15° to the eastward, the dip being 80 to 85° to the westward. The surfaces of the plates are usually yellowish-brown with limonite for scores of feet from the summit, owing to the waters that penetrate from the surface downward and oxydize the iron of the rock; but in the transverse joints or cracks, which are less accessible to the waters, there is usually a coating of stilbite and sometimes

* From a photograph by G. N. Lawson, of the class at Yale of 1890; taken in December, 1890.

† The shaping of the northern slopes of the Pine Rock ridge is a part of the same work of the ice; and the trend of the mass, like that of Sachem's Ridge, (Plate II), indicates the direction of movement of the glacier. The same is true for the northern slopes of Whitney Peak and Indian Head.

of other zeolites, as chabazite, analcite, heulandite.* The dike has a few transverse courses of fracture containing prehnite and occasionally apophyllite, but no longitudinal have been observed.

A sandstone ridge connects A and BB′, in which the rock is hard, and has the strike N. 40°–45° E., and the dip 45° S., becoming N. 30° E. and 30° to 35° in dip more to the west. It is mostly a coarse sandstone; but some layers contain stones 4 to 5 inches in diameter.

Origin of the Features of the Rock.

The existence of so many outlets of trap in the small space, and the irregular forms of the areas are unusual facts. BB′ is short, broad and blunt, shield-shaped; and CC′, is duck-like in shape, the irregular bosses at the northwest end (EE′) making the neck and head. These bosses are not in the line of the dike, and must be due to a local catastrophe. In view of the great inclination of the fissure, and its depth of 2000 to 3000 feet in the weak sandstone, a caving in of some part of its northern or hanging wall would be of extreme probability. Such a catastrophe would account for the stoppage of the outflow and the separation thus of BB′ and CC′; and such a stoppage of the up-thrust lavas would explain their escape by one or more extemporized outlets, and for the actual position of the apertures on the *north* side of the fissure; and thereby for the making of the bosses. The obstructed lavas of the fissure may also have found exit in the western dike, A.

The trap-mass D is possibly a result of a second smaller catastrophe of like character; but its separation from CC′, may be a result of erosion.

Another consequence of the great inclination of the fissure is the exposure of the dike of heavy trap to degradation through the removal of the supporting sandstone on the south side. Such undermining has produced the steepness of the southern front. And sea-shore *waves* or breakers were probably the chief agent—the shores being those of the broad center, or a central arm, of the New Haven Bay.

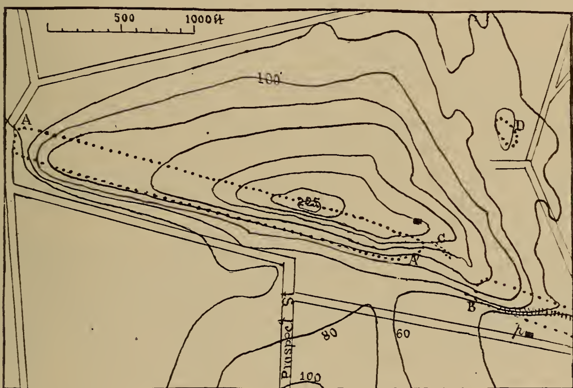
2. MILL ROCK AND THE WHITNEY RIDGE.

Mill Rock is one mile distant from the east end of Pine Rock. Its length to Whitneyville or Mill River, is four-fifths of a mile. This small area, as is seen on Plate II, and better in the following larger map, has four independent outlets of trap—

* The surface of the crust of zeolites is frequently tinged with the red iron oxide—which is a probable indication of heat as high at least as 200° F. during the formation of the minerals.

the western, AA′, the eastern, BB′; north of the gap between these, a short narrow dike C, and farther north, the isolated area, D. The width of the first, AA′, (as measured at its west end) is 200 feet; of the second, 140 or 150 feet; of the third, 1 to 10 feet; of the fourth, 50 feet, the length being 150. The mass BB′ continues to Mill River where the surface of the country declines to tide level. But the trap does not stop here; it crosses the river and extends on eastward, with an increased width, 180 feet, to the summit of Whitney Peak. The Whitney Peak dike belongs therefore to the Mill Rock region, although topographically part of the East Rock area. The trend of the Whitney Peak portion is S. 68° E.; of AA′, S. 78° E. The mean course for the whole series to the summit of Whitney Peak is about S. 72° E.

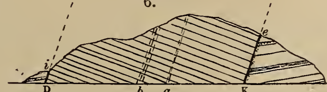
5.



Map of Mill Rock, excepting its eastern extremity. Trap areas with dotted outlines.

The dip or pitch of the main dike is about 72° to the northward, or 18° from the vertical. This inclination and the course of the columnar fractures are well exhibited at the west end of the dike, A, and are represented in figure 6.

6.



Section of Mill Rock, west end.

Besides the columnar fractures at right angles to the walls, there are also longitudinal fractures in interrupted lines, parallel to the walls. Two are seen at the west end of the Rock and are indicated in the above figure. They are now mineral veins. The more southern one, *a*, contains chiefly prehnite, with traces of copper ore, and the trap along its course is solid or little altered. The other is situated about half way between the sides. It contains abundantly the very hydrous mineral laumontite and the trap along it is decomposed; it contains also impure chlorite, and is fragile for a breadth of six to ten inches. A similar laumontite vein, but nearer the north wall of the dike, is seen at Whitneyville, and also in the trap of Whitney Peak.

The junction of the Whitney Peak part of the dike with BB′ takes place in the bed of the stream at Whitneyville, and is not now exposed to view owing to the dam and the buildings below it.*

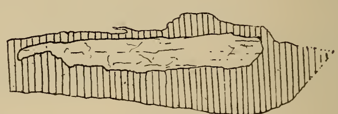
The level of the trap beneath the dam is but a few feet above and below tide level. The height of the Whitney Peak dike increases eastward; first by a sudden rise of 100 feet, and then more gradually in the last 500 yards to 280 feet. Whitney Peak has a bold front to the eastward with sandstone at its base showing a sudden stoppage of the fissure in that direction; and at the same place it widens southward—not by overflow, as the precipitous eastward front and the depth of the trap shows, but through the opening of a transverse fissure. The Rock has a steep wall 70 to 80 feet high, on the north side of the summit for nearly 100 yards; but this is due to the removal of the sandstone by glacier action, exposing the north wall of the trap dike.

The narrow dike C is about 110 feet long. It is situated in the face of a bluff of sandstone; and from the evidences of heat in the hardness of the rock, its mottled and light gray color in places, its steam tubes, and epidote, it is plain that the ejection determined the resisting power of the sandstone against denuding agencies. The following figures represent

7.

8.

9.



two cross sections from the western half, and a map of the last 40 feet of the eastern half. At 65 feet the outflow is divided,

* To the fact of this continuation I have recent testimony from Mr. Eli Whitney, who has superintended the constructions made there during the past forty years. Besides mentioning that the dam was built along the junction of the trap and sandstone, he says that below the dam for some distance, there is trap rock only, no sandstone outcropping there to his knowledge.

The gun factory at Whitneyville was established there by his father, the inventor of the cotton-gin, in 1798, for the manufacture of muskets for the United States Army.

a narrow stream of trap (fig. 9), coming out above a layer of the sandstone 5 to 6 feet thick, the main part of the dike appearing below. This envelope of sandstone by trap continues for 30 feet, when the two parts come together again. The depth at which the side stream goes off from the main dike is not known. The inclination of the dike is mostly 25° to 28° (fig. 7) from a vertical, but at 45 feet from the west end it becomes 40° (fig. 8), and 10 feet beyond this, 30°.

The sandstone of the Mill Rock region is of all degrees of coarseness up to cobble-stone conglomerate; and no distinction is observable between that of the west and east ends.

Origin of the Mill Rock features.

The subdivision of the trap into its four masses may be explained in the same way as that in the Pine Rock area. A downfall of the northern sandstone wall of the fissure, the hanging wall, would account for the separation of AA′ and BB′. Further, the obstruction thus occasioned to the great ascending stream—its width 150 to 200 feet—would have forced open passages to the surface for the discharge of the liquid trap, and thus may have been produced the small dike C, situated near the fissure wall, and the remoter mass D. The irregularities of the little dike C, and the situation of both C and D to the north of the line of the dike, accord with this idea of a downfall of a part of the northern wall. The liability to such a catastrophe in a wall made of the rude sandstone 3000 feet or more high, and having a large inclination, was augmented in both Pine Rock and Mill Rock by the tilted position and faulted state of the sandstone. The beds had already received their eastward dip of 15° to 25°, and breaks and faults innumerable that had been made in the adjustment to the new tilted position; it was therefore a tottlish structure overhanging a profound abyss. The fact here introduced that the eastward pitch of the sandstone was given it before the ejection of the trap is sustained by facts reported beyond. But an argument for it is afforded here: for if this *eastward* pitch were of subsequent origin, then the Whitney Peak end of the system should be the lowest. Instead of this it is greatly the highest; the ridge slopes westward.

It is possible that the fissures of AA′ and BB′ were, from the first, independent fissures to a considerable depth; for they are not in precisely the same line. If this were so, the above explanation, while in the chief points right, would require some modification.

As in Pine Rock, so with Mill Rock but to a less degree, the northward pitch of the dike made it easy of degradation by sea-shore action. Through such means, beyond doubt, the part of it extending from Mill River westward for 300 yards, was reduced to a width above ground of 40 to 50 feet. This narrowing commences just west of the Pumping House of the City Water Works (*p*, fig. 5), and continues without interruption to the river. It is part of the evidence of a greater New Haven Bay at some former time.

Why the range falls gradually to so low a level at Whitneyville, appears to be explained only on the view that less trap here came to the surface. I have elsewhere shown that it cannot be due to glacial removal. Neither is it probable that fluvial or marine waters have produced it. We have to attribute it to some condition existing or produced in the supply-fissures of eastern Mill Rock and Whitney Peak, at the time they were opened.

Besides the dikes of Pine Rock and Mill Rock, there is another transverse dike of special interest which intersects the West Rock ridge just below the margin of Wintergreen Lake, or about one and a quarter miles north of the southern termination of the ridge and four miles from New Haven Bay. It descends the eastern slope of West Rock in an interrupted ridge, forms part of the southern bank of Wintergreen Lake, sinks to the level of the West Rock surface at the summit, but stands out like a buttress along the steep west front of the Rock. From the last feature I have called it for the past twenty years, the "Buttress dike." It extends south-westward through the metamorphic region of the towns of Woodbridge and Orange to the mouth of the Housatonic—as long since mapped and described by Percival. This dike has a pitch northward, amounting to 25° from a vertical in the part of it intersecting West Rock, but in that through the metamorphic rocks it is nearly vertical.* The strike of the inclined columns in the buttress portion is S. 30–32° E. It is an example of a dike made subsequently to the cooling of another dike, that of West Rock. It has great importance in this connection, since it brings into the Jura-Trias system of mountain-movements a dike intersecting the metamorphic rocks outside of the Connecticut Valley, and one that branches off from the southern or New Haven part of the system.

3. THE EAST ROCK SERIES.

The form of the East Rock area and its position between Mill River and the Quinnipiac, are shown on Plate II. Through

* The rock of the dike is sparsely porphyritic; and the feldspar distributed through it in crystals a fourth to a third of an inch long is anorthite, as shown by G. W. Hawes (this Journal, III, ix, 188, 1875). This character makes it easy to identify the several parts of the dike; it is the only case in which this mineral has thus far been found in the Connecticut Valley trap.

Percival's account of the Buttress dike and its extension southwestward is on page 399 of his Report.

denudation by the sea, rivers and ice, it has lost all of the sandstone formation that may have covered the summit, and for the most part that over its slopes above the 200-foot contour-line. The form of its upper portion is therefore largely that of the trap in its constitution—the hard rock that was most successful in resisting wear. This fact gives special interest to the larger and more detailed topographical map making Plate III, as will appear beyond.*

To the north is Whitney Peak, which has already been described as the eastern extremity of the Mill Rock series. South of this and of a large area of sandstone, are East Rock and Indian Head, one in trap surface, but in fact the result of two independent outflows. To the south of Indian Head is Snake Rock, which also has its large trap mass, but is peculiar in having ridges of hard-baked sandstone that are higher than those of trap. The East Rock areas of trap here referred to are lettered on the map BB′, CC′C″, DD′. Besides these there is a more northern one, lettered AA′, which lies near the eastern foot of Whitney Peak.

The trap-mass AA′.—This northernmost mass, is about one hundred yards long. At its northern end it is only forty feet distant from the trap of Whitney Peak, and it is a question, therefore, whether it is not a part of the latter dike. But it is separated from it by outcropping sandstone, except where the interval is narrowest, and at this point there was until recently drained, a standing pool of water, a pretty good indication that sandstone exists beneath, since trap is commonly too much fissured to hold water or afford springs. Moreover, the mass AA′ has the trend of the East Rock series; and,

* The map of East Rock Park which is the basis of Plate III, was obtained from the Engineer department in New Haven, through the City Engineer, Mr. A. B. Hill. The roads of the Park from the termination of Orange St., around by the north to the summit of East Rock are lettered *F*, and the others *E*. These letters refer to two citizens of New Haven, Henry Farnam and James E. English, who liberally bore the expense of their construction. The topography is in part from the Bache Coast Survey map: but the accuracy of its contour lines was not sufficient for their transfer to the Park map. The heights are reckoned from high tide. The map is indebted to Prof. S. E. Barney, for the determination by leveling of the height of the highest point of East Rock, just south of the monument (358½ feet) and also of other points on its south and east sides, and for that of the junction of the trap and sandstone on the west front near Orange St. bridge (155 feet). The height of the bolt at the Coast Survey Station he found to be 343 feet, and the height of the top of the first step leading to the terrace about the monument, 355 feet. (Prof. Barney's figures are underscored on the map). The circuit road about the summit has a height of 320 to 350 feet; and the nearly parallel road on the east rises from about 216 feet near the quarries south of the summit, to 270 near the junction of the "Farnam drive" and "English drive," and thence declines northward to about 250 where it bends westward. The letters S on the map indicate an outcrop of sandstone in the vicinity of junctions with the trap.

In giving the topography of the Rock, the quarry excavations on the south side above a level of 216 feet are not introduced, it seeming best to represent the Rock in its original form. They are separately mapped on the plate.

besides, ledges of trap along the east side appear to indicate that the supply of liquid rock was from the eastward, like that of East Rock. On this view it is the northern mass of the East Rock series.

East Rock proper.—The trap mass BB′, or East Rock, curves around from N. 25° E., on the north to N. 75° W. at the southwest extremity. Adding to it the Indian Head mass, it ends in an east-and-west dike, and is a complete crescent in outline. It has a bold columnar front, in which the columns incline about 22° from a vertical—the position, being, as is usual, at right angles to the mean dip of the tilted sandstone. A view of the southwest front of the Rock is presented on Plate IV. Plate V illustrates the character and inclined position of the columns, and shows the contrast in the latter respect with Pine Rock.

The upper 200 feet are of trap. The junction of the columnar trap with the sandstone is exposed to view at several points along the front. One such exposure may be seen when crossing the Orange Street bridge. The view in Plate IV, in which the bridge appears in the foreground, has the exposure half way up the front to the right. The height of the junction plane above mean tide at this place is 155 feet. Another is faintly indicated on the same plate directly below the Refreshment House; the height of the junction is there 150 feet. In other exposures of the junction-plane to the north, the height is less and becomes only 85 feet near the Rock Lane bridge; and it is also less to the south being but 132½ feet at B′, the southwest angle of the trap mass. Since the strike of the sandstone of the region is about N. 30° W., the sandstone (or the junction plane) has its greatest height, 155 feet, where the front has this direction; and the bedding of the sandstone in the section for this reason appears to be horizontal. The diminished height to the northward is owing mainly to the exposures being at a lower level on the junction-plane because of the changed direction of the front, it becoming N. 10° E. near Rock Lane bridge. Through this interval the trap retains its thickness of about 200 feet. North of Rock Lane bridge the underlying sandstone is wholly covered by debris, so that the position of the junction-plane is doubtful.

The supply of the trap forming East Rock came up, as the slope of its surface shows, from the eastward; and it continues rising westward to the western and southwestern margin of the summit. The slope from the summit eastward and northward is gradual for about 300 yards, and then it pitches off at an angle of 45° to 50′ along the course of one of its dikes.

The position of the dike, and thereby of the supply-fissure, is well exhibited at *bc*. A bare wall of trap, 50 to 55 feet in height, descends at the angle mentioned. Since the surface there exposed became solidified against the northern sandstone wall of the fissure, the rock is of fine-grained texture and has an irregularly rifted aspect. The foot of the wall is about 200 feet above high tide, and from it the land, underlaid by sandstone, slopes off gently to the eastward. Since the direction of this wall of trap is S. 15° W., or that of the movement of the ice over this region in the Glacial era, the wall escaped the tearing action of the glacier, and so retains its original surface.

Farther south, along a line from *d* to *e*, there is a similarly steep slope, but it is made of displaced blocks of trap. At its base there is a flat, terrace-like surface, which is near 200 feet above tide level. This steep slope appears hence to have been the course of the wall of another part of the supply-fissure. The flat terrace, although nearly 100 feet wide, is without stones over its surface of either trap or sandstone except in its southern portion, and there occur sandstone in fragments along with trap, and an outcrop of sandstone over trap at S. This fact and the occurrence of a perennial spring in this southern part (at the point toward which the two paths on the map, Plate III, descend) make it probable that the terrace rests on sandstone, and that this sandstone was that bounding on the east, the supply-fissure above referred to.

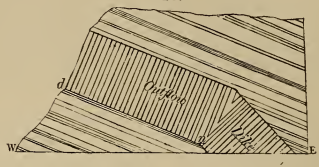
But there is trap again to the east of this terrace, showing that the lower eastern slopes were supplied from a more eastern fissure. Along from *c* to *d*, the trap of the outer fissure appears to have flowed over and coalesced with that of the inner. Again south of *e*, the distinction of the two fissures cannot be made out. But the fact that the supply-fissures, one or both had a large inclination—not far from 45°—is evident from the very steep slope of the surface.

Sections of the dikes of trap are nowhere exposed, and hence we are ignorant of the width of the supply-fissures. Judging from those of Mill Rock and Pine Rock, it may have been 150, 200 or 300 feet; but it was possibly much less.

The Outflows.—In East Rock, the trap which overlies the sandstone along the front, was that of outflows from the fissures westward between layers of the tilted sandstone. The fact that the columns of trap have a position at right angles nearly to the inclined layers of sandstone is believed to be good evidence of this intrusion of the melted trap.

Fig. 10 represents the view that has ordinarily been held with regard to the relative positions of the trap and sandstone. According to it the trap left the dike to flow westward between sandstone layers having a dip of 20° to 25°. A space was opened between the layers of sandstone which the liquid trap filled. It is plain that this chamber could not have been so opened in advance of the inflow; for the hanging wall of the weak sandstone inclined 65° would have had no support. It is hence evident that the ascending stream of trap, forced

10.

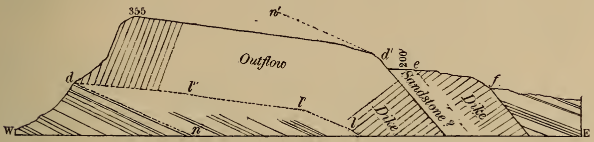


Ideal Section of East Rock before the removal of the sandstone from the summit.

along its course, opened a way between the layers; that a tongue of trap first entered, which would have been partly cooled against the cold rock; but the flow was kept up below this first intruding portion until the trap had all entered, the lifting of the overlying sandstone going on as it needed more space. This lifting would have brought a strain on the sandstone that would have broken the connection between the lifted portion and that either side, to the northward, westward and southwestward. To the question, therefore, how far did the trap flow westward, the conditions reply: to the wall of such a fracture; and it may not have extended many rods beyond the present limit. The sandstone of the western wall has disappeared in the general denudation over the New Haven region, excepting a small part at the southwest angle, where a zigzag path (Z, Plate III) ascends to its top; the height of this sandstone is 185 feet, which is twenty-five feet above the base of the trap where highest to the northward, and fifty feet above that just south at A′. The locality of this sandstone and the zigzag path is seen on the right margin of Plate IV. The sandstone of the northern wall remains to a height of 196 feet at *m:* the sandstone between Whitney Peak and East Rock is what is left of it. The dip of this sandstone at *m*, near the junction, is 30°, in the direction N. 73° E.; and the inclination of the columns of the trap just above is also 30°.

The theoretical section of East Rock in fig. 10 represents correctly the fact of the intrusion of the melted trap between sandstone layers. But since the bottom over which the flow took place is concealed from view, it is not quite certain that the sandstone layer on which the flow began continued to be the floor to its western limit. Moreover, there is a large discrepancy between the pitch of the trap over the summit and that in the section. An actual section of the rock from east to west (or more exactly E.S.E. to W.S.W. since this is approximately the direction of a transverse diameter) drawn to a scale, fig. 11, throws some light on these points.

11.



Section of East Rock, showing the correct profile.

This section is essentially right in its profile, but more or less doubtful in its interior lines. The height of the upper surface of the outflow where it left the dike at *d'* is 265 to 270 feet. It was not less than this; for we have this height for the top of the bare, unabraded wall of trap (adding the part of it under the Summer House west of the road). The length of the overflow to the present western front, is, as already stated, about 300 yards. The height of the western brow of trap in the section is 355 feet;* and that of the bottom of the trap in the western front, 155 feet. These are facts; and the divergence here from figure 10 is very great. Further, the mean angle of the trap surface over the summit is 10° instead of 22°, the mean dip of the sandstone. The latter dip is shown in the lines *dn*; and if the floor had originally this pitch throughout, the thickness of the trap would have been about 450 feet, this being the distance on the scale of the section between *dn* and *d'n'*, while actually it is only 200 to 210 feet.

The question arises: How was the lower slope of 10° attained, and how the lessened thickness. Are they a result of wear by glacial or other methods; or was the present slope approximately the original slope of the outflow? A large amount of observation over trap ridges leads me to believe that the loss over East and West Rocks by abrasion has been small, probably not over 50 feet. The glacier, as it was shoved along, might easily have torn off columns from the front, but it would have made little impression on the exposed surfaces. Moreover glacial abrasion would hardly have left the highest points of the summit so near the western edge.

If the outline of the summit approaches that of the original outflow, then—*d* being the lower limit of the trap on the front—a line drawn from *d* nearly parallel to the summit plane,

* This is the height 80 feet north of the Summit Refreshment House, just west of the road, this being the highest point over this northern half of the summit area.

would probably represent the position of the bottom of the outflow. The line *d l″ l′ l* has been drawn on this view. It supposes that the trap, on leaving the dike, passed between two layers of sandstone from *l* to *l′* and that afterward it broke away the layer beneath it and flowed on, either over the edges or surfaces of layers as the conditions favored.

The only spot where a section of the floor or plane of junction of trap and sandstone, is seen, is at A′, the south-southwest corner of the trap-mass, by the road-side. There, for a few yards, the trap *rests on upturned ledges* of sandstone, and not on one continuous layer. The section is too short for any reliable conclusion were it not sustained by facts from West Rock.

The section, fig. 11, also represents the *inner* and *outer* dikes described above, with the intervening (?) sandstone. The doubts with regard to the widths of these dikes and the area of sandstone have already been the subject of remark.

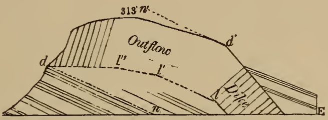
Columns stand out boldly on the steep western front of East Rock. But they have none of the normal forms, for the angle between the most prominent faces frequently approaches a right angle, resulting from a combination of the plane of fracture at right angles to the trap-mass and another transverse. The direction of these planes varies along the course of the Rock on account of the curve in its outlines. At the quarry, on the south side of the summit, at the termination of the zigzag path Z, there is a fine display of broad surfaces in the two directions meeting nearly at a right angle. The courses here are about N. 35° E. and N. 55° W. The surface of one of them for many square yards is covered with rosettes of garnets and scattered minute crystals of magnetite, their faces brilliant in the sunshine. Along the whole western front of the Rock there is a remarkable predominance of planes conforming to its plane through all its changes of direction. This is apparent on Plate IV, and some of the right angles are seen on Plate V.

The upper half of the columnar front (see Plate IV), down to a level of about 220 feet above tide-level, has columns four to eight feet in diameter; below this the size is in general half less; and for the lower twenty feet above the sandstone, they are quite small.

Indian Head.—Indian Head is much like a small edition of East Rock. The length of the outflow is 100 yards; the height 310 feet (313 above mean tide). A section made on the same principle with fig. 11 of East Rock is given in fig. 12.

Indian Head stands quite apart from East Rock. The gap now separating them, where highest, is about 200 feet above high tide, and therefore nearly 160 feet below the top of East Rock and 110 below that of Indian Head, and probably sandstone intervened for the greater part of this depth; for the two Rocks face one another with steep slopes, as well brought out on the map, Plate III. These continue to be

12.



Section of Indian Head.

steep to the very foot of each, where they approach one another down the eastern slopes. Their bases are here in independent valleys, designated on the map by the letters E and I, separated by a low trap ridge, R, so that East Rock and Indian Head, although the trap extends over the surface of the gap from one to the other, are nowhere united at base. The eastward sloping valley, I, lying at the northeast foot of Indian Head is continued in a westward sloping valley I′, at its northwestern foot, and the two together define its outline. The low trap ridge R, between E and I, although consisting at surface mostly of blocks of trap, has a solid ledge in its lower part. It probably crosses the gap westward; and the Summer House, near 201 on Plate III, may be on its western part. The valley E, at the southeast foot of East Rock, is perhaps, a result of glacial action; but why there should be two valleys side-by-side if erosion made either, is not explained.

The trap of Indian Head rises from the bottom of the small valley just mentioned apparently in two half-separated streams instead of one even stream; but this feature may be a result of erosion. The eastern outline of the trap (see Plate III) is in a line with the eastern of the East Rock trap, indicating that the supply-fissure corresponded in direction with the outer and not the inner of the East Rock courses of fissures. The two Rocks, although alike in features, are to a large degree independent. Abrasion helped to deepen the gap between them, but more by the removal of sandstone than of trap.

Indian Head is peculiar in having a long eastward projection from the southern end. It is described on a following page.

The mode of origin of the trap-masses of East Rock and Indian Head—by a forced flow of lava, opening through its uplifting action, a chamber in the sandstone for its accommodation—entitles the two to be called *laccoliths*. Through degradation, stripping them of the covering of sandstone, they stand side-by-side—a pair of laccoliths.

Snake Rock.—In Snake Rock, a broad mass of trap measuring about 900 by 450 feet in its two diameters lies encased in sandstone. The greatest height of the trap is but 160 feet, and that of the sandstone west of it over 200 feet. The trap covers the eastern slope of the Rock nearly to its foot, thus showing that the supply-fissure was on that side, as in other parts of the East Rock series, and also indicating by its steepness that the fissure was much inclined. At the south end of the Rock, in the yard behind the north corner of the Bassermann house, at a junction of the trap and sandstone, the dip is about 45°; and this is direct evidence as to the inclination.

The area of trap of Snake Rock has on the north the width of that of Indian Head; and the mass may hence owe its increased width northward to an outflow. If so, Snake Rock contains a half-emerged laccolith, its summit exposed, but the western wall of sandstone still standing and overtopping the trap. The sandstone shows everywhere the effects of hot vapors in all their varied forms, and before encroachments were made by a brewery there was a fine display of columnar sandstone in the southwestern bluff.

Origin of the breaks in the East Rock series.

The prominent breaks in the East Rock series are that between Indian Head and Snake Rock, and that separating the small northern area, AA′, from the main East Rock mass, BB′.

The Indian Head and Snake Rock masses, CC′ and DD′, approach one another bluntly within a hundred yards, and the area of sandstone between has parallel sides, as the map, Plate III, shows. In view of the steep pitch of the supply-fissure, a catastrophe to the western or overhanging wall is a most probable explanation of the break between them. The checking of so great a stream for a length of 100 yards might be expected to open escape-ways in some direction. The long eastern tail-like projection from Indian Head, C′C″, is the result of outflow along an east-and-west fissure. The pitch of the fissure, as the position of the trap shows, was about 25° to the northward. Its southern front is steep and rocky, the northern, gentle and grass-covered. It may be that this supply fissure was the escape-way then made, and the trap the part of the stream that would have occupied the interval had no such catastrophe occurred.

The relations of the northern trap-mass of the series, AA′, to BB′ are doubtful. Yet it is probable that the trap of AA′ was ejected from the north end of one of the two East Rock fissures, or lines of fissures. The ledge of very hard sandstone which extends southward from near the south end of AA′, passes by the east side of the dike-wall *bc;* and it probably derived its position and its excessive consolidation and lost bedding to a catastrophe that closed the fissure for the interval between them, which is only 200 feet wide, yet left it giving out heat, and generating volumes of hot vapors for the consolidating work.

The East Rock masses of trap may therefore be traced to two ranges of fissures. The western was the probable source of the most northern area, AA, and of the summit portion of that of BB′ on East Rock. The eastern, contributed to the lower slopes of East Rock; and also through its continuation southward gave origin to the trap of Indian Head and Snake Rock. But for the accident to the hanging wall of the great fissure, the trap of Indian Head and Snake Rock would have made one continuous mass, and the columnar front of the former might have been continued over part of the present Snake Rock area. The areas of trap in the East Rock series narrow both to the south and the north.

4. WEST ROCK.

The facts and conclusions relating to the West Rock region derive prominent interest from their pertaining to one of the long trap-ranges of the Connecticut Valley region. The area is represented on the accompanying map, Plate VI, from a survey made by the author with chain and hand-level in 1879 and 1880. The 20-foot contour-lines of the steep western and southern fronts of the Rock and the geographical positions are from Bache's Coast Survey map; but the other contour-lines exhibiting the surface features, which required for mapping detailed measurements, are those of the author.*

Features.—(1.) While the general course of the West Rock Range is north-and-south, the western foot of the blunt southern extremity bends round to an eastward course, and ends with north 30° east. The summit of the ridge also curves, in its last 500 yards, around to S. 70° E. or nearly to east-by-west. Its height in this part is 399 to 405 feet above high tide, the geodetic station at the extremity being 399 feet. The eastern foot of the ridge has no corresponding bend.

(2.) The trap of the Rock is a continued mass instead of being divided into several masses through a multiplication of outlets. But it has a large bay of sandstone, of triangular outline, in its southeastern portion, which from its form is called the Triangle. (3.) South of the Triangle there is a prolonged hook-like point making the southeast termination of the trap.

(4.) North of the Triangle commences the trap of the west slope of the mountain. For a distance of 500 feet near the foot, increasing to 800 feet above, the surface of the trap is here elevated sixty to eighty feet or more above the level

* The dotted line on Plate II is the north limit of the map, Plate VI. Heights *C* to *Oa* are plane-table results of Prof. H. A. Newton, from Bache's 399 as base.

farther north. Moreover it is raised into rounded ridges, and some of these ridges have a high inclined wall on the south side. The first of these walls adjoins the Triangle and has a height of seventy-five feet, a slope of about 45° and an even flat surface free from marks of abrasion. Another similar wall farther north is thirty feet high. The smaller troughs are mostly one to three yards deep. The angle of slope in the embossed surface between the 300-foot and 100-foot contour-lines is less than 17°; and in the surface north of it less than 14°. (5.) The long, hook-like point, above referred to, is not a simple ridge of trap, like that from an ordinary fissure, but consists, as seen along its northern side (Plate VI), of a series of rounded ridges which increase in height to the westward, like those of the elevated surface of trap on the other side of the Triangle. Moreover, all these wrinkle-like ridges, concave troughs and oblique walls, have a general parallelism. (6.) The embossed surface north of the Triangle has lost, through glacial abrasion, as a consequence of its elevation above the general level, all of the sandstone once covering it, even to the foot of the mountain, excepting small portions in two of the troughs. Farther north the sandstone remains in some places nearly to the 300-foot contour-line. (7.) The trap of the embossed area that was thus uncovered suffered little from the abrasion; for the rock of the surface has the fineness of grain and other characteristics of the contact rock. This is true also of the trap of the southeast point. Moreover, in many places on this point below 300 feet, the trap contains imbedded fragments of the sandstone which fell into it while it was still liquid. The trap of other parts of West Rock ridge rarely shows evidence of abrasion below a level of 300 feet. On the contrary, above this level it has lost by abrasion the fine-grained, brittle crust-portion, and presents at surface the coarseness of crystalline texture that belongs to the interior of the mass.

(8.) Another very important feature of West Rock is its affording a long east-and-west section through the breadth of a great trap range, exhibiting the contact-plane for several hundred feet of the outflowing trap and the underlying sandstone, as described and figured beyond.

The map, Plate VI, has the walls, troughs, and ridges of the surface shaded, to bring out better these features of the original surface of the trap. The southern front of the Rock has been made by degradation and hence has no shading. The southeastern point owes its straight outline on the south side to the quarrymen and the joints in the trap. The map shows what remained of the point in 1880. There is much less now.

The Supply-fissure.—The inclination and width of the fissures supplying the liquid trap for the West Rock range are undetermined. Exposures that will afford the facts are most likely to be found along the eastern base of the ridge. At one place where the surface of trap had been uncovered but not abraded, which was seemingly favorable for a safe conclusion, the slope was 25° to 30°, and suggested the angle of 30° for the inclination. But the trap at the place may have been part of the *outflow*, and not that of a dike. Observations along the eastern slope of the range farther north may obtain decisive facts.

The Outflow.—The slopes of the higher parts of the West Rock ridge, the pitch of the columns of the western front, and the resemblance in features of West Rock to East Rock, lead to a like conclusion for the two, that the outflow was laccolithic; in other words, that the liquid rock forced its way between layers of sandstone, and made the chamber it occupied. The present thickness of the mass is nearly 250 feet. The overlying sandstone is to a large extent the weak, chip-making rock of dark red and purplish color already described. It is remarkable that a rock of so feeble coherence could have been lifted in the way mentioned.

The questions suggested by East Rock here come up again: Whether the feeble slope of the surface from the west edge of the summit eastward to the 300-foot contour-line, and the small thickness of the trap, are due to abrasion, or whether the present conditions are nearly those of the original outflow. As the length of the outflow is nearly 500 yards, the mass, if forced up between layers dipping 25° eastward, would have had a much larger amount to lose by abrasion than in the case of East Rock.* Speculation is here set aside by the actual east-and-west section of the Rock which is presented along its southern front, and is shown in part on Plate VII, from a photograph.† It exhibits the trap resting, to the eastward, on

* The thickness does not admit of calculation, because the only datum besides the dip of the sandstone, is the height of the bottom of the trap over the sandstone on the west front (about 200 feet); the height of the outflow where it left the fissure is not ascertainable.

† The fine photograph was taken by M. W. Filley, of the firm of Bundy & Filley, of New Haven. The sandstone has here been exposed to view by the removal of the debris for macadamizing. The irregular line in the plate a third of an inch above the sandstone was the limit of the talus or debris slope; and the line below the sandstone is the profile of the quarry wagon road. Along the part of the section represented, the height of this road is ninety to one hundred feet. If the debris were wholly removed to the bottom of the slope, the height of the sandstone exposed to view would be, where greatest, over 150 feet.

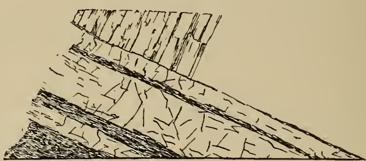
The photograph does great injustice to the view in the diminution of the vertical as compared with the horizontal scale, and also in flattening the angle of dip in the sandstone. 200 feet measured on the quarry road reaches from the eastern point of the sandstone section westward to within twenty-five feet of the line of the deep notch in the columnar front of the Rock (the place where the first section of sandstone ends); but this length applied vertically to the front above the road would make it only 180 feet in height, when in fact this height where greatest is over 300 feet. This error arises partly from the fact that the view was taken from the terrace opposite, which is only sixty feet high, but more from the error in an ordinary lens.

a tilted layer of the sandstone, the dip of which eastward is 25°. We are left to conjecture as regards the eastward and downward continuation of this layer to the supply-fissure (which the further removal of debris might perhaps uncover). But we know that the trap continues up this sloping layer for seventy-five yards from the commencement of the outcrop. It conforms to the theoretical view of an outflow as presented in fig. 10, on page 94.

But on reaching the end of the seventy-five yards, there is a change. The trap beyond rests on the edges of the layers in a series of ledges of the sandstone. Moreover there is but little rise westward along the floor; for a line drawn along the top of the ledges would be almost horizontal, and have therefore near parallelism to the surface of the trap at the summit west of the geodetic station.

The following figure represents the eastern extremity of the sandstone for a height of fourteen feet, together with the

13.



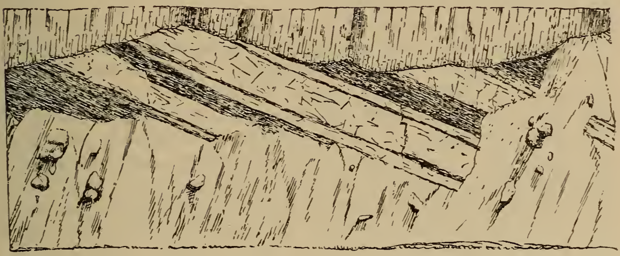
base of the overlying trap. The rock is partly a hard-baked granitic sandstone, and partly the feeble shaly chip-making purplish-red sand-rock. The trap columns above the sandstone have in the lower part an inclination of 20°, approaching thus verticality to the surface of the sandstone; but, higher up the bluff front, there is a gradual change to 5°, which is the prevailing inclination.* The upper layer of the sandstone where uncovered shows a surface without breaks or much unevenness.

A section of the sandstone, with the trap above, for the next seventy-five yards is represented in the following figure. The fact that the trap when melted flowed over the upturned edges is manifest. The chip-making rock constitutes much of the mass, and at its contact with the trap it is scarcely changed in color or texture. The trap is far more finely columnar than that to the east over the single sandstone layer, and probably because moisture reached the trap freely from between the upturned layers. Other sections farther west are of similar

* The angles of inclination here recorded are those presented to an observer in the front view of the rock here described.

character, excepting that the apparent dip is less. They may be followed westward along the quarryman's road for 400 yards, when they begin to pass into the normal sections of the western front, that is, sections in which the lines of bedding are horizontal because they are in the line of strike of the sandstone.

14.



The question here arises: Did the flowing trap, owing to its movement and weight, wear off the layers of sandstone and so make the succession of ledges on which it rests; or did it escape from its confining cover of sandstone into the open air and cover in its flow the exposed ledges of the region. The former is probably the correct view. Had the flow become subaerial there would have been at once a decline westward in the level of its upper surface; for the level would have fallen as soon as the resistance from confinement ceased. There is no evidence of such a decline. From points on the summit close to the western precipice the surface for the first 300 yards has generally a slope eastward of 1 to 4, or 1 to 5, corresponding to a pitch of 14° to 11°. The decline is eastward; not westward. Such a rise westward, even if only 5°, would be an impossibility except in a covered passage-way, that is, in the present case, one having a cover of the sandstone. Other evidence bearing in the same direction is afforded by the position of the columns along the western front, which pitch westward 15° to 20°.

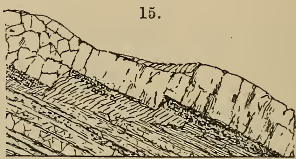
The summit slope eastward of 14° to 11° is less than the dip of the sandstone, and favors the conclusion that the underlying sandstone was in many places torn up by the heavily moving liquid trap, while left in place elsewhere. The floor so made consisted of alternations of wide strips that had the regular dip of the sandstone, with others abraded down to nearly flat and ledgy surfaces; and the former prevailed sufficiently to determine the direction of the contractional fracture-planes or the columnar structure. A reduction so nearly to horizontality as that shown in the south front of West Rock along with parallelism in the profile of the summit may not be common.

West Rock teaches that the section of East Rock in fig. 11, p. 95, may be no exaggeration. Yet it is more probable that the original condition was intermediate between this position and that indicated in this diagram.

Sections similar to that in the south face of West Rock may be looked for, with some probability of success, among many of the trap-ranges of the Connecticut Valley wherever they terminate in transverse sections. All that is necessary to ascertain the truth is to remove the talus of trap debris.

Three miles east of New Haven (in East Haven) a section was opened in cutting for a carriage-road through the second trap ridge west of Saltonstall Lake; it is but a few rods west of the railroad station. The facts are in all respects similar to those of West Rock, as shown in the annexed figure. The

15.



trap covers a series of ledges of upturned sandstone, and shows no traces of displacement subsequent to its cooling. The sandstone is intersected by extensive nearly vertical fractures, whose surfaces, owing to friction, are scratched and polished; and the larger planes extend up through the sandstone without any appearance of corresponding displacement in the trap. Moreover these polished slickensided surfaces have the white porcellanous coating common in the region; probably made by the grinding of the feldspar of the sandstone in the mutual friction of the walls.*

* At all the East Haven quarries, and in the ledges elsewhere exposed to view, these evidences of displacement and of much friction attending it abound. Fragments as large as the hand, slickensided on both surfaces and over planes of cross-fracture, are common; and so are walls of various inclinations hundreds of square yards in area. The sloping upper surfaces of the sandstone layers laid bare in the quarrying are sometimes polished and scratched in the direction of the dip for many square rods. There is abundant evidence of a vast amount of movement, though movement in a small way, during the progress of the upturning in which the sandstone received its universal eastward dip.

The section represented in fig. 15 has lost much of its original distinctness by the sliding down of debris from above.

The trap of this ridge, at a higher level above the sandstone, is more or less chloritic and in many places amygdaloidal. Part of the amygdules are slender cylinders, two to three inches long and like pipe-stems in size, occurring often in groups—the result probably of the sudden vaporization of particles of liquid carbonic acid.

In the railroad gap through the Saltonstall Ridge, the first west of Saltonstall Lake ("Pond Ridge" of Percival), the sandstone appears to lie in a similar manner unconformably beneath the western extension of the trap. But the section is now too much covered by debris for a satisfactory observation. Two miles east of the Saltonstall ridge in Branford, as described by Mr. E. O. Hovey,* the trap of a short range, the easternmost in this part of the sandstone region and near the gneiss boundary, overlies the *upturned* edges of the sandstone, and there is between the two rocks a layer of sandstone conglomerate containing nodules of trap, which he attributed to the rubbing action of the flowing trap on the sandstone.

These facts, ranging in this part of the Connecticut Valley over the whole breadth of the Jura-Trias formation, from the west side of the New Haven region where the trap is of the compact non-vesicular kind to the dikes of vesicular trap toward and near the eastern gneissic border, have great importance in their bearing on the subject of the other Jura-Trias ridges. The more eastern are placed by Professor Davis among the ridges made of horizontal subaerial flows, ejected before the upturning of the sandstone; and the more western he has regarded as horizontally ejected and subsequently upturned, although admitted to be interstitial intrusions. Neither of these conclusions are sustained by the facts which have been presented.

The facts prove further that the era of disturbance or of the upturning of the sandstone was not due in any way to the ejection or heat of the igneous rock. The latter event, although so extensive, was simply incident to the disturbance; the upturning preceded the eruptions.

Effects of Obstructions to the outflow.—Although the trap of West Rock—that is of the southern part of the West Rock ridge—is not divided into several areas, other effects of obstructions may be looked for, since the hanging wall of a large inclined fissure is sure to have its downfalls. The gaps or notches in the ridge indicate incipient division, and may be among the effects from such a cause. They may have been produced also by local narrowings of the fissure through horizontal or oblique movement of its walls, or in other ways; and it is a question whether the results of these two modes of origin can be dis-

* This Journal, vol. xxxviii, p. 361, 1889.

tinguished. The deeper and more abrupt notches we should be disposed to refer to the former cause.

As the Bache map of West Rock ridge indicates by its contour lines, within a mile and a quarter of the south end of West Rock, there are three gaps. Two are included on Plate II. At the first, the height of the ridge falls off sixty feet in the course of 500 yards. The second, situated 300 yards farther north, and called the "Judges' Notch" because near the "Judges' Cave," is similar to the first in depth, but narrows more down the western front. Half a mile farther north is the third, called the "Wintergreen Notch." It is one of the larger gaps in the ridge. Along the summit, both from the north and the south, there is a descent of 100 feet, from a height of 440 feet to 340. Figure 16, from the Bache map, exhibits the facts.* The decline is gradual on the south side, but very rapid northward; in the latter direction the level of 460 feet is reached at the same distance from the center of the gap as 440 on the south. This third gap is probably one of those caused by obstructions to the outflow, whatever the fact with the others. The stream, in consequence of the obstruction, reached a height at the gap of but 340 feet; but just beyond, the lavas that had been held back, made the abrupt rise in the ridge to 440 and 460 feet. The correctness of this explanation appears to be sustained also by the abruptness of the rise in the slopes east of the gap, as the contour lines in the figure show, and the great breadth of the nearly horizontal area farther east. It will be observed also that the summit of the ridge north of the gap is farther to the west than that on the south. (Arrows are inserted to make this distinct.) It is so because any given amount of trap depends for its height on the distance it flowed westward up the inclined sandstone layers. It may be observed that not only the height,

16.

Wintergreen Notch.

* The west side of the ridge in this part, as elsewhere, is the precipitous side, bold columnar above. Its upper 200 to 225 feet usually consist of trap, and the part below of sandstone; but the junction-plane at the Notch is concealed by trap debris, so that its actual height is not determinable.

460, but also 440 on the north side is to the west of 440 of the south side; but the height of 440 to the north is probably produced with a less thickness of trap. This notch is 300 yards south of the Buttress dike described on a former page; the position of this dike is shown on the above figure at *b*.

This example will suffice for illustration. Other gaps in the ridge occur farther north, but they are outside of the region here under consideration.

Obstructions to the outflow of lava while it was making its way between the layers of sandstone are also possible through any cause that would prevent the lifting of any portion of the overlying rock. The area of the Triangle has been described as an area of sandstone within the proper limits of the trap range. This sandstone was not lifted like the rest of the overlying stratum. Instead of this, it remained in place for the most part, and hence, forced the liquid rock to pass to one side of it. The lava, mainly took the north side; and so the trap of that side had its surface raised in level above the rock north and became the elevated embossed area already described. The great sloping trap wall making the north side of the Triangle is the wall of an oblique fissure in the sandstone formation. Along this fissure—45° in inclination,—the sandstone of the south side, or that of the Triangle, lay unmoved or nearly so, while that of the north side was shoved up as the lavas came in below. Other walls, and the small ridges both north and south of the Triangle, are evidences of similar fractures, in parallel directions, with analogous results. The unlifted sandstone was in some way put under a strain that produced the parallel fracturing and movements.

The origin of the southern or western walls of West Rock is sufficiently explained in the remarks on this subject respecting East Rock (page 94).

The southern front of West Rock has a columnar aspect. But in reality no columns stand out with the boldness they have in East Rock. The surface is mostly made up of the cleavage surface or joints that are in its plane; and where there has been quarrying, these joints have great width as well as height.

3. Relation of the east-and-west and north-and-south fissures, and the origin of these courses.

These two courses of fissures are so locked together in the New Haven region that they evidently are results of one system of movements. They occur together in Pine Rock; and West Rock has the general trend of the Pine Rock ridge represented in the embossed area and the southeast point.

Mill Rock ends to the eastward in a south-southwest fissure, transverse to its main course which is apparently parallel to the adjoining part of the East Rock trap. East Rock commences with a nearly north-and-south course, but bends around to east-southeast. Mill Rock and Pine Rock are not necessarily synchronous in eruption with East Rock or West Rock, but they belong to one epoch of disturbance.

The origin of these courses is not fully ascertained. I have long explained the north-by-east trend of West Rock, and of the other ridges of like direction to the north, on the general principle that the mountain-making forces of Eastern America operated over any part of the area, as a general thing in the same direction from Archæan time onward, examples occurring in the Taconic and Jura-Trias elevations of the western half of New England. In accordance with this view the strike of the Jura-Trias should be that of the underlying crystalline rocks. It does not follow that a like dip prevails in the schists beneath. It is true however that the predominant dip in them, and in the Jura-Trias fissures and bedding, is eastward. This last fact seems to favor the suggestion of Professor Davis that the foliation of the underlying schists has determined the courses of fissures in the Jura-Trias area. This suggestion would have support in the fact, were it not that in New Jersey, where the same is true as to the dip of the underlying schists, the Jura-Trias fissures and bedding dip westward.

In the New Haven region, the idea of an accordance between direction of foliation in the schists and of fissures in the Jura-Trias finds no support. The West Rock ridge crosses the line of strike of the metamorphic schists two miles west of it at an angle of 20°. East Rock has an east-of-north course only in its northern extremity, and curves around through nearly half a circle. Pine Rock and Mill Rock cut across any probable course of foliation in underlying schists and do it on lines that differ 50° in trend.

The origin of the east-and-west courses, which commence in the extremity of West Rock and continue to Whitney Peak, four miles, may have its explanation suggested by the remark on page 80. Or, it may be a consequence of the movement attending the production of the north-and-south fissures, and local to the New Haven region. The subject at present is one of conjectures.

On account of the interest of the dynamical question here brought into view, I introduce another illustration of the facts from a transverse ridge only six miles north of Whitney Peak and Mill Rock. It is called Mt. Carmel. The ridge is only one and a half miles long. It is higher than those already considered, the most elevated point being 736 feet above high tide.* But height means here, not larger accumulation of igneous rock or trap, but, simply, greater emergence above the sea-level; for this increase northward of height runs parallel with a like increase in the height of the metamorphic ridges just west; and it is continued, at a diminished rate, into Massachusetts.

Mt. Carmel has resemblances to Pine Rock. Its mean course is E. N. E.; and a north-and-south trend exists in its western part. But the north-and-south portion in Mt. Carmel is a large feature in the ridge and has direct continuity with the east-northeast portion.

The ridge is divided by a very deep and open gorge, into an eastern and a western section. The gorge is often called the "Neck," and the high summit adjoining it on the west, the "Head" of the "Sleeping Giant"—a name suggested by the form of the ridge as it appears lying on the northern horizon. Both have northern and southern slopes of sandstone, the southern going about half way to the top above its base, and the northern reaching a greater height.

The western section, while high and massive at its eastern extremity, falls off rapidly to the westward, and in half a mile is reduced to a narrow trap ridge not exceeding 100 feet in height above the adjoining country. Through this part within 300 yards, pass Mill River, a north-and-south carriage road (N. 20° W.) without change of grade, and, a few rods farther west a railroad. Along the railroad, and between the carriage road and the river, the course of the trap changes from about north-and-south to N. 10° E.; and as it crosses the river to N. 20° E. Thence it continues on to the summit, widening and increasing rapidly in height and curving still farther eastward.

At the section in the railroad cut, the trap is seen resting on its south wall of sandstone, the wall dipping about 45°—apparently indicating that the dike has this pitch. Between the carriage-road and Mill River, the north side of the trap has in many places a westward dip of the same angle, confirming the conclusion from the railroad section as to the large dip of the fissure. It is thus proved that the western section is a continuous mass of trap of gradually changing course and magnitude; and that it is strictly "transverse" in direction only along its eastern end. It is a dike to the westward and probably so throughout.

The eastern section is made one continuous mass of trap by Percival, and one also with the western portion. It is divided

* According to the leveling of two parties under Mr. Bache.

from east to west, as he states, by a valley, and in the valley there is a spring giving out a streamlet which flows northward. There are gaps in both the southern and northern sides, dividing them into a series of elevations. These elevations are indicated on Percival's map, so as to look as if he regarded them as separate dikes; but this is contrary to the description in his Report. I have looked for sandstone in two of the gaps of the south side, east of the "neck," and have found evidence in each that the trap is continuous, and descends in these gaps nearly half way to the base of the mountain. In the east-and-west valley the spring and streamlet are probable evidence that there is sandstone beneath; and on this ground, it may be that there are, in this eastern part of Mt. Carmel, two parallel east-and-west dikes.

Mt. Carmel appears to be a combination of dikes, without the "buried volcanoes" supposed to exist there by Professor Davis. In the view from the west side of Mill River there are in sight nearly 600 feet in height of massive trap, having no subdivision into sheets or layers, and nothing to suggest the idea of lava-streams in the depths below.

The union in this small ridge of approximately north-and-south and east-and-west courses is further proof of their mutual dependence in the system of movements attending the Jura-Trias mountain-making of the Connecticut Valley. But its origin remains unexplained.

Concluding Remarks.—A review of the principal conclusions in this paper is given in its introductory remarks (page 82), and a recapitulation here is therefore unnecessary.

The reader may have been led to the idea that the author would make the West Rock Ridge typical for other ridges of like features in the Connecticut Valley region, in disagreement with the conclusion of Professor Davis who holds that in the case of most of these ridges, if not of all, the trap was poured out in one, two or more horizontal sheets, separated, and overlaid horizontally, by beds of sandstone, and that the whole was afterward faulted and tilted so as to make the ridges. The author acknowledges that he is inclined to make the conclusions he has reached general. He, however, admits that he has not made the structure of the other ridges of the valley a special study. He believes his observations sufficient, however, to authorize the statement that a more intimate knowledge of the facts is required before any adverse views can be regarded as established.

ART. XI.—*Notes on a Reconnaissance of the Ouachita Mountain System in Indian Territory;* by ROB'T T. HILL.*

Synopsis.—General topographic features of Indian Territory including Oklahoma. The northern, middle and southern belts. The middle or mountainous belt. 1. The Eastern or Arkansas-Choctaw Division. 2. The Central or Chickasaw Division. 2*a*. The Wapenucka Sub-division. 2*b*. The Tishomingo Granite. 2*c*. The Arbuckle Mountains and Washita Water Gap. 3. The Wichita Division. Partial record of history recorded in the Ouachita System.

LITTLE has been written concerning the geography and geology of Indian Territory, and the writer presents this preliminary paper in hope that it will direct to that interesting region more careful and detailed study.

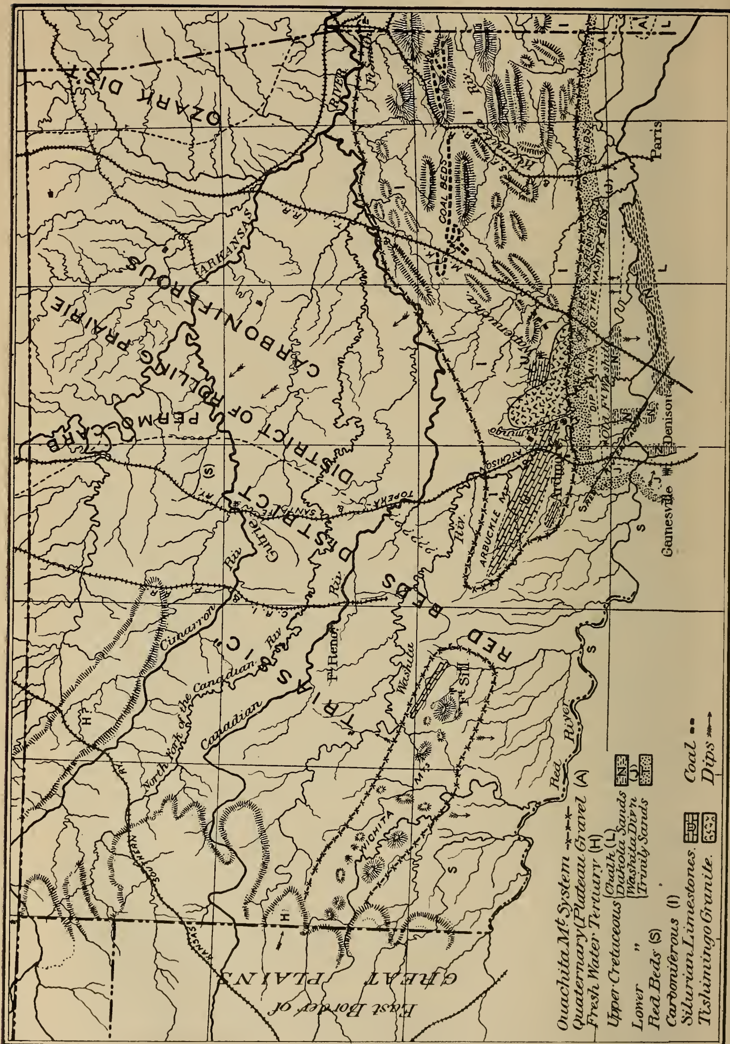
Topographically Indian Territory, especially its southern half, presents a great diversity of mountain, plain, forest and stream. Within this area is found the extension of nearly every topographic unit from the Missouri-Kansas region on the north to the Texas on the south, from the Great Plains of the west to the forests of Arkansas on the east; there are also many unique characteristic features of the region itself.

The territory may be provisionally divided into three parallel east and west belts, each containing a marked diversity of geologic structure and corresponding topographic expression.

The northern or Cherokee-Oklahoma belt includes the country north of the Canadian; the greater part is prairie with spots of timber decreasing in density toward the west. This belt may be sub-divided into three districts; the eastern or Cherokee, the middle or Oklahoma, the western or Arrapahoe. The Cherokee division, with the exception of a small area of Ozark hills in the northeast corner, is mostly composed of Carboniferous rocks with an undulating topography similar to that of southeast Kansas. The Oklahoma section is a typical red bed region in its western half, with undulating prairies and soft disintegrating structure. The Arrapahoe division is the ragged eastern border of the great plains country, with its characteristic fresh water deposits of sands and grits occupying the flat divides, as originally described in the adjacent west Kansas region by Dr. J. S. Newberry and more recently by Professor Robt. Hay.† These plains are the newest or culminating formation in western Texas, Kansas and Indian Territory; they are now slowly receding westward because of the head water erosion of the streams that indent this eastern border,

* To Mr. James S. Stone, of Newton, Massachusetts, the writer is greatly indebted for his faithful assistance in conducting this investigation. Also to Mr. W. L. Davidson, a student of the University of Texas.

† See Bulletin 57, U. S. Geological Survey.


OZARK DIST.
CARBONIFEROUS
DISTRICT OF ROLLING PRAIRIE
PERMO-CARB
TRIASSIC
RED BEDS
GREAT PLAINS
East Border of
ARKANSAS
COAL BEDS
ARBUCKLE
WICHITA
Paris
Denison
Gainesville
Ardmore
Ft. Reno
Ft. Sill
Guthrie
Cimarron
Canadian
North Fork of the Canadian Riv
Washita
Red River
Ouachita Mt. System
Quaternary (Plateau Gravel (A)
Fresh Water Tertiary (H)
Upper Cretaceous (Chalk (L)
Dakota Sands
Lower " Washita Div'n
Trinity Sands
Red Beds (S)
Carboniferous (I)
Silurian Limestones.
Tishimingo Granite.
Coal
Dips

and in this manner the underlying structure and topography are revealed. The northern belt of Indian Territory distinctly belongs to the Kansas division of the United States and the writer leaves its further description to St. John, Cragin, Hay and Jenney, investigators who possess more facts concerning its geology.

The middle or mountainous belt lies south of the Canadian-Arkansas River. A mountain system traverses it from east to west and marks the great barrier between the upper Mississippi Valley and the Texas-Arkansas regions of the United States.* To a description of these mountains this paper is mostly devoted.

The third and southern belt, the description of which must be left to a future paper, includes the region between the mountainous belt and Red River. It is the northern termination of the Texas region of the United States. It includes many topographic and geologic features which are the result of neozoic sedimentation against the southern border of the mountains.

The Mountain Region of Central Indian Territory.—With the exception of the Ozark hills in the extreme northeastern corner, the mountains of Indian Territory are the direct westward continuation of the Ouachita system of mountains which has been described† as the mountainous area between Hot Springs Arkansas and the Staked Plains of Texas, including the various points known as the Poteau, Seven Devils, San Bois, Shawnees, Jack's Fork, Black Fork, Winding Stair, Sugar Loaf,‡ Cavenal, Stringtown Hills, Limestone Ridge, Potato Hills, Arbuckles, Wichitas, Navajoes and other mountains. These mountains are south of the Arkansas-Canadian drainage and must not be confused with the Ozarks of southwestern Missouri. Dr. J. C. Branner's coming reports will doubtless give us needed light on this relation.

The mountain belt has three distinct sub-divisions: (1) an eastern or Arkansas, (2) a central or Chickasaw, (3*a*) western or Wichita. Its areal extent may be compared to an arch whose apex is southward, as marked by the course of the Canadian, Arkansas and Red River drainage; its eastern member in Arkansas and the Choctaw nation is a forest area of vertically folded Carboniferous shales and sandstones resembling the Appalachian country; the western member in the Chickasaw and Comanche nations, is a mostly treeless region and consists of low folds of hard white and blue Silurian lime-

* See this Journal, April, 1889.

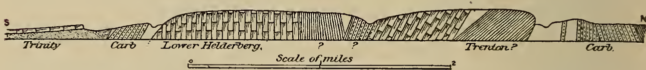
† Arkansas Geological Survey, 1888, vol. ii. The geology of Southwestern Arkansas, by Robt. T. Hill.

‡ Near Fort Smith, not the Cretaceous butte of the same name east of Caddo.

stones and eruptives; the keystone or central Chickasaw region, consists of an area of granite and Silurian limestones.

1. *The Eastern or Arkansas-Choctaw Division.*—The northern two-thirds of the Choctaw nation and the northeastern Chickasaw country are a direct continuation of the mountains and geologic features of west-central Arkansas. This region consists of numerous timber-covered ridges varying in altitude from 2700 feet along the Arkansas line to 1200 along the Missouri, Kansas and Texas railroad. The ridges are usually elongated, timbered, devoid of sharp peaks and owe their present form to the unequal erosion of the exaggerated structural folds. The general trend of these mountains, corresponding with the strike of the folds, is south of westward, but often, as seen near Stringtown and along the Kiamitia River, it is nearer north and south. The ridges consist of sandstones, clays and shales apparently of the Carboniferous period, but further investigation may reveal older rocks. The rocks occur in numerous parallel, overlapping folds, which are nearly vertical in the southern and central portion of their extent, but become horizontal along their northern outline.

1.



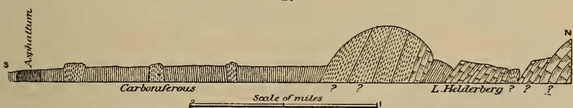
Section north and south across Red Bird Mts., showing relation of Mountain folds to Cretaceous Prairies.

The Saint Louis and San Francisco railroad, from Fort Smith, Arkansas, to Paris, Texas, passes through the heart of the region, and the type structure, as seen along this route, consists of vertical eastward folds dislocated by another and later movement, as seen south of Tushka Homa, the Choctaw capital. This road follows for miles the water gap of the Kiamitia River, which apparently flows in an anticlinal valley. A hundred miles west of this railway, the Missouri, Kansas and Texas road affords another parallel north and south section of the mountain system, but owing to the gradual cessation of timber and decreasing altitude entirely different scenic effects are revealed. The latter road follows the valley prairies between the mountain ridges, which here have the contour and altitude which, in Kentucky, would be called knobs. The railroad follows the strike of the structure from Atoka to Limestone Gap. The differences in elevation are the result of unequal weathering of the crumbling shales and the more resisting sandstones and limestones, the former being treeless valleys while the latter persist as mountainous ridges. (Fig. 3.) Timber grows upon the sandstone outcrops while the prairies occupy the more compact clays of the valley. Even where the vertical outcrops have been eroded to a level plain, the alternations of sandstones and clays can often be traced for miles by the timber which follows the sandstone outcrops in narrow ribbon-like parallel belts. (See fig. 2.)

The northern half of this area contains coal strata whose extent and known occurrence are indicated on the map. An admirable paper upon the structure of these coal beds has been published by Mr. H. M. Chance.* Mr. Arthur Winslow† has equally well defined them in Arkansas. Mr. J. T. Munson of Denison, Texas, has much unpublished information concerning the formation of this region, and to him the writer is indebted for his invaluable assistance and data.

The coal fields, for which the name Fort Smith-McAllister area is most appropriate, are of great commercial importance, for they are the chief source of fuel supply for the Arkansas-Texas region. These extend along the northern border of the mountains and are terminated on the southwest by the Silurian and granite field of the Tishomingo district which are an apparent barrier between this and the Texas-Ardmore coal

2.



Section north and south through Woodford, showing structure of Prairie and Mountain. Continuation of fig. 1.

field, the fuel of which is of an entirely different character and should not be confused with it‡ geographically, structurally, or economically.

Mr. Chance has published a section of the rocks of the eastern division. He estimates at least 8500 feet of coal-bearing strata, but the total thickness of the Carboniferous and Permo-Carboniferous, as seen in the folds near Ardmore, is greater by the addition of the uppermost or Permo-Carboniferous which here has a thickness of several thousand feet.

The most marked feature of these mountains is the excessive, compressed and vertical folding which the whole region has undergone, and the displacement of these folds by a lateral dislocation which has squeezed them into S-shaped flexures. So excessive is this folding that every stratum in

* Geology of the Choctaw Coal Fields by H. M. Chance. Transactions American Institute of Mining Engineers, Feb., 1890.

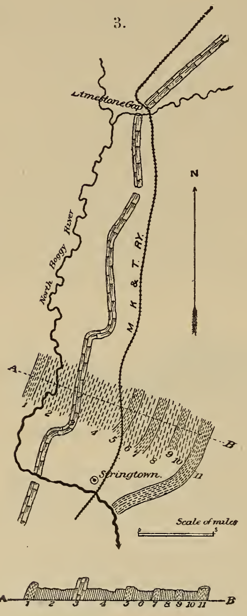
† Arkansas Geological Survey, Report for 1888, vol. iii.

‡ The writer is inclined to believe that the greater excess of ash in the coals of the more horizontal Texas region is due to the calcium carbonate and other impurities deposited in the joints during their long submergence beneath the Cretaceous seas, while the McAllister coals have remained above water.

the mountain region south of the coal fields can be said literally to be standing vertically as shown in the figures. This system of folding is complicated and the writer has not had time for the minute study necessary to interpret it. In general, two great trends or strikes are conspicuous, the first and oldest is about 25° south of west; this is frequently dislocated by an apparently later movement resulting in northeast and southwest trends, all of which are accompanied by overlapping and lack of continuity.* The direction of the folds has a marked effect on the political features of the region, all lines of transportation and public highways practically following the valleys of erosion in the trend of the folds.

The proof of two great dislocations of the Carboniferous strata is found in the mountains north of Atoka and in Limestone ridge where the vertical folds of the first epoch are deflected by S-shaped dislocations into the southeast course.

Of the many illustrations of this folding one of the finest is found in the peculiar limestone ridge which extends from near Lehigh to Limestone Gap and eastward. This is the principal limestone stratum of the Carboniferous system; it occurs at the base of Mr. Chance's section. It consists of about 200 feet of massive blue limestone and dolomite standing vertically. From near Wapenucka via. Lehigh to Limestone Gap, thence eastward to the St. Louis and San Francisco railroad, it forms a sharp ridge rising 100 feet above the adjacent valleys, a plan and cross section of which are given in the accompanying figure (3).



Limestone Ridge, showing deflected mountain folds.

The Missouri, Kansas and Texas railroad, between Stringtown and Limestone Gap, follows the valley east of this ridge; at the latter place a tributary of the Red river has cut through the ridge which, from this point, trends eastward as shown in

* Dr. John C. Branner, on page 30, vol. i, of his report, has previously expressed an opinion that in Arkansas these folds are of overlapping rather than of continuous strike, as stated by Comstock in the same volume.

Mr. Chance's map. Several sigmoid or S-shaped flexures occur along this section, and, also, in the sandstones of the Coal Measures of eastern Indian Territory and across the Territory to the Arkansas line.

The southern border of this old system has been degraded* by the shore lines of the ancient Cretaceous and Tertiary seas which overlapped it and planed it northward for many miles. The vertical edges of the planed off strata are buried beneath the Cretaceous sediments as shown in my former section along the Arkansas-Texas line, resulting in the complete interment of the Carboniferous system southward, throughout the great central denuded region of Texas where the only exposures of Carboniferous rocks are through erosion of the overlying Cretaceous layers. The structure of these mountains is of the Appalachian type, and Mr. Chance says that "topographically and structurally the Choctaw coal fields represent in miniature the features of the anthracite regions of Pennsylvania."

2. *The Central or Chickasaw Division.*—In the northeastern part of the Chickasaw nation the continuity of the Carboniferous rocks is terminated by an extensive area of Silurian limestones, which, in turn, are succeeded southward by underlying granites whose exact relation to the complicated Coal Measures is not determined, but which are exposed by the erosion of the latter and are unconformable beneath them.

2*a*. *The Eastern or Wapenucka* portion of this area is interesting, but little explored. It lies west of Boggy station along Delaware Creek at Bill Jackson's ranch, and near the quaint old Chickasaw academy of Wapenucka. There is a series of low limestone hills—apparently remnants of anticlinal folds—along whose strike flows the Delaware creek. In places these limestones resemble the blue Silurian limestone to be described in our discussion of the Arbuckle Mountains, but they are more horizontal in outcrop. In the collection of Mr. J. T. Munson, of Denison, who first called my attention to this interesting region, are fossils apparently Silurian in age Orthoceras and Brachiopoda, from Bill Jackson's ranch on the Delaware.†

Crinoidal limestones of Carboniferous age are the prevalent rocks and were collected near the academy at the southern border of the district, and the sandstones of apparent Carboniferous age and shales of that age begin there again. A single specimen of Favosites, of Silurian age, was collected from one

* Principal Events in North American Cretaceous History as revealed in the Arkansas-Texas Region, by Robt. T. Hill. This Journal, April, 1889.

† Professor Alpheus Hyatt, to whom I sent this specimen, says that he thinks there is little doubt that it is a fragment from the Hudson River group. The Orthoceras being closely related to one found at Cincinnati, and the brachiopod being probably *Orthis testudinaria.*

of the Delaware Mountains near the Hudson River limestone. The Delaware Mountains proper are a few long limestone ridges and detached buttes in the beautiful valley of Delaware Creek. Seven miles west of the academy, near Bill Jackson's, they are composed of limestone underlaid by the above mentioned Favosites sandstone—a porous gray quartzite with an occasional patch of limestone. The buttes are peculiarly distorted, their strata being disturbed at a very slight angle in many directions, which may be compared to the uneven curvature of a saddle.

The Delaware mountains were mentioned by Mr. Jules Marcou, who followed the old Fort Smith and Fort Washita trail which passed by them. He referred them to the Sub-Carboniferous or Mountain Limestone.* The scenery in the Valley of the Delaware is exquisite, the contrast between the low rounded hills and the extensive valleys with their peculiar buttes present a restful and varied landscape. The region promises rich scientific treasures to some future student who has time and facilities to work out its structure and history. It was impossible to trace the relation of the Wapenucka district to the Arbuckle Mountains to the westward, owing to dangers of exploration in a country where geologists are not welcome, but there is evidently a close connection if not continuity between them.

2*b*. *The Tishomingo Granite.*—In the heart of the Chickasaw nation south of and underlying the Wapenucka limestone district is an extensive granite area. This is the central division of our mountain region. It is a triangular area of sandy prairie land with low rounded granite hills and undulations, lying between the Santa Fe and M. K. and T. railroad and running east and west from Boggy depot to six miles west of Tishomingo, and northeast to Mill Creek and beyond.

The granite is well displayed two miles southwest of Boggy station; in Pennington Creek; at Tishomingo and other places. At its eastern outcrop it is composed of red feldspar, white and black mica, quartz and hornblende with numerous pegmatitic veins. Its composition and occurrence is nearly identical with the Burnet Texas granite, and it is unlike the igneous rocks of the Wichitas to be described later. In the western part of this area the feldspar is albite. There are numerous dikes of black rock intersecting this granite specimens of which from Pennington Creek have been sent to Professor J. F. Kemp for study. Concerning these he says: "They are a typical diabase. They are mostly idiomorphic plagioclase crystals, doubtless labradorite from the extinction angles, irregular greenish augite and a little magnetite. They show the so-called ophitic

* Geology of North America.

structure of diabase in a very marked degree." The dikes run west 20° S. and are seen at the crossing of Mill Creek road and Pennington Creek.

The northern margin of the granite area is overlaid by hard metamorphosed, sub-horizontal Silurian limestone of the same cherty and flaggy lithologic aspect as the Upper Potsdam rocks of Burnet County, Texas, but I could find no fossils. Carboniferous rocks cover its eastern point at Boggy station. Its southern border was the sea-shore of the ancient Trinity and other Mesozoic and Cenozoic seas and is buried beneath the Trinity sands. The western border is covered by Silurian and Carboniferous rocks.* I saw no evidence that this granite was of later age than the oldest of the Paleozoic rocks which rest upon it.

2c. *The Arbuckle Folds*—West of the Washita River the mountains again present a new and entirely different aspect. An elongated mass of low rounded barren limestone folds stands about 500 feet above the plain and extends east and west, between Wild Horse Creek and the Washita River for about forty miles, forming an almost impassable barrier for wagon travel. They are composed of folds of hard Silurian limestones. The trend of the mountains—north of west—corresponds with strike of the folds, but is opposite in direction to the prevalent trend of the Choctaw-Arkansas division. These folds are the hard persistent core of the structure, the softer and exterior Carboniferous layers having been eroded to the level of the Ardmore prairies. (See figures.)

West of Duncan the limestone hills are buried beneath the red beds for twenty miles, but again appear in the neighborhood of Fort Sill forming a low ridge north of and parallel to the Wichita Mountains, as is explained later.

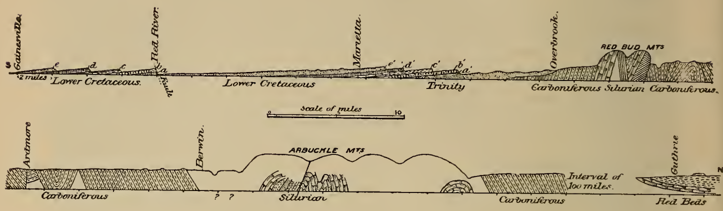
The Arbuckle Mountains constitute a great and wonderful development of the Silurian system, although this has not been hitherto appreciated, and afford a superb example of folded structure. This folding is beautifully shown in the valley of the Washita which has cut a deep and tortuous water gap through these mountains where, unobscured by forest growth, fold after fold of the stratified limestones and shales appear in startling boldness. Several journeys through this gap only increased the appreciation of the greatness of the task of thoroughly delineating the section, the complexity of which may be inferred from the accompanying figures.

Twenty miles south of the Arbuckle ridges proper, and separated from it by a valley based upon Carboniferous shales and sands, near the crossing of Hickory Creek and the Santa

* The only previous mention of this important granite area of which I am aware was made by Dr. R. H. Loughridge in the 10th Census Report on Cotton Production.

Fe road is a smaller but similar and parallel ridge of folded Silurian rocks extending westward to Healdton (see map). For these mountains there is no local name, and I have called them Red Bird from an adjacent post-office. They serve to prove the great width of the folded belt.

4.



Section across Indian Territory from south to north along Atchison, Topeka and Santa Fe Railway.

The accompanying north and south section and profile from Gainsville, Texas, to Guthrie, Oklahoma, gives at least an idea of the sequence and foldings of the Arbuckle region. Proceeding southward along the line of the Atchison, Topeka and Santa Fe, the typical gypsiferous red beds of Texas, Kansas, Indian Territory and New Mexico—the alleged Triassic* —are seen from Guthrie to Oklahoma City, lying in a disturbed, but comparatively sub-horizontal position, showing greater dips than the Cretaceous, but none of the complicated folding of the Paleozoic strata. South of the Canadian, the Carboniferous clays and sandstones appear with the excessive dips of the Ouachita folds. At Buckhorn Creek, east of Dougherty, the coal-bearing beds of the Carboniferous are seen dipping north at an angle of 65°, and involved in the folds of the adjacent limestone hills. In this vicinity there are terranes at the base of the Carboniferous, the age of which I could not determine, especially a great thickness of soft sandstone, but the succeeding limestones are undoubtedly a part of the Silurian system as determined for me from fossils by Professor Henry S. Williams.

Proceeding southward from Dougherty to Berwin the limestones, shales and sandstones of the pre-Carboniferous succeed each other, but so complicated is the vertical folding, that the writer must confess his utter inability to determine their proper succession, even after considerable study. These rocks occupy in cross-section, almost invariably a sub-perpendicular

* The basal portion of these Red Beds is of Permian age as shown in their Texas continuation by Boll, Cope and White. See American Naturalist, June 1879, September 1880.

position for a distance of twelve miles. From north to south, however, the following distinct sub-divisions are apparent.

Their relation however is indefinite, owing to folds and faults:

	feet.
1. Massive, hard blue limestones. Strata of 20 feet in thickness alternating with thin flaggy layers. Thickness (interrupted by a great fault)	+280
2. Massive limestones, but in thinner and more flaggy layers. Cherty	±100
3. Thin shaly argillaceous beds, fossiliferous, excessively folded and crumpled. Aggregate thickness including folds	+360
4. A massive bed of pure white loosely cemented sandstone, similar to that seen above the Lower Helderberg near Woodford	95
5. Thin flags and shales, mostly concealed but seen in contact with 6 at south side of river	?
6. A massive, yellow-blue limestone; finer grained than No. 1; rich in fossils (Trilobites, etc.) South bank of Washita at railroad bridge (Trenton)	+140
7. Concealed interval.	
8. Dark blue shales of great, but undetermined thickness.	
9. Carboniferous shales and sandstone, Berwin to Overbrook.	

Concerning the age of the pre-Carboniferous rocks only a little can be said, but sufficient to confirm the impression that they include Trenton (No. 6), Niagara? (No 1), Lower Helderberg, (No. 2). Could accurate collections be made, many other terranes would no doubt be shown to exist. The basis for these determinations are as follows. Near Woodford post office, ten miles west of the railroad, I collected from strata which are continuous with and apparently the same as No. 2, the following fossils, kindly determined by Professor H. S. Williams: *Spirifera lamellosa*, *Strophomena rugosa* (=*rhomboidalis*), *Rhynchonella nucleolata*, *Lingula? rectilatra*. Concerning these he says: "It is safe to say the horizon is Upper Silurian and probably equivalent to the Lower Helderberg of New York. It is above the Niagara, and this is an interesting feature." Concerning the fossils from No. 6, he says: "They are not very satisfactory but a *Trinucleus concentricus* shows No. 1092*a* to be of Lower Silurian, probably Trenton age." A fine specimen of *Lituites beckmani* Whitfield, in my possession, I have cause to believe came from this same locality, although I had previously been greatly deceived by its collector as to its locality and horizon.

It is not my desire to attempt any classification of these pre-Carboniferous rocks, but I believe from stratigraphic evidence that the shales at the south end of the gap may prove Devonian. Beneath the Trenton rocks there are exposed still older terranes, especially in the Red Bird Mountains, which may be Cambrian.

Continuing southward along our section the mountains cease coincident with the limestones, and after a mile of black shales (No. 7) the well-defined Carboniferous sands and shales begin near Berwyn and continue for twenty-nine miles along the railroad to the vicinity of Overbrook. These all occur in vertical folds, apparently coincident with or at least a part of the same system to which the Silurian limestones belong, but which, owing to their disintegrating character, have been leveled down to a low undulating plain. Ten miles south of Ardmore, the Trinity sands, the base of the Comanche series, rest unconformably against the Carboniferous (the Red beds being absent), and upon these in turn to the southward the sub-horizontal beds of the Lower Cretaceous, which I shall make the subject of another paper.*

A parallel north and south section twenty miles west of the Santa Fe road shows the presence of the Red beds and the absence of the Cretaceous, the latter having deflected southward through Texas.

It is not alone in the mountains of the Paleozoic areas, however, that this remarkable vertical structure is seen, but much of the Carboniferous prairie regions east of the Red beds are based upon it. For twenty miles north from the Red Bird to the Arbuckle Mountains the undulating prairies, void of any high relief whatever, except slight rises where the sandstones prevail, are based upon the almost vertical Carboniferous shales and sands, as shown in our diagrams. The wonderful degradation these folds must have undergone exceeds all possibility of description. Yet, as I have shown in my Arkansas report, there are many miles of planed-off folds buried beneath the Cretaceous sediments. This is the only instance in the southwest of a level upland plain underlaid by vertical structure. The great unconformity of sedimentation between the Silurian rocks and the supposed base of the Carboniferous is seen both at Buckhorn on the northern margin of the Silurian and at Hickory Creek near Red Bird on the southern side, as shown by difference of dip, and the presence of conglomerates in contact with the Silurian rocks, especially at the last-named place.

3. *The Wichita Division.*—The Arbuckle folds west of Duncan are buried beneath the Red beds for some thirty miles, but outcrop again some eight miles north of Fort Sill, marking the northern margin of the Wichita Mountains, forming a low foothill which is comparatively inconspicuous, owing to the overshadowing height and sharpness of the adjacent eruptives of the Wichita Mountains proper.

* See vol. ii, pp. 503–528, Bulletin Geological Society of North America.

These mountains rise abruptly above the level of the Red bed prairies, which surround them on every side, and their sharp jagged outlines present striking and exquisite scenery. The ragged peaks of igneous rock present a strong contrast to the stratified ridges of the eastern and central divisions of the system. Although in Arkansas the latter have a similar elevation above the surrounding plain, they have not the rugged peaks and points of the Wichitas, and are covered by forests. Their aspect is Appalachian—the arid Wichitas remind us of the Rockies. The eastern Ouachitas are the eroded remnants of stratified rocks with their characteristic topography, the Wichitas consist of igneous rocks—hard, firm, ragged and barren.

These mountains extend westward from Fort Sill 120 miles to the 100th meridian and were partially mapped out by Marcy and McCleland years ago,* and T. B. Comstock has recently made an interesting reconnoisance of them.† The most prominent of the many peaks are Mt. Scott and Mt. Sheridan; the former is 2400 feet above sea level, 1200 feet above Fort Sill on the plain below, and 1700 feet above Red River fifty miles distant. Though neither high nor extensive, the Wichitas are models of topography and mountain structure. Mt. Scott is a solid mass of red feldspathic granite with little quartz, while neighboring mountains are composed of greenstones, basalts, etc., indicating two widely different types of igneous rocks.

The westward continuation of these mountains is buried beneath the Tertiary sediments of the Staked Plains and with it the history of the relation of the Ouachita system to the Rocky Mountains. At one or two places in No Man's Land and north of Clarendon, Texas, I am told that erosion has cut down to the rocks of this mountain system but I have not been able to find the localities.

The composition of the Wichitas is unlike that of any mountain area of the southwest, and, so far as I could see, presents no structural resemblance either to the basin-surrounded mountains of the Trans-Pecos, or the early Paleozoic buttes and denuded folds of the central Texas region. Their age is not determined. They are certainly Post-Silurian and the Red beds have in part participated in the movements but the eruptives may be Post-Cretaceous or even later. The apparent absence of the Lower and Upper Cretaceous in the composition of the Wichitas is especially noticeable. Their trend and composition plainly places them in the Ouachita system.

* See Exploration of Red River of Louisiana, Marcy.

† See First (Second) Annual Report of the Texas State Geological Survey. Austin, 1889.

Résumé of History recorded in the Ouachita System.

1. There are evidences of a Post-Silurian movement in the Buckhorn and Red Bird unconformities.

2. The great folding and elevation of the system were after the close of the Carboniferous period, probably during the Permian, as shown by the participation of the rocks of the former period in the movement, and Pre-Triassic, if the upper Red Beds are of that age.

3. A second or lateral movement must have taken place after this folding by which the folds were bent into S-shaped flexures. This movement preceded the Red Bed epoch.

4. The marked but not excessive disturbance of the Red Beds indicates movement and displacement after their deposition and previous to the Trinity epoch.

5. The Lower Cretaceous Comanche series—which may be partly Jurassic—was deposited against and not over these mountains, and show in themselves no folding or other disturbance except such faulting as may be attributed to the Post Upper Cretaceous continental movement.

6. The Upper Cretaceous, the Marine Eocene and the Quaternary along the southeastern and eastern border of the system in Arkansas were also deposited against and not entirely over the system, and, like the Comanche series, reveal no participation in adjacent mountain folding, but merely alternations of subsidence and elevation.

7. This system has undergone extensive erosions throughout Post-Carboniferous time, and its sediments have contributed to all later deposits.

8. The western portion of the mountain system was in parts submerged during the Red Bed epoch [Triassic?] and completely degraded or buried beneath the sediments of the great Tertiary lake which constitutes the formation of the Llano Estacado.

9. The relation of this system to the Rocky Mountain movement is to be determined.

The mountains of the Ouachita system, including the eastern or Arkansas-Choctaw division, the central or Wapenucka Limestone district, the Arbuckle division and the Wichitas, should no longer be omitted from our maps, for together they constitute the foundation of all later geologic structure in the Texas region, differentiating it from the Kansas-Missouri region in both present and past geologic times back to the earlier Mesozoic epochs, and influencing all the main river courses of Indian Territory whose great southward bends are an adaptation to the strike of this mountain system, the Washita alone having cut through it.

The mountains are also interesting from their exceedingly diverse structure and composition, and from the fact that, with the exception of the Uintas, they are the only east and west system on our continent.

Art. XII.—*The Continuity of Solid and Liquid*;* by Carl Barus.

Introductory.

1. My earlier papers† entered somewhat minutely into the volume thermodynamics of fluid matter. The behavior of matter passing from liquid to solid and back again was only incidentally‡ considered. This feature, however, is the very one which gives character, or at least a more easily interpretable character, to the whole of the volume phenomena of the substance; and it was therefore reserved for special research.

The problem may be looked at from another point of view: Let it be required to find the relation of melting point to pressure. My results have long since shown§ that in a comprehensive study of this question the crude optical and other methods hitherto used as criteria of fusion (criteria which have no inherent relation to the phenomenon to be observed) must be discarded. In their stead the striking volume changes which nearly always accompany change of physical state, in a definitely constituted simple substance, are to be employed.

The literature‖ of the subject I will omit here, since the more important work has entered the text-books and since I shall probably have occasion to refer to it elsewhere.

The present experiments were made with naphthalene only. They are no means even near the degree of precision of which the applied plan of research admits. Thus far my chief object has been to carry the method quite through to an issue, preliminarily, and to test it at every point. The data are sufficient, however, to show that the procedure adopted, though I approached it with diffidence, can be brought under control throughout; and that the attainable accuracy need only be limited by the patience, skill and discernment of the observer. I was in some degree surprised, therefore, to find that my method led to new results at the outset.

2. *Earlier allied experiments.*—In applying the principle of § 1, I first made direct volume measurements with substances enclosed in capillary tubes of glass. In the case of naphtha-

* Geological interpretations are in the hands of Mr. Clarence King, by whom the work, as a whole, was suggested.

† This Journal, III, xxxviii, p. 407, 1889; xxxix, p. 478, 1890; xl, p. 219, 1890; xli, p. 110, 1891. Phil. Mag., V, xxx, p. 338, 1890.

‡ This Journal. xxxviii, p. 408, 1889; xxxix, pp. 490, 491, 494, 1890.

§ This Journal, l. c. More pointedly with an indication of methods in Phil. Mag., V, xxxi, p. 14, 1891.

‖ I will merely mention Sir William Thomson (1850), Bunsen (1850), Hopkins (1854), Mousson (1858), Poynting (1881), Peddie (1884), Amagat (1887), Battelli (1887) and some others. Cf. §§ 29, 30.

lene and some others, I thus obtained satisfactory results.* Such work is, however, limited to relatively low pressures (600 to 800 atm.); it does not admit of sufficient correction for the volume changes of the glass, and from the small quantity of substance examined, and the relatively frequent occurrence of *nuclear* condensation, volume lags are often obscured. Hence the definition which I was inclined to adopt after making these experiments, viz: that a pressure which when acting isothermally for an infinite time will just solidify the liquid and will just liquify the solid, stands to the given temperature in the relation of melting point and pressure, is not in accordance with facts.†

In a second method‡ I endeavored to ascertain the positions of the characteristic specific volumes by passing current out of the mercury index through the hot walls of the thin glass tube which contained contiguous columns of both the substance and the mercury. Supposing the tube surrounded by a liquid conductor transmitting pressure, the changes of resistance of the arrangement indicate the motion of the index and hence the degree of compression produced. Here, however, a new and unexpected annoyance was encountered, inasmuch as both the medium of oil contained in the piezometer and the glass possess seriously large pressure coefficients.§ Moreover it is only with great difficulty that the perfect insulation of an apparatus, in which water jackets form an essential part, can be maintained. I therefore abandoned the work.

In a third method similar to the preceding, I expressed the motion of the mercury thread or index in terms of the resistance of a very fine platinum wire, passing through the axis of the tube. Successive intercepts thus indicated the changes of volume to be observed. This method gave good indications of the pressure position of the melting points of the sample. It failed, however, to give serviceable values for the fluid volume changes. I found on trial that the contacts in such a case are essentially loose, and that thermocurrents can only with difficulty be eliminated or allowed for, seeing that the successive isothermal temperatures are to be considerably above the atmospheric temperature.

Finally all the methods here described must necessarily fail after the substance has been solidified; for in this case the thread or index is split up and forced into the interstices of the solid material. Thus it is manifestly impossible to retain the

* Cf. this Journal, xxxviii, p. 408, 1889.

† A considerable number of experiments made with naphthalene in this way showed the melting points 83·4°, 92·3°, 100°, to correspond to the pressures 100 atm. 350 atm., 565 atm. respectively. Thus the factor is +·036° C./atm. § 27

‡ Phil. Mag., xxxi, p. 14, 1891.

§ Ibid, pp. 18 to 24, et. seq.

original meniscus, and therefore impracticable both to arrive at the volume behavior of the solid and to rigorously coördinate successive series of experiments.

3. *Advantages of the method of this paper.*—Hence I endeavored to modify Kopp's* specific volume flask, in a way to make it available under any temperature or pressure. Here the readings are independent of the unbroken character of the meniscus immediately in contact with the solidifying substance, whereas on the other hand (as I shall presently show), the volume measurements can be made electrically,† with almost every desirable degree of accuracy. Furthermore by charging the flask with suitably apportioned quantities of substance and of mercury, the error due to the compressibility of the glass may be eliminated in any degree whatever, and an apparatus be obtained which is practically rigid in relation to pressure. The data show that from each single series of experiments I thus obtain the isothermals and isopiestics and therefore also the isometrics, both for the liquid and for the solid state, admitting the latter to be less accurate; further, the relation of solidification and of fusion to pressure, and finally, the pressure changes of the isothermal specific volumes of solid and liquid, at solidifying and melting points. From such results the character of fusion, and the probable positions of critical, § 26, and of transitional points, § 28, can already be pretty well predicted. It is then only necessary to examine a number of substances, normally existing under widely different conditions of thermal state,‡ in order to broaden the evidence and possibly to reach results of a uniform bearing on matter in general. Thus I endeavor to avail myself of the enormous internal pressure through incremental pressures applied externally.

Apparatus.

4. *Temperature.*—Inasmuch as pressure varies at a mean rate of over 30 atm. per degree of melting point, so that temperature is as it were the coarse adjustment and pressure, the fine adjustment for the conditions of fusion, the method of experiment should be such that temperature may be kept rigorously constant while pressure is varied at pleasure. To obtain constant temperature, I constructed a series of brazed

* Kopp: Ann. Chem. u. Pharm., xciii, p. 129, 1855. The results of this fine memoir are too rarely quoted.

† The absolute expansion and compressibility of mercury being now known. § 7.

‡ "Instead of tracing the isothermals of a single substance throughout enormous ranges of pressure, similarly comparable results may possibly be obtained by examining different substances conceived to exist in widely different thermal states." This Journal, l. c., xxxix, p. 510.

vapor baths of thin sheet iron, thickly jacketed with asbestus. They were cylindrical in form, 20^{cm} high and 10^{cm} in diameter. Axial tubulures, the upper of which projected outward, the lower both inward and outward, allowed the vertical tubular piezometer to pass axially through the vapor baths, and suitable stuffing boxes obviated leakage. Again the upward projection of the lower tubulure (both of which fit the piezometer snugly), formed an annular trough with the walls of the vapor bath, in which a sufficient quantity of the ebullition liquid could be placed, and boiled, by aid of the flat spiral burner below. The top of the vapor bath was provided with two other (lateral) tubulures, one of which served for the permanent attachment of a vertical condenser, and the other for the introduction of a suitable thermometer or thermocouple. Here also the quantity of ebullition liquid present, could at any time be tested, its amount increased or diminished, and its quality directly purified by fractional distillation or otherwise (an operation necessary, for instance, when amyl alcohol is used). § 20. With a good condenser, the boiling may be kept up indefinitely, for the condensed vapor falls back into the trough below. At temperatures below 100°, it is expedient to avail oneself of the high latent heat of water* and to boil this liquid under diminished pressure. Temporarily attaching Professor R. H. Richards' jet pump to the end of the condenser, pressure may be reduced at pleasure, and any boiling point between 50° and 100° reached and maintained indefinitely. For higher temperatures toluol, amyl alcohol, turpentine, naphthalene, benzoic acid, diphenylamine, phenanthren, sulphur, etc., subserve similar purposes more or less thoroughly.

Temperature was measured by a Baudin thermometer of known errors, and also computed from the vapor tension of steam under known conditions.

5. *Pressure.*—To obtain pressures as high as 2000 atm., I employed the screw compressor described elsewhere.† I made use, however, of a vertical piezometer, identical with the horizontal form described, except in so far as it could be removed from the barrel as a whole. As before, the piezometer is insulated from the barrel. When in adjustment the former was surrounded by the following parts, enumerated from below: an insulated guard preventing spilled water, etc., to reach the insulation; the lower cold water jacket, the flat burner, the vapor bath, and finally (wherever necessary) an upper cold water jacket. Internally the piezometer was filled with thick mineral oil.‡

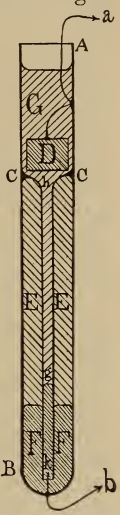
* I shall in future experiments also boil water under pressure.

† Proceed. Am. Acad., xxv, p. 93, 1890.

‡ Phil. Mag., (V), xxxi, p. 10, 1891.

For pressure measurement I am now able to avail myself of superb Amagat "manomètre a pistons libres," which can be attached to my compressor without further mechanism and with advantage.* The instrument is adapted to measure 3000 atm.

6. *The volume tube.*—This is shown in the annexed figure (diagram). It consists of an external cylindrical envelope *AB* of glass, closed below, open above, about 26^{cm} long and ·4^{cm} or ·5^{cm} in diameter. Throughout the greater part of its length, the tube is divided into two coaxial cylindric compartments, by a central glass partition tube *CkC*, open at both ends, and fused to the tube *AB* along the ring *CC*, about 7^{cm} from the top. *CkC* is about 17^{cm} long and ·13^{cm} in internal diameter, drawn as thin-walled and even in calibre as possible, so that the greater part of its lower length may be available for measurement.



The substance to be examined is introduced into the annular space *EE*, care being taken that when fused under the highest temperature and lowest pressure to be applied, its lower boundary may be 4^{cm} or more above the end *k*. Immediately in contact with *EE* and extending upward into the central tube is a plug of mercury *FF*, with its free meniscus at *g*. When *EE* is solid, *g* must be (say) 2^{cm} above the end *k*, and when *EE* is liquid *g* must even in the extreme case be at about an equal distance below the end *CC* of the tube *CkC*. The remainder of this tube, above *g*, is quite filled with a concentrated solution of zinc sulphates *Ghg*, into which an amalgamated zinc terminal *D*, has been submerged and fixed in position by the platinum wire *a*, fused to the sides of the tube *AB* as shown. The other terminal *b* passing through the sealed bottom of *AB*, is in metallic connection with the mercury *FF* therein contained.

The tube thus adjusted is completely submerged in the oil within the insulated tubular piezometer, with which the terminal *a* connects. The terminal *b* completely insulated from the piezometer by a coating of glass tube, is in metallic connection with the barrel. Thus the tube *AB* is held in position by tensely stretching the fixed wires *a* and *b*, and so adjusting their lengths that the parts *EE* and *hg* with reference to which the measurements are made, may lie wholly within the *vapor*

* Results thus obtained in comparing various high pressure gauges and methods of manipulation will be given in a current number of the Phil. Mag., xxxi, p. 400, 1891.

reservoir of the cylindrical vapor bath surrounding the piezometer. Many of these operations are delicate, but descriptions must be omitted.

An inspection of the figure shows at once that if a current enter the outside of the barrel, it will pass through *b*, *k*, *h*, *D* and *a*, into the outside of the piezometer, and thence back to the battery. The only relatively significant resistance encountered in such a course, can be confined to the path between *g* and *h*, through the thread of the zinc sulphate solution; but this resistance, cæt. par., varies directly with the length of *gh* and therefore proportionally to the volume contraction of the substance *EE*. If Kohlrausch's method* of intermittent currents, bridge and telephone be used for the resistance measurement of the electrolyte, solidification or fusion of *EE* breaks upon the ear with a loud roar, whereas the ordinary volume changes (solid or liquid) are indicated by intensifications of the sound in the telephone, sufficiently pronounced however to subserve the purposes of measurement.

It is seen that any breakage of the surface of separation between *EE* and *FF* is entirely without influence on these results, and that even in case of solidification of *EE*, when the mercury is forced into the interstices left after contraction, the compressibility of *EE* will still be measurable.

The charging of the tube free from air, is an operation which I have not yet accomplished satisfactorily. If a volatile substance like naphthalene be filled into *EE* and fused in vacuo, vapors objectionably condense in the tube *hk*. If *EE* be not fused, I doubt whether the air can be eliminated in vacuo. Hence in the present work, the substance was not air-free, a condition to which I gave less attention because I do not believe the melting points are appreciably influenced by dissolved air, nor that the other measurements made are seriously distorted by this error. In further measurements, however, I will endeavor to meet the difficulty by fusing the end *A* of the *inverted* tube *AB*, to the top of a barometer tube, provided with a lateral tubulure leading to a Sprengel pump. If then, after exhaustion the lower meniscus is adjustible, so that the whole barometric column can be raised quite into the tube *AB* or withdrawn from it at pleasure, a thorough vacuum filling may be effected. Rubber connections must be scrupulously avoided.

Method of Measurement.

7. *Constants of the tube.*—In order that the present measurements may be carried out absolutely, it is necessary to

* Kohlrausch: Verh. med. phys. Ges. Würzburg, xv, p. 1, 1880; Wied. Ann., xi, p. 653, 1880. Long: Wied. Ann, xi, p. 37, 1880.

know: (1) The volume of the charge at a fiducial temperature and pressure; (2) The volume of the plug of mercury under the same conditions; (3) The volume of the central tube *kh* (figure 1) per centimeter of length; (4) The resistance of the thread of zinc sulphate solution, per centimeter of length, under all the stated conditions of temperature and pressure. From (3) and (4) there follows at once (5) the resistance of the thread of zinc sulphate per unit of volume, under any stated conditions of temperature and pressure. Thus it is necessary to investigate preliminarily (6) the isopiestic relation of resistance and temperature of the given concentrated solution of zinc sulphate, and (7) the isothermal relation of resistance and pressure of the same solution. In other words one must know what may be called the isoelectrics of the measuring electrolyte. Furthermore it is necessary to find (8) the compressibility of the glass in its relation to pressure and temperature and (9) the compressibility of mercury under the same conditions; finally (10) the thermal expansion of the glass and (11) the thermal expansion of mercury under given conditions of pressure.

The measurements (8) to (11) I have not thus far made directly. They are here of small importance, seeing that the substances on which I operate are all characterized by relatively large volume changes. Such measurements, however, are easily feasible, since both the expansion constants and the compression constants of pure mercury (thanks to the recent labors of Tait, Amagat* and Guillaume) are now thoroughly known, and it is also known that the thermal changes of the elastics of glass are of no relative consequence,† even as far as 200°. If therefore the tube *AB*, figure 1, be filled with mercury, replacing the substance *EE*, the expansion and compression constants may be found by the method above stated, §3, once for all. In the present paper I assumed the compressibility of my glass‡ to be ·0000022, that of mercury,§ being ·0000039; moreover the coefficient of thermal expansion of the glass‖ to be .000025, that of mercury¶ between 60° and 130° being ·000182.

8. *Volume of the charge.*—Clearly the fiducial conditions to which the volumes are to be referred, are given by the (normal) melting point, under atmospheric pressure. By weighing the tube before and after charging, I found for the mass of naphthalene enclosed, ·763*g*. In a special and duplicate set of pycnometer measurements, I furthermore found for the density of fused naphthalene at 82°, ·724. Hence the volume of the

* Cf. E. H. Amagat: Ann. ch. et phys., VI, xxii, p. 95, 1891.
† Ibid., p. 136. ‡ Ibid., p. 125. § Ibid., p. 137.
‖ Landolt u. Boernstein's tables, 1883, p. 69. ¶ Ibid., p. 37.

charge at 82° is ·552 cm³, which I took for the volume at the normal melting point (80°).

9. *Expansion and compressibility of envelopes.*—The plug of mercury weighed 7·74 *g.* Its volume was therefore ·571 cm³, at 20°, and its mean volume between 60° and 130° (being between ·575 and ·582) sufficiently near ·58 cm³.

Thus the volume of the glass tube containing both the charge of naphthalene and mercury, was 1·13 cm³. Its expansion per degree centigrade ·000028 cm³, while the expansion of the mercury in place was ·000105 cm³, per degree, whence the apparent expansion ·00007 cm³ per degree. Therefore if in place of the fiducial volume ·552 cm³ (§ 8), the following volumes be substituted, viz:

60°	·5565 cm.³	100°	·5535 cm.³
80°	·5550	120°	·5519
90°	·5542	130°	·5311

the tube may be treated as free from thermal expansion. Here at 80°, ·555 appears instead of ·552, to allow for the fiducial volume of the stem *kh* (fig. 1), as will be shown in § 17.

Again the compression of the 1·13 cm.³ of glass, and the ·58 cm.³, of mercury will be:

100 atm.;	glass, ·00025 cm.³;	mercury, ·00023 cm.³;	difference, ·00002 cm.³
500	124	113	11
1000	249	226	23
1500	373	339	34
2000	497	452	45

Thus the corrections which would individually be appreciable (affecting the increments say 3 per cent) are differentially negligible (.3 per cent) where they fall below the electrical pressure coefficient of the zinc sulphate solution. §14, cf. §3.

10. *Resistance measurement.*—Using the interrupter and telephone (§6), I facilitated audition by connecting the diaphragm cup with a graphophone tube, and listening with both ears. The resistances, however, were rather higher than contemplated in Kohlrausch's method, when an ordinary Bell telephone is used. Hence the measurements particularly near and in the solid state are far below the limit of attainable accuracy. I shall in future measurements wind a telephone specially adapted for my purposes, and endeavor to use both ends of the magnet to actuate diaphragms. When zinc sulphate is enclosed between terminals of zinc, continuous currents and the galvanometer are available. In this way, I made most of the calibration measurements. Supposing the mercury index to be slightly deadened in its electronegative qualities by zinc, it may also be used in case of the tube.

Should the measuring thread of mercury *gk*, figure 1, break into parts alternating with threads of zinc sulphate (a possibility when the thread is worked up and down many hundred times, particularly in view of the suddenness of solidification), the constants of reduction are not thereby necessarily vitiated, always supposing the number of such breaks to be small. The shifting of coördinates thus produced can be corrected by check-work at a given temperature.* Long continued passage of intermittent currents, charges the mercury with zinc, but solution of mercury can not become serious, since the column is being continually washed by the terminal *D*. Some advantage would be gained by using zinc sulphate in the strength (1·286, Kohlrausch) which corresponds to maximum conductivity.

11. *Calibration.*—The tube *hk*, figure 1, being of insufficiently uniform caliber, volume must be expressed as a function of length. This I did by weighing threads of mercury, whose length had been measured in successive parts of the tube, obtaining the results of the first two columns of table 1. The fiducial zero is here arbitraily placed 2^{cm} below the ring *CC*.

Similarly the resistance of the filament of zinc sulphate *hg* must be expressed as a function of length, referred to the same fiducial zero, at some convenient atmospheric temperature. To do this, I drew a zinc wire down to a diameter slightly below the caliber of the tube. Opening the bottom of *AB*, and closing the top so as to hold the terminal *D* firmly in position, I inverted the tube and quite filled it with the solution. *AB* was then placed in a cold water bath, with the terminal *a* insulated, and the terminal *b* replaced by the zinc wire referred

TABLE 1.—*Volumes per unit of length. Electrical resistance per unit of length* $\theta=17{\cdot}8°$. *Volume per unit of resistance* $\theta=17{\cdot}8°$.

Length.	Volume.	Length.	Resistance.	Resistance.	Volume.
cm.	*cm.*^{3}	*cm.*	*ohms.*	*ohms.*	*cm.*^{3}
3·00	·0491	—·06	2720	2800	·0000
11·15	·1609	2·13	5780	5530	·0350
4·45	·0715	4·75	10190	8850	·0640
9·79	·1430	7·96	16200	12530	·0920
15·42	·2145	12·06	24340	16270	·1190
3·30	·0538	1·38	4630	20250	·1450
7·20	·1076	3·43	7920	24250	·1705
11·40	·1614	6·18	12790	28500	·1960
15·60	·2152	9·00	18220		
2·75	·0470	11·49	23140		
6·10	·0940				
9·65	·1410				
13·40	·1880				

* This I should have done after obtaining Table 9, §21; but the full details of manipulation could not all be foreseen at the outset.

to, and so adjusted that I could slide it up or down and fix it in any position at pleasure. Measuring the distance between the ring *CC* and the free end of the wire, with Grunow's cathetometer, and measuring at the same time the resistance corresponding to this length, I obtained the data necessary for constructing resistance as a function of length, for the temperature of the bath. In this way the second and third columns of table 1 were found.

Combining the results of these four columns by graphic interpolation, I obtained the fifth and sixth columns in which volume is expressed in terms of resistance, at the temperature $\theta=17{\cdot}8°$ with regard to the fiducial mark in question.

12. *Electrolytic resistance and temperature.*—The investigation of this relation is a general problem, quite apart from the

TABLE 2.—*The relation of electrical resistance to temperature and pressure, in case of a concentrated solution of zinc sulphate.*

Temperature.	Pressure.	Resistance.		Temperature.	Pressure.	Resistance.	
° *C.*	*atm.*	*ohms.*	R/R_{100}	° *C.*	*atm.*	*ohms.*	R/R_{100}
*6·3	100	26960	6·060	99·6	191	1237	·990
6·5	100	26960	6·060	99·6	186	1242	·994
66·8	140	6178	1·388	99·6	471	1222	·978
67·3	140	6120	1·376	99·6	448	1210	·968
68·0	140	6050	1·360	99·6	1011	1198	·958
67·8	140	6060	1·362	99·6	981	1203	·962
67·8	140	6075	1·365	99·6	503	1232	·986
67·7	140	6075	1·365	99·6	507	1232	·986
100·0	137	4550	1·023	99·6	126	1262	1·010
100·0	137	4540	1·020	126·0	157	1062	·850
100·0	479	4470	1·005	126·0	157	1062	·850
100·0	469	4480	1·007	127·8	149	1058	·846
100·0	1019	4370	·982	127·8	149	1058	·846
100·0	996	4380	·985	160·5	154	980	·784
100·0	1507	4310	·969	160·5	154	984	·787
100·0	1443	4320	·970	160·5	154	984	·787
100·0	129	4360	·980	‡6·4	138	7440	5·952
100·0	139	4360	·980	6·4	138	7500	6·000
127·6	158	3740	·840	6·4	138	7500	6·000
127·8	158	3730	·838	16·4	147	4980	3·984
127·8	158	3730	·838	16·4	147	5000	4·000
6·5	116	27140	6·100	16·4	147	5020	4·016
6·3	116	27000	6·067	61·3	170	1900	1·520
†6·7	72	7280	5·824	61·3	170	1900	1·520
6·7	465	7090	5·672	61·3	170	1913	1·530
6·7	458	7120	5·700	85·8	180	1359	1·088
6·7	906	7020	5·616	85·8	180	1359	1·088
6·7	830	7020	5·616	85·8	180	1364	1·091
6·7	498	7130	5·704	99·6	189	1247	1·000
6·7	492	7050	5·640	99·6	189	1253	1·002
6·7	139	7190	5·752	99·6	189	1253	1·002
6·7	147	7160	5·728				

* First Series. Diameter of tube. ·13cm.
† Second Series. Diameter of tube, ·30cm.
‡ Third Series. Diameter of tube, ·30cm.

special apparatus used. Nevertheless I made two sets of measurements, in the first of which I determined the resistance of the thread *hk*, fig. 1, between fixed terminals of zinc, when the whole apparatus was kept at successive constant temperature, and under pressures sufficient to insure the condensation of all polarization gases and the presence of a continuous liquid thread of zinc sulphate solution. The four columned table 2 contains these results, where R/R_{100} is the relative resistance at any stated temperature in terms of the corresponding datum for 100° C. At 100° moreover pressures are varied for the measurement of the pressure coefficients discussed in the next paragraph.

In the second and third parts of the table, the above tube *AB* was replaced by a plain straight tube. Resistances are much smaller here, but the column R/R_{100} makes all the data comparable.

If the values R/R_{100} be compared graphically, as a function of temperature for nearly the same pressures, the results of all the series in table 2 are in good accord. Moreover the results for the large interval 6° to 160°, lie on a curve whose form closely resembles an hyperbola. From this point of view the data are remarkably interesting: for if it be true, then a suitable inversion of the locus indicates that the electric conductivity of the electrolyte varies linearly with temperature. Such a result would not only possess theoretic interest, but would make measurements of the kind necessary in the present paper feasible with a high degree of certainty. The interpolations of this paper were made empirically however, and I must withhold further opinion until I can trace the locus as far as 300°. I may add that inasmuch as a solution of maximum conductivity is accompanied by a smaller temperature coefficient, advantages of such a solution are suggested, §10.

13. *Volume in terms of resistance.*—With the data of §§11 and 12 in hand, it is now possible to express the volume of the capillary tube *hk*, figure 1, in terms of the resistance of the thread of electrolyte, observed at any temperature. With this object in view, I computed tables for each of the temperatures of the isothermals below, §§15 to 21, facilitating the further reduction by graphic methods. Being merely of passing interest the tables are omitted here.

14. *Pressure coefficient of the electrolyte.*—The results in table 2 for variable pressure and constant temperature are summarized in the small table 4, below. Here θ denotes the temperature, R the resistance of the thread, and $k=\delta R/R_0\cdot\delta p$ where p symbolizes pressure, the pressure coefficient sought R_0 holds at 0° *C*.

TABLE 4.—*Pressure coefficients of concentrated zinc sulphate solution.*

θ	Pressure.	$k \times 10^6$	θ	Pressure.	$k \times 10^6$	θ	Pressure.	$k \times 10^6$
7°	119 / 479	−43	100°	157 / 482	−64	100°	137 / 1007	−43
	119 / 868	−35		157 / 996	−49		474 / 1475	−35

The mean value is $k=-45/10^6$, being negative, inasmuch as the resistance is here decreased by pressure. The pressure coefficient is nearly independent of temperature, and decreases somewhat with pressure. The results, however, are not quite consistent, and a detailed construction of the data in table 2 shows a difference of march in the pressure on and the pressure off movements. I have yet to learn whether this be due to insufficiently fixed terminals, or to polarization, as well as to find the conditions (change of concentration or of the solution) under which the pressure coefficient may be a minimum. As the results stand the mean value is probably within 20 per cent of the truth, and hence in the extreme case of 2000 atm., the uncertainty of the pressure coefficient will not affect the volume increments more than 2 per cent.

In an earlier paper,* I found $k=-50/10^6$ between 0 and 150 atm., agreeing substantially with table 4. I then called attention to the strikingly close proximity of this datum to the corresponding coefficient for mercury $k=-30/10^6$. The pressure coefficient is of considerable interest, inasmuch as it indicates a certain relation between elasticity and the chemical equilibrium of the solid or liquid operated on† specially for zinc sulphate, it may be noted that whereas the conductivity of a nearly concentrated solution (density > 1·29) decreases on further concentration, compression (which might be regarded as having a concentrative effect on the solution between the terminals) increases the conductivity.

Results of the measurements.

15. *Arrangement of the tables.*—The following tables 5 to 10, in which the isothermals of naphthalene are fully given, are constructed as follows: The first column contains the time in minutes at which the observation was made, the initial date being arbitrary. The (uncorrected) resistance as actually found at the pressure given, is shown under R in ohms. To this the correction for pressure coefficient, kp per unit of R, is to be

* This Journal, xl, p. 219, 1890. The work of this paper was done some two years prior to the publication.

† Phil. Mag., V, xxxi, p. 24 et seq., 1891.

added, after which R can be expressed as a volume increment, referred as yet to an arbitrary fiducial zero, §§ 13, 14. The corresponding volume (last column of the tables) is deduced from this by inserting the initial volume values of §9. Cf. §17.

Two data are usually given for each step of pressure, the second of which, obtained after long waiting (5^m or more) is more nearly isothermal than the first. In most cases, a small additional volume decrement takes place after solidification, either viscously or as the results of gradual decrease of temperature.

Parentheses occur to show that for the data enclosed the measurement was made along an (upper) part of the tube *hk*, figure 1, whose calibre was not sufficiently uniform. Without knowing the full expansions at the higher temperatures and lower pressures, it is a priori impossible so to fill the tube that all measurements fall within calibrated parts, and all other calibration conditions are complied with, §9. These approximations however refer to the liquid state, and are thus of less consequence in this paper, §1. If the isothermals of the liquid only were sought, it would be advisable to make the tube *hk* very much more nearly capillary from the outset.

The experiments were made on different days, and together extended over more than a week. This is too long a time to employ the tube without special readjustment, and some shifting of coördinates may therefore have occurred. §§10, 25, 26.

I may add finally that the melting point of naphthalene in air is about 80°, its solidification point below this, under proper conditions. The density of the solid is 1·14, and that of the liquid at 82°, is ·724, §8. Hence naphthalene melted in water sinks or swims, according as its temperature is sufficiently below or above 80°.

16. *Solid isothermal*, 63°.—Clearly the data obtained in operating on the solid will be less accurate than the liquid

TABLE 5.—*Isothermals of (solid) naphthalene, at* 63·5°, *referred to* ·55 *cm.*³, *at the normal melting point.*

Time.	Pressure.	R.	$kp \times 10^3$	Volume.	Time.	Pressure.	R.	$kp \times 10^3$	Volume.
m.	*atm.*	*ohms.*		*cm.*³	*m.*	*atm.*	*ohms.*		*cm.*³
16	70	7600	3	·4127	38	859	8240	39	·3965
19	68	7430	3	·4156	40	850	8120	38	·3988
20	289	7760	13	·4085	42	972	8310	44	·3945
23	281	7630	13	·4109	44	966	8310	44	·3945
25	491	8160	22	·4003	46	565	7600	25	·4097
29	481	8010	22	·4027	49	565	7605	25	·4097
34	675	8050	30	·4010	51	100	7270	4	·4183
37	662	7880	30	·4039	67	65	7340	3	·4173

data, §6. For in addition to relatively greater importance of the corrections for the compressibility of the envelopes, the fissured or honeycombed structure and the high resistances, §10, interfere with sharp measurement. Nevertheless by comparing the data with similar solid isothermals obtained at much higher temperatures, their validity may be inferred.

With reference to the series it is interesting to note that recoil of volume (pressure decreasing) is more rapid than compression. The reverse of this would have been anticipated, supposing that mercury lodged in the interstices. The liquid in the above case was allowed to solidify under pressure.

TABLE 6.—*Isothermals of naphthalene, at 83°, referred to ·55 cm.³ at the normal melting point.*

Time.	Pressure.	*R.*	$\frac{kp}{\times 10^3}$	Volume.	Time.	Pressure.	*R.*	$\frac{kp}{\times 10^3}$	Volume.
m.	*atm.*	*ohms.*		*cm.³*	*m.*	*atm.*	*ohms.*		*cm.³*
36	39	923	2	·5498	79	129	5250	6	·4241
39	226	1183	10	·5371	81	89	4747	4	·4358
44	221	1158	10	·5382	87	93	4348	4	·4453
46	250	1223	11	·5355	94	93	4348	4	·4453
51	244	1198	11	·5365	96	70	3651	3	·4630
53	267	1232	12	·5348	97	70	3256	3	·4732
59	265	1227	12	·5351	104	74	2031	3	·5062
60	303	1288	13	·5322	115	76	1695	3	·5172
63	322	1326	14	·5306	120	75	1480	3	·5250
64	317	5667	14	·4138	122	49	920	2	·5500
73	299	5712	13	·4128	127	52	905	2	·5508
75	127	5250	6	·4241					

TABLE 7.—*Isothermals of naphthalene, at 90°, referred to ·55 cm.³ at the normal melting point.*

Time.	Pressure.	*R.*	$\frac{kp}{\times 10^3}$	Volume.	Time.	Pressure.	*R.*	$\frac{kp}{\times 10^3}$	Volume.
m.	*atm.*	*ohms.*		*cm.³*	*m.*	*atm.*	*ohms.*		*cm.³*
16	57	773	3	·5542	60	316	4618	14	·4311
18	231	972	10	·5432	65	322	4555	14	·4326
24	222	957	10	·5439	67	280	3855	13	·4504
26	422	1188	19	·5322	73	283	2333	13	·4929
31	406	1155	18	·5338	76	283	1985	13	·5028
33	490	1247	22	·5293	81	278	1618	13	·5152
40	474	1232	21	·5302	83	175	897	8	·5472
42	507	1258	23	·5292	89	179	902	8	·5468
44	532	1288	24	·5276	91	81	793	4	·5530
46	555	5250	25	·4147	95	83	802	4	·5524
57	544	5290	24	·4139					

17. *Liquid-solid isothermal, 83°.*—Three independent series are in hand. The example given in table 6, is the second in number. It is from these isothermals that I obtained the

fiducial zero of the stem *hk*, figure 1. For at pressure zero the increment is ·0024 cm.³. Hence the value ·5524 of § 8, increased by ·0024 is the fiducial volume (·555 cm.³ nearly) here to be used, and from this the others are derived. § 9.

18. *Liquid-solid isothermals at 90°.*—Two independent series of results are in hand. The example given in table 7 is the second in number.

19. *Liquid-solid isothermals at 100°.*—Four independent series are in hand. The example given in table 8 is the second in number.

TABLE 8.—*Isothermals of naphthalene, at* 100°, *referred to* ·55 *cm.*³ *at the normal melting point.*

Time.	Pressure.	*R.*	$kp \times 10^3$	Volume.	Time.	Pressure.	*R.*	$kp \times 10^3$	Volume.
m.	*atm.*	*ohms.*		*cm.*²	*m.*	*atm.*	*ohms.*		*cm.*³
20	116	667	5	(·5575)	148	906	4882	41	·4124
27	116	667	5	(·5575)	150	769	4714	35	·4175
29	281	852	13	·5455	157	772	4714	35	·4175
36	274	835	12	·5464	159	644	4556	29	·4224
45	460	1020	21	·5360	165	652	4556	29	·4224
47	670	1223	30	·5255	167	560	3808	25	·4425
53	653	1198	29	·5266	168	560	3202	25	·4599
56	795	1331	35	·5204	169	562	2846	25	·4707
63	766	1300	34	·5219	171	558	2279	25	·4877
54	808	1353	36	·5195	173	558	1889	25	·5000
69	797	1353	36	·5195	176	558	1600	25	·5102
75	780	1336	35	·5202	178	558	1416	25	·5175
76	818	1370	37	·5185	180	557	1300	25	·5224
85	813	1370	36	·5187	184	552	1174	25	·5280
91	785	1336	35	·5202	187	553	1160	25	·5287
93	856	1415	39	·5167	208	553	1158	25	·5288
102	850	1410	38	·5169	213	546	1160	25	·5287
107	820	1370	37	·5185	216	429	988	19	·5375
108	908	1439	41	·5155	225	430	992	19	·5375
116	888	1439	40	·5155	227	287	845	13	·5459
121	890	1439	40	·5155	235	292	852	13	·5454
122	921	4814	41	·4141	237	81	645	4	(·5585)
133	914	4882	41	·4125	244	86	650	4	(·5583)

20. *Liquid-solid isothermals at 117°.*—The vapor bath in this case was filled with amyl alcohol from which the water had not been extracted. § 4. The results for solidification obtained are worthless, except in so far as they contain specific evidence of certain peculiarities of behavior of an unevenly temperatured tube, referred to below. §§ 25, 27. The data for fusion are in part available. I omit the table.

21. *Liquid-solid isothermals at 130°.*—Four independent series of results are in hand. The example given in table 9 is the second in number.

TABLE 9.—*Isothermals of naphthalene, at* 130°, *referred to* ·55 *cm.*³ *at the normal melting point.*

Time.	Pressure.	*R.*	$kp \times 10^3$	Volume.	Time.	Pressure.	*R.*	$kp \times 10^3$	Volume.
m.	*atm.*	*ohms.*		*cm.*³	*m.*	*atm.*	*ohms.*		*cm.*³
5	151	276	7	(.5811)	78	1907	3926	85	·4099
7	464	495	21	(·5586)	84	1880	3950	85	·4091
11	451	484	20	(·5601)	86	1574	3695	72	·4190
14	921	808	41	·5351	96	1575	3695	72	·4190
18	881	770	40	·5378	98	1463	2876	65	·4480
35	1338	1057	58	·5200	106	1463	1690	65	·4914
37	1336	1057	59	·5200	113	1458	1481	65	·5000
57	1464	1132	65	·5158	123	1456	1490	65	·4996
59	1459	1132	65	·5158	125	1245	1021	56	·5220
61	1581	1223	74	·5109	131	1244	1021	56	·5221
63	1656	1278	74	·5083	135	990	845	44	·5327
64	1651	1262	74	·5091	139	994	850	44	·5325
65	1737	1329	78	·5057	141	565	565	25	(·5536)
68	1723	1320	78	·5061	145	580	570	26	(·5531)
71	1794	3878	81	·4119	148	155	275	7	(·5811)
76	1777	3926	79	·4106	153	168	289	7	(·5796)

Deductions.

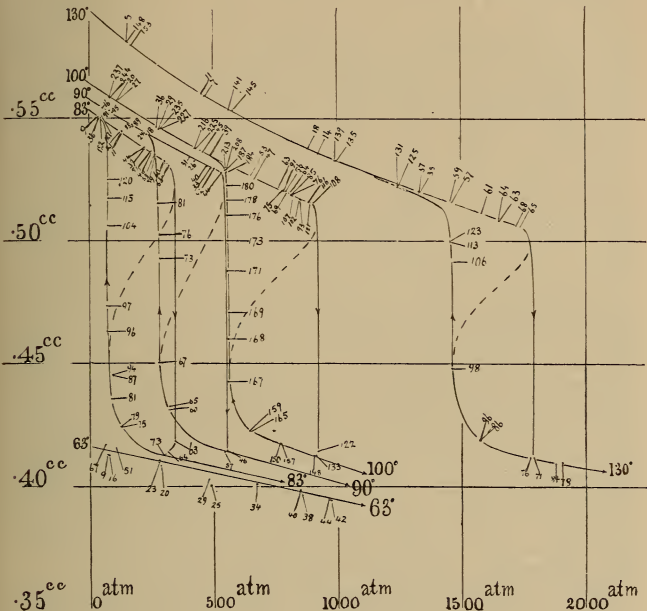
22. *Graphic construction.*—To obtain a survey over this series of individual data, it will be necessary to resort to the pictorial method, and to represent volume as a function of pressure, under the successive conditions of constant temperature. This has been done in the following chart. The ordinates are volumes (fiducial volume being ·5524 cm.³ at 80° nearly, and arbitrarily chosen), the abscissas are pressures. The temperatures of the isothermals are given at the beginning and the end of each curve; and the dates or times in minutes at which the individual observations were made, are shown by small numerals attached to the points. Thus it is easily seen whether an observation was taken during the *on* march or the *off* march of pressure; but to further facilitate inspection arrows are subjoined to the curves, showing their drift.

It is seen from these figures, that the solid is comparable in compressibility with the liquid. On this point, however, I shall now place no stress, for reasons repeatedly stated in the above paragraphs. §§ 4, 16.

23. *Hysteresis.*—The inherent character of all these curves is phenomenally cyclic, the isothermal pressure necessary to solidify naphthalene being at all temperatures decidedly in excess of the pressure at which it again liquifies. Thus the results which I obtained in other experiments and with other substances, some time ago,* are emphatically corroborated.

* This Journal, xxxviii, p. 408, 1890. The full paper and deductions made therein are as yet unpublished.

Evidences of the thoroughly static character of these phenomena are abundant, I mention: solid isothermal 100°, first series (not given above), where I waited from 50^m to 100^m at a pressure below the solidifying point of the liquid, without obtaining fusion, whereas, after this fusion is completed between



101^m and 112^m with only slightly further reduction of pressure; liquid isothermal 100°, second series (given above § 19, and chart § 22), where I waited from 47^m to 121^m at a pressure greater than that at which the solid fuses, without obtaining solidification, whereas this sets in at once between 121^m and 122^m, when the pressure interval is only slightly increased; solid isothermal 130°, second series, where I wait from 86^m to 96^m at a pressure below the solidifying point without change of volume or fusion whatever, etc. If high temperature conditions are unfavorable to volume lag, this evidence and much else which I might add, is accentuated.

I have already pointed out* that it is a phenomenon inherent in the passage from one molecular condition to another,

* This Journal, l. c., Phil. Mag. (V), xxxi, p. 27, 1891.

which lies at the root of all manifestations of hysteresis, whether observed electrically (Cohn, Ewing, Schumann), or magnetically (Warburg, Ewing), or as a purely mechanical result in my work,* during fusion, as above, during solution, § 29, etc.

24. *James Thomson's double inflections.*—Solidification almost always sets in at once. One would expect this: for if there be condensation or crystallization at any one point, it will form the nucleus from which the whole column will be solidified, so far as it lies in the field of volume lag. Only in one case (liquid isothermal 83° 60^m to 63^m) did I obtain evidence of curvature. Usually even at low temperatures the path is precipitous, because pressure cannot be lowered rapidly enough.

The reverse of this holds in case of fusion. Here the initial or stable contours of James Thomson's circumflexures are well marked. It is true that fusion cannot take place instantaneously, because heat cannot be supplied fast enough. It is also true that if temperature be not quite identical throughout the length of column, fusion will first take place at the hotter planes below, and proceed thence to the top.† In the present experiments, however, the phenomenon occurs with the same uniformity at all temperatures, and is quite pronounced in the steam bath. § 4. Hence, taking into additional consideration the evidence of § 22, I conclude that the initial contours are static and regard them as partially evidencing James Thomson's‡ well known inference relative to the doubly inflected contours of the isothermal paths accompanying change of physical state. When fusion actually sets in, the phenomenon is no longer observable; for the physical parts of the substance now exist in widely different thermal states. In figure 2 the full contours are indicated by dotted lines.

25. *The characteristic specific volumes.*—Mere inspection of the chart, figure 2, shows that the volume at which solidification takes place, *decreases* as temperature increases, while the volume into which the substance solidifies either increases or remains stationary in value. In table 10, I have inscribed the corresponding values of pressure and of volume, observed at the solidification points, in each of my four sets of results.§ The data are plotted in figure 3, the volumes being abscissas, the pressures ordinates. To distinguish the points of this diagram, they are surrounded by little circles, to which the number of the series is attached.

A similar and equally expressive table may be deduced by finding the characteristic volumes at the successive melting

* Cf. my results on the Bourdon gauge in a current number of the Phil. Mag.

† I have actually observed this in glass capillary tubes, when the vapor baths were imperfect. ‡ James Thomson: Phil. Mag. (IV), xlii, p. 227, 1872.

§ The above tables and figure 2 exhibiting but one of these sets.

points; but as these data are identical in purport with those of table 10, and since the melting volume is necessarily less easy of definition, § 23, I will omit them here.

TABLE 10.—*Volumes solid and liquid at the solidifying points, varying with pressure.**

Series.	Temperature 83°.		Temperature 90°.		Temperature 100°.		Temperature 130°.	
	Pressure. Solid volume.	Pressure. Liquid volume.	Pressure. Solid volume.	Pressure. Liquid volume.	Pressure. Solid volume.	Pressure. Liquid volume.	Pressure. Solid volume.	Pressure. Liquid volume.
I	260	260	550	550	875	875	1720	1720
	·415	·534	·413	·523	·416	·510	·415	·505
II	320	320	555	555	920	920	1790	1790
	·415	·530	·415	·527	·413	·515	·412	·505
III	345	345	550	550	870	870	1665	1665
	----	----	418	----	·413	·510	·417	·507
IV	----	----	----	----	900	900	1720	1720
	----	----	----	----	·412	·517	----	·505
	----	----	----	----	----	----	----	----

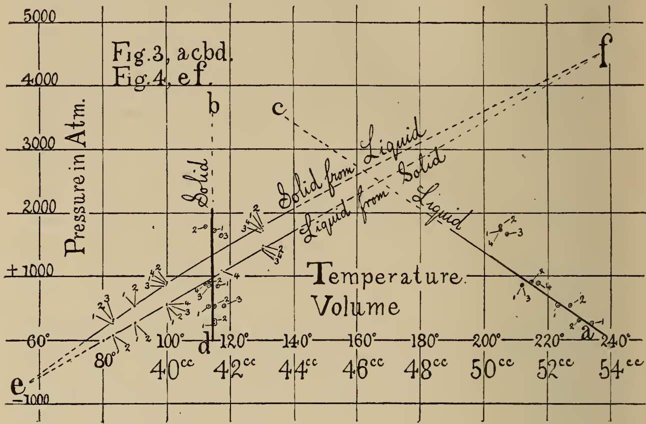
A noticeable feature of the diagram is the closer accordance of the three groups of points between 0 and 1000 atm., during which measurements steam was used as the medium of constant temperature, as compared with the single group of points between 1000 atm. and 2000 atm., when vapor of amyl alcohol was used. I account for this by supposing solidification in the last case to have been premature, and associate the result with insufficient constancy of the vapor bath. §§ 4, 20, 23. Hence, the liquid volumes found are too large. There may also have been some gradual change of the constants of the volume tube, which in the lapse of time became appreciable. §§ 15, 10. Further experiments must decide this point. Regarding solid volumes it is clear that no device can define them as closely as the liquid volumes; indeed the degree of definition attained is one of the virtues of the method. § 16.

In figure 3 I have therefore placed chief reliance on the water points (0 to 1000 atm.) and drawn the locus accordingly.

26. *Critical point.*—The area enclosed by the lines *ac* . . ., and *bd* . . ., supposing *b* and *c* eventually to coalesce, has the same signification as Andrews's area of vapor tensions. This would also be true of the similar figure for the characteristic volumes at the melting points, and more pointedly of the figure in which solidification volumes are taken at the solidifying points and fusion volumes at the melting points. § 25. All of these diagrams point out the probable occurrence of a *critical point in the region of positive pressure, reached in the direction of increasing temperature*, at which point solid would change to liquid and liquid to solid, without paroxysmal change

* See remarks on table 11, § 27.

of volume, and consequently without volume lag. In case of naphthalene the position of this point may be conjectured at several hundred degrees centigrade and several thousand (5000 to 10,000) atmospheres.



27. *Solidifying points and melting points.*—The cycles depicted in figure 2 have two prominent characteristics: They gradually decrease in vertical extent from left to right and they gradually decrease in lateral extent from a central area toward both sides of the chart. The former quality has already been interpreted. § 25, 26. The latter is now to be considered.

TABLE 11.—*Showing the relation of solidifying point and of melting point to pressure, at different temperatures. Naphthalene, melting at* 80°.

Series.	Temperature 83°.		Temperature 90°.		Temperat're 100°.		Temp. 117°.	Temperat're 130°.	
	Solid at	Melting at	Solid at	Melting at	Solid at	Melting at	Melting at	Solid at	Melting at
	atm.	*atm.*	*atm.*	*atm.*	*atm.*	*atm.*	*atm.*	*atm.*	*atm.*
I	**a*260	80	*a*550	275	*a*875	560	----	*a*1720	1430
II	**b*320	80	*b*555	280	*b*920	560	----	*b*1790	1465
III	*a*345	--	----	----	870	580	----	†1665	1410
IV	----	--	----	----	*b*900	570	1050	*a*1720	----

c { Factor: M. P. and pressure, 80° to 130°, 28·5 *atm.*/°C., or ·0351 °C./*atm.*
" : S. P. " " 80° to 100°, 36·0 *atm.*/°C., or ·0278 °C./*atm.*
" . S. P. " " 100° to 130°, 29·5 *atm.*/°C., or ·0339 °C./*atm.*

a, Not crept upon. *b*, crept upon. *c*, Factors taken chiefly with reference to series II.

* First result at <83°, second and third at >83°. Solidification gradual, the other solidifications take place at once.

† Temperature 129·6°.

Table 11 gives the values of the pressures corresponding to solidification and to fusion at the different temperatures, together with other relevant information, as sharply as these statements can be made. M. P. denotes melting point, S. P., solidifying point.

Let the solidifying points and melting points be constructed as functions of pressure. Figure 4 shows the points to lie on a spindle-shaped figure, running diagonally across the chart. They are again taken out of all the four sets of results and numbered accordingly. § 25. The parts of the curves actually observed are given in full lines, the inferential prolongations in dotted lines.

From the nature of the case the solidification points are not sharply determinable. § 23. Even leaving the nuclear solidification induced by inconstancy in the linear distribution of temperature out of sight (a marked example of which occurs in the series for 117°, § 20, where solidification and fusion are practically coincident), all percussion and jarring, too rapid increase of pressure, a vibratile wire running through the column as in some of my earlier experiments, will cause the whole labile structure to topple into solidification. Hence the solidifying points must be fairly *crept* upon and surprised, and hence my present results in which these precautions were taken show high solidifying points as compared with my other work. § 2, note.

These conditions do not hold with like importance in case of fusion; for the melting points as a rule show much greater coincidence.

In figure 4 I have therefore placed chief reliance on the data of series II obtained as they were with the experience of series I to guide me.

28. *Transitional point.*—If the two curves be prolonged in the direction of *increasing* temperature, their eventual coalescence is presumptive by §§ 25, 26. Clearly the occurrence of volume lag must cease when the paroxysmal volume changes vanish.

If the two curves be prolonged in the direction of *decreasing* temperature, then the data themselves indicate the probability of an intersection in the region of negative pressure. Beyond this, therefore, there would be an inversion of the conditions of fusion: in other words, the substance would solidify at a lower pressure than that at which it fuses, and fuse at a higher pressure than corresponds to solidification. I believe this remarkable suggestion to be interpretable as follows: The normal type of fusion changes continuously into the ice type of fusion, through a transitional type, characterized by the zero of volume lag. The position of the latter for naphthalene, so far as can now be discerned, may be placed at (say) 50° and (say) −1000 atm. It is noteworthy, that with the understanding here laid down, the normal type of fusion is reached from the ice type, in the direction of increasing temperature.*

29. *Solubility and pressure.*—In view of the detailed analogy which holds between many characters of fusion, and of solution, much that can be investigated for the simpler of these phenomena (fusion apparently) will be applicable to the other. A substance may be transferred from the solid into the liquid state either (1) by heating it, or (2) by dissolving it. In general, excess of temperature, or of solvent favor the diminution of viscosity here in question. A liquid on the verge of solidification or a concentrated solution is solidified or deposits solid on cooling; and in both cases the nice adjustment of labile molecular equilibrium is accompanied by volume hysteresis,—under-cooling, etc., in the one case, supersaturation, etc., in the other. Hence I conclude that if under proper thermal conditions pressure alone can solidify a liquid, it can also under proper solutional conditions induce crystallization or the deposit of solid from solution—thereby trenching upon, or (from a new point of departure) approaching the modern chemical doctrines which originated, I believe, with van't Hoff.

I am the more justified in drawing these inferences as in my last article† on the solvent action of hot water on glass, I have already adduced the necessary evidence. Since from one point of view, the isothermal compressibility of silicated water is increased proportionally to the time during which the solvent action has been going on; and from another, with the amount of basic silicate dissolved,—the deduction is closely at hand, that what pressure actually did in this instance, was a mere precipitation of a proportionate amount of the dissolved silicate. The volume changes thence resulting were blindly put into computation as increments of compressibility, because the precipitated silicate is again dissolved when pressure is withdrawn.‡

* [*Added to proof.*—Throughout the present paper, I have avoided the discussion of the isopiestics, since I shall consider them in detail in connection with special experiments. It is well to state, however, that the transitional temperature is related to the prospective intersection of the prolonged liquid and solid isopiestics, of a given substance, at the same pressure in both cases. Thus a reason why hysteresis may vanish is again suggested. A given substance on one side of the transitional temperature would differ molecularly from the same substance on the other side.]

† This Journal, xli, p. 110, 1891.

‡ [*Added to proof.*—In justice to myself let me say that the manuscript left my hands on Feb. 23d, some five months ago, and before the kindred deductions of Orme Masson (Nat. xliii, p. 345, 1891), or of Ramsay (Nat. xliii, p. 589, 1891) had reached me. I have not in any way altered § 29. In fact, what these gentlemen have deduced from the solution behavior liquid-liquid, I had legitimately derived from the solution behavior solid-liquid, as set forth in my own work. My preced-

Thus the work has a bearing on the nature of solution; for to my thinking, what I have ventured to call cohesive affinities* cannot differ except in degree from the affinities determining valency. At least proceeding on this assumption, I am led naturally to a theory regarding changes of the physical state of aggregation in general, which I will indicate elsewhere.

30. *Conclusion.*—In the above pages I have merely sought to describe the results directly given by experiment in so far as I understand them, and to draw conclusions which in the light of known facts seemed to be admissible or even obvious. In how far these conclusions are to stand or fall, will depend on similar investigations, to be made with a variety of other substances specially selected with reference to their position in a scale of thermal state. § 3. How such selection is to be made, I am now unable to intimate. Substances for instance which fuse continually, like glass or sealing wax, might at first sight be referred to positions near their critical temperatures: but I believe these cases are mere solution phenomena of relatively small interest. At all events at the outset, the experiments must deal with bodies of definite, simple and preferably crystalline character, to the exclusion of mixtures. I feel confident that in an examination of many types, some will be found lying relatively nearer the critical point, while others lie nearer or even beyond the transitional point; and that if the above method be applied with greater rigor than was done in the present paper, light will be thrown on the long neglected department of fusion and solution thermodynamics as related to pressure. From this stage of progress it will then be possible to approach nearer the next of the kindred phenomena, which I conceive to be nothing less than the kind of hysteresis or higher order of volume lag known as chemical affinity.

[*Added to proof.*—To obviate the occurrence of a bald statement like the last, I will indicate my views on the distribution, or successive orders of volume lags. These are to be sought—I, during the passage of a given atom into the next consecutive in a scale of decreasing atomic weights; II, during the occurrence of dissociation of the molecule, including solutions gas-fluid. They are demonstrable, III, in the region of Andrews's vapor tensions, including the Alexéef-Masson solutions liquid-liquid; IV, in the region of the solid-liquid phenomena of the present paper, including solutions solid-liquid; V, in the region of solid-solid phenomena categorically distinguishable as "permanent set" (Osmond, Carus-Wilson, Barus). They are to be sought for finally, VI, during the passage of a given atom into the next consecutive in a scale of increasing atomic weights.

The enumeration is systematic, and inasmuch as VI is virtually identical with I, the inherent nature of these changes is periodic. Hence under suitable thermal conditions, and continually increasing pressure, the evolution of atoms, of molecules, of changes of physical state, are successive stages of periodically recurring hysteresis.]

ing paper is at fault only in postulating an unnecessary change of hydration of the silicated water (l. c., p. 116).

It is gratifying to note that evidence of the similar solution behavior solid-solid is forthcoming, and to be found in the work of Osmond, of C. A. Carus-Wilson (Phil. Mag., xxix, p. 200), and of myself, as I have already pointed out (Phil. Mag., xxxi, pp. 26–28).]

* Ibid., p. 115.

ART. XIII.—*Note on the Asphaltum of Utah and Colorado;* by GEORGE H. STONE.

DURING the past year the writer has visited all the known asphalt fields of western Colorado and northeastern Utah, save those situated within the reservations of the Ute Indians, and two other exceptions noted below. It is intended at some future time to complete a map of the asphalt exposures and to publish a more detailed account of them than is possible in this preliminary paper.

Petrography of the Deposits.—The following named classes of deposit are represented:

1. *Asphaltic sand-rock*, known also as sand-asphalt and bituminous rock. This is the most abundant of all the asphaltic deposits. It consists of a sandstone the grains of which are in contact with each other and the spaces between the grains are wholly or partly filled with asphaltum. The proportion of asphalt varies up to about 15 per cent by weight and 27 per cent by volume Of course sandstones will contain different proportions of asphalt in their inter-granular spaces since those spaces depend on the sizes and shapes of the constituent grains and often on the presence of other cementing substances. When a bituminous sandstone contains more than about 15 per cent of asphalt, it may be assumed that it has not been under pressure of superincumbent rock sufficient to cause the grains to come in contact with each other.*

The thickest stratum of fully charged rock that I have seen was near 40 feet in thickness. Usually the strata of high grade rock are not more than 4 to 10 feet thick and they alternate with lower grade or barren strata of sand-rock, and sometimes with marls, shales or limestones. Hence the amount of rich rock,—"pay rock"—has often been enormously over-estimated, no account having been made of the poor strata. This is particularly the case with some of the published accounts of the asphalt beds of the valley of Ashley Creek, Utah.

2. *Bituminous Shales or Marls.*—Black or blackish marls or shales cover large areas both in Colorado and Utah. The richer layers have the smell of asphalt, though like Wurtzilite, they are difficultly soluble. The specimens examined by me

* The analyses of the California bituminous rock given in Seventh Annual Report, Wm. Irelan, Jr., State Mineralogist, Cal., 1887, pp. 51–53, show from 1·10 to 8 per cent of fixed carbon, and of volatile carbonaceous matter from 9·40 to 46·20 per cent, with small proportions of lime, etc. An asphaltic sand containing so large a percentage of asphalt as afforded by some of these analyses would probably have been produced by a relatively small quantity of sand being washed or drifted on to an outflow of soft asphalt.

yield no paraffin, or at most a mere trace to solvents and boiling water, and a considerably larger proportion after destructive distillation. They approach cannel coal in composition, but contain a very large proportion of ash, so that none of them contain more than 10, or perhaps 20 per cent of carbonaceous matter. The richer layers are commonly known in western Colorado as "oil rock," and burn readily with a bright, furious flame, leaving pieces of shale having the same size and shape as they had before being burned. These facts indicate that in their natural state these bituminous shales (they all contain so much lime as to be more nearly marls than shales) are asphaltic rather than paraffinic rocks. The richer layers are seldom more than 4 feet thick and are found in the midst of low grade rocks (shales, marls, and limestones). At one place I noted ten of the rich layers each two to four feet thick, distributed at intervals through about 400 feet of rock.

3. *Bituminous Limestones.*—Limestones and marls constitute a large part of the Tertiary rocks of the region under discussion, i. e. of the asphalt-bearing formations. Almost all the limestones are somewhat bituminous, and some strata will burn like the shales. They are colored from gray to yellowish-brown, light color, rather than blackish like the bituminous shales. Usually they do not contain distinct fossils, but are often oolitic, pisolitic or coarser concretionary, i. e. they are semi-crystalline. Fetid layers are not rare, and some of them are particularly offensive. Cavities in the bituminous limestones are often filled with hard asphalt, in some places taking the form of Wurtzilite, in other places Uintaite. The color of the Uintaite varies from the deepest black to brown and even gray-brown. The lighter colors are found in the centers of the lumps or in the cavities less open to the air. I have found asphalt in five classes of cavities in these limestones.

1. In small irregular or somewhat amygdaloidal cavities in fine granular limestone and having no visible outlets.

2. In fractures that cross the strata for only a short distance (gash veins of the miners).

3. In deep fissures (true fissure veins).

4. In caves or channels of subterranean streams, in which the asphalt was brought in after the stalagmitic growths were completed or nearly so.

5. In the interior of shells, or in the cavities found in the centers of concretions and nodules contained in the limestone.

The limestone yields on destructive distillation several per cent of volatile and combustible carbonaceous matter. In all cases unless in the fissure veins and stream caves it is evident that the asphalt must have been derived from the country rock, i. e. a bituminous liquid oozed out of the limestone into the cavities. Since the limestone is of a light color, this liquid must have acquired its dark color during the process of being changed into hard asphalt. This conclusion is confirmed by the lighter color of the least exposed asphalt. Evidently the bituminous matter that is now in the rock is not in the condition of ordinary black asphalt, but the liquid which oozed out of the rock was capable of being changed into such asphalt, hence the bituminous limestones may well be classed with the asphalt-producing rocks.

The rather light color of some of these masses of hard asphalt, which have all the properties of Uintaite except the deep black color, suggests the question whether the color of asphalt be not due to disseminated fixed carbon, in a state approaching charcoal, the product of partial oxidation, more than to the natural color of the hydro-carbons proper. I began some experiments and analyses to determine this point, but the work is incomplete.*

4. *Outflow or Overflow Asphalt.*—Under this class are here included all forms of asphalt that have oozed out of the rock that originally contained them. Some of these had the black color before, others have acquired it since the outflow. I leave it as an open question whether these oils were true asphalts before acquiring the black color.†

Mineralogically the outflow asphalts present the same difficulties of classification as do the petroleums. There are perhaps a dozen different grades in Utah and Colorado that might be described as distinct minerals by those on the alert for new species. The more important generic terms (they are all generic rather than specific) are the following: 1. Maltha, asphaltic tar, brea, mineral tar or pittasphalt. Here are included the viscous liquids. In Utah they all have an aromatic odor and black color. By degrees they harden to a solid, sometimes tough, waxy or horny, sometimes brittle. The

* Mr. S. H. Gilson, of Salt Lake, informs me that he has obtained by distillation of the limestone out of which a mass of Wurtzilite had oozed, a dark yellowish tarry material that closely resembles and appears to be identical with the distillate from the Wurtzilite.

† That the lighter constituents of petroleum can be changed to more viscous oils by protracted exposure to oxygen, appears to have been proved by experiments made some years ago by W. P. Jenney. The same conclusion is enforced by the hardening of the brea of California, also by the finding of asphalt in cavities in the Devonian and Silurian petroliferous rocks (see Report of Professor Edward Orton on the Trenton Limestone as a source of Natural Gas and Petroleum in Ohio and Indiana. Eighth Ann. Report Director U. S. G. S., 86–87). Such asphalt cavities have been observed by Shaler, Newberry, Linney, Orton and others. In the present state of the argument it is permissible to assume as a working hypothesis that the harder asphalts were derived from the softer or pittasphalts, and they in turn from more liquid bitumens. under exposure to the air or perhaps to aerated waters. How much this is quantitatively due to oxygen or other chemical agencies, and how much to evaporation of the lighter compounds, remains to be determined

hardened outflow is known as outflow or overflow asphalt. The maltha is found in small pools, or spread over the ground and often penetrates the spaces between the broken rock of the talus or sub-soil in a complex network of stringers, small veins and sheets. 2. Uintaite or Gilsonite. A brittle, easily soluble and fusible mineral. 3. Wurtzilite, a shining, tough mineral, fusible and soluble with great difficulty.*

Geological Age of the Deposits.—A fissure vein of wurtzilite is reported to be found in a region where none of the U. S. geological maps show rocks later than the Jurassic or early Cretaceous, and the same is true of one area of asphaltic sandrock. I have not examined these deposits and leave their age an open question. All the fields of sand asphalt that I have visited are plainly of Tertiary age. Most of them are in the Green River beds, some may be in the upper part of the Wasatch, and the thick beds found in the Ashley valley appear to be near the base of the very late Tertiary formation marked on Hayden's maps as Uinta and on that of Dr. C. A. White, (Ninth Ann. Report Director U. S. G. S., 87–88) named Brown's Park. The black asphaltic or bituminous shales (marls) are of Green River age. The bituminous limestones, so far as I have observed them, are of Green River and some perhaps are of Upper Wasatch age. The outcrop of the fissure veins of uintaite and some of the wurtzilite are in the Brown's Park rocks and therefore these veins were opened and filled after the Brown's Park epoch—obviously in case of outflow asphalt we have to determine not only the date of origin of the tarry bitumen but also the date of outflow. These fissure veins will be referred to again.

The Bituminous Rocks and Coal Beds.—In one place in the Ashley valley a coal bed about two feet thick has an underclay a few inches thick, and that rests directly on the asphaltic sand rock. The coal is a fair specimen of the Tertiary coals of the region. It is free burning, not caking, and no bitumen

* For a full description of Uintaite and Wurtzilite and their relations to albertite, grahamite and elaterite, see article by Professor W. P. Blake, Proceedings of American Institute of Mining Engineers, Feb. 1890. I have recently learned of a locality where the wurtzilite is said to soften under heat so as to be drawn out into strings that tend to shorten. This grade is very near elaterite in behavior and perhaps is identical with it. The Ute Indians have camped on almost all the uintaite and wurtzilite in this country. The valley of the DuChesne River, also those of the Lower White and adjacent parts of the Green River, are crossed by numerous fissure veins of these minerals, though wurtzilite is more often found as an out-flow product in the talus and scattered drift than in fissures. Both wurtzilite and uintaite are found in a great variety of situations. It is uncertain whether the hardening of the outflow into one or the other of these minerals is due more to original differences in the chemical composition of the outflows or to the physical conditions under which they hardened after the outflow. I have not heard of both minerals being derived from the same outflow. So far as at present known the facts seem to indicate that they are derived from malthas of different chemical composition.

has invaded it or its under-clay from the asphalt layer. The coal abounds in lumps of yellow, partially mineralized rosin, just like most of the softer coals of the mountain region.

In the Wasatch and Roan Mountains I have in several places found coal seams up to eighteen inches in thickness with the bituminous Green River shales and limestones both above and below them. Here the conditions for the formation of coal and asphalt rocks alternated.

Both the bituminous rocks and the coal beds are substantially conformable to the bedding, and both are somewhat lenticular.

A few years ago, Mr. C. A. Ashburner proposed as a basis of classification of coals the ratio of fixed carbon to volatile carbonaceous matter. As I understand it the term "fixed carbon" does not assume that all the carbon thus designated exists in the coal as carbon uncombined with hydrogen, etc., but refers to the residue after destructive distillation. It remains to be determined how far this test will apply to the asphalt. In western Colorado and Utah we find in the carbonaceous minerals all proportions of fixed carbon from one or two per cent in the maltha up to eighty-seven or more in the anthracite. The soft asphalts grade by insensible degrees into the hard asphalts (at least in their physical characteristics) and these in turn into jet, the cannel coals and bituminous shales, and these again into the caking coals, etc. Dana's Text-book of Mineralogy approves the theory that coals are chiefly composed of oxygenated hydro-carbons. In the Rocky Mountain region not only must a scientific classification of the coals take account of the oxygen contained in the different coals, but the industrial classification must do the same also. Many coals of this region when once inflamed will continue to burn for a long time even when protected from the air. This accounts for the long distances the lignites often burn under ground. On East Salt Creek, Col., the burning coal produced a layer of slag of unequal thickness up to twelve feet and the country shows the action of hot waters much like a volcanic region. Several places are known where the coal adjacent to the once burning coal has been changed to a natural coke, and as we go backward from the former fire the coke passes by degrees into the unaltered caking coal.

Origin of the Asphalt.—When the facts as to the Utah and Colorado bitumens are thoroughly collated and discussed, they will throw considerable light on the mooted questions as to the origin of petroleum, asphalt, gas, and other subterranean hydrocarbons. Most other areas were marine, while these deposits were made in the sediments of the extensive lakes which in Tertiary times extended from the Rocky Mountains several hundred miles westward. These rocks will therefore present conditions somewhat different from those of marine beds.

My partial exploration does not yet warrant discussion of all the questions at issue but certain points may here be mentioned.

From Professor Orton's report above cited I extract a few statements of theories.

Dr. T. Sterry Hunt counts limestones the principal source of petroleum and denies that it has been produced by distillation from bituminous shales, while Dr. J. S. Newberry finds in the shales the main source of oil and gas, and vigorously opposes the view that limestones are ever an important source of either. Professors J. P. Lesley, I. C. White and J. D. Whitney favor the theory of the origin of petroleum by the primary decomposition of organic matter, while Dr. Newberry and Professor S. F. Peckham favor theories of secondary distillation. Hunt regards petroleum as indigenous when in limestones, and adventitious in the other rocks, as sandstones and conglomerates.

Since petroleum and asphaltum appear to have so nearly the same origin, it is permissible to discuss them in the same connection, especially as Dr. Newberry has referred the origin of the Utah asphalt to the marine Cretaceous black shales (Fox Hills and Colorado groups).*

Regarding the above stated theories we remark:

1. Certain Tertiary limestones of Colorado and Utah now contain considerable solid bituminous matter and once contained a liquid substance which has oozed out of the rock into cavities where it became changed to hard asphalt. The asphalt occurs as a great number of rather small masses and its aggregate quantity is great. This sort of rock is well exposed in the remarkable cañons of Parachute Creek, Col.

2. Professor Whitney refers the Tertiary bituminous minerals of California to organic matter derived from marine infusorians (quoted from Orton). In the Tertiary lakes of the region under description we might expect there would be drift-wood, many diatoms and fresh-water algæ and possibly infusorians enough to contribute considerable organic matter to the limestones. Irrespective of this source of organic matter, there are great numbers of fossil molluscan shells in the limestones. Hence although the lime rocks are in part non-fossiliferous and in part may be composed of lime precipitated from solution, yet we seem here to find evidence of the presence of organic matter within them sufficient to account for the indigenous origin of petroloidal bitumens according to Hunt's theory.†

3. The black bituminous shales are also to be considered in this connection. Certain layers are quite rich in bitumens.

* Dr. Newberry as quoted by Salt Lake Journal of Commerce.

† This hypothesis is strengthened by the highly probable indigenous origin of the petroleum of the Trenton limestone in Ohio and Indiana, Orton, op. cit.

They are distributed through several hundred feet of shales (or marls) and occasional limestones. Each stratum bears its own proportion of bitumen over large areas. The richer strata are not those nearest the limestones and they alternate with low grade strata. There are no veins or highly bituminized tracts leading from the limestones out into the shales, nor any other field evidence that after deposition the shales were bituminized from the limestones. Indeed these black shales are a very impenetrable rock. When veins of asphalt cross both limestones and shales the asphalt has in no place that I have discovered passed out into the shales and super-charged them.

Certain of the shale strata contain great numbers of imprints of deciduous leaves, water plants and insects, larvæ, etc. The carbonaceous matter of the leaves is not in the form of asphalt, but of charcoal or free-burning coal and contains quite a large proportion of fixed carbon. It is thus proved that certain strata contained a large amount of organic matter. As above noted there are occasional thin coal beds in the midst of the bituminous shales, but they do not contain more than the average quantity of bitumen found in the coals of the period. Evidently the conditions for the production of coal are very different from those that produce oil and asphalt, but the surprising thing is that we do not find the two conditions passing into one another by transitionary steps.

Thus there is no proof that the shales were bituminized from the limestones and the coals have only their indigenous bitumen and volatile carbonaceous matter. So far as I have observed, the richer bituminous shales and asphaltic sand rocks are mostly non-fossiliferous and there is no direct evidence of the former presence within them of undecomposed organic matter, except a few shells in the sandstones, and some silicified and ferruginized wood.

4. If, according to the views of Dr. Newberry, the asphalt of the Utah Tertiary beds was derived from the Cretaceous black shales, then it must have passed upward either as a liquid or as a gas.

1. Did the asphalt originate in a liquid that passed from the black shales upward? It is admitted that the black shales contain more or less petroleum, though in general these shales afford only thin films of oil. This may, however, be due to the petroleum having drained off to lower levels during the upheavals incident to the elevation of the mountains. From the top of the Fox Hills rocks to the lowest of the Tertiary asphalt beds there intervene 3000 feet or more of Laramie and Wasatch rocks, mostly sandstone, with thick strata of shales, marls and limestones, also several coal beds, and a very impenetrable iron-cemented sandrock. If a liquid passed up through

these rocks it may have been either by a general diffusion through the inter-granular spaces, or it may have been along fractures or fissures.

Now the coal of this region is no more bituminous than the Laramie and Tertiary coals of other coal fields outside of the asphalt area. The Laramie sandstones of the asphalt area are just like those found outside that area. Nobody has yet reported even one deposit of bituminous rock of Laramie age. It is incredible there should have been any general diffusion of liquid bitumens through so great a thickness of various kinds of rocks, without some of the bituminous matter remaining in those rocks, even after they have drained for ages. Moreover, I do not see why such a supposed ascension of petroleoids should be confined to the area of the Tertiary lakes instead of being spread over all the extensive area covered by the black shales. At Florence, Colo., most of the oil is said to be contained in a stratum of sandstone situated in the midst of the black shales, and if the overlying shale and the Laramie rocks have been sufficient to keep down the oil without a general diffusion into the Laramie sandstones, how could happen such an enormous upward diffusion in the region of the Tertiary lakes?

On the other hand, it may be urged that the oils of the marine black shales passed up along great fissures. The Tertiary lakes in question lay along the southern base of the Uinta Mountains and eastern base of the Wasatch. It is the conclusion of Powell, King and others that the Uinta uplift began at the close of the Laramie period and continued through Tertiary time. Great fissure veins of Uintaite now cross the region south of the Uinta Mountains and the Yampa plateau. The fissures cut down through the Brown's Park, Bridger and Green River beds, and nobody knows how much deeper. The fact that they are situated within 30 miles of where a great mountain range was pushed up to say nothing of the Wasatch uplift to the west, makes it highly probable they go down to profound depths and intersect the marine Cretaceous shales. Did the asphalt or any portion of it come up through these fissures? The details of an hypothesis to this effect would be about as follows: The petroleum of the black shales passed up through the fissures and floated on the surface of the water of the lake. Here it gradually oxidized or at least thickened, acquired a black color and became tarry asphalt. The wind blew it upon the sandy shores where it penetrated the sand. Off shore the mud contained in the water became entangled in the asphalt and sunk, carrying its sticky burden with it.* And even if we assume the indigenous origin of the bitumens

* See description by Dr. Joseph Leidy of the action of the mud of the Schuylkill River, on gas tar. Orton, op. cit.

of the limestones or certain layers of the shales, we may also assume that a part of the bitumens originated as above described, or in some other way from the upward passage of oils through the fissures.

Such an hypothesis certainly accords with some of the facts. The rocks now dip from the Roan Cliffs northward to the DuChesne and White Rivers. The marginal portions of the rocks that were laid down in the Tertiary lake of this region have been removed by erosion. This is the region where a non-conformity would be exposed.* While, then, we do not know with certainty that the rocks at the southern margin of the Tertiary lake near the present course of the Green river dipped northward at the time this lake began to exist, yet it is a very natural supposition that they did so, and that it was owing to an uplift toward the south that the lake was formed. If reservoirs of oil existed in the black shales, a northward dip would tend to prevent their escape southward. And since the supposed fissures would let in the water from the lake as well as let out the oil, it is easy to account for the oil rising to the surface of the lake. The intermittent depositing of the asphalt could then be accounted as due to alternate opening and closing of the fissures, such as would be possible during the great Uinta uplift, or to other accidents of sedimentation.

Now the fissures that are at present exposed are of very late age, being made after the latest rocks were formed in this basin, and after the lake was drained by the Green River, and when the Uinta and Wasatch uplifts were far advanced. It is possible that they are the continuations upward of fissures made in earlier Tertiary time, or we may suppose there were earlier fissures that were at the last covered by the Brown's Park rocks. The present fissures are filled with hard asphalt that once was evidently liquid, and indeed the asphalt grows softer as we go down in the veins and in places is somewhat viscous, even quite near the surface. Where I have examined these veins there is no sign that this liquid has passed out into the wall rock and charged it. The only asphaltic rock exposed in the country bordering the fissures is of very low grade, and there is a very large amount of this impoverished rock in that region. There are no known fissure veins in the country where the asphaltic sand rock is rich. Thus there is no field evidence of the passage of asphalt outward from the fissures, but strong indications that the sand rocks were drained of their maltha to fill the fissures.†

* Such a non-conformity exists at the Grand Mesa east of Grand Junction, Colo., where the Tertiary beds overlie the Laramie.

† At two places in the Ashley valley there are very rich areas of sand asphalt at the foot of slopes of natural dip, as if the maltha had flowed down the slopes

If asphaltic tar as such rose in fissures and sub-aerially poured out over the ground or penetrated the pores of the adjoining sediments, we ought to find the richest areas nearest the fissures. But if oil or asphalt rose to the surface of the lake and then was driven far and wide by the winds and waves, the larger masses of asphalt might be far away from the fissures. The bedding and other structural phenomena would be the same whether this rose from the marine shales through fissures, or was derived from the primary decomposition of the organic matter buried in the sediments of the lake.

The fact that the asphalt was not formed till a considerable depth of Tertiary rocks was laid down, favors the hypothesis that it was derived from organic matter contained in the Tertiary beds. However I leave the matter open; though it must be admitted that thus far I have discovered no field evidence of the passage of oils or bitumens upward from the Cretaceous marine shales to form the asphalts of Tertiary time.

2 Was the asphalt derived from gas brought up to the surface? Professor Orton in the work cited well states the chemical objections to the theory of synthesis of more complex compounds from gas. However it is not my purpose to enter into a general argument, only to note the bearing of the facts discovered in Colorado. There are gas springs on the lower White River. In some places the gas is said to be accompanied by a trace of petroleum, but there is no proof that the one is derived from the other, and there is no deposit of asphaltum forming around the place. I find no field evidence that the asphalt under description originated in gas coming to the surface from below. The surface rocks at these gas springs are the very lowest of the Green River and uppermost of the Wasatch.*

5. Near the Utah line, on the head-waters of West Salt Creek, Col., is a field of sand asphalt which contains concretionary masses of the sand rock cemented with lime and iron, from the size of cherries up to four feet in diameter. The concretions are very compact and impenetrable and are free from asphalt, while the surrounding rock is thoroughly charged

(through the pores of the sand) before it became so hard as at present. In one place a large field of the asphaltic sand rock has been laid bare by erosion. The bed dips about 15°, and under the heat and force of gravity has flowed bodily like a glacier, so as to dip down the sides of ravines of erosion a short distance. Some have described this as over-flow asphalt The flow is not equal throughout the mass, but is more active along certain lines of fracture, so that the upper surface looks like an exposure of basaltic columns, while the prisms are marked one from the other by depressions one to four inches deep that are in some cases partly filled by true out-flow asphalt that has oozed out of the sand. As a body this is a mass of sand cemented by viscous asphalt and having a sort of plastic flow, the units of motion being the prisms except at the prismatic lines where the units are the sand grains.

* Prof. A. Lakes of Golden, Colo., like myself, found no oil at these gas springs.

with it. The concretions must have had their intergranular spaces filled with cement before the asphalt penetrated the pores of the sand around them.

A few miles farther west I found an asphaltic sand rock much cross-bedded. Alternate layers about half an inch thick contained more and less asphalt so that the rock was crossed by darker and lighter bands. The size of the grains of sand was so nearly uniform in the different layers that it did not seem probable some of the layers were originally more porous than others. A better interpretation is that the layers were charged from the surface during deposition of the rock, and the same causes that produced the intermittent deposition charged the layers unequally.

While here asphaltization was probably cotemporaneous with deposition, in the case of the concretionary rock abovementioned, asphaltization did not take place till after the cementing of the concretions. Geologically this may not have been long. At Thistle, Utah, a sand rock containing molluscan shells is charged with asphalt which has also filled the interiors of the shells. Here the time of asphaltizing is not certain.

In general the small amount of fine sediment and calcareous, ferruginous or siliceous cements occurring with the asphalt in the pores of the sand rock, favors the hypothesis that the rock was charged with asphalt contemporaneously with or soon after deposition, and before it had time to become cemented into a compact, solid rock. All the richer sand asphalt readily softens under heat, proving it has practically no cement but asphalt. Apparently it is the presence of the asphalt that has kept the other cements out. Moreover I do not see how asphaltization of sediments can in general be so nearly parallel with stratification unless the strata were asphaltized successively before new strata were overlaid.

6. Professor Peckham, as quoted by Orton, says: "It seems to me that the different varieties of petroleum are the products of fractional distillation, and one of the strongest proofs of this is found in the large content of paraffine in the Bradford oil under the enormous pressure to which it has been subjected."

Near the same horizon as the most of the sand asphalt are found some thin seams of paraffine, near the top of the Wasatch Mountains. This ozocerite or mineral wax is extractable with solvents and hot water, and therein is quite different from the paraffine that results from the destructive distillation of the bituminous shales of this region. For the fractional distillation necessary to leave the paraffines as residuum, Professor Peckham postulates considerable heat. In the Wasatch area I have failed to find evidence of local metamorphism or unusual heat. The ozocerite beds were deposited after the upheaval of the Rocky Mountains, and before the rising of the

Wasatch. The heat of these revolutions came respectively too early and too late, and I failed to find volcanoes very near. The fact that hard paraffines result from the fractional distillation of petroleum and from the destructive distillation of coals and asphalts would seem to make it probable the Wasatch paraffines resulted from such distillations. The absence of any other evidence of heat from the locality makes the presence of the paraffines more noticeable. The question arises, why should here be found the waxy paraffines, while all around so great quantities of asphalt were produced in rocks of nearly if not the same age? Evidently a great amount of work remains to be done before we can scientifically distinguish between the processes which severally resulted in the formation of coal, the oily and buttery paraffines, and the asphalts. While studying the subject a theory of a somewhat speculative nature has occurred to me. Paraffines have been found in the turpentine of pines.* Paraffines are among the most stable of the organic compounds. The hypothesis is suggested whether this waxy paraffine of the Wasatch region may not be due to that contained in the turpentine of conifers, and that this is a residuum of primary decomposition, all that remains of the original turpentine, the more unstable substances having disappeared. It is a fact that in the Rocky Mountain region the coal contains a large quantity of partially mineralized resin.†

Now if resin (dried and oxidized turpentine) has so long resisted decomposition and mineralization, it becomes by no means improbable that if a turpentine contained paraffine, that very refractory substance might remain after all the other ingredients had become decomposed and changed either to coal or to petroleoids, or indeed oxidized to carbonic acid. This question is evidently part of a larger question: how far were the hydro-carbons of the carbonaceous minerals formed within the living organisms from which these minerals were derived?‡

* Watt's Dictionary of Chemistry, III Supplement, art. paraffine. Also Roscoe and Schorlemmer, Chem., vol. iii, pt. 1, p. 140.

† According to Messrs. Remington and Gilson of Salt Lake City there is in Utah a bed of fossil resin several feet in thickness. It is still soluble in most solvents of resin, but will no longer unite with linseed oil to form a tough varnish. I have seen specimens of the mineral but have not made a field examination of the deposit and do not know its geological age.

‡ Mr. G. P. Wall, quoted by Orton, p. 500, gives a graphic picture of vegetable matter partially changed to asphalt. The description appears to refer to cellulose and woody fiber. What would become of the more soluble products of the plant, such as the oils, resins, paraffines and other non-oxygenated hydro-carbons? They appear to be able to withstand decomposition longer than the cellular tissues, and would certainly be dissolved in any petroleoid produced from those tissues. Would they simply enter into solution or into a chemical synthesis? These and other similar questions need to be solved before we can trace the relationships of the coals, petroleums, asphalts, fossil resins and acids, hard paraffines, etc.

Colorado Springs, March 3, 1891.

ART. XIV.—*Photographic Investigation of Solar Prominences and their Spectra;* by GEORGE E. HALE. With Plate VIII.

IT is now many years since any important advance has been made in our knowledge of the solar prominences. With the exception of spectrum photographs made at the Siam and Egyptian eclipses, and the momentary glimpses of mysterious "white prominences" during totality, almost nothing has been added to the collection of facts gathered nearly twenty years ago. After Professor Young's vigorous attack upon the chromosphere and prominence lines at Mount Sherman and elsewhere, other investigators seem to have been impressed with the belief that no further additions could be made to the long catalogue of lines drawn up by our most skillful solar observer, and the spectroscopic side of the matter was allowed to rest, though a continuous record has been kept of the forms of chromosphere and prominences. While it is probably true that the most persistent watching would be required to increase the number of known lines in the visual spectrum, it is rather singular that the importance of photography in a study of the ultra-violet has been entirely overlooked. While the positions of spots on the sun's disc are daily recorded by photography, the same cannot be said of the chromosphere and prominences, and even in investigations of the extremely complicated spot spectra, photography has been but little employed, experiments with it not having proved very successful.

It is unnecessary here to urge the importance of using photographic processes to assist the eye in nearly all classes of solar investigation. What has been said for photography in other fields of astronomical or physical research will apply with equal force in the present instance, and the results of many years speak forcibly for themselves. It is of course very desirable that the ultra-violet should be studied, and for this purpose visual observations are of no service. Again, prominence forms as photographed through different lines should be compared, and the sequel will show that photography affords the only means of investigating the white prominences.*

The history of attempts at solar prominence photography extends over twenty years, and it is remarkable that the earliest experiments were the only ones which gave any indications of possible success. In 1870 Professor C. A. Young made the first prominence photographs taken without an eclipse. Using the hydrogen γ line (G′), and a wide tangential slit, a magnified image of the prominence was formed upon an ordinary

* See also Technology Quarterly, vol. iii, No. 4.

collodion plate, and given an exposure of nearly four minutes.* Professor Young has very kindly shown me silver prints from the best original negatives; in these only the general outline of the prominence can be faintly seen. This is due partly to a small displacement of the image during the exposure, as the polar axis of the telescope was slightly out of adjustment. The nebulous character of G′ makes its use objectionable, but the serious difficulty with this line lies in the employment of a wide slit. The brilliancy of the background of atmospheric spectrum increases very rapidly when the slit is opened, while the prominence itself grows no brighter. Thus the contrast in a photograph is greatly decreased, and the general illumination of the field, due to diffused light from the grating, or fluorescence of the prisms or object glasses, conspires to hide all details of structure. For these reasons the method has never been employed in practice.

It is beyond the scope of the present paper to describe the various methods of prominence photography proposed by Braun in 1872, Lockyer and Seabroke in the same year, Lohse in 1874 and 1880, Zenger in 1879, and Janssen in 1881. Suffice it to say, that in no instance was any success attained sufficient to bring the method into practical use, and in 1889 it was impossible to see where any advance whatever had been made beyond the brief experiments of Professor Young with a simple open slit.

In undertaking an investigation of the subject in the summer of the year last named, the writer devised two methods of accomplishing the desired result with a narrow slit, for it was evident that with any line in the prominence spectrum as then known, the use of a wide slit could not have more than an extremely limited application. In the first method the rate of the driving clock of the equatorial is so changed that the sun's image drifts at right angles across the slit of a spectroscope of high dispersion. At the focus of the observing telescope (of equal focal length with the collimator) a photographic plate moves at the same speed, at right angles to the axis of the telescope, and in the direction of dispersion. A narrow slit just in front of the plate allows only the line in use to fall upon it, and thus prevents fogging. It will be easily seen that fresh portions of the plate will be uncovered as the prominence drifts across the slit, and the result will be a latent image upon the photographic plate.

The second method exactly reverses the operations of the first. The sun's image is held in a fixed position by the driving clock of the equatorial, while the plate at the focus of the observing telescope is also stationary. The slit of the spectroscope is caused to move steadily across the end of the collima-

* Journal Franklin Institute, Oct. 3, 1870.

tor, while a corresponding slit before the plate moves at such a rate that the line in use passes constantly through it.

Both of these methods, together with the experiments carried on with the first at the Harvard Observatory and more recently at the Kenwood Physical Observatory, have been already described,* and in the present paper I wish to consider especially the results obtained in Chicago within the last few weeks.

In my earliest attempts at photographing the prominence spectrum I was much surprised to find narrow, sharp, bright lines running up through the center of the dark shades of both H and K, apparently to the very top of every prominence. At Mount Sherman in 1872 Professor Young, whose eyes are exceptionally sensitive to the shorter wave-lengths, had been able to see similar reversals of H and K, but the difficulties of observation were so great that he considered it probable that the whole width of each dark shade at H and K was reversed, the eye being able to perceive only the maximum of intensity at the center. Once or twice he noticed a bright line estimated to be about one division of Ångström's scale below the central reversal of H, but with the utmost precautions the eye was incapable of any accurate determinations of position or appearance in this part of the spectrum. But with high dispersion and care in manipulation the photographic plate meets with no difficulties, and the lines are obtained with ease. Fig. 1 of Plate VIII shows the reversals photographed with a radial slit, while for the negative used in making fig. 2 the slit was parallel to a tangent at the limb, and about 30″ from it. All of the figures were made directly from the original negatives by a photographic process, and, with the exception of fig. 3, the scale is the same as that at the focus of the spectroscope, the fourth order spectrum of a 14,438 Rowland grating having been employed. Though an excellent one in every other respect the grating gives two orders of ghosts, and the line just below H seems to coincide with one of these; but careful measures of its positions, combined with its appearance as compared with the corresponding first order ghost of K, makes it more than likely that it is an independent line. A set of preliminary measures from two negatives renders it extremely probable that this line is due to hydrogen, as the wave-length agrees remarkably with that obtained by Ames for a hydrogen line at this point ($\lambda 3970{\cdot}25$)† but more measures from a number of negatives already in my possession will be needed to settle the question. There seems to be no corresponding line in the solar spectrum, but both the H and K reversals appear

* Technology Quarterly, vol. iii, No. 4, 1890. Astronomische Nachrichten, Nos. 3006 and 3037. Sidereal Messenger, June, 1891. Monthly Notices of the R. A. S., July, 1891.

† Phil. Mag., July, 1890.

to agree in position with narrow dark lines at the center of the dark shades. Above in the ultra-violet the photographs bring out three new lines, which there are good reasons to regard as the first three lines of the hydrogen stellar series, though their wave-lengths have not been determined as yet. The lowest of the three, which probably corresponds with the line called hydrogen α in Dr. Huggins's map, has occasionally been glimpsed in the prominence spectrum by Professor Young, and its identity can now be certainly determined for the first time.* But the photographs have also revealed a new and interesting fact. On all the plates made with the focus of the observing telescope accurately adjusted for this region, the first line above K is shown to be a fine, sharp double, the separation of the components amounting to a few tenths of a tenth-metre. A special study of this double will be made when a new photographic object-glass of six feet focus has been completed for the spectroscope. The fourth order spectrum of our concave grating of ten feet radius will also probably be brought into service for work on the solar spectrum in this region.

As already suggested, the two upper prominence lines are probably coincident with two lines in the hydrogen series. Only one of these appears in fig. 2, where it is very faint. A photographic search for the remaining lines of the series is now in progress at the Kenwood Physical Observatory.

The important variations in the relative intensities of prominence lines revealed in eclipse photographs have been partially confirmed by my photographs. So far only one prominence has appeared in which the ultra-violet hydrogen lines could be photographed, and this showed a corresponding increase of brilliancy in the visual spectrum. But the H and K reversals are invariably strong, and easily photographed. Preliminary measures show that both lines probably belong to calcium, but this is yet to be definitely determined, and the origin of the broad dark shades in the solar spectrum is decidedly uncertain. In spite of the constant presence of the H and K bright lines in prominences, it can hardly be supposed that the substance producing them can be ordinary hydrogen, for several reasons. In the first place there is no provision for K in Balmer's series, and H certainly does not fall in the position of the hydrogen line, as it is about 1·5 tenth-metre more refrangible. Again, H and K do not follow the hydrogen lines in their intensity

* Great confusion is likely to result from the indiscriminate use of the letter H for "hydrogen" or for Fraunhofer's H line, and also in applying the Greek letters to the hydrogen lines, for some call the c line α, and others apply the same letter to the first hydrogen line in the ultra-violet. It is desirable to adopt some common nomenclature, and probably the most natural is to begin with c, and call this line "hydrogen α," or else refer to each line by its wave-length.

variations, and in several cases I have photographed both H and K expanded and reversed over spots in which the C and F lines showed no signs of reversal. Some very recent photographs suggest the possibility that the substance producing the H and K bright lines occasionally ascends in prominences to a higher level than that reached by hydrogen itself (observed through C) in the same prominences, and the "white prominences" observed and photographed at several eclipses offer a most interesting case in point. At the Grenada eclipse of August 29, 1886, Prof. W. H. Pickering found in his photographs made during totality a spiral prominence 150,000 miles high, which had for the only lines in its spectrum H, K, and a faint trace of an ultra-violet line about half-way between K and L. There was also a brilliant continuous spectrum in the visible region, but as the usual hydrogen lines were absent, Prof. Tacchini was unable to see the prominence by the usual spectroscopic method, either before or after totality. In his report Prof. Pickering adds: "It is highly probable that a great number of prominences pass by entirely unnoticed, because we rely solely upon visual instead of photographic methods of observation."* At the present moment I have not the remaining literature of this subject within reach, and must trust to memory for a few more references to simular phenomena. In the report of the eclipse of Jan. 1, 1889, published by the Lick Observatory, Dr. Swift alludes to the peculiar white appearance of some of the prominences, and in comparing the prominences photographed at the same eclipse with those observed on the same day at Palermo, P. Tacchini notes the presence in the photographs of two prominences seen neither at Palermo or Rome, and concludes that they are white prominences, similar to the great white prominence shown in the Grenada photographs.† Capt. Abney's photographs of the prominence spectrum at the Egyptian eclipse, and a suspicion of Trouvelot's (given in the Comptes Rendus) that a certain floating prominence must have some invisible connection with the chromosphere, make evident the extreme desirability of some means of photographing both visible and invisible prominences in full sunshine. The various theories connecting sun-spots and prominences are based upon observations in the visual region, and the invisible prominences, which are shown by the Grenada photographs, to reach at times to great elevations, have been left entirely out of account. It will be seen shortly that this need no longer be the case, and we may hope soon to have a daily record of all classes of prominences, both visible and invisible.

* Annals of Harvard College Observatory, vol. xviii, No. V, p. 99.
† Atti della R. Accad., dei Lincei, 1889.

When the sharp and brilliant reversals of H and K were discovered at the beginning of my investigations in prominence photography at the Kenwood Physical Observatory, it at once became evident that a considerable advance had been made, for the substitution of either of these lines for the less refrangible hydrogen lines removed the serious difficulty of photographing the longer waves of the C region with short exposure. But apart from their position in the spectrum, the distinctive peculiarity of H and K specially fits them for prominence photography. The narrow bright lines, instead of being superposed on a brilliant continuous spectrum, as is the case with all of the other prominence lines, lie in the center of broad, dark bands, where the troublesome light of the atmosphere is missing. Thus both slits used in my apparatus for photographing the prominences could be much more widely opened, without the difficulty of fogging and loss of contrast experienced with the other lines. The result was that the first photograph made in this way proved a success. The prominence drifted slowly across a narrow tangential slit, and behind the second slit, at the focus of the observing telescope, a small cylinder with its axis parallel to the slit, carried a strip of sensitive film at a speed equal to that of the moving solar image. A smooth and uniform motion of the cylinder was produced by a small clepsydra. The photograph showed the form of the prominence very well, and with considerable contrast. It was then concluded, on account of the great width of the dark shades at H and K, that for prominences of not too great size (the image of the sun on the slit plate is two inches in diameter) it would only be necessary to use a wide slit, and give a short exposure. Fig. 3 shows the result of such an experiment. The wide slit was nearly tangent to the sun's limb, but did not quite touch it, in order to exclude the direct light. The exposure was about 2 seconds, and the dispersion that of the fourth order of a 14,438 grating. As an object-glass ($3\frac{1}{4}$ inches aperture and $42\frac{1}{2}$ inches focus) corrected for the visual region was used in the observing telescope of the spectroscope, the foci for H and K are slightly different. The photograph is about twice the size of the original, and was enlarged directly from it in the camera.

Although this method will serve to photograph the invisible prominences it is evident that there are two objections to it. In the first place it would be very troublesome to find invisible prominences, and to do so it would be necessary to take a large number of photographs with the slit tangent at various points on the limb. This could be remedied by using a curved or ring slit. Again, prominences surpassing a certain size could not be photographed, though for single narrow prominences reaching to a considerable elevation it would be desirable to make the direction of the slit coincide with the direction of the longest axis of the prominence, the direct light from the limb being excluded by a small strip of metal, sliding under the slit. To overcome all of these difficulties I have devised a new form of apparatus, which will much excel the rotating cylinder in ease of adjustment, and allow the use of ordinary glass plates, instead of the celluloid film, which decomposes if kept for any length of time. A new form of clepsydra, of much larger size and with an improved valve, will replace the smaller one before used. The equatorial is also to be supplied with a 12 inch photographic object glass, and a new tube parallel to the old one, so that by a suitable form of cell, either object glass may readily be used on either tube, as the spectroscope is too large and heavy to be easily moved. The instrument will also allow eye observations through the C line to be made at the same instant that a photograph is exposed through H and K, and this will be important in comparisons of the form and extent of prominences as observed through different lines.

Since the above article was put in type, it has been decided to add another illustration (figure 4), which shows a much larger prominence, and of such peculiar shade as to be particularly interesting. The following is the record made on the observatory journal: "Chicago, July 8, 1891, 23 hours 45 minutes, prominence through H and K. As at first seen prominence was low, changed rapidly. A great flame shot out of the center about 80,000 miles high and lasted about fifteen minutes when it resumed its first shape." As shown in the figure, a low portion of the prominence is seen near the limb of the sun. This was what was first observed. The high portion lasted only about fifteen minutes and then the prominence returned to its original form as shown on the low portion of the negative.

Brooklyn, July 6, 1891.

Art. XV.—*A Gold-bearing Hot Spring Deposit;* by Walter Harvey Weed.

A few months ago, a suite of specimens from the Mount Morgan gold mine, of Queensland, Australia, was received by the writer from Dr. R. L. Jack, the government geologist of Queensland, accompanied by the request that they might be examined and compared with the siliceous sinters from the hot spring region of the Yellowstone Park. These specimens possess unusual interest, since Dr. Jack's observations show that this remarkable mine, which paid a dividend of £1,200,000 sterling, in 1889, is the deposit of a hot spring, the ore being a siliceous sinter impregnated with auriferous hematite. The structure of this ore-body, as developed by the working of the mine, and a microscopical and chemical examination of the sinter, both confirm this hypothesis. It is therefore necessary to add this form of deposit to those already recognized in the classification of ore bodies.

As but little is generally known of the Mount Morgan mine a few notes condensed from Dr. Jack's report* are inserted:

This remarkable ore deposit forms the upper portion of the hill known as Mount Morgan, whose summit is about 500 feet above the surrounding lowland, and is some 1200 feet above sea level. The rocks in the immediate vicinity of the mine are bluish-gray quartzites forming part of a much disturbed series of beds of Carbonifero-Permian age. These beds are intersected by numerous dikes of igneous rocks, mainly rhyolite, and intrusive bodies of diorite and other eruptives. Reefs of gold-bearing quartz are common in this area of metamorphic rocks.

The workings of the mine show that the siliceous sinter forms a surface covering upon the slopes of the "mount." In such situations it has been found to be usually without gold, but the cup-shaped mass of sinter forming the central core and summit of the hill is impregnated with brown ironstone carrying as high as 169·86 oz. of gold to the ton.

The tunnels driven through the ore body at various levels show that the sinter though generally an unbroken mass is sometimes formed of large angular blocks, as if the deposit had been shattered. A dike of igneous rock now thoroughly decomposed and kaolinized, cuts the quartzites and extends upward through the sinter. There is no hydrothermal activity whatever, in the vicinity of the mine, at the present day, though hot springs occur in other parts of Queensland.

The sinter which Dr. Jack has sent as representative of that forming the main body of the ore deposit he describes as "a very light, frothy, spongy or cellular rock, so light from the entanglement of air in its pores as to float in water like pumice." In thin section this material is dark between crossed nicol prisms; its structure and general appearance is that of a hot spring deposit, though no sinters quite like it have as yet been found by the writer. It can be positively stated that this material is not a pumice, but is a hot spring deposit. The analysis No. 1 of the following table was made in the Laboratory of the U. S. Geological Survey by Mr. E. A. Schneider, shows this sinter to be a remarkably pure form of opal.

Analysis No. II, of a sinter from the Yellowstone Park, was made by J. E. Whitfield in the laboratory of the U. S. Geological

* Mount Morgan Gold Deposits. Second Report by Robert L. Jack, Government Geologist, Queensland, Australia, 1889.

Survey, and No. III. from Steamboat Springs, Nevada (Woodward).*

A specimen of the auriferous hematite from this mine possesses a stalactitic structure, and must have formed in a cavernous space in the sinter. Similar siliceous ironstones are formed about the hot springs of the Yellowstone, by the oxidation of the cooled overflow waters of the springs as they drip into cavities and holes in the sinter deposits.

Analysis of Siliceous Sinter.

	I.	II.	III.
Silica	94·02	93·88	92·67
Alumina	2·27	1·72	0·80
Ferrous oxide		0·14	
Lime	0·07	0·25	0·14
Magnesia	trace	0·07	0·05
Soda	----	0·28	0·18
Potash	----	0·23	0·75
Sulph. acid	----	0·20	----
Chlorine	----	----	----
Sodic chloride	----	0·18	----
Water (105°)	1·07	3·37	5·45
Ignition	2·29		
Total	99·72	100·33	100·04

Two peculiar specimens of the earthy portions of the ore-mass are thus described by Dr. Jack in a letter to the writer. "It occurs surrounded by siliceous sinter on the southern slope of the mountain 35 feet perpendicularly beneath the surface, and 39 feet from the mouth of the tunnel on No. 3 bench. The rock is full of tortuous anastomosing glazed pipes resembling worm borings," and has throughout a sort of volitic structure. In thin section the rock is seen to be composed largely of feldspathic material and opaline silica, showing occasional crystal grains. In the hand-specimen the rock appears to be formed of an aggregation of pellets averaging a millimeter in diameter. These pellets possess a compact outer envelope, about a more open cavernous center, and are formed entirely of white opaline silica. Grains of white decomposed rock, a leached eruptive, with occasional grains of quartz are also common. The network of channels, and concretionary pellets, which characterize this rock, is a not uncommon structure of the calcareous deposits of the Yellowstone Park, and is due to the ascent of gas bubbles, through the soft mass. Siliceous sinters have also been found, possessing a honeycombed structure of

* Reports of 40th Par. Survey, vol. ii, p. 826.

this nature, about the springs on the northern shores of the Yellowstone Lake.

It has long been known, that the Steamboat Springs of Nevada, are surrounded by deposits of sinter in the fissures of which ore deposition is now taking place, a small amount of gold being found in these contemporaneous mineral veins.* The Mount Morgan mine is, however, the only hot spring deposit known, that has been found to contain gold in commercially valuable quantities.

The most remarkable hot spring district of the world is undoubtedly that of the Yellowstone Park. The variety of these springs, and the extensive deposits which they have formed, naturally suggests the possible existence of metalliferous deposits. Yet a careful search for such deposits has been made for the past eight years, by the members of the geological survey party, under Mr. Arnold Hague, without bringing to light a single case of this sort. Extensive collections of the hot spring waters and of the hot spring deposits have been subjected to most careful analytical examinations in the laboratory of the Survey, without finding even a trace of the precious metals.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Chemistry of the Secondary Battery.*—The phenomena of charging and discharging a secondary cell are accompanied by chemical changes in the electrodes and in the electrolyte, attended with an evolution of gas. These phenomena have been investigated by Cantor for the purpose of ascertaining what these chemical changes are; the electrodes and the electrolyte both being analyzed before and after charging and the oxygen and hydrogen given off during the process measured. Some difficulty was found in ascertaining directly the changes in the electrodes ; so that they were indirectly determined by charging each plate of the cell separately, using as a second electrode, a plate whose chemical constitution remains unaffected. Under these conditions any change which takes place in the electrolyte must be due solely to the reaction taking place between it and the electrode, including the gas evolved. Since this gas can be determined and also the change which has taken place in the composition of the electrolyte, it is evident that from these data the change taking place in the electrode itself can be ascertained. The author's studies thus far have been confined to the negative plate, this plate consisting of a sheet of lead coated with a mixture

* Becker, Geology of the Quicksilver deposits, page 343.

of lead oxide and lead sulphate. This plate is made to form the cathode and a plate of platinum the anode in a solution of sulphuric acid. The following are the results obtained: The first action on the plates is to convert the lead oxide into sulphate. Then the hydrogen evolved in the electrolysis reduces this lead sulphate forming metallic lead and sulphuric acid. The metallic lead thus freshly reduced attacks the sulphuric acid, evolving hydrogen and forming lead sulphate again; these reciprocal processes continuing until a condition of equilibrium is reached and the cell is charged. This local action it is which has led Streintz and others erroneously to conclude that hydrogen is occluded in the lead plate.—*Monatsb.* ix, 433; *J. Chem. Soc.*, lx, 514, May, 1891. G. F. B.

2. *On the Dead Space in Chemical Reactions.*—A third paper has been published by LIEBREICH on the dead space in chemical reactions. The appearance of this dead space depends in the view of the author upon the less mobility of the molecules at the surfaces of liquids; a fact which he seems to have proved by a series of interesting experiments. From this it follows that the surfaces of liquids oppose resistance to the motion of solid bodies against them, when driven by a slight force, in the same way as a solid wall would do. Such phenomena may be produced when one liquid is allowed to rise through another of less density, in case the friction-coefficient of the liquids is sufficiently large. The author abundantly shows how by the application of different meniscus-shaped forms, the shape of the entering liquid currents suffers changes; while in a certain sense it adapts itself to them. In this way phenomena can be obtained quite analogous to those which are observed in the dead space in chemical reactions.—*Ber. Ak. Berl.*, 1890, 1239; *Ber. Berl. Chem. Ges.*, xxiv, (Ref.) 301, April, 1891. G. F. B.

3. *A new Reaction of Carbon monoxide.*—BERTHELOT has observed that a solution of silver nitrate, to which has been added just enough ammonia to redissolve the precipitate at first formed, becomes colored brown when a current of carbon monoxide is passed through it or when an aqueous solution of the gas is added to it, even in the cold. On heating it becomes darker and a precipitate is thrown down.—*C. R.*, cxii, 597; *Ber. Berl. Chem. Ges.*, xxiv, (Ref.) 348, May, 1891. G. F. B.

II. GEOLOGY.

1. *On the Relations of the Eastern Sandstone of Keweenaw Point to the Lower Silurian Limestone;* by M. E. WADSWORTH. (Communicated).—One of the assistants (Mr. W. L. Honnold) of the Michigan Geological Survey, has been engaged in the study of the relations of the limestone west of L'anse to the Eastern or supposed Potsdam Sandstone of the Copper-bearing range. This locality is described in Jackson's Report, 1849, pp. 399–452, Foster and Whitney's Report Part I, 1850, pp. 117–119, and in

Rominger's Report, 1873, I, part III, pp. 69–71; and the limestone considered from its fossils to be Trenton or some adjacent Lower Silurian strata. It was inferred by Jackson that the limestone underlies the sandstone but by the other observers that it overlies it although no direct contact was seen.

Excavations made by Mr. Honnold's party, and reported by him, have developed the contact of the two formations, and show that the two form a synclinal or oblong basin-shaped fold, with the limestone overlying, and in direct contact with the sandstone. The existence of this fold in the sandstone as well as in the limestone removes the difficulty previous observers have had in reconciling the obviously tilted limestone with the supposed horizontal sandstone, and proves that the Eastern sandstone exposed here is of Lower Silurian age and older than this limestone.

At the point of contact of the two formations, exposed by excavation, the sandstone and limestone appear to be comformable, and they are seen to constantly agree in dip and strike. The contact between the two formations is abrupt, without any beds of passage, although the upper layers of the sandstone contain considerable carbonate of lime and magnesia, and the lower layers of the limestone much silica.

These observations are considered to be confirmatory of the commonly received view of the Potsdam age of the Eastern Sandstone; while the contorted state of the sandstone, extending at least one and one-half miles west from the limestone locality, may have weight in deciding the relative age of the Eastern sandstone and the Copper-bearing rocks.

A careful study of the fossils will be made and additional field work done, when the results will be published in detail.

Michigan Mining School,
Houghton, Michigan, July 3d, 1891.

2. *Expedition to Mt. St. Elias in the summer of* 1890 *by Israel C. Russell.* 200 pp. 8vo, with 20 plates and several figures. —The third volume of the National Geographic Magazine contains an account of this expedition to Mt. St. Elias by Mr. Russell. It went out under the auspices of the National Geographic Society and the United States Geological Survey. Mr. Mark B. Kerr was the topographical assistant in the survey, and Mr. E. S. Hosmer of Washington, a volunteer general assistant. Although the summit of Mt. St. Elias was not reached, important additions were made by it to the knowledge of the glaciers of the region and highly interesting discoveries regarding its geology. The formations recognized are (1) sandstones and shales about Yakutat Bay, and westward to Icy Bay, which Mr. Russell names the *Yakutat system*; (2) shales, conglomerates, limestones, sandstones, etc., named the *Pinnacle system*, occurring in the cliffs of Pinnacle Pass, 5000 feet above the sea-level, and along the northern and western borders of the Samovar Hills on the borders of the Seward glacier; and (3) the metamorphic schists of the main

St. Elias range. The limestone of the second of these formations was found to be fossiliferous, and to afford a Pecten, *Mya arenaria*, *Mytilus edulis*, *Leda fossa*, *Macoma inconspicua*, *Cardium Islandicum*, *Litorina Atkana*—species that are now living, according to Dall, in the cold waters of the region. The age of the beds, is therefore, as stated, "Pliocene or early Pleistocene." The Yakutat beds are regarded as probably younger than those of the Pinnacle system.

The uplifts of the region producing the mountains, including St. Elias, are consequently referred to an epoch since "the close of the Tertiary." In the view of Mr. Russell "the southern face of Mt. St. Elias is a fault-scarp. The mountain itself is formed by the upturned edge of a faulted block in which the stratification is inclined northeastward. The mountain stands at the intersection of two lines of displacement, one trending in a northeasterly and the other in a northwesterly direction. The one trending northwestward extends beyond the junction with the northeasterly fault. The point of union is at the pass between Mt. St. Elias and Mt. Newton. The upturned block, bounded on the southwest by a great fault, projects beyond the northeasterly fault. It is this projecting end of a roof-like block that forms Mt. St. Elias."

This view of the mountain is before the future investigator. Another view, for like study, is the possibility that St. Elias existed in essentially its present form before the Quaternary, and had (along with the country about it) 5000 or more feet added to its elevation above the water-level at the time of the uplift of the Quaternary beds.

3. *Glacier scratches south of the "terminal Moraine" in Western Pennsylvania.*—Messrs. P. M. Foshay and R. R. Hice, in a paper in the 2d volume of the Bulletin of the Geological Society of America (p. 467), describe and figure glacial scratches observed by them on the western bluff of the rock gorge of the Beaver, near the mouth of the Connoquenessig, "two miles or more south" of the "terminal moraine" as located by Lewis and Wright. Some of the grooves are 5 feet wide and 18 inches deep. The authors remark that the grooves may be within "the fringe" of scattered erratics south of the line of the moraine, described by Lewis, but observe that they are as much glacier-made as those of Kelly Island in Lake Erie. For an article by Mr. Foshay on the pot-holes and pre-Glacial drainage of the same region, with a map, see vol. xl of this Journal, p. 397, 1890.

4. *Losses of Cape Cod by sea-encroachment.*—In the U. S. Coast and Geodetic Report for 1889, H. L. Marindin, Assistant, gives details with regard to the losses of Cape Cod. In the southern section, 6 miles long, the crest-line of the beach has receded in 19 years at the rate of 8 feet a year. In a middle section of 4 miles, the shore-line has receded 8 feet in 31 years. In the northern section of 14 miles (from the Nausett Three Lights to the Highland Light in Truro) the mean recession is 3·2 feet per year; and it indicates a removal in 40 years of 30,231,-

038 cubic yards, or 755,756 cubic yards per year, or 53,784 cubic yards per linear mile. The total loss from the three sections is stated at 32,233,030 cubic yards.

5. *Der Peloponnes Versuch einer Landeskunde auf geologischer Grundlage*, nach Ergebwissen eigener Reisen von Dr. ALFRED PHILIPPSON. 8vo. Berlin, 1891. (R. Friedländer and Son.) Part I of this work on the Geology of the Peloponnesus, extending to 272 pages, is accompanied by a large, colored geological map and many profile sections.

III. BOTANY.

1. *Botanic Gardens in the Equatorial Belt and in the South Seas* [*First Paper.*]—It it my purpose to give, in the following notes, some account of the more important Botanic Gardens visited by me during a recent journey. The tour carried me from Genoa, through the canal at Suez, to Ceylon, in which country Péradeniya and Hakgala were examined; thence to Adelaide in South Australia; Melbourne and Geelong in Victoria; Hobart in Tasmania; Dunedin, Christchurch, and Wellington, in New Zealand; Sydney in New South Wales; Brisbane in Queensland; Buitenzorg in Java; Singapore in the Straits Settlement; Saigon, Hong Kong, and Shanghai, in China; and Tokio in Japan. With the exception of Shanghai and Tokio the visits were made at favorable seasons: in northern China and in Japan the spring was not far advanced, but the early flowers were in perfection.

The journey was undertaken with a view of securing from the establishments in question for the University Museum at Cambridge, specimens illustrative of the useful products of the vegetable kingdom. In every instance, the writer met with a cordial reception and received innumerable courtesies, for which he desires to thank again the Directors, Curators, and Superintendents of the various botanical establishments. Every facility was afforded for careful inspection of the workings of the Gardens and Museums, and it should be added, of the educational institutions with which some of them were connected.

A satisfactory photographic outfit rendered it possible to supplement the collections of photographic views which were purchasable at most points; so that the series, now stored in the Museum at Cambridge, may be regarded as one of the largest yet brought together. It comprises views not only of groups of plants both in gardens and in their wild state, but of individual plants as well. Early next year these illustrations will be accessible to visiting naturalists.

The present sketch will follow essentially the route outlined in a preceding paragraph, beginning with the gardens in Ceylon.

Péradeniya and Hakgala. (*Ceylon*).—After the deserts of Egypt and Arabia, and of treeless Aden have been passed, the traveller comes by an abrupt transition upon tropical luxuriance of vegetation. There is to be sure, a distant glimpse of Socotra, but its shores are too far away to yield anything plainly discernible, and even Minicoy, an island lying between the Maldives and Laccadives, gives only a faint suggestion of plant life. Its low-lying land is fringed with scattered coconut palms, of which later one sees so many. Before reaching Ceylon the ship passes within sight of the southern point of India, but not near enough to show what its plants are like. In fact, therefore, the arrival in the harbor of Colombo brings a surprise. Coming down to the shore, and extending as far as the eye can reach on either side, are crooked coconut palms, here and there intermingled with trees having foliage of the deepest green. A botanist is struck at once by the superb capabilities of such a country for a tropical garden. These capabilities were not overlooked by the Dutch, who succeeded the Portuguese in possession. A Botanic Garden was founded by them at Slave Island in Colombo, but when the Dutch were driven out by the British it fell into neglect. There was, however, at this period, an excellent garden connected with the country place of the first English Governor, near Colombo, which at the begining of this century was under the charge of a naturalist, who gave it somewhat the character of a botanical garden.

In 1810, Sir Joseph Banks sketched the plan for a Botanical Garden in Slave Island, Colombo, and succeeded in transferring thither from Canton, Mr. Kerr, who became its chief. According to the work from which I have derived these facts, the Slave Island garden was found subject to floods, and consequently the establishment was moved to Kalutara. One finds here and there in Colombo traces of the old occupancy remaining in the names of some of the streets, "Kew" for instance. From Kalutara the garden was transferred in 1821 to its present site. Since that time the large garden has established four branches, in order to secure all the advantages which can come from having land at different altitudes and with different exposures.

The branch gardens are (1) *Badulla*, founded in 1886, in the eastern part of the island, with an elevation somewhat over 2,000 feet. "The climate here is somewhat drier than on the western side of the hill region, receiving but little rain with the south-west monsoon." (2) *Anurâdhapura*, dating from 1883, about a hundred miles north of the large garden, at the ancient capital of the island. Besides the interesting ruins at this point which are well worth seeing, there exists the oldest historical tree in the world, *Ficus religiosa*, (the sacred Bo), assigned to 288 B. C. This garden has a short rainy season, and a hot dry climate. (3) *Heneratgoda*, 33 feet above the sea, and thoroughly tropical, is on the railroad running from Colombo to Kandy. It was founded in 1876. Here certain plants which cannot be grown at Péradeniya are very successfully cultivated. (4) *Hakgala*, established in 1860, as a nursery for Cinchona cultivation, is near Nuwara-Eliya, (commonly pronounced "Newralia") the famous sanitarium. It is almost 6,000 feet above sea-level, in a place of surpassing beauty. Above the garden is a frowning double cliff 1,500 ft. high, and all around, the views are most attractive. The Gate affords one of the best of these. The landscape reaches over the Uva district towards the Haputale gap and the Madulsima hills. On entering the garden the bewilderment begins. On every hand one sees species in the most grotesque juxtaposition. Plants from Australia such as Casuarinas and Acacias are perfectly at home with East and West Indian, Japanese, and English plants. Of the latter there are many which seemed thrifty and well established.

Although the garden is used primarily for experimental purposes it has been laid out with regard to effectiveness of grouping and with remarkable success. A botanical visitor is, however, constantly trying to separate in his mind the different plants from the curious collocations which everywhere abound and demonstrate better than in any other place I have ever seen, the wide range of tolerance of climate. The superintendent, Mr. W. Nock, who has had large experience in the West Indies, has carried on some interesting experiments in acclimatizing plants from the western hemisphere, such as "cherimoyer" and the like. There are few plants in the garden more attractive from an economic point of view than the vegetables of doubtful promise, such as Arracacha, and those of assured culinary position "Choco" or "Chocho" (*Sechium edule*) for example. Some of the medicinal plants in hand were doing well in every way, while others have proved somewhat disappointing, for instance, jalap and ipecacuanha.

The ferns, especially the tree ferns, and the species of Eucalyptus form one of the marked successes at this garden. Mr. Nock stated that the most troublesome weed in the garden is a species, (perhaps more than a single species) of *Oxalis:* it is simply impossible to eradicate it.

(5) *Pérádeniya.*—The gardens are four miles from Kandy, and about eighty from Colombo. The railroad passes through lowlands and rice-fields, past native villages surrounded by plantains and coconuts, and through occasional jungles, until it reaches higher ground. The scenery changes rapidly, forests now and then appearing in the foreground, with occasional views of distant castellated mountains. As the mountains rise out of the terraced rice-fields and from the shrubs of the jungles, the eye catches on every hand glimpses of groups of bent coconut palms and straight arecas. It is difficult to realize that these palms mean, perhaps without exception, human habitations at their feet. Through these scenes of enchanting beauty, the railroad has made its way, demanding here and there very skillful engineering. The track is lined with *Lantana* which is slowly giving way before the encroachments of a still stronger invader, a Composite from Mexico. *Mimosa pudica* is also widely spread as a strong weed.

The drive from Kandy to the great garden is through a well shaded street lined with native houses. These are gathered at short intervals into villages.

My first visits to this garden were made, as were those in every other instance save one on the whole tour, without reporting to the Director. In this way a student can take things very leisurely, and look up matters of detail which it is not right or courteous to trouble the chiefs with : later, all special points of interest which have escaped notice are likely to be brought out by a walk with the Director. The establishment at Péradeniya consists (1) of 150 acres of garden proper and of arboretum, (2) of a museum and herbarium with library attached. The Director, Dr. Henry Trimen, widely known as an author and editor, controls not only these, but the branch gardens as well, making his headquarters at Péradeniya.

Once for all it may be said that botanists are made welcome in every way, finding every facility for carrying on systematic work. The climate is healthful, provided one takes ordinary and reasonable precautions against exposure to the direct rays of the sun in the hottest part of the day. If I remember rightly, the Director. even in his long walks through the garden and in his excursions seldom wears the conventional pith-helmet. American students need not fear that they will suffer greater discomfort from the hot weather at Kandy and Péradeniya than in summer in the United States and Canada. Access to Ceylon (and for that matter, Java) has now been made so easy by the newer swift steamers, that it seems advisable to mention these facts about the climate.

It is impossible to describe the wealth of material placed at the service of every visitor to the two great gardens of the equatorial belt, that under present review and the one at Buitenzorg, to be considered in a subsequent note. It is equally impossible to institute a comparison between the two.

In both of these vast establishments the student finds magnificent specimens of all or very nearly all the useful plants belonging to hot moist climates. Many years ago the writer had the privilege of seeing tropical plants at the Isthmus of Panama, but even the delightful impressions received on that occasion, which had perhaps become deepened with the lapse of time, were forgotten in the presence of the abounding luxuriance of these palms, bamboos, glossy-leaved evergreens, and tangled climbers.

At Péradeniya the most characteristic plants are so placed as to be seen to good advantage. This was frequently observed when in search of points of view for photographing individual specimens. Moreover, the system of labelling is about perfect. Dr. Trimen makes use of a large staff formed out of baked clay, shaped so as to give an inclined surface on which the name is plainly painted. These brick-red labels with their painted disk are not unattractive ; at any rate, they do not detract from the general effect of the broad lawns bordered by gigantic trees.

The most remarkable single tree in the garden is the Seychelle Palm or double coconut, now almost fifty years old. The giant and other bamboos, the grove of India-rubber trees near the main entrance, and the avenue of Oreodoxa, are only a few examples of the finer groups of single species. The most imposing group of different species is that of the palms not far from the gate. The classified arboretum is rich in fine specimens, the principal orders being represented on a generous scale.

The nurseries, kitchen-garden, rockery for succulents, ferneries, and clusters of economic plants are on a scale commensurate with the arboretum. As might be expected, the orchids are by no means so fine as the collections one sees in large private establishments in England and on the continent: it is not possible to command the conditions of growth for all the finer species with the same degree of certainty as in colder regions where a stove means something.

At the time of my visit, *Amherstia nobilis* and the great crape myrtle were in full flower, and a large Talipot palm in bloom was one of the most conspicuous objects. I was a little too early in Ceylon for some of the tropical fruits, and too late for a few others, but fortunately was able to remedy this lack farther on in Queensland and Java.

Among the finest of the photographic views of the gardens in Péradeniya are the following: (1) the main entrance, with the long lines of Assam rubber trees, and the cluster of different palms, (2) the avenue of royal palms, (3) the different bamboos at the ponds, (4) the distant view of the satin-wood bridge. The view from the Herbarium is also one of great beauty.

Visitors to the gardens are greatly assisted by the intelligent native servants detailed to act as guides. They have a fair knowledge of the whereabouts of almost all the important plants and seldom go wrong with regard to names. It should be stated also that the natives employed in widely different stations in the establishment prove, according to the Director and the Superintendent, generally efficient.

The Herbarium is rich in certain directions and can be consulted by students under proper restrictions. The Museum is as yet small.

It remains to be said that plants and seeds are for sale at the garden, at moderate prices. A Wardian case packed with forty assorted plants is shipped for 40 rupees, say about 16 to 20 dollars.

The influence for good which has been exerted in Ceylon by the garden and its branches is incalculable. The establishment has proved a center of scientific activity and of high economic value. G. L. G.

IV. Miscellaneous Scientific Intelligence.

1. *Die Denudation in der Wüste und ihre geologische Bedeutung. Untersuchungen über die Bildung der Sedimente in den Ägyptischen Wüsten;* Johannes Walther, A. O. Prof. Univ. Jena. pp. 224, large 8vo, with 8 plates and 99 cuts. Leipzig, 1891. (S. Hirzel.)—This memoir makes part of vol. xvi of the

Transactions of the Mathematico-Physical Section of the "Königl. Sächsischen Gessellschaft der Wissenschaften." It is a work of great interest, treating of the causes producing denudation in the Egyptian desert and its results, and is illustrated by many excellent and instructive figures. The chief causes of denudation mentioned are deflation, or the work of the winds directly in denudation by removing whatever is sufficiently loose or has been loosened by decomposition or otherwise, and the work in abrasion by transported sands; 2d, Insolation, or the effects of the sun or heat over the surface of rocks by changes of temperature and especially those of day and night; (3) Decomposition or alteration through any means; (4) The eroding and transporting action of waters, rains being not wholly absent. (5) Vegetation, as a means of modifying results. The results in the formation of deposits are also described. The work is of special value to American geologists.

2. *History of Volcanic Action in the area of the British Isles*, by A. GEIKIE. Anniversary Address before the Geological Society of London, Feb., 1891. Quart. J. G. Soc. xlvii.—More has thus been learned about volcanic action in Paleozoic time from the British Isles than from all the rest of the world. Dr. Geikie, in his Anniversary Address, commences a full review of the interesting subject. Although extending to one hundred pages, the review covers only the earlier part of the history, to the close of the Upper Silurian.

3. *Magnetic Declination in the United States for the Epoch of* 1890.—Mr. CHARLES A. SCHOTT has a paper of seventy-five pages on this subject, in the Report of the Superintendent of the Coast Survey, Prof. T. C. Mendenhall, for 1889, consisting chiefly of tables giving the results of observations reduced to the year 1890.

4. *Telescopic Work for Starlight Evenings*, by WILLIAM F. DENNING, F.R.A.S. 361 pp. 8vo. London, 1891 (Taylor & Francis).—There is a peculiar interest and fascination connected with the subject of Astronomy, which even the comparatively uneducated reader cannot but feel, and hence there exists here a field for popular presentation which is hardly equalled in any other branch of science. The present work is one of this class and is fresh in matter, attractive and popular in style and with its numerous illustrations cannot fail to bring pleasure and instruction to all who use it.

5. *Ostwald's Klassiker der Exacten Wissenschaften.* (Wm. Engelmann, Leipzig). Recent issues of this valuable series include:

No. 21, 23. Ueber die Wanderung der Ionen während der Electrolyse. Abhandlungen von W. Hittorf (1853–1859).

No. 22. Untersuchungen über das Radikal der Benzoesäure von Woehler und Liebig (1832).

No. 24. Unterredungen and Mathematische Demonstrationen über zwei neue Wissenszweige, die Mechanik und die Fallgesetze betreffend, von Galileo Galilei. Dritter und vierter Tag (1638).

APPENDIX.

ART. XVI.—*Restoration of Stegosaurus*; by O. C. MARSH. (With Plate IX.)

IN this Journal, in 1877, the writer described a remarkable extinct reptile from Colorado, under the name *Stegosaurus armatus*,* and later a much more perfect specimen of another species, *Stegosaurus ungulatus*, from essentially the same horizon, in the Jurassic of Wyoming.† The latter specimen was in fine preservation, and the more important parts of the skull and skeleton, and especially of the remarkable dermal armor, were secured. Subsequently, more than twenty other specimens of these and other species were obtained, so that nearly every part of the osseous structure thus became known, and only portions of the dermal armor were in doubt. A fortunate discovery cleared away most of the doubt in regard to one species, *Stegosaurus stenops*, as the type specimen had the skull, skeletón, and dermal armor together when entombed, and almost in the position they were when the animal died.

With this rich material at hand, an attempt has been made to give a restoration of one of the group, and the type specimen of *Stegosaurus ungulatus* has been selected as the basis. This has been supplemented by a few portions of the skeleton of *Stegosaurus duplex*, apparently a closely allied species from nearly the same locality, while some other parts, especially of the dermal armor, have been placed in accordance with their known position in *Stegosaurus stenops.*

The result is given in Plate IX, which is believed to represent faithfully the main features of this remarkable reptile, as far as the skeleton and principal parts of the dermal armor are concerned. This figure, one-thirtieth natural size, is reduced from a larger restoration, one-tenth natural size, made for

* This Journal, III, vol. xiv, p. 513, December, 1877.

† Ibid., vol. xviii, p. 504, December, 1879. See also, vol. xix, p. 253, March, 1880; vol. xxi, p. 167, February, 1881; and vol. xxxiv, p. 413, November, 1887.

a lithographic plate to accompany the monograph of the *Stegosauria*, prepared by the writer for the U. S. Geological Survey.

In this restoration, the animal is represented as walking, and the position is adapted to that motion. The head and neck, the massive fore limbs, and, in fact, the whole skeleton, indicate slow locomotion on all four feet. The longer hind limbs and the powerful tail show, however, that the animal could thus support itself, as on a tripod, and this position must have been easily assumed in consequence of the massive hind quarters.

In the restoration as here presented, the dermal armor is the most striking feature, but the skeleton is almost as remarkable, and its high specialization was evidently acquired gradually as the armor itself was developed. Without the latter, many points in the skeleton would be inexplicable, and there are still a number that need explanation.

The small, elongated head was covered in front by a horny beak. The teeth are confined to the maxillary and dentary bones, and are not visible in the figure here given. They are quite small, with compressed, fluted crowns, and indicate that the food of this animal was soft, succulent vegetation. The vertebræ are solid, and the articular faces of the centra are bi-concave or nearly flat. The ribs of the trunk are massive, and placed high above the centra, the tubercle alone being supported on the elevated diapophysis. The neural spines, especially those of the sacrum and anterior caudals, have their summits expanded to aid in supporting the massive dermal armor above them. The limb bones are solid, and this is true of every other part of the skeleton. The feet were short and massive, and the terminal phalanges of the functional toes were covered by strong hoofs. There were five well-developed digits in the fore foot, and only three in the hind foot, the first toe being rudimentary, and the fifth entirely wanting.

In life, the animal was protected by a powerful dermal armor, which served both for defense and offense. The throat was covered by a thick skin in which were imbedded a large number of rounded ossicles, as shown in the figure. The gular portion represented was found beneath the skull, so that its position in life may be regarded as definitely settled. The series of vertical plates which extended above the neck, along the back, and over two-thirds of the tail, is a most remarkable feature, which could not have been anticipated, and would hardly have been credited had not the plates themselves been found in position. The four pairs of massive spines characteristic of the present species, which were situated above the lower third of the tail, are apparently the only part of this peculiar armor used for offense. In addition to the portions of armor above mentioned, there was a pair of small plates just behind the skull, which served to protect this part of the neck. There were also, in the present species, four flat spines, which were probably in place below the tail, but as their position is somewhat in doubt, they are not represented in the present restoration.

All these plates and spines, massive and powerful as they now are, were in life protected by a thick, horny covering, which must have greatly increased their size and weight. This covering is clearly indicated by the vascular grooves and impressions which mark the surface of both plates and spines, except their bases, which were evidently implanted in the thick skin.

The peculiar group of extinct reptiles named by the writer the *Stegosauria*, of which a typical example is represented in the present restoration, are now so well known, that a more accurate estimate of their relations to other Dinosaurs can be formed than has hitherto been possible. They are evidently a highly specialized sub-order of the great group which has the typical *Ornithopoda* as its most characteristic members, and all doubtless had a common ancestry. Another highly specialized branch of the same great order is seen in the gigantic *Ceratopsia*, of the Cretaceous, which the writer has recently investigated and made known. The skeleton of the latter group presents many interesting points of resemblance to that of the *Stegosauria*, which can hardly be the result of adaptation alone, but the wide difference in the skull and in some other parts indicates that their affinities are remote. A comparison of the present restoration with that of *Triceratops*, recently published by the writer,* will make the contrast between the two forms clearly evident.

All the typical members of the *Stegosauria* are from the Jurassic formation, and the type specimen used in the present restoration was found in Wyoming, in the Atlantosaurus beds of the upper Jurassic. *Diracodon*, a genus nearly allied to *Stegosaurus*, occurs in the same horizon. *Omosaurus* of Owen, from the Jurassic of England, is the nearest European ally now known, but whether it possessed a crest of dermal plates like that of *Stegosaurus* is doubtful, although caudal spines were evidently present.

New Haven, Conn., July 15th, 1891.

* This Journal, vol. xli, p. 339, April, 1891.

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[THIRD SERIES.]

Art. XVII.—*On the Capture of Comets by Planets, especially their Capture by Jupiter;* by H. A. Newton.

1. Some years ago I obtained and published* a formula expressing in simple terms the total result of the action of a planet in increasing or diminishing the velocity of a comet or small body that passes near the planet. This formula is practically a modification of the integral of energy, the smaller terms in the perturbing function being omitted. A very brief and partial treatment of it was presented to the British Association for the Advancement of Science in 1879 at its Sheffield meeting.† Within the last two or three years several astronomers have made special study of the manner of Jupiter's action in changing the orbits of comets that pass very near him. M. Tisserand has given us an expression connecting the major axis, inclination and parameter of the orbit described before coming near to Jupiter with the corresponding elements of the orbit after leaving the neighborhood of the planet.‡ M. Schulhof has applied the formula of M. Tisserand as a criterion for determining the possible identity of various comets whose orbits pass near to Jupiter's orbit.§ Messrs. Seeliger, Callandreau and others have continued these investigations. The interest thus shown in the problem has led me to resume the study of the subject, and to work out the results of the formula obtained by me in 1878 more fully than they have been hitherto developed.

* This Journal, III, vol. xvi, p. 175, 1878.

† Report, 1879, p. 274.

‡ Sur la théorie de la capture des comètes périodiques, Bull. Astron., Tome vi, juin and juillet, 1889.

§ Notes sur quelques Comètes a courte période, Astron. Nachrichten, No. 2964.

2. One of the remarkable distinctions between the comets of long (or infinite) periods, and those of short periods, is that the orbits of the latter have almost without exception direct motions and small inclinations to the plane of the ecliptic, while the orbits of the former have all possible inclinations between 0° and 180°. At first sight this seems to imply that the two groups of comets are radically distinct in origin or nature one from the other. The most natural line of investigation therefore is the effect of perturbations in bringing or not bringing the comets to move with the planet after the perturbation.

3. The algebraic processes by which was obtained the formula for the change of energy which a small body experiences from passing near a planet were given in the article cited, and they need not be here reproduced. The following was the resulting equation, viz:

$$\Delta = -\frac{4mfa^2v_{\prime} \cos \varphi \sin \alpha}{pv_{0}}, \tag{1}$$

and it was obtained from the general differential equations of motion by making assumptions not greatly differing from those used in obtaining Laplace's well known theorem, that a sphere of suitable magnitude may be described about the planet as a center and that for a tolerable first approximation the comet may be regarded as moving when without this sphere in a conic section of which the sun is the focus, and as moving when within the sphere in a conic section (an hyperbola) of which the planet is the focus. In other words, only perturbations of the first order of magnitude are taken account of. A comet is treated throughout this paper as a small indivisible body whose mass may be neglected.

4. *Notation.* The symbols used in (1) and also other symbols which I shall have occasion to use may be thus defined.

Let $\mathfrak{C}_{\prime}$ be the orbit of the comet about the sun before the comet comes under the appreciable action of the planet;
- $\mathfrak{C}$ the orbit of the comet about the sun after perturbation by the planet;
- C the hyperbolic orbit of the comet relative to Jupiter when near the planet;
- $\mathfrak{J}$ the elliptic orbit of Jupiter about the sun;
- A the point on $\mathfrak{C}_{\prime}$ which is nearest to $\mathfrak{J}$;
- E the point on $\mathfrak{J}$ which is nearest to $\mathfrak{C}_{\prime}$;
- d the length of the straight line EA being the perpendicular distance between the orbits at their nearest approach;
- ω the angle between the tangent of $\mathfrak{C}_{\prime}$ at A and the tangent to $\mathfrak{J}$ at E;

Let h be the distance which the planet has yet to pass over to reach E when the comet is at A (h may be negative);
m the mass of the planet, sun's mass$=$unity;
a the unit of distance, in general the mean distance of the earth from the sun;
f the sun's attractive force at the unit of distance;
$v_{,}$ the planet's velocity in its orbit at E;
$v_{\circ}$ the comet's velocity in its orbit C when the comet enters the sphere of Jupiter's perceptible influence;
v the comet's velocity at A relative to the sun;
s $=v_{\circ}/v_{,}$;
$@_{,}$ the semi-axis major of $\mathfrak{C}_{,}$ (negative if $\mathfrak{C}_{,}$ is an hyperbola);
$@$ the semi-axis major of $\mathfrak{C}$ (negative if $\mathfrak{C}$ is an hyperbola);
p the perpendicular from the planet upon asymptote to C;
α the acute angle between the transverse axis of C and the asymptote to C.
φ the angle between the tangent to $\mathfrak{J}$ at O (drawn in the direction of the planet's motion) and the line from the planet to the vertices and center of C;
A the semi-transverse axis of C;
B the semi-conjugate axis of C (hence equal to p);
r the distance of the planet from the sun;
$r_{,}$ the distance of the comet from the sun;
$r_{\circ}$ the distance of the comet from the planet;
$\rho_{,}$ and ρ distances of the comet from the sun at selected epochs before and after perturbation;
$u_{,}$ and u the velocities of the comet at the selected epochs;
Δ the increase to which $v^2-\frac{2fa^2}{r_{,}}-\frac{2mfa^2}{r_{\circ}}$ receives by the planet's action during the whole period in which the comet is passing near to Jupiter.

5. If we assume two epochs, one before and one after the perturbation, at which the comet is equally distant from the planet, the term $2mfa^2/r_{\circ}$ is the same at both instants, and it disappears from the value of Δ. Therefore

$$\Delta = u^2 - \frac{2fa^2}{\rho} - u_{,}^{2} + \frac{2fa^2}{\rho_{,}}.$$

But by the well-known formulas from the law of gravitation,

$$u_{,}^{2} = 2fa^2\left(\frac{1}{\rho_{,}} - \frac{1}{2@_{,}}\right),$$

and

$$u^2 = 2fa^2\left(\frac{1}{\rho} - \frac{1}{2@}\right);$$

hence

$$\Delta = fa^2\left(\frac{1}{@_{,}} - \frac{1}{@}\right),$$

that is, from (1) $$\frac{1}{@_{,}} - \frac{1}{@} = -\frac{4m\cos\varphi\sin\alpha}{ps}.$$

This equation is valid whatever be $\mathfrak{A}_{,}$ the major axis of the orbit $\mathfrak{C}_{,,}$ and may be used to determine the major axis of either orbit from the elements of the other. My present purpose is, however, to study the action of Jupiter in changing orbits that are originally parabolas, and hence in general $\mathfrak{A}_{,}$ will be taken infinite. In that case

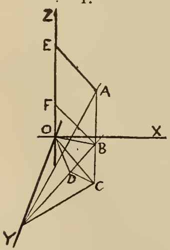
$$\mathfrak{A} = \frac{ps}{4m \cos \varphi \sin \alpha}. \qquad (2)$$

It will be found that the second number of (2) depends on ω, d and h, and these are known quantities when the elements of $\mathfrak{C}_{,}$ and $\mathfrak{J}$ are given. The use of the equation is moreover greatly simplified and enhanced by the fact that the plane of the planet's orbit is involved only in so far as that it must contain the tangent to $\mathfrak{J}$ at E.

6. In the second member of (2) all the factors are positive except cos φ, hence, if $\varphi<\frac{1}{2}\pi$, $\mathfrak{A}$ is positive and the orbit $\mathfrak{C}$ is an ellipse; but, if $\varphi>\frac{1}{2}\pi$, $\mathfrak{A}$ is negative and $\mathfrak{C}$ is an hyperbola. This result may be thus expressed; *if the comet passes in front of Jupiter the kinetic energy of the comet is diminished, if it passes behind the planet the kinetic energy of the comet is increased.* The reason for this may also be given in general language. If the comet passes in front of the planet the comet's attraction increases the velocity, and hence increases the kinetic energy of the planet and *vice versa.* But the total energy of the two bodies is constant; so that when that of the planet is increased, that of the comet is diminished and *vice versa.*

7. It is desirable now to transform the value of $\mathfrak{A}$ given in equation (2) so as to be able to determine the major axis of the new orbit of the comet directly from the circumstances of its initial approach to the planet before perturbation; in other words, to find $\mathfrak{A}$ in terms of ω, d and h. For this we must find in terms of ω, d and h, values for s, p, α and φ.

1.



8. *To find s.*—In fig. 1 let A and E represent the two points A and E as defined above (Art. 4), and the line AE represent d. Let AY be the tangent to $\mathfrak{C}_{,}$ at A, and EO the tangent to $\mathfrak{J}$ at E. It is an admissible supposition that the planet is describing the *straight* line OE, and that the comet in its unperturbed orbit is describing the *straight* line YA. At some certain moment the line joining the planet and the unperturbed comet must evidently be perpendicular to OE. Let OY be the line joining the bodies at that moment, so that the planet is at O when the comet is at Y, and EOY is a right angle. Instead, however, of supposing the

planet to move from O towards E we may apply an equal, opposite motion to the comet, and consider the planet to remain at rest at O. Draw AC parallel to EO and make AB equal to the distance described by the planet during the time that the comet is moving from Y to A. Join YB. Then since YA and BA represent in direction and magnitude the motions of the two bodies in a given interval, the third side YB of the triangle represents in magnitude and direction the motion of the comet relative to the planet. The angle YAB is the angle ω, and the three sides of the triangle YA, YB and BA are proportional to v, v_0 and $v_,$. Let the angle YBC be θ; then from the triangle YAB we have

$$v_0^2 = v_,^2 - 2v_, v \cos\omega + v^2,$$

and $$v : v_, : v_0 :: \sin\theta : \sin(\theta - \omega) : \sin\omega. \qquad (3)$$

Since v and $v_,$ can be computed from the given elements of the orbits of the planet and comet, we may readily compute from ω the value of s, or $v_0/v_,$. But if the planet is at its mean distance from the sun, and the comet's orbit is parabolic, $v^2 = 2v_,^2$, and we have

$$s^2 = 3 - 2\sqrt{2}\cos\omega. \qquad (4)$$

Also from the triangle

$$2v_,^2 = v_0^2 + 2v_0 v_, \cos\theta + v_,^2,$$

or $$2s\cos\theta = 1 - s^2. \qquad (5)$$

9. *To find p.*—The planet being regarded at rest at O and the *relative* unperturbed motion of the comet being along YB, this line may within admissible limits of error be treated as one asymptote of the relative orbit C. The perpendicular from O upon YB will then be by definition (Art. 4) the line p. Draw OX from O perpendicular to OY and OE, and let these three lines be coördinate axes. Let the line AB meet the plane XOY in C. Join OC, let fall OD perpendicular to YB, and join CD. Since EA is perpendicular to AY and also to EO, and so to its parallel line AC, therefore it is perpendicular to the plane YAC. Hence OC, parallel to EA is perpendicular to the plane, and so perpendicular to CD. Again CDY is a right angle; for $OD^2 + DY^2 = OY^2 = OC^2 + CY^2$, and $OD^2 = OC^2 + DC^2$. Hence $DC^2 + DY^2 = CY^2$, and consequently CDY is a right angle.

The quantity h is the line BC; for h is the distance which the planet, when the comet is at A, has yet to pass over before reaching E. But the comet was at Y when the planet was at O, and the planet describes BA, while the comet describes YA, leaving BC as the distance yet to be described or h. But the angle CBD is θ, so that we have

$$p^2 = OD^2 = OC^2 + CD^2 = d^2 + h^2\sin^2\theta. \qquad (6)$$

10. *To find α.*—The angle α is the acute angle between the asymptote and the transverse axis of the hyperbola, and hence from the nature of the hyperbola $\tan\alpha = B/A$. By known formulas we have, if the planet is at its mean distance

$$v_{\prime}^2 = 2fa^2\left(\frac{1}{r} - \frac{1}{2r}\right),$$

$$v_{\circ}^2 = 2mfa^2\left(\frac{1}{\infty} + \frac{1}{2A}\right).$$

$$\left.\begin{aligned} &\text{Therefore} \quad \frac{v_{\circ}^2}{v_{\prime}^2} = \frac{mr}{A}, \text{ or } A = \frac{mr}{s^2}. \\ &\text{Hence from (6)} \quad \tan\alpha = \frac{B}{A} = \frac{p}{A} = \frac{s^2(d^2 + h^2\sin^2\theta)}{mr}. \end{aligned}\right\} \quad (7)$$

11. *To find φ.*—The orbit of the comet relative to Jupiter lies in the plane YOB. Let i be the inclination of the plane YOB to YOX, measured positive from x positive to z positive; let l be the longitude of the direction YC, measured in the plane YOX from OY, that is, the angle made by YC with OY produced; let λ be the longitude of the direction YB measured in the plane YOB from OY, that is, the angle made by YB with OY produced. Imagine now a sphere described about Y as a center that shall cut the three planes XOY, BOY and BCY in three sides of a right angled spherical triangle. The hypotenuse of this triangle is λ, the base l, the perpendicular $\frac{1}{2}\pi - \theta$, and the angle opposite to the perpendicular is i; hence we have

$$\cos\lambda = \cos l \sin\theta, \quad (8)$$

$$\cos\theta = \sin i \sin\lambda, \quad (9)$$

$$\cot i = \sin l \tan\theta. \quad (10)$$

Also from the triangles OCY and BCY

$$\tan l = \tan \text{OYC} = -\frac{\text{OC}}{\text{YC}} = -\frac{d}{h\tan\theta}. \quad (11)$$

The angle φ is by definition the angle between the direction OE, and a line in the plane YOB that makes with YB an angle α. Hence we have readily

$$\cos\varphi = \sin i \sin(\lambda \pm \alpha). \quad (12)$$

These equations enable us to compute φ in terms of d, h and ω; for in succession θ may be computed by (3), l by (11), λ by (8), i by (10), and φ by (12).

12. These values of s, p, α and φ give by equation (2) the value of @. The suppositions that the planet is at its mean distance, and that $\mathfrak{C}_{\prime}$ is a parabola, are involved in that equation, but they are not necessary to the determination of @ when no such hypotheses are made, and changes in the equation

that are not serious would make it applicable without these limitations. The quantities in the several equations may be regarded as having values:—

d positive,
h positive or negative,
α positive and less than $\frac{1}{2}\pi$,
ω, θ, φ and i positive and less than π,
l and λ positive and less than 2π.

13. We may, however, also find directly the value of @ in terms of d, h, and the known functions of ω.

From (12)

$$\cos\varphi\sin\alpha = \sin i\sin\lambda\cos\alpha\sin\alpha \pm \sin i\cos\lambda\sin^2\alpha.$$

From (7)

$$\cos\alpha\sin\alpha = \frac{AB}{A^2+B^2}, \text{ and } \sin^2\alpha = \frac{B^2}{A^2+B^2}.$$

From (10) and (8)

$$\sin i\cos\lambda = \pm\frac{\cos l\sin\theta}{(1+\sin^2 l\tan^2\theta)^{\frac{1}{2}}} = \pm\frac{\cot l\sin\theta}{(\sec^2\theta+\cot^2 l)^{\frac{1}{2}}},$$

hence from (6) and (11)

$$\sin i\cos\lambda = \pm\frac{h\sin^2\theta}{(d^2+h^2\sin^2\theta)^{\frac{1}{2}}} = \pm\frac{h\sin^2\theta}{B}.$$

From these and (9)

$$\cos\varphi\sin\alpha\,(A^2+B^2) = AB\cos\theta \pm hB\sin^2\theta,$$

and hence from (2)

$$@ = \frac{s}{4m}\cdot\frac{A^2+B^2}{A\cos\theta\pm h\sin^2\theta} = \frac{s}{4m}\cdot\frac{A^2+d^2+h^2\sin^2\theta}{A\cos\theta\pm h\sin^2\theta}. \qquad (13)$$

Since m is the known mass of the planet, and θ, s and A are known functions of ω, equation (13) gives directly the value of @, the semi-axis major of the new orbit $\mathfrak{C}$ in terms of d, h and ω.

14. For a particular case of approach, equation (13) is convenient for computation. We may, however, now treat d, h and ω as independent variables whose varying values may express all the different possible cases of approach of the comet to the planet so far as change of periodic time of the comet is concerned. The dependence of @ upon the *three* variables cannot be very easily represented graphically in a single plane diagram. But by giving to ω successive values in multiples of 10°, viz: ω=10°, 20°, 30°, etc., to 170°, I have prepared a series of diagrams to exhibit in each case in succession the relation of @ to the other two variables. The values of θ, s and A for the several values of ω were needed in making the diagrams and they are given in Table I. Equations (4), (5)

and (7) are used in making the table. The disturbing planet is assumed to be Jupiter, so that m was taken equal to 1/1050 and $r=5{\cdot}2$.

TABLE I.

ω	θ	s	A	ω	θ	s	A
0°	0° 0′	0·414	·02886	100°	131° 48′	1·868	·00142
10	32 1	0·463	·02309	110	138 9	1·992	·00125
20	55 47	0·585	·01448	120	144 21	2·101	·00112
30	72 22	0·742	·00900	130	150 26	2·195	·00103
40	84 46	0·913	·00594	140	156 26	2·273	·00096
50	94 47	1·087	·00419	150	162 22	2·334	·00091
60	103 27	1·259	·00312	160	168 16	2·379	·00088
70	111 14	1·426	·00244	170	174 8	2·405	·00086
80	118 27	1·584	·00197	180	180 0	2·414	·00085
90	125 16	1·732	·00165				

15. Using these values of θ, s and A we may now represent graphically the dependence of @ upon the other two variables d and h for each specified value of ω. Let d and h be Cartesian coördinates, then for each point of the coördinate plane there is a value of @ The ambiguous sign will be fully satisfied by giving positive and negative values to h. For an assumed value of @ we shall have a curve whose equation is (13), and each point of this curve represents values of d and h for which the total action of the planet upon the comet will be to reduce the energy of the comet a constant amount. This locus will be called an *isergonal* curve.

16. *Faisceau of isergonal ellipses.*—The equation (13) of the isergonal curve may be written

$$4m@\ (\mathrm{A}\cos\theta+h\sin^2\theta)=s(\mathrm{A}^2+d^2+h^2\sin^2\theta),$$

and this is the equation of an ellipse. As @ changes its value we may treat it as a parameter and we have a faisceau of similar isergonal ellipses, each ellipse symmetrical with the axis of h. The radical axis of the faisceau $\mathrm{A}\cos\theta+h\sin^2\theta=0$, and the imaginary ellipse $\mathrm{A}^3+d^2+h^2\sin^2\theta=0$, are theoretically two members of the faisceau. For points on the radical axis @$=\propto$ and therefore for this locus there is no change in the energy of the comet.

17. *Center and area of the isergonal ellipse.*—The center of the isergonal ellipse is upon the axis of h; making $d=0$, and solving for h we have

$$h=\frac{2m@}{s}\pm\frac{2m@}{s\sin\theta}\left(1-\left(\cos\theta-\frac{\mathrm{A}s}{2m@}\right)^2\right)^{\frac{1}{2}}. \qquad (14)$$

The first term of the second member of (14) is the ordinate of the center, and the second term is the semi-axis major of the ellipse. The ratio of the axes being $1:\sin\theta$, and As^2 being $=mr$, the area of the ellipse will be equal to

$$\frac{4\pi m^2 @^2}{s^2 \sin\theta}\left(1-\left(\cos\theta-\frac{r}{2as}\right)^2\right).$$

18. *Maximum action of the planet.*—For two particular values of @ the isergonal ellipses become points. These values of @ result if the maximum effect of the planet in increasing and in decreasing the energy of the comet takes place, and they are obtained by making the two values of h equal to each other in (14), that is, by making $\cos\theta-\frac{As}{2m@}=\pm1$. Since at the same time $h=2m@/s$, we obtain

$$h=\frac{A}{\cos\theta\pm1},\quad \text{and}\quad @=\frac{As}{2m(\cos\theta\pm1)}. \qquad (15)$$

Let h' and h'', and $@'$ and $@''$ be the positive and negative values of h and @ in (15) and we may construct the following table of their values. As in Table I Jupiter is assumed to be the perturbing planet.

TABLE II.

ω	h'	h''	$@'$	$@''$	ω	h'	h''	$@'$	$@''$
0°	·01443	∝	3·14	— ∝	100°	·00426	—·00085	4·17	—0·83
10	·01250	—·15174	3·04	—36·90	110	·00489	—·00072	5·12	—0·75
20	·00927	—·03307	2·85	—10·15	120	·00598	—·00062	6·60	—0·68
30	·00690	—·01290	2·69	— 5·03	130	·00789	—·00055	9·09	—0·63
40	·00544	—·00654	2·61	— 3·13	140	·01149	—·00050	13·71	—0·60
50	·00457	—·00387	2·61	— 2·21	150	·01934	—·00047	23·70	—0·57
60	·00407	—·00253	2·69	— 1·68	160	·04192	—·00044	52·36	—0·55
70	·00382	—·00179	2·86	— 1·34	170	·16336	—·00043	206·30	—0·54
80	·00377	—·00134	3·14	— 1·11	180	∝	—·00043	∝	—0·54
90	·00390	—·00105	3·55	— 0·95					

19. *Explanation of Table II.*—The meaning of the numbers in this table may be explained by an example. If a comet moving in a parabola passes near to Jupiter, and the directions of the two original motions at nearest points of the orbits make an angle of 10°, then the greatest action of Jupiter (during the whole period of transit) in diminishing the velocity of the comet in its orbit about the sun will take place if the two orbits actually intersect ($d=0$), and if the comet in its unperturbed orbit arrives first at the point of intersection at the instant when Jupiter is distant therefrom ·01250 (the earth's mean distance from the sun being unity). The resulting semi-axis major of the comet's orbit about the sun will be 3·04.

On the other hand, the greatest effect in increasing the velocity of the comet will take place when the two orbits actually intersect, and the comet in its unperturbed orbit reaches the point of intersection later than the planet and when the planet is distant therefrom 0·15174. The semi-transverse axis of the resulting hyperbolic orbit about the sun will be 36·90.

20. *Resulting orbits of maximum perturbation.*—The position of the relative orbit about Jupiter in these cases of maximum perturbation for given values of ω is easily determined. From the equations (7), (6) and (15)

$$\tan a = \mathrm{B}/\mathrm{A} = h \sin\theta/\mathrm{A} = \sin\theta/(\cos\theta \pm 1).$$

The positive sign gives $2a=\theta$, and the negative sign gives $2a=\pi+\theta$. But the angle $2a$ in the first case is the angle of the asymptotes enclosing the branch of the hyperbola described about Jupiter by the comet. Since the two original orbits intersect, the plane of the relative orbit contains the planet's path, so that the comet passes directly in front of the planet and being turned backward leaves Jupiter exactly in the direction of Jupiter's quit.* The place of encounter with Jupiter will be near an apse of the comet's resulting orbit about the sun. The comet leaves the planet with the relative velocity v_0, so that if $s<1$ the motion about the sun in the new orbit will be direct; if $s>1$ the motion in the new orbit will be retrograde. That is, by (4) when $\omega < \frac{1}{4}\pi$ the resulting motion is direct; when $\omega > \frac{1}{4}\pi$ the resulting motion is retrograde.

In the second case the angle $2a$, being greater than 180°, stands for the angle between the asymptotes exterior to the orbit. Hence the comet passing behind the planet will be turned forward and will leave the planet in the direction of Jupiter's goal, and have a velocity that will send it permanently out of the solar system.

21. The results of Art. 20 assume that ω is given. To find for what value of ω the period of the resulting orbit is the shortest possible we may put $\mathrm{A}s^2=mr$ and $1-s^2=2s\cos\theta$ in (15) so that

$$@ = \frac{r}{1 - s^2 \pm 2s}.$$

To find the minimum for @ place $\frac{d@}{ds}=0$ in this equation. This gives $s=\pm 1$, in which result since s is inherently positive only the positive sign is used. But when $s=1$, $@=\frac{1}{2}r$, $h=mr$ and $\omega=\frac{1}{4}\pi$. *Hence the greatest effect of perturbation of a planet moving in a circular orbit in shortening the periodic time of a comet originally moving in a parabola is obtained if the comet's original orbit actually intersects the planet's orbit at an angle of* 45°, *and if the comet is due first at the*

* The *goal* and the *quit* of a moving body are those two points on the celestial sphere *towards* which and *from* which the body is moving.

point of intersection at the instant when the planet's distance therefrom is equal to the planet's distance from the sun multiplied by the ratio of the mass of the planet to the mass of the sun.

The relative velocity of the comet on leaving the planet's sphere of action would be equal to and directly opposite to the planet's velocity ($s=1$), and the comet would be left entirely at rest to fall to the sun. This case could not happen for planets like the earth where mr is less than the semi-diameter of the planet. In the case of the earth mr is less than 300 miles, and actual collision would result. But for Jupiter mr is greater than the distance of the second satellite from the planet. The nearest approach of the comet to the planet would be $mr\ (\sqrt{2}-1)$ which is more than four times the radius of Jupiter. Hence this case of maximum diminution of major axis could occur near Jupiter.

Fig. 2; $\omega=10°$.

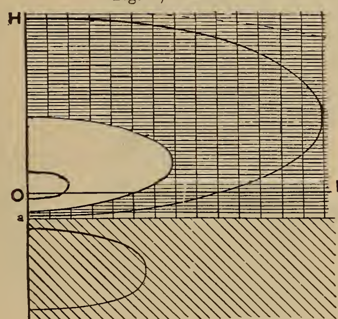
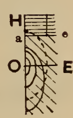


Fig. 3; $\omega=170°$.



22. *Isergonal ellipse for* $\omega=10°$.—If we make $\omega=10°$ the vanishing points of the isergonal ellipses will be (Table II) at $d=0$, $h=\cdot01250$, and $d=0$, $h=-\cdot15174$. In fig. 2 let OE and OH be the axes of d and h respectively. The vanishing points will be on the axis OH at distances h' and h'' above and below O. Upon this diagram are shown the halves of four isergonal ellipses. The scales used for d and h are not equal to each other, since the use of the same scale for both coördinates would make the figures of inconvenient shape. In this, and in all the figures 2–18, the unit in d is to the unit in h, as 1 to sin ω. But to indicate more clearly this scale, and at the same time to give a kind of shading to a part of the area, there are drawn above the radical axis ae lines parallel to OE, and parallel to OH, at intervals of $\cdot01$; that is, the sides of each of the small rectangles in the quadrant HOE are $\cdot01$, or about

925,000 miles. Only the positive values of d are represented in the figures. The positive vanishing point being 1·250 of these divisions above O, and the negative vanishing point 15,174 below O, we lay off $Oa=\frac{1}{2}(h'+h'')=-6{\cdot}962$ divisions, and draw ae for the radical axis. The smallest positive value of @ is (Table II) 3·04. As @ increases from 3·04 the ellipse increases in size, and the innermost curve represents what it becomes when @=5. The second curve (separating the blank and shaded areas) corresponds to @=20. Any parabolic comet passing Jupiter with an original angle of $\omega=10°$, and having d and h such as to be represented by a point within the blank area of fig. 2 will leave the vicinity of the planet in an elliptic orbit whose semi-axis major is less than 20, and whose period therefore is less than 90 years.

Fig. 4; $\omega=20°$.

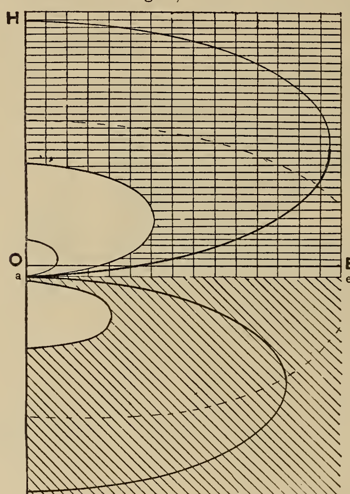
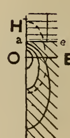


Fig. 5; $\omega=160°$.



The larger curve that lies above ae in the shaded area is the isergonal ellipse for @=50. As @ increases the lower part of the curve tends to approach the radical axis ae, with which it coincides when $@=\infty$. For points in the area below ae (distinguished by the oblique-line shading), the planet increases the velocity of the comets, and the comet would be thrown permanently out of the solar system. The smallest semi-transverse axis, the one corresponding to the vanishing ellipse is (Table II) 36·90, and the isergonal curve for @=−50 is drawn in the figure.

23. *Isergonal ellipses for* $\omega=170°$.—In figure 3 are drawn the three ellipses corresponding to the values of @, −5, −20, and −50. The ellipses above *ae* do not appear, inasmuch as the smallest possible elliptic orbit has a semi-axis major of 206·3 (Table II), and a period of about 3000 years. The radical axis *ae* is ·08146 (or over 8 divisions) above OE.

24. Figures 4 and 5 are like diagrams for $\omega=20°$ and $\omega=160°$. With altered numbers the explanations of arts. 22 and 23 apply with slight change to these figures. The line *ae* in figs. 4 and 5 is nearer to OE than is the same line in figs. 2 and 3. In

Fig. 6; $\omega=30°$.

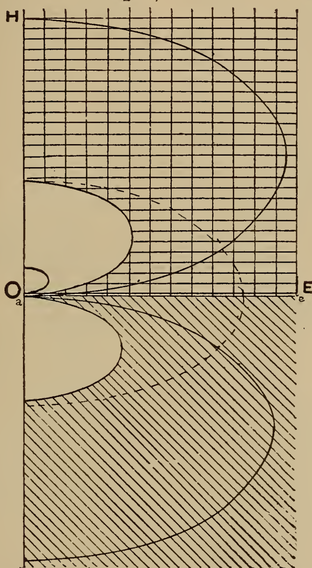


Fig. 7; $\omega=150$.

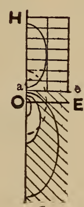


fig. 4 the line for @=−20 appears below *ae*, while above *ae* are the three curves for +5, +20, and +50, respectively. In fig. 5 the ellipse for @=50 is wanting since the minimum ellipse has a semi-axis major 52·36 (Table II), while below *ae* the three curves are present.

In figures 6 and 7 are contrasted in like manner the isergonal curves for the angles $\omega=30$, and $\omega=$the supplement of 30°. In fig. 6 the curve @=−5 is wanting, and in fig. 7 the two curves @=5, and @=20 are both wanting.

In like manner are to be explained the figs. 8–18. The numbers needed for drawing the figures are furnished by equation (13). The curves that in each figure separate the shaded area from the non-shaded area are the ellipses for @=20, and @=−20 The shading is introduced in order to compare more readily the corresponding curves in the figures.

25. The dotted curve in the several figures represents those values of d and h for which the total change of direction in the relative orbit is 10°; that is, $\alpha=85°$. It is that curve whose equation is A tan 85°=B, or $d^2+h^2 \sin^2 \theta = A^2 \tan^2 85°$. It is therefore an ellipse whose center is the origin of coördinates, and it is similar in each figure to the isergonal ellipses.

Fig. 8; ω=40°.

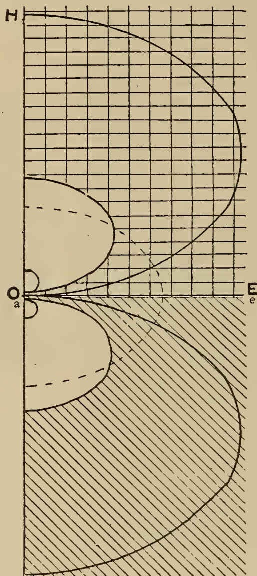
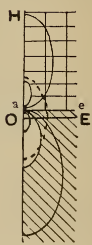


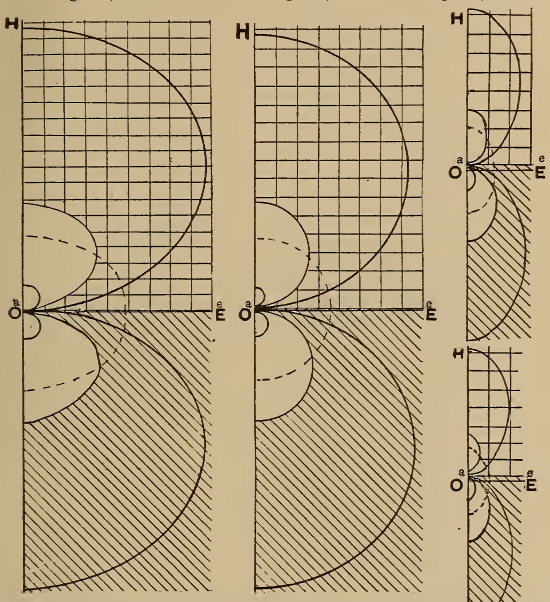
Fig. 9; ω=140.



26. *Hypotheses about the parabolic cometary orbits.*—It will be convenient to make two assumptions about the distribution of the parabolic comets, and the distribution of the goals of their motions. There seems to be no very well marked relation between the ecliptic, or to speak more strictly the invariable plane of the solar system, and the known parabolic cometary orbits. The following two assumptions do not seem likely therefore to introduce any very serious error into our reasonings.

If about the sun as a center a sphere $\mathfrak{S}$ be described with an arbitrary radius r, it will be *assumed* that near the surface of $\mathfrak{S}$, space is filled equably with comets. We may express this by supposing that in each cubic unit of space near $\mathfrak{S}$, there are at each and every instant n comets. As the orbits are all assumed to be parabolic, the n comets have a common velocity v.

Fig. 10; $\omega=50°$. Fig. 12; $\omega=60$. Fig. 13; $\omega=120°$. Fig. 11; $\omega=130$.



It will be furthermore *assumed* that the directions of the comets in each cubic unit of space near $\mathfrak{S}$ are at random, that is, that the quits and goals of the comet's motions relative to the sun are distributed equably over the surface of the celestial sphere.

27. *Number of comets entering* $\mathfrak{S}$.—If about a normal to $\mathfrak{S}$ as an axis there be described two cones cutting the celestial sphere in two small circles distant from the point where the normal meets the celestial sphere ψ and $\psi+d\psi$, then of the n comets there will be $\frac{1}{2}n \sin \psi d\psi$ comets whose quits are between the two circles. Each of these comets will move perpendicularly to the spherical surface $\mathfrak{S}$ with the velocity

$v \cos \psi$. Hence in a unit of times $\frac{1}{2} nv \cos \psi \sin \psi d\psi$ comets will cross a unit of the surface $\mathfrak{S}$ going towards the sun. The total entering the sphere in the unit of time will be this number multiplied by the number of units in the surface of $\mathfrak{S}$, or

$$4\pi r^2 \int_0^{\frac{\pi}{2}} \tfrac{1}{2} nv \cos \psi \sin \psi \, d\psi = \pi n v r^2.$$

Fig. 14; $\omega=70$.

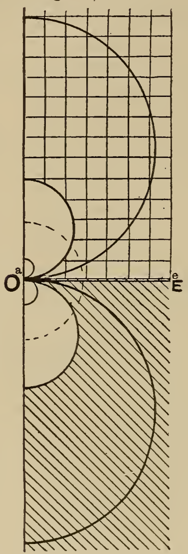
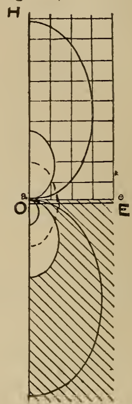


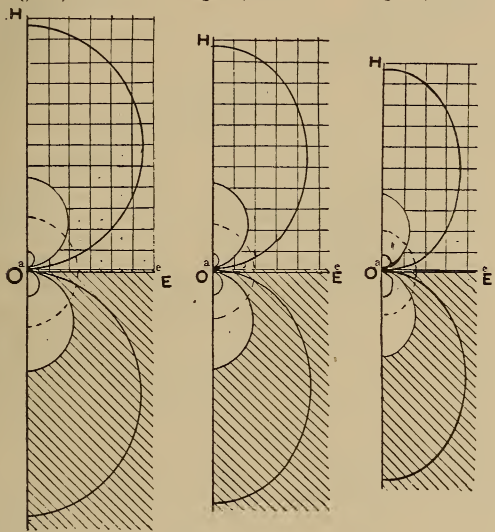
Fig. 15; $\omega=110$.



28. *Distribution of parabolic comets as to perihelion distance.*—This supposition of equable distribution of the goals of comets as they cross the spherical surface $\mathfrak{S}$ involves also a law of distribution of comets as to perihelion distance. The number of comets that enter the sphere in a given time whose motions make with the normal angles between ψ and $\psi + d\psi$ is proportional to $\sin \psi \cos \psi d\psi$. If N be the number of comets that enter $\mathfrak{S}$ in a given period of time with an angle with the normal less than ψ, we may write $d\mathrm{N} = k \sin \psi \cos \psi d\psi$, where k is some constant. But if q is the perihelion distance of a comet which at the distance r from the sun moves at an angle with the radius equal to ψ, then $q = r \sin^2 \psi$, and $dq = 2r \sin \psi \cos \psi d\psi$. But comets that enter $\mathfrak{S}$ with angles to the

normal between ψ and $\psi+d\psi$, have perihelion distances between q and $q+dq$. Hence N may also represent the number of comets that in the given period of time pass their perihelia, and whose perihelion distances are less than q. Therefore $\frac{dN}{dq}$ is a constant, and we conclude that if comets be grouped according to their perihelion distances the number of comets whose perihelion distances are less than q is proportional to q.

Fig. 16; $\omega=80°$. Fig. 17; $\omega=90°$. Fig. 18; $\omega=100$.



29. It follows as a corollary to art. 28 that if the two assumptions of art. 26 be made for the spherical surface 𝔖, the like distributions are true for every smaller concentric spherical surface. It would be but a reasonable extension of the assumptions to make them apply to larger spheres, if finite.

[To be continued.]

Art. XVIII.—*Pleistocene Fluvial Planes of Western Pennsylvania*; by Frank Leverett.

In the November number of this Journal there appeared a paper by Mr. P. Max Foshay, entitled "Preglacial Drainage and Recent Geological History of Western Pennsylvania," in which certain views are expressed which do not seem consistent with facts in my possession; and in which, although valuable suggestions are made regarding the possibilities of changes in drainage which the region may have undergone since the beginning of the glacial period, adequate data are not presented to sustain the broad and positive conclusions drawn. It therefore seems important that the subject be further considered and that attention be called to facts which render the problem more complex and its solution less certain than the paper leaves the readers to suppose.

A few general statements respecting the fluvial planes of the region (following essentially President Chamberlin*) will aid in showing the bearing of the facts I wish to present. In the district immediately southeast of the drift-covered portion of western Pennsylvania there are three well-developed fluvial planes distinct from the present flood-planes of the streams, representing as many distinct episodes in recent geological history. The lowest fluvial plane is the rock floor of the valleys, which in much of the region is at a lower level than the beds of the present streams. The middle fluvial plane is represented by the moraine-headed terraces which take their rise in the bulky outer moraine of the "Grand River lobe." These are at a somewhat higher level than the present flood-planes, for the altitude of the region now is such that the streams are deepening their channels. The highest fluvial plane is represented by elevated terraces 250 feet± above the present streams. This is much broader than the middle and lowest planes. Its remnant is a rocky shelf capped with distinctly fluvial material varying in depth up to 40 feet or more. Abandoned loops or "oxbows" occasionally occur, giving a complete cross-profile.

The time sequence of these planes is as follows: the high terraces are the oldest, the moraine-headed terraces are the youngest, while the rock floors of the buried channels are of intermediate age, for they represent the limit of an erosion and deepening that took place after the high terraces were formed and before the moraine-headed terraces were built up.

High-level terraces.—President Chamberlin has set forth in the bulletin referred to the fact that the high terraces were

* Bulletin No. 58, U. S. Geological Survey, pp. 24–37.

fluvial planes as late as the early glacial period. His observations together with the earlier ones of Dr. H. M. Chance of the Pennsylvania Geological Survey, are to the effect that

Explanation of Map.—The shaded portions represent moraines. Their mapping is complete only between the Cuyahoga river and Lake Chautauqua. Striae are represented by arrows and indicate the general divergence from the axes of the lobes. The numbers indicate villages and cities as follows: (1) Lottsville, Penn.; (2) Titusville, Penn.; (3) Meadville, Penn.; (4) Erie, Penn.; (5) Ashtabula, O.; (6) Painesville, O.; (7) Akron, O; (8) Canton, O.; (9) Braceville, O.; (10) Leavittsburg, O.; (11) Niles, O.; (12) Youngstown, O.; (13) Lowellville, O.; (14) Edenburg, Penn.; (15) Newcastle, Pa.; (16) Greenville, Pa., (17) Raymilton, Penn.; (18) Oil City, Penn.; (19) Beaver, Penn.

fluvial material containing crystalline erratics of Canadian derivation occurs along the Allegheny river on this terrace. This determination is of great importance since it brings all the erosion of the lower 300 feet of the Allegheny valley within the earlier glacial and the interglacial epoch, and throws doubt upon the preglacial age of the buried channels, although they are plainly older than the moraine-headed terraces of this region.

The fact that the Allegheny and Monongahela river-beds had become coated to considerable depth with fluvial débris (40 ft.±) by the close of the earlier glacial period is evidence that the streams had reached a base level at a still earlier date, and makes it probable, though not demonstrative, that the excavation to the level of the upper rock plane of the several lines of drainage which subsequently united to form the Allegheny was preglacial. If not preglacial, it must have been accomplished during the earlier part of the first glacial epoch.

In Mr. Foshay's paper the high level terrace along the Beaver river is discussed as "an old base-level plane," and Professor I. C. White, in his report on Beaver County, Pennsylvania, calls it the "fourth terrace."*

It has been identified by these writers as far north as the mouth of the Connoquenessing where the terminal moraine of the later drift lies upon it. Mr. Foshay calls attention to the important fact that this terrace has a northward descent from the mouth of Beaver river to the terminal moraine, and President Chamberlin has shown that the high terrace of the lower Allegheny and the Monongahela descends with the present streams to their junction not far above the mouth of the Beaver river; all of which evidence favors the hypothesis that the lower factors of the Allegheny river and the Monongahela discharged toward the Lake Erie basin along the course of the Beaver river before the first glacial epoch. This decline of the high level terrace from the mouth of the Beaver north to the point where it is lost under the moraine seems in itself to be good evidence that the old river took this northward course instead of that now followed by the Ohio, and this determination by Mr. Foshay is a valuable addition to our knowledge. It is somewhat short of a conclusive demonstration of the northward course of the stream in the fact that the decline is only 25 feet, that the distance is only ten miles, that the observations are few, (apparently only two), that the two remnants may not belong to strictly identical planes, that the decline is not greater than the possible differential northward depression of the region, and that the non-continuance of the high-level plane down the present course of the Ohio has not been demonstrated. If it shall be shown that no such high terraces follow down the Ohio, the presumption in favor of the

* 2nd Geol. Survey of Penn. Q, pp. 11, 12.

Beaver river route will be strong. If high-level terraces occur, as they doubtless do, on the Ohio between the mouth of the Beaver and Wellsburg, West Virginia, the supposed old divide, and these terraces *decline toward the mouth of the Beaver*, i. e. *contrary to the present stream*, then the demonstration that the old course was to the north through the Beaver valley will be essentially complete.

It is to be hoped that Mr. Foshay, who is practically on the ground, will pursue to a demonstration the hypothesis he has already rendered so highly probable.

As to the course which this old river pursued north of the moraine on the Beaver (assuming that it took this course)—whether along the present route of the Mahoning or that of the Shenango—there seems to be no demonstrative evidence. None of Mr. Foshay's data bear definitely on this point. The Shenango valley all the way from its mouth, 7–8 miles north of where the high-terrace is lost under the moraine, to the Pymatuning swamp on the Erie divide where it connects with the valley of Ashtabula creek flowing into Lake Erie, is broader than that of the Mahoning from its mouth to the Erie divide near Warren, Ohio; its bluffs are less abrupt and its general aspect that of a valley older as well as larger than that of the Mahoning. Moreover the lower Mahoning valley becomes very narrow in the vicinity of Lowellville, Ohio, having abrupt bluffs with a breadth at base of but about one fourth mile, which is too narrow to make it probable that it is a continuation of the old river under consideration, whose breadth above is much greater and whose slopes are more worn and receding. The narrowing at this point fits well the hypothesis that here was the preglacial divide between a stream running northwest into the Grand river basin and one running southeast to join the old river under discussion at the present mouth of the Mahoning. Furthermore, the main preglacial valley of the Grand river basin seems to have entered, not from the southeast along the lower Mahoning but from the south along the upper Mahoning from the direction of Alliance, Ohio, there being a comparatively low belt several miles wide along the upper (north flowing) part of the Mahoning, with low bluffs and a gradual rise both to the east and the west of the river. The relative elevations of the present divides on the Mahoning and Shenango routes respectively, do not help us much in this question, since, in the first place, we cannot trace, or at least have not traced, the terraces which mark the old river bed,—the present surface divide and the present rock divide being matters of more recent formation—and, in the second place, an eastward differential uplift is known to have taken place. The uplift referred to is well shown by the highest of the beaches in the eastern part of the expanded Lake Erie. This beach is fully 80 feet higher immediately north of Chautauqua lake than it is at the Grand river basin. Since this amount of differential uplift has occurred during the short time since the lake occupied this beach, it becomes necessary to allow for even greater changes either of depression or of uplift in the much longer period that has elapsed since the high-level terraces along the streams of western Pennsylvania were formed.

On the whole, therefore, the balance of evidence favors the Shenango as against the Mahoning route, but the question is still an open one. The definite conclusions of Mr. Foshay supported by map and proposed name do not seem to be warranted by the present state of evidence, or even to represent the probabilities of the case.

Interglacial valleys (*Buried channels*).—As the high-level base-plane has been demonstrably connected with the earlier glacial epoch by Dr. Chance and President Chamberlin, the channels cut in it are obviously of later age; and it is important that the existing broad distinction between the interglacial and preglacial channels of this region be kept in mind; the preglacial channels have, so far as yet identified, a fluvial plane far above that of the present streams, while the interglacial channels have a rock floor in large part below the present streams.

The study of the profiles of the valley floors within this drift-covered region, when combined with an attempt to restore former systems of drainage, is calculated to impress one with the fragmentary nature of available evidence. It is true that portions of Big Sandy, Oil and French creeks and of the Allegheny and Conewango rivers are sufficiently well explored by the numerous oil-well borings to give a satisfactory knowledge of the slope of the valley floors, but outside of the oil district the valleys have been explored only so far as is necessary to obtain water or to prove that oil and gas are not to be found. Throughout much of northwestern Pennsylvania and northeastern Ohio the depth of drift in valleys is known only at intervals of several miles, and very seldom has a series of borings been made that test the entire breadth of a valley.

Mr. Foshay calls attention to the very low altitude of the rock floor near the junction of the Mahoning and Shenango rivers, where it is said to be 50–75 feet below the level of the floor of the Ohio near Pittsburg, and perhaps lower than at the mouth of the Beaver, and bases his "Spencer River" channel largely upon this deep portion of the valley, no borings having yet been made farther up-stream along either the

Mahoning or the Shenango that reveal a rock surface so low as that near the junction of these streams, as may be seen from the following table which represents the deepest borings of which I have knowledge.

Table showing principal borings along the Mahoning-Grand River route.

Location.	Distance.	Altitude.	Drift.	Rock floor.	Authority.
Lawrence Junct., Pa.	0 miles.	760 feet.	150 feet.	610 feet.	White.
Edenburg, Pa.	4·6 "	780 "	200 ? "	580 ? "	"
State Line, O. and Pa.	9 "	810 "	80 "	730 "	Newberry.
Lowellville, O.	10·3 "	826 "	? "	? "	
Haselton, near Youngstown	15·6 "	831 "	90 "	741 "	Foshay*
Niles, O.	26 "	854 "	190 "	674 "	" *
Near Southington, O.	40 "	870 "	222 + "	648 — "	Leverett.
Mesopotamia, O.	47 "	850 "	208 ? "	642 ? "	"
Near Rome	57·5 "	820 "	170 + "	650 — "	"

* Given in letter to the writer.

The thickness of drift at Edenburg is a disputed question, some citizens maintaining that the greatest amount penetrated was 140 feet where the level of the well-mouth was 12–20 feet above the river, while others hold the opinion that the drift extends about 200 feet below the river. The borings were made nearly thirty years ago, and no records are known to have been preserved, consequently much allowance should be made for inaccuracies. It may be necessary to add 75 feet to denote the true altitude of the rock floor at this point. However, as there is a possibility that the rock floor is as low as indicated I leave it as given by Prof. White and Mr. Foshay.

The borings at Niles, Ohio (No. 11, on map), are cited by Mr. Foshay as fixing the position of the old channel at that point, if northward differential uplift be taken into account. The amount of differential uplift required if the rock floor is but 580 feet A. T. at Edenburg, is $7\frac{5}{6}$ feet per mile, allowing the stream no fall between Edenburg (No. 14), and Niles; and $9\frac{5}{6}$ feet allowing the stream a fall of one foot per mile, Niles being 12 miles farther north than Edenburg and about 22 miles distant by the stream, while the valley floor there is 94 feet higher than at Edenburg. If we are allowed to assume an uplift of $9\frac{5}{6}$ feet per mile, or even of $7\frac{5}{6}$ feet, nearly every large stream tributary to the Ohio from the State of Ohio, as well as the lower Allegheny and the Monongahela, could be carried into the Lake Erie basin, and we could if we saw fit attach to the Lake Erie basin all the southern tributaries of the Ohio from West Virginia and eastern Kentucky.

In the above calculation a continuous deep channel from Edenburg to Niles is assumed but there is evidence against the validity of this assumption. At Lowellville, Ohio (No. 13), the Mahoning, as has been noted by Dr. Newberry,* has a rocky bed, an examination of the valley at this village for the purpose of finding, if possible, evidence of a deep channel leading through it convinced me that not only is there no evidence of its existence but on the contrary the rock is exposed at frequent intervals throughout the whole width of the valley, the village as well as the river bed being upon rock. The outcrops are so frequent that there appears to be no room for a gorge so much as 100 yards in width, much less for one sufficient to be the outlet of such a stream as must have been discharged by the Monongahela and lower Allegheny rivers. It therefore appears that the hypothesis of a discharge northward along the Mahoning route involves a hypothetical uplift of an improbable amount, wholly unsustained by evidence, and further, that the constriction of the valley at Lowellville makes the route an inherently improbable one.

I have also examined the Shenango valley for the purpose of discovering a northward outlet for the deep channel at Edenburg. The rock floor of this valley is struck at several points about 125 feet below the present stream and seems to slope with the present stream, southward, instead of toward the Erie basin. At Greenville several borings have been made which test quite well the valley throughout its entire width, and no channel of greater depth exists unless it be a narrow gorge inadequate for the passage of a large stream. The level of the lowest part of the valley floor through much of the business portion of the city is about 815 feet A. T. This is 155 feet above the valley floor at Newcastle and at least 160 feet and possibly 235 feet above the rock floor at Edenburg. A calculation of the amount of northward differential uplift that must be assumed and subtracted from the altitude of the valley floor at Greenville to bring it to the lower of the levels at Edenburg gives $8\frac{11}{28}$ feet per mile, and if enough uplift be assumed to give the ancient stream a northward descent of one foot per mile this amount will be increased to about 10 feet per mile,—a greater uplift than it is legitimate to assume.

Additional evidence against the northward discharge of the waters from the great drainage basin of the Monongahela and lower Allegheny some 13,000 square miles in area, may be found in the narrow gorge of the Beaver above Beaver Falls; but the character of the evidence from the Ohio valley itself appears to render unnecessary further consideration of the probabilities of northward drainage. This valley receives

* Geology of Ohio, vol. iii, p. 804.

glacial terraces from its northern tributaries above Wellsburg, West Virginia, and all these terraces continue down the Ohio and have a fall as great as the present stream, showing that an open valley existed previous to the later glacial period and that its stream has since this glacial period been reëxcavating a channel partially filled by glacial gravels. Furthermore, gas well borings at Wellsburg, West Virginia, where Mr. Foshay has placed the old watershed, show the rock floor there to be but 590 feet A. T. or 10 feet lower than it is known to be at any point along the Ohio in Pennsylvania. A carefully prepared report of a well has been sent me by Millard E. Boyd, Esq., city engineer of Wellsburg, in which the character and thickness of drift are given and the altitude of the rock floor is referred to low water in the Ohio, from which it appears that the drift below the level of low water mark is gravel, showing vigorous drainage, and the rock floor is 40·58 feet below low water. Mr. Boyd states that within a radius of two miles about thirty wells have been made and that those on the same bottom with the one reported all show the rock floor to have about the same altitude (590 feet A. T.)

This evidence from the Ohio valley seems conclusive that the Monongahela and Allegheny rivers had their present course down the Ohio in the interglacial period and have held it continuously from that time to the present.

In view of the results arrived at by the study of this portion of the Upper Ohio district, we are naturally led to examine the nature of the evidence put forth by Mr. J. F. Carll some years ago,* as a demonstration that the buried channels of the upper Allegheny, Conewango, Oil, and French creeks have an outlet into the Lake Erie basin. In discussing this evidence the buried channels (interglacial fluvial planes) only are considered and no account is taken of the high terraces (preglacial fluvial planes) since these high planes have not been sufficiently investigated north of the glacial boundary to enable one to form an opinion concerning them.

The numerous oil well borings show that the valley floors of several northern tributaries of the Allegheny have higher altitudes near the mouths of these tributaries than they have a few miles upstream. For example, in the Conewango valley the rock floor is 129 feet lower at Fentonville, near the State line of New York and Pennsylvania, than it is at the mouth of the stream, 13 miles south, and the rock floor of Little Brokenstraw valley is 148 feet lower at Lottsville, Penn. (No. 1), than where its waters join the Allegheny 15 miles below. In other tributaries of the Allegheny the descent of the rock floor begins a few miles above the mouth; thus in Oil creek the

* Penn. 2d Geol. Survey III, 1880, pp. 330–366.

valley floor has its highest point near Titusville, Penn. (No. 2), and there is a descent of 66 feet in eight miles upstream. The valley floor of French creek rises for five or six miles upstream, but near Meadville (No. 3), 25 miles above its mouth, the rock floor is about 150 feet lower than at the mouth of the creek. The floor of Big Sandy creek rises from its mouth to the vicinity of Raymilton (No. 17), but descends above that village, being fully 40 feet lower at Sandy Lake than at Raymilton. Borings are sufficiently numerous to show a strong probability that these valley floors have no channels deep enough to drain them southward, but unfortunately they are not sufficient to demonstrate whether or not there is a continuous descent to the Lake Erie basin from any of the points noted. Mr. Carll has shown that there appears to be no obstacle to the northward continuation of the Conewango valley past Cassadaga lake into Lake Erie, though it is necessary to assume about 500 feet of drift filling at the watershed. Similarly, to give French creek a northern outlet by way of Conneaut lake and Conneaut creek a drift filling of over 300 feet at the watershed north of Conneaut lake must be assumed.

Inasmuch as the northward drainage of these buried channels remains an open question, a brief consideration of other hypotheses to account for the phenomena seems called for. A certain amount of northward descent may prove to be due to crust-deformation. The beaches about Lakes Erie and Ontario, and those of the Glacial Lake Agassiz, as is well known, indicate clearly a northward differential uplift accompanying the retreat of the ice, but they indicate nothing as to the depression that preceded this uplift. In the opinion of those who have given most attention to these beaches, the uplift was due mainly to the withdrawal of the load of ice. This hypothesis involves a previous depression occasioned by its accumulation and an imperfect restoration, owing to the removal of material from portions of the glaciated district and the presence of a load of drift and large bodies of water after the ice withdrew in parts of the glaciated district not thus encumbered in preglacial times. So far as we may reason from theoretical grounds, there should be expected a residuum of northward depression in the region under discussion, since a large amount of drift was deposited here. And this may prove to have been an important factor in giving these valley floors a northward slope, though it is hardly probable that it was the chief one.

A more important factor in the production of the peculiar valley phenomena of this region may prove to have been erosion effected beneath the ice either by the ice itself or by subglacial waters. Whether the ice greatly deepened valleys through which it flowed is an open question, but that subglacial waters exerted a peculiar eroding power in certain places near the ice margin is conclusively shown in various parts of the glaciated district by the presence of large channels made by them. Some of these are remote from present streams and have been little affected by post-glacial erosion. Their trend is in line with the striation and approximately at right angles with the moraine. They are often occupied by osars and hence are called "osar troughs." These troughs or channels sometimes rise toward the moraine at the rate of several feet per mile, and yet the material in the osars lying in them shows conclusively that the flow was in that direction. The water seems to have been forced upward toward the ice margin by the weight of the ice sheet and by hydrostatic pressure. These osar troughs were formed just before the ice made its final retreat, but the eroding power, of which they are the product, was probably in operation in earlier stages of the ice invasion. The outer moraine in the district under discussion is a complex one, the equivalent of several moraines farther west that indicate a succession of advances and retreats of the ice front. In the early stages the rock floors of these valleys may have been deepened in places by the subglacial streams in the same manner as the osar troughs were produced. By reference to the accompanying map it will be seen that every valley in which a very low rock floor has been reported has a trend approximately at right angles with the moraine and in line with the ice movement; that is, such a trend as to invite the flow of ice and of subglacial waters. Furthermore it appears that in every case the lowest known point of the rock channel in these several valleys is near the inner border of the moraine. In case it is found that no northward outlets exist the most plausible explanation for the low altitude at these points would seem to be a deepening of the channels here below their main outlets by subglacial waters assisted, perhaps, by the ice itself.

Summing up all the available evidence, it appears that no northward outlets have been found for the low channels just within the moraine on these several streams which are not embarrassed, either by a rise in the rock floor or an extraordinary amount of drift. In the streams under special consideration, the Shenango, Mahoning and Beaver, it appears that the rock floor rises in all directions from Edenburg, unless there be a descent down the Beaver. The obstacles to a northward discharge of these streams seem, on the whole, greater than those in the way of a southward discharge. In the Monongahela, lower Allegheny and the Ohio valleys, the available evidence all indicates southward discharge along the present course of the Ohio from the interglacial period to the present time.

Taking into consideration all the known facts, it certainly seems premature to urge, without distinct qualification, the acceptance of a hypothesis of northward drainage for any of these streams during the interglacial epoch, and much more so to impose a name for the unproven river.

Moraine-headed terraces.—President Chamberlin's description of the moraine-headed terraces and general remarks upon the history of the several fluvial planes embody so well the essential facts that further remarks are unnecessary. From his paper the following extracts are taken verbatim.*

"The third group of terraces are sharply distinguishable from those which have just been considered; first, in the fact that, instead of being rock platforms covered by fluvial material, they are made up bodily of coarse alluvium, mainly gravel. They have their chief development in the rivers entering the Ohio from the north, and when traced up they are found to head on one of the moraines of the later glacial epoch, or at least of a later glacial epoch following at a considerable interval an earlier one. The uppermost of these terraces has for its surface plane the ancient flood deposits of the glacier-fed streams. The lower terraces have been cut out of it by subsequent erosion. Near the moraine this upper glacial flood surface may be traced continuously, rising somewhat rapidly as the moraine is approached, and passing gradually into a series of undulations which merge into the gravelly knobs and basins, and thence into the unassorted hills of the moraine. This relationship was satisfactorily observed by Mr. Gilbert and myself, separately or jointly, on Conewango creek, near Russellburg; on the Little Brokenstraw, near Freehold; on the Big Brokenstraw, near Horn's Siding; and on Oil creek near Hydetown. On Sugar creek, French creek, and Sandy creek phenomena of similar significance appear, but they are less clear in their import. On Beaver river and Little Beaver creek analogous features are more satisfactorily displayed.

The streams of gravel starting in these morainic heads run down through the rock channels cut below the old river bottom as above described. The surfaces of these later glacial gravel streams are generally much below that of the earlier terrace deposits, but as they slope more rapidly there is no constant difference. An interval of from 100 to 200 feet may be taken as representative. The bottom of these later glacial gravels extends below the present river-beds, reaching depths varying from 40 feet to 250 feet or more, showing a considerable depth of channel before this late filling. These terraces reach their greatest height above the present stream, so far as observed, at the junction of the Beaver river with the Ohio. There the

* Bulletin No. 58, U. S. Geol. Sur., 1890, pp. 32–36.

terrace rises 127 feet above the Ohio, according to a lock-level measurement by Mr. Gilbert.

Similar moraine-headed terraces occur in Ohio on the Muskingum, Scioto, and Mad rivers and their tributaries, and seem to have their equivalent in terraces on the lower stretches of these rivers and on the Ohio. In other words, there is a general system of deep valley gravels, starting from the moraines indicated and sweeping down the valleys, growing progressively finer in material. Out of these glacial flood deposits a system of terraces has been cut by subsequent erosion. The still later glacial episodes seem to have introduced modifying elements, but these are unimportant in this connection.

The time and manner of origin of the moraine-headed terrace planes are placed beyond question by their morainic connections. They are clearly the products of the streams that issued from the glacier during the moraine-forming epoch. The carving of the terraces out of these planes was chiefly a subsequent work, of relatively minor importance in the present discussion. The coarseness of the gravels of this series indicates vigorous drainage, which in turn implies an open valley and at least a fair gradient below. It is equally evident that terraces of a much higher level and different gradient could not have been formed at the same time. Minor side-valley terraces might have been formed at flood stages, but only to the height of the maximum floods, and these must have had the same slope as the broad flood planes.

It is clear that the upper gravel-bearing terraces were not formed at the same stage as these moraine-appended ones, for they are not only of a different type, being alluvium-covered rock platforms, but they stand high above most of the morainic heads of the later deposits and show much greater antiquity in the erosion of their surfaces. For example, at Warren the old gravels have an altitude of 1415 feet above sea-level, with a terrace at 1395 feet, while the moraine-headed flood deposits of the later epoch at Russellburg, eight miles upstream, occur at about 1275 feet. On the Beaver river the moraine-headed gravel stream has an elevation of about 830 feet, while along the valley below pebbles referred to the earlier epoch range from 900 to 950 feet, and ten miles below there is a wide rock-based terrace at about 885 feet. But these higher gravels contain pebbles of granite and other crystalline rock, whose presence is only to be accounted for through glacial agencies, and the explanation of their origin must embrace that element."

"The higher glacial gravels antedated those of the moraine-forming epoch by the measure of the erosion of the channel through the old drift and the rock, whose mean depth here is about 300 feet, of which, perhaps, 250 may be said to be rock.

The excavation that intervened between the two epochs in other portions of the Allegheny, Monongahela, and Upper Ohio valleys is closely comparable with this.

In view of these facts it seems scarcely less than proven that it was the earlier invasion of ice that reversed the drainage and partially filled the valleys with debris, forming the capping of glacial gravel that rests upon the upper terrace."

"From the fact that the fluvial material in these abandoned channels and on the corresponding terraces in the Monongahela valley is wholly local, or southern, while among the analogous material of the Allegheny there mingle crystalline erratics of Canadian derivation, and from the evidence given above, we draw the inference that the partial filling was coincident with some stage of the earlier glaciation, presumably a late stage. This view gathers some support from the now well sustained belief that a general depression and slackening of drainage accompanied the earlier glaciation.

Following this episode of valley-filling and earlier glaciation there was a prolonged epoch of rapid erosion of the valley bottom, which was apparently coincident with an interglacial epoch, and was, perhaps the result of the resilience of the land after the glacial depression. During this epoch the rock gorges were cut down to the rock bottoms that now lie forty feet or more below the present river bottoms. Then came the later invasion that halted at the outer terminal moraine, whose overloaded floods, like those of the preceding glacial incursion, filled the valley bottoms with glacial alluvium; only, in this instance, in harmony with the more vigorous character of the later glaciation, the filling reached, at some points, 300 feet. Since that time there has been another stage of reëxcavation, giving origin to the lower gravel terraces.

This is doubtless far from being the whole history of events, and may be divergent from the truth in minor phases, but I believe with some confidence that it represents the general truth respecting the history of the abandoned channels and chief terrace deposits of the system of benches under consideration."

Madison, Wis., March 14, 1891.

ART. XIX.—*A method for the Determination of Antimony and its condition of Oxidation;* by F. A. GOOCH and H. W. GRUENER.

[Contributions from the Kent Chemical Laboratory of Yale College.—VIII.]

BUNSEN'S method of determining qualitatively the condition of oxidation of salts of antimony, by boiling these substances in solution with potassium iodide and hydrochloric acid and noting whether the liquid takes the color of free iodine, has been applied successfully to the quantitative determination of antimony in its highest condition of oxidation by Weller,* who distils the iodine from the solution, collects it in the distillate and, determining it volumetrically, calculates from the amount of it found the antimonic salt which sets it free according to the equation

$$SbCl_5 + 2H\text{-}I = SbCl^3 + 2HCl + I\text{-}I.$$

The advantage of treating the residue, rather than the distillate, in analytical processes in general which involve distillation is so obvious as to constrain us to seek conditions under which Bunsen's reaction may be applied in such manner that the antimony shall be held and estimated directly in the residue. The general plan of work was laid down in a similar process elaborated in this laboratory for the reduction of arsenic acid.† According to this process the arsenic to be reduced is taken in a solution of appropriate dilution, and treated with sulphuric acid in adjusted amount and an excess of potassium iodide. The liquid thus prepared is boiled to a definite degree of concentration, the iodine then remaining unexpelled, if any, is bleached by the very careful addition of dilute (centinormal) sulphurous acid, and the liquid is immediately diluted and neutralized. After cooling, the reduced arsenic is titrated by standard iodine in presence of starch.

We found in preliminary experimentation that the same general plan of treatment is available in the handling of antimonic compounds, but it is necessary to take precautions to prevent the deposition of the antimony from solution upon the addition of the sulphuric acid. Tartaric acid accomplishes this effect satisfactorily and does not, as the result proved, introduce undesirable complications. It transpired also that the dilution of the solution at which the crystalline iodide or oxyiodide separates out during the boiling is greater than is the case when similar amounts of arsenic are dealt with. It appeared, for example, that concentration to 45cm.^{3} was sufficient to cause crystallization and slight sublimation when the

* Ann. d. Chem. u. Pharm., ccxiii, 246.

† Gooch and Browning, this Journal, xl, p. 66.

amount of antimonious oxide present (with excess of potassium iodide and 10cm.^{3} of sulphuric acid, 1 : 1) was approximately 0·2 grm. Otherwise the process as employed in the reduction of arsenic appeared to be applicable to the similar treatment of antimony.

The following quantitative experiments were undertaken to discover the condition of concentration best suited to the reduction of antimonic salts under circumstances otherwise like those adapted to the reduction of arsenic, and to test the perfection of the process. Definite amounts of tartar emetic, purified by recrystallization, were used to make the antimonic salt to be afterward reduced, the antimony being raised to the highest degree of oxidation by titration with standard iodine after the addition of sodium tartrate (to prevent the precipitation of the antimony during the process of oxidation) and hydrogen sodium carbonate in the usual excess. In this process starch was sometimes employed to give the end reaction, and sometimes reliance was placed upon the appearance of the color of free iodine, experience having indicated that the use of the starch is not essential when the solutions are sufficiently small in volume, though as a matter of course, the correction demanded for the excess of iodine necessary to give color to the body of liquid is greater when starch is not used.

This treatment of the tartar emetic served the double purpose of providing a perfectly definite antimonic salt and restandardizing the solution of standard iodine, which was to be used subsequently in reoxidizing the antimony after its reduction, against the tartar emetic; and thus the imperfection of the process, whatever it may be, whether in the reduction or elsewhere, becomes apparent and is measured immediately by the difference between the amounts of iodine employed in the two oxidations. This mode of standardizing the iodine appears to be peculiarly advantageous in view of Fresenius's demonstration* that the iodometric estimation of antimony yields too high results, at least in the case of tartar emetic, when the standard iodine is standardized in the usual manner and, as is undoubtedly best, the characteristic starch-blue is taken for the end reaction rather than the premonitory and somewhat indefinite reddish tint.

The larger amounts of tartar emetic were weighed out dry; the smaller quantities were secured by measuring out definite portions of a solution of fixed strength. To every portion was added, in an Erlenmeyer beaker of 300 cm.^{3} capacity, one gram of tartaric acid previously treated with an excess of hydrogen sodium carbonate, and the oxidation was effected, as described, by iodine dissolved in potassium iodide to a solution

* Quant. Anal. 6te Aufl., 817.

approximately decinormal. Four grams of tartaric acid were added, and dilute sulphuric acid, if the solution still remained alkaline, to faint acidity. In addition 10 cm.^{3} of a mixture of sulphuric acid and water in equal parts were introduced, and the liquid was boilied after introducing a platinum spiral to prevent bumping, and a trap made of a two-bulb drying tube cut short and hung, large end downward, in the mouth of the flask, to prevent mechanical loss. At the chosen degree of concentration, determined by marks upon the flask, the boiling was stopped, the color bleached by the cautious addition of sulphurous acid (approximately centinormal), and the solution, nearly neutralized with sodium hydrate, made alkaline by hydrogen sodium carbonate added in an excess amounting to about 20 cm.^{3} of the saturated solution, was titrated with the standard (decinormal) iodine after the addition of a fresh portion of starch.

Table I, contains the account of experiments in which the larger amounts of antimony were employed.

TABLE I.

Final volume.	Tartar emetic taken.	Sb_2O_3 taken.	Iodine used in final oxidation.	Sb_2O_3 found.	Error.
cm.^{3}	grm.	grm.	grm.	grm.	grm.
100	0·5021	0·2178	0·3522	0·2004	0·0174—
80	0·5030	0·2181	0·3784	0·2153	0·0028—
60	0·5008	0·2172	0·3768	0·2144	0·0028—
60	0·5010	0·2173	0·3780	0·2151	0·0022—
60	0·5010	0·2173	0·3809	0·2168	0·0005—
55	0·5023	0·2178	0·3827	0·2178	0·0000
55	0·5015	0·2175	0·3806	0·2166	0·0009—
50	0·5007	0·2172	0·3814	0·2171	0·0001—
50	0·5039	0·2185	0·3839	0·2185	0·0000
45	0·5001	0·2169	0·3818	0·2173	0·0004+
45	0·5004	0·2170	0·3825	0·2176	0·0006+

The results of these experiments indicate unmistakably that complete reduction may be brought about under the conditions, but that concentration to a volume of from 45 cm.^{3} to 55 cm.^{3} during the boiling is not only advantageous but necessary. The mean error of the determination in which the final volume fell within these limits was zero between limits of 0·0009 grm. — or 0·0006 grm.+. In both determinations in which a final volume of 45 cm.^{3} was reached, and in one of the experiments in which the final volume was 50 cm.^{3}, the formation of the crystalline antimonious iodide or oxyiodide in the liquid was noted, and the deposition of a very slight sublimate of the same salt in the trap. It is evident, therefore, that it would be hazardous to attempt to push the concentration further.

In all these experiments hydriodic acid was present in amount equivalent to 1·1 grm. of potassium iodide—0·5 grm. introduced as iodine and 0·6 grm. introduced as such in the standard iodine where it plays the part of solvent.

In the experiments recorded in Table II, smaller amounts of antimony and correspondingly smaller quantities of the oxidizing solution were employed; otherwise, the same general mode of proceeding was followed. The limits of concentration fixed upon were, however, varied somewhat. The previous experiments showed plainly that anything like a complete reduction of the antimony could not be anticipated when the final volume was greater than 60 cm.^{3}, and the experience with the smaller amounts of antimony treated in the second series pointed to the fact, as the work progressed, that for them the crystallization and sublimation did not occur until the concentration had brought about a decrease in volume to 35 cm^3. The limits of final volume were placed therefore, for these experiments, at 60 cm.^{3} and 35 cm^3. Centinormal iodine was used for the oxidations and bleaching with sulphurous acid was found to be unnecessary, the amount of iodine liberated in these experiments being so small as to vanish in the concentration so completely that no color was visible (nor was it brought out by starch) after washing down the trap and cooling. There did remain a trace of color before the addition of the water but this seemed to us to be due in all probability to the incipient formation of the antimonious iodide or oxyiodide which is decomposed by the action of more water. At all events it disappeared on the addition of water and no reoxidation of the antimony was found subsequently.

Table II.

Final Volume.	Tartar Emetic taken.	Sb_2O_3 taken.	Iodine used in final oxidation.	Sb_2O_3 found.	Error.
cm^3.	grm.	grm.	grm.	grm.	grm.
60	0·0500	0·0217	0·0239	0·0136	0·0081 —
60	0·0500	0·0217	0·0258	0·0147	0·0070 —
60	0·0500	0·0217	0·0261	0·0148	0·0069 —
50	0·0500	0·0217	0·0316	0·0180	0·0037 —
⎧ 40	0·0500	0·0217	0·0385	0·0219	0·0002 +
⎪ 35	0·0500	0·0217	0·0380	0·0216	0·0001 —
⎨ 35	0·0500	0·0217	0·0381	0·0217	0·0000
⎪ 35	0·0500	0·0217	0·0382	0·0218	0·0001 +
⎩ 35	0·0500	0·0217	0·0382	0·0218	0·0001 +

These results show that for the smaller amounts of antimony the reduction was completed only by pushing the degree of concentration somewhat lower than was found to be necessary in treating the larger amounts. The only point in which these experiments differ essentially from those of the previous series is in the quantity of the iodine solution employed to effect this oxidation. So far as concerns the free iodine itself the conditions are similar in both series; for the iodine is converted in both cases to hydriodic acid exactly equivalent in amount to the antimony acted upon. The potassium iodide which is added in the iodine solution produces by action upon the sulphuric acid present an excess of hydriodic acid, which is, of course, dependent upon the absolute amount of the iodine solution employed. The hydriodic acid is the active agent in the reduction of the antimony, and to the greater mass-action in the former series of experiments might be attributed the more complete reduction for equal degrees of concentration. Accordingly the determinations of Table III were made to put this point to the test. In these experiments the conditions were identical with those of the determinations of Table II, excepting that in every case 1 grm. of potassium iodide was added to the liquid before boiling, thus bringing the total amount of hydriodic acid present to an equality with that present in the experiments of Table I, in which the larger amounts of antimony were treated. The results of these experiments bear out completely the hypothesis concerning the mass-action of the hydriodic acid—the smaller amounts of antimony being completely reduced in the presence of the large excess of hydriodic acid even at a final volume of 60 $cm.^3$ with a maximum error of 0·0002 grm.—

Table III.

Final Volume.	Tartar Emetic taken.	Sb_2O_3 taken.	Iodine used in final oxidation.	Sb_2O_3 found.	Error.
$cm.^3$	grm.	grm.	grm.	grm.	grm.
60	0·0500	0·0217	0·0378	0·0215	0·0002–
60	0·0500	0·0217	0·0379	0·0216	0·0001–
60	0·0500	0·0217	0·0379	0·0216	0·0001–

It is plain therefore that we have in the phenomena described the basis of a good method for the iodometric determination of the condition of oxidation of antimony; for, the amount of antimonious salt present in a mixture of antimonious and antimonic salts may be determined by direct titration in alkaline solution, and the total amount of antimony present is given similarly after the treatment by boiling, as described, with potassium iodide and sulphuric acid, the amount of antimonic salt being immediately calculable from the difference between the quantities of the standard iodine used as the oxidizer before and after reduction. The best method of proceeding appears to be that in which the concentration was restricted so that the point of sublimation and crystallization was not reached and in which the presence of an excess of potassium iodide was assured.

It seemed desirable, in this connection, to test the applicability of the method, as outlined, to the reduction and estimation of antimony and arsenic associated together, as so often happens in practice. The preceding experiments establish the fact that it is undesirable to attempt, in treating antimony, to force the concentration of the solution below 50 cm.^{3}, under the conditions laid down and when the amount of antimony present is equivalent to the maximum with which we have experimented, about 0·2 grm. of antimonious oxide. In the parallel process for the determination of arsenic concentration to 40 cm^3 was recommended in all cases (the maximum amount treated being equivalent to about 0·33 grm. of arsenious oxide), but it was not shown in the elaboration of that process that reduction would not take place at a concentration not quite so extreme. In the results recorded in Table V, which relate to experiments which duplicate the conditions found most favorable to the reduction of varying amounts of antimony,—the presence of the equivalent of 1·1 grm. of potassium iodide, and concentration to 50 cm^3—and differ from these only in the fact that arsenic was associated with antimony in every case, it appears that the reduction of arsenic may be effected simultaneously with that of the antimony.

Table IV.

Final Volume.	Tartar Emetic taken.	Sb_2O_3 taken.	As_2O_3 taken.	Iodine used in first oxidation.	Iodine used in final oxidation.	Difference between the amounts of iodine used in the two oxidations.	Error in terms of Sb_2O_3	Error in terms of As_2O_3.
cm.^{3}	grm.	grm.	grm.	cm.^{3}	cm.^{3}	cm.^{3}	grm.	grm.
50	0·1530	0·0870	0·0500	19·37	19·43	0·06 +	0·0004 +	0·0003 –
50	0·1503	0·0855	0·0495	19·05	19·02	0·03 –	0·0002 –	0·0001 –
50	0·1503	0·0855	0·0544	20·05	19·97	0·08 –	0·0006 –	0·0004 –
50	0·1503	0·0855	0·0495	19·05	19·00	0·05 –	0·0004 –	0·0003 +

It is plain that the error in these results, whether reckoned as falling upon the antimonious oxide or upon the arsenious oxide, is quite within the limits allowable in volumetric determinations by means of decinormal solutions. One point, however, in the determination of the combined amounts of antimony and arsenic by the method here proposed deserves special consideration. It has been shown in the work to which reference has been made that arsenic is reducible by the process outlined and determinable with accuracy by titration with iodine standardized against arsenious oxide. In this later work we show that antimony may be reduced similarly and estimated satisfactorily by titration against iodine standardized against tartar emetic. These two methods of standardizing do not yield identical results, and so we are confronted with an inherent error in the process for estimating antimony and arsenic at once, which cannot be overcome unless the individual amount of one or other constituent may be otherwise determined. If the determination of either the arsenic or antimony is possible it is, of course, easy to calculate with the use of the appropriate standard the amount of the solution of iodine which is really engaged in the oxidation of this particular constituent, and the remainder of the iodine actually employed, gauged by the second standard, will give the corrected amount of the second constituent.

In case no such correction is feasible it becomes a matter of interest to note the magnitude of possible error. Our experience, based upon many determinations throughout the course of the work detailed above, pointed to a difference in the value of the two standards amounting to about one-half of one per cent. If, therefore, the weight of reduced oxide amounts to the maximum which we have experimented with—about 0·2 grm.—the greatest possible error will be 0·0010 grm. + or 0·0010 grm. −, according as the entire 0·2 grm. is antimonious oxide estimated by the arsenic standard, or arsenious oxide estimated by the tartar emetic standard. The essential features of the process which we propose for the reduction of antimony and the determination of its degree of oxidation are recapitulated briefly in the following statement.

The salt of antimony, not exceeding the equivalent of about 0·2 grm. of antimonious oxide, is titrated, in presence of 1 grm. of sodium tartrate and the usual excess of sodium hydrogen carbonate, by means of iodine standardized against tartar emetic. The result of this titration gives the amount of antimonious salt present. To the solution are then added 4 grms. of tartaric, dilute sulphuric acid, if necessary, to neutralization, an excess of 10 cm.^{3} of half and half sulphuric acid, and enough potassium iodide so that there shall be present of hydriodic acid the equivalent of a little more than 1 grm. of the iodide. The liquid is diluted to 100 cm.^{3}, boiled in an Erlenmeyer beaker until the volume is decreased to 50 cm.^{3}, the precaution being taken to introduce a platinum spiral to prevent bumping and a trap, as described, to obviate mechanical loss. The color remaining after concentration, if there be any, is bleached by dilute sulphurous acid (approximately centinormal). The solution is nearly neutralized with sodium hydrate, treated with an excess of sodium hydrogen carbonate amounting to 20 cm.[3] of the saturated solution, cooled, and titrated in presence of starch by the standard iodine. This final titration gives, of course, the entire amount of antimony present. The difference between the indications of the two titrations is the measure of the antimony in the higher condition of oxidation. The method as outlined is accurate and rapid, and so simple as regards manipulation that a number of determinations can be carried through simultaneously with the use of ordinary apparatus.

ART. XX.—*A Method for the Estimation of Chlorates;* by F. A. GOOCH and C. G. SMITH.

[Contributions from the Kent Chemical Laboratory of Yale College.—VII.]

IT has been shown in recent work in this laboratory* that under conditions properly controlled, arsenic acid in excess is capable of expelling the iodine from hydriodic acid at the boiling temperature of the solution, being itself reduced correspondingly according to the equation

$$H_3AsO_4 + 2H\text{-}I = H_3AsO_3 + H_2O + I\text{-}I.$$

On cooling the liquid remaining after such treatment, and neutralizing, the arsenious oxide produced in the reaction may be reoxidized iodometrically in the usual manner, the iodine added to accomplish this purpose being the exact measure of the iodine originally present as hydriodic acid and expelled from the acid solution during the process of boiling.

If other sufficiently energetic and easily decomposable oxidizing agents are present at the same time with the arsenic acid, it would be natural to suppose that these substances will act similarly upon the hydriodic acid, and, furthermore, that the oxidizing power of the arsenic acid will not be called into play until that of the more unstable oxidizers has been exhausted. Chloric acid, for example, acts with great ease upon hydriodic acid, and it would be natural to suppose that in a mixture of chloric, hydriodic and arsenic acids the mutual action of the chloric and hydriodic acids will be manifest first and will go on steadily to completion, and that when this effect is accomplished, and then only, the action of the arsenic acid in liberating iodine from the residual hydriodic acid and in registering by its own reduction the amount of iodine thus set free will appear. It should be possible, therefore, if this theory of the reaction between these substances is correct, to found upon the method referred to for the estimation of iodine

* Gooch and Browning; this Journal, xxxix, p. 188.

a method for the estimation of chlorates—this to consist in heating the chlorate, in acid solution and under conditions otherwise appropriate, with a known amount of potassium iodide, somewhat in excess of that theoretically equivalent to the chlorate, and in presence of an excess of arsenic acid, the arsenious oxide produced in the process being determined iodometrically and serving to measure the amount of iodide left undecomposed by the chlorate. Of course, the difference between the amount of iodide left undecomposed and that originally introduced should be the measure of the chlorate entering into the reaction. That a better form of iodometric method than those we have had heretofore for the estimation of chlorates is desirable is obvious when it is recognized that Bunsen's original process—consisting in heating the chlorate with hydrochloric acid and potassium iodide, distilling and estimating the iodine collected in the distillate—fails (owing to the formation of the comparatively non-volatile iodine chloride in the simultaneous action of the oxidizer upon hydrochloric and hydriodic acids) to show the entire amount of iodine corresponding to the chlorate; and that Finkener's substitute for this process—which prescribes the heating of the chlorate, under pressure in a closed bottle and in an atmosphere of carbon dioxide, with a mixture of hydrochloric acid and potassium iodide previously prepared by treatment with sulphurous acid, boiling and subsequent cooling in an atmosphere of carbon dioxide—though excellent when properly carried out, demands careful preparation of materials and skillful handling in the execution.

We have studied the applicability of the process outlined above and record our experience in the following account.

A solution of potassium iodide, approximately decinormal, was standardized according to the method to which reference has been made and which may be summarized in brief, as follows: Portions of this solution were measured from a burette into Erlenmeyer beakers capable of holding 300 cm.^{3}, 2 grms., approximately, of pure dihydrogen potassium arseniate were added in solution, 20 cm.^{3} of a mixture of sulphuric acid and water in equal volumes were introduced with enough water beside to increase the entire volume to a little more than 100 cm^3. A platinum spiral was introduced to secure quiet boiling, a trap made of a straight two-bulbed drying tube cut short was hung with the larger end in the neck of the flask, and the liquid was boiled until the level had reached a mark upon the flask indicating a volume of 35 cm.^{3}, experience having shown that this degree of concentration is sufficient and that it is best not to exceed it. The liquid remaining was cooled and nearly neutralized by sodium hydrate, acid potassium carbonate was added to alkalinity, 20 cm.^{3} of a saturated solution of this salt were added in excess, and the arsenious oxide in solution was titrated by standardized decinormal iodine in presence of starch. The iodine added in the reoxidation of the arsenious oxide was taken as the exact equivalent of the iodine expelled in boiling. Several closely agreeing determinations made in this manner served to fix the standard of the solution.

The action of chloric acid under similar conditions was tested by following out exactly the process employed in standardizing the iodide, with the exception that weighed amounts of potassium chlorate, purified by recrystallization, were also introduced and that the precaution was taken to have the potassium iodide present in every case to an amount at least eight and a half times as great as that of the potassium chlorate —this amount being a little more than the equivalent weight of the iodide referred to the chlorate. The experiments involved amounts of the chlorate ranging from 0·2 grms. to 0·01 grm., and quantities of the iodide varying from eight and a half to fifty times those of the chlorate. The results with all essential details are contained in the following table:

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.
H_2SO_4 [1 : 1] taken.	H_2KAsO_4 taken.	KI = I taken.	taken.	Iodine corresponding to As_2O_3 reduced.	Difference between Iodine taken and Iodine added to oxidize As_2O_3.	$KClO_3$ taken.	$KClO_3$ found,—that is, equivalent to I in column VI.	Error.
cm.^{2}	grm.	grm.	grm.	grm.	grm.	grm.	grm.	grm.
20	2	2·0092	1·5356	0·2962	1·2394	0·2000	0·2000	0·0000
20	2	2·0092	1·5356	0·2973	1.2383	0·2000	0·1999	0·0001—
20	2	1·0380	0·7934	0·0570	0·7364	0·1185	0·1188	0·0003+
20	2	0·8706	0·6654	0·0435	0·6219	0·1000	0·1004	0·0004+
20	2	0·8706	0·6654	0·0429	0·6225	0·1000	0·1005	0·0005+
20	2	0·8706	0·6654	0·0435	0·6219	0·1000	0·1004	0·0004+
20	2	0·8706	0·6654	0·0435	0·6219	0·1000	0·1004	0·0004+
20	2	0·5023	0·3839	0·3208	0·0631	0·0100	0·0102	0·0002+
20	2	0·5023	0·3839	0·3201	0·0638	0·0100	0·0103	0·0003+
20	2	0·2009	0·1536	0·0889	0·0647	0·0100	0·0105	0·0005+
20	2	0·2009	0·1536	0·0903	0·0633	0·0100	0·0102	0·0002+
20	2	0·2009	0·1536	0·0903	0·0633	0·0100	0·0102	0·0002+
20	2	0·1339	0·1024	0·0405	0·0619	0·0100	0·0100	0·0000
20	2	0·1004	0·0768	0·0157	0 0611	0·0100	0·0099	0·0001—
20	2	0·1004	0·0768	0·0182	0·0586	0·0100	0·0095	0·0005—

The mean error of these determinations is a little less than 0·0002 grm +, between extremes of 0·0005 grm. + or 0 0005 grm. —, and the results are evidently excellent for an iodometric process in which titration is effected by decinormal solutions. An excess of iodide over an amount a little in excess of the equivalent proportion is without effect. The process is rapid and easy.

The paper upon the determination of iodine, to which reference has been made and upon which this process is based, prescribes corrections for the volatility of arsenious chloride and the slight deoxidation of arsenic acid when chlorides and bromides are also present in considerable amount. In this process, however, the amount of hydrochloric acid evolved from the maximum weight of chlorate treated—0·2 grm. of the potassium salt—calls for a correction so small as to be insignificant.

Art. XXI.—*Dampening of Electrical Oscillations on Iron Wires*; by John Trowbridge.

[Presented to the American Academy of Sciences, May 27, 1891.]

It has generally been assumed by those who have studied the subject of very rapid oscillations of electricity, such as occur in Leyden jar discharges, that the magnetic character of the conductor has very little influence upon the character of the discharge. Thus, in a note to an article on electrical waves, W. Feddersen states that electrical oscillations may suffer a slight weakening on iron.; but this diminution is very slight:—

"Beim Eisen könnte in Folge der Magnetisirungen eine Abweichung hervortreten; in dess zeigt der Versuch, dass dieselbe keinenfalls bedeutend ist, übrigens in dem Sinne erfolgen müsste, als wenn die Elektricität beim Eisen ein grössere Hinderniss fände, wie bei den übrigen Metallen."*

In Dr. Lodge's treatise on Modern Views of Electricity (ed. 1889), we find the following:—

"But in the case of the discharge of a Leyden jar iron is of no advantage. The current oscillates so quickly that any iron introduced into its circuit, however subdivided into thin wires it may be, is protected from magnetism by inverse currents induced in its outer skin, and accordingly does not get magnetized; and so far from increasing the inductance of the discharge circuit, it positively diminishes it by the reaction effect of these induced currents; it acts, in fact, much as a mass of copper might be expected to do." (p. 365.)

Fleming writes as follows:

"With respect to the apparent superiority of iron it would naturally be supposed that, since the magnetic permeability of iron bestows upon it greater inductance, it would form a less suitable conductor for discharging with great suddenness of electric energy. Owing to the fact that the current only penetrates just into the skin of the conductor, there is but little of

* Annalen der Physik und Chemie, No. 108, 1859, p. 499.

the mass of the iron magnetized. Even if these instantaneous discharges are capable of magnetizing iron, ... the electromotive impulses or sudden rushes of electricity do not magnetize the iron, and hence do not find in it any greater self-inductive opposition than they would find in a non-magnetic but otherwise similar conductor. Dr. Lodge's further researches seem to show that there is a real advantage in using iron for lightning conductors over copper, and that its greater specific resistance and higher fusing point enables an iron rod or tape to get rid safely of an amount of electric energy stored up in the dielective which would not be the case if it were copper."*

Fleming describes in full Dr. Lodge's experiments to prove the non-magnetizability of iron by sudden discharges :—

"In the experiments on alternative path, as described by Dr. Lodge, the main result is very briefly summed up by saying that, when a sudden discharge had to pass through a conductor, it was found that iron and copper acted about equally well, and indeed iron sometimes exhibited a little superiority, and that the thickness of the conductor and its ordinary conductivity mattered very little indeed. . . . In the case of enormously rapid oscillations the value of the impulsive impedance varies in simple proportion to the frequency of the oscillations, and depends on the form and size of the circuit, but not at all on its specific resistance, magnetic permeability, or diameter. . . . . . For discharges of a million per second and upwards, such as occur in jar discharges and perhaps in lightning, the impedance of all reasonably conducting circuits is the same, and independent of conductivity and permeability, and hardly affected by enormous changes in diameter."†

Turning now to the observations of Hertz, we find it stated that the material, the resistance, and the diameter of the wire of the micrometer circuit employed by him, have very little influence on the result. The rate of propagation of an electrical disturbance along a conductor depends mainly on its capacity and coefficient of self-induction, and only to a small extent on its resistance. Hertz concludes that, owing to the great rapidity of the alternations, the magnetism of the iron is unable to follow them, and therefore has no effect on the self-induction. When a portion of the micrometer circuit employed by Hertz was surrounded by an iron tube, or replaced by an iron wire, no perceptible effect was obtained, and thus the result was apparently confirmed that the magnetism of the iron is unable to follow such rapid oscillations, and therefore exerts no appreciable effect. The velocity of propagation in a wire has a definite value independent of its dimensions and material. Even iron wires offer no exception to this, showing

* Fleming, Induction of Electric Currents, p. 398. † Ibid, p. 411.

that the magnetic susceptibility of iron does not play any part in the case of such rapid motions.*

Although the impulsive impedance is apparently not affected by the magnetic character of the wire, experiments lead me to believe that discharges of the quick period of a Leyden jar are affected very appreciably by the magnetic nature of iron, steel, and nickel conductors. This effect is so great that it dampens the electrical oscillations, and makes it difficult to determine whether the time of oscillation is also affected by the permeability of the conductor.

The apparatus employed was similar to that described in the investigation of electrical oscillations with an air condenser.† Certain important modifications, however, were made. The plane mirror which was used in the former research was replaced by a concave mirror of ten feet focus and three and a half inches in radius. This mirror was mounted upon the end of the armature shaft of a one-half horse power electric motor.

The discharging apparatus consisted of a sharp cutting tool, insulated, and mounted on the edge of the rotating disk bearing the mirror. It was metallically connected with a grooved ring of brass mounted upon the shaft and insulated from it by hard rubber. Around this was wound a copper wire, one end of which was connected with the discharging wire, and the other drawn taut by a rubber band. The electrical discharge was thrown on to the circuit by thrusting forward a lever which brought a solid hinged frame containing a strip of soft type-metal into contact with the rapidly revolving steel-cutting tool. An electrical contact was thus insured by the tool cutting a groove in the strip of type-metal. In order to avoid a spark at the contact, the type-metal was thickly covered with a wax of peculiar composition. The only spark that occurred, therefore, was the one the oscillations of which I desired to study. At each trial the type-metal was moved so as to expose a new cutting surface. The type-metal was insulated from the rest of the apparatus, but connected with the outer coating of the Leyden jar; first both terminals of the Holtz machine were thrown off, and immediately after the cutting tool, ploughing its way through the type-metal, placed the outer coating of the Leyden jar in circuit with one of the two parallel wires leading to the terminals of the spark. The other wire was permanently in connection with the inner coating of the jar.

* "Ersetzen wir den bisherigen Kupferdraht durch einen dickeren oder dünneren Kupferdraht oder durch einen Draht aus anderem Metall, so behalten die Knotenpunkte ihre Lager bei. Die Fortplanzungsgeschwindigkeit in allen solchen Drähten ist daher gleich, und wir sind berechtigt, von derselben als einer bestimmten Geschwindigkeit zu reden. Auch Eisendrähte machen keine Ausnahme von der allgemeinen Regel. die Magnetisirbarkeit des Eisens kommt also bei so schmalen Bewegungen nicht in Betracht."—Ann. der Physik und Chemie. No. 34, 1888, p. 558.

† Proceedings of Am. Acad. of Arts and Sci., vol. xxv, p. 109.

Beside the short lead wires above described, the discharging circuit consisted of the two parallel wires 30 cm. apart and 510 cm. long. These were the only portions of the apparatus changed during the experiment, and they were replaced by wires of different material and of different size. The other conditions—length of spark, lead wires, and the copper cross wire connecting the outer end of the long parallel wires—remained undisturbed throughout the experiment.

The Leyden jar was charged each time as nearly as possible to the same potential, judging by the number of turns given the Holtz machine. It is unfortunate that no more accurate means of measuring it were at hand, although the different negatives showed but slight variation. The capacity of the jar to alternations of this period was 5060 electrostatic units.

I describe the discharging portion of the apparatus minutely, for the success of an investigation of this nature depends upon the suppression of all sparks save that which one wishes to observe; and the method surely and completely accomplished this. The photograph of the spark could thus be made to fall very accurately on the sensitive plate. When one considers that the image of the spark was flying through the air on a circle of a radius of ten feet with a velocity of a mile a second, it will be seen that an extremely small deviation in the point of contact between the cutting tool and the type-metal would have thrown the image entirely off the sensitive plate. A singular phenomenon was noticed in this connection. When a comparatively low potential was used, such as that afforded by the air condenser used in our previous investigation, the cutting tool ploughed two or three millimeters along the surface of the type-metal before a spark passed at the point in the circuit where it was desired. With higher potentials this phenomenon was also observed, but the extent of cutting was diminished.

It is possible that the insulating wax may have melted under the sudden blow of the cutting tool, and, flowing around it, prevented instant contact. This seems to us improbable, for a deep and clear-cut groove was made in the soft type-metal. Great attention was paid to the solid structure of this contact apparatus. It was entirely separate from the support of the revolving parts, and was perfectly steady.

The other end of the armature shaft was lengthened into a cylindrical chronograph, similar to that described in the article already cited, and its performance left nothing to be desired. A small Ruhmkorf coil, excited by two storage cells, and interrupted by a seconds pendulum, gave a record of the speed of the mirror. The stylus which drew the spiral turns on the barrel of the chronograph was drawn along the barrel by means of a small heavily loaded carriage, which, on being released at the moment the lever arm threw the type-metal in contact with the cutting tool, descended an inclined plane of adjustable height.

A small Töpler-Holtz machine charged a large Leyden jar, and it was found to work admirably in all states of the weather. The apparatus which I have thus described was the result of the experience of the previous year, and worked for months without failure; and the taking of photographs of the oscillatory discharge by it became a mere matter of routine.

The following cases were tried:

(1.) When the long parallel wires were of copper (diameter ·087 cm.), the number of double oscillations visible on the negatives averaged quite uniformly 9 or 9·5.

(2.) When the wires were of German silver (diameter ·061 cm.), three oscillations were visible.

(3.) But when an annealed iron wire (diameter ·087 cm.) was substituted, only the first return oscillation was distinctly visible, with occasionally a trace of the first duplicate discharge.

(4.) On substituting fine copper wire (diameter ·027 cm.), five complete oscillations were quite uniformly visible.

(5.) Fine German silver wire (·029 cm.), nickel wire (·019 cm.),* soft iron (·027 cm.), and piano steel wire (·027 cm.), gave but faintly the first return discharge after the pilot spark.

The pilot sparks were in all cases strong.

The single return discharge through the iron wire did not admit of measurement sufficiently accurate to furnish any basis for calculation of its self-induction. The time did not apparently differ, if at all, by more than fourteen or fifteen per cent. Some general reasoning based upon the number of oscillations may be of interest. It must be acknowledged, however, that this reasoning is open to criticism, although it affords the most plausible explanation. The phenomenon itself is not a doubtful one.

The time of a double oscillation for the large-sized copper wire was ·0000020 sec.; for the small copper wire, ·0000021 sec. The others as far as could be determined did not differ much from these values, and for this purpose either is sufficiently accurate. Denote by R′ the ohmic resistance of the parallel wires to alternating currents of this periodicity; by R, the resistance to steady currents.

$$p=\frac{2\pi}{t}=3,000,000 \text{ (pratically).}$$

Taking the cases up in order:

* Obtained by the kindness of Joseph Wharton, Esq., of Philadelphia.

(1.) Large copper wire,

$$R=0{\cdot}285\times10^9$$

and substituting in Lord Rayleigh's formula, $R'=\sqrt{\tfrac{1}{2}pl\mu R}$,

$$R'=0{\cdot}66\times10^9.$$

(2.) Large German silver wire,

$$R=9{\cdot}2\times10^9,$$

and substituting in the series

$$R'=R\left\{1+\frac{1}{12}\frac{p^2l^2\mu^2}{R^2}-\frac{1}{180}\frac{p^4l^4\mu^4}{R^4}+\ldots\right\},$$

$$R_{,}=9{\cdot}2\times10^9.$$

(3.) Large iron wire,

$$R=2{\cdot}5\times10^9,$$

and if there is a true time lag, as often stated, such as to prevent action of the magnetic property of the iron, and if on this assumption we make $\mu=1$,

$$R'=2{\cdot}78\times10^9$$

(4.) Fine copper,

$$R=3{\cdot}3\times10^9$$

$$R'=3{\cdot}5\times10^9.$$

(5.) Again, as before, call $\mu=1$ in iron, nickel, and steel. The length of these circuits was 7·41 meters, the remainder of the 10·20 meters — 2·79 meters—being of copper wire of $R'=0{\cdot}94$.

The value of R′ in the separate cases, including in each the resistance 0·94 of the copper portion, was as follows:

Soft iron	$15{\cdot}0\times10^9$
Piano steel	$20{\cdot}7\times10^9$
Nickel	$30{\cdot}6\times10^9$
German silver	$23{\cdot}0\times10^9$

The ratio of the strengths of successive discharges during the oscillation is given by the function $\varepsilon^{\frac{rT}{2L}}$, where r is the ohmic resistance, T the time of a double oscillation, and L the self-induction. The ratio of one discharge to the nth one after it is $\varepsilon^{n\frac{rT}{2L}}$. If we assume—and it is a large assumption, but one which perhaps the result will in some measure justify—that the ratio of the strength of the first to the strength of the last visible discharge is more or less a constant, we may make use of the above data. Denote $\frac{T}{2L}$ by A, and call the unknown resistance of the short connecting lead wires and of the spark x. Then will $r = \mathrm{R}' + x$, and n will be the number of complete oscillations visible.

Take cases (1) and (2), large copper and large German silver wires :—

$$\varepsilon^{n_1(\mathrm{R}'_1+x)\mathrm{A}} = \varepsilon^{n_2(\mathrm{R}'_2+x)\mathrm{A}};$$
$$n_1(\mathrm{R}'_1+x) = n_2(\mathrm{R}'_2+x);$$
$$9{\cdot}5\,(0{\cdot}66+x) = 3\,(9{\cdot}2+x);$$
$$x = 3{\cdot}4 \text{ ohms.}$$

Taking cases (1) and (4) similarly,

$$n_1(\mathrm{R}'_1+x) = n_4(\mathrm{R}'_4+x);$$
$$9{\cdot}5\,(0{\cdot}66+x) = 5\,(3{\cdot}5+x);$$
$$x = 2{\cdot}6 \text{ ohms.}$$

Experiments with other copper wires having R′ equal to 3·4 and 1·27 give 5 and 8 for the values of n respectively, or

$$x = 2{\cdot}4 \text{ ohms.}$$

The resistance (R′) of the lead wires forming part of x was 0·8 ohm, leaving as a possible value for the resistance of the spark about 2 ohms.

If, taking this value of x, we calculate the value of R′ necessary to damp out the oscillation in one complete double discharge in the case of the large iron wire, we shall have

$$9{\cdot}5\,(0{\cdot}66\times 3) = 1\,(\mathrm{R}'+3);$$
$$\mathrm{R}' = 30 \text{ ohms.}$$

But neglecting the magnetic property of the iron, its calculated resistance to alternating currents of this periodicity was $\mathrm{R}' = 2{\cdot}78$ ohms. This is obviously inadequate, and would point to the conclusion that the oscillation is not, as sometimes stated, too rapid to admit of the magnetic action of the iron.

If we substitute this value $\mathrm{R}' = 30$ in the equation

$$\mathrm{R}' = \sqrt{\tfrac{1}{2}\,pl\,\mu\mathrm{R}},$$

we have for the resulting value of the magnetic permeability $\mu = 230$. This lies between the limits $\mu = 103$ and $\mu = 1110$, found by taking the number of oscillations one and a half and one-half respectively for the case of the iron wire.

It should be noticed that this estimate of μ necessitates assuming that T and L remain the same within broad limits. Measurements of the single oscillation on the negatives show that this is near enough the case. Part of the more rapid decay of the oscillation in the iron may be well ascribed to the dissipation of energy by hysteresis. While we cannot place much reliance upon an estimate of its value in such a case,—its percentage effect probably increasing rapidly with the decay of the spark,—it is not difficult to show that its influence may be very great.

There still remains the fact, not generally recognized, that, in Leyden jar discharges through iron wires, the magnetic property of the iron has time very materially to modify the character of the spark.

We give an example of the measurement of the half-oscillation which was the only one visible on the photograph of the discharge over iron wires, all the others having been dampened or extinguished by the iron, in comparison with the measurement of the similar half-oscillation on copper wires of the same diameter as the iron wires. The number of oscillations on the copper wires was eight.

The total duration of the discharge on iron wires was only three millionths of a second, while that on similar copper wire was three hundred-thousandths of a second. A steel wire gave the same results as the annealed iron wires.

Comparative lengths of first half-oscillation in millimeters.

Fine iron wire.	Fine copper wire.
·23	·19
·21	·20
·19	·20
—	—
·21	·19

Large iron wire.	Large copper wire.
·20	·17
·20	·18
·19	·20
—	—
·19	·18

I wish to express my deep obligations to my assistant, Mr. W. C. Sabine, for his valuable suggestions and for his skill in the mechanical details of this investigation.

Conclusions.

1. The magnetic permeability of iron wires exercises an important influence upon the decay of electrical oscillations of high frequency. This influence is so great that the oscillations may be reduced to a half-oscillation on a circuit of suitable self-induction and capacity for producing them.

2. It is probable that the time of oscillation on iron wires may be changed. Since we have been able to obtain only a half-oscillation on iron wires, we have not been able to state this law definitely.

3. Currents of high frequency, such as are produced in Leyden jar discharges, therefore magnetize the iron.

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ART. XXII.—*Genesis of Iron-ores by Isomorphous and Pseudomorphous Replacement of Limestone, etc.;* by JAMES P. KIMBALL.

IT is the object of the present memoir briefly to develop the following proposition, namely, that well recognized products of epigenesis, like siderite and ferro-calcite, in their several forms and wide distribution especially on a petrographic scale, are as a rule also products of direct pseudomorphous replacement of isomorphous calcic carbonate, like limestone, calcite, calc-sinter, calcareous sediments, calc-schutt, etc. This proposition is not new. But some of the conditions remain unsettled. So also some of the deductions which have been thought, or may seem, to follow. These it is my purpose briefly to discuss.

Contingent to this proposition, it follows that secondary or indirect replacement of calcic carbonate by ferric hydrate is wrought through alteration of pseudomorphous siderite or ferro-calcite, and also, through progressive alteration, by ferric oxide and even magnetic oxide. Hence proximate derivation from siderite of many occurrences of iron-ores which nevertheless are ultimate products of indirect or progressive pseudomorphism of calcic carbonate—itself often a product of epigenesis from basic silicates. Such occurrences may therefore be regarded as instances of double pseudomorphism, sometimes on a petrographic scale; that is, pseudomorphism in the first instance by substitution or replacement; in the second instance by alteration.

Again, ferric hydrate apparently directly pseudomorphous after limestone is produced by immediate, perhaps spontaneous, oxidation of ferrous carbonate, resulting from interchange or double decomposition between solutions of this salt or ferrous sulphate and calcic carbonate in place. All these permutations proceed from the same reactions, but differ in results according to atmospheric environment—whether oxidizing or not. The instable salt as first separated, it is scarcely necessary to add, is thrown down from solutions either of ferrous carbonate or ferrous sulphate indifferently, in reaction with dissolved calcic carbonate or other alkaline mono-carbonates. This salt however, it is important early to remark, is the hydrous salt, from which geologists, it seems, are not accustomed to distinguish the anhydrous carbonate which is almost, if not altogether, exclusively its natural form.

Other adventitious occurrences of brown and red ferric oxide well recognized as exotic, that is, neither in original place, nor vicariously developed, form as such a separate class. These, however, as commonly understood, are products of like reactions between solutions of the same salts in circulating acidulous waters. These products, though sometimes accumulated under favorable conditions of environment and topography, are more commonly dissipated.

But for the instability of hydrous ferrous carbonate, it might be assumed to be transiently produced through reactions of ferrous salts and alkaline mono-carbonates in solution, not far from *loci* of replacement of calcic carbonate by siderite, as the result of transmission of solutions beyond range of reducing or preserving gases. Visible results of precipitation and spontaneous oxidation of this salt into ferric hydrate in these circumstances on the one hand, and direct precipitation of ferric hydrate through oxidation on the other hand, are identical. Hence the two processes in nature can seldom be distinguished.

The general proposition may now be advanced—that deposits of concentrated iron-ores occur far more extensively as pseudomorphous replacements than has hitherto been made to appear; and far more extensively than by original sedimentation of ferric hydrate in hydrographic basins (if indeed important deposits have ever been formed in this way), followed by chemical transmutations so far as essential to their plausible explanation upon theories of such a common genesis. In the present place, suffice it to indicate the impracticability of conceiving of sedimentation of ferriferous material without siliceous alternations; or of great accumulations of non-ferruginous, non-siliceous sediments at all, except in the case of marine limestones. These are preëminently the *habitat* or repositories of massive and stratiform iron-ores of all descriptions. Occurrences of iron-ores in this relation are often, and indeed generally, without transitions. On the other hand, it is easy to conceive, and in numerous instances to prove, effective replacement of limestones of all geologic periods. Among the great number of important stratiform occurrences of iron-ores —that *stratified* ores exist, there seems to me much reason to doubt—that is, homogeneous, non-laminated ores, formed in the natural order of succession of strata between which they are enclosed, and along with which they are commonly assumed, *prima facie*, to be imbedded.

(1.) As deep-sea chemical precipitation of ferric hydrate is out of the question, the circumstance of the presence in limestone of important lenticular deposits of this material or its derivatives, including siderite upon one theory of its genesis, would suffice to prove the invasion of mid-sea or calcareous sediments by at least suspended material from sub-ærial rock-decay. This condition is obviously incompatible with the more important developments of Palæozoic iron-ores, whose relations in the greater number of instances are with remarkably pure and persistent limestones, comparatively free from intercalations of argillaceous matter, also a residual product of rock-decay, and invariably accompanying ochreous matter in suspension. Again, replacement of limestone naturally progresses from exterior and divisional surfaces. This, as commonly observed, wherever incomplete, has invariably affected superficial or upper parts of formations under gentle dips, and seldom nether parts except under steep dips. Lenticular bodies of iron ores, not purely concretionary, are very rarely if ever found completely enclosed in pure limestone—that is, in any form corresponding to the filling of a hydrographic basin of marine limestone.

Conditions above briefly noticed are well illustrated, as I shall endeavor to show, by the more important developments of iron ores upon horizons of limestones and adjacent transition strata of all geologic periods.

(2.) The geologic importance of the phenomena of displacement of calcium-carbonate by ferrous carbonate was long since indicated by Bischof, mainly, as it appears, on mineralogic or *a priori* grounds.* Pseudomorphous siderite after calcite, occurring in drusy cavities in anamesite, as described by Blum and Sandberger, was attributed to removal of calcium carbonate by carbonated solutions of ferrous carbonate and deposition of this salt in its place. The same result, as well-known, is produced by reaction of solutions of ferrous sulphate, calcium sulphate being removed.

(3.) Pseudomorphic replacement of calcite by ochreous ferric oxyd was observed by Blum to have taken place indirectly, namely, first by substitution of ferrous carbonate followed by alteration of this comparatively unstable compound. As pointed out by Bischof, it seems probable indeed that pseudomorphs of this type are necessarily indirect—never direct.†

(4.) Aside from pseudomorphs by incrustation, pseudomorphous siderite commonly occurs by substitution of anhydrous isomorphous minerals. Pseudomorphism by alteration often succeeds pseudomorphism by substitution. Both processes, as inferred from relative densities, are attended with contraction. In the conversion of siderite into limonite, this, according to Hunt, amounts to nearly twenty per cent.‡ Hence the exhibition of cavities, anfractuosities and dislocations in products of either transformation, as witnessed both on a mineralogic and petrographic scale.

(5.) Whatever be the mode of accumulation of ferrous carbonate in various deposits, it can scarcely fail to be recognized as invariably a secondary product universally resulting from the decomposition of diffused proto-silicates of iron by means

* Bd. II, 1864, p. 154.

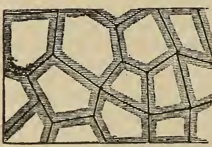
† Chem. Geol., Bd. III, 1866, 871.

‡ This Journal, xxvi, 1883, 202.

of carbonated waters; next in frequency, from solutions of ferrous sulphate in reaction with calcic carbonate; and, lastly, from like reactions with ferrous salts from reduction of ferric silicates.

(6.) The stability of this more or less alterable secondary product in fissures and deep-seated strata in an atmosphere of carbonic anhydride or reducing gases, was also long since pointed out by Bischof and W. B. Rogers, as well as its transformation into ferric hydrate through displacement of such gases by atmospheric air.

(7.) The frequent occurrence of limonite and hematite in limestone and their graduation into beds of this sedimentary material, as well as the presence of similar fossils in both, are facts adduced by Bischof to justify the conclusion that iron-ore deposits of this description have had their origin in replacement of limestone beds.* Yet, as by him remarked, replacement of amorphous limestone by ferric oxide obviously cannot be proved mineralogically as in the case of rare occurrences of incomplete pseudomorphs after calc-spar, like the specimen originally described by Blum. But every geologist has nevertheless observed ultimate replacement of limestone by brown and red ferric oxides, whether direct or indirect, among the more common phenomena of weathering. When as sometimes happens this is all but complete, and the original form of the limestone mass is preserved *in situ*, the replacement is likewise seen to be pseudomorphic—at least in a petrographic sense. Dana has given a good pictorial illustration of this kind in describing an occurrence in the Cone ore-pit at West Stockbridge.† The cut is here reproduced. Replacements of shells and parts of crinoids, still more common, are likewise pseudomorphic in the same limited sense.



The above proposition affords grounds for a ready and complete explanation of the common association of iron ores with limestone as far from accidental. This association would obviously be still more common had all replacements of thin limestone beds been only partially effected, as in replacements of thick limestone, which are necessarily incomplete or relatively superficial. Occurrences of the latter kind justify the conclusion that thin beds of limestone have in fact in numerous instances been wholly or pseudomorphously replaced. Hence frequent occurrences of lenticular beds of siderite and of its derivatives in place of thin limestones, of which no trace may remain except

* Bd. III, 1866, 873.

† This Journal, xiv, 1877, p. 136. See, also, Rep. Tenth Census, xv, 292, 296, 297, 299, 396.

form, and perhaps character of insoluble contents, on the one hand; and local developments of iron-ores, void of anything like regular form, within the compass of a thick limestone formation, and graduating into that material, on the other hand. The latter modes of occurrence (and by inference the former also) are particularly well illustrated by numerous stratiform iron-ore developments in strata of the Carboniferous period. These strata are understood by all to have accumulated under specially favorable conditions of environment for the production of the materials of iron-ores through internal chemical transmutations; and to have since subsisted under equally favorable atmospheric conditions for the preservation of alterable kinds of material produced, like siderite and sphærosiderite.

(8.) The possession of many physiographic characters by stratiform iron-ores in common with deposits *in situ*, formed in the natural order of strata between which they are imbedded, or rather enclosed, has naturally led geologists to seek an explanation of at least Carboniferous iron-ores of this description on theories of direct deposition either chemical or mechanical: that is, according to one theory, in original form of ferrous carbonate; or, according to another theory, as the product of transmutation of ferric hydrate in place into the same compound, through successive deoxidation and carbonating agencies, the potential influence of which in the development of this particular series of strata it may not seem difficult to imagine on grounds of either theory. As to further alteration from weathering action, regulated by circumstances of topography and environment, all are agreed.

The same agencies however may well be believed to have been equally potential in clearly recognized processes resulting in pseudomorphous replacement of limestone by ferrous carbonate, especially in the preliminary work of decomposing diffused clastic ferrous and ferric silicates, dissolving their soluble products, and in the generation and preservation unaltered of anhydrous ferrous carbonate in concrete form however produced.

(9.) While dissolved alkaline mono-carbonates, as well known, readily precipitate instable hydrated ferrous carbonate from solutions of ferrous salts, no artificial method appears to have been proposed for the production at ordinary temperatures of anhydrous ferrous carbonate.

(10.) The generation of this natural compound in the form of siderite and sphærosiderite is sometimes attributed to direct precipitation and concentration of hydrous ferrous carbonate in the presence of reducing gases, or of an atmosphere of carbonic anhydride. This presupposes dehydration at ordinary temperatures by some natural process as yet unexplained.

Upon another theory, commonly entertained as a collateral theory by the same geologists who employ the one just stated, its derivation is also attributed to direct deposition through volatilization of free carbonic acid from aqueous carbonated solution—likewise in atmospheres of hydro-carbon gases and carbonic anhydride.

(11.) No natural occurrence and therefore no mineral species of hydrous ferrous carbonate seems to have been recognized by mineralogists. A moderately instable white, earthy amorphous hydrate said by Massieu to have occurred in the mineral lode of Pontpéon, France,* seems to have possessed the same characteristics as an occurrence beneath an ochreous deposit of a carbonated spring near Laacher-See in the Eifel, but described by Bischof as siderite or the anhydrous salt.† The same locality is famous for exhalations of carbonic acid. Preservation of the artificial product appears to be impracticable except in an atmosphere displaced by carbonic anhydride, or, as easily supposable, by reducing gases.

(12.) Siderite pseudomorphous after crystalline anhydrous calcic carbonate not uncommonly occurs both in hexagonal and trimetric forms, though isomorphous only in the former case. This fact goes far to show that the phenomena of replacement of calcic carbonate by anhydrous ferrous carbonate are not simply those of isomorphism. Yet it is true that in crystalline as well as in amorphous siderite ferrous carbonate is extremely apt to be partially replaced with isomorphous carbonates of lime, magnesia, manganese and zinc. The first three, and sometimes all four, of these carbonates are freely developed even where sparry siderite distinctly occurs as a product of epigenesis, particularly in drusy cavities and fissures in basic rocks inaccessible to atmospheric air.

(13.) The much greater tendency to precipitation of ferric hydrate from aqueous solutions of ferrous carbonate than of the salt itself by dissipation, as assumed, of carbonic acid, is well exhibited by Roth in the case of numerous mineral waters and deposits of mineral springs, as well as the relative and proportional precipitation of alkaline and manganous carbonates.‡

The existence of stable siderite in calcareous sinter points to replacement of calcic carbonate previously deposited. Away from oxidizing atmospheres, anhydrous ferrous carbonate, if ever directly deposited, which there seems much reason to doubt, is probably by reaction of solutions of ferrous salts with these anhydrous carbonates, and at ordinary temperatures in no other way. But as all known reactions of this kind result in hydrous ferrous carbonate from which passage into the anhydrous carbonate at ordinary temperatures is difficult to

* Compt. Rend., lix, 238. † Chem. Geol., Bd. I, 1863, 550.
‡ Chem. Geol., Bd. I, 565, 577.

imagine, the problem still remains.—Whence the production of the anhydrous carbonate?

(14.) In this question one is confronted by the remarkable fact that writers within the field of chemical geology habitually fail to discriminate between the two carbonates either in noting rare occurrences of hydrous carbonate, if such they really be, developed in reactions commonly yielding this extremely alterable or evanescent form; or in tracing epigenesis of comparatively stable anhydrous carbonate, either crystalline or amorphous, from like reactions. On the contrary, it seems to have been assumed that chemical reactions, geologically considered, producing hydrous carbonate, might equally serve, at least eventually, to produce anhydrous carbonate. As in many other unexplained instances of dehydration, conceivable only at ordinary temperatures, this phenomenon has probably been supposed to be an effect of inscrutable operations of time Bischof, for instance, to whom we owe what still stands as the fullest conspectus of this subject, fails to distinguish as such the hydrous carbonate, which as yet appears to be exclusively the product of well understood reactions.

(15.) Now there seems much reason to doubt that anhydrous ferrous carbonate is ever directly deposited from acid solutions of ferrous salts except in circumstances of contact with isolated or solid anhydrous alkaline mono-carbonates, probably at the point of double decomposition, or in the nascent state of the ferrous salt. Such a mode of development, if assumed, must be considered due to the well known isomorphous relations of anhydrous ferrous carbonate and its pseudomorphic tendencies. This explanation appears at least consistent with the phenomena of replacement, both isomorphous and pseudomorphous, of amorphous calcic carbonate; and may perhaps be found adequate to explain most occurrences of crystalline siderite on the theory of its epigenic origin in all cases. Some of these points will now be further considered.

(16.) It is remarkable that although in the earlier volumes of his great work, Bischof was the first, I believe, to point out the importance of replacement of limestone as one mode of genesis of siderite, he assumes in his supplementary volume stratiform developments of this epigenic compound, particularly in Carboniferous series of strata, to have been directly deposited from its carbonated water solution as an effect of volatilization of carbonic acid, and to have been preserved from oxidation by hydro-carbon gases. Yet the constant association in these strata of carbonic acid along with those gases is remarked by Bischof in the same place.* Even by loss of half-combined carbonic acid, however difficult to imagine as taking place in an atmosphere impregnated with the same gas, it is extremely

* Chem. und Phys., Geol. Suppl., Band 1871, p. 64.

doubtful whether the anhydrous salt would be deposited. A no less important difficulty arises as to the *locus* of deposition. If this take place at the surface, the presence of these gases can scarcely be imagined; and if below—conditions are precluded for lenticular accumulations. Beneath the surface conditions exist for deposition by segregation or replacement only.

(17.) In any theory of the genesis of siderite, it becomes necessary first of all to explain occurrences of siderite in lenticular form, as widely distributed: that is, as a product of direct superficial deposition in hydrographic basins; or else of chemical replacement of lenticular beds originally deposited in that manner. Between these alternatives the former seems to me to be quite impracticable.

Lenticular deposits from either chemical or mechanical precipitation are formed exclusively at the surface, that is, in hydrographical basins or bottoms where conditions essential to stability of hydrous ferrous carbonate can not ordinarily be set up, or at least long maintained. Besides, wherever this salt is separated from standing water it must be assumed to pass spontaneously into a higher state of oxidation. Not only does it appear, then, that lenticular developments of ferrous carbonate can not have been superficially deposited, but that this compound can not have been derived from direct precipitation.

(18.) Senft's theory of the genesis of siderite and sphærosiderite seems to have been founded on special occurrences of stratiform and nodular clay-ironstone enclosed in clays and shales. These are explained as epigenic products resulting from saturation of buried argillaceous sediments with acid solutions of ferrous carbonate, supposed to yield the neutral salt upon evaporation; or again by interchange with stronger bases like lime. Spathic carbonates are likewise supposed by Senft to proceed from absorbents like calcareous material, clay or marl.* However applicable may seem parts of this theory to concretionary lenses and nodules of clay-ironstone contained in beds of residual clay and shales, it must be seen to be incompatible with the composition of spathic siderite of considerable purity, that is, when comparatively free from earthy admixtures, as well as with conditions of deposition in the form of lenticular beds. Like other explanations, it rests on the assumption that anhydrous ferrous carbonate may be separated by evaporation as well as by precipitation from acid solutions of ferrous carbonate, a reaction probably true only in a limited sense as above pointed out.

The reaction however incidentally mentioned by Senft, namely, the isolation of ferrous carbonate by interchange of solutions of ferrous salts with stronger bases like lime, is

* Gesteins und Bodenkunde, 1877, 28.

probably the prevailing one in the circumstances cited. For alkaline mono-carbonates, likewise resulting from decomposition of silicates, may safely be assumed to be present partly in undissolved or diffused form wherever ferrous oxide is available, or wherever ferrous salts are displaced from solution.

(19.) While such reactions may be readily believed to take place in fissures, particularly in contact with segregations of calcic carbonate, they can hardly be assumed with Senft also to extensively obtain in clay bottoms of standing water, or beneath peat-bogs and marshes, still less in a manner to result in direct deposition in bedded form from water. In such circumstances not the anhydrous salt but the hydrated ferrous carbonate, if either, would be deposited; this however quickly passing into ferric hydrate. Still more likely, ferric hydrate would be directly deposited from solution through dissipation of free carbonic acid. Yet I am not prepared to deny that from the condition of ferric hydrate however accumulated anhydrous ferrous carbonate may eventually be formed by de-oxidation and by carbonating processes. If so, this could be only after the original deposits are buried deep below superficial sediments and so excluded from atmospheric oxidation.

(20.) Hence, perhaps, the more commonly received metamorphic theory of the genesis of stratiform siderite, generally assumed to be stratified. This theory, based on the assumption of relative origin corresponding to the natural order of enclosing strata, involves, in short, alteration *in situ* of ferric hydrate commingled with vegetable matter originally accumulated in hydrographic basins. This process is also supposed to be excluded from atmospheric air under cover of successive sediments.

(21.) Some of the objections to this theory as a general explanation of the genesis of siderite will appear farther on. Especially will it, as I think, be found to fail to explain the prevailing occurrence of siderite and ferro-calcite in association with limestone, or on horizons of limestone, or in lenticular form otherwise than concretionary.

(22.) On the other hand, a theory of its derivation in such circumstances at least, by isomorphous and pseudomorphous replacement of calcareous material *in situ*, not only seems to fit the greater number of familiar occurrences of siderite, and thus to explain the almost universal association of this secondary product with limestone, and the graduation into each other of these two materials of widely opposite derivation; but to be alone adequate to explain the epigenesis and indeed existence of the anhydrous salt. Where of course limestone has been completely transformed into siderite, and all immediate evidences of their relation have disappeared, it may sometimes be found practicable to identify lenticular developments of siderite with horizons of limestone by stratigraphic relations. Impracticable though this may be in certain cases, it should not fail to be considered that as the thinner and less persistent limestones are the only ones liable to complete replacement, actual stratigraphic or even inferential identification is not in all cases to be expected.

(23.) Calling attention to the possible application of the theory of the formation of ore-deposits by replacement or substitution, Emmons expresses the possibility that "in the older and more crystalline rocks, where the calcareous beds are of limited extent, metallic deposits in large masses like those of iron, may have so completely replaced the calcareous material that little or no trace of it remains."* Complete ultimate replacement of isolated masses of emerged coral-reef by ferric oxide on the island of Cuba was described by me in 1884. To this example I shall again take occasion to refer.

"The limits of the actually demonstrated application of the theory of the formation of ore deposits," as remarked by Emmons in the paper just quoted, "are being every day extended, not only by studies of new districts, but by more careful and unbiased studies of old districts in which a different method of formation had previously been determined upon."

(24.) Argillaceous shales and other miscellaneous ferriferous sediments commingled with carbonate of lime, originally accumulated, or resulting from decomposition of component basic silicates or left behind from evaporation of circulating waters, may in whole or in part be transformed into clay iron-stone or siderite, containing insoluble residues of the original beds. This process is again one of replacement. Divisional parts or prisms of such beds separated by planes of cleavage and stratification, and by anfractuosities from shrinkage, pass by progressive superficial oxidation into concretionary or nodular limonite. This process has often been described.†

(25.) Diffused ferrous carbonate resulting from replacement of calcic carbonate, also diffused and more or less commingled with clay containing other insoluble residues of sub-aerial decay of basic rocks, may, especially in sediments as yet unindurated, be involved in what may be termed the extra-molecular tendency of fine clays to form concretionary aggregations. Thus it appears that impure ferrous carbonate in nodular form, so frequently imbedded in clays, shales and grits, is probably a product of secular metasomatic interchange and substitution under genetic conditions varying only slightly with circumstances of environment from conditions governing replacement of limestone beds by siderite.

* Trans. Am. Inst. Min. Eng. 1886. Extract p. 7.

† See Hunt, this Jour., xxvi, 1883, pp. 202, 206.

(26.) In the foregoing remarks no discrimination between limestone and dolomite has seemed necessary, nor specific reference to analogous compounds of magnesium in isomorphous relations to those of calcium. Nor, on the other hand, has it seemed important to refer to relations of the same kind subsisting between corresponding compounds of manganese and iron. For the sake of brevity, the same course will generally be followed throughout the present memoir. Yet it will not fail to be considered that epigenesis of compounds of manganese is practically in common with those of iron, and that in fact epigenesis of a given compound of one metal often involves that of a corresponding compound of the other. Quantitatively considered, this according to M. Dieulafait* appears in relative degree to depend less on the distribution of the two metals in the composition of silicates from which epigenesis proceeds, than might be supposed.

(27.) This chemist observed that the heat of combination developed in the production of (hydrous) ferric oxide and (hydrous) ferrous carbonate from ferrous oxide to be respectively 26·6 and 10·0 calories (Fr). In corresponding reactions resulting in the production of manganic oxide (hydrate) and (hydrous) manganous carbonate 21·4 and 13·6 calories were developed.†

When oxygen and carbonic anhydride both in excess come in contact with minerals containing ferrous and manganous oxides, the latter, as may therefore be inferred, will be converted into ferric oxide (hydrate) and manganous oxide (hydrate) and no carbonate will be formed. It is also inferred by Dieulafait that if these gases come in contact with the producing minerals slowly and in quantity insufficient to transform both oxides, the products will be insoluble ferric oxide (hydrate) and soluble (hydrous) manganous carbonate. This serves to explain at least the formation of ferric hydrate comparatively free from manganic hydrate, as well as the separate generation of manganic hydrate comparatively free from ferric hydrate—perhaps in another *locus* of deposition after further transmission of solutions.

Again it is inferred, that as much more heat is developed when ferrous oxide is converted into ferric oxide (hydrate) than when converted into (hydrous) ferrous carbonate, the latter can be formed only in circumstances where atmospheric air is displaced by reducing gases or carbonic anhydride, to the exclusion of oxygen.

* Comptes Rendus, ci, 609, 644.

† The parentheses are mine, the observer ignoring the distinction between hydrous and anhydrous compounds.

ART. XXIII.—*On the Constitution of certain Micas, Vermiculites and Chlorites;* by F. W. CLARKE and E. A. SCHNEIDER.

IN a previous paper upon the constitution of the silicates,* we sought to establish some new lines of attack upon the problem, especially with reference to the mica and chlorite groups. The present communication is to be regarded as a continuation of the same research, and by essentially the same methods; although in some instances the experiments have been less elaborate, when elaborateness seemed to be unnecessary. Throughout the investigation the fundamental hypothesis that the minerals studied are substitution derivatives of normal salts has been kept steadily in view; and, as we believe, it has been amply justified.

Of the so-called vermiculites, two only, jefferisite and kerrite, were considered in our former paper; and these were shown to be trihydrated micas, in which the original alkalies had been replaced by hydrogen. To these examples we now add several others; of which two varieties afford excellent checks upon the earlier work. The two minerals in question are an altered biotite from the zircon mine in Henderson County, N. C., and the protovermiculite from Magnet Cove, Arkansas, described some years ago by Kœnig. The analyses, with itemized water determinations, are as follows:

	Henderson Co.		Protovermiculite.	
	Analysis.	Mol. ratio.	Analysis.	Mol. ratio.
SiO_2	38·18	·636	34·03	5·67
TiO_2	1·68	·021	undet.	----
ZrO_2	none	----	----	----
Al_2O_3	14·02	·138	14·49	·142
Fe_2O_3	13·02	·081	7·71	·048
FeO	2·22	·031	0·14	·002
MnO	0·38	·005	0·09	·001
MgO	14·62	·385	20·89	·522
CaO	0·17	·003	1·88	·034
BaO	0·06	----	----	----
K_2O	5·40	·057	----	----
Na_2O	0·48	·008	----	----
H_2O, 105°	3·20	·178	11·23	·624
" 250°–300°	2·52	·140	4·55	·253
" above 300°	4·80	·267	5·41	·301
	100·75		100·42	
H_2O over H_2SO_4	3·20		11·34	

* This Journal, Oct., Nov. and Dec., 1890.

The analysis of protovermiculite agrees with that of König as well as could be expected, but is carried out somewhat more in detail. In its appearance the mineral was dark brown, broadly foliated, much decomposed, and very brittle. Before the blowpipe it exfoliates and fuses easily. The Henderson County mica was also brown, brittle and decomposed, exfoliating when heated and fusing at the edges. Both minerals were examined optically by Mr. Waldemar Lindgren. The protovermiculite he describes as "yellowish, containing in arborescent forms between the plates a great deal of a deep yellow or reddish substance, probably hydroxide of iron. Angle of optical axes larger than usual. Slight pleochroism; thicker plates remain light between crossed nicols." Of the Henderson County mica he says—"contains no titanium mineral. Contains a few grains of a colorless, strongly double-refracting mineral of uncertain nature, possibly zircon. Plates nearly dark between crossed nicols. Angle of optical axes small, but distinctly observed." In the material selected for analysis the impurities noted by Lindgren were so far as possible removed.

The composition of each mineral reduces quite easily, in accordance with the methods followed in our former work, to a mixture of simple isomorphous types. The only uncertainties appear to be in connection with the loosely combined water, which is driven off below 300°. In the Henderson County mica we have the molecules

$$\mathrm{Al}\begin{cases}\mathrm{SiO_4{\equiv}MgK}\\ \mathrm{SiO_4{\equiv}MgH}\\ \mathrm{SiO_4{\equiv}Al}\end{cases}\quad \mathrm{Al}\begin{cases}\mathrm{SiO_4{\equiv}H_3}\\ \mathrm{SiO_4{\equiv}H_3}\\ \mathrm{SiO_4{\equiv}H_3}\end{cases}\quad \mathrm{Fe}\begin{cases}\mathrm{SiO_4{\equiv}MgH}\\ \mathrm{SiO_4{\equiv}MgH}\\ \mathrm{SiO_4{\equiv}Fe}\end{cases}\quad \mathrm{Fe}\begin{cases}\mathrm{O}\\ \mathrm{O}\end{cases}\!\!>\mathrm{Mg}\ \ \mathrm{Fe{-}SiO_4{\equiv}H_3}$$

in the ratio $8:1:3\frac{1}{2}:3$. The loosely combined water is in the proper amount to monohydrate the four molecules; but its actual distribution is uncertain. In the subjoined table monohydration is provisionally assumed. In the protovermiculite we have the three molecules

$$\mathrm{Al}\begin{cases}\mathrm{SiO_4{\equiv}H_3}\\ \mathrm{SiO_4{\equiv}H_3}\\ \mathrm{SiO_4{\equiv}H_3}\end{cases}\quad \mathrm{Al}\begin{cases}\mathrm{O}\\ \mathrm{O}\end{cases}\!\!>\mathrm{Mg}\ \ \mathrm{Al{-}SiO_4{\equiv}H_3}\quad \mathrm{Fe}\begin{cases}\mathrm{O}\\ \mathrm{O}\end{cases}\!\!>\mathrm{Mg}\ \ \mathrm{Fe{-}SiO_4{\equiv}Al}$$

each plus three molecules of water, in the ratio $14:6:9$. As in the case of jefferisite and kerrite, the three molecules of loosely combined water are unlike; two being given off over sulphuric acid, and the third retained rather more tenaciously.

Reducing the original analyses to 100 per cent, uniting all similar oxides to similar type, reckoning FeO as MgO, Na_2O as K_2O, TiO_2 as SiO_2, etc., we get the following comparison between observation and theory:

	Henderson Co.		Protovermiculite.	
	Found.	Calc.	Found.	Calc.
SiO_2	39·70	39·90	34·10	34·18
Al_2O_3	14·12	14·25	14·52	14·78
Fe_2O_3	13·11	13·15	7·72	7·20
MgO	16·32	17·08	22·41	22·79
K_2O	6·17	6·17	----	----
H_2O, essential	4·83	4·87	5·43	5·40
" hydration	5·75	4·58	15·82	15·65
	100·00	100·00	100·00	100·00

These results, taken in connection with our work on jefferisite and kerrite, and with the mica theory upon which all our formulæ are based, are exceedingly suggestive. Kerrite is essentially a trihydrated hydro-phlogopite. Protovermiculite is the same substance, commingled with a tri-hydrated hydro-clintonite, in the ratio 1 : 1 very nearly. Jefferisite is a similar mixture of hydro-biotite and hydro clintonite, also trihydrated, and in the ratio 1 : 1. The Henderson County mica is essentially a biotite, about half way transformed into a vermiculite, and is interesting as a transition product. The hydration of its several admixed molecules is naturally uncertain. At an early date we hope to imitate experimentally the process by which a mica becomes transformed into its corresponding vermiculite.

But although the above-named minerals appear to be very simple in their structure and relationships, a like simplicity does not characterize all of the vermiculites. In some members of the group there seem to be a small admixture of chloritic molecules, and it is even probable that many intermediate stages between mica and chlorite may exist. As bearing upon this question we have a series of vermiculitic minerals from Chester and Delaware Counties, Pennsylvania, some of which have already been studied by Cooke, Gooch, Leeds and others, while some have escaped examination hitherto. To begin with we may consider the hallite, from Nottingham, Chester County, and the vermiculites from Lenni, (not Lerni), Delaware County. The hallite, received through the kindness of Mr. W. W. Jefferis, was dark bluish green, and agreed perfectly with the published descriptions. The Lenni mineral, partly from the collection of the late Isaac Lea, and partly gathered in the field by one of us, is represented by several varieties, which in a large series of specimens, are seen to shade into each other. Three varieties were examined: one, silver white, resembling outwardly an ordinary mica; a second, bronzy brown, like jefferisite; and the third, dark green, similar to clinochlore. All four substances were examined microscopically by Mr. Lindgren, who found in the hallite some spear-shaped, rhombic, or more rarely hexagonal inclusions of a dark brown mineral, not further identified. His optical notes will be published in an official bulletin, later. Analyses as follows, with itemized water determinations:

	A. Hallite.	B. Lenni 1.	C. Lenni 2.	D. Lenni 3.
SiO_2	35·54	36·72	35·09	34·90
TiO_2	undet.	0·18	0·58	0·10
Al_2O_3	9·74	10·06	12·05	10·60
Fe_2O_3	9·07	5·37	6·67	8·57
Cr_2O_3	----	0·26	0·46	0·23
FeO	0·28	0·12	0·11	0·22
MnO	0·25	0·31	0·27	0·17
NiO	0·16	0·20	0·20	0·19
MgO	30·05	29·40	27·62	28·21
BaO	----	----	trace	----
H_2O, 105°	2·64	6·40	5·70	4·99
" 250°–300°	1·23	2·68	1·98	1·60
" red heat	10·91	8·69	9·22	9·88
	99·87	100·39	99·95	99·66
Loss over H_2SO_4	undet.	6·92	5·84	5·21

In these analyses we at once see that the combined water is mostly in excess of the crystalline water, and that the formulæ deduced must be correspondingly modified. The molecular ratios are as follows:

	A.	B.	C.	D.
SiO_2	·592	·614	·591	·583
R_2O_3	·152	·134	·163	·159
RO	·760	·744	·698	·712
H_2O, fixed	·606	·483	·512	·549
Aq.	·215	·504	·427	·366

In order to learn something as to the distribution of the hydroxyl indicated by these ratios, resort was had to the process of heating in dry, gaseous, hydrochloric acid, as described in our former paper. From this test, however, the brown Lenni vermiculite was omitted, as being intermediate in its character between the white and the green. Each experiment was made at the temperature 383°–412°.

	A.	B.	D.
Hours heated	16½	16	17
R_2O_3 removed	3·42	1·08	1·56
MgO "	8·09	6·30	6·57
Molec. ratio MgOH	·202	·158	·164

Here it is assumed, on the grounds of our former work, that the magnesia rendered soluble by gaseous HCl is present as

MgOH. Representing this by the symbol R′, the three vermiculites give the following empirical formulæ:

Hallite	$R'''_{304}R''_{558}R'_{202}H_{1010}(SiO_4)_{592}O_{436}$,	215 aq.
White Lenni	$R'''_{268}R''_{586}R'_{158}H_{808}(SiO_4)_{614}O_{259}$,	504 aq.
Green "	$R'''_{318}R''_{548}R'_{164}H_{934}(SiO_4)_{583}O_{408}$,	366 aq.

These reduce at once, subject to small uncertainties as to hygroscopic water, to mixtures of molecules of the hydro-clintonite and hydro-phlogopite types, with small amounts of chloritic compounds $Mg(SiO_4)_2(MgOH)_6$ and $Mg_2(SiO_4)_2H_4$. Upon this basis the three minerals become:

Hallite	$Al(SiO_4)_3Mg_3H_3$	3 aq.	7 molecules.
	$AlO_2MgSiO_4H_3$		18 "
	$Mg(SiO_4)_2(MgOH)_6$		3 "
	$Mg_2(SiO_4)_2H_4$		2 "
White Lenni	$Al(SiO_4)_3Mg_3H_3$	3 aq.	6 "
	$AlO_2MgSiO_4H_2$		5 "
	$Mg(SiO_4)_2(MgOH)_6$		1 "
Green Lenni	$Al(SiO_4)_3Mg_3H_3$	3 aq.	4 "
	$AlO_2MgSiO_4H_3$		8 "
	$Mg(SiO_4)_2(MgOH)_6$		1 "

The actual ratios observed were slightly more complex, but the foregoing expressions accord well with the analyses. Here, as previously, we may reduce the analyses to typical form and 100 per cent, reckoning Fe_2O_3 as Al_2O_3, etc. The comparison is as follows:

Analyses reduced.

	A (Hallite).	B (White).	D (Green.)
SiO_2	36·93	37·56	36·33
Al_2O_3	16·13	14·92	16·83
MgO	31·58	30·41	29·44
H_2O	11·34	8·86	10·26
Aq.	4·02	9·25	6·84
	100·00	100·00	100·00
MgO in MgOH	8·09	6·30	6·57

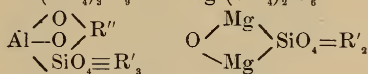
Calculated.

	A.	B.	D.
SiO_2	36·47	38·11	36·61
Al_2O_3	15·82	14·25	16·97
MgO	31·75	30·49	29·95
H_2O	11·27	8·92	10·47
Aq.	4·69	8·23	6·00
	100·00	100·00	100·00
MgO in MgOH	8·93	6·10	6·66

When we consider the nature of the vermiculites, as products of alteration, the agreement here shown is fully as close as could be expected. Many well crystallized minerals, fresh and unaltered, are less simply interpreted.

On the 19th of February, 1891, Professor Tschermak read before the Vienna Academy a paper on the chlorite group, in which he referred certain vermiculites to that class of minerals. He also put forth some views concerning the constitution of the chlorites, which, however, we cannot discuss until they have been published in full.* One fundamental molecule, regarded by Tschermak as a constituent of most chlorites, we may adopt for present purposes, under slightly different structural form from his. This is the "amesite substance, $SiAl_2Mg_2H_4O_9$, written by Tschermak $SiAl_2H_2O_7(MgOH)_2$. In default of experimental evidence this may be transformed into $OMg_2Si_4(AlH_2O_2)_2$, when it becomes part of a natural chloritic series parallel with the micas—thus:

Normal orthosilicate	$Al_4(SiO_4)_3$	$Mg_4(SiO_4)_2$
Whence we derive,	Micas.	Chlorites.
	$Al_3(SiO_4)_3R'_3$	$Mg_3(SiO_4)_2R'_2$
	$Al_2(SiO_4)_3R'_6$	$Mg_2(SiO_4)_2R'_4$
	$Al\ (SiO_4)_3R'_9$	$Mg\ (SiO_4)_2R'_6$



In other words, the "amesite substance" in our chlorite series is the basic equivalent of the clintonite molecule among the micas, and is applicable to the solution of certain obscure problems. Some of the vermiculites, as Tschermak suggests, are probably chlorites, and two examples have come under our notice in which this view is partly sustained. Both were originally received from Mr. Jefferis; one from the corundum mine at Newlin, Chester County, Pa., and the other from Middletown, Delaware County, in the same State. The Newlin mineral was dull green, and much resembled culsageeite both outwardly and optically. The Middletown vermiculite was bright golden yellow; strongly exfoliating before the blowpipe and fusible on the edges. It was found upon the farm of Mr. James Painter, whence Mr. Jefferis named it provisionally "Painterite," a name which seems also to have been applied to a peculiar brownish, waxy, feldspathic matrix in which the broad golden laminæ were imbedded. A second sample of it was later collected by one of us. According to

* This paper has appeared in extenso since this was written. We cannot, however, discuss it thoroughly at present.

an optical examination by Mr. Lindgren the matrix of the "painterite" is a mixture of plagioclase, probably labradorite, with serpentine. The "painterite" itself shows hexagonal markings on the surface, and contains, Mr. Lindgren says, inclusions of ferric oxide. Optically he found it to show slight double refraction between crossed nicols, the angle of the optical axes being small but distinct. In the Newlin mineral the axial angle was usually large, being at least 25°. Analysis as follows: A, Newlin. B, Painterite from Jefferis. C, Painterite collected by Schneider. D, matrix of painterite.

	A.	B.	C.	D.
SiO_2	31·23	34·86	33·95	52·47
TiO_2	----	trace	trace	none
Al_2O_3	17·52	11·64	12·52	21·72
Cr_2O_3	0·14	----	----	----
Fe_2O_3	4·70	3·78	4·40	1·23
FeO	1·20	0·20	0·20	0.17
MnO	0·20	----	----	----
NiO	0·33	0·14	0·23	----
MgO	31·36	31·32	30·56	9·26
CaO	----	0·07	none	3·25
K_2O	----	----	----	0·63
Na_2O	----	---	----	5·09
H_2O, 105°	1·08	1·64	1·56	1·14
" 250°–300°	0·40	1·03	0·59	----
" ignition	12·15	15·75	16·46	4·74
	100·31	100·43	100·47	99·70

Upon treating the three vermiculites with gaseous hydrochloric acid at 383°–412°, the following results were obtained:

	A.	B.	C.
Hours heated	8	12½	19
R_2O_3 removed	1·09	·80	·78
MgO "	5·86	8·26	9·56
Molec. ratio MgOH	·146	·207	·239

The molecular ratios are:

	A.	B.	C.
SiO_2	·520	·581	·566
R_2O_3	·202	·138	·150
RO	·808	·789	·770
H_2O	·675	·875	·914
Aq	·080	·148	·119

In these examples the water (Aq) expelled below 300° is so small in amount that it may be left out of consideration. Part of it undoubtedly represents hydrated molecules, which, however, are relatively so few in number that they may be for present purposes disregarded.

From the remaining ratios, writing MgOH as R′, the subjoined empirical formulæ are directly derived:

Newlin	$R'''_{404}\ R''_{662}\ R'_{146}\ H_{1204}\ (SiO_4)_{520}\ O_{903}$.
"Painterite" B.	$R'''_{276}\ R''_{582}\ R'_{207}\ H_{1543}\ (SiO_4)_{581}\ O_{709}$.
" C.	$R'''_{300}\ R''_{531}\ R'_{239}\ H_{1589}\ (SiO_4)_{566}\ O_{763}$.

Reduced to structural form these give less satisfactory results than the previously considered vermiculites. The Newlin mineral may be regarded as nearly a hydroclintonite, $AlO_2MgSiO_4H_3$ with an admixture of an amesite-like compound $Mg_2OSiO_4(MgOH)_2$ in the ratio 4:1. In reality the mixture is more complicated, and must contain other molecules. The "painterite" C, is wholly chloritic, containing the amesite molecule $Mg_2OSiO_4(AlH_2O_2)_2$, with the molecules $Mg(SiO_4)_2(MgOH)_6$ and $Mg(SiO_4)_2H_6$, in the ratio 16:4:18. These compare with the actual analyses, reduced to typical form and 100 per cent, thus:

	Newlin.		"Painterite."	
	Found.	Calc.	Found.	Calc.
SiO_2	32·42	31·57	35·03	35·59
Al_2O_3	21·39	21·47	16·22	16·13
MgO	33·57	33·69	31·77	30·84
H_2O	12·62	13·27	16·98	17·44
	100·00	100·00	100·00	100·00
MgO in MgOH ..	6·09	8·42	8·56	9·49

The "Painterite" B reduces less easily, but satisfies all the required conditions. It is like C, but contains other chloritic molecules in somewhat complex ratios. It must be remembered that all these minerals are *mixtures*, and the fact that they are reducible at all to simple expressions is a strong point in favor of the theory adopted for the chlorites and micas in general.

A very interesting example of the way in which the chloritic vermiculites approach the serpentines in composition and character has been furnished us by Mr. G. P. Merrill of the U. S. National Museum. It was found by him at Old Wolf Quarry, Chestnut Hill, Easton, Pa., and is described by him as follows:

"It occurs in the form of bright yellowish green inelastic scales of all sizes up to an inch in diameter, associated with a compact tremolite rock which is here quarried and pulverized for use as a filler in paper manufacture. The character of the rock is greatly varied, but at the quarry opening the prevailing material is tremolite more or less altered into serpentine, the vermiculite, and other secondary products, including calcite in both fibrous and granular forms.

The vermiculite, although occurring in plates of considerable thickness readily separable into thin foliæ, never, so far as observed, shows good crystal outlines. Optically it is biaxial and negative, though the axial angle is small, basal plates in the thin section showing a black cross which scarcely opens at all during the revolution of the stage. Cleavage plates a millimeter or more in thickness show plainly the biaxial character, though the figure is somewhat distorted. Dispersion $\rho < v$.

The surface of the plates is at times plainly marked by sharp lines crossing at angles of 60° and 120° and along which the mineral frequently separates readily. Before the blowpipe the mineral exfoliates and fuses readily on the edges to a thin glass."

According to Mr. Merrill this mineral is sometimes seen in cabinets labelled "talc;" and indeed in its appearance it resembles both talc and serpentine. Upon analysis the following results were obtained, the percentage of K_2O representing two identical determinations.

	Analysis.	Molec. ratios.
SiO_2	43·71	·728
Al_2O_3	3·59	·035
Fe_2O_3	0·90	·006
MgO	38·58	·964
K_2O	2·22	·023
Na_2O	0·13	·002
H_2O, 105°	0·46	----
" 250°–300°	0·09	----
" ignition	10·70	·594
	100·38	

Treated with dry, gaseous HCl at 383°–412° for 16½ hours, 4·36 per cent of magnesia became soluble, corresponding in molecular ratio to 109 mol. MgOH. Hence the mineral, although resembling serpentine in general composition, differs from the latter in its proportion of this molecular group.

Upon treatment with aqueous HCl of sp. gr. 1·12, a small portion remained undecomposed. Ten grams of the mineral were therefore digested with the acid for three days on the water-bath, and the residue was afterwards boiled out with a solution of sodium carbonate to remove liberated silica. The remaining residue, amounting to 3·10 per cent of the original material, was then analyzed separately, and found to contain:

SiO_2	64·53
Al_2O_3, Fe_2O_3	2·03
MgO	33·04
	99·60

All the potash went into solution; whence it seems probable that no muscovite was present. The ratios of the insoluble residue agree very closely with those of talc, and we may therefore assume that mineral to be present as an impurity. Deducting from the molecular ratios given above the quantity of talc indicated by experiment we get for the empirical formula of the mineral the expression

$$Al_{82}K_{50}Mg_{938}H_{1170}\ SiO_4)_{695}O_{281},$$

which becomes, if the excess of oxygen is regarded as hydroxyl, with $(MgOH)_{109}$ as observed,

$$Mg_{829}K_{50}H_{889}(MgOH)_{109}(AlH_2O_2)_{82}(OH)_9.$$

The small excess of hydroxyl is probably due to undistributed errors of analysis, and may be added to the MgOH, bringing the latter to 118, and reducing the Mg to 820. Then, generalizing, by uniting all the univalent groups and atoms we get as an ultimate formula

$$Mg_{820}(SiO_4)_{695}R'_{1139},$$

which equals, almost exactly,

$$125\ Mg_3(SiO_4)_2R'_2 + 223\ Mg_2(SiO_4)_2R'_4,$$

a result in accordance with our serpentine-chlorite theory. The distribution of the several components of R′ is, however, not clear, and remains to be ascertained. No other discussion of the analysis appears to give as satisfactory results as this, and we have tried several methods of reduction, representing various hypotheses.

One other mineral examined during this investigation remains to be noticed; a pale yellowish-green mica collected by Mr. G. P. Merrill at a granite quarry in Auburn, Me., near where the Maine Central railroad crosses the Androscoggin river. It occurs in direct contact with ordinary, broadly foliated muscovite, sometimes forming marginal growths about the plates of the latter mineral, like lepidolite. Analysis gave:

SiO_2	46·54
Al_2O_3	34·96
Fe_2O_3	1·59
MgO	0·32
K_2O	10·38
Na_2O	0·41
F	none
H_2O, 105°	0·71
" ignition	4·72
	99·63

This is the composition of muscovite, which the mica undoubtedly is. The case is interesting, however, as showing a secondary growth of muscovite on muscovite, with a marked difference in outward appearance between the two formations.

Laboratory U. S. Geological Survey, Washington, D. C., April 27, 1891.

ART. XXIV.—*A Further Note on the Age of the Orange Sands;* by R. D. SALISBURY.

IN a recent number of this Journal, President Chamberlin and the writer set forth what seemed to us sufficient reasons for believing the whole of the Orange Sand series of sands and gravels to be of Pre-pleistocene age. The arguments there adduced we still believe to be sufficient to warrant the conclusions drawn from them.

Since that article appeared, some new facts have come to our knowledge which afford new and more direct proof of the correctness of the position then taken. Until this season's work in the field began, it was not known to us that the Orange Sand gravels reached so far north as the southern border of the glacial drift. They had been searched for along the southern border of the drift north of the area where they are best known, in the hope that they might be found beneath the glacial deposits, but this search had been fruitless, so far as the particular question at issue is concerned.

During the early part of this season's field-work, the writer spent some time in the region between the Mississippi and Illinois rivers above the point of their junction. In this region, in the counties of Calhoun, Pike, Adams and Hancock, the Orange Sand gravels were found to obtain a considerable development. These counties are well north of the southern limit of the glacial drift, and the gravel is uniformly found to occupy a position beneath it. Among other places, this relationship is well shown near Bloomfield, Adams county, where till may be seen resting directly on the brown flint gravels. Here, as at several other localities, the gravel is cemented by iron oxide into a firm conglomerate, though at other points but a few rods away, the gravel is but partially or not at all cemented. It will be remembered that this habit of being firmly cemented at one point, and nearly or altogether free from cement at another, is one of the prominent characteristics of the gravel farther south.

But the Pre-pleistocene (presumably Tertiary) series of the counties named is not limited to the brown flint or "Orange" gravels. Accompanying these, there are very considerable beds of sand, essentially like those accompanying the corresponding gravels to the south. These are best exposed, so far as the writer's knowledge goes, a short distance south of Liberty, Adams county, but they have a considerable development in various parts of this county. At the above locality, till may be seen resting on the sand.

Apart from the obvious proof of the preglacial age of these gravels and sands afforded by the superposition of the drift upon them, the character of the till affords a further proof of the same thing. If the sands and gravels occupied the region before the ice invasion, they should have made their contribution to the drift. This they have done, and so generously that at many points and over considerable areas the character of the drift has been in very large measure determined by this contribution.

To the arguments adduced in the article referred to above for the Pre-pleistocene reference of the Orange Sand gravels and sands, must now be added the further arguments of (1) superposition of the earlier glacial drift upon them, and (2) the contribution of these sands and gravels to this drift.

Subsequent to the writer's determination of the existence of Pre-pleistocene material in the region indicated, reference to the reports of the Illinois Geological Survey revealed the fact that in the reports on Pike and Hancock counties, the Illinois geologists had made note of the fact that ferruginous flint gravels occur beneath the drift in these counties, and that they had further correlated them with the gravels in the southern part of the state. To them, therefore, belongs the credit of the first recognition of these gravels, as wholly distinct from the drift.*

ART. XXV.—*Note on the Causes of the Variations of the Magnetic Needle*; by Professor FRANK H. BIGELOW.

IN May, 1890, I published in Bulletin No. 18 of the U. S. Scientific Expedition to West Africa, a preliminary statement of a new theory of terrestrial magnetism which had been conceived in order to account for the observed variations of the free magnetic needle. Since that time my efforts have been directed towards obtaining a clear conception of the mode of action of the forces whose relations were indicated in the Bulletin, and I am now prepared to add a note as a further preliminary statement of the progress made in this study.

On re-examination of the mode of analysis already published, I find that the main conception is not to be modified and that the successive steps are correct. When making an attempt to reduce the observations by means of this treatment, namely, the combination of current functions by the use of harmonics, it was evident that a very complex system of computation

* I am unable at this writing to refer to the Illinois reports, and therefore cannot cite the exact references to the statements therein made. R. D. S.

would be required. My endeavor was, therefore, to simplify the fundamental treatment so as to secure not only a sound theory, but also a working process for handling the observations. To do this two distinct sets of trial computations were made, first by the theory of moments about the rectangular axes whose origin was in the spherical surface passing through the north end of the needle, concentric with the surface of the earth, and forming equations whose solution would give the required constants of the phenomenon. This also failed to be sufficiently simple and direct to show the action in its general relations. The second attempt was an empirical one, for the time abandoning theory, and building up from the simultaneous observations in various parts of the earth such an exhibition of facts as would display the real nature of the laws behind them. This trial has been successful far beyond anticipation, and that too in a simple and practical form. The theory is at best complicated, as it depends upon the laws of magnetic induction in their most complex conditions, but it unifies and classifies harmoniously all the visible motions of the needle.

My method and result are, briefly, as follows: The month of June, 1883, was selected because of the material collected in the publications of the International Polar Commission applicable simultaneously over a large area of the earth, also because the north polar stations were at that time exposed to sunlight throughout the twenty-four hours. The stations used were: Point Barrow, Fort Rae, Kiugua Fjord, Jan Mayen, Bossekop, Sodankylä, Pawlowsk, Wilhelmshaven, Vienna, Tiflis, Za-Ki-Wei, Cape Horn, South Georgien. The monthly means for each hour local time of the horizontal and vertical forces and the declination were reduced to the coördinates, x positive to the north in the mean magnetic meridian of the month, y positive to the west, z positive inwards along the normal, the plane xy being the horizon at the surface of the earth or through the north end of the needle. The differences between the mean and the hourly values, namely ΔH, ΔD, ΔZ, were plotted on paper, smoothed out, the resulting values dx, dy, dz, combined to show the total deflecting force at the station with its magnetic azimuth and altitude, this form of azimuth being finally transformed into north geographical azimuth. My idea was that the needle floating freely in a magnetic line indicated simply its direction, and that the deflections were produced by a component coming to it from space, the motive being to discover the condition of such components over the earth at the same time. Next, a large model was constructed on which these component forces were represented in direction and magnitude. By assigning certain meridians for the hours, and supposing the permanent pole to take up its position from one meridian to another, there was finally collected upon these meridians representing a series of local hour angles, now referred to the sun as if the earth had ceased to rotate on its axis, an exhibition of what exists over the globe at the same instant of time.

The result is most interesting and gratifying, but I can only indicate now what could be elaborated by a mass of computations. It is difficult to convey any view of the complicated system of lines of force produced by inserting a magnetized or polarized sphere in a field of force, supposing the sphere at rest; if it rotates it is much more troublesome. These references, however, may be cited: Sir W. Thomson in § xxxii, p. 486, Papers on Electrostatics and Magnetism, illustrates some of the forms produced in the case of symmetry, that is, the axis of polarization being parallel to the field; in article 434, Vol. II, Maxwell's Electricity and Magnetism a similar illustration is found; in article 436 of the same is given an example of the sphere being placed at an angle to the field. The mathematical treatment of these cases, when once the constants involved are known, leads to certain typical lines of force entering the sphere at definite angles corresponding to the latitude of the point. Furthermore when the sphere is rotated the whole system recedes through an angle depending on the constants, as indicated in the Bulletin. My model gives the angles and directions corresponding to such a system, if we take the *radiant sunlight as the uniform field of force, directed positive towards the sun.* The entering and emerging forces are on the respective sides of the earth, and the whole system is receding by about twenty-three degrees. The peculiar form of the polar station lines and the inclination of their planes of action to the meridians is well displayed. The stations all over the world bear the same testimony. The action of the coronal field is entirely similar but not strong enough to appear on the model. The separation of the two fields is merely a question of close computation.

There remains one more important point. The positive direction of the earth's permanent magnetism is from the north towards the south side of the ecliptic y, the uniform field is positive towards the sun z, the motion of the earth in its orbit x, is perpendicular to the field. If these are taken as the usual rectangular x, y, z, they form a consistent positive or right-handed cyclic system. In a word, the permanent magnetic condition of the earth may be principally due to the orbital motion of the earth through the radiant field of sunlight. The rotation of the earth on its axis causes a modification of the direction of the axis of polarization, by diminishing the angle between the two axes, and as the result of the annual motion may cause it to rotate in a secular period about the axis of figure, or if the magnetization has already become set in the body of the earth, may cause a succession of secular waves to sweep over it from east to west, as is shown to be the case in the history of the agonic lines and the long period deflections of the needle.

This surprising identification of magnetic and light action of the radiations of the sun in direction will be recognized as harmonizing with the conclusions arrived at by Maxwell and Hertz in their investigations. If light is to be studied as a magnetic phenomenon it adds a large field to the work allotted to meteorology. Furthermore, several important physical constants relating to the cosmical action of the sun and the earth, and also the implied nature of the sun and the earth as physical bodies are becoming accessible. Attention is directed to the fact that such a force acting towards the center of the sun, being cosmical or universal, is of the kind required to account for the outstanding motion in the perihelion of Mercury, not included in the development or the law of gravitation or its positive side. My next step is to form the necessary equations of condition and solve them for the constants involved in the magnetic observations.

Washington, D. C., July 31, 1891.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY.

1. *On Boron tri-iodide.*—According to MOISSAN, boron tri-iodide can be obtained in three ways: either (1) by passing boron chloride and hydrogen iodide through a red hot porcelain tube, (2) by acting with iodine upon boron directly at 700°—800°, or (3) and most conveniently by acting upon amorphous boron, previously dried in a current of hydrogen at 200°, with dry hydrogen iodide gas, the boron being heated in a combustion tube to a temperature near that of the softening of the glass. In this way purple colored scales are obtained containing some free iodine; from which they may be freed by solution in carbon disulphide agitation with mercury, and evaporation of the solvent. The boron tri-iodide thus obtained is colorless but becomes colored on exposure to light. It is very hygroscopic, fuses at 43°, boils at 210°, burns in the air at a red heat, has at 50° the approximate density of 3·3 and is easily soluble in carbon disulphide, carbon tetrachloride and benzene. By water it is decomposed into boric and hydriodic acids, and it reacts with phosphorus, silver fluoride and magnesium (at 500°) with combustion; though not with

aluminum, sodium or silver. With alcohol and ether it reacts, yielding ethyl iodide and ortho-boric acid in the former case and ethyl iodide and ethyl ortho-borate in the latter.—*C. R.*, cxii, 717; *Ber. Berl. Chem. Ges.*, xxiv, (Ref.) 387, May, 1891.

G. F. B.

2. *On Hydrazine hydrate and the compounds of Diammonium with the Halogens.*—The researches of CURTIUS and SCHULZ have shown that hydrazine hydrate $N_2H_4 . H_2O$, prepared by distilling the sulphate with potassium hydrate, is a liquid boiling at 118·5° under 739·5 mm. pressure and having at 21° the specific gravity 1·0305. Its molecular mass at 100° in vacuo is 50, corresponding to the formula $N_2H_4 . H_2O$. At 170° under the ordinary pressure, the hydrate is completely dissociated into diamide and water. At higher temperatures the molecular mass diminishes markedly not reaching 50 again at ordinary pressures even at 300° to 400°. In a lead bath, however, numbers approaching 100 were obtained. Hydrazine hydrate in aqueous solution gave approximately the molecular mass 68, corresponding to the composition $N_2H_4 . (H_2O)_2$. Comparing this hydrate with ammonia, as to its action on indicators, this action was shown to be as sharp in all cases except that of phenol-phthalein. When aqueous solutions of hydrazine are neutralized with a haloid acid, and evaporated first on the water-bath, then over potassium hydrate, halogen-diammonium salts are formed, by preference with two equivalents of acid. The bromide and iodide with one equivalent of acid are formed when the free halogen is made to act on an alcoholic solution of hydrazine, a portion of the hydrazine being decomposed. The bi-acid salts crystallize in the regular system, are soluble in water, almost insoluble in alcohol. The mon-acid salts are easily soluble in water and warm alcohol. Tri-hydrazine di-iodhydrate $N_6H_{12} . (HI)_2$ is formed when iodine is added to an alcoholic solution of hydrazine so long as crystals appear. As to the molecular mass of the halogen diammonium compounds in aqueous solution, it is found to be with the mono-halogenides, the difluoride and the sulphate equal to one-half, with the di-halogenides generally equal to one-fourth and with the tri-hydrazine di-iodhydrate equal to one-fifth the simplest formula.—*J. pr. Ch.*, xlii, 521; *Ber. Berl. Chem. Ges.*, xxiv, (Ref.) 256, Apr. 1891.

G. F. B.

3. *On the Synthesis of Indigo-carmine.*—HEYMANN has succeeded in effecting the synthesis of indigo-carmine, the disulpho-acid of indigo, by acting upon phenyl-glycocoll with fuming sulphuric acid. If, for example, phenyl-glycocoll be mixed in a test tube with ten to twenty times its mass of fuming sulphuric acid containing 20 to 25 per cent of sulphuric oxide, and gently warmed, it dissolves with a yellow color, evolving sulphurous oxide gas. On pouring the solution upon ice, it rapidly assumes the greenish blue color of indigo-carmine. For its production, the following method gives the best results: One part of phenyl-glycocoll is mixed with 10 to 20 parts of sand and then intro-

duced into 20 times its mass of fuming sulphuric acid, warmed to 20° or 25°, containing 80 per cent sulphuric oxide; the temperature not being allowed to rise above 30°. The glycocoll goes easily into solution with a yellow color which at once with evolution of sulphurous oxide passes into the deep blue color of the indigo-solution. To remove the concentrated acid, the mass is diluted with sulphuric acid of 66° B. The coloring matter is isolated by farther dilution with ice and the addition of salt. As so prepared the product is completely pure indigo-carmine. The colors obtained in dyeing with it far exceed in brilliancy those obtained from the best varieties of commercial indigo. Its identity with the natural product was established by means of its chemical reactions, by dyeing tests and by spectroscopic examination. The yield is about 60 per cent of the glycocoll taken.—*Ber. Berl. Chem. Ges.*, xxiv, 1476, May, 1891. G. F. B.

4. *Leçons sur les Métaux*, professées à la Faculté des Sciences de Paris. Par ALFRED DITTE, Professeur de Chimie à la Faculté. Premier Fascicule. 4to, pp. 44, lviii, 621. Paris, 1891. (Vve Ch. Dunod.)—To judge from the part of Professor Ditte's book now before us, the complete work will be a valuable addition to chemical literature. It is written largely from the standpoint of energy. In his preface the author says: "The principles of Thermo-chemistry and the consequences which flow from them, teach us not only to explain reactions, but also frequently to foresee them and to discover in advance what phenomena will be produced when two or more substances are put together under determined conditions. On the other hand when two reactions are simultaneously possible the laws of dissociation enable us to define rigorously the conditions of eqilibrium which must be established between them. In general a rational application of these principles and these laws enables us to say, often even before making the experiment, why one given reaction is certain to result, while another reaction is impossible; why an action which begins without difficulty, ceases after a time; and finally why a particular phenomenon occurring under certain circumstances, does not take place under other circumstances entirely similar apparently in appearance." The introductory portions of the book are therefore devoted to calorimetry and the general principles of Thermo-chemistry as laid down by Berthelot. In the First part, a general study of the metals is given, covering about four hundred pages. It includes the principles of metallurgy, the physical properties of the metals and their alloys, their compounds with the non-metals, the action of water, acids, etc., on the metals, and lastly metallic salts. The Second part is devoted to the study of the metals specially. Throughout the book all the reactions are given as energy-reactions, and represent the heat-changes concerned, thus:

$$SnCl_2 + 2HO = SnO_2 + 2HCl_{diss.} + [67{\cdot}9 + 2.39{\cdot}3 - 64{\cdot}6 - 2.34{\cdot}5]$$
$$[+ 12{\cdot}9].$$

The notation used in the book is the old equivalent notation; which seems unfortunate since it is not in accord with that based on the atomic theory now generally employed. The great advantage of considering the heat-changes in all reactions, and the evident care with which the descriptive part has been written, will make Professor Ditte's book acceptable to the chemist. We shall look with interest for the remaining parts. G. F. B.

II. Geology and Natural History.

1. *Composition of the Till or Bowlder-Clay;* by W. G. Crosby (Proc. Bost. Soc. Nat. Hist., xxv, 1890).—In this paper Professor Crosby gives the results of an investigation of the glacial deposits in the vicinity of Boston. His analyses show that the proportion of true clay in the till is small and that of rock-flour, or very finely pulverized rock, is large. He concludes that the proportion of stones over two inches in diameter is not over 5 to 10 per cent. His results give for the gravel, 24·90 per cent; the sand, 19·51; the rock-flour, 43·86; the clay, 11·67 = 99·94. In his table, each of these divisions of the material, is farther subdivided into coarse, medium and fine. Moreover, he gives his results for each of the different localities studied. In the redistribution of the material by the glacial flood, the rock-flour goes with the clay, adding to its volume, so that the clay-beds embrace fully half of the original material of the till. The rock-flour was found to be essentially quartz-flour—this being the final result of disintegration and the consequent decomposition—according with Daubrée's observation that the milky turbidity of the Rhine, even for hundreds of miles from the Alpine glaciers, is due chiefly to impalpable quartz. It is further concluded that of the material of the till, one-third is probably of preglacial erosion, and two-thirds of glacial erosion. The amount of rock-flour is evidence in favor of this. But the fact does not, Professor Crosby observes, lend support to the view that the glacier "profoundly modified the topography of the glaciated area." These are a few of the important facts and conclusions in Professor Crosby's excellent paper.

2. *Geology of the Rocky Mountain Region in Canada with special reference to changes in Elevation and to the History of the Glacial Period;* by Dr. G. M. Dawson.—The eighth volume of the Transactions of the Royal Society of Canada, contains, among its papers, the very valuable Presidential Address of Dr. G. M. Dawson on the above subject. The Mesozoic and Tertiary history occupies 22 pages, and the Glacial history the following 50 pages.

3. *The Greenstone Schist areas of the Menominee and Marquette regions of Michigan;* by Professor G. H. Williams. 218 pp. 8vo, with plates and cuts. Bulletin U. S. Geol. Survey, No. 62.—The important subject here discussed ably and with great fulness, by the author is—the Methods in which a massive crys-

talline rock may be modified by the action of orographic forces. The three methods mentioned—the Macro-structural, Micro-structural and Mineralogical, are severally considered, and the results under each, as recognized by the author, are described in detail, and illustrated by his microscopic study of the Greenstone schist and the associated rocks.

4. *Some Botanic Gardens in the Equatorial Belt and in the South Seas.* (Second paper.)—The voyage from Colombo, Ceylon, to Adelaide, South Australia, is not far from 4,400 miles, After leaving the harbor, land covered with tropical vegetation and shores fringed with mangrove are kept in sight, until the once prominent port at Point de Galle sinks from view, and then a fairly straight run is made for Cape Leeuwin. Rounding this, the distant shores of West Australia are skirted as far as the Head near King George's Sound, at Albany, after which no land is seen until Kangaroo Island is reached about the fourteenth day out. The landing is made in a steam launch which runs in all weathers, sometimes in pretty rough water, through an open roadstead, up to a jetty at the Semaphore, the terminus of a suburban railway leading to the City of Adelaide. Passengers by the Peninsular and Oriental line land at Glenelg, a little farther south.

The clouds of grasshoppers which met us at the landing did not presage a very happy condition of things in the fields and gardens. But the mischief thus far wrought by them had been local and hardly so severe as had been dreaded. It was now the middle of December (the southern summer) and the ground seemed dry, but the crops around the city were in good color and strong.

For a comparatively new city, Adelaide is fairly well shaded with trees. The suburbs are attractive. Northeast of the city proper, and within a few minutes walk from the principal streets, the University and the Botanic Garden are found near together.

Adelaide.—The Botanic Garden occupies an area of about forty acres, and adjoins parklands which are used as an arboretum. From his entrance at the main gate, throughout his whole tour of the garden, the visitor is struck by the more or less successful attempts at decorative management of shrubbery and marble statuary, indicating that there has been a desire to make a place which is easily accessible very attractive to the public. The result is generally pleasing; in fact, it is all good, except in the case of the water, which leaves much to be desired.

Australian plants are represented by pretty good specimens, but the conditions for culture are not favorable. The soil appeared thirsty and for the most part light; hence the fair success attained shows excellent judgment in cultivating. As will be seen by the photographs at Cambridge, the large specimen trees would be a credit to any garden, and the groups of European florist-plants are about as good as one could expect to see anywhere. It was said to me that these European groups are among the main attractions of the garden to the citizens. The citizens with whom I conversed were justly proud of the establishment.

The Victoria regia house is one of the principal features of the garden, but the condition of the plants at the time of my visit was a disappointment. It seemed as if the method of heating by water from an open boiler might be at fault. It was not easy to see how the water could contain as much air as in the ordinary method of heating by pipes through the tank, and it appeared as if this was at the bottom of the mischief.

The other houses looked well for the season. The selections in them appeared judicious and many individual plants were of exceptionally good growth. Considerable prominence was given to horticultural, and, one may say, utilitarian aspects of vegetation. This doubtless serves to augment the interest felt by the general public, from whom directly or indirectly all the funds come.

A Museum for economic botany, well-arranged, and full of good illustrations of the subject, occupies a conspicuous place in the grounds. Its most attractive department is a collection of the leguminous plants which have proved pernicious to stock. The carpological series is good, and the products of the useful plants are well displayed. In a separate apartment was seen the herbarium of the director, Dr. R. Schomburgh, who was even then prostrated by illness which has since terminated fatally.

Although confined to his room and a great sufferer, the venerable Director received me on two occasions and conversed freely about his plans, all of which looked in the direction of increasing the local interest in Botany and Horticulture.

Very profitable botanical excursions can be made from Adelaide. The hand-book for the neighborhood is a recent Flora by Professor Tate of the University. It is handy and accurate. Visitors who may have time for botanical studies in any of the Australasian colonies should be reminded that in almost every large city there can be found a botanist or two well acquainted with the most desirable localities for herborizing. Judging from my own experience in obtaining their advice, these local botanists are not easily wearied in well-doing. Some of the local collections are enriched by notes taken on the spot, and possess great interest.

Melbourne.—It was my good fortune to make the journey from Adelaide through Ballaarat to Melbourne in company with Mr. Samuel Dixon, of South Australia, who has acquired an excellent knowledge of the flora, and has occupied himself with some of the more interesting industrial questions connected with the forage plants of the Colonies. The first and last part of this railway journey of about 500 miles was made in the afternoon and early morning, and gave a glimpse of high lands and of the dreary desert scrub, with here and there a view of good soil and rich growth.

In passing, it may be noted that the railway journey northeast from Adelaide to the famous silver mines at Broken Hill in New South Wales brings before the tourist capital illustrations of true Australian deserts. In fact, the town of Broken Hill lies within sight of one of the spots where the great explorer Sturt was imprisoned by the lack of water. The scanty vegetation furnishes, as so many Australian plants elsewhere do, striking instances of adaptation to a dry climate; the locality is so readily accessible that it should not be left unvisited. Mr. Dixon gave many facts relative to the utilization of deserts and of desert plants in that region, which he has incorporated in an instructive article published in the Proceedings of the Royal Society of South Australia (vol. viii).

I had also the benefit of Mr. Dixon's guidance, the following day, in my first informal visit to the Botanic Garden of Melbourne.

The garden is about a mile south of the city itself, and lies on the narrow river, the Yarra, which flows through Melbourne. The situation is good, but the soil in some parts is far from the best. The Australian flora is represented by fine old specimens, if one can call anything old in such a new country, and by young plants which have been added in recent years.

The garden abounds in effective views which are much appreciated by the citizens. As in all new countries, for instance, our own, there is a good deal of pleasant rivalry between the larger places; in the botanical gardens of Australia there is found a convenient object for comparison. The judicious visitor cannot go far wrong in his answers to anxious inquiries as to respective excellences of the gardens, where there is so much to please and so little that calls for unfavorable criticism.

In the Melbourne Garden the most attractive groups of plants are (1) the Proteaceous, composing a striking mass of shrubs and small trees many of which happened to be in flower: (2) the Eucalypts, by no means all of them equally good as representatives, but most of them having distinctive characters recognizable as a whole; (8) the Myrtaceæ, and the Acacias.

The best photographs of the Melbourne garden are those which show the groups in question, and two in which the Governor's residence is seen in the distance. The Director is much embarrassed by the peculiar condition of the labor question in Australia. Somewhat similar difficulties arise wherever the one in charge cannot employ or dismiss the workmen for whose good work he is held responsible.

Mr. W. R. Guilfoyle, the Director, with his capable assistants, is organizing a Museum of Economic Botany, and bringing together other appliances for the illustration of botany.

Not very far from the Garden lives Baron Ferdinand von Mueller, Government Botanist. He is surrounded by his Herbarium and Library to which he has devoted his life and fortune. The correspondence which he carries on is incredibly voluminous, and it is understood to be conducted wholly with his own hand.

His Handbook of Victorian Plants is easy to use after one becomes accustomed to the dichotomous arrangement, and it is very helpful in the minuteness of its descriptions. The Baron has done hard work in economic botany as applied to Australia and in the endeavor to make the useful plants of the colonies better known in the Old World and in America. As everybody knows, such work is always a thankless and ungracious task, for the mistakes and failures in the introductions are likely to outnumber the successes. In everything concerning the advancement of the colonies, Baron Mueller has taken a hearty interest and is in every way identified with his adopted home.

Besides the incipient economic Museum at the Botanic Garden and the large collections under the charge of Baron Mueller there is an interesting botanical department connected with the Melbourne Museum. This is under the direction of Mr. J. Cosmo Newbery, and is now being re-arranged previous to its final disposition in the new Museum building. The specimens which illustrate the cereals and their products were nearly arranged at the time of my visit and indicated that the new system would be successful from an educational point of view.

The environs of Melbourne include many municipalities which are commonly counted in with Melbourne proper, when the city is compared with its sister cities. Passing outside the circle of associated communities, the botanist comes upon very instructive botanical ground. One does not have far to go by rail to stand before the giant specimens of Eucalyptus, and by boat to be in the presence of queer Australian plants, like Epacris and so on, growing wild.

Sydney.—The third great Australian Garden is in New South Wales, about six hundred miles from Melbourne, Victoria. For beauty of situation it stands without a rival. It has a commanding position on the shore of the harbor, and possesses remarkable elements for landscape treatment.

The harbor of Sydney (Port Jackson) is one of the most celebrated in the world, usually being associated with that of Rio de Janeiro, as the finest in existence. Like outstretched divergent fingers, promontories extend into this charming sheet of water. On parts of the slopes of two of these the Botanic Gardens, covering about forty acres, have been established. As was to be expected, the representation of native plants is somewhat different from that in the other gardens, owing to difference in the climate. In certain directions, for instance, palms from the smaller islands of the Polynesian archipelago, the garden is exceptionally rich. The specimens are numerous and well grown. A good deal of attention has been paid also to economic plants. The most interesting photographs which I could secure were (1) Individual plants; (2) the Palms of Lord Howe's Island, etc.; (3) the general view from the brow of the hill. To Mr. Charles Moore, the director, I am indebted for many views of the garden, taken some time since. The collection of all these now at Cambridge illustrates fairly well the wide range of cultivation possible in this favored climate.

Botany Bay of the early navigators lies within easy excursion distance of the city of Sydney. There and in the contiguous peninsulas, one can see growing wild the native plants which gave the place its appropriate name.

In point of fact, the garden at Sydney was visited considerably later by me than those at Adelaide and Melbourne, a journey through Tasmania and New Zealand intervening. But it has seemed best to bring the three larger gardens together in a single sketch, reserving the visit to the economic museum in Sydney for a third communication.

Before leaving the subject of these three gardens, it may not be out of place to call attention again to the deep interest and local pride felt by the people of the respective cities in these establishments. Every intelligent person with whom I conversed upon the subject appreciated the importance of such institutions in a country with undeveloped resources. It was also felt that, since these gardens, and the smaller ones, for that matter, keep in touch with Kew, the botanical interests of the colonies, particularly in their economic aspects, were receiving due attention.

The Botanic gardens of the south do not appear to sustain any close connection with the Universities. They are, of course, available for purposes of investigation, but they are governmental and not academic institutions.

It is frequently said that in the southern hemisphere everything is reversed from what is found in the northern. This is certainly not true of the budgets for botanical gardens. These institutions are everywhere very popular, but I did not find in any case that too much money was provided for the running expenses. In fact, I observed no instance where a somewhat larger income would not have improved the condition of affairs. But the directors and superintendents of the larger gardens, and the curators of the smaller ones made the best use of the rather scanty funds placed at their disposal.

The position of government botanist (in Victoria), filled by the distinguished von Mueller, seems at first anomalous. But when it appears that, as matter of fact, this position has left its incumbent far more free to elucidate botanical questions affecting all the colonies, than if he were burdened with administrative duties connected with the botanical garden in one colony, the establishing of the office has had happy results. It may not be out of place to say that on every hand in the colonies Baron von Mueller's preëminence receives hearty recognition, even in quarters where the relations might naturally have been somewhat strained. The willingness with which the government botanist comes to the assistance of young botanists and amateur collectors in the colonies may have had much to do with the general interest in botanical matters exhibited in the three most populous colonies. G. L. G.

APPENDIX.

Art. XXVI.—*Notice of New Vertebrate Fossils;* by O. C. Marsh.

Recent researches on a number of extinct animals have made it evident that several of them are new to science, and that others possess some characters of interest which have not hitherto been observed. In the present paper, some of the results of this investigation are placed on record, and others will be given in a later communication.

CERATOPSIDÆ.

Triceratops elatus, sp. nov.

One of the largest members of the *Ceratopsidæ*, representing a distinct species, is at present known from the skull only, which was secured during the past year. Although this skull is about six feet and a half in length, it belonged to an animal scarcely adult, as indicated by some of the cranial sutures. The rostral bone is not coössified with the premaxillaries as in old animals, and the superior branch of the former bone has its extremity free. The nasal horn-core, however, is firmly coössified with the nasals. It is of moderate size, with an obtuse summit directed upwards. The main horn-cores were quite long, with their extremities pointed and directed well forward. These horn-cores are compressed transversely, the section being oval in outline.

One of the most striking features of the skull is the parietal crest, which was quite elongate, and much elevated, more so than in any of the species hitherto discovered, and this has suggested the specific name.

The length of this skull from the front of the rostral bone to the back of the parietal crest was about seventy-eight inches, and the greatest transverse expanse of the posterior crest was about forty inches. The summit of one of the frontal horn-cores was about twenty-eight inches above the orbit, and fifty-three inches from the base of the quadrate.

This interesting specimen was found in the Ceratops beds of the Laramie, in Wyoming, by Mr. J. B. Hatcher of the U. S. Geological Survey, whose previous discoveries are well-known.

Torosaurus latus, gen. et sp. nov.

Another well-marked species of this group, which may be referred to a new genus, is represented by one skull, and parts of the skeleton, from nearly the same horizon as the specimen above described. One of the most striking features of the present species is seen in the posterior crest, which, instead of being complete as in the skulls hitherto found, is perforated by a pair of large openings. These are in the parietals, but they have the inner margin of each squamosal for their outer border. They are well behind the supra-temporal fossæ, but doubtless were originally connected with them. They may be called the supra-temporal fontanelles. The squamosal bones, moreover, are very long and slender, and distally only show near the ends sutures for union with the parietals. Another distinctive character is seen in the main horn-cores, which are placed well back of the orbit. The nasal horn-core is short, with the apex compressed, and directed forward.

This genus is of much interest, as it represents an earlier and less specialized form than either *Ceratops* or *Triceratops*, both of which have the posterior crest complete. The existing Chameleons show the other extreme, where the outline only of the parietal crest has been attained.

Some of the principal dimensions of this skull are as follows:

Length from apex of nasal horn-core to extremity of squamosal	80 inches.
Distance from same apex to front of orbit	21 "
Distance from same to front of parietal opening	54 "
Width between posterior extremities of squamosals	56 "

This important specimen was discovered by Mr. J. B. Hatcher, in the Laramie of Wyoming.

Torosaurus gladius, sp. nov.

A second species of apparently the same genus is represented by various portions of a skull in good preservation. In this specimen, the nasal horn-core is short and obtuse, and nearly upright. The main horn-cores are elongate, oval in outline, and in position resemble those of the skull above described. The most remarkable features in the present specimen are the squamosal bones, which are greatly elongated, and so attenuated as to have the general shape of the blade of a sword, thus suggesting the specific name. These bones, moreover, show but slight evidence at their distal extremity of union with the parietals, as the inner margin is rounded for nearly half the length. This feature will distinguish the present species from all others hitherto described.

The following are some dimensions of portions of this specimen:

Length of horn-core from top of orbit to summit	27	inches.
Antero-posterior diameter of same horn-core at base	8	"
Transverse diameter of same	5	"
Length of squamosal behind exoccipital groove	55	"
Greatest width	15	"
Width at middle	9	"

These interesting specimens were also found in the Laramie of Wyoming by Mr. J. B. Hatcher.

ANCHISAURIDÆ.

Ammosaurus, gen. nov.

The Yale Museum has recently secured two interesting specimens of Dinosaurs from the Triassic sandstone of the Connecticut valley. In comparing these with the known species of *Anchisaurus* from this formation, the fact became evident that among them are two well-marked genera. One of the specimens, which is described below, cannot now be distinguished generically from the type of *Anchisaurus*, while the one described by the writer as *Anchisaurus major* is quite distinct, and hence a new genus is here established for its reception. The distinctive characters are well marked in the pelvic arch.

There are three vertebræ in the sacrum, but they are not coössified with each other, being free, as in the *Crocodilia*. The ilium is comparatively small, and has a slender pre-acetabular process. The pubes are broad, elongate plates, perforate above, and not coössified with each other. In form, they resemble the corresponding bones in *Zanclodon*, where, however, the two are coössified, and imperforate. The ischia meet the pubes by an extensive union. Their distal ends are slender, directed backward, and closely adapted to each other. This species may now be known as *Ammosaurus major*.

Anchisaurus colurus, sp. nov.

The new species is represented by perhaps the most perfect Triassic Dinosaur yet discovered, as the skull and greater portion of the skeleton were found in place, and in fine preservation. It is smaller than the specimen above described, but similar in its general proportions, yet the two may be readily distinguished by the pelvic arch and posterior limbs. The pubes are distinct from each other, imperforate above, and the distal portions are only moderately expanded. The process that projects backward to meet the ischium is slender, and the face for union with that bone is quite small. The sacrum and ischia resemble those of *Ammosaurus* above described.

The skull is of moderate size, and of delicate structure. In its general shape, it somewhat resembles the skull of *Hatteria*. The supra-temporal fossæ are very large, and the orbits especially so. The quadrate is inclined forward, and the upper and lower temporal arches are slender. Compressed, cutting teeth are present both in the premaxillary and maxillary bones. The lower jaws have similar teeth, and the rami are not united to each other at the symphysis in front.

The vertebræ and limb bones are hollow, and the whole skeleton is lightly built. The neck is long, and the tail of moderate length. The scapula is elongate, and the coracoid very small and imperforate. The humerus has a strong radial crest, and the radius and ulna are nearly equal in size. There were five digits in the manus, the first, second, and third being armed with strong claws.

The femur is longer than the tibia, and has a flattened head, somewhat like that of a crocodile. The tibia is short and stout, and the fibula well developed. The astragalus is not coössified with the tibia, and the calcaneum is distinct. There were five digits in the pes, but only four functional, the fifth being represented by the metatarsal alone.

The skull of this reptile is about five and one-half inches long, and the lower jaw four and one-half inches. The scapula and humerus are of equal length, each about six inches long. The femur is about eight inches in length, and the tibia about six. The animal when alive was about five and one-half feet long. The present remains were found near Manchester, Conn.

A more complete description of this interesting reptile, with illustrations, will soon be published.

BRONTOTHERIDÆ.

Allops crassicornis, sp. nov.

The present species is represented by the nearly perfect skull of an adult, but not old animal. The skull is of medium size, with the zygomatic arches moderately expanded. The nasal bones do not project beyond the premaxillaries. The horn-cores are very short and massive, with rounded summits, and thus form one of the striking features of the skull. The dentition is complete, and in fine preservation. The single incisor is quite small, and situated close to the canine. The latter is of moderate size, and projects but little above the rest of the dental series. There is no diastema between the canine and the first premolar, which is small, and has its inner face on a line between the canine and the second premolar. The second, third, and fourth premolars are large, and have a strong inner basal ridge. The last molar has its anterior margin somewhat in advance of the front border of the posterior nares.

The length of this skull on the median line is about thirty inches, and the width across the zygomatic arches twenty-three inches. The width across the horn-cores is fourteen inches. The extent of the superior dental series is sixteen inches.

The type of this species was found in the Brontotherium beds of South Dakota, by Mr. J. B. Hatcher.

Brontops validus, sp. nov.

This well-marked species is based upon a skull in fine preservation, which agrees in its main characters with the other species of this genus, but is particularly short and robust. The zygomatic arches are widely expanded, almost as much as in any skull of this group. The nasal bones have only a moderate extension in front, and do not reach the end of the premaxillaries. The free portion is broad and massive. The horn-cores are of moderate size, nearly round in section, and have their obtuse summits directed somewhat backward. The occipital crest slopes forward, and is expanded transversely. The length of this skull on the median line is about twenty-six inches. The greatest transverse diameter across the zygomatic arches is twenty-two inches, and across the summits of the horn-cores, fourteen inches.

The type specimen of the present species is from the Brontotherium beds of South Dakota, where it was secured by Mr. J. B. Hatcher.

Titanops medius, sp. nov.

The present species is from nearly the same horizon as the type of the genus, but is of smaller size. It is represented by one skull in fair preservation, with the horn-cores and dentition complete. The free portion of the nasals is very small, and projects but slightly beyond the anterior line of the horn-cores. The latter are compressed antero-posteriorly, and project laterally nearly at right angles to the median line of the skull. The two incisors on each side are quite small, and separated from each other and from the canine. There is a slight diastema behind the canine. The first premolar is small, and triangular in outline. The second premolar is of moderate size, and the third and fourth premolars have only an incomplete inner basal ridge.

The width of this skull across the horn-cores is twenty-three inches, and the distance from the end of the nasals to the front of the posterior nares is sixteen inches. The extent of the upper dental series is seventeen inches. This specimen is from near the top of the Brontotherium beds of South Dakota, where it was discovered by Mr. J. B. Hatcher.

New Haven, Conn., August 10th, 1891.

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Art. XXVII.—*Some of the Possibilities of Economic Botany;* by George Lincoln Goodale.

[Presidential address delivered before the American Association for the Advancement of Science, at Washington, August, 1891.]

Our Association demands of its president, on his retirement from office, some account of matters connected with the department of science in which he is engaged.

But you will naturally expect that, before I enter upon the discharge of this duty, I should present a report respecting the mission with which you entrusted me last year. You desired me to attend the annual meeting of the Australasian Association for the Advancement of Science, and express your good wishes for its success. Compliance with your request did not necessitate any material change in plans formed long ago to visit the South Seas; some of the dates and the sequence of places had to be modified; otherwise the early plans were fully carried out.

I can assure you that it seemed very strange to reverse the seasons, and find mid-summer in January. But in the meeting with our brethren of the southern hemisphere, nothing else was reversed. The official welcome to your representative was as cordial, and the response by the members was as kindly as that which the people in the northern hemisphere would give to any fellow-worker coming from beyond the sea.

The meeting to which I was commissioned was held in January last in the Cathedral city of Christchurch, New Zealand, the seat of Canterbury College.

Considering the distance between the other colonies and New Zealand, the meeting was well attended. From Hobart, Tasmania, to the southern harbor, known as the Bluff, in New Zealand, the sea voyage is only a little short of one thousand miles of rough water. From Sydney in New South Wales to Auckland, New Zealand, it is over twelve hundred miles. If, therefore, one journeys from Adelaide in South Australia, to Christchurch, New Zealand, where the meeting was held he travels by land and by sea over two thousand miles. From Brisbane in Queensland, it is somewhat farther. Although certain concessions are made to the members of the Association, the fares by rail and by steamship are high, so that a journey from any one of the seats of learning in Australia proper to New Zealand is formidable on account of its cost. It is remarkable that so large a number of members should have met together under such circumstances, and it speaks well for the great strength and vigor of the Association.

The Australasian Association is modelled rather more closely after the British Association than is our own. The president delivers his address upon his inauguration. There are no general business meetings, but all the details are attended to by an executive committee answering to our council; none except the members and associates are invited to attend even the sectional meetings and there are some other differences between the three associations. The secretaries stated to me their conviction that their organization and methods are better adapted to their surroundings than ours would be, and all of their arguments seemed cogent. Although the Association has been in existence but three years, it has accomplished great good. It has brought together workers in different fields for conference and mutual benefit; it has diminished misunderstandings, and has strengthened friendships. In short it is doing the same kind of good work that we believe ours is now doing, and in much the same way.

Your message was delivered at the general evening session immediately before the induction of the new officers. The retiring president, Baron von Mueller, and the incoming president Sir James Hector, in welcoming your representative, expressed their pleasure that you should have seen fit to send personal greetings.

In replying to their welcome, I endeavored to convey your felicitations upon the pronounced success of the Association, and your best wishes for a prosperous future. In your name, I extended a cordial invitation to the members to gratify us by their presence at some of our annual meetings, and I have good reason to believe that this invitation will be accepted. I know it will be most thoroughly and hospitably honored by us.

On the morning of the session to which I refer, we received in the daily papers, a cable telegram relative to the Bering Sea difficulties (which were then in an acute stage). In your stead, I ventured to say, "In these days of disquieting dispatches, when there are rumors of trouble between Great Britain and the United States, it is pleasant to think that 'blood is thicker than water.'" This utterance was taken to mean that we are all English-speaking kinsmen, and even before I had finished, the old proverb was received with prolonged applause.

The next meeting of the Australasian Association is to be held in Hobart, the capital of Tasmania, under the presidency of the governor, Sir Robert Hamilton. The energetic secretaries Professor Liversidge, Professor Hutton and Mr. Morton, promise a cordial welcome to any of our members visiting the Association. Should you accept the invitation, you will enjoy every feature of the remarkable island, Tasmania, where the meeting is to be held. You will be delighted by Tasmanian scenery, vegetation and climate, but that which will give you the greatest enjoyment in this as in other English South Sea colonies, is the fact that you are among English-speaking friends half way around the world. You will find that their efficient Association is devoted to the advancement of science and the promotion of sound learning. In short you will be made to feel at home.

The subject which I have selected for the valedictory address deals with certain industrial, commercial and economic questions: nevertheless it lies wholly within the domain of botany. I invite you to examine with me some of the possibilities of economic botany.

Of course, when treating a topic which is so largely speculative as this, it is difficult and unwise to draw a hard and fast line between possibilities and probabilities. Nowadays, possibilities are so often realized rapidly that they become accomplished facts before we are aware.

In asking what are the possibilities that other plants than those we now use may be utilized we enter upon a many-sided inquiry.[0]* Speculation is rife as to the coming man. May we not ask what plants the coming man will use?

There is an enormous disproportion between the total number of species of plants known to botanical science and the number of those which are employed by man.

The species of flowering plants already described and named are about one hundred and seven thousand. Acquisitions from unexplored or imperfectly explored regions may increase the

* For references, notes, etc., see p. 300.

aggregate perhaps one-tenth, so that we are within very safe limits in taking the number of existing species to be somewhat above one hundred and ten thousand.[1]

Now if we should make a comprehensive list of all the flowering plants which are cultivated on what we may call a fairly large scale at the present day, placing therein all food[2] and forage plants, all those which are grown for timber and cabinet woods, for fibres and cordage, for tanning materials, dyes, resins, rubber, gums, oils, perfumes and medicines, we could bring together barely three hundred species. If we should add to this short catalogue all the species, which without cultivation, can be used by man, we should find it considerably lengthened. A great many products of the classes just referred to are derived in commerce from wild plants, but exactly how much their addition would extend the list, it is impossible in the present state of knowledge to determine. Every enumeration of this character is likely to contain errors from two sources: first, it would be sure to contain some species which have outlived their real usefulness, and, secondly, owing to the chaotic condition of the literature of the subject, omissions would occur.

But after all proper exclusions and additions have been made, the total number of species of flowering plants utilized to any considerable extent by man in his civilized state does not exceed, in fact it does not quite reach, one per cent.

The disproportion between the plants which are known and those which are used becomes much greater when we take into account the species of flowerless plants also. Of the five hundred ferns and their allies we employ for other than decorative purposes only five; the mosses and liverworts, roughly estimated at five hundred species, have only four which are directly used by man. There are comparatively few Algae, Fungi, or Lichens which have extended use.

Therefore, when we take the flowering and flowerless together, the percentage of utilized plants falls far below the estimate made for the flowering alone.

Such a ratio between the number of species known and the number used justifies the inquiry which I have proposed for discussion at this time—namely, can the short list of useful plants be increased to advantage? If so, how?

This is a practical question; it is likewise a very old one. In one form or another, by one people or another, it has been asked from early times. In the dawn of civilization, mankind inherited from savage ancestors certain plants, which had been found amenable to simple cultivation, and the products of these plants supplemented the spoils of the chase and of the sea. The question which we ask now was asked then. Wild plants were examined for new uses; primitive agriculture and horticulture extended their bounds in answer to this inquiry. Age after age has added slowly and cautiously to the list of cultivable and utilizable plants, but the aggregate additions have been as we have seen, comparatively slight.

The question has thus no charm of novelty, but it is as practical to-day as in early ages In fact, at the present time, in view of all the appliances at the command of modern science and under the strong light cast by recent biological and technological research, the inquiry which we propose assumes great importance. One phase of it is being attentively and systematically regarded in the great Experiment Stations, another phase is being studied in the laboratories of Chemistry and Pharmacy, while still another presents itself in the museums of Economic Botany.

Our question may be put in other words, which are even more practical. What present likelihood is there that our tables may, one of these days, have other vegetables, fruits and cereals, than those which we use now? What chance is there that new fibers may supplement or even replace those which we spin and weave, that woven fabrics may take on new vegetable colors, that flowers and leaves may yield new perfumes and flavors? What probability is there that new remedial agents may be found among plants neglected or now wholly unknown? The answer which I shall attempt is not in the nature of a prophecy; it can claim no rank higher than that of a reasonable conjecture.

At the outset it must be said that synthetic chemistry has made and is making some exceedingly short cuts across this field of research, giving us artificial dyes. odors, flavors, and medicinal substances, of such excellence that it sometimes seems as if before long the old-fashioned chemical processes in the plant itself would play only a subordinate part. But although there is no telling where the triumphs of chemical synthesis will end, it is not probable that it will ever interfere essentially with certain classes of economic plants. It is impossible to conceive of a synthetic fiber or a synthetic fruit. Chemistry gives us fruit-ethers and fruit-acids, and after a while may provide us with a true artificial sugar and amorphous starch; but artificial fruits worth the eating or artificial fibers worth the spinning are not coming in our day.

Despite the extraordinary achievements of synthetic chemistry, the world must be content to accept for a long time to come, the results of the intelligent labor of the cultivator of the soil and the explorer of the forest. Improvement of the good plants we now utilize, and the discovery of new ones must remain the care of large numbers of diligent students and assiduous workmen. So that, in fact, our question resolves itself into this: can these practical investigators hope to make any substantial advance?

It will be well to glance first at the manner in which our wild and cultivated plants have been singled out for use. We shall, in the case of each class, allude to the methods by which the selected plants have been improved, or their products fully utilized. Thus looking the ground over, although not minutely, we can see what new plants are likely to be added to our list. Our illustrations can, at the best, be only fragmentary.

We shall not have time to treat the different divisions of the subject in precisely the proportions which would be demanded by an exhaustive essay; an address on an occasion like this must pass lightly over some matters which other opportunities for discussion could properly examine with great fulness. Unfortunately, some of the minor topics which must be thus passed by, possess considerable popular interest; one of these is the first subordinate question introductory to our task, namely, how were our useful cultivated and wild plants selected for use?

A study of the early history of plants employed for ceremonial purposes, in religious solemnities, in incantations, and for medicinal uses, shows how slender has sometimes been the claim of certain plants to the possession of any real utility. But some of the plants which have been brought to notice in these ways have afterwards been found to be utilizable in some fashion or other. This is often seen in the cases of the plants which have been suggested for medicinal use through the absurd doctrine of signatures.[3]

It seems clear that, except in modern times, useful plants have been selected almost wholly by chance, and it may well be said that a selection by accident is no selection at all. Nowadays, the new selections are based on analogy. One of the most striking illustrations of the modern method is afforded by the utilization of bamboo fiber for electric lamps.

Some of the classes of useful plants must be passed by without present discussion; others alluded to slightly, while still other groups fairly representative of selection and improvement will be more fully described. In this latter class would naturally come, of course, the food-plants known as

I. The Cereals.

Let us look first at these.

The species of grasses which yield these seed-like fruits, or as we might call them for our purpose seeds, are numerous;[4] twenty of them are cultivated largely in the Old World, but only six of them are likely to be very familiar to you, namely, wheat, rice, barley, oats, rye and maize. The last of these is of American origin, despite doubts which have been cast upon it. It was not known in the Old World until after the discovery of the New. It has probably been very long in cultivation. The others all belong to the Old World. Wheat and barley have been cultivated from the earliest times; according to De Candolle, the chief authority in these matters, about four thousand years. Later came rye and oats, both of which have been known in cultivation for at least two thousand years. Even the shorter of these periods gives time enough for wide variation, and as is to be expected there are numerous varieties of them all. For instance, Vilmorin, in 1880, figured sixty-six varieties of wheat with plainly distinguishable characters.[5]

If the Chinese records are to be trusted, rice has been cultivated for a period much longer than that assigned by our history and traditions to the other cereals, and the varieties are correspondingly numerous. It is said that in Japan above three hundred varieties are grown on irrigated lands, and more than one hundred on uplands.[6]

With the possible exception of rice, not one of the species of cereals is certainly known in the wild state.[7] Now and then specimens have been gathered in the East which can be referred to the probable types from which our varieties have sprung, but doubt has been thrown upon everyone of these cases. It has been shown conclusively that it is easy for a plant to escape from cultivation and persist in its new home even for a long time in a near approximation to cultivated form. Hence, we are forced to receive all statements regarding the wild forms with caution. But it may be safely said that if all the varieties of cereals which we now cultivate were to be swept out of existence, we could hardly know where to turn for wild species with which to begin again. We could not know with certainty.

To bring this fact a little more vividly to our minds, let us suppose a case. Let us imagine that a blight without parallel has brought to extinction all the forms of wheat, rice, rye, oats, barley and maize, now in cultivation, but without affecting the other grasses or any other form of vegetable food. Mankind would be obliged to subsist upon the other kindly fruits of the earth; upon root-crops, tubers, leguminous seeds, and so on. Some of the substitutions might be amusing in any other time than that of a threatened famine. Others would be far from appetizing under any condition, and only a few would be wholly satisfying even to the most pronounced vegetarian. In short, it would seem, from the first, that the cereals fill a place occupied by no other plants. The composition of the grains is theoretically and practically almost perfect as regards food ratio between the nitrogenous matters and the starch group; and the food value, as it is termed, is high. But aside from these considerations, it would be seen that for safety of preservation through considerable periods, and for convenience of transportation, the cereals take highest rank. Pressure would come from every side to compel us to find equivalents for the lost grains. From this predicament I believe that the well-equipped Experiment Stations and the Agricultural Departments in Europe and America would by and by extricate us. Continuing this hypothetical case, let us next inquire how the Stations would probably go to work in the up-hill task of making partially good a well-nigh irreparable loss.

The whole group of relatives of the lost cereals would be passed in strict review. Size of grain, strength and vigor and plasticity of stock, adaptability to different surroundings, and flexibility in variation would be examined with scrupulous care.

But the range of experiment would, under the circumstances, extend far beyond the relatives of our present cereals. It would embrace an examination of the other grasses which are even now cultivated for their grains, but which are so little known outside of their own limit, that it is a surprise to hear about them. For example, the Millets, great and small, would be investigated. These grains, so little known here, form an important crop in certain parts of the east. One of the leading authorities on the subject[8] states that the Millets constitute "a more important crop" in India "than either Rice or Wheat, and are grown more extensively, being raised from Madras in the south to Rajputana in the north. They occupy about eighty-three per cent of the food-grain area in Bombay and Sinde, forty-one per cent in the Punjab, thirty-nine per cent in the Central Provinces," "in all about thirty million acres."

Having chosen proper subjects for experimenting, the cultivators would make use of certain well-known principles. By simple selection of the more desirable seeds, strains would be secured to suit definite wants, and these strains would be kept as races, or attempts would be made to intensify wished-for characters. By skillful hybridizing of the first, second and higher orders, tendencies to wider variation would be obtained and the process of selection considerably expedited.[9]

It is out of our power to predict how much time would elapse before satisfactory substitutes for our cereals could be found. In the improvement of the grains of grasses other than those which have been very long under cultivation, experiments have been few, scattered and indecisive. Therefore we are as badly off for time-ratios as are the geologists and archæologists, in their statements of elapsed periods. It is impossible for us to ignore the fact that there appear to be occasions in the life of a species when it seems to be peculiarly susceptible to the influences of its surroundings.[10] A species, like a carefully laden ship, represents a balancing of forces within and without. Disturbance may come through variation from within, as from a shifting of the cargo, or, in some cases from without. We may suppose both forces to be active in producing variation, a change in the internal condition rendering the plant more susceptible to any change in its surroundings. Under the influence of any marked disturbance, a state of unstable equilibrium may be brought about, at which times the species as such is easily acted upon by very slight agencies.

One of the most marked of these derangements is a consequent of cross-breeding within the extreme limits of varieties. The resultant forms in such cases can persist only by close breeding or by propagation from buds or the equivalents of buds. Disturbances like these arise unexpectedly in the ordinary course of nature, giving us sports of various kinds. These critical periods however, are not unwelcome, since skillful cultivators can take advantage of them. In this very field much has been accomplished. An attentive study of the sagacious work done by Thomas Andrew Knight shows to what extent this can be done.[11] But we must confess that it would be absolutely impossible to predict with certainty how long or how short would be the time before new cereals or acceptable equivalents for them would be provided. Upheld by the confidence which I have in the intelligence, ingenuity, and energy of our Experiment Stations, I may say that the time would not probably exceed that of two generations of our race, or half a century.

In now laying aside our hypothetical illustration, I venture to ask why it is that our Experiment Stations and other institutions dealing with plants and their improvement, do not undertake investigations like those which I have sketched? Why are not some of the grasses other than our present cereals studied with reference to their adoption as food grains? One of these species will naturally suggest itself to you all, namely, the Wild Rice of the Lakes.[12] Observations have shown that, were it not for the difficulty of harvesting these grains which fall too easily when they are ripe, they might be utilized. But attentive search might find or educe some variety of *Zizania*, with a more persistent grain and a better yield. There are two of our sea-shore grasses which have excellent grains, but are of small yield. Why are not these, or better ones which might be suggested by observation, taken in hand?

The reason is plain. We are all content to move along in lines of least resistance, and are disinclined to make a fresh start. It is merely leaving well enough alone, and so far as the cereals are concerned it is indeed well enough. The generous grains of modern varieties of wheat and barley compared with the well-preserved charred vestiges found in Greece by Schliemann,[13] and in the lake-dwellings,[14] are satisfactory in every respect. Improvements, however, are making in many directions; and in the cereals we now have, we possess far better and more satisfactory material for further improvement both in quality and as regards range of distribution than we could reasonably hope to have from other grasses.

From the cereals we may turn to the interesting groups of plants comprised under the general term

II. Vegetables.

Under this term it will be convenient for us to include all plants which are employed for culinary purposes, or for table use such as salads and relishes.

The potato and sweet potato, the pumpkin and squash, the red or capsicum peppers, and the tomato, are of American origin.

All the others are, most probably, natives of the Old World. Only one plant coming in this class has been derived from Southern Australasia, namely, New Zealand Spinach, (*Tetragonia.*

Among the vegetables and salad-plants longest in cultivation we may enumerate the following—turnip, onion, cabbage, purslane, the large bean (Faba), chick-pea, lentil and one species of pea, garden pea. To these an antiquity of at least four thousand years is ascribed.

Next to these, in point of age, come the radish, carrot, beet, garlic, garden cress, and celery, lettuce, asparagus and the leek. Three or four leguminous seeds are to be placed in the same category, as are also the black peppers.

Of more recent introduction the most prominent are, the parsnip, oyster plant, parsley, artichoke, endive and spinach.

From these lists I have purposely omitted a few which belong exclusively to the tropics, such as certain yams.

The number of varieties of these vegetables is astounding. It is, of course, impossible to discriminate between closely allied varieties which have been introduced by gardeners and seedsmen under different names, but which are essentially identical, and we must therefore have recourse to a conservative authority, Vilmorin,[15] from whose work a few examples have been selected. The varieties which he accepts are sufficiently well distinguished to admit of description and in most instances of delineation, without any danger of confusion. The potato has, he says, innumerable varieties, of which he accepts forty as easily distinguishable and worthy of a place in a general list, but he adds also a list, comprising, of course, synonyms, of thirty-two French, twenty-six English, nineteen American and eighteen German varieties. The following numbers speak for themselves, all being selected in the same careful manner as those of the potato: celery more than twenty; carrot more than thirty; beet, radish and potato more than forty; lettuce and onion more than fifty; turnip more than seventy; cabbage, kidney bean and garden pea more than one hundred.

The amount of horticultural work which these numbers represent is enormous. Each variety established as a race (that is a variety which comes true to seed) has been evolved by the same sort of patient care and waiting which we have seen is necessary in the case of cereals. but the time of waiting has not been as a general thing so long.

You will permit me to quote from Vilmorin[16] also an account of a common plant, which will show how wide is the range of variation and how obscure are the indications in the wild plant of its available possibilities. The example shows how completely hidden are the potential variations useful to mankind.

"Cabbage, a plant which is indigenous in Europe and Western Asia, is one of the vegetables which has been cultivated from the earliest time. The ancients were well acquainted with it, and certainly possessed several varieties of the head-forming kinds. The great antiquity of its culture may be inferred from the immense number of varieties which are now in existence, and from the very important modifications which have been produced in the characteristics in the original or parent plant.

The wild Cabbage, such as it now exists on the coasts of England and France, is a perennial plant with broad-lobed, undulated, thick, smooth leaves, covered with a glaucous bloom. The stem attains a height of from nearly two and a half to over three feet, and bears at the top a spike of yellow or sometimes white flowers. All the cultivated varieties present the same peculiarities in their inflorescence, but up to the time of flowering they exhibit most marked differences from each other and from the original wild plant. In most of the Cabbages, it is chiefly the leaves that are developed by cultivation; these for the most part become imbricated or overlap one another closely, so as to form a more or less compact head, the heart or interior of which is composed of the central undeveloped shoot and the younger leaves next it. The shape of the head is spherical, sometimes flattened, sometimes conical. All the varieties which form heads in this way are known by the general name of Cabbages, while other kinds with large branching leaves which never form heads are distinguished by the name of Borecole or Kale.

In some kinds, the flower-stems have been so modified by culture as to become transformed into a thick, fleshy tender mass, the growth and enlargement of which are produced at the expense of the flowers which are absorbed and rendered abortive. Such are the Broccolis and Cauliflowers."

But this plant has other transformations.

"In other kinds, the leaves retain their ordinary dimensions, while the stem or principal root has been brought by cultivation to assume the shape of a large ball or turnip, as in the case of the plants known as Kohl-Rabi and Turnip-rooted Cabbage or Swedish Turnip. And lastly, there are varieties in which cultivation and selection have produced modifications in the ribs of the leaves, as in the Couve Tronchuda, or in the axillary shoots (as in Brussels sprouts), or in several organs together, as in the Marrow Kales, and the Neapolitan Curled Kale."

Here are important morphological changes like those to which Professor Bailey has called attention in the case of the tomato.

Suppose we are strolling along the beach at some of the seaside resorts of France, and should fall in with this coarse cruciferous plant, with its sprawling leaves and strong odor. Would there be anything in its appearance to lead us to search for its hidden merit as a food plant? What could we see in it which would give it a preference over a score of other plants at our feet? Again, suppose we are journeying in the high lands of Peru, and should meet with a strong-smelling plant of the Night-shade family, bearing a small irregular fruit, of subacid taste and of peculiar flavor. We will further imagine that the peculiar taste strikes our fancy, and we conceive that the plant has possibilities as a source of food. We should be led by our knowledge of the potato, probably a native of the same region, to think that this allied plant might be safely transferred to a northern climate, but would there be promise of enough future usefulness in such a case as this, to warrant our carrying the plant North as an article of food? Suppose, further, we should ascertain that the fruit in question was relished not only by the natives of its home, but that it had found favor among the tribes of South Mexico and Central America, and had been cultivated by them until it had attained a large size; should we be strengthened in our venture? Let us go one step further still. Suppose that having decided upon the introduction of the plant, and having urged everybody to try it, we should find it discarded as a fruit, but taking a place in gardens as a curiosity under an absurd name, or as a basis for preserves and pickles; should we not look upon our experiment in the introduction of this new plant as a failure? This is not a hypothetical case.

The Tomato,[17] the plant in question, was cultivated in Europe as long ago as 1554;[18] it was known in Virginia in 1781 and in the Northern States in 1785; but it found its way into favor slowly, even in this land of its origin. A credible witness states that in Salem it was almost impossible to induce people to eat or even taste of the fruit. And yet, as you are well aware, its present cultivation on an enormous scale in Europe and this country is scarcely sufficient to meet the increasing demand.

A plant which belongs to the family of the tomato has been known to the public under the name of the strawberry tomato. The juicy yellow or orange-colored fruit is enclosed in a papery calyx of large size. The descriptions which were published when the plant was placed on the market were attractive, and were not exaggerated to a misleading extent. But, as you all know, the plant never gained any popularity. If we look at these two cases carefully we shall see that what appears to be caprice on the part of the public is at bottom common sense. The cases illustrate as well as any which are at command, the difficulties which surround the whole subject of the introduction of new foods.

Before asking specifically in what direction we shall look for new vegetables I must be pardoned for calling attention, in passing, to a very few of the many which are already in limited use in Europe and this country, but which merit a wider employment. Cardon, or Cardoon; Celeriac, or turnip-rooted celery; Fetticus, or corn-salad; Martynia; Salsify; Sea-kale; and numerous small salads, are examples of neglected treasures of the vegetable garden.

The following which are even less known may be mentioned as fairly promising.[19]

(1) *Arracacia esculenta*, called Arracacha, belonging to the Parsley family. It is extensively cultivated in some of the northern States of South America. The stems are swollen near the base, and produce tuberous enlargements filled with an excellent starch. Although the plant is of comparatively easy cultivation, efforts to introduce it into Europe have not been successful, but it is said to have found favor in both the Indies, and may prove useful in our Southern States.

(2) *Ullucus* or Ollucus, another tuberous-rooted plant from nearly the same region, but belonging to the Beet or Spinach family. It has produced tubers of good size in England, but they are too waxy in consistence to dispute the place of the better tubers of the potato. The plant is worth investigating for our hot dry lands.

(3) A tuber-bearing relative of our common Hedge-nettle, or *Stachys*, is now cultivated on a large scale at Crosnes in France, for the Paris market. Its name in Paris is taken from the locality where it is now grown for use. Although its native country is Japan, it is called by some seedsmen Chinese Artichoke. At the present stage of cultivation, the tubers are small and are rather hard to keep, but it is thought "that both of these defects can be overcome or evaded."[21] Experiments indicate that we have in this species a valuable addition to our vegetables. We must next look at certain other neglected possibilities.

Dr. Edward Palmer,[20] whose energy as a collector and acuteness as an observer are known to you all, has brought together very interesting facts relative to the food-plants of our North American aborigines. Among the plants described by him there are a few which merit careful investigation. Against all of them, however, there lie the objections mentioned before, namely:

(1) The long time required for their improvement, and

(2) The difficulty of making them acceptable to the community, involving

(3) The risk of total and mortifying failure.

In the notes to this address the more prominent of these are enumerated.

In 1854 the late Professor Gray called attention to the remarkable relations which exist between the plants of Japan and those of our Eastern coast. You will remember that he not only proved that the plants of the two regions had a common origin, but also emphasized the fact that many species of the two countries are almost identical. It is to that country which has yielded us so many useful and beautiful plants that we turn for new vegetables to supplement our present food-resources. One of these plants, namely, *Stachys*, has already been mentioned as rather promising. There are others which are worth examination and perhaps acquisition.

One of the most convenient places for a preliminary examination of the vegetables of Japan is at the railroad stations on the longer lines, for instance, that running from Tokio to Kobe. For native consumption there are prepared luncheon boxes of two or three stories, provided with the simple and yet embarrassing chop-sticks. It is worth the shock it causes one's nerves to invest in these boxes and try the vegetable contents. The bits of fish, flesh and fowl which one finds therein can be easily separated and discarded, upon which there will remain a few delicacies. The pervading odor of the box is that of aromatic vinegar. The generous portion of boiled rice is of excellent quality with every grain well softened and distinct, and this without anything else would suffice for a tolerable meal. In the boxes which have fallen under my observation there were sundry boiled roots, shoots and seeds which were not recognizable by me in their cooked form. Professor Georgeson,[22] formerly of Japan, has kindly identified some of these for me, but he says "there are doubtless many others used occasionally."

One may find sliced Lotus roots, roots of large Burdock, Lily bulbs, shoots of Ginger, pickled green Plums, beans of many sorts, boiled Chestnuts, nuts of the Gingko tree, pickled greens of various kinds, dried cucumbers, and several kinds of seaweeds. Some of the leaves and roots are cooked in much the same manner as beet-roots and beet-leaves are by us, and the general effect is not unappetizing. The boiled shoots are suggestive of only the tougher ends of asparagus. On the whole, I do not look back on Japanese railway luncheons with any longing which would compel me to advocate the indiscriminate introduction of the constituent vegetables here.

But when the same vegetables are served in native inns, under more favorable culinary conditions, without the flavor of vinegar and of the pine wood of the luncheon boxes, they appear to be worthy of a trial in our horticulture, and I therefore deal with one or two in greater detail.

Professor Georgeson, whose advantages for acquiring a knowledge of the useful plants of Japan have been unusually good, has placed me under great obligations by communicating certain facts regarding some of the more promising plants of Japan which are not now used here. It should be said that several of these plants have already attracted the notice of the Agricultural Department in this country.

The Soy Bean (*Glycine hispida*). This species is known here to some extent, but we do not have the early and best varieties. These beans replace meat in the diet of the common people.

Mucuna (*Mucuna capitata*) and Dolichos (*Dolichos cultratus*) are pole beans possessing merit.

Dioscorea; there are several varieties with palatable roots. Years ago one of these was spoken of by the late Dr. Gray, as possessing "excellent roots, if one could only dig them."

Colocasia antiquorum has tuberous roots, which are nutritious.

Conophallus Konjak has a large bulbous root, which is sliced, dried and beaten to a powder. It is an ingredient in cakes.

Aralia cordata is cultivated for the shoots, and used as we use Asparagus.

Œnanthe stolonifera and *Cryptotænia Canadensis* are palatable salad plants, the former being used also as greens.

There is little hope, if any, that we shall obtain from the hotter climates for our southern territory new species, of merit. The native markets in the tropical cities, like Colombo, Batavia, Singapore and Saigon, are rich in fruits, but outside of the native plants bearing these, nearly all the plants appear to be wholly in established lines of cultivation, such, for instance, as members of the Gourd and Night-shade families.

Before we leave the subject of our coming vegetables, it will be well to note a naïve caution enjoined by Vilmorin in his work, Les Plantes Potagères.[23]

"Finally," he says, "we conclude the article devoted to each plant with a few remarks on the uses to which it may be applied and on the parts of the plants which are to be so used. In many cases such remarks may be looked upon as idle words, and yet it would sometimes have been useful to have them when new plants were cultivated by us for the first time. For instance, the giant edible Burdock of Japan (*Lappa edulis*) was for a long time served up on our tables only as a wretchedly poor Spinach, because people would cook the leaves, whereas, in its native country, it is only cultivated for its tender fleshy roots."

I trust you are not discouraged at this outlook for our coming vegetables.

Two groups of improvable food-plants may be referred to before we pass to the next class, namely, edible fungi and the beverage plants. All botanists who have given attention to the matter agree with the late Dr. Curtis of North Carolina that we have in the unutilized mushrooms an immense amount of available nutriment of a delicious quality. It is not improbable that other fungi than our common "edible mushroom" will by and by be subjected to careful selection.

The principal beverage-plants, Tea, Coffee and Chocolate, are all attracting the assiduous attention of cultivators. The first of these plants is extending its range at a marvellous rate of rapidity through India and Ceylon; the second is threatened by the pests which have almost exterminated it in Ceylon, but a new species, with crosses therefrom, is promising to resist them successfully; the third, Chocolate, is every year passing into lands farther from its original home. To these have been added the Kola, of a value as yet not wholly determined, and others are to augment the short list.

III. Fruits.

Botanically speaking, the cereal grains of which we have spoken, are true fruits, that is to say, are ripened ovaries, but for all practical purposes they may be regarded as seeds. The fruits, of which mention is now to be made, are those commonly spoken of in our markets, as fruits.

First of all, attention must be called to the extraordinary changes in the commercial relations of fruits by two direct causes,

(1) The canning industry, and

(2) Swift transportation by steamers and railroads.

The effects of these two agencies are too well known to require more than this passing mention. By them the fruits of the best fruit-growing countries are carried to distant lands in quantities which surprise all who see the statistics for the first time. The ratio of increase is very startling. Take for instance, the figures given by Mr. Morris at the time of the great Colonial and Indian Exhibition, in London. Compare double decades of years.

1845, £886,888.
1865, £3,185,984.
1885, £7,587,523.

In the Colonial Exhibition at London, in 1886, fruits from the remote colonies were exhibited under conditions which proved that, before long, it may be possible to place such delicacies as the Cherimoyer, the Sweet-cup, Sweet-sop, Rambutan, Mango and Mangosteen, at even our most northern seaports. Furthermore, it seems to me likely that with an increase in our knowledge with regard to the microbes which produce decay, we may be able to protect the delicate fruits from injury for any reasonable period. Methods which will supplement refrigeration are sure to come in the very near future, so that even in a country so vast as our own, the most perishable fruits will be transported through its length and breadth without harm.

The canning industry and swift transportation are likely to diminish zeal in searching for new fruits, since, as we have seen in the case of the cereals, we are prone to move in lines of least resistance and leave well enough alone.

To what extent are our present fruits likely to be improved? Even those who have watched the improvement in the quality of some of our fruits, like oranges, can hardly realize how great has been the improvement within historic times in the character of certain pears, apples, and so on.

The term historic is used advisedly, for there are pre-historic fruits which might serve as a point of departure in the consideration of the question. In the ruins of the lake-dwellings in Switzerland,[24] charred apples have been found, which are in some cases, plainly of small size, hardly equalling ordinary crab apples. But, as Dr. Sturtevant has shown, in certain directions, there has been no marked change of type, the change is in quality.

In comparing the earlier descriptions of fruits with modern accounts it is well to remember that the high standards by which fruits are now judged are of recent establishment. Fruits which would once have been esteemed excellent, would to-day be passed by as unworthy of regard

It seems probable that the list of seedless fruits will be materially lengthened, provided our experimental horticulturists make use of the material at their command. The common fruits which have very few or no seeds are the banana, pineapple and certain oranges. Others mentioned by Mr. Darwin as well known are the bread-fruit, pomegranate, azarole or Neapolitan medlar, and date palms. In commenting upon these fruits, Mr. Darwin[25] says that most horticulturists "look at the great size and anomalous development of the fruit as the cause and sterility as the result," but he holds the opposite view as more probable, that is, that the sterility, coming about gradually, leaves free for other growth the abundant supply of building material which the forming seed would otherwise have. He admits, however, that "there is an antagonism between the two forms of reproduction, by seeds and by buds when either is carried to an extreme degree which is independent of any incipient sterility."

Most plant-hybrids are relatively infertile, but by no means wholly sterile. With this sterility there is generally augmented vegetative vigor, as shown by Nägeli. Partial or complete sterility and corresponding luxuriance of root, stem, leaves and flower, may come about in other obscure ways, and such cases are familiar to botanists.[10] Now it seems highly probable that either by hybridizing directed to this special end, or by careful selection of forms indicating this tendency to the correlated changes, we may succeed in obtaining important additions to our seedless or nearly seedless plants. Whether the ultimate profit would be large enough to pay for the time and labor involved is a question which we need not enter into ; there appears to me no reasonable doubt that such efforts would be successful. There is no reason in the nature of things why we should not have strawberries without the so-called seeds ; blackberries and raspberries, with only delicious pulp ; and large grapes as free from seeds as the small ones which we call "currants" but which are really grapes from Corinth.

These and the coreless apples and pears of the future, the stoneless cherries and plums, like the common fruits before mentioned must be propagated by bud division, and be open to the tendency to diminished strength said to be the consequence of continued bud-propagation. But this bridge need not be crossed until we come to it. Bananas have been perpetuated in this way for many centuries, and pineapples since the discovery of America, so that the borrowed trouble alluded to is not threatening. First we must catch our seedless fruits.

Which of our wild fruits are promising subjects for selection and cultivation?

Mr. Crozier of Michigan has pointed out[26] the direction in which this research may prove most profitable. He enumerates many of our small fruits and nuts which can be improved.

Another of our most careful and successful horticulturists believes that the common blueberry and its allies are very suitable for this purpose and offer good material for experimenting. The sugar-plum, or so-called shadbush, has been improved in many particulars, and others can be added to this list.

But again we turn very naturally to Japan, the country from which our gardens have received many treasures. Referring once more to Professor Georgeson's studies,[27] we must mention the varieties of Japanese apples, pears, peaches, plums, cherries and persimmons. The persimmons are already well-known in some parts of our country, under the name "kaki" and they will doubtless make rapid progress in popular favor.

The following are less familiar: *Actinidia arguta* and *volubilis*, with delicious berries;

Stauntonia, an evergreeen vine yielding a palatable fruit;

Myrica rubra, a small tree with an acidulous juicy fruit;

Elæagnus umbellata, with berries for preserves.

The active and discriminating horticultural journals in America and Europe are alive to the possibilities of new Japanese fruits, and it cannot be very long before our list is considerably increased.

It is absolutely necessary to recollect that in most cases variations are slight. Dr. Masters and Mr. Darwin have called attention to this and have adduced many illustrations, all of which show the necessity of extreme patience and caution. The general student curious in such matters can have hardly any task more instructive than the detection of the variations in such common plants as the blueberry, the wild cherry, or the like. It is an excellent preparation for a practical study of the variations in our wild fruits suitable for selection.

It was held by the late Dr. Gray that the variations in nature by which species have been evolved were led along useful lines, a view which Mr. Darwin regretted he could not entertain. However this may be, all acknowledge that by the hand of the cultivator variations can be led along useful lines; and furthermore the hand which selects must uphold them in their unequal strife. In other words it is one thing to select a variety and another to assist it in maintaining its hold upon existence. Without the constant help of the cultivator who selects the useful variety, there comes a reversion to the ordinary specific type which is fitted to cope with its surroundings.

I think you can agree with me that the prospect for new fruits and for improvements in our established favorites is fairly good.

IV. Timbers and Cabinet Woods.

Can we look for new timbers and cabinet woods? Comparatively few of those in common use are of recent introduction. Attempts have been made to bring into great prominence some of the excellent trees of India and Australia which furnish wood of much beauty and timber of the best quality. A large proportion of all the timbers of the South Seas are characterized by remarkable firmness of texture and high specific gravity.[28] The same is noticed in many of the woods of the Indies. A few of the heavier and denser sorts, like Jarrah, of West Australia, and Sabicu of the Caribbean Islands, have met with deserved favor in England, but the cost of transportation militates against them. It is a fair question whether, in certain parts of our country, these trees and others which can be utilized for veneers, may not be cultivated to advantage. Attention should be again called to the fact that many plants succeed far better in localities which are remote from their origin but where they find conditions substantially like those which they have left. This fact, to which we must again refer in detail with regard to certain other classes of plants, may have some bearing upon the introduction of new timber trees. Certain drawbacks exist with regard to the timber of some of the more rapidly growing hard-wood trees which have prevented their taking a high place in the scale of values in mechanical engineering.

One of the most useful soft-wooded trees in the world is the Kauri. It is restricted in its range to a comparatively small area in the North Island of New Zealand. It is now being cut down with a recklessness which is as prodigal and shameful as that which has marked our own treatment of forests here. It should be said, however, that this destruction is under protest, in spite of which it would seem to be a question of only a few years when the great Kauri groves of New Zealand will be a thing of the past. Our energetic Forest Department has on its hands problems just like this which perplexes one of the new lands of the South. The task in both cases is double: to preserve the old treasures and to bring in new.

The energy shown by Baron von Mueller, the renowned Government Botanist of Victoria and by various Forest departments in encouraging the cultivation of timber trees will assuredly meet with success; one can hardly hope that this success will appear fully demonstrated in the lifetime of those now living, but I cannot think that many years will pass before the promoters of such enterprises may take fresh courage.

In a modest structure in the City of Sydney, New South Wales, Mr. Maiden[28] has brought together, under great difficulties, a large collection of the useful products of the vegetable kingdom as represented in Australia. It is impossible to look at the collection of woods in that Museum or at the similar and more showy one in Kew, without believing that the field of forest culture must receive rich material from the Southern hemisphere.

Before leaving this part of our subject, it may be well to take some illustrations in passing, to show how important is the influence exerted upon the utilization of vegetable products by causes which may, at first, strike one as being rather remote.

(1) Photography makes use of the effect of light on chromatized gelatin to produce under a negative the basis of relief plates for engraving. The degree of excellence reached in modifications of this simple device has distinctly threatened the very existence of wood engraving, and hence follows a diminished degree of interest in box-wood and its substitutes.

(2) Iron, and in its turn steel, is used in ship-building and this renders of greatly diminished interest all questions which concern the choice of the different oaks, and similar woods:

(3) But on the other hand there is increased activity in certain directions, best illustrated by the extraordinary develment of the chemical methods for manufacturing wood pulp. By the improved processes, strong fibers suitable for fine felting on the screen and fit for the best grades of certain lines of paper are given to us from rather inferior sorts of wood. He would be a rash prophet who should venture to predict what will be the future of this wonderful industry, but it is plain that the time is not far distant when acres now worthless may be covered by trees under cultivation growing for the pulpmaker.

There is no department of Economic Botany more promising in immediate results than that of Arboriculture.

V. Vegetable Fibers.

The vegetable fibers known to commerce are either plant hairs, of which we take cotton as the type, or filaments of bast-tissue, represented by flax. No new plant hairs have been suggested which can compete in any way for spinning with those yielded by the species of Gossypium, or cotton, but experiments more or less systematic and thorough are being carried on with regard to the improvement of the varieties of the species. Plant hairs for the stuffing of cushions and pillows need not be referred to in connection with this subject.

Countless sorts of plants have been suggested as sources of good bast-fibers for spinning and for cordage, and many of these make capital substitutes for those already in the factories. But the questions of cheapness of production, and of subsequent preparation for use, have thus far militated against success. There may be much difference between the profits promised by a laboratory experiment and those resulting from the same process conducted on a commercial scale. The existence of such differences has been the rock on which many enterprises seeking to introduce new fibers have been wrecked.

In dismissing this portion of our subject it may be said that a process for separating fine fibers from undesirable structural elements and from resin like substances which accompany them, is a great desideratum. If this were supplied, many new species would assume great prominence at once.

VI. Tanning Materials.

What new tanning materials can be confidently sought for? In his "Useful Native Plants of Australia," Mr. Maiden[28] describes over thirty species of "Wattles" or Acacias, and about half as many Eucalypts, which have been examined for the amount of tanning material contained in the bark. In all, 87 Australian species have been under examination. Besides this, much has been done looking in the same direction at the suggestion and under the direction of Baron von Mueller, of Victoria. This serves to indicate how great is the interest in this subject, and how wide is the field in our own country for the introduction of new tanning plants.

It seems highly probable, however, that artificial tanning substances will at no distant day replace the crude matters now employed.

VII. Resins, Etc.

Resins, oils, gums and medicines from the vegetable kingdom would next engage our attention if they did not seem rather too technical for this occasion, and to possess an interest on the whole somewhat too limited. But an allied substance may serve to represent this class of products and indicate the drift of present research.

India Rubber.[19]—Under this term are included numerous substances which possess a physical and chemical resemblance to each other. An Indian Ficus, the early source of supply, soon became inadequate to furnish the quantity used in the arts even when the manipulation of rubber was almost unknown. Later, supplies came from *Hevea* of Brazil, generally known as Para rubber, and from *Castilloa*, sometimes called Central American Rubber, and from *Manihot Glaziovii* Ceara rubber. Not only are these plants now successfully cultivated in experimental gardens in the Tropics, but many other rubber-yielding species have been added to the list. The Landolphias are among the most promising of the whole: these are the African rubbers. Now in addition to these which are the chief source of supply, we have *Willughbeia*, from the Malayan Peninsula, *Leuconotis*, *Chilocarpus*, *Alstonia*, *Forsteronia*, and a species of a genus formerly known as *Urostigma*, but now united with *Ficus*. These names, which have little significance as they are here pronounced in passing, are given now merely to impress upon our minds the fact that the sources of a single commercial article may be exceedingly diverse. Under these circumstances search is being made not only for the best varieties of these species but for new species as well.

There are few excursions in the Tropics which possess greater interest to a botanist who cares for the industrial aspects of plants than the walks through the Gardens at Buitenzorg in Java and at Singapore. At both these stations the experimental Gardens lie at some distance from the great gardens which the tourist is expected to visit, but the exertion well repays him for all discomfort. Under the almost vertical rays of the sun, are here gathered the rubber-yielding plants from different countries, all growing under conditions favorable for decisions as to their relative value. At Buitenzorg a well-equipped laboratory stands ready to answer practical questions as to quality and composition of their products, and year by year the search extends.

I mention this not as an isolated example of what is being accomplished in Commercial Botany, but as a fair illustration of the thoroughness with which the problems are being attacked. It should be further stated that at the Garden in question assiduous students of the subject are eagerly welcomed and are provided with all needed appliances for carrying on technical, chemical and pharmaceutical investigations. Therefore I am justified in saying that there is every reason for believing that in the very near future new sources of our most important products will be opened up, and new areas placed under successful cultivation.

At this point, attention must be called to a very modest and convenient handbook on the Commercial Botany of the Nineteenth Century by Mr. Jackson of the Botanical Museum attached to the Royal Gardens, Kew, which not only embodies a great amount of well-arranged information relative to the new useful plants, but is, at the same time, a record of the existing state of things in all these departments of activity.

VIII. Fragrant Plants.

Another illustration of our subject might be drawn from a class of plants which repays close study from a biological point of view, namely, those which yield perfumes.

In speaking of the future of our fragrant plants we must distinguish between those of commercial value and those of purely horticultural interest. The former will be less and less cultivated in proportion as synthetic chemistry by its manufacture of perfumes replaces the natural by the artificial products, for example, Coumarin, Vanillin, Nerolin, Heliotropin, and even Oil of Wintergreen.

But do not understand me as intimating that Chemistry can ever furnish substitutes for living fragrant plants. Our gardens will always be sweetened by them, and the possibilities in this direction will continue to extend both by contributions from abroad and by improvement in our present cultivated varieties. Among the foreign acquisitions are the fragrant species of *Andropogon*. Who would suspect that the tropical relatives of our sand-loving grasses are of high commercial value as sources of perfumery oils?

The utility to the plant of fragrance in the flower and the relation of this to cross-fertilization, are apparent to even a casual observer. But the fragrance of an aromatic leaf does not always give us the reason for its being.

It has been suggested for certain cases that the volatile oils escaping from the plants in question may, by absorption, exert a direct influence in mitigating the fierceness of action of the sun's rays. Other explanations have also been made, some of which are even more fanciful than the last.

When, however, one has seen that the aromatic plants of Australia are almost free from attacks of insects and fungi, and has learned to look on the impregnating substances in some cases as protective against predatory insects and small foes of all kinds, and in others as fungicidal, he is tempted to ask whether all the substances of marked odor which we find in certain groups of plants may not play a similar rôle.

It is a fact of great interest to the surgeon that in many plants there is associated with the fragrant principle a marked antiseptic or fungicidal quality; conspicuous examples of this are afforded by species of *Eucalyptus*, yielding Eucalyptol, *Styrax*, yielding Styrone, *Thymus* yielding Thymol. It is interesting to note, too, that some of these most modern antiseptics were important constituents in the balsamic vulneraries of the earliest surgery.

IX. Florists' Plants.

Florists' plants and the floral fashions of the future constitute an engaging subject which we can touch only lightly. It is reasonably clear that while the old favorite species will hold their ground in the guise of improved varieties, the new introductions will come in the shape of plants with flowering branches which retain their blossoms for a somewhat long period, and especially those in which the flowers precede the leaves. In short the next real fashion in our gardens is probably to be the flowering shrub and flowering tree, like those which are such favorites in the country from which the Western world has gladly taken the gift of the Chrysanthemum.[29]

Twice each year of late, a reception has been held by the Emperor and Empress of Japan. The receptions are in autumn and in the spring. That in the autumn, popularly known as the Emperor's reception, has for its floral decorations the myriad forms of the national flower, the chrysanthemum; that which is given in spring, the Empress' reception, comes when the cherry blossoms are at their best. One has little idea of the wealth of beauty in masses of flowering shrubs and trees, until he has seen the floral displays in the Imperial Gardens and the Temple grounds in Tokio.

To Japan[29] and China also, we are indebted for many of the choicest plants of our gardens, but the supply of species is by no means exhausted. By far the larger number of the desirable plants have already found their way into the hands of cultivators, but often under conditions which have restricted their dissemination through the flower-loving community. There are many which ought to be widely known, especially the fascinating dwarf shrubs and dwarf trees of the far East, which are sure to find sooner or later a warm welcome among us.

X. Forage Plants.

Next to the food plants for man, there is no single class of commercial plants of greater interest than the food-plants for flocks and herds. Forage plants, wild and cultivated, are among the most important and highly valued resources of vast areas. No single question is of more vital consequence to our farthest west and southwest.

It so happens that the plants on which the pastoralist relies grow or are grown on soil of inferior value to the agriculturist. Even soil which is almost sterile may possess vegetation on which flocks and herds may graze, and, further, these animals may thrive in districts where the vegetation appears at first sight too scanty or too forbidding, even to support life. There are immense districts in parts of the Australian continent where flocks are kept on plants so dry and desert-like that an inexperienced person would pass them by as not fit for his sheep, and yet, as Mr. Samuel Dixon[30] has well shown, these plants are of high nutritive value and are attractive to flocks.

Relegating to the notes to be published with this address brief descriptions of a few of the fodder plants suggested for use in dry districts, I shall now mention the salt-bushes of various sorts, and the allied desert plants of Australia as worth a careful trial on some of our very dry regions in the farthest west. There are numerous other excellent fodder plants adapted to dry but not parched areas which can be brought in from the corresponding districts of the southern hemisphere and from the East.

At an earlier stage of this address, I have had occasion to refer to Baron von Mueller, whose efforts looking towards the introduction of useful plants into Australasia have been aided largely by his convenient treatise on economic plants.[0] It may be said in connection with the fodder plants, especially, that much which the Baron has written can be applied *mutatis mutandis* to parts of our own country.

The important subject of introducing fodder plants has been purposely reserved to the last because it permits us to examine a practical point of great interest. This is the caution which it is thought necessary to exercise when a species is transferred by our own choice from one country to another. I say, by our choice, for whether we wish it or not certain plants will introduce themselves. In these days of frequent and intimate intercommunication between different countries, the exclusion of foreign plants is simply impossible. Our common weeds are striking illustrations of the readiness with which plants of one country make for themselves a home in another.[31] All but two of the prominent weeds of the eastern States are foreign intruders.

There are all grades of persistence in these immigrants. Near the ballast grounds of every harbor, or the fields close by woolen and paper mills where foreign stock is used, you will observe many foreign plants which have been introduced by seed. For many of these you will search in vain a second year. A few others persist for a year or two longer, but with uncertain tenure of the land which they have invaded: others still have come to stay. But happily some of the intruders which seem at first to gain a firm foot-hold, lose their ground after a while. We have a conspicuous example of this in a hawkweed, which was very threatening in New England two years ago, but is now relaxing its hold.

Another illustration is afforded by a water-plant which we have given to the old world. This plant, called in our botanies *Anacharis*, or *Elodea*, is so far as I am aware, not troublesome in our ponds and water-ways, but when it was carried to England, perhaps as a plant for the aquarium, it was thrown into streams and rivers with a free hand. It spread with remarkable rapidity and became such an unmitigated nuisance that it was called a curse. Efforts to extirpate it merely increased its rate of growth. Its days of mischief are however nearly over, or seem to be drawing to a close, at least so Mr. Lynch of the Botanic Garden in Cambridge, England, and others of my informants think. The history of the plant shows that even under conditions which so far as we can see, are identical with those under which the plant grew in its home, it may for a time take a fresh lease of life and thrive with an undreamed-of energy.

What did *Anacharis* find in the waters of England and the continent that it did not have at home, and why should its energy begin to wane now?

In Australasia one of the most striking of these intruders is Sweet-briar. Introduced as a hedge plant it has run over certain lands like a weed, and disputes every acre of some arable plats. From the facility with which it is propagated, it is almost ineradicable. There is something astounding in the manner in which it gains and holds its ground. Gorse and brambles and thistles are troublesome in some localities, and they prove much less easy to control than in Europe. The effect produced on the mind of the colonist by these intruding pests, is everywhere the same. Whenever in an examination of the plants likely to be worthy of trial in our American dry lands, the subject was mentioned by me to Australians, I was always enjoined to be cautious as to what plants I might suggest for introduction from their country into our own. My good friends insisted that it was bad enough to have as pests the plants which come in without our planning or choice, and this caution seems to me one which should not be forgotten.

It would take us too far from our path to inquire what can be the possible reasons for such increase of vigor and fertility in plants which are transferred to a new home. We should have to examine all the suggestions which have been made, such as fresh soil, new skies, more efficient animal friends, or less destructive enemies. We should be obliged also to see whether the possible wearing out of the energy of some of these plants after a time, might not be attributable to the decadence of vigor through uninterrupted bud-propagation, and we should have to allude to many other questions allied to these. But for this time fails.

Lack of time also renders it impossible to deal with the questions which attach themselves to our main question, especially as to the limits of effect which cultivation may produce. We cannot touch the problem of inheritance of acquired peculiarities, or the manner in which cultivation predisposes the plant to innumerable modifications. Two of these modifications may be mentioned in passing, because they serve to exemplify the practical character of our subject.

Cultivation brings about in plants very curious morphological changes. For example, in the case of a well known vegetable the number of metamorphosed type-leaves forming the ovary is two, and yet under cultivation, the number increases irregularly until the full number of units in the type of the flower is reached. Professor Bailey of Cornell has called attention to some further interesting changes in the tomato, but the one mentioned suffices to illustrate the direction of variation which plants under cultivation are apt to take. Monstrosities are very apt to occur in cultivated plants, and under certain conditions may be perpetuated in succeeding generations, thus widening the field from which utilizable plants may be taken.

Another case of change produced by cultivation is likewise as yet wholly unexplained, although much studied, namely the mutual interaction of scion and stock in grafting, budding, and the like. It is probable that a further investigation of this subject may yet throw light on new possibilities in plants.

We have now arrived at the most practical question of all, namely—

In what way can the range of commercial botany be extended? In what manner or by what means can the introduction of new species be hastened?

It is possible that some of you are aware of the great amount of uncoördinated work which has been done and is now in hand in the direction of bringing in new plants.

The competition between the importers of new plants is so great both in the Old World and the New that a very large proportion of the species which would naturally commend themselves for the use of florists, for the adornment of greenhouses, or for commercial ends, have been at one time or another brought before the public or are being accumulated in stock. The same is true although to a less extent with regard to useful vegetables and fruit. Hardly one of those which we can suggest as desirable for trial, has not already been investigated in Europe or this country, and reported on. The pages of our chemical, pharmaceutical, medical, horticultural, agricultural and trade journals, especially those of high grade, contain a wealth of material of this character.

But what is needed is this, that the promising plants should be systematically investigated under exhaustive conditions. It is not enough that an enthusiast here, or an amateur there should give a plant a trial under imperfectly understood conditions, and then report success or failure. The work should be thorough and every question answered categorically, so that we might be placed in possession of all the facts relative to the object experimented upon. But such an undertaking requires the coöperation of many different agencies. I shall venture to mention some of these.

In the first place,—Botanic Gardens amply endowed for research. The Arnold Arboretum, the Shaw Garden, and the Washington Experimental Garden, are American illustrations of what is needed for this purpose. University gardens have their place in instruction, but cannot wisely undertake this kind of work.

In the second place,—Museums and Laboratories of Economic Botany. Much good work in this direction has been done in this country by the National Museum and by the department in charge[33] of the investigation of new plants. We need institutions like those at Kew in England, and at Buitenzorg in Java, which keep in close touch with all the world. The founding of an establishment on a scale of magnitude commensurate with the greatness and needs of our country is an undertaking which waits for some one of our wealthy men.

In the third place,—Experiment Stations. These may, within the proper limits of their sphere of action, extend the study of plants beyond the established varieties to the species, and beyond the species to equivalent species in other genera. It is a matter of regret that so much of the energy displayed in these stations in this country, and we may say abroad, has not been more economically directed.

Great economy of energy must result from the recent change by which coördination of action is assured. The influence which the stations must exert on the welfare of our country, and the development of its resources is incalculable.

In the last place, but by no means least, the coöperation of all who are interested in scientific matters, through their observation of isolated and associated phenomena connected with plants of supposed utility, and by the cultivation of such plants by private individuals, unconnected with any State, governmental, or academic institutions.

By these agencies, wisely directed and energetically employed, the domains of commercial and industrial botany, will be enlarged. To some of the possible results in these domains, I have endeavored to call your attention.

Notes.

[0] The following are among the more useful works of a general character, dealing with the subject. Others are referred to either in the text or notes. The reader may consult also the list of works on Economic Botany in the catalogue published by the Linnæan Society.

Select Extra-tropical Plants, readily eligible for industrial culture or naturalization, with indications of their native countries and some of their uses. By Baron Ferd. von Mueller, K.C.M.G., F.R.S., etc, Government Botanist for Victoria. (Melbourne), 1888. Seventh edition, revised and enlarged.

At the close of his treatise on industrial plants, Baron von Mueller has grouped the genera indicating the different classes of useful products in such a manner that we can ascertain the respective numbers belonging to the genera. Of course many of these genera figure in more than one category.

He has also arranged the plants according to the countries *naturally producing them.*

Useful Native Plants of Australia, (including Tasmania). By J. H. Maiden, F.L.S., Curator of the Technological Museum of New South Wales, Sydney. (Sydney), 1889.

See also note 19.

Handbook of Commercial Geography. By Geo. G. Chisholm, M.A., B.Sc. London, 1889.

New Commercial Plants with directions how to grow them to the best advantage. By Thomas Christy (London), Christy and Co.

Dictionary of popular names of the plants which furnish the natural and acquired wants of man. By John Smith, A.L.S. (London), 1882.

Cultivated Plants. Their propagation and improvement. By F. W. Burbage. (London), 1877.

The Wanderings of Plants and animals from their first home. By Victor Hehn, edited by James Steven Stallybrass, (London) 1885.

Researches into the Early History of Mankind, and the Development of Civilization. By Edward B. Tylor, D.C.L., LL.D., F.R.S., 1878.

[1] The number of species of Phænogamia has been given by many writers as not far from 150,000. But the total number of species recognized by Bentham and Hooker in the Genera Plantarum (Durand's Index) is 100,220, in 210 Natural Orders and 8,417 genera.

[2] Dr. E. Lewis Sturtevant, to whose kindness I am indebted for great assistance in the matter of references has placed at my disposal many of his notes on edible plants, etc. From his enumeration it appears that if we count all the plants which have been cultivated for food at one time or another, the list contains 1,192 species, but if we count all the plants which "either habitually or during famine periods are recorded to have been eaten," we obtain a list of no less than 4,690 species, or about three and one-half per cent of all known species of plants. But, as Sir Joseph Hooker has said, the products of many plants though eatable, are not fit to eat.

[3] The Folk-Lore of Plants. By T. F. Thiselton Dyer, 1889.

[4] In Dr. Sturtevant's list, 88 species of Gramineæ are counted as food-plants under cultivation, while the number of species in this order which can be or have been utilized as food amounts to 146. Our smaller number 20 comprises only those which have been grown on a large scale anywhere.

[5] "In Agricultural Museum at Poppelsdorf, 600 varieties are exhibited."

[6] E. L. S. in letter. Quoted from Seedsman's catalogue.

[7] The best account of the early history of these and other cultivated plants can be found in the classical work of De Candolle "*Origine des Plantes Cultivées* (Paris) translated in the International series, *History of Cultivated Plants*, (N. Y.) The reader should consult also Darwin's *Animals and Plants under Domestication.*

[8] *Food-grains of India*, A. H. Church, London, 1886, p. 34. In this instructive work the reader will find much information regarding the less common articles of food Of *Panicum frumentaceum* Professor Georgeson states in a letter that it is grown in Japan for its grain which is used for food, but here would take rank as a fodder plant.

[9] In order to avoid possible misapprehension, it should be stated that there are a few persons who hold that at least some of our cereals, and other cultivated plants, for that matter, have not undergone material improvement but are essentially unmodified progeny. Under this view, if we could look back into the farthest past, we should see our cereals growing wild and in such admirable condition that we should unhesitatingly select them for immediate use. This extreme position is untenable.

Again, there are a few extremists who hold that some plants under cultivation have reached their culminating point, and must now remain stationary or begin to retrograde.

[10] Gray's Botanical Text Book. Vols. i and ii.

[11] *A Selection from the Physiological and Horticultural Papers*, published in the Transactions of the Royal and Horticultural Societies, by the late THOMAS ANDREW KNIGHT, Esq., President of the Hort. Soc. London. (London) 1841.

[12] *Illustrations of the Manners and Customs and Condition of the North American Indians.* By GEORGE CATLIN, London, 1876. A reprint of the account published in 1841 of travels in 1832–40.

"Plate 278 is a party of Sioux, in bark canoes (purchased of the Chippewas), gathering the wild rice, which grows in immense fields around the shores of the rivers and lakes of these northern regions, and used by the Indians as an article of food. The mode of gathering it is curious and, as seen in the drawing, one woman paddles the canoe, whilst another with a stick in each hand, bends the rice over the canoe with one, and strikes it with the other, which shakes it into the canoe, which is constantly moving along until it is filled." Vol. ii, p. 208.

[13] Schliemann's carbonized specimens exhumed in Greece are said to be "very hard, fine-grained, sharp, very flat on grooved side, different from any wheats now known." Am. Antiq., 1880, 66.

The carbonized grains in the Peabody Museum at Cambridge, Mass., are small.

[14] *Prehistoric Times* as illustrated by Ancient Remains and the manners and customs of modern savages. By JOHN LUBBOCK, Bart., (New York), 4th edn., 1886.

"Three varieties of wheat were cultivated by the Lake Dwellers, who also possessed two kinds of barley and two of millet. Of these the most ancient and most important were the six-rowed barley and small "Lake Dwellers'" wheat. The discovery of Egyptian wheat (*Triticum turgidum*), at Wangen and Robenhausen, is particularly interesting. Oats were cultivated during the bronze age, but are absent from all the stone age villages Rye was also unknown," p. 216.

"Wheat is most common, having been discovered at Merlen, Moosseedorf and Wangen. At the latter place, indeed, many bushels of it were found, the grains being in large thick lumps. In other cases, the grains are free, and without chaff, resembling our present wheat in size and form, while more rarely they are still in the ear." 115 species of plants have been identified. Heer, Keller.

[15] *Les Plantes Potagères*, VILMORIN, Paris. Translated into English under the direction of W. Robinson, Editor of the (London) "Garden," 1885, and entitled *The Vegetable Garden.*

[16] l. c., English Edn., p 104.

[17] According to notes made by Mr. Manning, Sec. Massachusetts Horticultural Society, (Hist. Mass. Hort. Society) the tomato was introduced into Salem, Mass., about 1802 by Michele Felice Corné, an Italian painter, but he found it difficult to persuade people even to taste the fruit (Felt's Annals of Salem, vol. ii, 631). It was said to have been introduced into Philadelphia by a French refugee from San Domingo in 1798. It was used as an article of food in New Orleans in 1812 but was not sold in the markets of Philadelphia until 1829. It did not come into general use in the north until some years after the last named date.

[18] "In Spain and those hot regions, they use to eat the (Love) apples prepared and boiled with pepper, salt, and olives; but they yield very little nourishment to the bodies, and the same nought and corrupt. Likewise they doe eat the apples with oile, vinegar, and pepper mixed together for sauce to their meat even as we in these Cold Countries do Mustard." GERARD'S *Herbal*, 346.

[19] *Commercial Botany of the Nineteenth Century.* By JOHN R. JACKSON, A.L.S. Cassell and Company, London, 1890.

Mr. Jackson, who is the Curator of the Museums, Royal Gardens, Kew, has embodied in this treatise a great amount of valuable information, well arranged for ready reference.

[20] *Department of Agriculture Report* for 1870, p. 404–428. Only those are here copied from Dr. Palmer's list which he expressly states are extensively used.

Ground-nut (*Apios tuberosa*); *Aesculus Californica; Agave Americana; Nuphar advena;* Prairie-potato, (*Psoralea esculenta*); *Scirpus lacustris; Sagittaria variabilis;* Kamass-root (*Camassia esculenta*); *Solanum Fendleri* (supposed by him to be the original of the cultivated potato); Acorns of various sort; Mesquite, (*Algarobia glandulosa*); *Juniperus occidentalis;* Nuts of *Carya*, *Juglans*, etc.; Screw-bean (*Strombocarpus pubescens*); various Cactaceæ; *Yucca;* Cherries and many wild berries; *Chenopodium album*, etc.

Psoralea esculenta = prairie potato, or Bread-root. Palmer in Agl. Report, 1870, p. 402.

The following from Catlin, l. c., i, p. 122:

"Corn and dried meat are generally laid in the fall, in sufficient quantities to support them through the winter. These are the principal articles of food during that long and inclement season; and in addition to them, they oftentimes have in store great quantities of dried squashes, and dried 'pommes blanches,' a kind of turnip which grows in great abundance in those regions. . . . . . These are dried in great quantities and pounded into a sort of meal and cooked with dried meat and corn. Great quantities also are dried and laid away in store for the winter season, such as buffalo berries, service berries, strawberries, and wild plums."

"In addition to this we had the luxury of service berries without stint; and the buffalo bushes, which are peculiar to these northern regions, lined the banks of the river and the defiles in the bluffs, sometimes for miles together, forming almost impassible hedges, so loaded with the weight of their fruit that their boughs everywhere gracefully bending down or resting on the ground. This last shrub (*Shepherdia*), which may be said to be the most beautiful ornament that decks out the wild prairies, forms a striking contrast to the rest of the foliage, from the blue appearance of its leaves by which it can be distinguished for miles in distance. The fruit which it produces in such incredible profusion, hanging in clusters to every limb and to every twig, is about the size of ordinary currants and not unlike them in color and even in flavor; being exceeding acid, almost unpalatable until they are bitten by frost of autumn, when they are sweetened and their flavor delicious, having to the taste much the character of grapes, and I am almost to think would produce excellent wine." George Catlin's *Illustrations and manners, customs, and condition of the North American Indians*, p. 72, vol. i.

For much relative to the food of our aborigines, especially of the western coast, consult The Native Races of the Pacific States of North America. By H. H. Bancroft, (New York), 1875. The following from vol. i, p. 538, indicates that inaccuracies have crept into the work: "From the earliest information we have of these nations" (the author is speaking of the New Mexicans), "they are known to have been tillers of the soil; and though the implements used and their methods of cultivation were both simple and primitive, cotton, corn, *wheat*, beans, and many varieties of fruits which constituted their principal food were raised in abundance."

Wheat was not grown on the American continent until after the landing of the first explorers.

[21] Gard. Chron., 1888.

[22] Pickled Daikon, the large radish, often grated.

Ginger-roots—Shoga.

Beans (*Glycine hispida*), many kinds, and prepared in many ways.

Beans (*Dolichos cultratus*), cooked in rice and mixed with it.

Sliced Hasu, Lotos roots.

Lily bulbs, boiled whole and the scales torn off as they are eaten.

Pickled green plums, (Ume-boshi) colored red in the pickle, by the leaves of *Perilla arguta* (Shiso).

Sliced and dried cucumbers, Kiuri.

Pieces of Gobo,—Roots of *Lappa major.*

Rakkio,—Bulbs of *Allium Bakeri*, boiled in Shogu.
Grated Wasabi,—Stem of *Eutrema Wasabi.*
Water-cress,—Midzu-tagarashi (not often).
Also sometimes pickled greens of various kinds, and occasionally chestnut-kernels boiled and mixed with a kind of sweet sauce.
Nut of the Ginkgo tree.
Several kinds of seaweeds are also very commonly served with the rice. Professor C. C. Georgeson in letter.

[23] l c. Preface in English Edition.

[24] "Carbonized apples have been found at Wangen, sometimes whole, sometimes cut in two, or, more rarely, into four pieces and evidently dried and put aside for winter use. . . . . . They are small and generally resemble those which still grow wild in the Swiss forests; at Robenhausen, however, specimens have occurred which are of larger size, and probably cultivated. No trace of the vine, the walnut, the cherry, or the damson has yet been met with, but stones of the wild plum and the *Prunus padus* have been found." LUBBOCK, *l. c.*, p. 217.

[25] *Animals and Plants under Domestication* (Am. Edn.), vol. ii, p. 205–209.

[26] *American Garden*, N. Y. 1890–91.

[27] *American Garden*, N. Y. 1891.

[28] *Useful Native Plants of Australia*, by J. H. MAIDEN, Sydney.

[29] *The Flowers of Japan* and the Art of Floral Arrangement. By JOSIAH CONDER, F.R.I.B.A., Architect to the Imperial Japanese Government. Yokohama, 1891. See also two other works by the same author: Theory of Japanese Flower-arrangements, and Art of Landscape-gardening in Japan. (1886.)

[30] Mr. SAMUEL DIXON'S list is in vol. viii (for 1884–85) of the *Transactions and Proceedings and Report of the Royal Society of South Australia.* Adelaide, G. Robertson, 1886.
Bursaria spinosa, "a good stand-by," after the grasses dry up.
Pomaderris racemosa, "stands stocking well."
Pittosporum phyllaeroides, "sheep exceedingly partial to its foliage."
Casuarina quadrivalvis, "tenderness of fiber, wool would be represented by it in our finer wool districts."
Acacias, The Wattles. "Value as an astringent, very great," being curative of a malady often caused by eating frozen grass.
Acacia aneura (mulga). "Must be very nutritious to all animals eating it." This is the plant which is such a terror to the stockmen who have to ride through the "scrub."
Cassia, some of the species with good pods and leaves for sheep.
The foregoing are found in districts which are not wholly arid.
The following are, more properly, "dry" plants.
Sida petrophila, "as much liked by sheep as by marsupials."
Dodonaea viscosa, Native Hop-bush. "Likes warm, red, sandy ground."
Lycium australe, "Drought never seems to affect it."
Kochia aphylla: "All kinds of stock are often largely dependent on it during protracted droughts."
Rhagodia parabolica: "Produces a good deal of foliage."
Atriplex vesicaria: "Can be readily grown wherever the climate is not too wet."
I have transferred only those which Mr. Dixon thinks most worthy of trial. Compare also Dr. VASEY'S valuable studies of the plants of our dry lands, especially Grasses and Forage plants (1878), Grasses of the arid districts of Kansas, Nebraska, and Colorado (1886), Grasses of the South (1887.

[31] The weeds of German gardens and agricultural lands are mostly from Mediterranean regions, but the invasions in the uncultivated districts are chiefly from America, (such as *Oenothera*, *Mimulus*, *Rudbeckia*). Handbuch der *Pflanzengeographie*, von Dr. OSCAR DRUDE, (Stuttgart), 1890, p. 97.

[33] The list of economic plants published by the Department in Washington is remarkably full, and is in every way creditable to those in charge.

ART. XXVIII.—*On the Vitality of some Annual Plants;* by THEO. HOLM. (With Plate X.)

THE curious fact, that there may be individuals of annual species of which the life-time is not limited merely to one year, has been noticed by several botanists. Exceptions of that kind often seem to be nearly accidental, but in most cases they are, however, to be considered as due to certain external factors, as for instance climate and soil or cultivation. Indeed, the number is not very small of the species in which a fluctuation has been observed from being annual to perennial or at least biennial in a modified sense, as well as of those for which similar intergradation-forms have been recorded between the biennial on the one side and the annual and perennial ones on the other.

Irmisch* mentions for instance, that *Echinospermum Lappula*, which is usually biennial may occur as annual, having already developed the flowers in the first year; he observed that the same is true in the case of *Hyoscyamus niger*, of which even the annual form has been described as a proper species (*H. agrestis*) since it is very different in habit from the biennial type. The same author has also observed, that *Hypericum humifusum* and *Malva neglecta* may occur as both annual and perennial. *Sedum annuum*, which has been described as annual by Hartman, Areschoug and Blytt, was observed by Warming† to be biennial, and even that this seemed to be the normal for this plant.

Hildebrand‡ enumerates several species, which, although they occur under widely different conditions in both hemispheres, nevertheless seem to be constant as to their life-duration and habit; such species for example are the annual *Polygonum aviculare*, *Erigeron Canadensis*, *Papaver Rhœas*, etc., while of perennials *Thymus serpyllum*, *Verbena officinalis*, *Urtica dioica*, etc. He enumerates on the other hand several other species, which show a tendency to vary from annual to biennial, among which are many *Cruciferæ; Compositæ* and cultivated *Gramineæ*, besides some usually biennial species, which may occur as perennials, as for instance some *Cruciferæ*, *Umbelliferæ*, *Papilionaceæ*, etc. Similar aberrant forms are evidently far from rare in this country, though the author has not

* Thilo Irmisch: Zur Morphologie der monocot. Knollen und Zwiebelgewächse, 1850, p. 211.

† Eug. Warming: Om Skudbygning, Overvintring og Foryngelse. (Naturhist. Forenings Festskrift, 1884, p. 16.)

‡ Fr. Hildebrand: Die Lebensdauer und Vegetationsweise der Pflanzen, ihre Ursachen und ihre Entwickelung. (Engler's Botanische Jahrbücher, vol. ii, 1881, p. 51.)

succeeded in finding any special observations in the literature, and as he has had the opportunity of observing a few cases of that kind, they seem to likely to be of some interest, at least locally.

Hypericum nudicaule Walt. (*H. Sarothra* Michx.) is undoubtedly typically annual, but a few individuals were, however, collected late in the fall, which seemed to prove an exception. The base of one of these specimens is figured on plate X, fig. 1, and we see here two densely leaved branches proceeding from the lower part of the stem, and probably developed in the axils of the cotyledons. These shoots with numerous imbricate leaves might be supposed to be able to winter over and in the following year to give rise to flowers; the root-system in these individuals was unusually strong, showing not only a primary root, but also a few, and rather strong, lateral ones.

Another example is *Delphinium consolida* L., which as far as known to the author has not been recorded as otherwise than annual in Europe and here. The plant is rather rare in the vicinity of Washington, but occurs as escaped from cultivation on the banks of the Potomac. It was observed here to vary from annual to perennial, although both forms were growing together, and the perennial form showed a strong, persistent primary root and several flowering stems, besides a cluster of buds for the following year.

This kind of variation was also observed in *Cyperus flavescens* L., a plant, which is rather common in wet places around Washington, and I have sometimes met with individuals, which certainly seemed to be perennial. One of these is figured on plate X, fig. 6, and shows in contrast to the annual type a distinct rhizome with creeping stolons, from the nodes of which several strong roots proceed. It must be admitted that this specimen shows the general aspect of a perennial, stoloniferous *Cyperus*, able to give rise to new individuals by a vegetative propagation. Whether this species has been recorded as perennial also in other countries, I do not know, but Lange* mentions, however, the fact that he has collected the plant in France, where some specimens showed "tuberous stolons," and therefore questions its character as annual. Grenier and Godron† have, nevertheless, described the plant as merely annual. It might be mentioned here, that a similar variation also exists in *Carex cyperoides* L., which under normal conditions is truly annual; Lange states (l. c. p. 118) that the periodical disappearance of this plant in several parts of Europe has been explained by the fact, that it is able to veg-

* Joh. Lange: Haandbog i den danske Flora, 1886–88, p. 116.
† Grenier et Godron: Flore de France, vol. iii, 1855.

etate for several years without flowering, if the locality becomes inundated.*

It seems then, that this ability to vary among *Cyperaceæ* is easy to explain, although it may not be a necessary consequence in all cases; our specimens of *Cyperus* were observed as occurring together with numerous annual individuals and under the very same conditions.

The *Gramineæ* may undoubtedly include several other species, besides the cultivated ones, mentioned by Hildebrand (l. c.) in which this same variation may take place. *Tragus racemosus* Hall, represents at least the same case as that of *Cyperus*. It has always been considered as annual, lately by Dr. Vasey,† although some specimens in U. S. National herbarium prove, that it can also occur as perennial. These specimens have long stolons above-ground with abundant formation of leafy shoots at each node, from where long roots are also developed. A part of a stolon has been illustrated in plate X, fig. 2, where we see not only the crowded shoots, but also a secondary formation stolons (S). All these shoots were developed in the axils of leaves, belonging to the stolons, and they showed besides the proper leaves also the characteristic prophyllum (fig. 3). This small leaf had a rather unusual shape than otherwise observed; it was not only distinctly bicarinate, but showed at its apex two long teeth, corresponding to those of an ordinary palet (fig. 4). A transverse section (fig. 5) of the prophyllum shows the prominent keels and the very thin margins, besides the presence of not only two, but even six nerves, those of the keels being the strongest.

This manner of growth seems to be rather common in North American *Gramineæ*, especially those, which ramify, and there is no doubt that under favorable conditions they might change their habit from annual to perennial or at least biennial.

The *Cruciferæ*, which include representatives of all the three types of growth, are, as mentioned above, quite apt to vary in a similar manner. The genus *Arabis* is very instructive in this regard, as for instance *A. dentata* Torr. et Gr., of which the lower part of a perennial specimen has been figured on Plate X, fig. 7, which shows the character of a biennial in a perennial form. We see here a leafy shoot terminating the main axis, from the leaves of which flowering stems will be developed next year. We see further, that the base of this shoot is surrounded by now faded leaves, merely indicated by the petioles, and from the axils of which proceed the ascending flowering stems of the year.

* Compare: Bull. de la Société botan. de France, 1860, p. 186.

† Geo. Vasey: Grasses of the Southwest, Part I, 1890. (Bull. of U. S. Dept. of Agriculture).

The plant illustrates then at once the two stages of a biennial growth: the leafy roset, which will winter over, and the flowering stems from a similar roset of the preceding year. The age of this specimen is at least three years, for there is a distinct stem-part (S^1) to be seen between the primary root and the now faded roset of leaves. This part of the stem is in contrast to the upper part which is horizontal and fixed to the ground by strong roots in addition to the persistent primary one. The plant has undoubtedly merely developed a leafy roset in its first year, when the seed germinated, probably flowered the second year and produced the stem-part S^1, flowered again in the third year, producing contemporarily a shoot that will flower next year, until finally an inflorescence will terminate the main axis and the entire individual die away after the ripening of the fruits.

The closely allied *A. lyrata* L. has been mentioned by Hildebrand (l. c.) as being annual or biennial. It occurs, however, also as perennial, and most commonly so in the Southern United States. I have collected several specimens in the vicinity of Washington, which were all decidedly perennial, and most of the individuals in the National Herbarium from other parts of North America showed the same fact. Some specimens from Japan were, however, annual, with flowers and leaves developed in the first year and at the same time. The perennial form shows nearly the same habit as above described for *A. dentata*, but commonly with a profuse development of lateral leafy shoots together with the inflorescences, so that the life is secured for a considerably longer time than in the preceding species.

That also *Arabis lævigata* Poir. may occur as perennial has been recorded by Hildebrand (l. c.), but without data; Gray has considered this species as truly biennial, in which form it occurs exclusively around Washington, where it is very abundant.

Washington, D. C., July 22d, 1891.

EXPLANATION OF PLATE X.

FIG. 1.—*Hypericum nudicaule.* The base of the stem, showing two densely leaved shoots. Natural size.

FIG. 2.—*Tragus racemosus.* Part of a stolon A–A, with secondary branches S and several crowded shoots. Natural size.

FIG. 3.—Same. Part of a stolon, showing two leafy shoots in the axils of two leaves, belonging to the stolon. P, the prophyllum. Slightly enlarged.

FIG. 4.—Same. The prophyllum; *a*, side, and *b*, back view.

FIG. 5.—Same. Transverse section of the prophyllum.

FIG. 6.—*Cyperus flavescens.* The base of a perennial specimen, showing the stolons. F, the base of the flowering stem. Natural size.

FIG. 7.—*Arabis dentata.* The base of the plant, showing the primary root (R) and some secondary ones (*r*). L, L^1 and L^2 indicate the leafy rosets of 1st, 2d and 3d year. F, the lower part of flowering stems. Natural size.

ART. XXIX.—*A Method for the Separation of Antimony from Arsenic by the Simultaneous Action of Hydrochloric and Hydriodic Acids;* by F. A. GOOCH and E. W. DANNER.

[Contributions from the Kent Chemical Laboratory of Yale College—IX.]

A METHOD for the separation of arsenic from antimony based upon the difference in volatility of the lower chlorides was introduced originally by Fischer.* This method of treatment consisted in the reduction of the chlorides by means of ferrous chloride and the volatilization of the arsenic by repeated distillations of the mixture with hydrochloric acid of twenty per cent strength added in successive portions. The process has been subsequently modified by Hufschmidt† by the substitution of gaseous hydrochloric acid, introduced in continuous current into the distilling mixture, for the aqueous acid, and later changed further and improved by Classen and Ludwig,‡ who employ ferrous sulphate, or ammonio-ferrous sulphate, in place of the less easily prepared ferrous chloride. In its latest form the method is exceedingly exact, but the conditions are such that the antimony in the residue must be determined gravimetrically. It has been our endeavor to so arrange the process that the determination of the antimony may be made by a rapid volumetric method, and this we have attempted to accomplish by substituting for the iron salt, which utterly precludes the direct volumetric estimation of the antimony, another reducer—hydriodic acid—which can interfere in no way with the subsequent determination of the antimony by the well known iodometric method.

It has been shown in previous work in this laboratory that arsenic§ and antimony‖ may both be reduced by the action of hydriodic acid applied under appropriate conditions. In those processes, however, it was essential that the arsenic should not volatilize, and the conditions were adjusted accordingly. In the present case we have to test the reducing action of hydriodic acid in the presence of strong hydrochloric acid and at the boiling temperature of the solution—conditions arranged to bring about the volatilization of the arsenic as rapidly as possible. Certain preliminary experiments gave indication that a half gram of arsenic oxide could be completely volatilized by the action of potassium iodide in excess in the manner described, and that an equivalent weight of antimonious oxide

* Ann. Chem. u. Pharm. 208, 182. † Ber. d. deutsch. chem. Ges., xvii, 2245.
‡ Ber. d. deutsch. chem. Ges. xviii, 1110.
§ Gooch and Browning, this Journal, vol. xl, p. 66.
‖ Gooch and Gruener, this Journal, vol. xlii, p. 213.

(added in the form of tartar emetic) was retained entirely in the residue under similar conditions of treatment. Moreover, it appeared that this action could be brought about in solutions measuring no more than 100 cm.^{3} at the beginning and no less than 50 cm.^{3} at the end of the distillation, so that a very considerable saving of time over that demanded by the process of distillation as left by Classen and Ludwig could be effected. Accordingly we proceeded to test the action of the hydriodic acid quantitatively, following the same general lines. The distillation-apparatus consisted of a flask of 250 cm.^{3} capacity, provided with a hollow glass stopper tightly fitted in a ground joint, the stopper itself being sealed upon a large glass tube bent suitably to connect the interior of the flask with an upright condenser, while through the hollow stopper, and sealed into it, passed a smaller glass tube reaching nearly to the bottom of the flask. The arrangement was such that a current of gas entering the smaller tube would pass nearly to the bottom of the flask and then out through the hollow stopper into the condenser without meeting joints of rubber or cork. Into this flask was weighed, for the experiments of Table I, about a half gram of carefully recrystallized tartar emetic, and a half gram of pure di-hydrogen potassium arseniate and a gram of potassium iodide were added in concentrated solution, the volume of liquid being made up to 100 cm.^{3} by the addition of strong hydrochloric acid. A brisk current of hydrochloric acid gas was passed into the solution through the tube sealed into the glass stopper of the flask until complete saturation was effected, and then the liquid was heated and distilled in the continuous current of hydrochloric acid gas until the volume of 30 cm.^{3} was reached. Iodine was evolved as soon as the liquid became warm and the greater part of it passed into the distillate with the first 10 cm.^{3} When the final concentration was reached the solution was in each case colorless, but on cooling there appeared in one of the two experiments of this set a pale yellow tint which vanished with the dilution involved in the transfer and washing from the flask previous to titration. The addition of starch to the cooled and diluted liquid developed no color. To the liquid were added 1 grm. of tartaric acid, to keep the antimony in solution during subsequent treatment, sodium hydrate nearly to neutrality, and hydrogen sodium carbonate in excess amounting to about 20 cm.^{3} of the saturated solution; and the antimonious oxide in solution was titrated by decinormal iodine standardized against tartar emetic. The details of these experiments are given in Table I.

In Table II are comprised the accounts of experiments similar in general to those of Table I, excepting that the final volume after concentration was a little more, and the antimony was in every case oxidized in alkaline solution by standard iodine previous to the introduction of hydrochloric acid and distillation.

Table III includes the records of experiments similar in every respect to those of Table II excepting that as starch showed a slight color in the cooled liquid after distillation, the solution was treated with an excess of sulphurous acid which was subsequently oxidized exactly by standard iodine previous to neutralization and the final titration.

H_2KAsO_4 taken.	KI taken.	Volume initial.	Volume final.	Color on cooling.	Color with starch.	Sb_2O_3 taken.	Sb_2O_3 found.	Error.
grm.	grm.	cm.^{3}	cm.^{3}			grm.	grm.	grm.
				I.				
0·5	1·0	100	30	pale yellow	none	0·2282	0·2271	0·0011–
0·5	1·0	100	30	none	none	0·2283	0·2266	0·0017–
				II.				
0·5	0·5	120	50	none	none	0·2258	0·2235	0·0023–
0·5	0·5	100	50	pale yellow	none	0·2252	0·2235	0·0017–
0·5	0·5	100	50	pale yellow	none	0·2178	0·2163	0·0015–
0·5	0·5	100	50	trace	none	0·2231	0·2231	0·0000
0·5	0·5	100	40	trace	none	0·2261	0·2235	0·0026–
				III.				
0·5	0·5	100	50	pale yellow	faint	0·2268	0 2265	0·0003–
0·5	0·5	100	50	pale yellow	faint	0·2306	0·2300	0·0006–
0·5	0·5	100	50	pale yellow	faint	0·2272	0·2264	0·0008–

The same general phenomena were observed in all these experiments, and deficiencies in the amounts of antimony indicated, whether the element was present in the lower or higher degree of oxidation before distillation, appear in all, but most notably in the results of Tables I and II. These losses cannot be attributed, entirely at least, to mechanical transfer in the process, inasmuch as the greater losses are not associated with the greater concentrations; and, furthermore, according to our qualitative experiments made under the conditions of these determinations, no antimony, so far as we could observe, passes into the distillate. If the coloration of the liquid on cooling were due to the liberation of iodine by the action of air upon the hydriodic acid the iodine thus set free might be counted upon to oxidize a corresponding portion of the antimony in the neutralization, and so to occasion a deficiency in the indications of titration. Against this supposition, however, we have the evidence of experiment that the greatest losses are not found in those cases in which color was developed in the cooling liquid. Moreover, in all cases, excepting those of Table III, starch gave no test for free iodine in the diluted liquid, though it must not be overlooked that the presence of a considerable amount of hydrochloric acid tends to impair the delicacy of the test. If, on the other hand, the color is not due altogether to free iodine it is difficult to account for its development unless it is caused by the formation of antimonious iodide as the solution of strong hydrochloric containing also hydriodic acid cools. On the whole, we are inclined to attribute at least a part of the apparent deficiency to the presence, at the time of neutralization, of a small amount of iodine chloride, which, in accordance with what is known of its modes of formation, might be formed by the oxidizing effect of the antimonic and arsenic oxides upon the mixed acids. At all events, it is evident that if iodine chloride were present we should expect to note the phenomena which we do see; it would give, in small quantity, little or no color to the liquid, would not show the starch reaction for free iodine in the acid solution, and would be destroyed with the formation hydrochloric and hydriodic acids by the addition of sulphurous acid to the still acid liquid, leaving the antimony unchanged and determinable iodometrically in alkaline solution after the exact oxidation of the excess of sulphurous acid by iodine in acid solution; on the other hand, it would act in alkaline solution like the free halogens and tend to diminish the antimony indicated by titration. Whatever the real cause or causes of the deficiency may be, it appears in the results of Table III that the treatment with sulphurous acid affects the indications favorably. The mean error of three closely agreeing determinations is 0·0006 grm.—and this is plainly within the limits of allowable variation in iodometric work with decinormal solutions.

It appears, therefore, that hydriodic acid may be made to serve satisfactorily as a substitute for the ferrous chloride of Fischer's original method, or for the ferrous sulphate of the modification of Classen and Ludwig, the determination of the residual antimony being perfectly practicable. The method of proceeding which we advocate is briefly summarized in the following statement: To the solution of the oxides of arsenic and antimony, taken in amounts not exceeding 0·5 grm. of each, potassium iodide is to be added in a little more than the equivalent quantity, and enough strong hydrochloric acid to raise the entire volume of the solution to 100 $cm.^3$ Hydrochloric acid gas is passed into the liquid to saturation as well as during the distillation to follow, and the distillation is carried on until the volume of the liquid decreases to 50 $cm.^3$ or a little less. The liquid is cooled rapidly, treated first with an excess of sulphurous acid and then with iodine to the exact oxidation of the former reagent; and, after the addition of 1 grm. of tartaric acid to every 0·2 grm. of antimonious oxide, the acid present is nearly neutralized with sodium hydrate, the neutralization being completed by hydrogen sodium carbonate added in excess to an amount corresponding to 10 cm.^{3} of the saturated solution for every 0·1 grm. of antimonious oxide present. Titration with decinormal iodine standardized against tartar emetic gives the antimony quickly and with a fair degree of accuracy. The whole process requires about an hour and a half for completion.

ART. XXX.—*Notes on Allotropic Silver;* by M. CAREY LEA.

Relations of the Yellow to the Blue Forms.—The gold-and copper-colored forms on the one hand, and the blue, bluish-green and steel-gray on the other hand stand in close relations to each other. In previous papers there has been described a crystalline state intermediate between these active forms and ordinary silver, which intermediate condition, while retaining the bright yellow color of the active form is nearly as indifferent to reagents as ordinary silver. Into this intermediate state both the yellow and blue forms are capable of passing, and apparently the intermediate states of both kinds of allotropic silver are identical: *the intermediate form of blue silver is yellow.* Thus when lumps of blue silver are heated in a test tube to about 180° C. they assume a gold color and luster. The same change takes place at the same temperature when films of blue silver are placed in a hot air bath.

But relations much closer than these exist. Blue silver can be converted into yellow at ordinary temperatures and consequently with retention of its active properties. This is accomplished through the agency of sulphuric acid. When a solution of silver is obtained by the action of sodium hydroxide and dextrine on silver nitrate* it appears to contain the blue variety, for if allowed to precipitate spontaneously by long standing, or if precipitated by acetic acid, dilute nitric acid, or by many neutral substances, it gives a form of silver which is dark red while moist and dries with a blue surface

* Forty grams each of sodium hydroxide and of yellow or brown dextrine (not white) are dissolved in two litres of water and 28 grams of silver nitrate in solution are added in small quantities at a time, with frequent stirring, so that several hours shall elapse before the last portion is added. The solution is always slightly turbid when viewed by reflected light, by which it shows a beautiful deep green color. By transmitted light it is deep red, and when diluted, absolutely transparent. By diminishing the proportion of silver nitrate to one-half, a solution nearly or quite clear by reflected as well as by transmitted light is obtained.

color. (It is always a little difficult to characterize these substances by their colors since the surface color which they show when dry—either in mass or in films—is mostly complementary to their color when wet. As the surface color is much the more characteristic, I have adopted the course of naming them by that.)

The behavior of the red solution obtained by soda and dextrine with dilute sulphuric is very interesting and instructive. When 100 c.c. of solution are poured into 100 c.c. of water to which 3 c.c. of sulphuric acid have been previously added, a dark red precipitate falls, which, when dry, especially in films, is blue. The mixed liquid from which the precipitate is formed is acid. Increasing the proportion of acid to 4, 5 and 6 c.c. successively, the substance obtained has a green surface color becoming more yellowish green in proportion as the acid is increased in quantity. With 7½ c.c. the substance no longer dries green but yellow. Increased proportions of acid produce substances drying with a coppery shade.

It will be seen that from a single solution, and using one substance only as a precipitant, we can obtain the whole range of different forms of allotropic silver, by simply varying the proportions of the precipitant.

That these forms of silver should subsist in the presence of sulphuric acid in excess is remarkable. For the most part the presence of this acid tends to quickly convert allotropic to ordinary silver. For example, bright yellow allotropic silver obtained with ferrous tartrate was washed on a filter with water containing 1/500 its volume of sulphuric acid: in two or three hours the entire mass was converted into gray ordinary silver.

It is observable that the substances precipitated with the least acid, have a very splendid luster, and that this luster diminishes steadily as the proportion of acid is increased. Up to 6 c.c. to 100 the effect is hardly noticeable, after that it becomes more marked.

But we can also obtain the converse of this reaction. Just as the solution which naturally would yield the blue product, can be made to yield the yellow by the presence of excess of strong acid, so the solution which normally yields the yellow substance, may be made to produce blue (or rather green) silver by adding alkali. Thus a mixture of dilute solutions of ferrous sulphate and of Rochelle salt added to mixed solutions of silver nitrate and of Rochelle salt, results in the formation of gold-colored silver. But if we add a little sodium hydroxide, either to the iron solution or the silver mixture, we shall get a bluish green product, whose properties show that it belongs to the blue class and not to the yellow. Even if a solution of the hydroxide is added immediately after the iron solution has been poured into the silver, the result is the same.

There is therefore a well marked tendency of acids to give rise to the formation of the yellow product and of alkalies to the blue. But this is a tendency only. Both substances can be produced from neutral solutions, and slight changes are sufficient to alter the product formed. Thus, ferrous tartrate, in dilute solution acting on silver tartrate gives rise to the formation of the gold-colored substance, but when citrates are substituted, the blue substance is obtained.

Production of Allotropic Silver by Inorganic Substances.—For reasons which will be mentioned presently, the reduction of silver must take place gradually to produce the allotropic form, and for a time it seemed an invariable condition that an organic substance of some sort should be present. This, however, proves not to be essential. In a paper presented to the American Academy and kindly read for me by Professor Remsen at the meeting in April last, I alluded briefly to having found a reaction depending upon inorganic agents only. It is as follows: Sodium hypophosphite added to silver nitrate does not effect reduction, but when hypophosphorous acid is set free by the addition of phosphoric acid, a red coloration appears, indicating the presence of allotropic silver. The coloration is transitory, no doubt because of the strong tendency of free mineral acids to convert allotropic to normal silver, but red and blue stains form on the sides of the vessel.

Phosphorous acid gives similar results, though perhaps less well marked.

Action of Light on Blue Silver.—This action differs with different varieties: it was more especially examined with the form that is obtained from the soda dextrine silver solution already described by pouring the solution into an equal bulk of water to which sulphuric acid had been added in the proportion of 4 c.c. to each 100 c.c. of water. This form was selected because it is easy to obtain with great constancy of result, and because it is one of the forms of blue silver most sensitive to light.

Exposed to light, this substance first becomes more distinctly blue, losing a slight greenish shade. With continued exposure it passes to a yellow-brown shade, and finally to a perfectly pure golden-yellow of great brilliancy and luster. The last is the intermediate or crystalline form.

The action of light on this form of silver is remarkable in this respect, that its first effect is to *increase* the sensitiveness to reagents.

This result was so unexpected and *a priori* so improbable, that it was subjected to the most careful verification before being accepted. The action is very easily shown by exposing a film of the substance to light, covering part of the surface with an opaque screen. After twenty or thirty minutes of exposure to strong summer sunshine, the film may be plunged into a one per cent solution of potassium ferridcyanide, when the part exposed colors much sooner and more strongly than that which was covered. The effect is shown still better by placing the film in a frame, covering part with paper rendered absolutely opaque by coating it with thick tin foil, part with translucent paper (thick white writing paper or very thin brown paper) and leaving part wholly exposed. After four or five hours action of strong summer sunshine, the film is to be treated with weak ferridcyanide. The part wholly exposed having passed into the gold-colored crystalline condition (if the exposure has been sufficient) is wholly unacted upon, the part covered by the translucent paper is rapidly attacked, that wholly protected is attacked slowly. So that the portion moderately acted on by light has very markedly increased in sensitiveness thereby.

It follows that upon this form of silver *light has a reversing action*, first exalting its sensitiveness, then completely destroying it.

It is impossible to overlook the analogy which exists between this action of light, and that which light exerts on silver bromide.

The latter substance though incomparably more sensitive to light, is subject to the same reversing action, first gaining in sensitiveness to reducing agents and then, by continued exposure, becoming less sensitive than originally, a change commonly known as solarization.

Causes determining whether in the reduction of Silver, the Allotropic or the Normal form shall be produced.—I have examined the phenomena connected with the reduction of silver under a great variety of conditions. These for the most part do not deserve particular mention but seem to lead up to this generalization: that the reduction of silver may be direct or indirect, direct when it passes from the condition of the normal salt or oxide to that of the metal, indirect when the change is first to sub-oxide or to a corresponding sub-salt. So far as my observation has gone when the reduction is *direct* the reduced silver always appears in its ordinary form. But when the reduction is *indirect* the silver presents itself in one of its allotropic states.

The following reactions support this view.

Three of the principal modes of formation of allotropic silver are: (1) reduction of silver citrate or tartrate by ferrous citrate or tartrate; (2) acting on silver nitrate or oxide by dextrine and fixed alkaline hydroxide; (3) acting on silver nitrate or carbonate by tannin and fixed alkaline carbonate. Now, if in either of these three cases we interrupt the action before it is complete by adding an excess of dilute hydrochloric acid we shall obtain a dark chestnut-brown or sometimes purple-brown substance which on examination proves to be a mixture of silver subchloride and photochloride. When, after complete removal of the excess of hydrochloric acid by thorough washing or better by boiling with distilled water, the substance is treated with cold dilute nitric acid that portion of the sub-chloride which is not combined with the normal chloride is broken up and there remains photochloride of a very rich and intense rose-color.*

The production of silver sub-chloride in all these cases would seem to indicate that the reduction when the acid was added was incomplete, and that in case (1) a sub-salt, and in cases (2) and (3) a sub-oxide was first formed as an intermediate step before complete reduction. Either of these substances would of course give rise to the formation of subchloride when treated with hydrochloric acid. It is important to observe that this result is to be obtained only by interrupting the reaction before it is complete. When, for example, allotropic silver in solution is produced by the action of sodic hydroxide and dextrine and after complete reduction, hydrochloric acid is added, the liquid becomes filled with gray normal silver, which presently collects to a cake. When this cake is well washed and boiled with water, and then treated with dilute nitric acid, solution takes place: a trace of photochloride is left behind. It has been mentioned elsewhere that hydrochloric acid, though without action on ordinary silver, is capable of forming a variable quantity of protochloride when placed in contact with allotropic silver.

I have not met with any exception to this general principle that when a reaction leading to the formation of allotropic silver is interrupted by the addition of hydrochloric acid, subchloride is abundantly formed as one of the products.

In all such cases the reduction is evidently indirect. The silver does not lose at once the whole of its oxygen, but apparently passes through an intermediate form, probably Ag_4O, the reduction of which tends to the formation of allotropic silver.

These facts lead directly up to the question: does silver exist in its subsalts in the allotropic form? There are some

* This is a very beautiful reaction and deserves more particular mention than can be given here. It is perhaps the best means for obtaining silver photochloride, for which purpose I have often employed it, both on account of its facility and certainty, and the very beautiful color of the product.

facts that would support this view, especially the very rich and varied coloration of the subsalts corresponding to the almost infinite variety of color of allotropic silver, while normal salts of silver when formed with colorless acids are mostly colorless. On the other hand, the greater activity of allotropic silver and its less specific gravity would seem to indicate a simpler molecular constitution than that of normal silver.

ART. XXXI.—*Structural Geology of Steep Rock Lake, Ontario;* by HENRY LLOYD SMYTH. With Plate XI.

GEOGRAPHY.

STEEP ROCK LAKE is situated in the Province of Ontario, Canada, northwest of Lake Superior and south of the Canadian Pacific Railway. It lies about twenty-five miles east of the center of the rough quadrilateral formed by the Canadian Pacific Railway on the northeast, the Lake of the Woods on the northwest, the United States boundary on the southwest, and the shore of Lake Superior from Pigeon River to Port Arthur, on the southeast. As given on the map of the Province, scale 1 inch = 30 miles, published by the Crown Lands Department, Toronto, 1884, the geographical position of the extreme southern point of the lake, where it receives the waters of the Aticokan River from the east, is about lat. 48° 52′ N. and long. 91° 30′ W. from Greenwich; or, it is about halfway upon the map between Lac des Milles Lacs and Rainy Lake.

TOPOGRAPHY.

Steep Rock Lake is one of the many that, collectively, connected by longer or shorter links of river make up the River Seine from Island Falls as far as, and doubtless below, the Aticokan River. In shape the lake resembles, as shown on the map, an irregular and slightly distorted letter M, of which the western or left arm, (looking north), runs north and south, and the eastern or right arm northwest and southeast. This peculiar form is closely related to the character and to the structure of the rocks in which the lake lies as will be seen in what follows. The Seine River, after a beautiful fall, two hundred feet across, and forty to fifty feet high, over granite, some three hundred yards northeast of the lake, flows into it at a point about a mile southeast of the northwest extremity of the eastern arm. It leaves the lake at the extreme southern end of the western arm. Between the points of entrance and exit there is no current observable by the eye and the difference in level must be exceedingly small.

As regards dimensions:—from the southern extremity of the eastern arm to the mouth of the river near the Falls is about 3½ miles; from the Falls to the Elbow, 3 miles; from the Elbow to the Upper Narrows, 1½ miles; and from the Upper Narrows south to the Aticokan River 3½ miles. The entire lake including the portion of Lake Margaret shown on the map could be inscribed within a rectangle 6 miles from east to west, and 5½ miles from north to south, or within an area of 33 square miles. As the name implies the lake has bold rocky shores, which, in places rise 150 feet from the water in nearly perpendicular cliffs. The total length of shore line is approximately 28 miles not counting the smaller bays and indentations. Not less than ¾ of this length shows rock in place either at the water's edge or within a few hundred feet of it, and of this perhaps ¼ may be studied without leaving the boat.

The contour of the water line shows a very beautiful dependence upon structural conditions. The eastern arm follows the general strike of the rocks from the bay north of Lake Margaret portage northwest to Falls Bay. On the northeastern shore of this arm the lower limestone makes several bold headlands that rise abruptly from 60 to 100 feet above the water. In the bays between these headlands the basement granites intersected by a large number of greenstone dikes form the shore, and rise more gently into the broken hummocky hills that generally characterize the granitic areas of the region. A few hundred feet back from the southwestern shore the great trap intrusions or flows of Horizon IV make a continuous ridge, which is estimated to reach a height of 250 feet above the water. This ridge runs, without interruption, the top showing only a few minor sags, from the shore west of the portage into Lake Margaret, for 3 miles along the strike in a northwest direction as far as the wide expansion of Falls Bay.

The gneissic phases of the granites, and associated irruptives compose the west shore of Falls Bay, from the great limestone exposure at the head, south to the Elbow. As far south as Wiegand's Point, the granite cliffs are high and very steep and are broken across only in two or three places. On the south shore of Falls Bay from Trap Point to Jack Pine Pt. the shore line cuts the strike of the rocks nearly at right angles, and from Jack Pine Pt. south to Pine Beach obliquely at a less angle. The ridges descend rather gradually to the lake along this shore, the harder rocks making little headlands separated by sand and shingle beaches.

From the southern point of Pine Beach the shore again follows the strike of the rocks, as it sweeps round the south pitching axis of the middle anticlinal; and in the stretch from Bowlder Point to the Upper Narrows, in which the strike locally varies between N. 2° W. and N. 18° E. the water line minutely corresponds to the minor deflections. This shore shows continuous rock exposure, and the cliffs reach a height in places of 40 or 50 feet above the water, having perpendicular faces along cleavage surfaces.

The highest land about the lake is north and west of Conglomerate Bay, and in the peninsula between it and Northwest Bay. Except for a fringe of the Conglomerate and lower limestone (Formations I and II) along Northwest Bay, and of the upper horizons of the series east of the fault line that crosses the southeast extremity, the peninsula is composed entirely of the basement gneisses and granites, which rise from the water west of Conglomerate Bay in a steep cliff (along a surface of faulting) 100 feet or more high. The hills in the northern part of the peninsula may reach a height of over 300 feet, but this as well as other figures concerning elevations is an eye-estimate only, and not a measurement.

Geology.

The rocks exposed around the shores of Steep Rock Lake and of Lake Margaret, are divisible into three principal groups. The lower division consists of granites and gneisses, which typically are medium grained, hornblendic, and granitoid, with faint foliation. Locally they present considerable variations in composition and very great variations in structure.

Resting upon these basement rocks is a series of rocks showing a thickness of about 5000 feet in exposure along the shores of the lake. Upper members that are not seen upon the lake probably exist in the trough of the eastern synclinal, southeast of Jack Pine Pt. The series is divisable into nine formation which as far as known are perfectly persistent along the strike throughout the area studied. It offers many important points of difference, lithologically, in structure, and in its relations to the underlying granites, from any series of rocks previously described in western Ontario. Leaving the question of correlation to be discussed after the series has been described it will be called for purposes of description in this paper, the Steep Rock Series.

At the southeastern extremity of the eastern arm, at the north end of the portage into Lake Margaret, lying across the edges of the Steep Rock Series, begins a succession of later granite porphyries, and massive hornblende rocks, striking

N. 55 to 65 E., which pass upward, in going south across the strike, into the schists of the Aticokan River. These will be termed the Aticokan Series.

Basement Complex.—The granites were very hastily examined in the narrow fringe in which they are exposed along certain shores of the lake. They were studied mainly with reference to their distribution and structural relations to the overlying Steep Rock series; no attempt can now be made to separate geographically the various kinds of rocks which are included in the basement series, or to indicate their relations to one another.

The predominant rock in the basement series is a hornblende muscovite granite of medium grain, composed of clear to bluish quartz, feldspar, a green hornblendic mineral, and muscovite. The color on the weathered surface is white, slightly tinged with green, and on the fresh fracture a darker well marked green. This is the usual type. Occasionally a red granite carrying biotite is seen, which owes its color to flesh-colored feldspar. True gneisses are rare, but they are occasionally found as at locality 50 on the ridge north of the mouth of the creek emptying into the bay north of Lake Margaret portage, and in the peninsula east of Northwest Bay, at locality 125. At both localities the rock is a coarse hornblende gneiss, exhibiting a parallel arrangement of the constitutent minerals, and pegmatization. At locality 125 the coarse gneiss carries angular inclusions, which are finer grained and darker than the mass of the rock, but similar in composition.

Distinguishable from these gneisses in which the origin of the gneissic foliation is unknown is a great body of chloritic gneisses which have unquestionably been derived from the hornblende granite by crushing. These are found at and near the turn of folds; for example, at the head of Falls Bay, north of the Elbow, and along the north and west shores of Northwest Bay. Good examples are seen on the west shore from the head of Falls Bay to the Elbow where the whole series has been forced round through an angle of more than 120°. All stages in the process are seen. At one end of the series is found the typical hornblende granite, traversed by little wavy fissures, generally parallel to the regional direction of cleavage, N. 43° E., along which part of the hornblende is represented by thin leaves of fresh chlorite. At the other end of the series the quartz and feldspar are greatly granulated, and the hornblende has entirely disappeared; the chlorite is arranged in parallel bands, and the rock has developed in it a highly perfect schistose structure.

All these granitic rocks are traversed by an immense number of dikes of greenstone, and more rarely of quartz porphyry, all of which for structural reasons are conveniently considered with the basement complex.

These belong to three eras of irruption. (1) Those which supplied pebbles to the conglomerate at the base of the Steep Rock series. (2) Those which are seen to traverse both the granitic and Steep Rock series, and to have participated in the folding. (3) A single massive dike of porphyrite (?), which cuts through the most schistose phase of the granite at the turn of the sharp fold at the head of N.W. Bay, and is clearly subsequent to the latest period of folding of the region. The dikes of class 2 are best seen along the N.E. shore of East Bay. They are rudely parallel, the walls are straight and nearly vertical, trending from N. 45° to N. 65° E., and in a general way cutting the granites and the lower horizons of the S. R. series in a direction normal to the contact and strike. They vary in width from one to two feet up to 70 feet, and clearly were the chimneys through which passed up the material for the great mass of interbedded traps on the south side of the same arm.

The contact phenomena with the country rock are uniformly as follows: When the dike is less than 6 or 8 feet in width it is fine grained, without crystalline structure, and throughout is highly schistose in the general regional direction. The wider dikes have massive and crystalline interiors, but are fine grained and schistose in a direction parallel to the induced regional cleavage, for a distance of 2½ or 3 feet from the wall. The country rock also is schistose next to the wall of the dike, the belt affected being narrower where the adjacent rock is granite than where it is limestone.

With regard to distribution, it may be said in a general way that all shore lines north of the water, from Lake Margaret to Northwest Bay, are, with few exceptions, made up of the rocks of the basement complex. The exceptions are the headlands in East Bay and at the Elbow which are of limestone, the great mass of limestone at the head of Falls Bay, and the limestone between Camp Bay and Conglomerate Bay, and the Conglomerate along the latter.

Steep Rock Series.—The Steep Rock series consist of 9 well marked and persistent horizons exposed about the lake. It is very probable that other higher members exist in the land area southeast of the shore from Jack Pine Pt. to Pine Beach. The 9 formations are given in the table below which reads upward in ascending order:

IX. Dark Gray clay slate.
VIII. Agglomerate.
VII. Greenstones and greenstone schists.
VI. Upper conglomerate.
V. Upper calcareous green schist.
IV. Interbedded crystalline traps.
III. Ferruginous formation.
II. Lower limestone.
I. Conglomerate.

In the foregoing description of the basement complex the northern limit of the Steep Rock series has roughly been indicated. Formations I and II occur in isolated patches north of the water on shores that are otherwise occupied only by the granites. Along the whole course of the lake they dip, at very steep angles, ranging from 60° to 80° away from the basement rocks, upon which they hang as a time-worn fringe, having no extension inland. The shore line lies sometimes in the granites and sometimes in the Steep Rock series, but in a general way follows closely in direction the boundary between them. It is only along these northern shores that formations I and II are seen at all, and as they are usually found together, separated from the higher members by intervening water, it will be convenient to keep them apart from the rest for purposes of description. The basal member of the Steep Rock series, which is generally found between the granites and the lower limestone, is a bed having a maximum thickness of nearly 100 feet, presenting the various phases of a conglomerate, coarse and fine, a quartzite and a quartz schist with feldspar. The formation occurs as a coarse conglomerate at the eastern end of Conglomerate Bay. The lowest member exposed at the water consists of rounded and water-worn pebbles of quartz and greenstone, of considerable size, the largest seen being a foot in diameter, imbedded in a green schistose matrix. The strike of the rock is about N. and S., as indicated both by the alignment of the pebbles, and the lines of junction of layers carrying no pebbles No granitic pebbles were found at this locality. In the higher portion of the bed pebbles become smaller and relatively fewer, and the rock passes into a green schist, with small clastic grains of quartz.

On the northern end of the island in Northwest Bay formation (I) is represented by a fine conglomerate consisting of closely-packed small quartz grains (128) with little cementing material, holding occasional pebbles up to 3 or 4 inches in diameter, of rounded and water-worn quartz, bluish, milky-white and dark. A layer of limestone of uncertain thickness is also interbedded The lowest formation does not usually occur as a coarse conglomerate in East Bay. It there consists, as a rule, of beds of quartz pebbles, none larger than buckshot, with little cement, alternating with layers of massive quartzite.

In crossing from the base of the limestone to the granite it becomes at first slightly and then more and more feldspathic as the latter is approached. Near the junction both rocks are very similar in composition, so that it is quite impossible to draw the line between them from considerations of composition. There is an apparent transition from one rock into the other. This transition zone, which is from 20 to 30 feet in width, is uniformly highly schistose, in the regional direction N. 43° E., which, in the eastern arm, where the strikes are from N. 50° to 60° W., crosses the courses of the contact and the bedding nearly at right angles. The schistose structure is traceable through the transition zone into the undoubted granite in which it dies out gradually, being represented a few feet away by little discontinuous wavy cracks, along which chlorite is usually developed, and by a faint foliation.

From these facts it appears certain that the granitic complex supplied by erosion the materials for Formation I, and that the contact is therefore one of unconformability. There is no unconformability of structure; for the only normal structure possessed by the basement rocks, that of schistosity, was demonstrably imposed upon them at a time long subsequent to the accumulation of the various materials which now compose the Steep Rock series. The absence of a sharp line of demarkation between the complex and Formation I, which may seem to be a difficulty in the way of accepting the existence of an unconformability, is believed to be capable of a satisfactory explanation. In considering the orotechnic history of the region the transition zone will be shown to represent, not a transition in time, but a mechanical transition in composition, dating from a time subsequent to the accumulation of the rocks of the Steep Rock series.

Formation II, the lower limestone, lies above Formation I, with which it is seen in direct contact at a number of localities. The rock is very uniform in character wherever exposed. It is a dark to light bluish gray limestone, not at all highly crystalline, often banded with layers of lighter color, along planes of original bedding. The light bands vary in width from a fine line up to 6 or 8 inches. Bedding planes are also often marked by thin cherty seams. Basal portions are frequently massive and siliceous, and in some localities are highly charged with pyrites the decomposition of which causes the rock to weather brown. The upper part of the formation is a breccia, composed of fragments of limestone, showing original structure, and of trap, imbedded in a matrix that seems to be mostly made up of a consolidated calcareous flour. It is widely distributed, and is nearly if not quite coextensive with the limestone. The total thickness of the lower limestone cannot be determined precisely, as it is nowhere seen in contact with the overlying Formation III, but quite surely is not less than 500 nor more than 700 feet. A much greater thickness is exposed in the north side of Conglomerate Bay, in part resulting from duplication by faulting. On the eastern arm, where the rocks are comparatively undisturbed the limits indicated are those given above.

Formation III is found only on the south shore of the eastern arm which it fringes from the Point N.W. of Lake Margaret Portage to Falls Bay, in much the same way that the limestone fringes the north shore. As a whole the formation consists of an extremely soft, fissile dull green, very pyritiferous rock, which carries in some localities many pebbles of limestone and a few of trap. In the lower parts of the formation the limestone fragments, which are identical with the rock of Formation II, are rather numerous, and some are large, one, angular in shape, being over two feet in diameter. Others are apparently rounded and waterworn. In other localities pebbles are not found at all. For the most part the only structure observable is the regional cleavage which is very perfectly developed. At two localities a fine banding parallel to the strike of the rock was observed. At loc. 27, south of trap bluff this banding is very prettily shown. The rock carries a few rounded pebbles of limestone. The banded structure is thrown into little compressed S.W. pitching folds the tangent plane to which is parallel to the plane of the dip in the limestone across the bay. Apart from the limestone inclusions and this banding the rock shows no trace of sedimentary origin. Under the microscope it is seen to contain no clastic material and all the evidence, which is not however conclusive, seems to point to its having been originally a volcanic ash. At two localities a bed of banded jasper and iron ore, generally magnetite, is found, which belongs near the base of the horizon. A high bluff of trap in East Bay, probably a lenticular intrusion, must also be included in it. Except on this south shore of the eastern arm Formation III is everywhere covered by the waters of the lake, within the area studied. Sufficient evidence of its continuity is afforded however by the presence of bowlders from the characteristic iron ore horizon at several widely distant points. The thickness varies considerably but may be taken at a maximum of 600 feet.

Formation IV consists of interbedded eruptives, which may reach a maximum thickness of 1000 feet. The rock is very uniform in character, the variations occurring being mainly in texture. It is normally a massive, rather coarsely crystalline greenish-gray rock, made up of plagioclase and hornblende, and is probably a diorite. Locally it includes layers of green schist which are to be regarded as mechanical derivatives, analogous to the chloritic gneissic phases of the basement granite. The formation is best seen south of the eastern arm, where it forms a long ridge running from Lake Margaret portage N.W. to Falls Bay, and in the two natural sections made by the shore line at both the northern and southern ends. Small patches are exposed at a number of localities about the lake. It is uncertain whether this is an intrusive sheet or a flow.

Formation V is a very calcareous green schist containing thin seams of limestone. The included layers are quite pure finely crystalline limestone. Thin sections of the less calcareous portion show that the rock consists of 50 to 60 per cent of calcite, and for the rest, of argillaceous material and secondary quartz. Originally it was probably in the main a very calcareous shale, with thin beds of limestone. The thickness is about 600 feet.

Immediately above the limestone comes Formation VI, a conglomerate, having a maximum thickness of about 100 feet. It varies in habit, from a hydromica schist, carrying many grains of quartz, the clastic character of which is evident in thin section, to a rather coarse conglomerate, the pebbles in which seem to be entirely of quartz and granite. The locality in which it may be best seen is on Falls Bay, on the shore east of Jack Pine Point.

Formation VII. The type rock of this horizon is a light greenish gray, massive, close textured rock, which weathers a light brown. In thin section it appears to be of eruptive origin, but owing to the complete alteration of the bisilicate it is uncertain whether it was originally a diabase or a diorite. Departing from this as a type, on the one hand are found members which show crystalline structure macroscopically, and on the other banded green schists which to the eye have every appearance of being altered sediments. Under the microscope however they show no trace of sedimentary origin. This banding is of two kinds. (1), a fine banding due to an alternation of thin seams differing slightly from one another in color and in texture. (2), a coarser, due to the interbedding of layers of the massive varieties with the schistose. These layers are of all thicknesses, from a few inches up to several feet. The structure, of both varieties, appears to be antecedent to the last folding of the series, since it is often greatly contorted, and frequently intersected by the regional cleavage, and in general is parallel to the true strike. A graphitic schist, twenty feet or more in thickness, is also included. There is an evident stratigraphical succession in the various members, the banded schists predominating towards the top. The peculiar gray green color and close texture are characteristic of the rocks of this horizon. The thickness is about 1400 feet.

Formation VIII. The agglomerate is best seen at Jack Pine Point and at locality 79 to the south of it. At locality 79, it consists of pebble-like inclusions, greatly resembling the type rock of Formation VI, imbedded in a light gray-green fissile matrix which is bright on the cleavage surfaces. The inclusions vary in size from a fraction of an inch up to 5 or 6 in. long diameter. They are elongated, and have rounded outlines, though tapering to rather sharp points. They are all of the same material, which is the same as the matrix apparently, differing from it only in lacking the schistose structure. They are hardly distinguishable from the matrix in color, on the fresh fracture, but on the weathered surface the inclusions stand out, and weather a lighter brown. Under the microscope the inclusions are seen to consist of an eruptive rock entirely similar to the massive form of VII. On Jack Pine Point the agglomerate is beautifully plicated and the inclusions follow the little folds. (Fig. 1.)

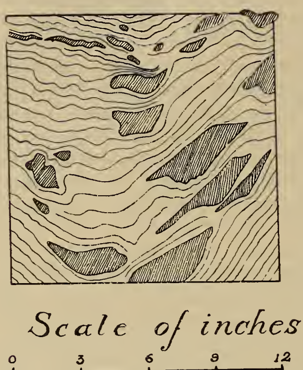

Fig. 1.—Agglomerate, Loc. The shaded inclusions in nature are lighter in color than the enclosing green schist. The waving lines indicate plications in the matrix.

Formation IX. Above the agglomerate, at locality 81 a fine grained clay slate is found, which besides a perfect slaty cleavage in the regional direction, shows alternating light and dark bands, which probably represent planes of deposition.

Structure.—The Steep Rock Series is folded into an eastern synclinal, a middle anticlinal and a western synclinal, which is faulted across the axis near the sharp turn.

A line drawn from the limestone exposure at the head of Falls Bay to Jack Pine Point indicates approximately the position of the axial plane of the eastern synclinal. East of this line the various members uniformly strike to the west of north. The dips are high to the S.W. ranging from vertical to 60, and on the average may be taken at 70. From the agglomerate at Jack Pine Point southward to the point north of Pine Beach, where the upper part of Formation IV is exposed, the shore line again crosses the intermediate formations in descending order, the strikes bending round gradually to N. 20° E. A line drawn a little west of south through the eastern point of the limestone of the Elbow marks the intersection of the axial plane of the middle anticlinal with a horizontal plane. West of this line the limestone of the Elbow, Formation VI, and the various members of Formation VII, which alone are exposed on the southern and western shore, strike again to the northwest, gradually bending round along the latter to the east of north. The limestone at Conglomerate Bay abuts against a cliff of the basement granite, the line of separation marking the position of a fault. About 6000 feet S.W. along the line of this fault, which is well marked by a breccia in the peninsula N.W. of the upper narrows, Formations I and II are found again on the opposite side, striking N.W., and farther north on the large island in N.W. Bay, bending round again to the southwest. On the west shore of the lake west of N.W. Bay green slates, probably belonging to Formation VII, are found west of Formation II, and again on Birch Point indicating another fault which trends to the west of north. These two faults so complicate the structure of the western part of the lake, that the relations of the rocks, which are all recognizable as belonging to one or another of the IX formations of the series, could not be worked out in the time available.

There are two points in the general structure of the rocks of the lake which are especially noteworthy and significant. They are:

1st. The high pitch of the axes of the great folds. At the turn of the middle anticlinal at the Elbow, dips, which are well marked in the limestone, range from vertical to 75° to the south, (Section II.) At the turn of the western synclinal in Northwest Bay the dip is about 60° in the same direction. We have here, then, folds with very high south-pitching axes, the pitch in the case of the anticlinal being nearly 90° and in the case of the synclinal at a lower angle. In the case of the eastern synclinal the pitch is also high, though apparently considerably less than 90°, as indicated by the greater thickness of the series measured along the axis than across it. The Steep Rock series therefore dips away from the granites, at the turns of folds, at angles which do not differ materially from those observed in the long straight stretches; as, for example, that in East Bay.

2nd. The regional cleavage. Throughout the whole area is observed a regional cleavage, which has a tolerably uniform direction between the limits N. 38° and N. 48° E., and traverses all the rocks of the region, both the eruptive and sedimentary members of the Steep Rock Series, and the rocks of basement complex. It has largely obliterated the original lamination of the sediments and banded schists of the Steep Rock Series, and is now the dominant structure.

In inferring the orotechnic history of the region the origin of the N.E. cleavage must be ascribed to a force acting perpendicular to it, or in a N.W. and S.E. direction; and since this cleavage runs through, and in many cases masks all previous structure, the force which produced it must have been the last force which has left its marks upon the rocks of the lake. To this force also must be ascribed the action which left the Steep Rock series in its present folded attitude.

What was the position of the rocks just before this cleavage-producing force acted upon them? It could not have been horizontal, for in the long stretch in East Bay, where the strike runs nearly straight for four miles, and in the limestone exposures N.W. of the Elbow, the plane of the dip nearly coincides with the direction of this force, and the cleavage planes intersect it nearly at right angles. A N.W. and S.E. force acting parallel to the present strike in the plane of the dip, could not have tilted these portions of the Steep Rock Series into their present nearly vertical position. It seems necessary to suppose, therefore, that before the cleavage-producing force acted, that part of the Steep Rock Series that we know, existed as a N.W. and S.E. striking monocline, having a high dip to the S.W. as the result of previous folding by a N.E. and S.W. force.

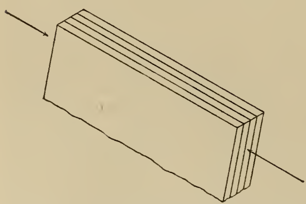

Fig. 2.—Diagram showing the attitude of the Steep Rock Series just previous to the second folding.

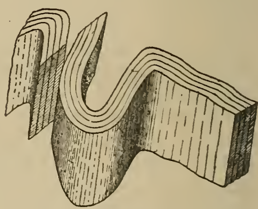

Fig. 3.—Diagram showing attitude of Steep Rock Series after second folding.

The folding of the Steep Rock Series indicates therefore two periods of orotechnic action. In the first period, the force acted in a N.E.–S.W. direction, and folded the series about horizontal axes, having a N.W.–S.E. direction. That part of the series now exposed about the lake was left as a N.W.–striking monocline, with a high dip towards the S.W. In the second period, the cleavage-producing force acted in a N.W.–S.E. direction upon this monocline and produced upon it two effects. 1st, it caused it to yield as a whole, not by vertical arching over horizontal axes, to which the nearly vertically standing leaves of the series would oppose their maximum rigidity, but by horizontal buckling about nearly vertical axes, to which the opposed rigidity would be a minimum. Figures 2 and 3 illustrate this point. 2nd, consequent upon the regional movements attending the folding were produced minute fissures, and a rearrangement of particles along planes perpendicular to its direction; or, in other words, the regional cleavage.

These two periods of orotechnic action explain also the schistose dikes and the transition zones between Formation I, and the granitic complex. The dike at locality 41 will serve as an example of the class. It is from 60 to 70 feet in width and cuts the granitic complex, the southeast wall running N. 48° E. For a distance of three feet from the wall the dike is very schistose and fine grained. The interior is massive and crystalline. Under the microscope the interior is seen to be a quartz diorite, consisting of quartz, plagioclose, hornblende,—in places altered to chlorite and epidote, magnetite and apatite. The feldspars are nearly all saussurized. A slide from the schistose portion shows it to be a hydromica schist, with a great deal of normal chlorite. The quartzes are strained and broken, and the magnetite is granulated and drawn out into fissured "augen." Some epidote is arranged along planes of foliation. The rock shows shearing and crushing in an eminent degree.

Previous to the first orotechnic period we may suppose that the Steep Rock series lay in a horizontal position upon the basement complex. The parallel dikes, of which 41 is an example, which supplied the materials for the interbedded eruptives of the series, constituted a system of thin vertical beds running through and binding together the grantitic complex, and the sediments and interbedded eruptives of the upper series. The effect of the first force was to arch the series about horizontal axes parallel to the present strikes in East Bay, and perpendicular to the course of the chimney series of dikes. It acted parallel to the direction of these dikes and therefore opposed to their greatest rigidity. As the upper series bent under the action of the force, there must have been a difference in the rate of yielding of the bedded sediments and thin horizontal eruptives, on the one hand, and the vertical dikes and massive granitic complex on the other. This difference in rate of yielding must have produced grinding: 1st, of the basal sediments on the granitic complex; 2nd, between the vertical dikes and the rocks through which they passed, whether sediments, interleaved eruptives, or of the complex.

The grinding would result in shearing and comminution of both rocks in zones adjacent and parallel to the contacts. The transition zone at the junction of the basement complex and Formation I, represents the depth to which the granites, previously weakened by disintegration, were affected by the grinding. In this zone there was also doubtless a certain intermingling of particles produced by the action of gravity.

The later orotechnic force has imposed schistose structure in these zones of comminution just as in the sedimentary members of the upper series.

Behavior of the complex.—How have the crystalline rocks of the basement complex yielded to the tremendous stresses which produced the buckled folds in the upper series? This most interesting question must be left incompletely answered. A few points, however, are clear. Great relief was afforded by the fault across the northern end of the lake. The dip of the fault plane, unfortunately, was not observed, but it is conceived that the movement was essentially horizontal, and that the 6000 feet of observed throw is nearly the full measure of its amount. In the zone adjacent to the Steep Rock Series, in which alone the granites were studied, the presence of numerous folded dikes, in the localities in which the whole series has been specially folded, seems to show that the granites yielded by bending and not by faulting. One of these is shown in figure 4. It is one of many seen in the stretch of shore north of Wiegand's Point. This bending in the granites implies, of course, according to Heim's law, a tremendous load upon them.

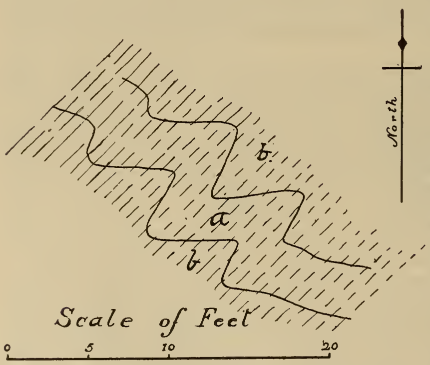

Fig. 4.—Plan of folded Dike. a=Greenstone Dike. b=Chloritic gneiss, autoclastic from granite. The surface dips gently to the North, 15°.

Thickness.—The thickness of the members of the Steep Rock series given in the description of the separate formations, is that measured in the section across East Bay, and is undoubtedly too great. This part of the series underwent tremendous longitudinal compression by the cleavage-producing force; the thinly bedded members have been thrown into little compressed folds, and the more massive members have been contorted on a larger scale. In both ways the thickness of the series measured in section has been largely but indeterminately increased. In the stretch from the Elbow north to the head of Falls Bay, west of the axial plane, the series is much thinner, probably as the result of three causes: (1) A general stretching in this direction. (2) A possible faulting along the axis. This has not been observed, however. (3) A probable thinning out of the trap horizon in going west.

For these reasons a measurement across the series there would probably be at least as much less than the true thickness as the East Bay section is greater. A mean between them, or 4500 feet, may be taken as an approximation to the true thickness.

General Considerations.—The study of the Steep Rock series shows some results both positive and negative which have a general interest in connection with the geology of the region N.W. of Lake Superior.

1st. The contact of Formation I with the basement complex is one of erosion.

2d. The complex at the time of the deposition of the Steep Rock series was made up of consolidated crystalline rocks, and there is no evidence whatever that it has since undergone fusion, or recurred to the condition of a magma.

3d. The rocks of the Steep Rock series have been subjected at two periods, more or less distant, from one another, to the action of great orotechnic forces, which acted—the first in a N.E. and S.W. direction, and the second in a N.W. and S.E.

4th. The latter force has imposed upon all the rocks of the region a N.E. structure, which has largely, but not entirely, obliterated preëxisting lamination in the sediments and schists of the Steep Rock series.

5th. The two orotechnic actions have produced great developments of autoclastic* schists, both in the granites and in the rocks of the Steep Rock series; the present structure in which was induced and determined in direction by the last force.

The consideration of the Aticokan series, with a more general discussion of the mutual relations of the three series of rocks, and an attempt at correlation, must be deferred to another paper.

The author wishes to express his great obligations to Prof. Raphael Pumpelly for many valuable suggestions. Mr. C. Livy Whittle, of Cambridge, Mass., has kindly examined a number of thin sections from the Steep Rock series, and the results of his study are incorporated in the above description of formations.

Port Arthur, Ontario, June, 1891.

* That is, schists formed in place from massive rocks by crushing and squeezing, without intervening processes of disintegration or erosion, removal and deposition.

ART. XXXII.—*On the so-called Amber of Cedar Lake, North Saskatchewan, Canada;* by B. J. HARRINGTON, McGill College, Montreal.

THE occurrence of mineral resins in some of the coals and lignites of the Northwest and British Columbia has been known for many years, and the results of a partial examination of specimens from three localities were published by the writer in the report of the Geological Survey for 1876–77, p. 471. The conclusion then arrived at was that none of the specimens could be referred to amber or succinite, though in some respects closely resembling that substance. Attention was also called to the statement of Goeppert that he knew of no instance of true amber being found in the brown coals of northern Germany, the substance occurring in those beds being "retinite."

During the summer of 1890, Mr. J. B. Tyrrell, M.A., of the Geological Survey of Canada, visited a locality on the west shore of Cedar Lake, near the mouth of the North Saskatchewan, where a mineral resin resembling amber in appearance has been found in large quantity. With regard to it Mr. Tyrrell says: "It occurs mixed with sand and many fragments of partly decayed wood, on a low beach behind a gradually shelving shore and along the face of a deep, wet, spruce swamp. The pieces were, for the most part, smaller than a pea, but could be readily seen glittering among the sand and vegetable debris. Some pieces were found as large as a robin's egg, and Mr. King [of the Hudson's Bay Company] informed me that he had collected pieces very much larger. It has evidently been washed up on the shore by the waves, but its exact age has not been positively determined.

"The first place at which it was seen was in a small bay behind a limestone point projecting towards the north, but the most extensive deposit is more than a mile south of this point, where a rounded beach stretches across the margin of a low swamp. This beach is about a mile in length and from eighty to one hundred and twenty feet in breadth. The amber is found most plentifully along its ridge, where it constitutes between five and ten per cent by volume of the sand and vegetable debris, and holes dug to a depth of two feet show no diminution in its quantity. Towards the edge of the lake, however, the sand is freer, both from fragments of wood and amber. It is difficult to make an accurate estimate of the quantity of amber on this mile of beach, but it may confidently be said to be found throughout the distance in a band thirty feet wide, with a minimum depth of two feet."*

* Summary report of the Geological Survey Department for 1890, p. 22

The writer is indebted to Mr. Tyrrell for specimens of this so-called amber from Cedar Lake, and the results of their examination, as far as completed, will now be given. The substance was in pieces, for the most part very irregular in shape, some being more or less angular, others approximately spherical, and others flattened, discoid or lenticular. Some of the pieces were smaller than a pea, but they ranged from this up to the size of an ordinary bean (about 2 centimeters long). In color they varied from pale yellow to dark brown, and many, when examined by transmitted light, appeared clouded or banded from the presence of black carbonaceous matter. Superficially they were generally dull, owing, perhaps, to chemical change, but on fresh surfaces the luster was resinous. The fracture was conchoidal. Though electric on friction, they appeared to be less strongly so than ordinary amber.

Light-colored fragments, free from black carbonaceous matter, were selected for examination, and any superficial crust carefully removed by scraping. The hardness of these selected pieces was fully 2½. The specific gravity, as obtained with a quantity of material in the specific gravity bottle, was 1·055 (at 20° C.), and a single fragment gave by suspension with a hair 1·0543 (20° C). The material for analysis was finely powdered and dried over sulphuric acid *in vacuo*. The combustions were made with lead chromate in the usual way, and the ash determined with a separate portion in a platinum crucible. The following are the results obtained:

	I.	II.	Mean.
Carbon	80·01	79·91	79·96
Hydrogen	10·37	10·55	10·46
Oxygen	9·53	9·45	9·49
Ash	0·09	0·09	0·09
	100·00	100·00	100·00

Excluding the ash the results become:

	I.	II.	Mean.
Carbon	80·08	79·98	80·03
Hydrogen	10·38	10·56	10·47
Oxygen	9·54	9·46	9·50
	100·00	100·00	100·00

The ash was brick-red in color and found to contain silica, alumina, iron, lime, and magnesia.

The only solvents whose action upon the resin has been tried as yet are absolute alcohol and absolute ether, and the effect of these was ascertained as follows: One gram of the finely powdered resin was mixed with ten grams of pure quartz sand in a cylinder of filter paper and extracted in Soxhlet's apparatus, in the case of the alcohol for three and a half hours (24 siphonings) and in the case of the ether for two hours (24 siphonings). In each case the sand and filter paper were previously extracted by the special solvent for several hours. The extract from the resin was evaporated in a weighed platinum dish and the residue dried at 100° C. The results obtained were as follows:

Dissolved by absolute alcohol	21·01	per cent.
" " " ether	24·84	"

The effect of more prolonged action of the solvents has not as yet been ascertained. The alcoholic extract after drying was brownish in color, while that obtained with ether was only faintly yellow.

When small fragments of the resin were heated in closed tubes it was found that they began to soften at about 150° C., the point of softening being roughly ascertained by pressure with a platinum rod. At 180–190° C. the fragments were sufficiently yielding to be pressed into one mass by the platinum rod. Heated up to 300° C. the resin did not melt into a flowing liquid, put became soft and elastic, and had darkened a good deal from partial decomposition.

Fragments of genuine amber behaved in a similar manner, but began to soften at about 140° C. At 180° they could be readily pressed into one mass, and in the one experiment tried they seemed to darken more readily than the Cedar Lake resin when heated up to 280°–300° C. The ordinary statement that amber fuses at 287° C. is certainly misleading, the fact being that it begins to soften at a very much lower temperature, gradually getting softer and softer as the temperature rises, but not becoming a flowing liquid until decomposition takes place.

On heating the Cedar Lake resin in a test tube or retort no crystals of succinic acid were obtained, although they were readily obtained from true amber by similar treatment.

It is customary to assign to amber the formula $C_{40}H_{64}O_4$, which gives: carbon 78·94, hydrogen 10·53, oxygen 10·53; but this is apparently based upon very insufficient data—so far as the writer is aware, upon the single analysis of Schrötter (carbon 78·82, hydrogen 10·23, oxygen 10·95), which really corresponds much more closely to $C_{39}H_{60}O_4$. Such a substance as amber, too, coming from a variety of localities and originally derived from very different plants can scarcely be expected to agree closely in composition with one definite formula.

The Cedar Lake resin contains more carbon than the amber analyzed by Schrötter and less oxygen, and in this respect comes nearer to Walchowite and to some of the recent copals from India. The relations of some of these bodies will be made plain by the following tables:

	Carbon.	Hydrogen.	Oxygen.	Ratio of C, H, and O atoms.	Ratio of C, H, and O atoms, taking C = 40.
I. Amber	78·82	10·23	10·95	9·60 : 14·95 : 1	40 : 62·29 : 4·16
II. Krantzite	79·25	10·41	10·34	10·22 : 16·11 : 1	40 : 63·05 : 3·91
III. Cedar Lake Resin	80·03	10·47	9·50	11·23 : 17·63 : 1	40 : 62·79 : 3·56
IV. Copal (Bombay)	79·70	10·40	9·90	10·75 : 16·83 : 1	40 : 62·62 : 3·72
V. Copal (Calcutta)	80·34	10·32	9·34?	11·46 : 17·67 : 1	40 : 61·67 : 3.49

I. Phillips' Mineralogy (1852), p. 630. Anal. by Schrötter. II. Dana's Mineralogy (1869), p. 741. Anal. by Landolt. IV. Watts's Dictionary of Chemistry (ed. i.), vol. ii, p. 19. Anal. by Filhol. V. Watts's Dictionary of Chemistry (ed. i), vol. ii, p. 19. Anal. by Filhol.*

Though resembling amber in some of its characters, the Cedar Lake resin may here be classed provisionally as "retinite," on account of its differing from amber in its deportment with solvents,† in not yielding crystals of succinic acid on distillation, and in having a somewhat different ultimate composition. The name retinite as used by some mineralogists is a convenient general term to include such substances as Walchowite, Krantzite, Jaulingite, Rosthornite and the Cedar Lake resin, which last, by way of distinguishing it from other retinites, may be called Chemawinite (from Chemahawin or Chemayin, the Indian name of a Hudson Bay post, not far from where the resin occurs).

Though the origin of this substance is not certainly known, there can be little doubt that it has been derived from one of the Tertiary or Cretaceous lignites occurring on the Saskatchewan. Some of these are known to contain resins, one of which, examined by the writer, was not essentially very different from the Cedar Lake material. It behaved similarly on heating, had a hardness of over 2, a specific gravity of 1·066, and dissolved in absolute alcohol to the extent of 29·30 per cent.

Some of the larger pieces of the Cedar Lake resin might, perhaps, be employed for ornamental purposes (beads, etc.), and possibly the material might be utilized by the varnish-maker. This question will be discussed when the examination of the resin is completed.

* In the last analysis, as given by Watts, there is an error. The total is given as 100, whereas it is really only 99·80. It is here assumed that the error is on the oxygen—the constituent determined by difference. A similar error occurs in Schrötter's analysis of amber, as given by Dana.

† The statements in works on mineralogy with regard to fossil resins are often vague and sometimes conflicting. Thus, in speaking of the action of such solvents as alcohol or ether, we are told nothing as to the strength of the solvent, the duration of its action, etc., and the results given are, therefore, often of little value.

ART. XXXIII.—*Geological Horizons as determined by Vertebrate Fossils;** by O. C. MARSH. With Plate XII.

IN 1877, the author endeavored to bring together some results of his researches in the Rocky mountain region and in other parts of the country, relating to the succession of vertebrate life.† This led to a comparison of the relative value of the three different groups of fossils; plants, invertebrates, and vertebrates, in marking geological time. In examining the subject with some care, the author found that, for this purpose, plants are not satisfactory witnesses; that invertebrate animals are much better; but that vertebrates afford the most reliable evidence of climatic and other geological changes. The subdivisions of the latter group, and, in fact, all forms of animal life, are of value in this respect, mainly according to the perfection of their organization, or zoölogical rank. Fishes, for example, are but slightly affected by changes that would destroy Reptiles or Birds, and the higher Mammals succumb under influences that the lower forms pass through in safety. The special applications of this general law, and its value in geology, readily suggest themselves.

In accordance with this principle, the author next attempted to define the principal geological horizons in the West which he had personally investigated, and then taking in each the largest and most dominant vertebrate form which characterized it, used the name for the horizon. In the same way, some of the principal horizons of the East were named, and the whole brought together in a section to illustrate vertebrate life in America.‡

The names thus given to various horizons were not intended to replace those already applied, but merely to supplement them, and by new evidence, to clear up those in doubt. The same principle had long before been found to work admirably in Europe, where certain characteristic invertebrate fossils, especially Ammonites, had served to mark definitely various subdivisions of a single formation. The wider application of the principle to vertebrate fossils, from their earliest known appearance to the present time, has already helped to complete the record of vertebrate life in America, and rendered an equal service to systematic geology.

Since this method of defining geological horizons by vertebrate fossils was first used by the author in 1877, many important

* Abstract of Communication made to the International Geological Congress Washington, D. C., August 28th, 1891.

† Introduction and Succession of Vertebrate Life in America. Address before the American Association for the Advancement of Science, Nashville, Tenn., August 30, 1877.

‡ The same address, Frontispiece.

discoveries have been made, especially in the West, and much information bearing on the subject has been obtained from various quarters. In 1884, the author revised and extended the first section for his monograph on the *Dinocerata*, and it seems fitting on the present occasion to bring together once more some of the later evidence, and place on record the more important horizons now known to the author by personal exploration, or by other investigations which he has verified.

The accompanying section, Plate XII, is designed to represent in outline, in their geological order, the successive horizons at present known with certainty from characteristic vertebrate fossils. The correlation of these horizons with those determined on other evidence is important, and considerable progress in this direction has already been made, but the results cannot be presented here.

In comparing the present section with the one first published by the author, it will be noticed that no vertebrates are yet known in the Archæan or Cambrian, but a single fortunate discovery in Colorado has recently carried back the first known appearance of Fishes, from the lower Devonian to the lower Silurian, or more specifically, from the Schoharie Grit to the Trenton.

The next point of importance is in the Triassic, in the horizon of the Connecticut river sandstone where so many foot-prints have been found, and attributed to Birds. Recent discoveries in these beds have shown that at least three distinct forms of carnivorous Dinosaurian reptiles, all of moderate size, lived at that period, and doubtless did their share in leaving foot-prints behind them. In two of the skeletons secured, the bones of the hind feet are still in position, and in life could have made some of the foot-prints previously discovered.

Near the base of the Jurassic, a new horizon may now be defined as the Hallopus beds, as here alone remains of the remarkable reptile named by the author *Hallopus victor* have been found. Another diminutive Dinosaur, *Nanosaurus*, occurs in the same strata. This horizon is believed to be lower than the Baptanodon beds, although the two have not been found together. The Hallopus beds now known are in Colorado, below the Atlantosaurus beds, but quite distinct from them.

The Baptanodon beds have been found at many localities, in Dakota, Wyoming, and northern Utah, everywhere beneath the Atlantosaurus beds, and having below them, at various localities, a series of red beds, which may, perhaps, contain the Hallopus horizon, but are generally regarded as Triassic.

Beside the two species of *Baptanodon* described by the author, the next vertebrate in importance, in the same horizon, is a small Plesiosaur, which may be called *Parasaurus striatus.* One specimen only has been found in northern Wyoming.

The Atlantosaurus beds of the upper Jurassic are now known to be one of the best marked horizons yet discovered. They have been traced for more than four hundred miles along the eastern flank of the Rocky mountains, and nearly everywhere contain great numbers of fossil vertebrates, especially gigantic Dinosaurs and other reptiles, as well as many diminutive mammals of primitive types. The same deposits have been found on the western slope, with the Baptanodon beds beneath them.

The most remarkable of the new horizons recently determined are the Ceratops beds in the Laramie series, at the top of the Cretaceous. This horizon is as strongly marked as that of the Atlantosaurus beds, and has now been traced for nearly eight hundred miles along the eastern base of the Rocky mountains. Toward the north, it is underlaid by marine Cretaceous strata containing Fox Hill fossils, but further south, various older formations are found immediately beneath it. The overlying strata, when present, are usually of Tertiary age. The Fort Union Eocene beds on the upper Missouri, the Brontotherium beds of the Miocene in Wyoming, and further south in Colorado the Pliohippus beds of the Pliocene, may be seen immediately above. The vertebrate fauna of the Ceratops beds is remarkably rich and varied. The gigantic horned Dinosaurs named by the author the *Ceratopsidæ* especially abound, and determine the horizon with accuracy. Other Dinosaurs are numerous; and a few Birds, and various Mammals of Mesozoic types have also been secured.

In the various horizons of the Tertiary, as repeated in the present section, no changes of importance have been required, as more recent discoveries fully confirm their value and accurate determination.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Absorption Spectrum of Liquid Oxygen.*—In a preliminary examination of the absorption spectrum of liquified oxygen, Olszewski observed four bands corresponding to the wave lengths 628, 577, 535 and 480, these bands being the same as those noted by Liveing and Dewar in the spectrum of gaseous oxygen at high pressures, in addition to two bands in the ultra red agreeing with the Fraunhofer lines A and B. More recently Olszewski has prepared liquid oxygen in larger quantity and has examined its absorption spectrum more critically. Using a layer

30 mm. thick and 50 mm. high, contained in a thin glass vessel surrounded by three glass beakers to protect it from outside heat, it was found possible to maintain it at atmospheric pressure at its boiling point $-181{\cdot}4°$ for half an hour or more ; and thus to submit it to observation for that time. The four absorption bands above mentioned were observed, and in addition a fifth band corresponding to the Fraunhofer line A, more intense than the band of wave length 535 but less so than the others. No absorption band corresponding to the line B was seen. In 1883 liquid oxygen was described as colorless ; but with larger quantities, the author has noticed that in a layer of greater thickness than 15 mm., it has a distinct blue color by transmitted light. Since special care was taken in the purification of the gas, and since ozone was proved to be absent, the author believes this color to be characteristic of liquid oxygen. Moreover, he suggests that the blue color of the sky may be due to the oxygen in the atmosphere.—*Ann. Phys. Chem.*, II, xlii, 663 ; *J. Chem. Soc.*, lx, 773, July, 1891. G. F. B.

2. *On the Production of Ozone in Rapid Combustion.*—The statement of Ilosvay that ozone is not produced in rapid combustion having been questioned, he has reëxamined the matter and concludes that the tests by which the presence of the ozone was established by Loew and Cundall were not satisfactory. He finds that neither in the products of combustion nor in the air taken from around a flame is any substance present which (1) gives the odor of ozone, (2) renders thallous oxide paper brown, or (3) permanently decolorizes a solution of sulphophenyl-azo-α-naphthylamine so that naphthylamine no longer restores the color. By carefully depriving the gas used of sulphur compounds, he obtained in only a single experiment a reaction with thallous oxide paper ; and this after about seven hours. Taking special precautions to keep the temperature of the flame low, however, and employing a special collecting apparatus, he obtained the thallous oxide reaction in about 4 to 5 minutes and the other reaction in 10 to 15 minutes. Examined in this way the author finds the flame of methane to give less, the flames of hydrogen and carbon monoxide more ozone than that of illuminating gas. Moreover it appears that the relative amounts of nitrous acid and ozone formed by a flame depend upon its temperature and upon its surface ; the ozone formation being favored by a low temperature. Oxygen did not give as good results as air. Even if the oxygen is partially converted into ozone by blowing a current of this gas or of air on a flame, this fact the author thinks does not contradict his statement that ozone is not formed during rapid combustion. These results agree with those of Dewar and those of Elster and Geitel. The former chemist ozonized oxygen by passing it over white hot platinum. Since therefore the conditions essential to the production of ozone are not present in ordinary combination, this cannot be the source of the ozone of the atmosphere.—*Bull. Soc. Chim.*, III, iv, 707 ; *J. Chem. Soc.*, lx, 798, July, 1891. G. F. B.

3. *On Sulphuryl Peroxide.*—By the action of the silent electric discharge upon a mixture of either sulphuric oxide or sulphurous oxide and oxygen, Berthelot obtained several years ago a crystallized compound to which he gave the name persulphuric acid and the formula S_2O_7. The same substance was also obtained by Berthelot by the electrolysis of a 40 per cent sulphuric acid. Shortly afterward TRAUBE made a preliminary examination of this compound and concluded that its formula was SO_4 and not S_2O_7; and further that it was not an acid oxide as Berthelot supposed, but a neutral substance, sulphuryl peroxide. The present paper deals with the analytical results of his investigation. Although he has not succeeded in isolating the peroxide, he has obtained it free from the 40 per cent sulphuric acid in which it was dissolved. This was done by diluting the solution with 2 to 4 times its volume of water and adding to it freshly prepared barium phosphate. The sulphuric acid is thrown down as barium sulphate and the filtrate contains the peroxide dissolved in phosphoric acid with some barium phosphate. It does not seem capable of existing in solution in pure water. As the peroxide easily evolves oxygen and is reduced to sulphuric oxide, the composition of the dissolved compound was ascertained by taking a known volume of the solution, determining first the active oxygen therein by a known solution of ferrous sulphate, titering back with permanganate, and then the sulphuric acid as barium sulphate. In two experiments, the active oxygen was found to be 9·62 and 35·96 milligrams, the SO_3 present being 49·5 and 178·5; giving the ratio 1 : 5·1 and 1 : 5 in the two cases. Hence 16 parts active oxygen are combined with 80 parts of SO_3; i. e., $SO_3 + O = SO_4$; or perhaps $(SO_3) + O_2 = S_2O_8$. In order to determine its neutral character, the electrolyzed sulphuric acid after dilution with one to two parts of water and cooling to $-10°$, was saturated with dilute alkali; a process which did not affect the SO_4. On boiling the neutral solution thus obtained for a half hour, until a drop gave no blue coloration with zinc-iodide-starch solution, the active oxygen was expelled and the solution became intensely acid. Evidently if the peroxide had been an acid oxide and had formed an acid with the water present, a salt K_2SO_5 would have resulted from the saturation of this acid by potassium hydroxide. And this on giving up oxygen would have produced K_2SO_4 still neutral. This evidence of neutrality on the part of the peroxide was confirmed by quantitative data. The ratio of the active oxygen in the solution before boiling to the sulphuric acid produced by the boiling was determined; the acid by titration with sodium or potassium hydroxide, using rosolic acid as an indicator; and the active oxygen either by ferrous solution and permanganate or by potassium iodide and sodium thiosulphate. The ratio varied from 1 : 4·56 to 1 : 5·10; giving 1 : 4·85 as a mean. The active oxygen as determined by the iron method was somewhat higher than that given by the iodine method, owing to the presence of acid carbonate of the alkali in the solution, which decreased the free acid

in this solution and also decreased the quantity of the active oxygen as determined by the iodine method. The author regards this compound either as sulphuric oxide in which a single atom of oxygen is replaced by a double one, $SO_2(O_2)$ or as hydrogen peroxide in which the hydrogen is replaced by SO_2, corresponding to Brodie's class of neutral peroxides. Berthelot's S_2O_7 he regards as SO_4+SO_3. Since in not too dilute sulphuric acid, it dissolves without evolution of oxygen, the equation $S_2O_7+H_2O = H_2SO_4+SO_4$ shows the identity of the product thus obtained with that produced by electrolysis.—*Ber. Berl. Chem. Ges.*, xxiv, 1764, June, 1891. G. F. B.

4. *A Dictionary of Applied Chemistry;* by T. E. Thorpe assisted by eminent contributors. Vol. II, 714 pp., 8vo. London, 1891, (Longmans, Green & Co.)—The first volume of the Dictionary of Applied Chemistry—the successor, on the technical side, to Watts's Dictionary of Chemistry—was noticed in volume xxxix of this Journal, (p. 519). The second volume has now appeared and carries the work on from Eau to Nux, and hence the completion of the whole may be looked for at an early date. Some of the more important subjects discussed at length, and in many cases with liberal illustrations, are the following: Explosives, by W. H. Deering; fermentation, by P. F. Frankland; fuel, by B. H. Brough; coal gas, by Lewis Wright; gold, by E. J. Ball; india rubber, by C. A. Burghardt; iron by Thomas Turner; lead by P. P. Bedson; matches, by E. G. Clayton; napthalene, by W. P. Wynne. The same thorough but concise treatment before noted characterizes this volume and makes the work as a whole indispensable to all interested in any of the many departments of technical chemistry.

5. *Measurement of time of Rotation.*—The ordinary methods of determining the time of very rapid rotation depend in general upon the contact of a stylus on the prong of a tuning fork with a rotating wheel or cylinder, or on the use of the electric spark with a pendulum to indicate the time of rotation. K. Prytz departs from both of these methods and employs a falling body upon or against which the rapidly rotating body spirts a fine jet of coloring matter. In this way retardation of contacts is prevented, and the time is referred directly to the time of a falling body. The author gives in detail the method of holding the small glass tube containing the coloring matter, and the method of obtaining the records. Examples of determination of time by this method are given and the author claims that the time of a complete revolution of his apparatus could be determined to 0·00002 of a second.—*Ann. der Physik und Chemie*, No. vii, 1891, pp. 638–651. J. T.

6. *Method of determining Specific Heat by means of the Electrical Current.*—The method of determining specific heats by the use of Joule's law has not proved useful, except in non-conducting liquids. Professor Pfaundler has obviated the difficulty of conduction through the liquid by employing glass

spirals filled with mercury. These spirals were placed in a Wheatstone's bridge in order to control the ratio of the resistance during the flowing of the current and to keep it constant.—*Wiener Berichte*, April 9, 1891. J. T.

7. *Optical relation of Organic Dyes.*—E. VOGEL discusses the sensitizing power of the various compounds of eosine and gives charts of the sensitizing power. He recommends for orthochromatic photography that ordinary dry plates containing a weak amount of iodide of silver should be bathed in the following: 25^{ccm} solution of the coloring matter, erythrosine, in water, (1:1000); $0{\cdot}5^{ccm}$ solution nitrate of silver (1:20 water); 2^{ccm} ammonia, spec. grav. 0·94; 75^{ccm} distilled water. The author finds that the eosine dyes which are the most strongly fluorescent are the poorest sensitizers. Among the other conclusions of the writer we find the following: The sensitizing power of the eosine dyes depends: 1. On the sensitiveness to light of the dye. 2. On the proportion of light rays that is absorbed in other than chemical work. The more energy of the latter that is consumed in other than chemical work the smaller the chemical action.—*Ann. der Physik und Chemie*, No. vii, 1891, pp. 449–472. J. T.

8. *Maxim's Flying Machine.*—It is stated that Mr. Maxim is now constructing a flying machine at Crayford, which is nearly ready for launching. "It will be propelled by a light screw making 2500 revolutions per minute. The motive power is said to be a petroleum condensing engine weighing eighteen hundred pounds, and capable of raising a forty thousand pound load. The real suspending power will lie in an enormous kite measuring 110 feet long and 40 feet wide."—*Nature*, July 30, 1891. J. T.

9. *Small Electrometers.*—At a meeting of the Physical Society held in London, June 26, Professor BOYS described small portable electrometers of his design. In one of these the needle was cross-shaped and made of zinc and platinum, and reliance was placed upon contact electricity to keep the needle at different potentials. The instrument was very sensitive.—*Nature*, July 16, 1891. J. T.

10. *Influence of brightness upon phenomena of interference of light.*—According to Michelson and Morley the red hydrogen line is a close double. They found that if the light of this line was employed to obtain interference bands, that these bands disappeared with a difference of path of 15,000 wave-lengths, and also with a difference of path of 45,000 wave-lengths, and from a similar phenomena produced by the double sodium line it was concluded that the hydrogen line H_a consisted of two components at a distance apart of $\frac{1}{60}$ of that of the sodium lines. EBERT concludes from his investigation of this subject that this difference in the position of minima is not connected with duplicity of the line but depends upon particular conditions of the source of light; and believes that peculiarities in the appearances of the hydrogen line in stars of certain types depends also upon character of emission of the light. The method of high interfer-

ences promises to give an insight into the relation between the character of the light and the distribution of light in its spectral lines.—*Ann. der Physik und Chemie*, pp. 790–807, no. 8, 1891.

J. T.

11. *Thought transference.*—Professor LODGE, President of the section of Mathematics and Physics at the late meeting of the British Association, used the following language: "May there not also be an immaterial (perhaps an etherial) medium of communication? Is it possible that an idea can be transferred from one person to another by a process such as we have not yet grown accustomed to, and know practically nothing about? In this case I have evidence. I assert that I have seen it done and am perfectly convinced of the fact."—*Nature*, Aug. 20, 1891, p. 386.

J. T.

II. GEOLOGY.

1. *Fifth Triennial Meeting of the International Congress of Geologists.*—The International Congress commenced its sessions at Washington, on Wednesday, the 26th of August. The meeting was called to order by Prof. T. McKenney Hughes, of Cambridge, England. After the election of officers, in which Dr. J. S. Newberry was chosen President, the chair, in the absence of Dr. Newberry, was taken by Prof. Joseph LeConte, one of the Vice-Presidents. The principal subjects discussed during the sessions are the following: The Ice-period in America and northern Europe and the classification of pleistocene formations, which was opened by President T. C. Chamberlin and occupied Thursday; the Correlation of European and American geological formations, opened by Prof. G. K. Gilbert, occupying Friday; the Graphic system used in geological work, opened by Major Powell, on the forenoon of Monday. The afternoon of that day was given up to discussions relating to the geology of the regions to be visited by the Western excursion.

On the subject of Correlation, the value of the effects of physical events or conditions and of relations in flora, in fauna, in Invertebrate species and Vertebrate species was variously discussed. The weight of opinion appeared to favor the view that Vertebrate species, when present, afforded the best evidence as to chronological relations. Prof. Zittel gave the highest place to Vertebrates. An abstract of Prof. Marsh's remarks is contained in the paper on page 336.

The next meeting of the Congress, or that of 1894, will be held in Switzerland, probably at Berne; and, on special invitation received from the Geological Survey of Russia, the following, in 1897, will probably be held in St. Petersburg.

The party for the excursion to the Yellowstone Park, Colorado, etc., included about eighty members of the Congress, of which more than half were those from abroad. The following ladies were of the number: Miss Mary Forster of London, Mrs. Mary

Caroline Hughes of Cambridge, England, Madame Marie Pavlow of Moscow, Madame Henriette Sihleano of Bucharest, Roumania, Madame Maria G. Stefanescu of Bucharest, Mrs. S. F. Emmons, Miss Mary G. Markoe and Miss C. A. Smith, of Washington, and Mrs. H. S. Williams of Ithaca. Through the Park the party has the special guidance of Messrs. Hague and Iddings. The excursion will occupy 25 days ; or for those who go also to the Colorado Cañon, an additional ten days. The latter trip is under the direction of Major Powell. A geological guide-book of 150 pages, prepared by Mr. S. F. Emmons, was distributed to members of the party. The party left Washington on the second of September.

2. *The Geological Society of America.*—The Geological Society held its Summer meeting in Washington on the 24th and 25th of August. The President of the Society, Prof. Alexander Winchell, having died since the preceding meeting, the chair was taken by Prof. G. K. Gilbert, Vice-President. Resolutions in honor of the late President prepared by a committee were offered by the chairman, Prof. Orton. An excellent memorial of Dr. Winchell was read by his brother Prof. N. H. Winchell.

Many foreign geologists were present at the meeting of the society and several presented papers having an American importance ; among these were Prof. Alexis Pavlow, of the University of Moscow, on the marine beds terminating the Jurassic and Cretaceous and on the history of their fauna ; Dr. Gustav Steinmann on a geological map of South America ; Dr. Friedrich Schmidt, on the Eurypterus beds of Oesel as compared with those of the Waterlime of North America ; Baron Geràld de Geer, of Stockholm, on the Quaternary changes of level in Scandinavia ; Prof. A. N. Krassnof, of Russia, on the black earth of the steppes of southern Russia and its relations to the soil of the American prairies. Of the other valuable papers, that of C. D. Walcott, on the Lower Silurian ichthyic fauna presented in full the evidence he had obtained in favor of his announced discovery, carrying down the first fossil fishes from the middle Upper Silurian to the Trenton Period in the Lower Silurian. The associated fossils were examined by Prof. Hall and pronounced by him, as decided by Mr. Walcott, unquestionably Trenton.

3. *A United States Association of Government Geologists.*—A meeting was held at the Columbian University August 28, having for its object an official organization of the directors of the state and national geological surveys. There were present Maj. J. W. Powell, director of the United States Geological Survey, and the state geologists : Prof. James Hall, of New York ; Prof. J. M. Safford, of Tennessee ; Prof. J. W. Spencer, of Georgia ; Prof. E. A. Smith, of Alabama ; Prof. J. A. Holmes, of North Carolina ; Mr. Arthur Winslow, of Missouri ; Mr. E. T. Dumble, of Texas ; Prof. J. Lindahl, of Illinois. Maj. Powell was elected chairman of the meeting, and Mr. Winslow secretary. After a few preliminary remarks in explanation of the reasons for calling the meeting, Mr. Winslow read a paper suggesting a plan of

organization and explaining the objects of, and the results to be derived from, such an official organization. The following are among the important objects in view :

The determination of the proper objects of public geological work ; the improvement of methods ; the unification of methods ; the establishment of the proper relative spheres and functions of national and state surveys ; coöperation in works of common interest and the prevention of duplication of work ; the inauguration of surveys by states not having such at present to coöperate with the other state surveys and with the national survey.

A committee of six was elected to consider the matter of organization, with the power to frame a constitution and by-laws, to be reported to the association at a time and place to be selected by the committee. This committee consists of Maj. J. W. Powell, chairman, and Prof. E. A. Smith, Prof. J. A. Holmes, Dr. J. C. Branner, Mr. Arthur Winslow, and Prof. N. H. Winchell. At the meeting of the Committee, Saturday evening, Aug. 29, the secretary, Mr. Arthur Winslow, was instructed to draft a constitution and by-laws to be submitted to the committee at a meeting to be called in connection with the annual meeting of the Geological Society in December next. The object of the association is an important one and much good should come from it.

4. *The Fauna of the Lower Cambrian or Olenellus Zone;* by C. D. Walcott. pp. 511 to 774, with plates xliv to xcviii of the Tenth Annual Report of the Director of the U. S. Geol. Survey. —Mr. Walcott, who has added greatly by his labors to the knowledge of Cambrian life and geography, gives a review in this memoir of his former work on the fauna of the Lower Cambrian, with additions from his more recent results. After a chapter on the history of Cambrian discovery, the stratigraphy of the Cambrian is reviewed and its distribution over the American continent and elsewhere, as at present known, is described. The latter subject is illustrated as regards America by a map on which sections are drawn for each locality having their relative heights ; and the former by various actual sections, some of which show contacts with older rocks. Mr. Walcott observes that the fauna lived, not on the outer coasts of America but in interior straits or channels between emerged ranges of older rocks ; that it occupied the eastern and western portions of the continent, but that "as far as known, the Lower Cambrian is absent from the interior of the continent," indicating thereby, he says, very uniform condition over the central portions. He remarks that the Upper Cambrian sea is shown to have been transcontinental by the presence of identical species of fossils in Northern New York, Lake Champlain valley, St. Lawrence valley, Tennessee, Alabama, Wisconsin, Minnesota, Texas, the Black Hills of Dakota, Nevada and Montana. In the Olenellus period, also, there was a similar assemblage of forms on the opposite sides of the Continent.

The chapter on the Geographical distribution goes into details as to the rocks and species of each locality over the Continent, with comparisons of the special fauna. It is followed by another on the relations of the Lower Cambrian fauna to those of the overlying Cambrian.

This latest review of the species makes the tribes represented in the American Lower Cambrian include: Sponges of four genera; Hydrozoa of the group of Graptolites, and perhaps Medusæ; Actinozoa or true Coral polyps; Echinoderms, of the group of Cystids; Annelids; Brachiopods of 10 genera and 29 species; Lamellibranchs, probably of two species; Gasteropods, of the genera Stenotheca, Platyceras and Pleurotomaria; Pteropods, of 4 genera and 15 species; Crustaceans of Ostracoid type, of the genera Leperditia, Aristozoe and Isoxys; and of the Phyllopod type, in his Protocaris; and Trilobites of 16 genera and 53 species.

Notes of new facts and views relating to the genera and species follow, his former papers being referred to for full descriptions. Fifty plates of figures of the various species close the memoir. Mr. Walcott observes that nothing is learned from the rocks with regard to the genesis of these Lower Cambrian types.

5. *Relation of secular Rock-disintegration to certain transitional crystalline schists;* by R. PUMPELLY (Bull. Geol. Soc. Amer., ii, 209).—This paper is a very valuable contribution to geological science. Some of its facts and conclusions are here cited. A dike of basic rocks intersecting the pre-Cambrian Clarksburg mountain gneiss, near Williamstown, Mass., does not pass up into the overlying Cambrian quartzyte. The dike bears evidence of having been decayed before covered by the quartzyte; and thus leads to the conclusion that the region was dry land before the deposition of the Cambrian. In Hoosic Mountain, which has a core of pre-Cambrian granitoid gneiss, this gneiss has over it a formation, in an anticlinal, consisting of well defined conglomerate at the north end, a gneiss with parallel foliation on the east, a fine-grained, white gneiss, with little mica and rather obscure foliation on the west. The lateral transition of the Lower Cambrian quartzyte of the valley was traced into these white gneisses, "definitely settling the Cambrian age of this conglomerate-gneiss formation." At many points there is complete structural conformity between the pre-Cambrian and the overlying Cambrian gneiss. But on the Clarksburg mountain, where similar facts occur, the quartzyte mantling the granitoid gneiss is crinkled into minute fan-like plications, and the granitoid gneiss has similar plications in perfect parallelism. This fine lamination disappears a short distance from the line of contact. It is evident, says Mr. Pumpelly, that this structure in the older rock was formed at the same time and by the same pressure as that in the younger. The hypothesis of a pre-Cambrian decay of the granitoid gneiss affords a key to the problem in the Green mountains here exemplified. The transitional beds between the two rocks are made of the results of

this decay. The apparent conformity in foliation is due to the shearing action consequent on the slipping movement.

About Iron Mountain, Missouri, Mr. Pumpelly observed, in 1873, evidence of ancient disintegration, and pointed out a conglomerate at the base of the mountain as of Silurian age, and a result of pre-Silurian disintegration. Borings recently made by Prof. W. B. Potter have resulted in the discovery of extensive areas of residuary ore-fragments lying on the pre-Silurian surface.

Mr. Pumpelly has under investigation the Archæan rocks of New England and their relations to the associated rocks, and his paper shows that he has already reached results of great importance.

6. *The Greylock Synclinorium;* T. Nelson Dale (American Geologist, July, 1891).—This paper is an abstract of a Report to R. Pumpelly, U. S. Geological Survey. The chief conclusion confirms the view of Emmons and later observers that the Greylock mountain mass is synclinal in general structure. The author makes it a combination of synclinals and anticlinals, but chiefly of two large synclinals. His paper is illustrated by one of the several sections which will appear in the full report.

7. *Report on the Arkansas Geological Survey for 1888*, Vol. IV. John C. Branner, State Geologist. 262 pp. 8vo, with many plates. Little Rock, Ark., 1891.—This concluding volume of the Report for 1888, is occupied with an account of the geology of Washington Co., by F. W. Simonds, Assistant Geologist, and a list of the plants of Arkansas by J. C. Branner and F. P. Coville. The rocks include four strata of limestone alternating with sandstones and shales of the Lower Carboniferous (Subcarboniferous), with a thin stratum of shale at the base, probably Devonian, and the Millstone Grit, of the "Barren Coal Measures," at the top. The lowest limestone abounds in chert. The greatest thickness given for the Millstone grit is 500 feet, and for the formations below less than 300 feet.

8. *Tungsten minerals in Canada;* by W. F. Ferrier, Geol. Survey of Canada. Communicated by permission of the Director, Alfred R. C. Selwyn.—I have lately made an interesting discovery of tungsten minerals at a Canadian locality, some of them occurring in remarkably fine crystals. This is the first time that this metal has been noted in Canada. A detailed description is in preparation and will shortly appear.

Geological Survey of Canada, Ottawa.

III. Botany.

1. *Some Museums and Botanical Gardens in the Equatorial Belt and in the South Seas* (Third Paper).—Before describing the remaining gardens in Australasia, it will be well to make mention of the *Technological Museum at Sydney*, which contains illustrations of the valuable treatise on the useful plants of Aus-

tralia, by Mr. J. H. Maiden. After the fire which destroyed the Sydney Exhibition building, in September, 1882, Mr. Maiden began the discouraging task of forming a new collection of technological products. The building which was placed at his disposal was formerly the Agricultural Hall of the Exhibition, and is only poorly adapted to the purpose of displaying specimens. In the part of this simple structure which is in his charge, he has brought together an exceedingly large and valuable Museum, which possesses so many features of practical interest for a new country, that no apology will be needed for giving it here what may seem at first to be a disproportionate amount of space. The classification includes (1) Animal products, exclusive of foods. (1a) Economic entomology. (2) Vegetable products, from the raw material through the various stages of manufacture to the finished fabric or other article. This section includes gums, resins, oils, woods, fibers, tans, dyes, drugs, perfumes, Forestry and forest products. (3) Waste products. (4) Foods. (5) Economic Geology. (5a) Ceramics. (5b) Glass. (6) Original specimens of artistic workmanship, coins and medals. (7) Photographs, electrotypes, plaster and other reproductions of examples of art workmanship, where originals are not to be obtained. (8) Ethnological specimens. (9) Metallurgy. (10) Mine-engineering. (11) Strength of materials, etc. (12) Military and Naval. Fire-arms for hunting. Traps, etc. (13) Transportation. (14) Agriculture. (15) Instruments of precision. Apparatus for diagnosis, etc. (16) Sanitary appliances. (17) Educational arrangements. (18) Chemical and pharmaceutical products. (19) Models of patents. (20) Trade Journals. This outline of a classification which is substantially the same as that used at South Kensington, has been found well adapted to the wants of the young Colonial community, and might be found very useful in our smaller Technological Museums in this country.

It is, however, of the collection of products of plants brought under the heads, 2, 3, 4 and 11, that special mention should be made now. These are described in a work of about 700 pages by Mr. Maiden, *Useful Native Plants of Australia*. First come the human foods and food adjuncts. Then follow the forage plants and the plants which are noxious to stock. Other classes are: drugs, gums, resins, kinos, oils, perfumes, dyes, tans, timbers, fibers, and lastly a few miscellaneous products. The volume is, in fact, a capital catalogue of the specimens exhibited in the Museum, giving needed information regarding uses and sources. The indexes are copious and exact, with sufficient cross references.

The system of registering all accessions is nearly the same as that used in our National Museum at Washington, permitting the curator and his assistants to keep track of everything coming in and going out. The labels are full and instructive.

It was a pleasure to see the well-filled room on public days, reminding one of the divisions at South Kensington which are profitably used by British workmen. Here, in a far distant colony, educational appliances of the same kind, specially adapted to the modified surroundings, are thoroughly appreciated by the public. The success has been so great that branch museums have been established in other parts of New South Wales, all under the care of the curator of the head office at Sydney.

As noted in a former paper, there are other technological museums in Australasia, somewhat on the plan of that at Sydney, and all of them are accomplishing much in the development of the colonies. It is pleasing to note, further, that these, together with the natural history and the art museums, are well supported, being everywhere in these colonies recognized as important factors in education. Some of these museums have been already referred to : in this communication reference must be made to still others. The Sydney Museum, under the curatorship of Dr. E. P. Ramsay is very rich in some of the departments, notably that of ornithology. At the time of my visit, in February, a large portion of the building was undergoing repairs and additions were being made. In Sydney, as in other centers of learning in the colonies, there are strong local societies for the encouragement of science, but until the formation of the Australasian Association for the Advancement of Science, there was no general organization. Professor Liversidge of Sydney, who was the prime mover in the establishment of the Association, must view with great satisfaction the happy results which have followed his successful work.

Brisbane, the capital of Queensland, is in latitude 27° 28′ S. and about five hundred miles north of Sydney (over 700 by rail). The climate is very much like that of northern Florida and permits a wide range of plants to be cultivated in the Botanical Gardens. There are two Botanic Gardens in this city, neither of them very large but both kept in good condition and of much use to the colony. The one which is properly a governmental establishment occupies a portion of one of the peninsulas formed by the curves of the Brisbane river, and, owing to its lying so low, is sometimes partly inundated by freshets. At the time of my visit, the traces of damage from one of these floods had not been wholly obliterated. The grounds contain many interesting sub-tropical plants with not a few which are truly tropical. Changes which have been inaugurated by the new curator, Mr. Philip MacMahon, promise to be substantial improvements both in selection and arrangement.

The other garden is close by the two parks, Bowen and Victoria, and attracts a large number of visitors on pleasant days. It is under the management of the Society of Acclimatization, and has for its curator Mr. Souter. The classes of plants are much like those in the government garden, but a good proportion of the specimens are older or at least larger. The propagating department was very interesting. A catalogue of the plants of the gardens has been prepared by the active colonial botanist of Queensland, Mr. F. M. Bailey. The manual of the Queensland Flora by Mr. Bailey is full and convenient.

Mr. Bailey was formerly a resident of South Australia and possesses a large acquaintance with Australian plants. He places his knowledge most freely at the service of those who, like myself, have during a hurried journey, only a limited time in which to examine localities of special interest.

Attention should be called in passing to the fact that two Americans now fill positions of responsibility in the colonial departments of agriculture. These are Dr. N. A. Cobb, of Sydney, and Professor E. N. Shelton, of Brisbane. Dr. Cobb, formerly of Worcester, Mass., studied at Jena. He is now conducting investigations in animal and vegetable pathology in New South Wales. Professor Shelton is instructor in agriculture in Queensland. The writer is indebted to them and their associates for innumerable courtesies.

Of the remaining gardens in Australia proper, I had opportunity to examine with care only one, namely, that at Geelong. This is in the colony of Victoria, about fifty miles from Melbourne. It is situated delightfully on the shores of Coris Bay, and like many others of its class, is practically a city park. Such pleasure grounds differ from those in our own country chiefly in the prominence which is given to interesting species of plants. Not only are foreign plants used freely for decorative purposes, but they are chosen apparently with a view to impart to the park distinctive features as a botanic garden. Nearly all of the gardens, large and small, make great use of what are called bush-houses. These are simple frame structures roofed with slats having gaps between, admitting plenty of air, but affording shelter and shade. They are particularly adapted to Ferns and Aroids, and lend themselves readily to artistic treatment of foliage.

Tasmania.—In this colony I had the pleasure of visiting the garden at Hobart. In this a good deal of attention has been given to trees, especially Conifers, and the results are satisfactory. The garden is picturesque and interesting. Mr. Francis Abbott, the superintendent, finds himself considerably hampered by the scarcity of available labor, but he makes the most of the scanty means at command. The island itself is a botanical garden on a vast scale. Within a few miles of Hobart, one enters the thickets on the slopes of Mt. Wellington, surrounded by Eucalypts and tree ferns, and by flowers of extraordinary beauty. Even here one has at command a handbook of the local flora, namely, a work by Rev. Mr. Spicer. It is designed for schools, but it answers a good purpose for tourists in giving descriptions of the commoner plants of the island. The charming walk over the famous Huon road and up Mt. Wellington must not be omitted by any visitor who would see Tasmania vegetation at its best.

The New Zealand Gardens.—The southernmost one visited was at Dunedin, in Otago. It is a modest city pleasure ground, supported on the most meagre allowance, but presenting some interesting features. The collection of rare New Zealand plants, made by Mr. John McBean, is worthy of attentive study. At Christchurch, in Canterbury, the garden is much more extensive. Its curator, Mr. Taylor, had but very lately taken charge, but he indicated certain improvements in prospect. The native plants are well shown by good specimens, a good deal of care having been taken to secure types and varietal forms. It was my good fortune to be conducted through this garden in one of my visits, by Professor Kirk, whose labors in connection with the New Zealand Flora are everywhere known. He is now engaged in editing a new edition of Sir Joseph Hooker's Handbook of the Flora of New Zealand, a work now out of print. Professor Kirk's Forest Flora of New Zealand is a magnificent volume carefully illustrated. The fidelity of the drawings is remarkable.

The last of the gardens in New Zealand visited by me was that at Wellington. It is situated on the hill back of the city, and possesses chiefly the characteristics of a park.

Dunedin, Christchurch, and Wellington, to which we may add also Auckland, have excellent local museums. The one at Dunedin is growing rapidly in the direction of zoology. This is under the charge of Professor T. Jefferey Parker. Christchurch museum is widely known from the collections of bones of extinct birds which were brought together by the late Dr. Julius von Haast. The museum is extensive in many departments, particularly ethnology, but it needs re-arrangement. This it will doubtless receive soon from its new curator, Dr. H. O. Forbes, the naturalist whose studies in the Eastern Archipelago are familiar to all our readers. The cathedral city of Christchurch is the home of Professor Hutton of Canterbury college. Wellington is the capital of New Zealand. Its museum is extensive, but inadequately provided with proper exhibition rooms. The display of ethnological specimens is exceedingly good, being arranged in the most effective manner. The Auckland museum is also rich in ethnological specimens.

I have purposely deferred to the last, a brief description of the local museum at Hobart, Tasmania. Mr. Alexander Morton, the curator, has carried out to the furthest extent his plan of establishing a Tasmanian exhibition. In the first place, it is comprehensive, taking in all departments of natural history, as well as geology, archæology and ethnology, in other words, natural history in the widest sense. As a rule, specimens from other places are used wholly for comparison. The arrangement in each department is simple and perfectly intelligible to the person of average intelligence, and each specimen is very fully described on its label. Almost every museum in all Australasia seeks rightly to make the exhibits attractive and instructive, especially in the line of local matters. The collections at Hobart are therefore only a conspicuous example of what can be done on a small scale and with very limited means.

Another characteristic of all the Australasian museums is highly commendable, namely the tenacity with which they all cling to rare specimens of archæological and ethnographical interest, instead of utilizing them for exchange. Those of us who deplore the disintegration of collections will sympathize heartily with the policy adopted in the South.

By and by, the time will doubtless come when, under some system of federation, a capital city for all the colonies will be selected, in which a central museum may gather for comparison all the rarer of these now scattered treasures, but it is to be hoped that none of these which are unreplaceable will be suffered to leave the country, at least until the fragmentary history of the fast vanishing races is secured. This was impressed upon the writer on his visit to one of the museums before alluded to, in which there was a fairly large collection of ceremonial knives and weapons. The curator pointed out the slight differences existing between the allied groups and stated that some of the types of manufacture are no longer to be met with, in a genuine form. It is worthy of note that excellent imitations of some of the rarer types are to be obtained of dealers, but it is seldom that genuineness is claimed even for the cleverest of the copies.

Frequent reference has been made in these papers to the very general interest felt by the Australasian public in matters pertaining to applied science. It is because of this widespread interest that the botanic gardens and museums are so well sustained. Further, it is on this account that the various institutions which deal with technology, as in Adelaide, Melbourne, and Sydney, are generously supported. There are certain social and economic factors which render it less easy than might be supposed, to give to these and kindred institutions all the aid they need ; taking these factors into consideration, it must be confessed that practical scientific education receives in the southern hemisphere a greater degree of attention than it does in the northern : far greater when we take into account the comparatively small population of Australasia.

Before leaving the subject of the gardens of the South, it will not be deemed out of place to refer to the excellent private gardens found in all the larger towns. The writer enjoyed the privilege of visiting some of the finer of these collections, a few of which contained specimens which would be considered real acquisitions by any amateur horticulturist in the world.

A sketch of the Queensland Coast will come most conveniently in the fourth paper of this series. G. L. G.

IV. Miscellaneous Scientific Intelligence.

1. *American Association for the Advancement of Science.* Fortieth Meeting, at Washington.—The meeting was opened on the 19th of August, under the Presidency of Prof. Albert B. Prescott, of Ann Arbor, Michigan. The valuable address of the

retiring President, Prof. Goodale, on some of the Possibilities of Economic Geology makes the opening article of this number.

The Vice-Presidents of the sections appointed are the following. A, Mathematics and Astronomy, Prof. J. R. Eastman, of the Naval Observatory, Washington; B, Physics, Prof. B. F. Thomas, State University, Columbus, Ohio; C, Chemistry, Dr. Alfred Springer, Cincinnati; D, Mechanical Science and Engineering, Prof. J. B. Johnson, Washington University, St. Louis; E, Geology and Geography, Prof. H. S. Williams, Cornell University; F, Biology, Prof. S. H. Gage, Cornell University; H, Anthropology, W. H. Holmes, Ethnological Bureau, and I, Economical Science and Statistics, Prof. S. Dana Horton, Pomeroy, Ohio.

Prof. Putnam is continued as Permanent Secretary. Rochester, New York, was selected as the next place of meeting.

List of papers accepted for reading.

Section A. Mathematics and Astronomy.

A. S. Christie: A digest of the literature of the mathematical sciences.

G. L. Doolittle: Latitude of the Sayre Observatory.

G. C. Comstock: The secular variation of terrestrial latitudes.

G. W. Holley: Groups of stars, binary and multiple.

J. A. Brashear: Description of the great spectroscope and spectrograph, constructed for the Halstead Observatory, Princeton, N. J. Note on some recent photographs of the reversal of the hydrogen lines of solar prominences.

Frank H. Bigelow: Standardizing photographic film without the use of a standard light. Exhibition and description of a new scientific instrument, the aurora-inclinometer.

David P. Todd: On a modified form of zenith telescope for determining standard declinations. On the application of the "photochronograph" to the automatic record of stellar occultations, particularly dark-limb emersions.

O. T. Sherman: The zodiacal light as related to terrestrial temperature variation.

Ormond Stone: On the long-period terms in the motion of Hyperian.

A. Macfarlane: Principles of the algebra of physics.

Henry M. Parkhurst: The tabulation of light-curves; description, explanation, and illustration of a new method. Stellar fluctuations; distinguished from variable stars; investigation of frequency.

Thomas S. Fiske: On certain space and surface integrals.

J. Loudon: The fundamental law of electromagnetism.

F. P. Leavenworth: Method of controlling a driving clock.

Wm. E. Heal: On the bitangential of the quintic.

J. E. Kershner: Parallax of α Leonis.

Section B. Physics.

William Hoover: On the logarithmic mean distance between pairs of points in any two lines.

E. W. Morley: A new method for measuring the expansion of solids.

E. W. Morley and W. A. Rogers: Measurement of the expansion of Jessop's steel by a new method.

Gustavus Hinrichs: Statement of the general law determining the fusing and boiling point of any compound under any pressure as simple function of the chemical constitution of the same. The calculation of the boiling point of a liquid under any pressure. Determination of the discontinuity of the fusing points of paraffins by means of analytical mechanics.

William Orr: A scheme for a science of color.

B. F. Thomas: Note on magnetic measurements at Ohio State University. Notes on rotating contact methods of measurement of variable electric magnitudes.

M. A. Veeder: The periodicity of the Aurora.

C. B. Thwing: Color photography by Lippmann's process. Behavior of silver emulsions under long exposure to light.

A. Macfarlane: On the nomenclature for physical units.

A. McAdié: Some experiments in atmospheric electricity.

W. M. Stine: Some forms of carbon and alkaline storage batteries. The tangent galvanometer as a voltmeter.

H. A. Hazen: Do tornadoes whirl? Artificial rain.

N. H. Genung and F. J. Rogers: Observations with a new photometer.

F. J. Rogers: Magnesium as a source of light.

Brown Ayres: Note on the measurement of resistances by alternating currents. The nature of "counter-electromotive force." What should be our fundamental units?

Section C. Chemistry.

Chas. L. Reese: Preliminary notes on the influence of swamp waters on the formation of the phosphate nodules of South Carolina.

E. T. Cox: Land and river phosphate pebbles or nodules of Florida.

Alfred Springer: A latent characteristic of aluminum.

Paul C. Freer: The influence of negative atoms and groups of atoms on organic compounds.

E. Goldsmith: Gabbro phonolyte.

H. A. Weber: Raphides the cause of the acridity of certain plants.

Gustavus Hinrichs: The calculation of the boiling point of a paraffin under any pressure. The calculation of the boiling points of isomeries from their moment of inertia. Determination of the true position of the carbon atoms in organic compounds by means of analytical mechanics.

F. P. Dunnington: Distribution of titanic oxide on the earth's surface.

Thomas Taylor: The precipitation of fish oil in linseed oil, when used as an adulterant, by silver nitrate solution. The separation and precipitation of oleic acid from linseed oil by silver nitrate.

Walter Maxwell: Biological functions of the lecithins.

Edward W. Morley: Synthesis of weighed quantities of water from weighed quantities of oxygen and hydrogen.

Edward Hart: Dinitro-sulfo-phenol.

W. M. Stine: Continuous-feed apparatus for distilling water.

C. L. Speyers: The atomic theory.

P. L. Spencer and E. E. Ewell: Imitation coffees.

H. W. Wiley and W. H. King: The composition of floridite.

Wm. H. Seaman: Tri-nitro toluene, a substitute for musk.

L. P. Kinnicut: Purification of Worcester sewage by chemical precipitation. Fire clay from Mount Savage.

W. A. Chapman: An inquiry relative to the causes leading to the formation of ore deposits.

J. G. Spenzer: Delicacy of the tests for phenol.

J. U. Nef: An aceto-acetic ether.

W. S. Yeates: On plattnerite from Idaho.

E. A. v. Schweinitz: The chemistry of some disease germs. A convenient arrangement for a Pasteur filter, where air pressure is available.

H. W. Wiley: Notes on pinite. Notes on the chemical composition of muck soil from Florida. Composition of crystalline artificial calcium phosphate.

J. Thomas Davis: Meat preservatives.

W. H. King: Determination of phosphoric acid in presence of iron and alumina.

Section D. Mechanical Science and Engineering.

James E. Denton: Economy produced by the use of water injected as a fine spray into air compressors. Note on the efficiency of the screw propeller. On a method of holding samples of wood and brick for determination of tensile strength. Relative economy of compound and triple expansion engines.

David P. Todd: On experimental results obtained with a new form of direct-action propeller.

B. E. Fernow: The Government timber tests.

John B. Johnson: The United States tests of American woods, made at the Washington University Testing Laboratory.

Chas. L. Bouton: On the crushing of short prisms of homogeneous material.

Thomas Gray: On expansion steam calorimeters. Tests of electric railway plant On the power absorbed in the cutting of metals.

D. S. Jacobus: Maximum error due to neglecting the radiation-correction of a Barrus universal calorimeter. Relative economy of carbonic acid as the working fluid of refrigerating machines.

William Kent: On the efficiency of the steam jackets of the Pawtucket pumping engine. On the opportunity for mechanical research at the World's Fair.

Section E. Geology and Geography.

John T. Campbell: Source of supply to lateral and medial moraines.

A. E. Foote: New meteoric iron from Arizona containing diamonds.

G K. Gilbert: Post-glacial anticlinal ridges near Riply and Caledonia, New York.

Warren Upham: Processes of mountain building and their relationship to the earth's contraction.

Henry Lampard: Notes on an extinct volcano at Montreal, Canada.

E. D. Cope: (A) On a new horizon of fossil fishes. (B) On the cranial characters of *Equus excelsus* Leidy.

Joseph F. James: On problematic organisms and the preservation of Algæ as fossils. On the age of the Mount Pleasant, Ohio, beds.

William Hallock: Preliminary report of observations at the deep well near Wheeling, W. Va.

T. C. Hopkins: The Eureka shale of northern Arkansas.

T. C. Chamberlin: The altitude of the eastern and central portions of the United States during the Glacial period.

W. J. McGee: Neocene and Pleistocene continental movements.

A. Wanner: Fossil tracks in the Triassic of York county, Pa.

M. N. Mitievier: New footprints of the Connecticut Valley.

Lester F. Ward: The plant-bearing deposits of the American Trias. Principles and methods of geologic correlation by means of fossil plants.

Henry F. Osborn: A reply to Professor Marsh's note on Mesozoic Mammalia.

James M. Safford: Exhibition of certain bones of Megalonyx not before known.

R. D. Salisbury: On the probable existence of a second driftless area in the Mississippi basin.

Frank Leverett: The Cincinnati ice-dam.

Leon S. Griswold: The structure of the Ouachita uplift of Arkansas.

C. R. Van Hise: The relations of the Archæan and the Algonkian in the northwest.

Herman L Fairchild: Results of a well-boring at Rochester, N. Y.

E W. Claypole: On a deep bore near Akron, Ohio.

R. W. Shufeldt: A study of the fossil Avifauna of the Silver Lake region, Oregon.

J. Crawford: The peninsula and volcano Cosignina. The geological survey of Nicaragua.

F. B. Taylor: The highest old shore line on Mackinac Island.

J. E. Todd: Striæ and slickensides at Alton, Illinois.

Section F. Biology.

Simon H. Gage: Notes on the physiological and structural changes in Cayuga Lake lampreys. The transformation of the vermilion spotted newt.

Ida H. Hyde: Notes on the heart of certain mammals.

John A. Ryder: On the kinds of motion of the ultimate units of contractile living matter.

E. D. Cope: On the insertion of the scapular and pelvic arches and limbs of Lacertilia. On coloration in certain Reptilia.

Geo. F. Atkinson: On the structure and dimorphism of Hypocrea tuberiformis.

J. M. Macfarlane: Another chapter in the history of the Venus fly trap.

D. H. Campbell: On the prothallium and embryo of Osmunda Claytoniana and O. cinnamomea. On the phylogeny of the Archegoniata.

Byron D. Halstead: A new Nectria. Notes upon bacteria of cucurbits. Notes on an Anthracnose.

Joseph N. Rose: The Compositæ collected by Dr. Edward Palmer in Colima. The flora of Carmen Island.

Theobald Smith: Uses of the fermentation tube in bacteriology with demonstrations.

James M. Flint: The foraminifera with a new device for the exhibition of specimens.

E. M. Hasbrouck: A monograph of the Carolina paroquet.

C. V. Riley: Parasitism in Coleoptera, in Diptera, in Braconidæ, and Ichneumonidæ. Micro-organisms as insecticides.

A. J. Cook: Enemies of the honey-bee. Abnormal bees.

John B. Smith: Notes on the homology of the hemipterous moth. Epipharynx and hypopharynx of Odonata. The mouth of Copris Carolina, and notes on the homology of the mandible.

O. P. Hay: On the turtles of the genus Malaclemys. On the ejection of blood from the eyes of horned toads.

G. Brown Goode: The present condition of the study of the deep-sea fishes

Chas. W. Stiles: On the importance of a table at the Naples station.

B. T. Galloway: Further observations on a bacterial disease of oats.

Geo. Vasey: Botanical field-work of the Botanical Division.

M. B. Waite: Results from recent investigations of pear blight.

I. A. Brashear: The spectroscope in botanical studies.

Theodore Gill: The persistence and relation of faunal realms. The New Zealand fish fauna.

Joseph Jastrow: A case of the loss of sense of smell. A novel color illusion, and a new method of color mixture.

Mary E. Murtfeldt: Modification of habit in paper-making wasps.

Wm. Palmer: The fate of the fur seal in American waters.

C. E. Bessey and A. F. Woods: Transpiration or the loss of water in plants.

Wm. J. Beal: Movement of fluid in plants.

L. H. Pammel: Absorption of fluids by plants.

J. C. Arthur: Gases in plants.

Herbert Osborn: Origin and development of parasitic habit in Mallophaga and Pediculidæ.

H. Garman: The origin and development of parasitism among the Sarcoptidæ.

Wm. H. Ashmead: On the habits of the Proctotrypidæ.

L. O. Howard: The biology of the Chalcididæ.

Section H. Anthropology.

Wm. H. Seaman: The essentials of a good education, with a new classification of knowledge.

Walter Hough: The custom of kava drinking as practiced by the Papuans and Polynesians.

J. W. Powell: A linguistic map of North America.

Thomas Wilson: Jade implements from Mexico and Central America. Gold ornaments in the United State National Museum from the United States of Colombia. Evidences of the high antiquity of man in America. Geographical arrangement of prehistoric objects in the U. S. National Museum. Curious forms of chipped stone implements found in Italy, Honduras, and the United States. Inventions of antiquity.

J. OWEN DORSEY: Siouan onomatopes interjections, and phonetic types. Games of Teton, Dakota, children.

G. H. PERKINS: On a collection of stone pipes from Vermont. On bone, copper and slate implements found in Vermont.

MERWIN MARIE SNELL: The importance and methods of the science of comparative religion.

ANITA NEWCOMB MCGEE: An experiment in human stirpiculture.

ZELIA NUTTALL: Relics of ancient Mexican civilization.

EDWARD S. MORSE: Bow-stretchers. Prehistoric bows.

ALICE C. FLETCHER: The Nez Percé country.

FRANK LEVERETT: Relation of a Loveland, Ohio, implement-bearing terrace to the moraines of the ice-sheet.

LAURA OSBORNE TALBOTT: Utility of psychical study of child life.

ALBERT GATSCHET: Origin of the name Chautauqua.

FRANK HAMILTON CUSHING: Outlines of Zuñi creation and migration myths considered in their relation to the Ka-ka and other dramas or so-called dances.

F. W. PUTNAM: An ancient human cranium from Southern Mexico.

C. M. WOODWARD: The length of a generation.

CHAS. A. HIRSCHFELDER: Burial customs of the Hurons.

JAMES MOONEY: The Messiah religion and the ghost dance.

FRANK BAKER: Study of a dwarf.

ATREUS WANNER: Stone drills and perforations in stone, from the Susquehanna River.

GERARD FOWKE: Some Archæological contraventions.

W. H. HOLMES: On the distribution of some implements in the tide-water province. Aboriginal novaculite quarries in Arkansas.

JOSEPH JASTROW: Study of automatic motion.

W. H. BABCOCK: Race survivals and race mixture in Great Britain.

Section I. Economic Science and Statistics.

J. S. BILLINGS: The census counting machine (with exhibition of the machine at work).

ALEX. S. CHRISTIE: On a measure of the reliability of census enumeration.

LESTER F. WARD: A national university; its character and purposes. The science and art of government.

W. J. MCGEE: The southern oil fields.

J. R. HINTON: Agriculture by irrigation; some social economic possibilities.

B. E. FERNOW: Water management the problem of the future.

C. R. DODGE: The needs of the American flax fibre industry.

B. W. SNOW: The necessity for State supervision of railway extension.

LAURA OSBORNE TALBOT: The economic value of cooking schools in the District of Columbia.

RICHARD T. COLBURN: The code of inheritance.

HENRY FARQUHAR: Numerical relations between amount and value of United States potato crop and amount of importations. United States mercantile marine and duty rates.

H. W. WILEY: The muck soils of the Florida Peninsula.

ROBERT T. HILL: The artesian wells and underground waters of central Texas.

MANLEY MILES: Energy as a factor in rural economy.

ALEX. D. ALEXANDER: World's Columbian Exposition.

EDWARD ATKINSON: Free coinage; Why not?

EDWARD T. PETERS: The coinage ratio in our silver policy.

GEO. A. PRIEST: The Eleventh Census and statistics of manufacture. A permanent Census Bureau.

Mrs. M. C. BAKER: Tabulation errors of census.

C. V. RILEY: The locust or grasshopper outlook.

CHAS. S. HILL: Immigration as an economic sociologic problem. The economy and thrift of machinery.

Entomological Club.

L. O. HOWARD: The Encyrtinæ with branched antennæ.
H. G. HUBBARD: Insect life in the hot springs of Yellowstone National Park.
E. A. SCHWARZ: Preliminary notes on the insect fauna of the Great Salt Lake, Utah.
J. A. LINTNER: On the occurrence of the Pear midge, Diploris pyrivora. Notes on the Pear tree Psylla, Psylla pyricola, in the Hudson River Valley. On the eye-spotted bud moth, Tinetocera ocellana, in Western New York. On some of our Orgyias. Exhibition of the luminous females of Phengodes, species.
J. B. SMITH: Note on the habits of Xyleborus dispar. Habits of Volucella fasciata. Notes on the classification of the Lepidoptera. A revision of the genus Cucullia. Staining insect structures.
E. W. CLAYPOLE: Means of preserving larvæ for class use. A substitute for cork.
H. E. WEED: Screw worm feeding on vegetable matter.
D. S. KELLICOTT: Notes on two borers destructive of mountain ash.
B. P. MANN: The bibliography on Entomology.
C. V. RILEY: Notes on Sphecius speciosus. Some interesting Phylloxeræ. Notes on the larval habits of Megaphycis.
M. E. MURTFELDT: Longevity and vitality of Ixodes and Trombidium. Modification of habit in paper wasps.

2. *The British Association.*—The meeting of the British Association was opened at Cardiff, Wales, on Wednesday, the 19th of August. The able address of the President, Professor William Huggins, treating of the progress of Astronomy through spectroscopic observations, is published in full in Nature of August 20th. The reader is referred to this and the following numbers of Nature for the addresses, also of the Presidents of Sections, and for abstracts of the more important papers presented. The next meeting will be held at Edinburgh, under the Presidency of Sir Archibald Geikie, commencing on the 3d of August, 1892.

OBITUARY.

WILLIAM FERREL, the eminent meteorologist, died at his home in Kansas City, Missouri, on the 18th of September, at the age of seventy-four. He commenced his active scientific career in 1857, when he was made assistant in the office of the American Ephemeris and Nautical Almanac. This position he held for ten years, when he was appointed to the staff of the U. S. Coast Survey. In 1882 he was made assistant, with the rank of professor, in the Signal Service Bureau, where he remained until October, 1886. Some of his most important work was was done in connection with the Coast Survey; he invented the maxima and minima tide-tide predicting machine, which is now used in predicting the tides. His list of published works include a number of volumes devoted to researches on the tides, meteorological problems, etc.; of these, a volume on Recent Advances in Meterology was published in 1883, and a Popular Treatise on the Winds—a work of marked value—in 1889. The recent volumes of this Journal contain a number of important memoirs by Mr. Ferrel upon thermal radiation, cyclones, tornadoes and related subjects, chiefly in terrestrial physics.

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SCIENTIFIC INTELLIGENCE.

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[THIRD SERIES.]

Art. XXXIV.—*The Solution of Vulcanized India Rubber;* by Carl Barus.

1. Introductory.—In my work* on the solubility of glass in water, I showed that in proportion as the state of dissociation or the molecular instability of glass is increased with rise of temperature, the solvent action of water increases at an enormously rapid rate; that inasmuch as the solution takes place between a solid and a liquid, sufficient pressure must be applied to keep the fluid in the liquid state, whenever the vapor tension at the temperature in question exceeds the atmospheric pressure. Thus, at 100°, the action of liquid water on glass is nearly negligible; but even at 185° solution occurs at so rapid a rate that capillary tubes may become filled with solid hydrated silicate, in place of water, in an hour. Here, however, about 10 atm. must be applied to keep the solvent in the liquid state essential to speedy reaction.

2. *The present application.*—Having attempted to apply the same principle to the actual solution of vulcanized India rubber, I obtained confirmatory results at once. To my knowledge this material has not heretofore been advantageously dissolved in a volatile reagent, or in any reagent by which it is speedily and copiously taken into solution, and from which it may be conveniently obtained. Cf. § 4, note.

It follows by analogy from § 1, that the rubber must be hot enough to be in a state of dissociation, i. e., that the coherence of the rubber-sulphur molecules must show an instability in regard to whatever solvent may be used. It follows, more-

* This Jour., xxxviii, p. 408, 1889. Ibid, xli, p. 110, 1891.

over, that the system of rubber and solvent is to be kept under pressure sufficient to insure the liquid state of the solvent. It follows obviously that this temperature must only be so high, cæt. par., as to change in the least degree possible, the useful character of the rubber eventually to be deposited from solution. Hence, I act on vulcanized India rubber at the lowest convenient temperature facilitating the solvent action, and at a pressure preferably exceeding the vapor tension of the solvent at the given temperature. Whatever other favorable action pressure may exert (such, for instance, of forcing the fluid into the physical pores of the semi-solid by a principle akin to Henry's law) is clear gain. In my machine* it is rather more convenient to act under 100 atm., or more, than at lower pressures. Hence I did not scruple to use pressures as large as, or above, this, testing the adequacy of low pressures, however, by special experiment. §§ 18, 20.

The samples of vulcanized rubber acted on were five in number, and their character may be detailed as follows:

a. Very elastic† sheet rubber, usually not pigmented, translucent in thin films, brownish in color, used for rubber bands and sheeting, chemical rubber tubing, etc.

b. Less elastic and harder rubber, pigmented gray, opaque, largely used for rubber tubing, etc.

c. Non-elastic, pigmented rubber, flexible, opaque gray, used for low class rubber tubing and low class merchandise in general.

d. Ebonite.

e. Same as *a*, rotted by age and exposure.

3. *Solution in carbon disulphide.*—From experiments made at 100° and 160°, it appears that elastic sheet rubber (*a*), is not fully soluble in CS_2 in a reasonable time, if at all. It is quite soluble at 185°, and soluble to a remarkable degree and at a remarkably rapid rate at 210°. Hence the pressure under which solution is to take place, should here be greater than

* See Proc. Am. Acad., xxv, p. 93, 1890, or Phil. Mag., October, 1890, p. 338. The present method of work is simple: Glass tubes 10^{cm} to 15^{cm} long, and $\cdot 3^{cm}$ or $\cdot 4^{cm}$ in diameter, closed at one end, and drawn out to a capillary canal with three enlargements at the other, were filled with a charge of vulcanized rubber and solvent, and then introduced into the steel piezometer tube. I made use of the temperatures of boiling turpentine (160°), aniline (185°), naphthalene (210°), and diphenylamine (310°). To separate the charge from the oil of the piezometer which transmits pressure, I first employed a thread of mercury inserted into the capillary canal. Finding, however, § 17, that this metal acted on the charge, I replaced it by a thread of water, or contiguous threads of gasolene and water. Charges were usually introduced in the ratio of one part by volume of rubber to three or more of solvent, § 18. About 1^{cc} to 2^{cc} of solution were obtained per heating. I made considerably over 150 experiments, most of them at 210° and 100 or 200 atm. Experiments on a larger scale were also made in great number, chiefly with the object of studying the product deposited from solution. § 20.

† By elastic I mean extensible with resumption of the original shape when the pull ceases.

15 atm., but need not exceed 30 or 40 atm. Inasmuch as CS_2 thus unites with rubber in any proportions, clear brown solutions of any viscosity may be obtained. Diluting such (thick) solutions with cold CS_2, the solvent is first greedily absorbed; but the final complete solution of the unagitated syrupy rubber takes places very slowly. Finally, by exposing any of the solutions to air, the CS_2 evaporates, and the dissolved vulcanized rubber is regained without sacrifice of its original non-viscid quality. Similarly fissured brittle sheet rubber or tubing (*e*), which has become useless for practical purposes by age, is quite soluble in CS_2 at 200°, so far at least as its undecomposed portion is concerned. Elastic gray rubber (*b*), dissolves completely to a gray liquid, in which the pigment is suspended. § 16. The concentrated solution hardens at once on exposure to air, reproducing a rubber of nearly the qualities (*b*). The same is true of the non-elastic sample (*c*). Treatment at 310° resulted in a decomposition of the rubber.

Commercial ebonite (*d*) is first partially devulcanized at 200°, (excess of rubber) and eventually dissolves in excess of solvent. The partially devulcanized product is elastic on drying, but finally hardens to a tough solid having a leathery quality. The solution leaves a black stain, with free sulphur apparent after evaporation. § 15. Gases are frequently evolved during solution of highly vulcanized rubber in CS_2. §§ 17 and 19.

As a whole my experiments show that excess of sulphur is first removed by the solvent, after which the vulcanized rubber itself passes into solution. § 15.

4. *Solution in liquids of the paraffine series.*—The elastic rubbers (*a* and *e*) dissolve easily in liquid mineral oils, at 200°. The pressure necessary will, of course, vary with the boiling point of the oil used, and may be as high as 50 atm. in the very volatile gasolenes. Commercial gasolene, though a good solvent of the rubbers *a* and *e*, is less powerful in case of *b* and *c*, unless excess of solvent be used. On exposure to air, the gasolene evaporates, leaving a residue which soon hardens. Mineral oils of a higher carbon order than gasolene, petroleum,* for instance, dissolves the rubbers *a* and *e* even more easily. The solution, however, dries only after much time and probably only in thin films. Solubility seems to increase as the oil lies higher in the carbon series. §§ 12, 18.

* Looking up the literature of the subject, I found that John J. Montgomery (Cf. Letters Patent No. 308,189, November, 1884, U. S. Patent Office), describes a process for the solution of vulcanized rubber. His statement of the temperature and pressure necessary are substantially correct, although he confines his experiments to a petroleum oil boiling at 200° or higher. The oil is subsequently driven off by injections of steam. This is the nearest approach to an available and true solution (a solution which does not remain permanently sticky like the turpentine and other solutions) which I have found. The essential peculiarity of the methods in the above text is solution in volatile solvents.

5. *Solution in turpentine.*—In case of the elastic rubber (*a*), complete solution is at once effected at 200°, whereas at ordinary temperatures the time necessary is enormous, if indeed the solutions in the two cases be the same. The syrupy liquid obtained at 200° seems to dry in very thin films. Special experiments made at 160° showed that no reasonably speedy solution takes place even in liquid turpentine at this temperature, thus corroborating the inferences of §§ 1, 2, 3. Gray rubber (*b*) is acted on with greater difficulty at 210°. The solution leaves a white glossy stain which hardens. Pressure need not exceed 5 atm.

6. *Solution in chloroform and carbon tetrachloride.*—Elastic sheet rubber (*a*) dissolves at once in liquid $CHCl_3$ at 210°. Pressure should exceed 15 atm. and need not be larger than 25 or 30 atm. Solutions of any degree of viscosity seem to be obtainable. They dry at once on exposure to air, leaving a hard residue relatively dark in color. Possibly this was due to the presence of sulphur in the chloroform. § 15. Gray rubber (*b*) is attacked with decomposition of the solvent and evolution of gas.

7. *Solution in aniline.*—Solution in the liquid at 200° takes place at once, in case of elastic rubbers (*a*). Pressure need not exceed a few atmospheres. Thin films apparently dry on long exposure.

8. *Solution in animal oils.*—Neither in the case of sperm oil, nor of lard oil was the elastic rubber (*a*) dissolved on removing from the piezometer. Both distintegrated on standing, to a solution, often with slow evolution of gas.

9. *Treatment with glycerin.*—At 200° no solution occurs. Glycolic alcohols were not examined. Cf. § 12.

10. *Solution in benzol and higher aromatic hydrocarbons.*—The elastic sheet rubber (*a*) dissolves at once in liquid C_6H_6 at 200°. Pressure should exceed 7 atmospheres, but need never be higher than 30 atm. The solution exposed to air hardens rapidly. Solution of gray rubber (*b*) is less easy.

Solution of elastic rubber (*a*) in liquid toluol at 200° also takes place with great ease. The liquid dries slowly. Pressures of less than 10 atm. suffice.

11. *Solution in ethylic and higher ethers.*—Elastic sheet rubber (*a*) dissolves at once in liquid ethylic ether at 200°. Pressure should exceed 25 atm., but need not be greater than 40 or 50 atm. The solution hardens immediately on exposure to air. Gray rubber (*b*) is attacked with difficulty.

12. *Treatment with alcohols.*—At 200° india rubber (*a*) is not dissolved in liquid methyl or in liquid ethyl alcohol, and only slightly so in liquid amyl alcohol. Thus, again the solubility seems to increase with the molecular weight of the solvent. § 18.

13. *Treatment with ketones.*—India rubber (*a*) treated with liquid acetone at 200°, is converted into a sticky paste from which it hardens at once on exposure to air. Pressure should exceed 15 atm., but need not be greater than 30 or 40 atm.

14. *Treatment with water and mineral acids.*—In no case was there a trace of true solution at 210°. Water probably enters the physical pores of the elastic rubber (*a*), as this substance becomes superficially rough and warty on drying in steam at 200°, after being treated with liquid water at the same temperature. It does not melt. § 18. Strong hydrochloric acid (1 : 2) has no obvious effect, while strong sulphuric acid (1 : 3) seems only to char the rubber. Treating gray rubber (*b*), with HCl, I found its solubility in CS_2, C_6H_6 and gasolene to have decreased.

15. *Treatment for vulcanization. Liquid ebonite.*—Liquid ammonic polysulphide at 185° or 200° does not change the appearance of gray rubber (*b*) markedly; but the sample loses its elasticity and shows a semi-plastic consistency. This I believe to be due to additional vulcanization induced by the polysulphide. If now the sample be treated with liquid CS_2 at 200°, the solvent is decomposed with the evolution of much gas, and the rubber restored to its original elastic quality. The gas is liberated throughout the mass of the rubber, and the sample, when taken out of the tube, has the form of an enormously inflated cellular sack, which issues from the glass tube explosively, but soon collapses on exposure to air. As a whole these results agree with the behavior found for ebonite in § 3. In both cases it is possible to pass from a more vulcanized to a less vulcanized solvent by treating an excess of rubber. It will be shown below, § 19, that the gas evolved is probably due to the double decomposition of water and CS_2.

More interesting is the direct vulcanization of a rubber solution, to liquid ebonite, by aid of a solution of sulphur. In case of elastic sheet rubber (*a*), this even begins at 160°; but it is more complete at 185° and 210°. In case of pure (non-vulcanized) rubber dissolved in CS_2 with excess of sulphur, scarcely any change of the flesh color is observed at 160°, and the sulphur crystallizes out of the solvent in needles, on exposure. At 185° and 210°, however, the charge turns black, showing complete vulcanization. If equal masses of vulcanized rubber (*a*) and sulphur be treated, the product, after heating to 210°, is not dissolved nor soluble, until the excess of sulphur is removed. §§ 3, 15. Gas is often evolved. §§ 17, 19. In proportion as less sulphur is used relatively to the rubber, the product becomes more immediately soluble and less gas is evolved. Adding about 20 per cent of dissolved sulphur to the elastic rubber (*a*), I obtained serviceable solutions of ebonite, on treating at 200° either in CS_2 alone, or in mixtures, § 16, of this liquid with gasolene, benzol, etc. In most cases these harden very quickly to a jet-black enamel. With less sulphur the color is brown in thin films.

16. *Solution in mixtures of solvents, and solution of mixed gums.*—By acting on vulcanized rubbers with mixed solvents of the above kind, I obtained very satisfactory results. All the rubbers mentioned (*a* to *e*), ebonite excepted, pass easily into true solution by such treatment. Thus the gray elastic rubber (*b*) dissolves at once in a mixture of CS_2 with gasolene, or benzol, or ether, etc.; or of benzol and toluol; or less easily in mixtures of benzol and gasolene; etc. Ebonite is partially devulcanized, and would probably be dissolved in large excess of solvent. § 3. No gas was evolved in any case, § 19, which is an advantage of this method. In all cases the solutions hardened rapidly on exposure to air, yielding the pigmented rubber if the solution be shaken, or a purer rubber, if the sediment be removed by subsidence and decantation.

Equally feasible is the solution of mixed gums in a suitable solvent at 200°. Thus I made solutions of mixed vulcanized rubber and gutta percha in CS_2, which dried at once on exposure to air; mixtures of rubber and shellac dissolved in CS_2, drying more slowly; mixtures of vulcanized rubber and rosin dissolved in CS_2 and in gasolene, which dried in thin films only after long exposure; etc.

17. *Direct devulcanization.*—When, by any of the above methods a solution of vulcanized rubber is obtainable, direct devulcanization may be attempted by mixing the charge with some sulphur absorbent. Such material must be chosen which at 200° acts neither on the rubber nor the solvent. Metallic filings do not appear to be available. Treating ebonite with CS_2, C_6H_6, or gasolene, to which copper filings had been added, I found the charge, after exposing to 200°, to be disintegrated, while an enormous amount of gas was evolved. Scarcely any of the solvent was left in the tube. The direct action of copper or of sulphur, on CS_2, etc., at 200° is insufficient to account for this reaction. § 19. The gas must, therefore, be produced at the expense of the ebonite, or of the reagent in presence of ebonite; and since all the solvents used behave alike, at the expense of the ebonite. This may furnish some clue as to the chemical character of the rubber as related to the gases evolved. Gaseous decomposition frequently sets in on exposure of highly vulcanized rubber solutions even to ordinary room temperatures, whereas at 0° and under slight pressure (1 or 2 atm.) the gas remains in combination. Bright steel is

scarcely attacked.* In fusing impregnated india rubber, § 18 I frequently noticed that the colder ends of the mass were opaquely discolored. Possibly, therefore, the sulphur at 200° may be gradually segregated by diffusion or evaporation. My experiments on this subject failed.

18. *Fusion of impregnated rubber.*—If vulcanized india rubber be impregnated or saturated by digesting it with the cold reagent (any solvent of pure rubber), for a suitable time (a few minutes to many hours), the swelled mass not only shows a relatively low melting point, but it remains liquid after cooling, provided the solvent is not allowed to escape. This is an observation of practical importance, since the retorts† can thus be charged with solid or dry rubber, a minimum of solvent be used in treating or lost by evaporation, and concentrated solutions be obtained often fit to be used at once. The rubber so melted hardens on exposure. Finally the pressure necessary in this case is the smallest possible, and may be below the data given for the divers solvents above.

The quantity of solvent retained by solid rubber is very large: Thus elastic sheet rubber will hold 7 or 8 times its weight of CS_2, or 1 to 2 times its weight of naphtha. Gray rubber (elastic) absorbs more than its weight of naphtha; etc.

Experiments may be cited as follows: Non-impregnated vulcanized rubbers (*a* to *e*) do not melt if exposed in a closed tube at 210°. Only in the case of very slightly vulcanized pure rubber gum is there a trace of fusion perceptible at the edges, and here it may even be due to a stain of dirt (oil) accidentally left there. Gray rubbers (*b*, *c*) with a superficial coating of exuded sulphur, turn black from the formation of a film of ebonite.

All the india rubbers (*a* to *e*) fuse at 210°, when previously saturated, or nearly so, with cold carbon disulphide, and exposed in a close-fitting glass tube. If the pressure be reduced by a capillary aperture at one end of the otherwise closed glass tube, or if the tube be only partially filled and the empty end kept cool, the impregnating solvent is merely distilled off, and no fusion takes place. Whereas at 160° fusion scarcely occurs, melting seems to be complete in the well impregnated elastic rubber (*a*) at 175°. There is therefore an approximate coincidence of the thermal data in the present and in the above paragraphs.

* Fortunately, therefore, steel apparatus is available on a large scale. An interesting question occurs as to what becomes of the carbon, in the case where sodium, mercury, copper, etc., are attacked by hot liquid CS_2 and not by cold CS_2.

† The present experiments were made in *closed* glass tubes, nearly filled with the impregnated rubber. After fusion the mass frequently appeared to have shrunk. Cf. § 2.

Similar results were obtained with benzol, with gasolene and higher petroleum oils, etc. Fusion is absent or only incipient at 160°, and more than complete at 210°, provided the gasolene be not too volatile. §§ 4, 12. In general the gray rubbers (*b*, *c*) fuse to a more viscous mass than the gum rubbers (*a*), the consistency of cold solutions in the latter case about that of treacle.

The occurrences of this paragraph therefore would resemble the fusion of a salt in its water of crystallization, but for the exceptional behavior that impregnated vulcanized rubber after fusion retains a consistency which is liquid relatively to the original non-impregnated charge. The analogy with the solution of starch, or of gluten, is thus more close and immediate. In all these cases the solid swells up when impregnated with the solvent, and fuses to a relatively less viscous consistency, or to a thin solution, when a certain temperature (below 100° in case of starch and gluten and above 160° in case of vulcanized india rubber) has been reached. Hence it is not unreasonable to suspect that even ordinary dry wood, or woody tissue, which swells to a marked degree when impregnated with water, may pass into actual solution if the temperature at which the water acts is sufficiently high, and the pressure above the vapor tension of water at that temperature.*

I mention finally that the reduction of melting point produced in vulcanized india rubber by the impregnating reagents may perhaps advantageously be discussed in accordance with Raoult's law; but owing to the difficulty of defining the melting point of the unimpregnated rubber, and the close proximity of the melting points after impregnation with different reagents (CS_2, C_6H_6, gasolene) my views on this subject have not taken shape. It is known that in general that the melting point produced by a dissolved colloid is relatively very small, from which an exceedingly large molecular weight of the colloid has been inferred. The above results show that in the converse experiment, where the melting point of the colloid is lowered by a solvent, the effects will probably be normal and pronounced.

Nevertheless I doubt whether the thin rubber fluids obtained are true solutions, i. e. represent a case in which the division of the solid has actually reached a definite molecule; for on

* I have since tested this surmise at some length, but found in every case that cellulose is decomposed before solution in water takes place. In spite of the presence of water under pressure, the phenomenon seems to be a dry distillation. I may here refer to the remarkably close analogies in the thermal behavior of rubber and gelatine which have recently been discovered by Bjerken (Wied. Ann., xliii, p. 817, 1891). The author has reason to believe that moist gelatines are heterogeneous mixtures of solid and liquid. The behavior of rubber, as discussed above, is characterized at low temperatures by a fixed maximum of absorbed solvent. The term mixture is scarcely applicable at once.

long standing in sealed vessels a gradual thickening of the liquid with final coagulation seems to be the invariable result. Thus there must be a gradual growing together of the individual particles, until finally the whole solution forms one coherent gelatinous mass.

To summarize: Suppose the coherence of rubber to be due to (cohesive) affinities, capable of being saturated like ordinary affinities. Then in case of impregnation with a solvent, a part of these combine with the similar affinities of the solvent. The result is the decided decrease of tenacity (observed). To liquefy the impregnated sample, the residual cohesive forces of the rubber must be withdrawn, and this can be done by heat. The liquid so obtained, I do not conceive to be a true solution, but rather a suspension of particles, the exceeding fineness of which is determined by conditions discussed elsewhere.* Diffusion is thus an excessively slow process, and hence the liquid on cooling need not become solid again. In proportion as the individual particles unite however, coagulation gradually sets in, and its structure is probably that of a fine sponge holding solvent in its interstices. If the coagulated solution be reheated (under pressure), a thin viscid solution is again obtained, which in its turn coagulates.

19. *Behavior of reagents.*—The frequent occurrence of gaseous products in the above experiments made special experiments on the decomposition of reagents necessary. Benzol and gasolene were found stable at 210°, and often above this temperature, both in the presence of water, or of sulphur. § 21. Carbon disulphide, however, in addition to relatively slight decompositions producible by sodium, or mercury, or copper (§ 17), at 210°, is doubly decomposed by water at this temperature, with the evolution of much gas, presumably H_2S and CO_2. CS_2 remains stable in the presence of zinc white (a common rubber pigment), or of sulphur, or of bright steel, at 210°. § 17. Hence a thread of mercury to shut off the experimental tubes, § 2, is generally objectionable, as is also a thread of water in case of CS_2. Moreover the absence of gaseous reaction in case of mixed solvents, § 16, is to be attributed to the fact that CS_2 and the water are intentionally separated by layers of benzol or gasolene.

An interesting question is suggested here, as to whether it be possible to express affinity on a scale of temperatures. Let it be required to determine the affinity of a metal for sulphur. At ordinary temperatures not even sodium decomposes CS_2, whereas such decomposition occurs if the temperature be sufficiently high. Hence the temperature at which the decomposition definitely sets in (for copper sooner than for iron, etc.) is

* Barus: this Journal, xxxvii, pp. 126–128, 1889.

a reciprocal expression of the affinity of the given metal for sulphur,—bearing always in mind that the stability of the solid metallic molecule also enters into the consideration. The arbitrary reagent CS_2, in its relations to all the metals to be examined, fulfills a similar purpose to an arbitrary spring balance in measuring gravitational forces. § 21.

20. *Summary of the results.*—In the above paragraphs I have therefore indicated a method by which vulcanized india rubber of any quality or character whatever, as well as the undecomposed or reclaimable part of rubber waste, may be dissolved or liquified in a reasonably short time;* the solutions possessing any desirable degree of viscosity or diluteness, from which india rubber may be regained on evaporation of the solvent.

I shall elsewhere describe divers forms of apparatus by which the above operations may be carried out on a larger scale. They are of no interest here; but I mention them since it is only from such work that a full insight into the quality of the rubber deposited from any given solution may be obtained. Experiments made in bulk in this way showed the material deposited from solution to be considerably inferior to the original rubber, both as regards tenacity and elasticity. Its chief value in the physical laboratory will therefore be that of furnishing an air-tight cement or an acid-proof varnish, capable of withstanding more than 200° centigrade. Rubber newly deposited from any of the above solutions presents a very curious case of slowly reacting elasticity. If a thread, say 0·1 cm. thick, be twisted and then let go on a frictionless surface, it will squirm like a live worm for some minutes. If it be stretched, the original length is regained with visible slowness.

Throughout my work the approximate constancy of the dissolution temperature irrespective of the solvent has been the marked feature. Thus in case of CS_2, of turpentine, of the vulcanization of dissolved pure india rubber, etc., no action took place below 160°. Even this temperature is higher than is needful for vulcanization effected in the dry way, where 110° to 140° are deemed sufficient. Moreover the solution of vulcanized rubber in CS_2, for instance, takes place quite as easily under 700 atm. as under, say 20 atm., as is particularly manifest from the fusion of impregnated rubber, and in special high pressure experiments. In my work on the compressibility of liquids† I showed that compressibility is essentially associated with the extra-molecular forces whereas the molecule remains relatively incompressible. Temperature, however, has immediate access to the molecule; and thus it follows that

* Practically at once, if the material is not too bulky.

† This Journal, xxxix, p. 510, 1890.

whereas the effect of temperature in experiments like the above is manifest, the effect of pressures of the order applied is relatively inappreciable.

21. *Digression.*—From the above paragraphs I infer that the difficulty encountered in endeavoring to dissolve carbon is probably attributable to a relatively high dissociation temperature of the solid carbon molecule. I made many experiments to test this view, in all of which I failed to obtain solution even at low red heat and 600 atm. of pressure. My work thus corroborates the negative results of Hannay* on the direct solution of carbon. My tests were made with gasolene, water, benzol and carbon disulphide, usually at 500° and 500 atm. In case of gasolene I observed at higher temperatures. Usually the reagents were decomposed (particularly CS_2, C_6H_6 and $CHCl_3$) with the evolution of much gas, while the carbon remained appreciably unaffected. Decomposition by metals (copper corroded by CS_2, and gasolene acted on by palladium) showed sooty deposits only.

Art. XXXV.—*Report of the Examination by Means of the Microscope of Specimens of Infusorial Earths of the Pacific Coast of the United States*; by Arthur M. Edwards, M.D.

Some time since I had transmitted to me by Mr. George Gibbs, the geologist of the Northwest Boundary Expedition, a collection of earths gathered at different points on the Pacific coast of the United States in the states of Washington, Oregon and California, as well as British Columbia, with a request that I would make an examination of them by means of the microscope, the more particularly for the purpose of determining the characters of the organic remains to be found in them. Through this means I have been enabled to study and record the discovery of several deposits of minute organisms, and at the same time very materially assist in unraveling the geology of some points of the country hitherto found to be somewhat difficult of comprehension.

At the time these examinations were made, that is to say, in the latter part of the year 1861, very little was known concerning many points in the geology of our Pacific Coast, and my own experience in the study of such earths had been rather slight. Hence, when I made my report in 1862, I was unable

* Hannay: Proc. Roy Soc., lxxx, p. 188, 1880; Chem. News, xli, p. 106, 1880. Cf. Hannay and Hogarth: Chem. News, xli, p. 103, 1880; Mallet and Hannay: Nature, xxii, p. 192, 1880.

to go very fully into the subject of the evident mode of formation of the strata containing the microscopic organisms. Since that time the Geological Survey of the State of California has been undertaken and a much more extended suite of gatherings has come into my hands.

Through the knowledge acquired from the examination of these collections made at various points from Puget Sound to the southernmost border of California, I have been enabled to furnish such information that the history of both the marine and fresh water, so called, Infusorial deposits of that portion of the country has been pretty thoroughly worked out. With regard to the marine strata very little has, as yet, been published. The results arrived at concerning one class of the fresh water strata has been made known in a communication of Professor Whitney's read before the California Academy of Natural Sciences, February 4th, 1867. (Proc. Cal. Academy, vol. iii, p. 319.) These he has therein shown to be the beds of enormous extinct lakes or inland seas, the material of which has been altered in character by the superposition upon it at different periods of lava or sand and gravel or ashes and pumice. In this way it can be readily understood that, as the volcanic action ceases, a new growth of microscopic organisms might take place over the erupted material lying upon the older deposits and, in fact, that many such layers might accumulate one over the other. Such has been the case at various points upon the Pacific Coast from Puget Sound to Lake Mono in Eastern California, which is the most southern point from which I have received such material. At some future time I may have more to say with regard to this class of deposits, for I have examined many of them during the progress of the Geological Survey of California and, when my report thereon is published, I shall be enabled to go more fully into the subject. As I have several specimens from strata of this character to describe in the present report I shall, for the time being, indicate them as sub-Plutonic, which is the most distinctive appellation I can now find for them.

Among the specimens which I have examined in connection with this survey, and aside from those which do not contain any organic remains, and hence will be treated of separately, I have then, first, the sub-Plutonic, which I have just alluded to, and which are always of fresh water origin; second, the fresh water deposits of more recent formation and, in fact, which are now under process of growth all over the world beneath ponds and lakes, and which I have hitherto been in the habit of calling sub-Peat, but I have lately preferred to designate as Lacustrine Sedimentary, as I consider that they are better so indicated. Besides these two classes of deposits, which differ from each other only in time and in the fact that in the most recent a certain amount of organic matter usually remains and the material is light and readily pulverulent. We have in the older one, on account of the volcanic heat added to, or without aqueous action, the material has had all of its organic matter removed. And it has become a less or more hard rocky mass of a light color. Hence we have strata of a totally different character. These are of marine origin and of an age supposed to be coincident with the Miocene Tertiary. At all events they are much older than the most ancient fresh water stratum containing Diatomaceæ as yet discovered. Of the mode of formation of these last mentioned strata I shall not now pause to treat, as I have already thrown out some hints respecting my opinions upon this point in some remarks made before the Essex Institute, Salem, Mass., January 4th, 1869, an abstract of which will be found in the Bulletin of that association, vol. i, page 11. I have treated of the same subject in a paper read before the American Association for the Advancement of Science, at the Salem meeting, August 25th, 1869. Hereafter I will treat fully of this subject in my report on the microscopic material of the Geological Survey of California now in preparation.

It will be readily perceived that it is fortunate that my report on the matter herein treated of was not published at the time it was sent in, and I feel that I can congratulate myself that Mr. Gibbs has again submitted the matter to me for revision, for at the present time I can do more justice to it and throw light upon some points which, at the time, I was unable to fully comprehend.

The constantly recurring records of the discovery of fossiliferous deposits containing the remains of such minute organisms as the Diatomaceæ, Radiolaria and Rhizopoda, constituting the well known 'Infusorial earths' of most geologists reveal the fact that these atomies play a very important part in the world's future; and while almost every newly found specimen exhibits one, if not more, of what have been considered new species, it proves, at the same time, the cosmopolitan character of many already known forms, which are thus seen to occur spread over the globe in great profusion from the equator to the poles. In some cases these widely-spread species will not vary appreciably, be their dwelling place under the burning sun of the tropics, the more equable climate of the temperate zone or the frozen fields of the poles. Other forms, however, on the contrary, appear to vary to so great an extent with every few degrees of latitude that specimens gathered at the equator and in localities a very little removed therefrom, either north or south, might be supposed, on superficial exam ination, to be distinct. So markedly is this the case that we not unfrequently find that hasty observers have so classed them and even made use of locality for the determination of specific distinctions. That the Diatomaceæ, which are the organisms with which I shall most particularly treat in this paper, are extremely cosmopolitan in their habits; in fact, perhaps more so than any other group, would seem to be already established, but the imperfect state of our knowledge of them and their life-history at present, leaves us a great deal in the dark as to the full extent of their variation during the lapse of time or through local distribution. Much has yet to be done in this field of investigation and large and widely extended collections made of both the recent and extinct forms, before we can assert that we know anything very certain with regard to their position in the chain of being, their habits, history, or range of variations in time or space. I do not, at the present time, desire to go more fully into this branch of the subject, merely confining myself to a thorough report upon the specimens submitted to me by Mr. Gibbs. The student who desires to follow researches in a field which will yield profitable returns cannot choose for himself one in which less is known, perhaps, than this, and when its applications to geology are considered, for my part, I can hardly imagine one more enticing.

Below I give a list of the specimens sent to me for examination by Mr. Gibbs and which were collected by him during the prosecution of the Northwest Boundary Survey.

* Hot spring, Harrison's lake, British Columbia.
Nahchess river, Washington.
Alkaline deposit, Similkamen river, Washington.
* Steilacoom creek, No. 1, Washington.
* " " No. 2, "
* Point Roberts, "
* Bluff west of Camp Simiahmoo, Washington.
* Camp Simiahmoo, No. 1, Washington.
* " " No. 2, "
* " " No. 3, "
Winass river, "
* Point Ludlow, "

Those localities marked with asterisk (*), are from the west or coast side of the mountain range, while the others are from the eastern slope. This is a point of importance and to be borne in mind as will be shown farther on. The principal point to be decided in examining these specimens was whether they contained any traces of organic remains by means of which their marine or fresh water could be determined. Therefore they were first superficially examined so as to note if any such remains appeared and those that showed signs of yielding definite results were set aside for further study after they had been properly prepared. In this way all of the specimens submitted to me were examined.

Most of them were found to contain no traces of organic remains by means of which might be ascertained their origin, as desired. The presence of the siliceous skeletons of Diatomaceæ in any earth, or deposit of any kind reveals at once the fact that such a deposit has formed beneath the surface of water or, if the remains are not evenly distributed throughout its mass, it may have been overflowed by water having Diatomaceæ living in it. Besides this, it may be also ascertained as to whether it has been thrown down from fresh water or in the ocean. Although this branch of the subject has not received the attention that its importance deserves yet we can with some considerable degree of certainty even determine as to whether the water from which such a deposit was thrown down was a lake, a bog or marsh, an estuary or the open ocean. As the matter comes to be more fully studied and the knowledge of facts is increased we shall doubtless be able to determine these and similar points with a greater degree of accuracy.

The indestructible nature of these skeletons, on account of their consisting mainly if not entirely of silica, deposited during the life of the plant in its tissues, preserves for the student of nature a record of former aqueous submergence, and, as their distinctive characters are not very difficult of recognition by careful students we thus have typical forms of organisms to use for the purpose of determining the marine or fresh water origin of any specimen under examination. At the same time it must be remarked that by far the greatest portion of the time that has been spent by most observers on the Diatomaceæ has been evidently mainly for the purpose of discovering new forms rather than ascertaining the life-history or even the distinctive characters of already known species. So that our lists have become but a heterogeneous mass of mere names applied to often accidental, sometimes distorted or even fractured specimens. I can not too earnestly enter my protest against the recognition of the species-monger as a naturalist; such observations and records as those I allude to do not only not advance our knowledge but certainly retard its progress by placing new obstacles in the path of the student of nature. Elsewhere I have spoken more fully on this subject and shown how it is that this branch of biology has fallen undeservedly into disrepute among scientific naturalists; at the present time I will refrain from saying more than I have already put upon record.

From what has been said with regard to distinguishing the origin of a deposit by means of the minute remains present in it, it will be readily understood that we can thus determine to a certain extent its age, as to whether the overlying water has been fresh, brackish or salt. In the last case we shall find present such oceanic genera as Triceratium, Coscinodiscus, Aulacodiscus, or Actinocyclus. If the source of the deposit has been the shallow water along shore we should expect to find littoral species among which would be some of the Pleurosigma or Amphiprora; often, of course mixed with deeper water forms or even fresh water varieties accidentally mixed by being washed down from elevated stations. On the other hand if we find the genera Tabellaria, Cocconema or Himantidium to be present, the fresh-water origin of the gathering is established. So a group of mixed marine and fresh-water species would indicate the formation of such a deposit under very peculiar circumstances, but such mixtures are extremely rare. One of the few of this character which I have seen being a gathering of living specimens from the St. Johns river in Florida, which on account of its course being nearly North and South, is so affected by the tides that the marine species of Diatomaceæ at least are carried up almost to its head. At some future time when the life history of these minute forms is better understood observers will doubtless be able to ascertain from the examination of gatherings of the siliceous skeletons whether they have grown and been deposited in a lake, river or brook, near the level of the sea or at high altitudes as well as the fact of the fresh or salt character of the water. In fact I feel convinced that a time will come when this mode of study applied to deposits generally will reveal many circumstances connected with the formation of most of the strata constituting the available mass of the earth. At the present time so little is known of certainty with regard to the life-history of the Diatomaceæ; the attention of observers having been mainly turned towards the finding of new forms and manufacturing them, when found, into so-called species, that little can be stated definitely with regard to their distribution or habit. For years I have been engaged in gathering material to illustrate this point and I am in hopes that, as facilities for collection increase valuable information will be accumulated. With regard to the mixture of forms considered peculiar to fresh or salt water respectively, a case of supposed mixing of species in a lake into which the ocean had access at certain periods of high tides is recorded by Dr. Gregory in the celebrated 'Glenshira sand,' as it has been called, and such may have been the circumstances under which this deposit was thrown down for we have an example of a similar phenomenon in the case of the Mystic Pond, near Boston, Mass. Here the bed of the pond is much below that of the river which serves as its outlet, so that at the time of high tides the salt water, which on account of its superior density creeps up beneath the fresh water, runs over the bar at the entrance and flows down into the pond, thus mixing the forms of life found therein. An account of this locality with a list of the forms of Diatomaceæ observed in the mud brought up from the bottom of the pond by Messrs. Greenleaf and Stodder will be found in the Proceedings of the Boston Society of Natural History, vol. viii, page 119. So also I have examined a locality of a like kind upon Phillips' Beach between Swampscott and Marblehead, Mass. Here a small mass of fresh water fed at uncertain periods by intermitting streams, by drainage or by infiltration of water through the beach sand, by which the salt is removed, lies a short distance within and at a lower level than the shore and in it grow many fresh water plants and are found several fresh water animals. Yet at times of high tide or during storms the salt water must find egress, for in it I observed marine species of Diatomaceæ in the mud taken from the bottom and, in fact, some few were noticed living in the water of the pond.

The microscope thus applied to geology, in the hands of experienced and competent observers, besides the above, reveals the fact as to whether a gathering under examination be of recent origin, deposited in a pond, lake, river, marsh, bay, or ocean in existence at the time; or contain mostly extinct forms or be situated in time below the alluvial, and hence to be classed among the truly fossil strata. So that by means of such an examination we come to classify specimens containing Diatomaceæ according to the age or mode of occurrence of these forms, and I have provisionally grouped my gatherings into, first: Recent, both marine and fresh water; second, Lacustrine sedimentary, now forming, although in many cases dating their period or origin as far back as the Post-Glacial. The recorded occurrences of similar deposits of fresh water forms in the Tertiary I consider extremely doubtful; third, we have then the deposits to which I have given the distinctive title of sub-Plutonic and the mode of occurrence of which I have alluded to above; fourth, thereafter and lastly we have the true Marine Fossiliferous strata which, as far as recorded, have been found only in the Lower Miocene Tertiary. A subdivision of some of these groups is convenient; as, for instance, the recent gatherings may be so arranged as to indicate the peculiar habitat of the species contained in it; the so-called "natural leathers" and "paper;" the soundings from the sea-bottom or shell cleanings, as well as harbor muds, the contents of the intestines of marine and fresh water animals and the like be indicated. However, I think that nearly all gatherings may be fairly grouped under the four heads I have adopted.

As the tendency of most persons who have turned their attention to the Diatomaceæ, which are the organisms I shall more particularly consider in this report, has been towards looking for differences where similitudes should have been searched after, I must be permitted to say a few words on that point. The progress of time, the more especially if it be very much extended, may, and in fact will, so change the apparent characters of all living organisms that they can hardly, in the present condition of our knowledge, be distinguished one from another; but they will most assuredly revert to the parent type, even if the modifying influence be continued in power, so strong, so persistent, so fundamental is the inherent germ-force implanted in the individual. The Diatomaceæ are not so liable to be influenced by outward circumstances, apparently, as some other groups; but, at the same time, understood energies do affect them very materially, so as to change their outline, for instance, leaving their main characters of sculpture intact. I very much doubt if time has as great or as lasting an effect in causing such modifications as locality and, therefore, must consider the use of this point as a basis for distinguishing species to be unscientific and unjustified, at least with regard to these organisms.

Among the specimens I have to report upon herein, we have examples of all of the four groups I have adopted, as Recent, Lacustrine, Sedimentary, and sub-Plutonic, under which head are to be placed the tripolis of commerce and Marine Fossil strata.

The first Lacustrine Sedimentary deposit discovered in this country was that found by the late Prof. J. W. Bailey at West Point, N. Y., and was described by him in volume xxxv of this Journal. Since that time similar deposits have been discovered at many widely separated points in this country and in Europe, which bears out the opinion expressed by Prof. Bailey that strata resembling the West Point earth in general characters would be found under every bog in the country. In Europe such has been the case, as the Lough Mourne, Premnay, Peterhead, Toome Bridge and Mull in Great Britain and others on the Continent bear testimony.

After receiving from Mr. Gibbs the collection of specimens I have already given a list of, he also sent three more, and these I shall include here, as they come from the same portion of country as the first. They are marked as below:

* Shookum Chuck, a branch of the Chihalis river which flows into Gray's Harbor, Washington.
* Colseed Bay, Hood's Canal, Washington.
Pit River, eight miles from Fort Crook, Cal.

These may all be supposed to belong to the western or coast slope of the mountain range, although Mr. Gibbs says that that from Pit river, the eastern branch of the Sacramento, may belong to either side.

Of the fifteen earths but seven were found to contain the remains of Diatomaceæ.

* Hot Spring, Harrison's lake, B. C.

This consists of a saline mass evidently deposited by the hot spring, but contains no organic remains.

Nahchess river, Washington.

No organic remains.

Alkaline deposits, Similkamen river, Washington.

This specimen is of very much the same general character as the first.

* Steilacoom Creek, No. 1, Washington.
* Steilacoom Creek, No. 2, "
* Point Roberts, Washington.
* Bluff west of Camp Simiahmoo, Washington.

No organic remains.

* Camp Simiahoo, No. 1, Washington.

A lacustrine sedimentry deposit, containing:

Amphiprora navicularis. Gomphonema intricatum. Himantidium bidens. Himantidium gracile. Melosira varians. Pinnularia major. Pinnularia viridis. Pinnularia mesolepta. Stauroneis anceps.

Camp Similkamen, No. 2, Washington.

No organic remains.

* Camp Similkamen, No. 3, Washington.

A lacustrine sedimentary deposit, containing:

Amphiprora navicularis. Cocconema leptoceros. Cocconema lanceolatum. Cymbella ?. C. ?. Gomphonema (Pinnularia) amphioxys. Gomphonema olivaceum, Himantidium arcus. Himantidium biceps. Himantidium bidens. Himantidium ?. Navicula elliptica. Navicula cuspidata. Navicula amphigomphus. Nitzschia (Synedra) spectabilis. Orthosira distans. Pinnularia gigas. Pinnularia dactilus. Pinnularia nobilis. Pinnularia mesolepta. Pinnularia viridis. Pinnularia tabellaria. Pinnularia Johnsonii. Pinnularia ?. Stauronies phœnicenteron. Surirella craticula.

Amphiprora navicularis is the one Ehrenberg has given that name to and is quite common in lacustrine sedimentary deposits in this country although I do not remember ever to have seen it anywhere else. The form I have called *Nitzschia spectabilis* evidently belongs to that genus and appears to be identical with *Synedra spectabilis* C. E. Wenish (Syn. Brit. Diat. 1853, 139), who describes a form as *Nitzschia scalaris* W. S., thus claiming the authorship, although he gives *Synedra scalaris* as the original form and Kützing as the founder. The fact is that *Synedra scalaris* was founded by Ehrenberg (Amer. 137, II, ii, 18) and his form was from freshwater at Surinam, and Andover, Conn. A form answering to it in every way is not uncommon in this country in both the recent state and in deposits. It varies much in size and in coarseness of its markings but always preserves essentially the same characters. I cannot see in what particulars *Synedra scalaris* differs from *Synedra spectabilis* except in size, a character which can hardly be considered specific. I prefer to group all of these forms together.

In this specimen *Himantidium soleirolii* occurs with the internal cells described by Ralfs in the Quart. Jour. of Mic. Sci., vi, 14, and which peculiarity has also been seen in Meridion and Odontidium.

Winass River, Washington.

A hard white mass not readily broken down and contains no organic matter, that having been burned out; in fact it is a specimen of the kind of strata I have mentioned above which Prof. Whitney has shown to have been affected by volcanic heat. On the Columbia River these strata were found for the first time by Fremont and examined by Bailey who however did not understand their distinctive character. They are of particular interest as having been hitherto only found on the Pacific shore of this continent. Nowhere else apparently have there existed such enormous masses of fresh water which have become dried up by the elevation of the country, through volcanic agency and subsequent hardening of the material constituting their beds by the action of lava. This particular specimen is made up for the most part of one species of Cyclotella and there are present a few individuals of *Odontidium mesodon*, *Orthosira punctata* and *Orthosira arenaria*.

* Point Ludlow, Wash. A sub-Plutonic deposit containing:

Cyclotella rotula. Epithemia granulata. Pinnularia major. Pinnularia ?. Orthosira orichalea. Surirella ?.

* Skookum Chuck, Wash. A sub-Plutonic deposit containing:

Cocconeis placentula. Cocconema cymbiforme. Cocconema lanceolatum. Cyclotella Kützingiana. Cymbella Ehrenbergii. Encyonema cœspitosum. Epithemia adnata. Epithemia gibba.

Epithemia gibberula. Epithemia granulata. Gomphonema dichotomum. Odontidium mutabile. Orthosira ?. Pinnularia ?. Synedra capitata. Synedra radians. Tabellaria flocculosum.

* Colseed Bay, Hood's Canal, Washington. A lacustrine sedimentary deposit containing:

Cocconeis placentula. Cyclotella rotula. Epithemia adnata. Epithemia luna. Gomphonema vibrio. Melosira ?. Navicula elliptica. Navicula ?. Pinnularia major. Pinnularia ?. Orthosira orichalea. Odontidium ? Tetracyclus ?.

Pit River, 8 miles from Fort Crook, Cal. A sub-Plutonic deposit.

Amphora ovalis. Cyclotella Astrea. Cyclotella rotula. Cymbella ?. Cymatopleura elliptica. Fragillaria striatula. Gomphonema capitatum. Gomphonema constrictum. Gomphonema ?. Epithemia gibba. Epithemia luna. Surirella splendida. Surirella linearis. Tetracyclus lacustris. Stauroneis punctata. Pinnularia major. Orthosira ?. Navicula cuspidata.

Having now given the results of the examination of the first parcel of earths submitted to me by Mr. Gibbs I will point out some of the results arrived at. Bailey having had sent to him several specimens of so-called 'infusorial earths' as those brought home by Fremont, Blake and others, ascertained, as he supposed, that all of those collected upon the eastern slope of the Sierra Nevada Mountains were of fresh water origin, while those from the Coast Range contained the remains of Diatomaceæ only. It became interesting, therefore, in examining the specimens put into my hands to ascertain if therefrom I was prepared to confirm or refute this assertion of Bailey's, upon which, of course, geologists had depended for drawing deductions. Up to the time of the publication of the paper of Professor Whitney in the Proceedings of the California Academy, which I have alluded to, the true character of these sub-Plutonic deposits was entirely misunderstood. And this arose, doubtless, to a certain extent, from their occurring only in one portion of the world where naturalists have traveled little and where the microscope as applied to geology has as yet not made much progress. But the lacustrine sedimentary, or sub-Peat, deposits are found all over the world and have been much examined by microscopists. That these and the first mentioned should have been classed together and neither of them understood is, perhaps, not so surprising when we consider that few microscopists are naturalists; that instrument having been too often used as a toy and not employed as an instrument of research. It is not to be wondered at perhaps that Bailey did not comprehend the origin and geological position of these two classes of strata and it is to be hoped that what I have said herein will at least help to prove interesting upon this point. Both of these classes of deposits have been called 'fossil,' but if either of them can be properly so designated it must be the sub-Plutonic one alone; the others are of recent origin and identical deposits are now undergoing formation all over the world. Thus, all through the New England States they are very common. At Bemus Lake, in New Hampshire, the bed of that piece of water when stirred up by means of a pole is seen to be almost white in color and consist entirely of the dead shells of Diatomaceæ. As Bailey's conclusions, although they had been founded upon extremely slight foundations, had been accepted by geologists generally it came to be asserted that no fresh water deposits of Diatomaceæ were to be found upon the coast side of the Sierra Nevada, only marine strata being there seen and not extending to the western slope of the mountains. Hence, it became of interest to determine whether the deposits discovered since Bailey's time in that part of the country bore out his theory or not, and this was one of the questions put to me when these specimens were placed in my hands.

As will be seen, all of the seven deposits which I found to contain the remains of Diatomaceæ, in the above mentioned collection, are of fresh water origin, three of them being decidedly of recent formation, or lacustrine sedimentary, and the other four from the beds of extinct lakes, or sub-Plutonic. It will also be noted that all of them with the exception of one, that from Winass River, are from the western side of the mountains, that one being from the east. However, from what I have already said respecting the mode of formation of these fresh water strata containing Diatoms it will be understood that but little of geological value attaches to the examination of such strata by means of the microscope unless they are proved by other evidence to be of greater age than the present period. So that my examination even taken for what the results obtained are worth does not bear out Bailey's theory.

The second parcel of earths which I received for examination were for the most part collected by Dr. J. S. Newberry during prosecution of the survey of the Colorado River by the expedition under the command of Col. Ives, and also while connected with the Pacific Railroad Survey under Lieut. Williamson. They were as below:

	1.	26.	Shores of Lower Klamath Lake, borders of Oregon and California.
*	2.	23.	Monterey, Cal.
*	3.	1.	San Francisco, Cal.
*	4.		San Diego, Cal.
*	5.	55.	Pit River Valley, Cal.

*	6.	56.	Near Monterey, Cal.
*	7.	53.	Pit River, Lower Cañon, Cal.
*	8.	54.	Pit River, Lower California.
*	9.	60.	Monterey, Cal.
*	10.	57.	Monterey, Cal.
*	11.	58.	San Francisco, Cal.
*	12.	54.	Pit River, above Lower Cañon, Cal.
*	13.		Dalles of the Columbia, Oregon.
*	14.	28.	San Diego, Cal.
*	15.	9.	San Pablo Bay, Cal.
	16.	516.	Black Cañon, Colorado River, Cal.
	17.	506.	"White Rock," Colorado River, Cal.
	18.	519.	"White Rock," Colorado River, Cal.
	10.	496.	"White Rock," Colorado River, Cal.
*	20.	17.	Monterey, Cal.
*	21.	24.	Monterey, Cal.
	22.	155.	Psucseeque Creek, Oregon.
*	23.		Monterey, Cal.
?	24.	907.	[Smithsonian Catalogue.]
*	25.		San Joaquin Valley, Cal.

I have indicated the geographical position of the localities in this list, as far as known, in the same manner as employed in the preceding catalogue, that is to say, those marked with a star (*) are from the western side of the mountains, while the others, with the exception of No. 1, 20, which is from the gap between the Sierra Nevada where it joins the Cascade, which is a portion of the Coast Range, are from the east of the slope.

1. 26. Shores of Lower Klamath Lake, borders of Oregon and California.

The position of the bed from which this specimen was taken and its relation to the overlying trap will be understood from what Dr. Newberry has said in his report on the geology of this section of country. (P. R. R. Report, vol. vi, part II, Geology, pp. 37 and 38.) It is sub-Plutonic.

Cyclotella rotula. Epithema granulata. Orthosira orichalcea. Pinnularia viridis.

* 2. 23. Monterey, Cal.

Of this as well as those numbered No. 3, 4, 6, 9, 11, 14, 15, 21, 23, and 25, I will speak hereafter together, as they all came from the same strata of the Miocene Tertiary.

* 5. 55. Pit River Valley, Cal.

From a sub-Plutonic deposit. On the banks of the Pit River these so-called "infusorial marls" present a very strikingly peculiar appearance and often modify very greatly the character of this whole tract of country. Dr. Newberry (p. 32) has pointed out the characters of this district and, in connection with the examination of these specimens it may be of interest here to quote somewhat from his report. He says that 'they appear on both sides of Pit River at intervals of several miles, being in many places interrupted or covered by the beds of clay. They are perhaps best exposed in the cañon formed by the passage of the river through 'Stoneman's Ridge,' the most conspicuous of the lines of upheaval, which form what is known as the lower cañon of Pit River. They here exhibit a thickness of about fifty feet, but are considerably tilted up, and covered by a thick bed of trap, which has been poured out over them. In some places this alternation of Diatomaceous deposit and trap is often repeated as, for example, on the Psucseeque Creek, a tributary of the Des Chutes River; the bank is capped by hard columnar trap and beneath this are successive strata varying in thickness and forming steps of thirty to forty feet wide. These steps, which at this point number twelve, have been formed by the more ready wearing away by weathering of the 'infusorial' deposits, they being protected above and below to a certain extent by layers of tufa, concrete or trap. These deposits represent the enormous extinct fresh water seas which at one time extended over a large part of our continent. Those who are interested in the subject will find more particulars in the sixth volume of the Pacific Railroad Survey, in the paper by Professor Whitney I have alluded to above, and in a paper read May 16, 1870, before the New York Lyceum of Natural History by Dr. J. S. Newberry and published in the Proceedings for that month. I found the following:

Amphora ovalis. Cyclotella operculata. Cyclotella rotula. Epithemia granulata. Gomphonema intricata. Orthosira granulata?. Pinnularia nobilis.

* 8. 54. Pit River, Lower Canon, Cal. A sub-Plutonic deposit.

Campylodiscus ?. Cocconema lanceolatum. Cocconeis pediculus. Cyclotella rotula. Cyclotella operculata. Encyonema cœspitosum. Epithemia granulata. Gomphonema cœspitosum. Gomphonema intricatum. Orthosira punctata. Pinnularia nobilis. Surirella ?.

This deposit, together with No. 5. 55. agree in many respects with some infusorial earths described by Bailey in vol. xvii, of this Journal for March, 1854. The earths he describes were sent to him by Lieut. Robert Williamson and were collected in Oregon and California. In fact one of Lieut. Williamson's earths is labelled "Pit River, Washington Territory," and agrees with the two deposits described above and marked Nos. 5. 55. and 8. 54. as I have ascertained from personal examination of the original material in the Bailey Collection, Boston.

* 10. 57. Monterey, Cal.

A sub-Peat deposit of *Melosira varians* with sporangia. There are small quantities of *Synedra radians*, *Nitschia linearis* and *Fragillaria virescens.*

* 13. Dalles of the Columbia, O.

A sub-Peat deposit containing sand and *Orthosira punctata.*

* 20. 17. Monterey, Cal.

A specimen of a Miocene, Oligocene or Eocene Tertiary as is proved by the shells of Foraminifera contained in it.

* 2.	23.	Monterey, Cal.
* 3.	1.	San Francisco, Cal.
* 4.		San Diego, Cal.
* 6.	56.	Near Monterey, Cal.
* 9.	60.	Monterey, Cal.
* 11.	58.	San Francisco, Cal.
* 14.	28.	San Diego, Cal.
* 15.	9.	San Pablo Bay, Cal.
* 21.	24.	Monterey, Cal.
* 23.		Monterey, Cal.
* 25.		San Joaquin Valley, Cal.

These specimens are evidently gatherings made at different parts of a marine fossiliferous deposit discovered by W. P. Blake and described by him in the Proceedings of the Philadelphia Academy of Natural Sciences, vol. vii, page 328 for 1854–5. The locality is mentioned as being about two miles distant from the town of Monterey and the stratum is revealed on the side of a hill some 500 to 600 feet high, consisting for the most part of this white 'infusorial earth' interstratified with compact siliceous layers of a dark material supposed to be bituminous in character. The earth is similar in most of its characters to the celebrated stratum underlying the city of Richmond, Virginia. The Diatomaceæ agree very closely with those of Richmond, Petersburg, Piscataway and Nottingham deposits which extend from the Patuxent River in Maryland to Petersburg in Virginia. The genera most largely represented are:

Actinocyclus.	Biddulphia.	Grammatophora.
Actinoptychus.	Campylodiscus.	Isthmia.
Arachnoidiscus.	Coscinodiscus.	Navicula.
Asteromphalus.	Creswellia.	Rhabdonema.
Aulacodiscus.	Gephyria.	Triceratium.
Auliscus.		

Thus then we have described seven new fluviatile fossiliferous deposits from Oregon, California and Washington, four of which are from the Western side of the mountains, one from the gap and one from the east, proving that the fresh-water deposits are confined to neither side of the mountains. The Monterey deposit is marine Miocene Tertiary.

New York, 1870.

NOTES ON THE ABOVE.

The deposit from Lake Mono, Cal., to Winas River, Wash., are parts of the same, and it extends from Winas River, Wash., on the north and Lake Mono, Cal., on the south to Great Salt Lake, U., on the west. That is to say the most northern point I have it from is Winas River, Wash., and the southernmost point is Mono Lake, Cal., on the west and Great Salt Lake, U., on the east. They were investigated by I. C. Russell (U. S. Geological Survey, 1885), in Western Nevada when he described "Lake Lahontan," which includes Honey Lake, California, Humboldt, Pyramid, Winnemucca, North Carson, South Carson and Walker Lakes, Utah; by C. K. Gilbert (U. S. Geological Survey, 1890), when he described "Lake Bonneville," which includes Great Salt Lake and Sevier Lakes, Utah, and at Mono Lake, California, by I. C. Russell, which includes two or three little lakes. (U. S. Geological Survey, 1886–7.) The three are made separate lakes by Gilbert but when we look at a map of the Great Basin we see they are all one. This one great lake or Occidental Sea extends from Washington on the north to Arizona on the south, and California on the west to Utah on the east. The country is flat, making the Great Plain of Fremont, and this great fresh-water sea is shown by the Diatomaceæ composing the freshwater marls, of a white or nearly white color, which in some places, as at Psucseeque Creek, are twelve in number, and intercalated with lava which flowed from the volcanoes of the Lassen's Peak district over the whole extent of surface. At the same time the country was raised and earthquakes were common and are still common and the Sierra Nevada is rising now. This sea was drained into the Pacific Ocean, first by the Colorado, and afterwards by the Columbia, and subsequently the Klamath, Pit, Feather and San Joaquin rivers. It was bounded by the Rocky Mountains on the east and the low range of mountains made up principally by the Coast Range on the west. The species of Diatomaceæ present are *Lysigonium oricalcheæ* M. (*Gallionella distans* C. C. E.) and *Cyclotella operculata* C. A. A. (*C. Kützingiana* T.) mixed with several other species in small quantity. But the Lysigonium and Cyclotella are common and always present. Thus showing that it was a lake of still water, for these species now grow in freshwater lakes and not in running water or in the ocean.

My reasons for making this one Occidental Sea and including Mono, Honey, Lower Klamath, Goose, Clear, Upper and Middle in Modoc Co., Eagle Horse and Swan Lakes in California; Upper Klamath, Rhett or Tule Wright, Christmas or Warner and Maleur Lakes in Oregon; Chelan, Great Salt, Utah, Sevier Lakes in Utah and Red Lake in Arizona besides several small lakes in these States, are the finding of one or two species of Diatomaceæ in the freshwater marls as two and sometimes twelve strata interstratified with lava. The flat plain, the Great Plain of Fremont, whose rocks are present as faulted monoclines over the surfaces, takes in the eastern portion of California, three-quarters of Oregon, half of Washington nearly the whole of Idaho, all of Utah and Arizona and half of New Mexico and perhaps extends into Mexico.

Whether this includes the Sacramento and San Joaquin Rivers, that empty by way of the Golden Gate into the Pacific Ocean is doubtful, but extremely likely, as the Sierra Nevada is later in time of formation than the Coast Range. Tulare Lake, Cal., the sink of the Kern River, is also most likely the end of an Intra-glacial deposit. But this has not been geologically investigated.

The geological period of the Occidental Sea is most likely Oligocene Tertiary though Gilbert places "Lake Bonneville" in the Pleistocene. That is to say "Lake Bonneville" was finally dried out in the Pleistocene. The Occidental Sea was formed and the freshwater marl laid down in the early Tertiary.

This determines, of course, that the species are confined to the ocean, brackish or freshwater. Some experiments I am making would seem to point to the fact that the Diatomaceæ originated in freshwater and were carried down to brackish water and so to the sea. Brackish forms, as *Nitzschia scalaris* C. G. E. have been seen growing in great profusion in a freshwater pond without any outlet, and brackish forms, as *Amphiprora alata* C. G. E., *Amphora aponina* F. T. K., *Bacillaria paradoxa* G., *Cyclotella operculata* F. T. K., *Fragilaria capucina* L. W. D., *Melosira nummuloides* F. T. K., *Navicula minutua* W. S., *Nitzschia angularis* W. S., *N. dubia* W. S., *N. linœris* W. S., *N. reversa* W. S., *Shizonema conferta* W. S., *S. crucigera* W. S., *S. Smithii* C. A. A., *Surirella ovata* F. T. K., and *Synedra tabulata* F. T. K. have been grown in freshwater. The concentration of freshwater in the western lakes, as at "Lake Bonneville" and "Lake Lahontan" have resulted in brackish water.

Newark, N. J. 1891.

Art. XXXVI.—*The Tonganoxie Meteorite;* by E. H. S. Bailey. With Plate XIII.

[Contributions from the Chemical Laboratory of the University of Kansas, No. II.]

In "Science" of Jan. 2, 1891, Dr. F. H. Snow published a preliminary notice in regard to the discovery of the Tonganoxie meteorite. The specimen was picked up in 1886, by Mr. Quincy Baldwin, on his farm a mile west of the town of Tonganoxie, Leavenworth County, Kansas. The true nature of the specimen was not understood by the original owner. He experimented with it so far as to make a fish hook from a fragment of it, and thought its occurrence was an indication that there was an iron mine on his farm. Since, however, he was unable to find any more specimens, the iron mine theory was abandoned. Mr. Baldwin disposed of the meteorite to Mr. H. C. Fellow, then Principal of the Friends' Academy in Tonganoxie, and from him it has been purchased by Dr. Snow and it is now in the Museum of the University of Kansas.

The specimen originally weighed a little over twenty-six pounds, but a slice has been cut from the smaller end, in order to obtain a plane surface, that the structure might be studied, and the present weight is twenty-three and one-quarter pounds [10·55 kilos.] Its shape is that of an irregular triangular pyramid; the length being 9½ inches, the width 6½ inches, and the depth 4½ inches. The specific gravity is 7·45, as compared with water at its greatest density. This specific gravity was taken by weighing the whole meteorite.

As can be seen by an examination of fig. 1, the surface of the meteorite shows numerous depressions, some of them quite large. The entire exterior is covered with a reddish black coating. This seems to be composed of scales of oxide of iron. These scales are brittle and readily attracted by the magnet. After the specimen had been for some time exposed to the air, after being handled, numerous droplets of chloride of iron appeared on the surface. These seem to exude from minute cracks or to come from under the scales. The occurrence of chloride of iron, and its exuding in this way, is by no means uncommon in meteorites. To the fact of its presence is probably due the great tendency to scale noticed above. This iron salt gradually changes to a brown friable oxide.

The analysis shows the following composition:

Iron	91·18
Nickel	7·93
Cobalt	0·39
Phosphorus	0·10
Copper	a trace
	99·60

A test made for sulphur, on the same sample analyzed above, showed only a possible trace, but an examination was made of a sample of turnings, somewhat oxidized, and a very perceptible precipitate of barium sulphate was obtained. Scattered over the polished surface may be seen occasional long slender crystals, sometimes branching, and also several nodular masses, of a bronze color. These are without doubt troilite; [iron-nickel sulphide]. The larger particles are near the center of the polished end, as though the last to crystallize. The troilite cannot be seen till the surface has been polished with oil and emery. As this mineral is so irregularly distributed there was probably only a very small quantity in the particular piece analyzed. The Widmanstättian figures came out very perfectly with nitric acid. Figure 2, reduced one-fifth from a photograph, shows the characteristic forms The octahedral form of crystallization is apparent, but it is not possible to distinguish the Neumann lines, that are believed to indicate the cubic form of crystallization. It is however possible, as some observers have noted, that some other surface, if polished, would show this form. A crack extends across the surface on the etched side, and other small cracks lead into it. These are all filled with a black mineral, probably made up of the oxidized metals. The cracks in an irregular way follow the lines between the crystals.

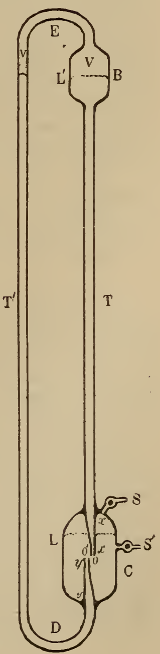
On examining this meteorite with the magnetic needle, it was found that there were several distinct poles. Mr. A. G. Mayer has plotted the lines of magnetic force, so as to show their true relation. The position of the poles might be expected to be near the ends, but this is not the case in this specimen.

As the meteorite is irregular as described, and quite flat and comparatively free from cavities on one side, the question naturally arises, is it not a fragment thrown off from a much larger mass. A careful examination of the mass will render such a theory, to say the least, very probable, but whether this mass was brought here by human or geologic agencies, or whether its companions still exist in the vicinity, it is at present impossible to state. A careful search in the vicinity of the farm where it was found, fails to reveal any other specimens.

University of Kansas, July 10, 1891.

ART. XXXVII.—*Proposed Form of Mercurial Barometer*; by W. J. WAGGENER.

THE form of barometer to be described in this paper is shown in the accompanying figure. It should be made with all its parts of glass united into a single piece in the form of a tubular loop having two dilatations, B and C; the latter serving as cistern. S and S′ are two carefully made stop-cocks connecting the cavity of C with the atmosphere. Through S, the atmospheric air is to be admitted when the instrument is in use. *xx* and *yy* are prolongations of the tubes T and T′ into the cistern, their openings, *o*, *o′*, being very near together and to the center of the cistern. The capacity of the latter should be about four times that of the vacuum, Vv, so that the openings *oo′* shall always be immersed in mercury whatever the position of the barometer.



To prepare the instrument for use, the manipulations will be as follows:

1. Place it in a nearly horizontal position and fill the whole cavity with mercury.
2. Close the cocks and place the instrument in the erect position.
3. Open the cock S. Mercury flows out, the Torricellian vacuum forming at E, C remaining filled with mercury.
4. Close the cocks tightly and leave the barometer for some time, first in the erect, afterward in other positions, so that the air and moisture of the cavity may enter the vacuous space.

5. Regarding the instrument as in the figure, rotate it around the line of sight and in the plane of the paper, thus causing any air or vapor accumulated in the vacant space to pass into the cistern, whence it can no more pass into other parts of the cavity.
6. Repeat the foregoing manipulations in order, until the vacuum in V is as nearly perfect as possible. (Probably No. 1 need not be repeated often.)

Doubtless the apparatus would work well if made without the return tube T′ and its prolongation *yy*, being sealed at D and E; but the complete loop has evident advantages, among which is the fact that it allows the tubes to be of small bore without impeding the flow of the mercury and the transfer of air-bubbles, thus greatly diminishing the amount of mercury required.

The principal features of this construction occurred to me some two years since, but my attention was taken from it by other matters until recalled by reading an account of the method proposed by G. Guglielmo,* this method being essentially the same as that involved in the foregoing manipulations; but his apparatus seems to me less perfect and convenient than that described above. He claims that this method gives better results than that of boiling the mercury, but it is evident that heat can easily be used with the loop form of tube, if desired.

Boulder, Colorado, July 29, 1891.

Art. XXXVIII.—*Color Photography by Lippmann's Process;* by Charles B. Thwing, Evanston, Ill.

In a communication to the Académie des Sciences on the second of February last, M. G. Lippmann opened an entirely new line of experimentation on the problem of the photographic reproduction of the colors of nature. To Lippmann's account of his discovery is appended in Comptes Rendus a note by Mons. Edw. Becquerel to the effect that the process of Lippmann differs radically from the discovery made by himself in 1848, in that while Becquerel was able by photo-chemical means to produce a colored image of the spectrum which could not be exposed to light since the action of the usual fixing agents reduced the deposit to a mere film of metallic silver, Lippmann, on the other hand, had by a physical process obtained an image which retains its colors after treatment with hyposulphite of soda, and is, therefore, as permanent as an

* Atti della reale Accad. dei Lincei, August, 1890.

ordinary negative. The peculiarities of Lippmann's method consist, first, in the use of a plate which is transparent and free from grains; second, in the exposure of the plate with its film side resting against a reflecting surface of mercury. The interference of the reflected with the incident ray of light divides the film into a number of layers at the maxima which will correspond in their distance apart with the wave length of the incident light, and will, therefore, be able to reproduce by reflection the color which produced the layers.

Lippmann says that the plates are positive for reflected and negative for transmitted light (négatif par transparence). By negative he means showing the complementary color. In that one of Lippmann's negatives which I have seen and all those obtained by myself, the plates are opaque to transmitted light, showing only differences of density like an ordinary negative. The reverse side of the plate, however, shows the complementary colors, somewhat fainter than the original colors which appear on the film side of the plate.

If the plates were, in reality, negative by transmitted light, it might be possible to obtain by two steps instead of the one employed in ordinary photography, a number of copies from a single negative. The remaining method is to copy the reflected image, and, as the reflected colors are bright, this may not prove impossible. In my experiments certain modifications were introduced with a view of determining several points which are not brought out by the original experiment as reported by Lippmann. It is difficult to obtain a plate which shall be transparent and yet possess any sufficient degree of sensitiveness. The plates I have found most satisfactory hitherto are of collodion on a thin substratum of albumen.

Following is the formula employed:

(1)	Cadmium bromide	25 g.
	Alcohol	280 c.c.
	Hydrochloric acid	5 c.c.
	Of (1)	5 c.c.
	Ether	40 c.c.
	Pyroxyline	2 g.

Sensitize by adding, drop by drop, a solution of silver nitrate, 1 g., in alcohol, 10 c.c., and pour without waiting for the emulsion to ripen.

The film obtained is a pale opalescent blue, almost perfectly transparent, and requires an exposure of twenty minutes or more in direct sunlight to produce images of the green and red. It should be remarked, however, that the image is not latent but appears nearly as strong without the use of a developer as when development is resorted to. Suitable developers will doubtless reduce the time of exposure.

The plates were exposed against mercury, not, however, to the spectrum, as with Lippmann, but to light transmitted by strips of variously colored glass, one object being to determine whether the ordinary colors of objects, consisting, as they do, of a mixture of rays of several different wave lengths, would be reproduced with the same fidelity as were the pure rays of the spectrum. The composition of the light transmitted by the strips of colored glass employed as determined by the spectroscope is shown in the following table:

Red: All the red with distinct traces of orange and green.
Orange: The entire spectrum reduced in intensity.
Green: A band extending from the middle of the blue to the middle of the red.
Blue: Blue, with bands throughout the green and red.
Purple: Green and red.

The results obtained, though by no means conclusive at all points, seem to indicate: First, that mixed colors may be reproduced with some fair degree of accuracy, though some curious modifications sometimes occur. Thus, a thickening of the film between exposure and final drying, will occasionally change all the colors in the direction of the red end of the spectrum. A shortening of the distance between the thin plates, and a consequent displacement toward the violet, on the other hand, may be produced by allowing the incident light to strike the reflecting surface of mercury, at an angle other than the normal, thus shortening the distance between the maxima which mark the layers of reflecting deposit in the sensitive film. Second, that an exposure sufficiently long to give a clear image of the red is quite certain to obliterate the blue by over-exposure. Third, that an over-exposure may completely reverse the colors, causing the original colors to appear on the reverse, and the complementary on the film side of the plate.

Art. XXXIX.—*New Analyses of Uraninite*; by W. F. Hillebrand.

Since the publication of a former paper on the occurrence of nitrogen in uraninite and on the composition of uraninite in general* no advance has been made toward clearing up the mystery surrounding the composition of that mineral, although

*This Journal, III, xl, p. 384; Bull. U. S. Geol. Survey, No. 78, 1889-1890, p. 43.

considerable work has been done in certain directions, some of which is of sufficient interest to be produced later in a separate publication. In addition several analyses of uraninite have been made, the material being in part from localities hitherto unrepresented by analytical data, and these form the subject of the present paper.

A first glance sufficed to show that the specimens were not fresh and that therefore analysis could throw no light on the ultimate composition of the mineral, but valuable data to be obtained as to the presence or absence of nitrogen and of the rare earths furnished ample excuse for the work.

	I. Llano Co., Texas. *a.* Hillebrand	*b.* Hidden and Mackintosh.	II. Marietta South Carolina.	III. Ville-neuve P. Quebec, Canada.	IV. Johann-georgen-stadt, Saxony.
UO_3	44·17	46·75	83·95[5] (UO₃ + UO₂)	41·06	59·30
UO_2	20·89	19·89		34·67	22·33
ThO_2	6·69	7·57	1·65	6·41	none. (ThO₂ to Y group)
ZrO_2	0·34		0·20	?	
CeO_2	0·34		0·19	·40	
La group.	2·36		2·05	1·11	
Y group.	9·46[1]	11·22[4]	6·16[6]	2·57[7]	
CaO	0·32		0·41	·39	1·00
PbO	10·08	10·16	3·58	11·27	6·39
H_2O	1·48	2·54(ign.)	undet.	1·47	3·17
N	0·54		"	0·86	0·02
SiO_2	0·46[2]		0·20 (SiO₂ + Insol.)	0·19	0·50
Insol.	1·47[3]	1·22		0·13	
Fe_2O_3	0·14	0·58	*tr.*	0·10	0·21
X			*tr.*[8]	0·09[9]	5·03[10]
	98·74	99·93	98·39	100·72	97·95
Sp.G.	8·29	8·01			6·89

1 At. wght. 111·4. 2 From thorogummite. 3 Mainly fergusonite. 4 At. wght. 124·2. 5 As U_3O_8. 6 Atomic weight 113·6. The oxalates of this group were white, not pink like those in I*a*, but the color of the ignited oxides was the same in both cases and very light. 7 Atomic weight 111·2 approximately. 8 MgO, Na_2O. 9 Bi_2O_3. 10 Includes: Al_2O_3(?) 0·20, Bi_2O_3 0·75, CuO 0·17, MnO 0·09, MgO 0·17, Na_2O 0·31, P_2O_5 0·06, As_2O_5 2·34, V_2O_5, WO_3, MoO_3(?) 0·75, SO_3 0·19=5·03.

No. I*a* is a re-analysis of nivenite from Llano County, Texas, the material for which was kindly given by Mr. W. E. Hidden. It agrees in the main with the original analysis of this variety by Hidden and Mackintosh,* which is reproduced under I*b*, and it confirms the presence of nitrogen, suspected but not proven by them. A small remnant of their original powdered sample gave me 0·52 per cent of nitrogen. In *a* the earths appear in slightly greater total amount than in *b* and they are more subdivided into groups and elements, which accounts fully for the difference between the atomic weights of the metals of the yttrium group of the two analyses. It was rendered certain by a second test that a group of earths whose

* This Journ., III, xxxviii, 1889, p. 481.

sulphates are insoluble in potassium sulphate other than those of Th, Zr, and Ce is present.* A very satisfactory turmeric paper reaction for zirconia was obtained in this analysis as also in that next following, which would go to show that the hypothetical ZrO_2 of several of my earlier analyses was probably in fact zirconia. The cause of the considerable loss shown by the analysis is not known. It may be mentioned that nivenite is more soluble than any uraninite heretofore examined by me, not even excepting cleveite. One hour sufficed for complete decomposition in very dilute sulphuric acid ($1H_2SO_4$ to $6H_2O$) at the temperature of boiling water.

No. II is from a new locality, Marietta, Greenville Co., South Carolina, and the total amount found, a few small fragments, was kindly given by Mr. W. E. Hidden for examination. It was impossible to free the least altered portions from the yellow and orange alteration products with which they were intimately commingled, therefore the analysis represents the composition of a mixture. Unfortunately also the portion in which UO_2 and N were to be estimated was lost, but it was seen that the mineral was very soluble and gave off considerable gas. From the preponderance of the yttrium group over the other rare earths the mineral is to be classed with nivenite and cleveite rather than with those varieties rich in thoria, a a conclusion already foreshadowed by its ready solubility.

No. III is an analysis of uraninite from the Villeneuve mica mine, Township of Villeneuve, Ottawa County, Province of Quebec, Canada. To Mr. G. C. Hoffmann, of the Canadian Geological Survey, who first recognized and reported this occurrence,† I am indebted, for the material analyzed. It was evidently somewhat altered and was accompanied by oxidized alteration products. Hoffmann gives the density of a piece as 9·055. Crystalline form was lacking, but it unquestionably belongs to the crystallized uraninites, being found like most if not all of them in coarse granite (pegmatite).

No. IV represents the composition of a specimen from Johanngeorgenstadt in Saxony, received from Mr. A. Lösch, of St. Petersburg, through Mr. E. A. Schneider of the U. S. Geological Survey. Notwithstanding the altered and crumbling character of the specimen it is proper to publish the analysis, since the only one previously made that has come under my observation, by Pfaff in 1822, is very incomplete. By panning, a very fair article as regards visible impurity was

* It may be here remarked that the subdivision of the earths into the groups indicated by $(La,Di)_2O_3$ and $(Y, Er)_2O_3$ in all my former analyses should not be taken too literally. By the former is meant those earths insoluble in potassium sulphate and by the latter those soluble in that reagent.

† Annual Report Can. Geol. Sur., vol. ii, 1886. Report T, p. 10.

obtained. It is not known wherein the loss is to be sought. Like the great mass of the Bohemian mineral this showed no evidence of ever having been crystallized, and as in that also rare earths are absent, and also nitrogen except for an uncertain trace.

From the analyses of uraninite thus far made it appears that the species may be broadly divided into two groups, the one of which is characterized by the presence of rare earths, the other by their absence. With the former group nitrogen appears to be invariably associated, while in the latter it is present, if at all, only in minute quantity. Besides these chemical differences there is one of another kind, for probably all varieties of the first group occur in more or less well defined crystals, while the members of the second group are generally, if not altogether, massive and free from crystalline form. These differences suggest naturally a dissimilarity of origin and environment. Examination shows that the manner of occurrence and the association of other minerals is different and in such a way as to render an unlike immediate origin probable. All of the rare earth uraninites, with exception of the zirconiferous variety from Black Hawk, Colorado, occur as an apparently original constituent of coarse granites (chiefly pegmatitic), while the others are evidently of secondary formation, as evidenced by their presence in metalliferous veins in more or less intimate association with numerous sulphides of silver, lead, cobalt, nickel, iron, zinc, copper, etc. The Colorado variety occupies an anomalous position as regards the two groups. I prefer to regard it provisionally as a member of the second group, where its mode of occurrence and want of crystalline form as well as small percentage of nitrogen seem to place it, although its zirconia and traces of other earths would admit it to the first.

Attention is called to the above points merely to show that the chemical and physical differences of the two groups may be susceptible of more simple explanation than would appear from the face of the analyses.

Laboratory U. S. Geological Survey, Washinton, D. C., June.

ART. XL.—*The Tertiary Silicified Woods of Eastern Arkansas;* by R. ELLSWORTH CALL.

(Published by permission of the State Geologist of Arkansas.)

THE occurrence of silicified wood in the sands and gravels of the Tertiary of the Lower Mississippi Valley has long been known. Aside, however, from the numerous localities mentioned by Hilgard,* nearly all of which are in the state of Mississippi, little attention has been given it. Numerous geologists have spoken of it or incidentally studied it in connection with other investigations, but hitherto no attempt has been made to recognize the species and fix their taxonomic value, if, indeed, they possess any such value. Among those who have investigated the Orange Sands and other Tertiary deposits of the Mississippi Valley and who have added to our information as to the occurrence of these fossils are Hilgard,† Penrose,‡ and Knowlton.§

The last named has made the only microscopic study of these fossils which is on record. Since his investigations are based upon material which, for the most part, was collected by the writer, it is thought that it will be useful to place on record in this form, a more detailed statement of the conditions of the occurrence of the silicified woods, their peculiarities, their structural relations and their stratigraphical position, in the hope that it may eventually prove to be of use in correlating the deposits in which they are found.

These fossil woods occur throughout the area covered by Tertiary sands and gravels in the State of Arkansas. When in large masses they are apparently rarely far removed from beds of Tertiary lignite; if in small masses or in small fragments they occur in the gravels of nearly all the region and in the beds of the streams and brooks of the area covered by the Tertiary. Occasionally whole trunks of trees are found, often partially buried in the sands or deeply imbedded in the gravels which cover the flood plains of the creeks and ravines within the Tertiary area and especially along Crowley's Ridge, from Helena to the Missouri line. Specimens have been obtained from logs or stumps *in situ* and in undisturbed Tertiary beds at the following points: Hope, Hempstead county;

* Agriculture and Geology of Mississippi, 1860, pp. 20, 21, *et seq.*

† Agriculture and Geology of Mississippi, 1860, pp. 20, 21, *et seq.*

‡ First Annual Report of the Geological Survey of Texas, 1889; "A Preliminary Report on the Geology of the Gulf Tertiary of Texas from Red River to the Rio Grande." By R. A. F. Penrose, Jr., pp. 1-101.

§ See Annual Report of the Arkansas Geological Survey for 1889, vol. ii, pp. 249–267, Plates IX–XI.

Camden, Ouachita county; near Red Land, Cleveland county; at Red Bluff, Jefferson county; at Helena, Forrest City, Wittsburg, Wynne, Harrisburg, Jonesboro, Gainesville, Boydsville, and St. Francis in the country traversed by Crowley's Ridge in the eastern part of the State. All of these localities have furnished examples of silicified wood from large logs or stumps in place and always imbedded in Tertiary sands or gravels. It is a remarkable fact that hitherto, in Arkansas, silicified woods have been seen but very rarely in the Tertiary clays. At all the localities mentioned above, except one, the wood is found only in gravels or sands, *in situ*, or in redeposited gravels and sands in the low valleys.

The geological section of the Crowley's Ridge region, to which area this paper especially refers, shows the following sequence, seen in the generalized section in St. Francis county which is characteristic for the southern portion.

Generalized Southern Section on Little Crow Creek.

1. A loess soil, with enough sand to render it decidedly siliceous. This is the surface member and is usually of but little depth.
2. Typical loess, varying in depth from thirty to ninety feet, eroding rapidly, and presenting a characteristic loess topography. This member caps the ridge even at its highest points.
3. A clayey, pebble-bearing, bluish or otherwise dark colored loess clay which forms the base of the typical loess deposits and probably marks the first stage in the loess deposition. This member varies somewhat in different localities, being often quite thin and is even sometimes wanting. The pebbles are most abundant in the lowermost portion.
4. Orange-colored gravels, irregular in thickness, rudely stratified, sometimes well assorted so that only coarse gravels, or *vice versa*, are seen; there are occasional pockets or lenses of sand derived from the underlying member. In rare instances this bed lies directly upon the clays. Silicified coniferous wood often occurs in this member.
5. Party-colored sands, of variable fineness, often quite irregularly stratified, sometimes overlying the pebble bed but usually occurring underneath it. The sand grains are well rounded. There are occasional masses or pockets of red, drab, white, or yellow pipe clay.
6. Blue, black or drab clays, horizontally stratified, with small sometimes large pieces of coniferous lignite. This member constitutes the greater portion of the body of the ridge. Along its margin it is to be seen only in the deepest ravines, or along the St. Francis and such of its small tributaries as flow from the ridge. It is often penetrated in deep wells, as at Forrest City, and underlies the whole region. The lower exposed portion is fossiliferous, the fossils are marine, and Claibornian in age. The clays are therefore Eocene Tertiary.

Slight differences in the section appear in various portions of the Ridge but are not worthy of remark in this connection. The generalized section for the northern portion of the Ridge, made at a point seventy-five miles north of St. Francis county shows the following sequence:

Generalized Northern Section near Gainesville, Greene County.

1. A humus, largely siliceous, or a soil mainly sand. At the highest hilltops this soil contains gravel or may be entirely replaced by waterworn gravel.
2. Gravel bed, commonly removed by erosion.
3. Sands of Tertiary age, false bedded, party-colored, coarse or fine, banded often with drab, red or white pipe clay, or the last may be in pockets or lenses. These sands are generally loose, but in certain localities they have metamorphosed into a very hard, glassy quartzite. The areas of metamorphism are linearly distributed over many square miles but are confined chiefly to the west side of the ridge. Silicified woods are found in this member at many localities, but none has yet been discovered in the metamorphosed portions.
4. Drab, blue and black clays of Eocene Tertiary age, horizontally stratified, occasionally fossiliferous, the fossils being chiefly the leaves of deciduous trees. These clays contain rare beds of lignite of small extent and erratic vertical distribution. Moreover, the clays are commonly gypsiferous and are further characterized by abundant small plates of muscovite in the cleavage planes. Silicified wood was seen at a single locality, on Cache River.

The absence of fossils in nearly all the members of the Arkansas Tertiary renders necessary their distinction upon lithological and structural data. The large masses of silicified wood in the upper members of the series are the only organic forms known above the Eocene clays. If in any way these silicified woods may be genetically connected with the lignite beds a means of correlation will not certainly be had but the fact may sometime possess taxonomic value. Studies made in eastern Arkansas seem to show that all or nearly all of the silicified woods of the Tertiary sands and gravel beds are derived in some manner from the underlying beds of lignite. In many places whole tree trunks, stumps standing in place, or large fragments of silicified wood occur so related to lignite deposits as to show that they are derived therefrom. In the northwestern portion of Greene county, on the west side of Crowley's Ridge, are masses of wood partly in the form of lignite and partly silicified. The lignitized part is buried in Eocene clays; the silicified ends are buried in Eocene Tertiary sands. It would appear that in this case, before the sands were eroded away, the portion of the trunk which had been buried therein was subjected to the action of waters containing silica in solution and the lignitic matter was replaced by silica.

The silica is, of course, all present as secondary quartz, is often massive but, also, frequently crystallized. Especially is holocrystalline quartz abundant in specimens of wood that were partially decayed when the older lignification process began. In the drusy cavities of such lignite are found large numbers of perfect and rather large quartz crystals. These are often, in some specimens always, characterized by a uniform dark or brownish color which is due to inclusions of limonite.*

Professor F. H. Knowlton, of the U. S. Geological Survey, has studied microscopically both the lignite and silicified woods found in eastern Arkansas. The results of his work may be found in vol. ii of the Arkansas Geological Survey, Reports for 1889. His studies have developed the interesting fact that the woods belong to both dicotyledonous and coniferous types. This occurrence is the first known dicotyledonous wood found in this country in rocks older than Pleistocene and is the first dicotyledonous form determined by internal structure. If, therefore, examinations of both lignites and silicified woods are made and it results that the same form or forms are represented in both, a strong reason exists for genetically connecting the silicified woods with the lignites.

Unfortunately for taxonomic purposes all the forms described by Prof. Knowlton are new, but some otherwise valuable results have been reached. In the first place he finds, among the four new species studied, two forms which are clearly dicotyledonous, and two others distinctly coniferous in relationship. The species are:

Coniferous.	Dicotyledonous.
Cupressinoxylon Arkansanum,	*Laurinoxylon Branneri*,
Cupressinoxylon Calli,	*Laurinoxylon Lesquereuxiana.*

There was also a single additional specimen whose affinities appeared to be dicotyledonous and to belong to *Laurinoxylon;* the condition of the material would not admit of closer determination. The specimens found indicate comparatively few species but these few must have existed in great numbers. One of the most valuable and pertinent facts in this connection is the finding of the dicotyledonous *Laurinoxylon Branneri* in the lignite bed of Bolivar Creek, as lignite, deeply buried in Eocene clays in massive form.

* An especially fine example of this nature was taken from a section in Tertiary sands 13 miles southeast of the town of Camden on the line of the Camden and Alexandria railroad. Of the many thousands of quartz crystals which this specimen exhibits not one has been seen which is free from inclusions of limonite.

Thus far sufficient distributional facts to give a taxonomic value to the fossil woods have not been discovered. Until extensive collections throughout the whole region of the southern Tertiary have been made it will not be possible to use these forms for purposes of differentiation or of correlation. It is be lieved, however, that since in the Tertiary sands of Arkansas, Louisiana, Texas and Mississippi the same relations of silicified woods to lignites have been observed, it may be possible to coördinate the divisions recognized in those states by geologists and devise a system of nomenclature that will explain the relationships of the various beds to each other, though it cannot be done at present.

During the progress of the study of the region by the writer it became more and more clear that the silicified wood had some intimate relation to the pockets or beds of lignite which are scattered throughout the ridge. It was early noticed that no lignite occurs in the sands or gravels above the clays, and that no detached masses of silicified wood occur entirely in the clays. As the investigation proceeded it became a favorite hypothesis that the silicified wood was transformed lignite, and that careful microscopic study would probably prove the hypothesis to be correct. Professor Knowlton's investigations appear to verify the hypothesis.

The opinion that the silicified wood was, in some way, to be connected with the lignites of the beds underlying the sands was suggested by Hilgard* many years ago. Speaking of the occurrence of fossils in the Orange Sands he says: ". . . . The closest scrutiny I have bestowed on hundreds of extensive exposures, has failed to detect any fossil apparently peculiar to the formation as such. This might seem paradoxical enough to any one acquainted with the frequent occurrence of silicified wood in these strata, but it soon becomes quite obvious to an attentive observer that the regions of the frequent occurrence of this fossil in the Orange Sand are coextensive with those in which fossil wood, either silicified—when imbedded in siliceous sands—or lignitized, occurs in the underlying lignitiferous Cretaceous or Tertiary strata. It is not unusual to find trunks of silicified wood imbedded partly in the unchanged lignitic strata, partly in the Orange Sand; the portion contained in the latter being nearly or wholly deprived of carbon, while the part imbedded in the lignitic material is, if at all silicified, of an ebony tint and often contains pyrites." Again, "I am convinced that the great part, if not all of this fossil wood is derived from the underlying strata and will be represented in their flora."

* This Journal, II, vol. xli, p. 313, 1866.

There can be little question, therefore, that the process of silicification has occurred, in some cases at least, since these masses were torn from the underlying beds by the waters which deposited the sands above the clays.* As ordinarily understood the process is purely a chemical one and perhaps very slow. It consists in the replacement, particle by particle. of the carbon of the lignite by silicic acid, or silicon dioxide. It is by no means essential that the organic matter be unchanged when the process begins. If the belief that this wood represents what was once lignite be a correct one, then the process of silicification can occur in the case of organic matter which has already undergone a partial change.

Where found in clays in a silicified condition, it has probably resulted from the same processes that are seen to obtain in the highly siliceous sands or gravels which overlie them. Though the impervious nature of most clays renders the percolation of of silica-charged waters a matter of great difficulty such percolation certainly occurs in them. The silicified masses of wood are often far too large to have been removed from the clays and deposited in the overlying gravels by an ordinary wave or current action for they sometimes weigh tons. In the form of lignite the same masses could have been transported by currents but since very large pieces have been rarely, if ever, found far from lignite deposits even that proposition has very little weight.

The vertical distribution of the silicified woods of the Arkansas Tertiary is limited by the line of contact between the sands and clays which constitute the Arkansas series. Below this line the silicified wood never occurs, with the single exception above,† so far as observations have yet extended. Above it no

* Dr. R. A. F. Penrose, Jr. (*op cit.*, pp. 24, 26, 50, *et seq.*), has placed on record the numerous occurrences of silicified wood in the Tertiary of Texas; he finds it in both sands and clays. In his description of the Sabine River beds he says: "Silicified wood is of very frequent occurrence in these strata; sometimes occurring as small fragments; and at other times as large trunks of trees. On the Brazos River. in the northern part of Milam County, was seen a trunk one and a half feet in diameter, protruding from a clay bed. Ten feet of it were exposed, while the rest was imbedded in the clay. In many places such fragments are collected in great quantities, but it is especially plentiful in the lower part of the Fayette beds. It is generally dark brown or black inside, and weathers gray or buff color on the outside. Sometimes it occurs partly lignitized and partly silicified. It frequently shows shrinkage cracks which are filled with quartz or chalcedony, and are often lined with quartz crystals."

In this case stratification was but partial or was still in progress and since there is exposed in the face of the bluff a log which was partially lignitized and partly silicified it proves all but conclusively that, even in the Texan Tertiaries, the lignitic precedes the siliceous condition of these woods.

† In this case the stumps are still standing, the roots, also silicified, ramifying in all directions in Eocene blue clays. Less than one hundred feet east. however, the line of contact between the sand beds and the clays was disclosed in a vertical cut in a hillside. This line was at or near the elevation of the stumps. It

lignites have ever been found. The vertical range is therefore limited by the thickness of the sand and gravel bed which is commonly, in Arkansas, between fifty and eighty feet.

There is a marked difference in the vertical range of this fossil in the Tertiary of Arkansas and the Tertiary of California. In the latter State the vertical range is often many hundreds, even several thousands, of feet. Whitney says:* "It will be proper to add to some of the most important facts gathered during the investigation of the gravel deposits in regard to the mode of occurrence of the fossil plants of the Pliocene epoch. The vertical range of these has been alluded to, and it may be more distinctly stated that either fossil wood or leaves have been found at every elevation, from the lowest to the highest, where gravels occur. Even as high as Silver Mountain City, at 7,000 feet of elevation, large masses of fossil wood are found in the volcanic deposits; and in Plumas county the same occurrence has been noted on several of the highest mountains in the region, as Penman's Peak and Clermont, peaks from 7,000 to 8,000 feet high . . . . . Fragments and often large masses of wood are found, both in the gravels and the associated clayey and tufaceous beds. In the gravel they frequently bear the marks of transportation from a distance, as would be expected."

In the California Tertiary the most completely silicified and best preserved specimens of wood occur in connection with deposits of a volcanic character, sometimes a rhyolitic ash.† It is suggested by Whitney that these relationships have something to do with the process of silicification. For that region Whitney believes that not only were the woods silicified after their imbedding in white pulverulent volcanic ash but "the lava itself exhibits signs of having been acted on by silicifying agents after its deposition." That the greater part of the series of beds included in the gravel formation has been thoroughly permeated with waters holding silica in solution and that chemical changes induced thereby are sufficient to explain the phenomena appears quite probable. The relations which the phenomena sustain to the facts of volcanism so abundant in that region are set forth and the conclusion is drawn that that relation explains silicification in these woods. In California it becomes a subordinate problem under volcanism.

The chemical processes which obtained in the case of the Arkansas gravels were not coördinate with those of California,

was clear that, if the stumps did not actually project into the overlying sands, they were but a short distance below and under conditions to favor silicification from waters percolating through the clay to them.

* Auriferous Gravels of the Sierra Nevada, pp. 235, 236. See also this Journal, II, vol. xli, p. 359. 1866.

† Op. cit., pp. 327–329.

for there is no evidence of volcanism or any similar phenomena associated with their silicification. The silica in the eastern locality must be sought in the accompanying sand beds and was probably brought into solution by the action upon it of organic acids.

The study of the Arkansas Tertiary silicified woods appears to justify the following conclusions:

1. The silicified woods of eastern Arkansas are all of Tertiary age.
2. They are derived from the beds of Eocene clays that underlie the sands and gravels in which they commonly occur.
3. They are silicified lignite; the process of silicification has occurred either while they were still in clays or most often after they were removed and buried in the sands or gravels.
4. They possess as yet no taxonomic value in determining the relative ages of the members of the Tertiary series.

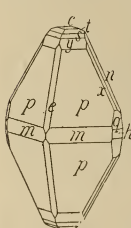
Geological Survey, Little Rock, Ark., July 15, 1891.

ART. XLI.—*Occurrence of Sulphur, Orpiment and Realgar in the Yellowstone National Park*; by WALTER H. WEED and LOUIS V. PIRSSON.

SULPHUR.

IN the Yellowstone National Park there are besides the well known geyser basins, many small hot spring areas and localities where fumeroles and solfataras are still active. At most of these places deposits of sulphur occur, in and around the vents from which sulphurous vapors issue. At the Highland Hot Springs and at Crater Hills these vents are quite abundant and large deposits of sulphur are found frequently having most beautiful clusters of delicate crystals. The latter locality, from which the specimens herein described were obtained, is a small group of hills whose white and steaming slopes form a prominent feature of the eastern part of Hayden Valley, the open grassy country traversed en route from the Grand Canyon of the Yellowstone to the Lake or the Firehole geysers. The hills, often called Sulphur Mountain, rise about 150 feet above the surrounding level, and are formed of fragmentary material wholly rhyolitic, decomposed and cemented by the vapors that rise at innumerable points through the hills. There are but few springs at this locality; the most prominent and most active is an ever-splashing bowl of green sulphurous waters known as the Chrome Spring. Behind this basin the slopes are light colored, chalky white, rose-pink and dull yellows being the predominant tints Large masses of rough clinker-like rock lie scattered about the slopes, resting upon small pieces of the same cemented material or upon the smoother slope of white pulverulent silica resulting from the complete decomposition of the rhyolitic material by the acid waters and vapors.

Several parts of the slopes show the dull yellow color of sulphur, such places usually being further marked by many steaming orifices a few inches across. These vents are generally lined with a layer of radially fibrous sulphur, whose surface is thickly set with delicate frost-like clusters of crystals. Many of the vents are partly closed by the sulphur and others completely sealed but filled with hot vapor which is copiously emitted when the roof is broken. No temperatures above 200° F. were obtained from any of the vents. It is in these closed vents that the largest and most beautiful crystal clusters have been found. Upon taking such a specimen from one of these vents it is a deep orange tint, and of course quite hot; as it cools the crystals loosen with a loud and continuous crackling so that a slight jar is sufficient to cause many of the clusters to fall to pieces when cooled. These crystal clusters are of interest as sulphur in the crystal form has been described from but one American locality—Nevada.* In examining a mass of these crystals it is seen that the crystalline mass is of great brittleness, owing largely to the fact that the crystals are generally hollow. Often a mere skeleton of what would otherwise be a good sized crystal is present. One that would be an inch high and proportionately broad and wide consists only of narrow strips preserving the edges of the pyramids on each other; this frame work is then filled with other crystals and parallel growths, also of hollow delicate material. In general the mass is made up of confused crystal aggregates closely united below and toward the top branching into arborescent forms. Often small solid crystals occur attached to the mass. Several of these were selected for measurement. They proved to be of the usual orthorhombic symmetry. The habit is strongly pyramidal. One of them that is typical of the series is shown in the figure. The forms which were identified on this crystal are:



c, 001, *O*.	*e*, 101, 1-ĭ.	*y*, 112, ½.	*x*, 133, 1-3̆.
m, 110, *I*.	*n*, 011, 1-ĭ.	*s*, 113, ⅓.	*q*, 131, 3-3̆.
h, 130, *i*-3̆.	*p*, 111, 1.	*t*, 115, ⅕.	

The identification of these forms is shown by the following tables of calculated and measured angles. For

* E. S. Dana, this Journal, xxxii, p. 389, 1886.

the calculated angles the axes of Kokscharow* have been taken in which,

$$\breve{a} : \bar{b} : \acute{c} :: 0\cdot81309 : 1 : 1\cdot90339.$$

Forms.	Calculated.	Measurement.
$p \wedge p$ 111 ∧ $\bar{1}$11	94° 52′	94° 51′, 94° 41′, 94° 40′
$p \wedge p$ 111 ∧ 11$\bar{1}$	36 40½	36 43, 36 44½
$p \wedge m$ 111 ∧ 110	18 20¼	18 20½, 18 22½
$p \wedge e$ 111 ∧ 101	36 47	36 45, 36 50
$p \wedge n$ 111 ∧ 011	47 26	47 35, 47 15
$p \wedge x$ 1$\bar{1}$1 ∧ 133	27 29	27 25, 27 27, 27 30
$p \wedge q$ 111 ∧ 131	29 10½	29 08, 29 17
$p \wedge y$ 111 ∧ 112	15 11¾	15 13½
$p \wedge s$ 111 ∧ 113	26 29¾	26 28½, 26 30½
$p \wedge t$ 111 ∧ 115	40 33½	40 34
$p \wedge c$ 111 ∧ 001	71 39¾	71 41½

In general the planes, even though minute, gave fair reflections owing to the brilliancy of their surfaces. The only exception to this was the plane i-$\breve{3}$ 130, from which no satisfactory reflections could be obtained. It is easily identified however since it lies in the zones 110 ∧ 1$\bar{1}$0 and 001 ∧ 131.

Though no tests were made the material is apparently of great purity. It is very homogeneous and is of a delicate sulphur-yellow.

Orpiment and Realgar.

The presence of arsenic in the hot spring waters of the Yellowstone Park, and the deposition of the hydrous arseniate of iron, scorodite, by them, has already been noticed in this Journal.* While studying the hydro-thermal phenomena of the region for the U. S. Geological Survey, under the direction of Mr. Arnold Hague, a careful search for deposits of the arsenical sulphides was rewarded by the discovery of realgar and orpiment, at the Norris Geyser Basin. This locality, though possessing few geysers worthy of comparison with those of the Firehole basins, is peculiarly interesting by reason of the newness of its geysers and the great variety of its chemical deposits. It covers an area of some six square miles situated amid the forests of the great rhyolite plateau of the Park whose gradual slopes rise on every side. The area of present activity is included between a loop of the Gibbon river and two spurs of Gibbon Hill, an eminence of rhyolite that rises above the general level of the country to the south. The multitude of

* Min. Russl., vi, p. 368, 1874.
* A. Hague, this Journal, vol. xxxiv, Sept., 1887.

vividly colored pools and equally bright tinted waterways, the white sinter flats, and the creamy rose and yellow shades of the decomposed rhyolite, the whole surrounded by a setting of dark green pines, presents a strange picture not easily forgotten.

The specimens of realgar and orpiment come from the western part of this basin, between the 100 spring plain and the Gibbon river. The deposits of siliceous sinter so abundant elsewhere in the basin are here quite scanty and form a thin coating upon rock composed of small angular fragments of pearlite, obsidian, and other forms of rhyolite—generally more or less decomposed and mixed with quartz grains, the whole compactly cemented by silica deposited by the hot spring waters. Several small outflows of clear and hot acid water issue from this cement rock, their united overflow forming a small stream which flows through a shallow gutter in the rock and joins the Gibbon river a few hundred yards beyond. Near the vents the channels are lined with an incoherent deposit of milky sulphur which frequently coats and obscures a growth of *algæ.* The gray surface of the rock shows no trace of the brilliantly colored arsenical sulphides, and it is only upon breaking this rock about the vents and prying up the plates at the margins of the channels that the realgar and orpiment are noticed. Plates of rock thus obtained show a brilliant red and yellow surface of the mixed sulphides and large pieces of rock from about the vents are penetrated and filled with deposits of the yellow orpiments, the dark red realgar, and the mixture of the two. Many of the specimens show layers of waxy dark red translucent realgar an eighth of an inch thick, covered by incoherent amorphous orpiment and alternating layers often occur. The orpiment generally possesses a tangled filamentous structure upon the surfaces of the plates as if deposited upon algæ threads, and where the surface of the plate is covered with realgar as is frequently the case, it too possesses this curious form, the mineral being in stalagmitic aggregates with a general fibrous matted structure.

In the channels the rocks show no surface coloring from the deposition of the sulphides but many small pebble-like masses occur, lying in the bottom of the stream, which consist almost entirely of dark red translucent realgar. This appears to be the most promising material collected for mineralogical examination, but unfortunately none of the specimens proved to contain any crystals which could be measured and identified under the microscope it proved to be in rounded stalagmitic growths consisting of a confused crystalline aggregate. Such light reflecting surfaces as were seen proved to be small cleavage planes. In the closed tube the substance melts and then forms a reddish translucent sublimate. In the open tube with a good current of air volatilizes and deposits in the upper part small glittering octahedrons, which under the microscope in polarized light proved isometric (As_2O_3). Before the blowpipe on charcoal gives characteristic odors for sulphur and arsenic. Fused with carbonate of soda gives the reactions on dissolving for sulphur and arsenic.

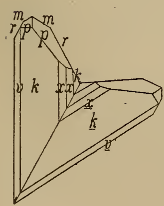
The association of the realgar and orpiment is such that no definite statement can be made as to which forms first, but realgar is certainly the last formed upon many of the specimens. Whether it is formed through a conversion of the orpiment or as a separate deposition is uncertain, but the specimens seem to indicate that the latter is the case. Siliceous sinter is the only other mineral occurring with these arsenical sulphides.

Art. XLII.—*Mineralogical Notes*; by L. V. Pirsson.

1. *Cerussite.*—Some specimens of cerussite, obtained through Messrs. English & Co., of New York, from the Red Cloud Mine in Yuma Co., Arizona, contain twin crystals in which the twinning plane is the uncommon form $i\text{-}\mathring{3}$, 130. Since, moreover, they show some unusual developments in their crystal form, it has been thought that a description of them would be of interest. The specimens are in the cabinet of Prof. George J. Brush.

The greater number of those observed have the form shown in fig. 1, which presents them in a basal projection. This

1.



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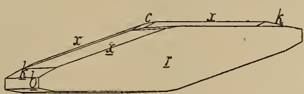

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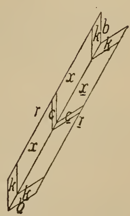


gives a much better idea of these crystals, shaped like arrowheads, than an orthographic projection. They are of various sizes up to half an inch in length, the largest observed. They resemble the example of this method of twinning given by Kokscharow* in the development of the brachydomes. The figure shows them in ideal symmetry; they are generally attached by the barb-shaped end; sometimes one barb or individual is free with the faces developed as in the figure; in other forms both individuals are attached and the barb-like part is wanting. They occur on the specimen seen, with cerargyrite and wulfenite. The forms observed on these crystals are:

r, *i*-3̆, 130; *k*, 1-ĭ, 011; *v*, 3-ĭ, 031; *x*, ½-ĭ, 012; *m*, I, 110; *p*. 1, 111.

Also the pinacoids *i*-ī, 100 and *i*-ĭ, 010, the pyramid ½, 112 and the brachy-diagonal pyramid 2-2̆, 121 have been identified in zones on the reflecting goniometer and measured with some accuracy, but they are too minutely developed to give any character to the crystals and are hence omitted in the figures. The crystals are well suited for measurement, the faces generally giving good reflections of the signal.

Fig. 2 shows a crystal from the same place with a different habit, the large ½ brachydome *x* and great development of the brachy-prism *r* having resulted in a long spindle-shape form. Fig. 3 shows the same individual in basal projection. It occurred, attached at the end with the re-entrant angle, which in consequence was somewhat broken. Otherwise the crystal is quite perfect and in size about an inch long. The zone of brachydomes is somewhat striated, causing a rounding off toward the point. The signals of the prominent faces are, however, very distinct and give good measurements. On this crystal the forms observed were:

b, *i*-ĭ, 010; *c*, *O*, 001; *r*, *i*-3̆, 130; *k*, 1-ĭ, 011; *x*, ½-ĭ, 012.

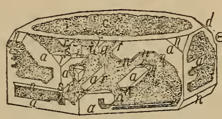
The following table shows the identification of the forms by calculated and measured (supplementary) angles.

		Calculated.	Measured.
k ∧ *p*	011 ∧ 111	43° 50′ 40″	43° 51′
m ∧ *p*	110 ∧ 111	35 46 20	35 45, 35 50, 35 49
k ∧ *r*	011 ∧ 130	59 03 10	59 00
p ∧ *p*	111 ∧ 111	49 59 30	49 58
m ∧ *r*	110 ∧ 130	29 57 30	30 00, 30 01
p ∧ *r*	111 ∧ 130	45 19 55	45 16, 45 22
v ∧ *v*	031 ∧ 031	49 30	49 27
k ∧ *x*	011 ∧ 012	15 59 30	16 00, 16 04
k ∧ *k*	011 ∧ 011	108 16	108 12, 108 14
r ∧ *x*	130 ∧ 012	72 38 30	72 35
c ∧ *x*	001 ∧ 012	19 52 30	19 48
r ∧ *b*	130 ∧ 010	28 39 30	28 37, 28 31
k ∧ *b*	011 ∧ 010	54 08	54 17
	001 ∧ 112	34 46	34 54
	121 ∧ 121	85 59	86 00

* Min. Russl., vi, pp. 106, 1870. Also Atlas Taf. lxxx, figs. 20 and 20 bis.

2. *Hematite and Cassiterite.*—Interesting specimens of hematite and cassiterite intimately associated and crystallized have been forwarded by Prof. F. A. Genth for crystallographic examination. The place from which they come is Mina del Diablo, Durango, Mexico. Among them a number of undoubted pseudomorphs of cassiterite after hematite were observed. They are too small and lusterless for the forms to be determined, but the whole grouping is precisely the same as that of hematite in the familiar "Eisenrose" habit, consisting of radiating plates. Often the central portion of these plates consists of a piece of hematite, the outer surrounding part of tin oxide. There were also seen pseudomorphs of cassiterite after some octahedral mineral, probably magnetite.

4.



These occurrences of cassiterite and hematite have already been described by Genth and vom Rath,* but in these specimens lately examined an additional point of interest was noted. This is the presence of cellular crystals of hematite filled with cassiterite. One of these is shown in fig. 4. The forms present on this crystal are

c, 0001, O; a, $11\bar{2}0$, i-2; r, $10\bar{1}1$, R; η, $01\bar{1}1$, -1; s, $02\bar{2}1$, -2; n, $22\bar{4}3$, $\frac{4}{3}$-2; d, $10\bar{1}2$, $\frac{1}{2}$; Θ, $20\bar{2}1$, 2.

Those chiefly developed are the prisms and the basal pinacoids which give the crystals its habit. In reality these faces are present to a considerable degree only along the edges, the remaining parts being sunken and filled with a roughened surface of cassiterite which runs on through the crystal. The polish and luster of as much of the face as is present is, however, very fine and brilliant.

A thin section of this individual was prepared parallel to the unit prism to ascertain if the cassiterite had here also any definite orientation in regard to the hematite. None was observed. The two minerals, both appearing fresh and unaltered, were present in irregularly mingled masses. The cassiterite was formed of an intimate crystal aggregation as shown by its slight but uniform action on polarized light.

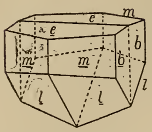
From these facts it would seem as if the two minerals had been formed simultaneously and the hematite having a greater tendency to crystallize than the cassiterite had assumed its crystal boundaries without regard to the latter.

3. *Gypsum.*—The crystals which are illustrated in fig. 5 are from Girgenti, in Sicily, and are now in the cabinet of Prof. Geo. J. Brush. They are twinned according to the usual method,

* Proceedings Am. Phil. Soc., 1887, xxiv, 23.

the twinning axis a normal to 100 and the following simple forms are present, *m*, *I*, 110; *b*, *i*-$\bar{i}$, 010; *l*, -1, 111; and *e*, $\frac{1}{3}$-$\bar{i}$, $\bar{1}$03. Since the orthodome $\frac{1}{3}$-$\bar{i}$, lacks only about two degrees of forming a right angle with the orthopinacoid, the two domes in twin position practically present the appearance of a basal plane and the whole crystal that of hemimorphic orthorhombic rather than of monoclinic symmetry. This pseudo-basal plane is rough and oscillatory and the very slight salient angle cannot be detected. The crystals are of good size and very symmetrical except at the end where the twin pyramids are; they are attached by this point and are as a consequence broken and disturbed at this place.

5.



4. *Pennine*.—The crystal form and optical properties of the violet chrome pennine or kämmererite from Texas, Penn., were originally described by Cooke* from specimens from the cabinet of Prof. Brush. At the request of Prof. E. S. Dana I have recently studied the suite of specimens in Prof. Brush's collection from this locality and thanks to the present perfection of apparatus for crystallographic investigation, I have been able to make out several forms observed by Prof. Cooke but which he was not then able to determine. The forms observed on these crystals are as follows:

O, 0001; R, 10$\bar{1}$1; *y*, $\frac{2}{5}$, 20$\bar{2}$5; *φ*, $\frac{4}{13}$, 4·0·$\bar{4}$·13; *z*, $\frac{1}{3}$, 10$\bar{1}$3; *ρ*, $\frac{1}{2}$-2, 11$\bar{2}$4 *χ*, 1-2, 11$\bar{2}$2.

The last three are new. The habit is shown in figs. 6 and 7. Fig. 6 is very similar to that given by Cooke, omitting the pyramids of the second order. As observed by him the crystals are generally twins. The planes forming the re-entrant angle are nearly always more or less striated, moreover this reentrant angle is, so far as observed, invariably formed by the unit rhombohedron R (10$\bar{1}$1). Fig. 7 shows a case where there was practically no striation and the angle could be measured. The presence of pyramids of the second order is a noteworthy characteristic, on no crystal out of a large number was it ever wanting. With one or two exceptions, on very small crystals, they were invariably striated as shown in fig. 7. These striations all lie in one zone, and this having been determined, it was possible to measure from the base along this zone, the reflections of various pyramids which stood out in the band of light connecting them.

In this way the presence of $\frac{1}{3}$-2 (11$\bar{2}$6), $\frac{4}{5}$-2 (22$\bar{4}$5), $\frac{9}{10}$-2 (9·9·$\bar{18}$·20) and $\frac{7}{4}$-2 (7·7·$\bar{14}$·8) was determined by moderately

* This Journal, vol. xliv, pp. 201, 1867.

good measurements, some of which were repeated on several crystals.

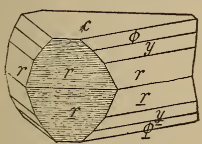
The following table shows the identification of the forms by calculated and measured angles. For the calculated the elements of Cooke are taken, in which

$$a:c = 1:3{\cdot}4951. \quad c \wedge R\ (0001 \wedge 10\bar{1}1) = 76°\ 05'.$$

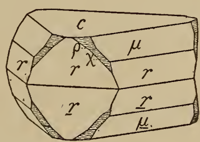
	Forms.	Calc.	Meas.
$c \wedge r$	$0001 \wedge 10\bar{1}\bar{1}$	103° 55′	104°
$c \wedge \phi$	$0001 \wedge 4{\cdot}0{\cdot}\bar{4}{\cdot}13$	51 09	51° 06′
$c \wedge y$	$0001 \wedge 20\bar{2}5$	58 13	58 05
$c \wedge z$	$0001 \wedge 10\bar{1}3$	53 22½	53 48
$c \wedge \rho$	$0001 \wedge 11\bar{2}4$	60 13½	60 35
$z \wedge \rho$	$10\bar{1}3 \wedge 11\bar{2}4$	25 54	25 22
$c \wedge \chi$	$0001 \wedge 11\bar{2}2$	74 05	74 10

The form 1-2 $(11\bar{2}2)$ was also identified by the fact that it lies in the zone between $\frac{1}{3}$ $(10\bar{1}3)$ and r, R, $(10\bar{1}\bar{1})$.

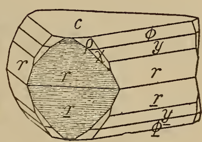
6.



7.



8.



5. *Mordenite.*—The author desires to correct a small error which crept into the determination of the constants of this mineral as given in this Journal, xl, page 236. These should read

$$\grave{a}:\bar{b}:\dot{c}\ ::\ 0{\cdot}40099:1:0{\cdot}42792 \text{ angle } \beta = 88°\ 29'\ 46''$$

instead of the figures there given, which are

$$\grave{a}:\bar{b}:\dot{c}\ ::\ 0{\cdot}40101:1;\ 0{\cdot}42623 \text{ angle } \beta = 88°\ 30'\ 30''.$$

Mineralogical Laboratory, Sheffield Scientific School,
New Haven, Nov., 1890.

Art. XLIII.—*Peridotite Dikes in the Portage Sandstones near Ithaca, N. Y.;* by J. F. Kemp.

In the valuable paper on the peridotite* at Syracuse, N. Y. which appeared in this journal in August, 1887, the following statement is made and it doubtless expresses a very widespread and general impression. "This rock is interesting as being the only known instance of igneous intrusion in the unaltered and undisturbed Palæozoic strata of New York" (p. 144). Since the writer's first residence in Ithaca (1886), the occurrence of trap dikes in the vicinity has been a subject of frequent discussion in the geological laboratory of Cornell University. Conversations with alumni who were students under the instruction of Professor C. F. Hartt (1868–1878), revealed the fact that he made frequent mention of them and created the impression that they were well recognized phenomena in two of the neighboring gorges. They do not appear to have become a matter of record except in two cases. Professor O. A. Derby (now in Brazil) in a short paper in the Cornell Review (which was the student publication of that date), vol. i, p. 70, 1874, entitled "Hints to Geological Students," mentions a number of localities involving in all four dikes. Three of these are in Cascadilla Creek on the confines of the university and the fourth, said to be the best for study, is in Six-Mile Creek, two or three miles distant. Professor F. W. Simonds (now of Texas) published in 1877, a short article in the American Naturalist (vol. xi, p. 49) on the Geology of Ithaca, N. Y., and vicinity. The Six Mile Creek dike is again mentioned and described as filling a crack in the sides of the gorge but as pinching out before it reached the surface. Long before this, however, in 1842, in the Report on the 3rd District, N. Y. State Survey, p. 169, Vanuxem recorded four narrow dikes in the Genesee slate near Ludlowville, which is ten miles north of Ithaca. The locality has been recently visited by the writer but only the two dikes near the upper falls of Vanuxem could be found. They are each about an inch wide and only show over a short space as they disappear above and below. They were inaccessible and from the distance of a few feet their igneous nature was not conclusively shown. The other two could not be found. Vanuxem also mentions another dike (l. c. pp. 207–208) at Manheim Bridge east of Little Falls, N. Y., more than one hundred miles

* G. H. Williams: The Serpentine (Peridotite) occurring in the Onondaga Salt Group at Syracuse, N. Y., this Journal, August, 1887, p. 144. See also Proc. Geol. Soc. Amer., vol. i, pp. 533, 534.

northeast of Ithaca and seventy-five miles from Syracuse, but what its character is or whether it is indeed igneous is unknown to the writer.

The dike in Six Mile Creek near Ithaca was re-located in 1887, and slides were at once prepared. It proved to be a thin mass $1\frac{1}{4}$ to 2 inches wide and fills one of the numerous, parallel, north and south joints which are extremely abundant in the shaly sandstones of the region. It crosses the stream like a narrow ribbon and pinches out a few feet above the surface of the water. It has a light brown or drab color with darker spots scattered through and is provided with numerous scales of a reddish mica. It effervesced and in the slides showed a mass of alteration products with very strong suggestions of an eruptive structure, but as the material was so decomposed it was decided to be too meagre, to deserve mention. It was subsequently submitted to Messrs. G. H. Williams, Diller and Derby and the last two were strongly of the opinion that it was igneous and suggested blasting. Later discoveries make this procedure hardly necessary and prove the specimen to be undoubtedly an eruptive rock in advanced decomposition.

During a visit from Professor Derby, the past autumn, the subject of dikes was again brought up and the probable location of one in Cascadilla Creek was indicated. The point is under the discharge raceway of the reservoir forming Willow pond, just east of the entrance to the Cornell Campus. In a recent drouth it became accessible. The dike is about three feet in width and strikes north and south right across the course of the creek. It is in a recess formed by its weathering and a corresponding recess appears on the opposite side, filled however with dirt. It is covered with sand in the creek.

The rock itself is very dark green to black. Its surface is mottled by black protuberances which look very much as if they were pebbles. But they readily crumble under the fingers to a black dirt. The fresher portions have a porphyritic aspect and suggest a peridotite at once, and this is verified by the slides. In the sections the rock is seen to be highly altered. The black masses prove to be the remains of large olivine and enstatite or bronzite crystals.

The latter show very generally the striated appearance so characteristic of these pyroxenes but the silicate itself has changed to serpentine and carbonates. The crystals are 3–5^{mm} in diameter. The recognizable olivine is in smaller crystals than the pyroxene as a general thing, but appears in no inconsiderable amount. It is very probable that the larger, unstriated alteration masses were also olivine. The characteristic reddish biotite of the peridotites is distributed through the rock, and is still quite fresh. The crystals run about 0·2–0·3^{mm} long. Their distribution indicates at times an excellent flow structure. Magnetite is abundant both in irregular grains and rude crystals. A small amount of a reddish brown mineral, of high index but not entirely isotropic, is also present. It is probably perofskite. The groundmass consists in large part of numerous small acicular crystals of highly inclined extinction which are augite. The groundmass seems originally to have been glassy. An analysis which was kindly made in the chemical laboratory at Cornell by Mr. W. H. Morrison, graduate student in chemistry yielded the following results.

	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	K_2O	Na_2O	Loss	Total.
2/2	37·44	11·92	28·60	5·45	1·97	1·02	0·97	12·67	=100·04

The analysis shows at once the advanced stage of the decomposition and yet indicates a very basic rock. Qualitative tests failed to show chromium.

The rock resembles very closely the Syracuse serpentine described by Dr. G. H. Williams in its general macroscopic appearance and in many of its microscopic characters. The large phenocrysts are the same but the olivine is less fresh than at Syracuse. The reddish mica is present in both. It has also been compared with the peridotite from Elliott Co., Ky.,* and that of Pike Co., Ark.,† and evidently belongs to the same family of rocks but as might be expected it resembles the Syracuse rock most closely.

The occurrence is interesting because it shows the further distribution of igneous rocks in a region supposed to be free from them. Ithaca is some seventy-five or eighty miles south of Syracuse and much higher in the geological scale. The local rocks are shaly sandstones of the Portage stage and are extensively seamed by a series of north and south joints and another series, of west-northwest strike. The dikes in all cases follow the northerly series. It is not improbable that they belong to the same eruptive outbreak that found a larger manifestation at Syracuse. If so the intrusion is put at a date later than the Upper Devonian, but beyond this no further determination can be made with the data at hand.

Geological Laboratory, Columbia College, New York City.

* J. S. Diller: The Peridotite of Elliott Co., Ky. Science, Jan. 23, 1885, p. 65. Bulletin No. 38, U. S. G. S., 1887.

† Branner and Brackett: Peridotite of Pike Co., Ark. This Journal, July, 1889, p. 50.

ART. XLIV.—*A New Locality for Meteoric Iron with a Preliminary Notice of the Discovery of Diamonds in the Iron*;* by A. E. FOOTE. With Plates XIV, XV.

Historical sketch of the discovery.—In the latter part of March, 1891, the mining firm of N. B. Booth & Co., of Albuquerque, New Mexico, received a letter from a prospector in Arizona informing them he had found a vein of metallic iron near Cañon Diablo, sending them at the same time a piece with the request for an assay. Sometime in April this piece was examined by a Colorado assayer who reported "76·8 per cent of iron, 1·8 per cent lead, ½ oz. silver, and a trace of gold. From its appearance we should take it to be a furnace product."†

This result was naturally not satisfactory to the mining firm and a mass weighing forty pounds was broken into several fragments with a trip hammer. One of these was sent to the President of the Santa Fe Railroad, and another to Gen. Williamson, the land commissioner of the Atlantic and Pacific Railroad Co., in Chicago. Gen. Williamson consulted me as to the probable value of the so-called mine of "pure metallic iron," stating on the authority of the prospector that the vein had been traced for a distance of about two miles, that it was forty yards wide in places, finally disappearing into a mountain and that a car load could be taken from the surface and shipped with but little trouble.

A glance at the peculiar pitted appearance of the surface and the remarkable crystalline structure of the fractured portion convinced me that the fragment was part of a meteoric mass, and that the stories of the immense quantity were such as usually accompany the discovery of so-called native iron mines, or even meteoric stones. As soon as possible, in June, I made a visit to the locality and found that the quantity had, as usual, been greatly exaggerated.

There were some remarkable mineralogical and geological features which, together with the character of the iron itself, would allow of a good deal of self deception in a man who wanted to sell a mine.

Description of Locality.—Nearly all of the small fragments were found at a point about ten miles southeast from Cañon

* Read before the American Association for the Advancement of Science, August 20th, 1891.

† This assay was of such a remarkable character that I took the trouble to stop at the city where it was made and ask how such extraordinary results were obtained. I was informed that the lead, silver and gold were probably the results of the materials used in making the assay.

Diablo near the base of a nearly circular elevation which is known locally as "Crater Mountain." I believe this is the same as Sunset Knoll figured on the topographical sheets of the U. S. Geological Survey. This is 185 miles (297·72 kilometers), due north from Tucson and about 250 miles (402·34 kilometers) west of Albuquerque.

The elevation, according to the survey, rises 432 feet (131·67 meters) above the plain. Its center is occupied by a cavity nearly three quarters of a mile (1·2 kilometers) in diameter, the sides of which are so steep that animals that have descended into it have been unable to escape and have left their bleached bones at the bottom. The bottom seemed to be from fifty to one hundred feet (15·24 to 30·48 kilometers) below the surrounding plain. The rocks which form the rim of the so-called "crater" are sandstones and limestones and are uplifted on all sides at an almost uniform angle of from thirty-five to forty degrees. A careful search, however, failed to reveal any lava, obsidian or other volcanic products. I am therefore unable to explain the cause of this remarkable geological phenomenon. I also regret that a severe gallop across the plain had put my photographic apparatus out of order so that the plates I made were of no value.

About two miles (3·22 kilometers) from the point at the base of the "crater" in a nearly southeasterly direction, and almost exactly in a line with the longest dimensions of the area over which the fragments were found, two large masses were discovered within about eighty feet (24·38 meters) of each other. The area over which the small masses were scattered was about one-third of a mile (0·53 kilometer) in length and one hundred and twenty feet (36·57 meters) in its widest part. The longer dimension extended northwest and southeast.

Description of the specimens.—The largest mass discovered weighs 201 pounds (91·171 kilos,) and as the photograph shows, Plate XIV, has a somewhat flattened rectangular shape showing extraordinarily deep and large pits, three of which pass entirely through the iron. The most remarkable example of such perforation is the Signet Iron from near Tucson, Arizona, now in the National Museum and figured in Prof. F. W. Clarke's Catalogue.*

One other large mass was found weighing 154 pounds (69·853 kilos.) This is also deeply pitted. A mass weighing approximately 40 pounds (18·144 kilos) was broken in pieces with a trip hammer and it was in cutting one of the fragments of this mass that diamonds were discovered. Plate XV.

* The Signet Iron was discovered about 30 miles (48·28 kilometers) from Tucson. Dr. Geo. H. Horn states that 25 years ago he was told by the Spaniards that plenty of iron could be found on a range of hills extending northwest and southeast half way between Albuquerque and Tucson.

Besides these masses of considerable size a careful search made by myself with the assistance of five men was rewarded by the discovery of 108 smaller masses. Twenty-three others were also discovered making a total of 131 small masses ranging in weight from $\frac{1}{16}$ of an oz. (1·79 grm.) to 6 lbs. 10 oz. (3·006 kilos.)* A brownish white slightly botryoidal coating found on a number of the meteorites, is probably aragonite.

A thorough examination of many miles of the plain proved that the car load of iron existed only in imagination. Accompanying the pieces found at the base of the "crater" were oxidized and sulphuretted fragments which a preliminary examination has shown are undoubtedly of meteoric origin. About 200 pounds (90·718 kilos) of these were secured, from minute fragments up to 3 pounds 14 oz. or (1·757 kilos.) These fragments are mostly quite angular in character, and a very few show a greenish stain, resulting probably from the oxidation of the nickel. This oxidized material is identical in appearance with an incrustation which covers some of the iron masses and partially fills some of the pits.

Composition.—After obtaining the meteorite I was unable to return to Philadelphia for sometime, and, therefore, sent a fragment of the 40 pound mass (18·144 kilos) to Prof. G. A. Koenig for examination. Prof. Koenig was compelled to leave town before this examination was completed. I take the following, therefore, from his letters to me and from an account furnished the daily *Public Ledger* by Dr. E. J. Nolan, Secretary of the Academy of Sciences, of a preliminary notice made by Prof. Koenig, June 23rd, before the Academy of Natural Sciences of Philadelphia. In this account he says:

"In cutting the meteoric iron for study it had been found of a extraordinary hardness, the section taking a day and a half, and a number of chisels having been destroyed in the process. When the mass, which on the exterior was not distinguished from other pieces of meteoric iron, was divided, it was found that the cutting apparatus had fortunately gone through a cavity. In the attempt to polish the surface so as to bring out the characteristic Widmannstättian figures, Dr. Koenig received word that the emery wheel in use had been ruined.

On examination, he then found that the exposed cavities contained diamonds which cut through polished corundum as easily as a knife will cut through gypsum. The diamonds exposed were small, black, and, of course, of but little com-

* Oct. 18th.—During September I received three additional large masses weighing respectively 632, 506 and 145 pounds (or 286·678, 229·516 and 65·771 kilos.) The two latter were each perforated with three holes. A number of smaller masses up to 7 pounds, (3·175 kilos.) were discovered by digging. The three large masses and one of 23 pounds, (10·432 kilos) were covered with grass and earth.—A. E. F.

mercial value, but, mineralogically, they are of the greatest interest, the presence of such in meteorites having been unknown until 1887, when two Russian mineralogists discovered traces of diamond in a meteoric mixture of olivine and bronzite. Granules of amorphous carbon were also found in the cavity, and a small quantity of this treated with acid had revealed a minute white diamond of one-half a millimeter, or about $\frac{1}{50}$ of an inch in diameter. In manipulation, unfortunately, this specimen was lost, but others will doubtless be obtained in the course of investigation. The minerals, troilite and daubréelite, were also found in the cavities. The proportion of nickel in the general mass is three per cent, and the speaker was not as yet able to account for the extraordinary hardness apart from the presence of the diamonds in the cavities."

Prof. Koenig in a letter to me gives the following points as definitely known.

"(1.) *Diamonds*, black and white established by hardness and indifference to chemical agents. (2.) *Carbon* in the form of a pulverulent iron carbide occurring in the same cavity with the diamonds. The precise nature of this carbide, whether containing hydrogen and nitrogen is not ascertained except in so far that after extracting all iron by nitro-hydrochloric acid, the black residue goes into solution with deep brown color upon treating it with potassium or sodium hydrate. From this solution acids do not precipitate anything. (3.) *Sulphur* is not contained in the tough malleable portion of the meteorite but in the pulverulent portion. (4.) *Phosphorus* is contained in the latter, and not in the former. (5.) *Nickel* and *Cobalt* in the proportion of 2 : 1 are contained in both parts nearly equally. (7.) *Silicon* is only present in the pulverulent portion. (8.) The Widmannstättian figures are not regular. (9.) The iron is associated with a black hydroxide containing Fe, Ni, Co, P, in the ratio of the metallic part and therefore presumably derived by a process of oxidation and hydration of the latter."

Conclusions.—As this meteoric iron contains only 3 per cent of nickel while that from the Santa Catarina Mountains, 30 miles (48·28 kilometers) southeast of Tucson and 215 miles (346 kilometers) from this locality, contains from 8 per cent to 9 per cent, according to the analysis of Brush and Smith, they are quite distinct although somewhat alike in external appearance. They also somewhat resemble the Glorietta meteoric irons from about 300 miles (482·8 kilometers) to the east northeast, in New Mexico. These contain 11·15 per cent of nickel.

The most interesting feature is the discovery for the first time of diamonds in meteoric iron.* This might have been predicted from the fact that all the constituents of meteoric iron have been found in meteoric stones, and *vice versa*, although in different proportions.

The incrustation of what is probably aragonite shown by some of the masses has rarely been noticed (I find two records by J. Lawrence Smith which he states to be unique, and both of these were from regions south of this one). The incrustation is especially interesting as showing that the meteoric irons must have been imbedded a long time, as the formation of aragonite would be exceedingly slow in this dry climate.

The remarkable quantity of oxidized black fragmental material that was found at those points, where the greatest number of small fragments of meteoric iron were found, would seem to indicate that an extraordinarily large mass of probably 500 or 600 pounds (226·796 or 272·156 kilos) had become oxidized while passing through the air and was so weakened in its internal structure that it had burst into pieces not long before reaching the earth.

Art. XLV.—*The South Trap Range of the Keweenawan Series;* by M. E. Wadsworth, State Geologist of Michigan.

In a former communication published in the August number of this Journal, it was shown that the eastern or supposed Potsdam sandstone, east of the copper-bearing rocks, underlies, in an apparently conformable synclinal fold, a limestone of Trenton or of some adjacent Lower Silurian formation. It was then suggested that the contorted state of the sandstone might have some weight in deciding the relative age of the eastern sandstone and the adjacent copper-bearing rocks.

In endeavoring to contribute something to the solution of the relation of these two series of rocks, a party under the charge of Mr. A. E. Seaman of the Michigan Geological Survey was directed to go to "Silver Mountain," and thence to study the "South Trap Range," in order to ascertain, if possible, the exact relations of the lava flows of that range and the eastern sandstone. Part of this work has been done, and,

* Attention may be called to the discovery by Haidinger (1846) of cubic crystals of a graphitic carbon in the Arva meteoric iron, and also of somewhat similar crystals from the Youngdegin, W. Australia iron, described by Fletcher (1887) under the name of cliftonite. Both have been regarded as pseudomorphs after diamond.

although far from being as decisive as could be wished, yet the observations would appear to be of considerable interest and importance.

"Silver Mt." (Sec. 1, T. 49, R. 36 W.) was found to be composed of interbedded lava flows, of which at least ten flows were made out with more or less certainty. These flows dip to the northwest at an angle of from ten to sixteen degrees. No sandstone was found nearer than two miles. This has a slight dip to the northwest. On Sec. 29, T. 47, R. 37 W., a series of melaphyr flows were observed dipping at a low angle to the north or a little west of north. The angle of their greatest inclination being from 15° to 20°.

These flows are interbedded with sandstone which holds fragments of the melaphyr. A felsite dike also cuts through the beds.

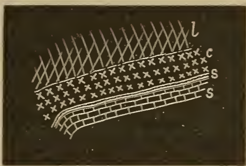
Similar lava beds are found on Sec. 25, T. 47, R. 38 W., and Sec. 30, T. 47, R. 37 W., which lie at a low angle, 9° to 16° north or a little west of north; while on Sec. 1, T. 46, R. 39, the flows dip from 9° to 20°, the principal dip being to the north at an angle of 14°. Outcrops of the same old basaltic rocks occur on Sec. 35, T. 47, R. 38 W. and Sec. 8, T. 46, R. 39 W., which show a very low inclination.

The most important observations were made in Secs. 11, 13 and 14, T. 46, R. 41 W., where the sandstone was found overlaid by some of the lava flows. The sandstone is found in contact with schists presumably of the Archæan or Azoic Age. The base of the sandstone is of a conglomeritic character composed of rolled pebbles of quartz cemented by an argillaceous matrix formed from the debris of the underlying steeply inclined and contorted schists. This sandstone dips at a low angle of from 12° to 14° northerly, its strike being S. 60° E.

The conglomerate passes into a coarse reddish sandstone which can be traced in pits and exposures northwesterly, where the same coarse red sandstone is seen to pass up into a fine grained indurated sandstone or quartzite, which in its turn passes into a fine-grained indurated argillaceous schist and chert. This indurated zone is in immediate contact with the overlying lava flow of the south trap range. The structure here is apparently that of a series of flows arising along a pipe or fissure, and shows the remains of the solidified neck with the downward bent sandstone or schist strata, together with the strong induration produced by the overflowing lava. The structure is indicated in the accompanying figure.

It may be remembered that this structure is similar to that observed by the present writer in 1879, on the Douglass Houghton and Hungarian Rivers, except that at the latter two places much decomposition has occurred, leaving it a disputed question whether the superposition of the lava on the sandstone is due to its having flowed over it, or to a reversed fault.

In connection with the above it may be pointed out that the eastern sandstone on Traverse Island, in Keweenaw Bay, was found by the Michigan Geological Survey to dip westerly at an angle of from five to fourteen degrees, and that the present writer showed that the eastern sandstone in the vicinity of Torch Lake, generally dipped from five to twenty-three degrees northwesterly toward the copper-bearing series, and that it actually passed under the lava flows.



l, lava flows; *c*, cherty bands; *s*, *s*, indurated sandstones.

The above observations would go to show that the lava flows of the "South Trap Range," east of Lake Gogebic do not dip at a high angle, as has been generally asserted, and further that the eastern sandstone is not horizontal, as has been generally stated, but that the two dip at a low angle, generally 5° to 20°. These observations also indicate that the eastern sandstone, and the lava flows of the South Trap Range are one formation, and are as conformable as eruptions of lava can be with a contemporaneous sedimentary deposit.

The study of the South Trap Range will be continued.

Michigan Mining School, Houghton, Mich., October 1st, 1891.

ART. XLVI.—*Geological Facts noted on Grand River, Labrador;** by AUSTIN CARY.

THE map of Labrador shows on its eastern coast one deep indentation. This body of water, comprised of Hamilton inlet and Lake Melville, is 140 miles long in all, and washes at almost every point the Archæan rock of the country.

* Prof. Leslie A. Lee in planning the Bowdoin expedition to Labrador the past summer determined to send a party up the Grand River to investigate its falls and obtain such scientific information as might be possible. This paper embodies the geological facts noted by that party. Their meagerness and lack of detail must be largely attributed to the hurried nature of the trip and the serious accidents met with.

Lake Melville receives at its head three large rivers. One of these, the Grand or Hamilton river, the largest in the peninsula, prolongs for many miles the general westerly trend of the inlet. Not only this, but the valley in which it flows is a continuation of the basin of the inlet, largely similar in character, direction and width. For sixty miles the river flows on loose sedimentary material, lying again between steep rocky walls nowhere less than six or eight miles apart. The continuity of this valley, from this point to the open sea seems evident. It is a wide trough, 200 miles long, cut into the edge of the Labrador plateau and through its outlying hills.

Seldom does the river in this region touch the rocky wall, but at a point 25 miles from the mouth it has dug into the southern wall, and a remarkably round gneissic hill some 400 feet high has been formed. Here also a half mile of fall and rapid makes a drop in the river of 70 feet. At the bottom of the section of sedimentary material thus exposed, fossiliferous Champlain clays were found, the total height of the section at this point being something over 200 feet. Toward the river mouth, it gradually drops to the level of the stream, while 40 miles farther up terraced banks of sand rise to a height of 400 or 500 feet.

At a point between 60 and 70 miles from Lake Melville the sides of the rocky valley approach till they are but about a mile apart. This is well within the Labrador plateau which in this region is tolerably level, so that from the deeply sunk river bed its edges have the appearance of high, steeply sloping ridges. Parallel, and from a half mile to three miles apart, they extend for more than 200 miles, their regularity broken only by the deep-worn valleys of the largest streams, and by occasional perpendicular bluffs. Changes in direction are generally slow and easy.

Marks of former deposit and wear are everywhere. Sand terraces border the river in quiet regions, while beaches of waterworn stones mount the sides of the valley to a great height. Typical potholes were noted in one place 50 feet or more above the present river level. It is worth remark that while the general height of the plateau, as set by a former traveler* is 2000 feet; this altitude is not generally gained by a single slope. At many places when the bank rises by a steep angle or a bluff to a height of 500 or 600 feet, the remaining height is gained by a much more gradual slope.

The Grand River in this region flows through one large lake called Waminikapou. This is but a portion of the river valley 40 miles long from which the loose material has been

* Holme, Proc. Roy. Geog. Soc., April, 1888.

cleared out. From one to three miles wide, it contracts to about a quarter mile at its outlet, where the current passes out between perpendicular rocky bluffs, the talus from which serves in part to dam up the water.

Of the geological features observed on this river the great cañon at the head of our travel is judged the most remarkable. At the upper end of this structure the river, which above here has been flowing on the plateau level, makes an abrupt drop and flows off with many sharp turns, a succession of falls and rapids, between abrupt walls. These walls, without a single break, continue for 20 miles, during which they are very often absolutely perpendicular, and at few points so sloping that it is possible to reach the river's bed on foot. About 100 yards wide at the bottom, the gorge at its head is 150 feet deep, at its foot as much as 800. Grand in dimensions and unique in character as is this gorge, it has never been appreciated by the few men who have seen it. We suggest for it the name "Bowdoin Cañon."

At its mouth the cañon opens into the side of the river valley described above and at right angles to it. The difference in structure here is very marked. The broader valley extends both ways the same in direction and character; but while, as seems probable, the main drainage of the country flowed originally through this channel, it now holds but a small stream compared with the volume pouring out of the cañon.

Several interesting facts were noted at the fall which seem to determine its present position. The river above this point is flowing on a hard, moderately coarse syenite which is horizontally jointed. At the crown of the fall the jointing, as is shown by a very plain section, takes a gradual curve. This curve the water follows downward until having reached a very considerable angle, it takes a perpendicular drop. The walls of the basin into which the river falls, while inaccessible to close inspection, were intersected by what appeared to be two or three trap dikes; while just here also was a region of special jointing and seaming. Somewhat below the fall the rock was noted as having changed to a syenitic gneiss. Our party spent four days in travel on the plateau in the neighborhood of the fall and cañon. So far as observed the plateau surface is worn down to a pretty even general level with perpetual minor elevations and depressions. Almost its whole surface is covered with angular bowlders. One rounded hill, from 500 to 800 feet in height was ascended, by far the highest elevation in a radius of many miles. It was christened by the party Mount Hyde. Glacial markings and bowlders were found on its summit.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the so-called "Black Sulphur" of Magnus.*—Knapp has examined the mode of formation and the properties of the so-called "black sulphur" first described by Magnus. He finds that the best mode of preparing it is to heat suddenly a mixture of sulphur and oil; such for example as is obtained by dissolving almond oil (0·2 to 0·4 gram.) in ether, mixing the solution thoroughly with 50 grams flowers of sulphur and then evaporating the ether. If a small portion of this mixture be dropped from the point of a knife on to the bottom of a red hot platinum crucible, most of it is volatilized, but there is left a loose black residue, which after cooling is removed. By repeating the operation, the product may be increased indefinitely. Even with the greatest precautions, the yield is very small, only 0·685 gram having been obtained in this way from 100 grams of sulphur and 0·4 gram of oil, as a mean of 23 experiments. The oil treated alone in this way gave only 0·011 gram of residue. As thus obtained the "black sulphur" contains some yellow sulphur, and if the materials were not pure, also some ash. Its density varies from 2·622 to 1·843, this want of homogeneity being due to the difficulty of regulating the temperature. It is insoluble in hot and cold water, alcohol, ether, hydrochloric acid, nitric acid, aqua regia, ammonia, caustic alkalies even when concentrated, and potassium cyanide. On evaporating it with potassium hydroxide solution, it is attacked just as the hydroxide is becoming solid and dissolved to a humus-brown mass soluble in water with a deep brown color, yielding a solution in which acids give a brown precipitate. On heating the black sulphur in the air it undergoes no change other than the loss of moisture and yellow sulphur until the temperature reaches 200°–300°, when sulphurous oxide is formed. At a red heat the mass takes fire. In the absence of air, the black sulphur slowly loses weight and continues to do so for many hours even at a red heat, no vapor of sulphur or empyreumatic vapors being evolved. After the weight becomes constant, the residue burns away in the air entirely. The amount of this residue was 43·59 per cent. Its quantity did not seem to vary when the heating took place in carbon dioxide and no brown sulphur vapors appeared in the vessel, although considerable potassium sulphide was formed when the delivery tube from this vessel was conducted under potassium hydroxide solution. The sulphur in the "black sulphur" was estimated by evaporating a known portion with potassium hydroxide and potassium nitrate solutions and heating, until the residue was white. Three determinations gave 53·77, 56·76 and 57·07 per cent of sulphur, respectively. The residue left at a red heat contained 22·78 per cent of sulphur. Thus 44–46 per

cent of the sulphur is expelled at a red heat, while the residue contains 10 per cent only of sulphur mixed with 33–34 per cent of carbonaceous matter. Only 13–14 per cent of the total sulphur is dissolved by potassium dichromate and bromine. Hence the author concludes that the "black sulphur" of Magnus is not in itself a modification of sulphur, but consists of such a modification either adhering to or condensed with, a carbonization product of the oil, itself containing sulphur. The new form of sulphur does not vaporize below a temperature which is far above the boiling point of yellow sulphur. Moreover its vapor is colorless and not brown; and it evolves sulphurous oxide below a visibly red heat without combustion. Though evidently unstable in the free state, it can exist readily in contact with any surface which affords a substratum for its development. This the author finds in the blue color developed by sulphur on platinum, silver and lead sulphide, and in the blue of ultramarine.—*J. pr. Ch.*, II, xliii, 305; *J. Chem. Soc.*, lx, 877, Aug. 1891. G. F. B.

2. *On a new form of Silicon.*—WARREN has described a new form of silicon crystallizing in well-defined oblique octahedrons, obtained by subjecting potassium silicofluoride to an intense heat in contact with impure aluminum. On separating the graphitoidal silicon thus produced, by the aid of acids, the new variety was obtained though only in small amount. The yield was increased by proceeding as follows: Pieces of aluminum the size of a walnut were thrown into a clay crucible containing a mixture of 4 parts of potassium silicofluoride, one part potassium carbonate and 2 parts potassium chloride, in a state of fusion. After the violent action was over, the crucible was heated to whiteness for about five minutes. On cooling a button was obtained containing 80 per cent of silicon. This was placed in a plumbago crucible with 12 parts of aluminum and 2 parts of tin and the whole was covered with a layer of sodium silicate. After heating to the highest attainable temperature for two hours, the crucible was cooled and the aluminum button was broken. It contained the new modification of silicon in large perfect crystals, having a full metallic luster and resembling the crystals of cast iron seen on breaking a pig of this metal. The silicon crystals are infusible and insoluble in all acids except hydrofluoric.—*Chem. News*, lxiii, 46; *J. Chem. Soc.*, lx, 799, July, 1891. G. F. B.

3. *On a new Alkaloid from Conium maculatum.*—The new alkaloid which was observed in *Conium maculatum* by Merck of Darmstadt, has been submitted to a careful chemical examination by LADENBURG and ADAM. As received it was a white powder, easily soluble in water, alcohol, ether and benzene and forming salts with acids. The new base was purified in two ways: first by distillation and second by recrystallization from toluene. Both portions had the same melting point and both gave on analysis similar numbers: carbon 66·66 and 67·14, and hydrogen 12·33 and 12·35, the nitrogen being 9·88. This agrees

with the formula $C_8H_{17}NO$ which is that of conhydrine. Being quite similar to this base the authors call it pseudoconhydrine. It boils at 229°–231°, the distillate solidifying crystalline, and fusing at 100°–102°. It is optically active, $\alpha_D = 4·30°$. Its constitution has not been fixed.—*Ber. Berl. Chem. Ges.*, xxiv, 1671, June, 1891. G. F. B.

4. *On Iron-tetracarbonyl and Nickel-tetracarbonyl.*—Mond and Quincke have succeeded in forming a compound of iron with carbon monoxide analogous to the compound of nickel with this gas described by them in conjunction with Langer. When very finely divided iron, obtained by reducing iron oxalate in a current of hydrogen at the lowest possible temperature, but little over 400°, and then cooled in the gas to 80° is treated with carbon monoxide, the escaping gas imparts a yellow color to the flame of a Bunsen burner into which it is passed, this result continuing even at ordinary temperature for several hours. On passing the gas through a heated glass tube at 200° to 350° a metallic mirror is formed, while at higher temperatures black flakes are produced. Upon dissolving these mirrors in acid, the solutions gave all the known reactions of iron in remarkably brilliant colors. A solution in nitric acid, precipitated by ammonia, weighed and reduced by hydrogen gave 70·48 and 69·94 per cent of iron in the oxide in two cases, the theoretical amount being 70·00. Even under the most favorable circumstances, however, the quantity of iron obtainable in this way is very small. On treating 12 grams of finely divided iron with carbon monoxide for six weeks, only about two grams of the metal volatilized. After a time the action diminished in intensity, and it was found necessary to heat the iron in a current of hydrogen at 400° for about twenty minutes every five or six hours. When 2½ liters of carbon monoxide passed per hour over the iron, the issuing gas contained not more than 0·01 gram of iron per liter; equivalent to less than 2 c.c. of $Fe(CO)_4$. Sulphuric acid absorbs the gas completely, but the solution decomposes very rapidly. Benzine and heavy mineral oils partially absorb it, producing tawny colored solutions which decompose on exposure to the air with separation of iron hydroxide. The analysis of the gas was effected by saturating a mineral oil with it by passing it through the oil for 8 to 16 hours, raising the temperature to 100° under a pressure of 500 mm. of mercury to free it from air and dissolved CO, and then to 180°, at which temperature the iron compound was decomposed, the carbon monoxide being evolved and the iron separating in the metallic form. The ratio of the CO to the Fe was found to be in five experiments 4·144, 4·030, 4·150, 4·264, and 5·042; thus rendering it probable that the substance is iron-tetracarbonyl, corresponding to the nickel compound. The authors suggest that this iron compound may play a part in the process of cementation.—*J. Chem. Soc.*, lix, 604, Aug., 1891; *Ber. Berl. Chem. Ges.*, xxiv, 2248, July, 1891. G. F. B.

Berthelot also has observed the formation of this iron-carbonyl compound. If finely divided iron, obtained by reducing the precipitated oxide at the lowest possible temperature or by igniting the oxalate in hydrogen, be treated at 45° with carbon monoxide, the escaping gas contains iron and burns with a brighter, sometimes whiter, flame than the monoxide itself. This flame produces spots on a porcelain surface held in it, these spots consisting of iron and its oxide. On passing the gas through a heated tube a metallic ring is deposited consisting of iron containing carbon. With concentrated hydrochloric acid, the gas gives ferrous chloride. On standing over water containing air, iron oxide is deposited. The quantity of the iron compound is very small. Berthelot has also examined nickel-tetracarbonyl and finds that it is permanent and without marked dissociation-pressure at ordinary temperatures. When preserved under water it is not decomposed if air be absent. When heated suddenly to above 60° it explodes, producing carbon and carbon dioxide besides nickel and the monoxide ; according to the equation $C_4O_4Ni = (CO_2)_2 + C_2 + Ni$. It is not soluble in water, dilute acids or alkalies or acid cuprous chloride ; though hydrocarbons, especially oil of turpentine dissolve it. Mixed with air or oxygen it detonates on ignition and sometimes spontaneously as when the dry gas mixed with oxygen is agitated over mercury. In presence of water, a greenish-white gelatinous precipitate is formed which contains nickel, oxygen, water and combined carbon, and which deposits carbon on heating. In the liquid state, nickel-tetracarbonyl shows similar reactions. Concentrated sulphuric acid explodes it, while its vapor when mixed with nitrogen is gradually converted by this acid into four times it volume of carbon monoxide, the nickel going into solution. Ammonia does not act at once on the pure gas, while if oxygen be present white fumes appear immediately. Hydrogen sulphide gives a black sulphide, hydrogen phosphide a black mirror-like deposit. Nitrogen dioxide when mixed with the liquid or its vapor, produces a blue cloud which gradually sinks to the bottom of the vessel ; the resulting gaseous mixture containing nitrogen dioxide, carbon monoxide and a new nickel compound. The author calls attention to the analogy between carbon monoxide and the radicals contained in the so-called metallo-organic compounds.—*C. R.*, cxii, 1343 ; *Ber. Berl. Chem. Ges.*, xxiv, Ref. 593, July, 1891.

G. F. B.

5. *On a sensitive Reaction for Tartaric acid.*—Mohler has observed that when crystals of tartaric acid are thrown on sulphuric acid of 66° B., containing one per cent of resorcinal, and the whole is heated gradually, a fine red-violet coloration is produced when the temperature approaches 125° ; complete carbonization taking place at 190°. Water destroys the color. The coloring matter could not be isolated since it was not soluble in ether, amyl alcohol, acetone, chloroform, or benzine. Using other phenols, similar colors are produced ; phloroglucinol giving a red

and pyrogallol a fine violet color. Since these reactions are not given by succinic, malic, citric or benzoic acids, tartaric acid may readily be detected when mixed with any of these acids. To detect 0·01 milligram, the author evaporates the solution to be tested to dryness, one c.c. of the resorcinal solution is added, and the whole is gradually heated to about 125°. At first reddish streaks appear and then the sulphuric acid becomes colored throughout. If organic substances which char with sulphuric acid are present, the tartaric acid is removed by precipitation as lead tartrate and then tested, nitrates and nitrites should not be present.—*Bull. Soc. Chem.*, III, iv, 728; *J. Chem. Soc.*, lx, 867, July, 1891. G. F. B.

6. *Photography of the Spectrum in natural color.*—H. W. Vogel gives a historical account of the photography of color and an explanation of the failures to accomplish it. It appears that Zenker, in 1868, indicated the method of depositing layers of silver of suitable thickness to produce by interference of light colored photographs, a method which Lippman has lately developed. Lord Rayleigh's (1886) explanation of the colors in photographs produced by adjusting the layers of silver to wave lengths in order to produce colors by interference is a repetition of the explanation of Zenker. In the earlier processes Ag_2Cl was used in the sensitive film and the fixing of the image produced in this film, by hyposulphite of soda, destroyed by separation of fine silver particles the regular layers which were necessary to produce interference colors. Lippman uses pure bromide of silver which, under the operation of fixing, leaves the film in homogeneous, regular layers suitable for producing interference colors.—*Verhandl. d. Physik. Ges. Berlin*, 10, p. 33, 1891; *Photogr. Mittheil.*, 28, p. 7. J. T.

7. *Discharge of Electricity through exhausted Tubes without Electrodes.*—J. J. Thomson points out that the oscillations of the discharge from a Leyden jar produce during the short time of their duration enormous currents in the wire connecting the coatings of the jar, and therefore produce by induction very great electromotive force in the neighborhood of the wire. He therefore investigates the discharge by induction in rarefied vessels by wrapping these vessels with the wire connecting the coatings of a Leyden jar; thus producing luminous discharges in these vessels without the direct passage of electricity from metallic terminals in the gas. Professor Thomson points out that the phenomena bear upon his theory of tubes of electrostatic induction. He regards the distinction between electrostatic and electromagnetic electromotive forces as one introduced for convenience of analysis rather than as having any physical reality. "The only difference which could be made, from a physical point of view, would be to define those effects as electrostatic which are due to tubes of electrostatic induction having free ends, and to confine the term electromagnetic to the effects produced by closed endless tubes. It is only when the electromotive forces are produced ex-

clusively by the motion of the magnets that all the tubes are closed : whenever batteries or condensers are used, open tubes are present in the field." The bearing of Professor Thomson's experiments on the aurora is extremely interesting. The most remarkable appearance was presented when the discharge passed through oxygen. In this gas the bright discharge is succeeded by a phosphorescent glow which lasts for a considerable time, sometimes for more than a minute. The spectrum of the afterglow is a continuous one, without bright lines. The only gas besides oxygen which shows the afterglow is air. The spectrum of the air glow showed bright lines. Professor Thomson is continuing his investigation.—*Phil. Mag.*, Oct., 1891, pp. 323–336. J. T.

8. *Ratio of Electromagnetic to Electrostatic units.*—J. J. Thomson and G. T. C. Searle have undertaken a redetermination of the value of this ratio. A complete account of their experiments can be found in *Phil. Trans.*, Lond., 181 A., pp. 583–621, 1890. The value obtained is $v = 2{\cdot}9955{\cdot}10^{10}$ cm. sec.$^{-1}$.
J. T.

9. *Expansion of Water.*—A useful table of the expansion of water from temperatures 0° to 31° is given by W. Marek.—*Ann. der Physik und Chemie*, No. 9, 1891, p. 171. J. T.

10. *Experiments in Aerodynamics*, by S. P. Langley. 115 pp. 4to, with 10 plates. Washington, 1891 (Smithsonian Contributions to Knowledge, 801).—When the investigation of a subject like that of "flying machines"—at once so stimulating to the popular imagination and yet almost an *ignis fatuus* in the view of sober minds—is made the subject of careful scientific experiment in skillful hands the results are sure to be of unusual interest and value. This is eminently true of Prof. Langley's investigations in aerodynamics which briefly demonstrate experimentally that mechanical flight under proper direction is practicable and further that the support of heavy bodies in the air, combined with very great speeds is not only possible but within the reach of mechanical means now available.

The experiments detailed in this memoir were carried on at Allegheny Observatory between 1887 and 1891. They describe in the first place the "suspended plane"—a thin brass plane a foot square weighing two pounds hung vertically by a spring from a surrounding frame and capable of receiving rapid lateral motion. Briefly expressed the important result of the experiments is to prove that the downward pressure diminishes as the velocity increases, the spring contracting as the plane is carried forward. A second instrument served to show graphically the direction of the total resultant pressure on a square inclined plane and to roughly measure its amount—this is called the "resultant pressure recorder." Still another instrument, the "plane-dropper," was used to demonstrate that a horizontal plane in lateral motion requires an increased time for its descent, and also to measure the time of fall for different planes and other related points, thus giving the soaring speeds of wind-planes set at varying angles and making it possible to compute the work expended in their uniform horizontal flight. Thus it is proved that less work is required in the aerial motion of heavy inclined planes at higher speeds than at lower ones. In the quantitative experiments connected with this part of the subject, a "component pressure recorder" was used together with a "dynamometer-chronograph" to record the speed, the resistance to forward motion at the instant of soaring and other attendant phenomena.

Reference must be made to the memoir itself for the details of the methods and results of the experiments with the instruments, alluded to. It is interesting, however, to note the conclusion reached, that, "so far as the mere power to sustain heavy bodies in the air by mechanical flight goes, such *mechanical flight is possible with engines we now possess*, since effective steam engines have lately been built weighing less than 10 pounds to an horse-power, and the experiments show that if we multiply the small planes which have been actually used, or assume a larger plane to have approximately the properties of similar small ones, one horse power rightly applied can sustain over 200 pounds in the air at a horizontal velocity of over 20 meters per second (about 45 miles per hour) and still more at still higher velocities." The author adds further that the experiments "afford assurance that we can transport (with fuel for a considerable journey and at speeds high enough to make us independent of ordinary winds) weights many times greater than that of a man." He goes on to say (we quote the author's words) that he has "not asserted without qualification that mechanical flight is practicably possible since this involves questions as to the method of constructing the mechanism, of securing its safe ascent and descent and also of securing the indispensable condition for the economic use of the power I have shown to be at our disposal, the condition, I mean, of our ability to guide it the desired horizonal direction during transport—questions which in my opinion are only to be answered by experiment and which belong to the inchoate art or science of *aerodromics* on which I do not enter. I wish, however, to put on record my belief that the time has come for these questions to engage the serious attention not only of engineers but of all interested in the possibly near practical solution of the problem, one of the most important in its consequences of any which has ever presented itself in mechanics ; for this solution it is here shown cannot longer be considered beyond our capacity to reach."

11. *The Chemical Analysis of Iron.*—A complete account of all the best known methods for the analysis of iron, steel, pig-iron, iron-ore, limestone, slag, clay, sand, coal, coke and furnace and producer gases by ANDREW ALEXANDER BLAIR. Second edition. 314 pp. Philadelphia, 1891 (J. B. Lippincott Company).—The first edition of this valuable and attractive work was noticed in volume xxxvi (p. 387) of this Journal. In the

present edition some new analytical methods have been added, the table of atomic weights has been revised and the errors noted during its use for the past three years have been corrected.

12. *Die Fortentwickelung der elektrischen Eisenbahn-Einrichtungen*, von L. Kohlfürst. Vienna, 189 (A. Hartleben's Verlag).—This volume is published in the same form as those of the "Elektro-technische Bibliothek" repeatedly noticed in this Journal. It is devoted to the various applications of electricity to railroad traffic, in the telegraph, telephone, signals, etc., and gives much information on these practical subjects compressed into a small space.

II. Geology and Mineralogy.

1. *Report of Exploration of the Glacial Lake Agassiz in Manitoba;* by Warren Upham. 156 pages 8vo, with two maps and a plate of sections; forming Part E, Annual report of the Geological and Natural History Survey of Canada, vol. iv, for 1888–89.—The departure of the ice-sheet of the Glacial period is shown to have been attended with the formation of a vast lake in the basin of the Red River of the North and of Lake Winnipeg, held by the retreating ice-barrier. It exceeded in extent the combined areas of the great lakes tributary to the St. Lawrence, and had a maximum depth of about 600 feet. Seventeen shore-lines, marked by beach-ridges of gravel and sand, are found at successive levels upon the northern part of this lacustrine area which are referable to stages of the glacial lake while it outflowed southward by way of Lakes Traverse and Big Stone and the Minnesota River. At lower levels, eleven later shore-lines belong to stages of outflow northward, previous to the recession of the ice from the region crossed by the Nelson River, whereby Lake Agassiz was reduced to Lake Winnipeg. The earliest and highest beaches have a gradual ascent of about one foot to the mile northward along an explored extent of 400 miles from south to north; but in the lower beaches there is a gradual decrease of this ascent, and the latest and lowest beaches are very nearly level. It is thus known that the area of Lake Agassiz was undergoing a differential northward uplift during the time of the ice-departure, and that the uplift was nearly completed within that time. On the adjoining country of Minnesota and North Dakota eleven distinct terminal and recessional moraines indicate the maximum extension of this ice-sheet and stages of halt or re-advance interrupting its general retreat; and five of these moraines, namely, the Dovre, Fergus Falls, Leaf Hills, Itasca, and Mesabi moraines, were accumulated after Lake Agassiz began to exist in the Red River Valley.

An appendix of this report gives a tabulation of glacial striæ on the region of Lake Agassiz and the country northward to Hudson Bay and the Mackenzie; and another appendix notes altitudes determined by the Canadian Pacific railway surveys in Manitoba and westward to the Pacific.

2. *Geological Survey of Texas, 2nd Annual Report*, 1890. E. T. DUMBLE, State Geologist. 756 pp. 8vo, with maps, plates and sections. Austin, Texas, 1891.—The introductory chapter of this second Annual Report by Mr. Dumble reviews the work of the year, and the subjects of metallic and other mineral and economical resources of the State. It is followed by an account of the geology and resources of the iron ore district of East Texas, by E. T. Dumble, Wm. Kenedy, J. H. Herndon and J. B. Walker; on the geology of northwestern Texas, by W. F. Cummins; on the geology and resources of the central mineral region of Texas, by T. B. Comstock; and on the geology and mineral resources of Trans-Pecos, Texas, by W. H. von Steeruwitz, with a report on the Cretaceous rocks of the region by J. A. Taff.

Mr. Cummins, in his account of the Permian—the lower division of the Red Beds,—makes them in places 5000 feet thick, and every where conformable with the Carboniferous. He divides the formation into the Wichita or Lower, consisting of sandstones; the Clear Fork beds, limestones, shales and sandstones, and some gypsum; and the Double Mountain beds, including limestones, shales and thick beds of gypsum. The overlying Triassic commences with sandstones and conglomerates, which resemble and are supposed to be the equivalent of the Shinarump conglomerate of Powell—made the beginning of the Trias by Mr. C. D. Walcott. The Permian series is not separable from the Triassic by any marked unconformability, yet it is evident, Mr. Cummins remarks, that there was not continuous sedimentation between the two.

3. *Preliminary Notice of a New Yttrium-Silicate;* by W. E. HIDDEN. (Communicated).—Associated with the huge crystals of gadolinite, with yttrialite and the other yttrium minerals, found in Llano County, Texas, two years ago, I have discovered a few masses of a new species that is exceedingly rich in the yttrium earths. A preliminary examination has shown its density to be 4·515. Its color is pale drab-green when pure. In thin splinters it is perfectly transparent. Its alteration products are of a waxy brick-red color and quite easily distinguished from those of gadolinite and allanite. It is easily soluble in acids, leaving gelatinous silica. The following are the results of an unfinished analysis by the writer:

SiO_2	25·98	
Y_2O_3 etc.	61·91	atomic weight =118.
FeO	4·69	
UO_3	0·40	
CaO	0·19	
Ign. loss	2·01	

No thoria is present and but very little of the cerium earths. The oxygen ratio of the bases found to the silica is 83·47 : 86·60, or pointing to 1 : 1 if the analysis had been completed. Its formula would then be 3 SiO_2, $2R_2O_3$ or of a mineral quite distinct from the gadolinite and yttrialite with which it is found associated. For this silicate so remarkably rich in yttria, I propose the name of ROWLANDITE, after Professor Henry A. Rowland, whose spectrographic work on the so-called "rare-earths" is so novel and important. As opportunity offers a more extended description will be given of this very interesting new species.

4. *Anatase from the Arvon Slate Quarries, Buckingham Co., Va.;* by GEORGE H. WILLIAMS (communicated).—The rarity of American localities for anatase is a sufficient warrant for recording a recent discovery of this mineral in its original position, made by the writer during June last. In the course of a trip through central Virginia occasion was taken to visit the State quarries five miles south of Bremo Bluffs on the James River railroad in Buckingham County. The largest of these quarries, belonging to the Williams Brothers, is situated at the terminus of the short branch railroad, Arvon station. This contains the best quality of slate, but it is proportionately devoid of anything of mineralogical interest. About a mile west of this place, however, where the slate of this district was first opened in what is now known as the Robert's quarry, the cleavage is less perfect and regular, while cross joints are of frequent occurrence. These irregularities, which detract so seriously from the economic value of the slate, make this quarry more interesting than the other to the geologist and mineralogist. Here beautifully crinkled varieties of slate occur, and one regularly mottled sort is quite abundant, which in the field was surmised to contain ottrelite, but was found on more careful examination to owe its knots ("knoten") to small rhombohedrons of some carbonate which is but feebly transparent on account of the great number of inclusions, probably of carbonaceous matter, which it contains. Huge blocks of this imperfect or "bastard slate" have been thrown aside as worthless, and it was on the end of one of these, cut off very evenly at right angles to the cleavage by a cross joint, that the anatase crystals were found.

The surface presented by this joint plane was of large size and was completely covered with small quartz crystals, among which were scattered minute individuals of pyrite and the anatase. The latter was fairly abundant and closely resembles the black, metallic, steep pyramidal variety, so well known from the Tavetsch valley in Switzerland. Hardly any crystals were noticed over a millimeter in length, while most were less than this. No forms except the unit pyramid, 1 (111), and the base, 0 (001), were observed. The pyramidal faces are horizontally striated and often built up into little flights of steps by an oscillatory combination, as is so frequently the case with the Swiss crystals. The faces have a high metallic luster but are broken by growth, irregularities, and vicinal planes, which makes the reflected images multiple and the measurements unsatisfactory. The best crystal gave :

(111) : (1$\bar{1}$1)	98° 7′	97° 51′ (calc. v. Kok.)
(111) : (001)	111° 36′	111° 42′
(111) : (11$\bar{1}$)	136° 20′	136° 36′

The smaller crystals when placed under the microscope are found to be translucent with a rather pale yellow color, metallic lustre, and high refractive index. These show parallel extinction and a uniaxial figure.

I am indebted to my friend, Prof. W. G. Brown of Washington and Lee University, for chemically examining one of the crystals, which he found to be composed largely of titanic oxide.

Baltimore, Aug., 1891.

5. *Ilvaite;* by G. Ch. Hoffmann (communicated).—Several specimens of what proved to be the rare mineral, ilvaite, were received for identification from a gentleman who described it as occurring in large irregular masses in a vein about twenty feet wide, near the head of Barclay Sound, Vancouver Island, British Columbia. Portions of the material were fairly free from foreign admixture containing only small quantities of a white translucent, cleavable calcite, this, however, was in some fragments supplemented by inclusions of altered tremolite, and in others by a brownish-yellow andradite. It had a more or less closely compacted crystalline structure. The lateral faces of crystals were not infrequently striated longitudinally, and sometimes exhibited a slight iridescent tarnish. Color, iron-black ; streak, greenish-black ; luster, sub-metallic, brittle ; fracture, uneven. Before the blow-pipe fuses quietly at about 2·5 to a black magnetic globule. Hardness, 5·5 ; specific gravity, 3·85. Readily decomposed by hydrochloric acid, forming a yellow jelly.

An analysis conducted upon very carefully selected and prepared material, dried at 100° C., afforded the following results :

SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	H_2O
29·81	0·16	18·89	32·50	2·22	13·82	0·30	1·62 = 99·32

6. *Synthese du Rubis*, par E. Fremy. 30 pp. 4to, with 28 colored plates. Paris, 1891, (Vve. Ch. Dunod.)—The synthetic formation of minerals in general is a subject of great interest and one in which French chemists have made remarkable progress of late years. The results reached by one of the laborers in this field, M. Fremy, in the artificial production of rubies are given in this beautiful volume. In the most successful method, the rubies were obtained in an earthen crucible by the reaction at a very high temperature of a mixture of alumina (with more or less potash) upon barium fluoride, with bichromate of potash as coloring matter. They are well crystallized, clear, of brilliant color and sometimes weigh one-third of a carat. The author claims for them usefulness both in jewelry and in watchmaking. A series of fine colored plates show sections of the crucibles with the rubies scattered through the gangue, also clear isolated rhombohedral crystals (magnified), and further, the rubies cut and mounted for ornament in various forms.

7. *Brief notices of some recently described minerals.*—BRANDTITE. A hydrous arsenate of manganese and calcium, formula $Ca_2MnAs_2O_8+2H_2O$, found at the Harstig mine, near Pajsberg, Sweden. It is analogous to roselite and fairfieldite in composition and closely similar to the former species in its triclinic crystals. The color is white with vitreous luster, hardness =5–5·5; sp. gravity =3·671. An analysis gave:

As_2O_5	P_2O_5	MnO	CaO	PbO	FeO	MgO	Cl	H_2O	insol.
50·48	0·05	14·03	25·07	0·96	0·05	0·90	0·04	8·09	0·04 = 99·71

Named by Nordenskiöld and later described by Lindström.—*G. För. Förh.*, xiii, 123, 1891.

GANOPHYLLITE.—A hydrous silicate of alumina and manganese from the Harstig mine, Sweden. It occurs in monoclinic crystals with perfect basal cleavage. The color is brown; hardness =4–4·5; sp. grav. =2·84. An analysis gave:

SiO_2	Al_2O_3	Fe_2O_3	MnO	CaO	MgO	PbO?	K_2O	Na_2O	H_2O
39·67	7·95	0·90	35·15	1·11	0·20	0·20	2·70	2·18	9·79 = 99·85

The formula calculated is $7MnO . Al_2O_3 . 8SiO_2 . 6H_2O$; the author, A. Hamberg, proposes to include it among the zeolites.—*G. För. Förh.*, xii, 586, 1890.

PYROPHANITE.—A manganese titanate, $MnTiO_3$, like the preceding species from the Harstig mine. It occurs in rhombohedral crystals isomorphous with hematite and ilmenite and is probably tetartohedral like the latter species. The color is deep blood-red; hardness =5; sp. grav. =4·537. An analysis gave:

TiO_2 50·49 MnO 46·92 Fe_2O_3 1·16 Sb_2O_3 0·48 SiO_2 1·58 = 100·63

Also described by Hamberg, *ibid.*

OFFRÉTITE.—A new zeolite near phillipsite in composition, from Mt. Simionse, Montbrison, France. It occurs in white hexagonal crystals with sp. grav. =2·13. An analysis gave:

SiO_2 52·47 Al_2O_3 19·06 CaO 2·43 K_2O 7·72 H_2O 18·90 = 100·58

Described by F. Gonnard, *C. R.*, cxi, 1002, 1890.

KALLILITE.—A nickel ore from the Friedrich mine near Schönstein a. d. Sieg. It occurs in massive form with a light bluish gray color. Analysis gave:

S	Sb	As	Bi	Ni	Fe	Co
14·39	44·94	2·02	11·76	26·94	0·27	0·89 = 101·21

This corresponds essentially to NiSbS. Described by Laspeyres, *Zs. Kryst*, xix, 12, 1891.

SYCHNODYMITE.—A cobalt ore also described by Laspeyres (l. c., p. 17) from the Kohlenbach mine at Eiserfeld near Siegen. It occurs in isometric crystals of a dark steel-gray color. Analysis gave:

S 40·33 Cu 17·23 Co 35·64 Ni 5·74 Fe 0·82 = 99·76

This corresponds to $(Co, Cu, Ni)_4S_5$, like polydymite.

UMANGITE.—A selenide of copper occurring with eucairite in the Sierra de Umango, Argentine Republic. It occurs in fine granular massive forms, with metallic luster, dark cherry-red color; hardness =3; sp. grav. =5·620. Analysis gave:

Se 36·18	Cu 44·27	Ag 0·45	Fe 0·16

The calculated analysis is Cu_3Se_2. Described by F. Klockmann, *Zs. Kryst.*, xix, 269, 1891.

ANTLERITE.—A basic sulphate of copper of a light green color, occurring in massive form at the Antler mine, Yucca Station, Mohave Co., Arizona. After deducting 6 to 8 p. c. gangue, the mean of two analyses gave :

	SO_3	CuO	ZnO	CaO	H_2O
Sp. grav. = 3·93	20·98	67·91	0·16	0·05	10·94 = 100·04

The formula suggested is $3CuSO_4 . 7Cu(OH)_2$. Described by W. F. Hillebrand, *Bull. 55, U. S. G. Surv.*, p. 54, 1889.

PLUMBOFERRITE.—A mineral from the Jakobsberg mine, Nordmark, Sweden, occurring in black cleavable masses. Analysis gave :

Fe_2O_3	PbO	FeO	MnO	MgO	CaO
60·38	23·12	10·68	2·20	1·95	1·67 = 100

Described by Igelström in 1881, and again in 1891, *Zs. Kryst.*, xix, 167.

8. *Catalogue of Minerals and Synonyms*, by T. EGLESTON, 378 pp. 8vo. New York, 1891 (John Wiley & Sons).—The mineral collector, perplexed by the confusing multiplicity of mineral names, will find much assistance from the present volume. It gives a very full alphabetical list of mineral synonyms with references to the names of the recognized species, under which they are arranged chronologically with the author's name. This work is expanded from a similar earlier list, which appeared as Bulletin 33, of the U. S. National Museum (noticed in this Journal, xxxviii, 494, 1889).

III. BOTANY.

1. *Some Museums and Botanical Gardens in the Equatorial Belt and the South Seas.*—(Fourth paper). The Queensland Museum, at Brisbane, under the charge of Mr. de Vis, is rich in specimens illustrating the Natural History and Ethnology of the Colony. It is well arranged, although much crowded, and is thoroughly appreciated by the community. Here, as elsewhere in the Colonies, much attention is paid to the collection and conservation of objects which are of special significance in the locality : hence many of the collections are treasure-houses of incalculable value to the colonial and to the general student. Even the smaller collections of minerals and of aboriginal curiosities are well managed, so that the amount of material at the command of a student in any of the departments of Natural History, Geology, Ethnology, and Anthropology, is large and readily available. To this is to be added the statement, that the Curators of the collections, although sedulously guarding the unique specimens, afford every facility for their comparison and examination.

The voyage from Brisbane northward to Java is intensely interesting. In the first place, the steamers stop at various points along the coast of Queensland, giving opportunity for a hasty glance at the natural features, while in the second place, the waters through which one sails, are protected by the long barrier reef. These coral reefs extend from 24° 30′ south latitude as far as Torres Straits at the North, in latitude 10°. The distance between the irregular reef and the shore varies greatly, being in some places about one hundred miles, in others less than ten miles. For a good part of the voyage near the upper extremity of the great York peninsula, the shore is plainly in sight, while on the other side of the ship one can see the low-lying islands of the Barrier Reef. The whole distance from Brisbane to Thursday Island, 1430 miles, is under the direction of coast pilots.

The voyage at this part is almost like a sail along the banks of a wide river. The shore is frequently fringed by mangroves, while on the higher land the tropical trees are thickly crowded. For considerable distances, the steamer keeps so close to the shore, that one can discern the habit of the larger trees. At certain straits one can see distinctly even the hills of the white ants, and the forms of the lower shrubs.

It is impossible to forget, as one sails along this coast, how closely every part is connected with the discoveries of Capt. James Cook. The names of some of the headlands and bays bear witness to the arduous efforts of this intrepid navigator, and serve as the lasting memorials of the perils and adventures of Cook's "first voyage." Among these names are: Weary Bay, Cape Flattery, Cape Tribulation, Repulse Island, and so on; together with many which simply note the dates on which the places were touched during the voyage, such as Whitsunday Passage, Pentecost Island, Wednesday Island, Thursday Island. The place last named has the safest harbor in the region. It is at this point that the coast pilot relinquishes his charge to the captain.

At Thursday Island, our ship was placed in quarantine, owing to a case of supposed scarlatina. This disease had been epidemic at our port of departure, Brisbane, and a single slight case on board appeared to justify the health officer of the port in preventing any of the passengers from landing. Therefore we remained nearly a day in sight of an interesting shore, with no opportunity to visit it or receive collections from it.

The passage through Torres Straits is considered one of the most dangerous bits of navigation in the world, owing to the presence of numerous small islands and hidden reefs, with currents which are as yet not fully understood. It was at this place that the "Quetta" sank just one year before we passed the spot; her commander was in charge of our own steamer and gave us harrowing details of that disaster.

At Torres Straits we were only a few miles from the southern part of New Guinea, but we passed it at night and did not catch a sight of land. The first land sighted, but still at a considerable distance, was Timor Laut, after we had traversed the Arafura

Sea. Many of the larger islands in the lower part of the Banda and Flores seas are seen plainly, the steamer often going near enough to enable passengers to make out points of interest on land. Every facility was afforded me for securing photographs of this region. Some of the views are fairly satisfactory. Sumbawa, Lombok, Bali and Madura, are among the vivid recollections of this portion of the voyage. The volcanic character of the commanding mountains which, with their outlying flanks, make up the islands, is impressed upon every feature of the scenery. The same is true of the long island of Java which we skirted on its northern side.

At Tanjong Priok, Java, the harbor of Batavia, we were everywhere surrounded by tropical vegetation. All the land there lies very low, and has a bad reputation on account of the fevers prevalent at the coaling station. Passengers make their way, past very considerate custom-house officials, to the train in waiting, and thence over a level plain, to Batavia, a few miles away. The city of Batavia is full of interest to a naturalist, but the attractions at points farther up the railroad leave but scant time for the city.

My objective point was, of course, Buitenzorg, the locality of the famous garden. For a good many years, accounts by friends in Holland had led me to form high expectations with regard to this Javan garden. I may say that in no respect were these expectations unrealized. It is impossible, as I have said in a former paper, to compare the garden at Pérádeniya, in Ceylon, with this in Buitenzorg, although they belong to the same class. No intelligent visitor can fail to be gratified by these glimpses of well-arranged tropical vegetation: if the traveler can take into his tour both of the gardens, by all means let him do so; but let him not fail to go out of his way to see at least one of them.

Etymologically, Buitenzorg is almost the exact equivalent of *Sans Souci;* besides, each has its palace. Hence, as might be inferred, Buitenzorg possesses a strong park-like character at that portion which is near the government grounds. Aside from this, the arrangement is that of a botanic garden proper, and everything is made tributary to it.

The large specimens of trees have proved in some cases embarrassing to the director in his endeavors to rearrange the plants, but he has wisely left the most important of these in their old places, seeing to it, however, that they are so conspicuously labelled that no confusion is likely to result.

At the time of my visit, a display of tropical fruits had been arranged in one of the large plant houses for the inspection of the Crown Prince of Russia, and I had the pleasure of examining carefully what was considered one of the largest collections ever brought together. Nothing could give a better idea of the immense resources of the garden.

Dr. M. Treub, the Director of the Garden, has carried out well-matured plans for the establishment of a station for phytologic study, and the government has given him adequate support. In his admirable laboratories, students can find every appliance for their investigations. The *Annals of the Botanic Garden at Buitenzorg* show how well these advantages have already been improved. Dr. Treub authorizes me to state to American students of Botany, that he would be happy to communicate with any who are prepared to undertake special investigations. Arrangements are now in progress at Cambridge, by which it may be possible for one American student of Botany to be supported in Buitenzorg, for a term of one year : it is among the possibilities that a fund may be obtained by which such an subvention may be made permanent, and that American botanists may have this privilege of examining tropical plants under the most favorable conditions. It is not amiss to say in connection with this subject that the climate of Buitenzorg is healthy and agreeable, and also that the surroundings are exceedingly interesting in numerous ways.

On a contiguous mountain, the garden supports an annex. Here are cultivated the plants which are impatient of the temperature of Buitenzorg. Experiments in acclimatization can be carried on in both places. Not very far away from the the main garden, are the economic grounds, and in these are the laboratories recently established to supplement those at the main garden. The products of useful plants can here be examined chemically and physically, by the side of the plants which produce them. The suites of varieties under cultivation are very large, and constantly receive additions from other tropical regions.

It is needless to say that the region lying to the east of Buitenzorg, the hill country, with its ruined temples and with its active volcanoes, ranks among the most interesting places in the world, whether regarded from an ethnological or a geological point of view.

The voyage from Batavia to Singapore, 380 miles, takes one past the island of Banca and close by Sumatra, but the vegetation cannot be made out clearly except at one or two points.

The garden at Singapore, under the direction of Mr. Ridley, is very attractive. The plants are in good condition and everything is kept up to a high standard of efficiency. Here also there is an experimental garden filled with useful plants in great variety. Mr. Ridley has wisely left one part of his garden in its wild state. In this bit of untouched jungle, uninvaded by even a single foreign plant, except at the border, one can see many of the tropical plants in the thickest of their unrelenting struggle for existence. With creepers swaying from the lofty tropical trees, intertwined in confused tangles ; with pitcher-plants at one's side and under foot ; with the chatter of monkeys overhead, and the cries of the startled birds all around, one can appreciate the endless variety of organisms in favored regions in the tropics. The Malaccan garden which lies a short distance to the north of Singapore I did not have time to visit.

The last of the tropical gardens seen by me on the present journey was in French China, at the city of Saigon. Everything here was frightfully dry after a comparatively rainless season, but strenuous efforts were being made to renovate the grounds before the arrival of the Russian Crown Prince. The grounds appeared to have been given up almost as much to an attempt to make a Zoological Garden as a Botanical one, but many of the animals had been temporarily carried to another place, and the display was very meagre. The plants were mostly young and although very interesting, possessed no features worthy of special remark. The supply of water for the garden at Saigon did not seem copious or good. Under such circumstances, it must be a discouraging task to organize a botanic garden. At the time of my visit, the directorship was vacant, and the grounds were in charge of a foreman. The gardens are here, as in other tropical ports, one of the principal attractions for the steamship passengers and for the townspeople. This fact leads the directors to make the grounds as attractive as possible from a scenic point of view, without injuring them for the purposes for which they are primarily designed.

Hong Kong has a very charming park which may also rank as a Botanic Garden. It is beautifully laid out on a very irregular hill or series of slopes. Many of the specimen trees are in excellent condition, and all of them are effectively grouped.

The small parks at Shanghai cannot in their present condition be regarded as gardens. The climate favors the growth of warm temperate plants, and these, as cultivated in the private gardens of the China coast, are said to be among the most interesting examples of Chinese horticultural work accessible to visitors. Time did not permit me to examine any of them. G. L. G.

IV. Miscellaneous Scientific Intelligence.

1. *Leidy Memorial Museum.*—As a memorial to the late Dr. Joseph Leidy it is proposed to raise a fund to establish and endow the Leidy Memorial Museum as an independent part of the great museum now forming at the University of Pennsylvania. The amount desired for this purpose is $50,000. The interest derived from this fund will be devoted exclusively to Dr. Leidy's family during the lifetime of his widow. Subscriptions may be made payable at once or in instalments extending over two or three years as may be approved by the donors. Contributions of all sizes will be received gladly; it is designed to make this a general tribute. Checks should be drawn to the order of Robert R. Corson, Treasurer, 37 Forrest Building, Philadelphia, Pa.

2. *Bibliotheca Zoologica*, II, Dr. O. Taschenberg. Neunte Lieferung, sig. 321–360, pp. 2611–2928. Leipzig, 1891 (Wm. Engelmann).—The ninth part of this great work has recently appeared, containing the closing part of the bibliography on Insects, also on Molluscoidea, from Bryozoans to Gasteropods.

3. *Catalogue of Minerals.*—Messrs. George L. English & Co. have issued a supplement of 20 pages to their Catalogue of Minerals. It gives a list of new species, with republished notes on various old species, especially of American source.

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WITH PLATE XVI.

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[THIRD SERIES.]

ART. XLVII.—*On Percival's map of the Jura-Trias trap-belts of Central Connecticut, with observations on the upturning, or mountain-making disturbance, of the Formation;* by JAMES D. DANA. With a map. Plate XVI.

IN my paper on the features of non-volcanic igneous ejections as illustrated in the Four "Rocks" of the New Haven region at page 79 of this volume, the resemblances in general structure and system of arrangement between the West Rock trap-ridge and the other trap-ridges of the Jura-Trias in the Connecticut valley are referred to as evidence of oneness in method of origin; and also of oneness in time of origin, whether before or after the upturning of the sandstone, the great mountain-making event of the valley. This evidence—now contested though formerly considered conclusive—cannot be fully appreciated without a knowledge of the general arrangement of the trap-belts of the valley. Happily, we have an excellent map of these belts in Percival's geological chart, published in his Report of 1842 on the Geology of the State of Connecticut.*

* An octavo volume of 496 pages, with a folded geological chart of the State.
James G. Percival, born and brought up in the township of Berlin, southwest of Hartford, was early familiar with all the intricacies of that knotty region of trap-belts. He became a great scholar in all the learning of the day—an excellent mathematician, a professor of chemistry in 1824, a learned linguist and philologist, one of the best of geographers; and in all departments he was an acute and thorough student and observer. Along with this he had a wonderfully good eye for topography, and a memory which retained all the facts that ever entered it. Nearly all the money he received went for the purchase of books, and he thus acquired a very valuable library at the expense of poverty to himself. At

The Map: some of the Features of the area, and facts connected with its Southern termination.

As Percival's Report is little known among geologists I introduce a photo-engraved copy of the middle portion of his chart, which includes the larger part of the Jura-Trias area, along with borders of the eastern and western metamorphic regions of the State. It makes Plate XVI.

The Jura-Trias area, or that of the Connecticut valley sandstone, is the colored portion. The length from the Sound to the northern limit, 3 miles north of Hartford, is about 37½ miles. It contains all of the more complicated portion of the trap-region of Connecticut, the part omitted having only the continuation of the two western belts and another smaller on the western margin of the area.

The narrow linear areas on the map are the trap-belts. They include, according to Percival, simple trap-dikes and dikes with outflows between layers of sandstone. The breaks in the trap-belt of a range generally correspond to actual intervals in the extrusions of trap. But in some cases, as in the body of Mt. Carmel, they indicate only abrupt depressions in the ridge, Percival appearing to regard them as a consequence of partial interruptions in the outflow; and in the southern end of West Rock, where the bay of sandstone just north (Plate VI) evidently suggested a similar supposition.

About New Haven the figures 1, 2, 3, 4, mark successively East Rock, Mill Rock, Pine Rock and the West Rock Ridge. The long southern part of the latter is lettered W S I, and the northern W S I I. North of North Haven at 6 is Mt. Carmel. In the northern part of the town of Meriden are the "Hanging Hills"; and 3, 4, 5, 6, 7, 8, 9, and others beyond are parts of the longest and most elevated trap-range of the valley; it continues to Mt. Tom in Massachusetts, nearly 56 miles, and has a height of 996 feet at its southern end according to Guyot's barometric observations.

To the east of New Haven and New Haven Bay, in East Haven, the bow-shaped trap-ridge, E I, is the Saltonstall

his death it was sold for $20,000. Such was the man that made the remarkable survey of the trap-belts of Connecticut. He received but small pay from the State, and at last had to content himself with a very insufficient sum for the publication of his Report—"not exceeding $1,500, for printing and superintending." The Report is therefore but an abstract, as he says in his Preface, of what with more generous treatment he would have published.

His geological science was not altogether that of the present day; for he believed that the crystalline formations were segregations out of a world-wide magma; but he still, as he says, recorded in his note-book more than 8,000 dips and strikes, realizing their value in investigation far better than many a recent student of such rocks. It is greatly to be regretted that a full Report was not published.

Percival was born in 1795 and died in 1856.

ridge (Pond ridge, of Percival) on the west side of Saltonstall Lake. To the north of this ridge, and a little to the eastward, is another bow-shaped ridge, the Totoket; and the line of these two ridges is continued northward by other high trap-ridges, extending along the western borders of the townships of Durham and Middletown and beyond toward Hartford.

In the metamorphic region, outside of the Jura-Trias, there are two dikes, one on the east, and another on the west. They are referred by Percival rightly to the same system as those within the area. That on the west is the "Buttress Dike" in its course through Woodbridge and Orange, lettered W. 1. The eastern one commences in Branford and is continued through North Branford, where it is lettered 3 E. 1., and northeastward, as mapped by Percival, to the Massachusetts line.

The large river in the northeast corner of the map is the Connecticut. At Hartford its course becomes changed from south-by-west to south; and at Middletown it leaves the Jura-Trias area and goes off southeastward to the Sound, the waters having been forced from their former course by the barrier to the west made of belts of trap and adjoining hard sandstone—an event which took place whenever this trap region was raised above the sea-level. The valley lying to the west of the Mt. Tom trap-range contains to the north the large bend of the Farmington River; the left side of the bend received waters from the northwest, the right continues the flow northeastward to the Connecticut. South of this there are the head-waters of the Quinnipiac, and still farther south, Neck River, the stream also called Mill River.

The southern end of the area, as is shown on the map, narrows rather abruptly, owing mainly to the bending westward of the eastern side. While the width is eighteen miles in the latitude of Middletown, it is hardly two at the entrance to New Haven Bay, the southern end of the Jura-Trias estuary. The granitoid gneiss of the eastern shore and of Light House Ledge extends to within two miles of the slaty rocks (chloritic hydromica schist) of the western cape, or Savin Rock;* and as the depth off the latter cape is but a few feet and over sands for a long distance out, the actual width of the interval may not be more than a mile and a half. The outline on the east is followed closely by the easternmost trap-dike, showing, apparently, that the narrowing is a fundamental feature of the

* The granite and gneiss of the eastern Cape are probably Archæan, and the hydromica schist of the western side with the feebly crystalline limestone which occurs in it, and with other schists to the west, may be early Paleozoic.

area, and not one due to a subsequent uplifting of the coast-region and its denudation. This narrow channel at the end is the more remarkable in view of the fact that only five miles north of the outcropping granite of the shore, the sandstone, —as the recent condition of the boring at the Winchester Repeating Arms Factory shows—extends to a depth below the sea-level of at least 3,100 feet. The metamorphic rocks of the hills to the west are only two miles distant, and hence that side of the trough has a mean pitch of 1 : 3¼, or about 17½ degrees, but much larger than this, probably in the western or outer of the two miles, and smaller in the inner. The southern extremity of the Jura-Trias trough or geosyncline has, hence, something of the shape of the prow end of a boat.

These facts seem to prove that the Jura-Trias trough, or at least its lower 3,100 feet, did not extend out into the Sound but had its termination in what is now New Haven Bay.

For explanations of the lettering on Percival's map and other details, reference must be had to his Geological Report. The scale of the map is nine-tenths of an inch to five miles.

The uplifts, whether before or after the trap-ejections.

Is the West Rock trap-range in which the uplifting preceded beyond question the eruption, typical for all the north-and-south trap-ranges? The form of the trap-belt on the map is strikingly like that of other trap-ranges in the valley, in the little width of its outcrop, in the composite character of the belt, in its hooked extremity, in the curvature and overlapping feature of the parts, and in its gradual disappearance seventeen miles to the north just west of where another greater range—the Mt. Tom Range begins. The fact that this western range was erupted after the upturning of the sandstone affords hence some reason for suspecting that this was true also of the rest of the trap in the system of ridges.

In East Haven, east of New Haven, the first trap-ridge west of Saltonstall Lake afforded, at its southern end, the section on page 104, proving that this belt also, like that of West Rock, was erupted after the upturning of the sandstone. This ridge is only 500 yards west of the Saltonstall Ridge, and it may be reasonably believed that the bow-shaped ridge was also an outflow after the upturning. This conclusion is sustained by the further fact that the third example of trap overlying upturned sandstone mentioned on page 105, stands directly to the east and only 3000 yards away. Moreover Dr. E. O. Hovey, in his paper already referred to, makes the trap of Saltonstall ridge intrusive; and the conclusion, according to my own examination with him of his facts, I believe to be right.

Again, Dr. Hovey has proved that the first trap-belt *east* of the Saltonstall belt, just across the lake, is a dike. It is shown by the hard-baked condition of the sandstone on its east side. He infers also that it was subsequent in origin to the Saltonstall belt, since the overlying sandstone contains stones of vesicular trap which were derived with little doubt, like those of the Jura-Trias bowlder-conglomerate south of the northeastern extremity, from this northeastern extremity. The position of the hills of bowlder-conglomerate is shown on the map (Plate XVI).

Further the bow-shaped form of Saltonstall ridge is repeated almost exactly in the larger ridge next north, the Totoket, and hence whatever is true of one as to origin is pretty certain to be true of the other. And what then of the other ridges farther north in the same line?

We note also that these bow-like shapes, in the trap, with the dip of the associated sandstone on the east side of each—as observed by Professor Davis, and later for Saltonstall ridge by Dr. Hovey—toward the center of the arc, is not the form or condition to be looked for in regions of monoclinal uplifts. The dip is nearly centroclinal not monoclinal.

The map enables the reader to observe that the facts here cited favoring ejection *after* the upturning, that is, after the great mountain-making event of the valley, are from the whole width of the southern end of the Jura-Trias area; and it is also seen that from this end northward there are suggestive facts bearing in the same direction. Still they are not complete demonstration that this is true for the northern part of the area. We have to leave the question here until other long east-and-west sections of north-and-south trap ridges as complete as that of West Rock have been reported upon.

In the account of the East Rock ridge (page 98 of this volume) the separation of the Snake Rock trap-mass from that of East Rock and Indian Head, and the bow-like shape of the latter with centroclinal dip in this southeastern part, have been attributed to the caving in of the hanging wall of the eastward-dipping fissure that supplied the lava. It is worthy of consideration whether the south end of the Totoket bow and the northern of the Saltonstall line may not have had a similar origin.

Character of the Mountain uplifts made at or near the close of the Jura-Trias period.

Like the post-Carboniferous mountain-uplifts, the parallel-series made at the close of the Jura-Trias were commenced by the accumulation of sediments in gradually deepening depressions of the earth's crust, or geosynclines; but while the era of deposition in the former ended in displacements producing great flexures of the accumulated formations besides profound faults, that of the latter ended in producing monoclinal uplifts, and also, it is believed, great faults. Further, while the post-Carboniferous uplifts of the Atlantic border include three individual mountain-ranges: (1) That of the Appalachian area from Alabama to the Catskills, 1500 miles long; (2) That extending from Newfoundland southwestward through Nova Scotia, and probably to Rhode Island, in all 1000 miles long, and that of the Gaspé-Worcester range,* the post-Jura-Trias system embraced eight or more individual ranges, of cotemporaneous origin, each of the several basins having been independent in its geosyncline and in its uplifts.

Of the two mountain-making epochs, only the latter included, among the events of each mountain-individual, extensive igneous eruptions. Of the ejections in the Connecticut Valley, those of West Rock Ridge and of at least two others in East Haven occurred, in the course, or near the close, of the mountain-making movements. If this proves to be the time of the event in general for the other trap ridges of the valley, then all were a result of, or a sequel to, the movements. But if, as Professor W. M. Davis holds, the trap of most of the ridges originally alternated in sheets with horizontal layers of sandstone and both were uplifted together into monoclines, then the ejections occurred while deposition in the geosyncline was in slow and quiet progress. The decision of the question is, therefore, one of dynamical importance. Professor Davis states that the eruptions had nothing to do with the upturning, and this is true in either case.

Fault planes concerned in the uplift.

The conformity between the general direction of the structure-lines of the Jura-Trias formation and that of the crystalline schists adjoining and the mountain ranges to the west, has long been recognized. The view suggested by Prof. Davis goes beyond this in supposing a conformity also between the dips of the foliation-planes and those of the fault-planes. He says: "A group of inclined slabs compressed by a horizontal force about at right angles to their strike might yield in part by minute internal rearrangement, and in part by slipping on their divisional surfaces, so as to reduce their breadth by standing more nearly vertical, that is, more nearly at right angles to the compressing force. In so doing, the upper surface of the group would be somewhat elevated, and at the same time the bevelled edge of every slab would be tilted over by a tolerably constant angle in one direction, and separated from the neighboring slabs by a dislocation with the uplift on

* This Journal, xxxix, 380, 1890.

the side of the direction of dip. In case the compression varied at different depths, diminishing downwards, a shearing force would be introduced, by which the slabs could be thrown over past the vertical."* Accordingly, his figure represents the sandstone overlying the inclined upper surfaces of the successive slabs or blocks, and as deriving in this way its eastward dip. The fault-planes, it will be understood, are not those of the fissures that supply the trap; for in his view the trap and sandstone were in alternating sheets before the upturning took place. These fault-planes are nowhere open to view, and hence the idea has not been sustained by actual comparisons. It is presented by Prof. Davis simply as an hypothesis for future consideration.

Assuming with him, as we may safely, that the dip of the fault-planes is eastward, I mentioned in my former paper as an exception to the hypothesis, a want of correspondence between the strike of the West Rock dike and other dikes near New Haven and that of the schists within a mile to the westward of West Rock, confining my statement of facts to those of the New Haven region. This objection is not quite apposite, since the comparison is made with the direction of trap-dikes and not with the strike of the sandstone which most nearly represents that of the fault-planes. I now mention other facts bearing on the question. West of the New Haven region, along a line through Orange and Birmingham sixteen miles long, there are five changes between eastward and westward in the dip of the metamorphic schists, and in the course of them there are variations in the dip from horizontal to vertical. The last of the five is a case in which a broad and low anticlinal, consisting of coarse gneiss and mica schist with a bed of crystalline limestone, has the beds for a long distance nearly horizontal. As the mean width of the Jura-Trias area in Connecticut is twenty miles, there is therefore room for equally large variations in the dip of the crystalline schists beneath it. Again, in Berkshire county, Massachusetts, as well as to the north and south, among the metamorphic rocks of the earlier Paleozoic, or Taconic, series, the dips vary from east to west, and from zero to 90 degrees. Such facts, however exceptional, make it necessary to substitute for the expression "planes of foliation," that of planes having the mean or the prevailing, direction of the foliation; for these would be the planes of easiest cleavage in schists of great thickness.

Again, as another modification in the statement of the hypothesis, it appears necessary to make the chief foliation-planes not those of the rocks constituting the upper one, two

* This Journal, xxxii, 349, 1886. See also 7th Annual Report of the Director of the U. S. Geological Survey.

or three miles of the crust, but those below, where Archæan rocks and those subjacent to the Archæan exist. For the fractures were begun below, and in these nether rocks foliation has probably, as a consequence of Archæan pressure or tension, much greater uniformity than in those of the surface. Still the more superficial foliation would have its influence.

Again, the direction of planes of fracture, or of faulting, would have depended largely on the direction of the lateral thrust or pressure in the earth's crust producing the strain, whether normal or oblique, to the plane of easiest cleavage; an idea which, under large extension has been applied by the writer in an explanation of the origin of the courses in the feature-lines of the globe.

The production of an eastward slope in the upper surface of the faulted blocks by compression and molecular transfer, sufficient by the hypothesis to produce the dip in the sandstone, may be questioned; and also the view that the horizontal force concerned would make, in gneiss, and in other rocks equally firm, faulting along foliation-planes of the high eastward dip of 60° to 80°, instead, for the most part, of fractures oblique to these planes. To obtain a dip of 20° in the top-surface of the westernmost slab or block (and the sandstone over it), the displacement a mile down would have to amount to 1800 feet; and to render the westward shove below, to this distance, possible, the compression would have to take much from the thickness of this western block on its western side, and much from the rock next west, a part from each. This would be required whether the other blocks were compressed or not. When done, it would suffice to give the same dip to the top-surface of all the blocks in the series without their compression; but these would also be compressed, and the result would be a large increase eastward of dip—a condition which does not accord with observation.

But suppose the blocks to be so displaced, and pushed up thereby nearly to verticality, or beyond it, then they would have had little or no westward thrust against the sandstone, and accordingly none is appealed to in the statement of the hypothesis. Yet, a pitch of 10° to 25° in the sandstone implies much diminution in the width of the area. If the mean dip is 18° the diminution would be, theoretically, 5 per cent, equivalent to 1 foot in 20; or if 14°, 3 per cent.* The effect should have been manifested in wide longitudinal fissures if this were not prevented by a westward thrust of the sandstone.

* The sandstone in some portions is nearly horizontal, as in the region of the Portland quarries, on its eastern border; and occasionally the dip is westerly. Hence a mean dip of 14° is probably most correct. Small flexures also occur but only locally.

I pass here to an explanation of the origin of the dip in the sandstone which appears to me to harmonize best with the facts.

Daubrèe's experiments on the effects of lateral pressure, published in his "Géologie Expérimentale" (and briefly presented in my Manual of Geology), have appeared to me to sustain the idea that the great fault-planes of the earth's crust made by lateral pressure must be, as a general rule, very oblique. I have accordingly been led to suppose that the fault planes in the case of the Jury-Trias were examples, and I have referred in my Geology to the dip of nearly 45° in the East Rock dike as having this explanation. Two, three or more such fault-planes, coming up from the depths below and entering the geosyncline, would have among their effects: (1) the narrowing of the arc of the Connecticut valley geanticline; (2) the forcing of the sandstone to accommodate itself to the diminished width through fractures, faults and displacements; (3) the production of earth-shakings of great violence which would have produced other fractures through the 5000 feet or so of sandstone and multitudes of pieces by minor fractures. In this state of the sandstone, the shoving of it to the westward by the westward-and-upward movement of the faulting blocks, would make monoclines with eastward dips, and not flexures, because the blocks into which the formation had been divided were each too short for flexures and the piles of layers would necessarily, under the circumstances, become pushed up one over another. I stated in my former paper that slickensided surfaces of the East Haven sandstone covered blocks of all sizes, from those no larger than the hand to those constituting large sections of a quarry, and also in some places the upper and under surfaces of the layers of sandstone; and this fact accords well with the above explanation of the method of upturning.

If this view is the right one, the westward dip of the Jura-Trias sandstone in New Jersey and to the south was due to fault-planes having a reverse direction from that in the Connecticut valley, that is, a westward dip. The fundamental fact awaiting explanation is not, therefore, the opposite directions of dip in the Connecticut Valley and New Jersey sandstone, but the opposite directions of fault-planes in the subjacent rocks. The two directions of strain appear to have anticlinal relations.

The above explanations, for the reasons already stated, have no reference to the origin of the fissures for the trap ejection. If they are mostly of later date than the upturning, tension may have had much to do with their production. In any case, the old fissure, or part of them, would probably have again been used.

Art. XLVIII.—*The Detection and Determination of Potassium Spectroscopically*; by F. A. Gooch and T. S. Hart.

[Contributions from the Kent Chemical Laboratory of Yale College—X.]

Bunsen and Kirchhoff originally determined the delicacy of the spectroscopic test for potassium by exploding in a darkened room a mixture of potassium chlorate with milk sugar, and observing the amount of finely divided chloride which it was necessary to diffuse through the given space in order to bring out unmistakably the spectrum of the metal. These investigators were able to state that the presence of no more than $\frac{1}{1000}$ of a milligram of the potassium salt is sufficient to give to the flame the characteristic spectrum of the element. By similar methods, the delicacy of the tests for lithium carbonate and sodium chlorate were shown to be a thousand times and three thousand times as delicate respectively. Practically, the detection of lithium and sodium spectroscopically is extremely easy and satisfactory, the only difficulty being that the exceeding delicacy of the sodium test, and the ubiquitousness of sodium salts often make a decision doubtful as to whether that element is present essentially in the substance under examination, or by accident. With potassium the case is different, and experience shows that, when the test is to be made for very small amounts of potassium, the simple method in vogue for developing the luminosity of lithium and sodium—the dipping of a single loop of platinum wire in the liquid or solid substance, and the placing of the loop in the Bunsen flame—fails, because, as it seems to us, so great a proportion of the material is dispersed before the heat of the flame effects the dissociation of the metal which precedes the production of the spectrum.

We have endeavored to improve the conditions of exposure of the test-substance by making use of more powerful flames and by substituting for the single loop the hollow coils of platinum wire first recommended, so far as has come to our knowledge, by Truchot* in the description of a method for the quantitative determination of lithium. Such coils are easily made by winding the wire somewhat obliquely about a rod of suitable size, pressing the coils close together, and gathering the free ends into a twisted handle. The size of the coils is adjustable without difficulty, so that each coil may be made to hold almost exactly any appropriate amount, and to take up this amount with very little variation in successive fillings, provided only that the precaution be taken in the process of filling to plunge the coil while hot into the liquid, and to keep its axis inclined obliquely to the surface of the liquid

* Compt. Rend., lxxviii, 1022.

while withdrawing it. How closely the capacity of such coils may be adjusted, and how uniformly they may be filled is shown in the figures of the accompanying record.

	I.	II.	III.	IV.	V.	VI.
	grm.	grm.	grm.	grm.	grm.	grm.
Weight of filled coil	0·1996	0·2780	0·2794	0·2844	0·3572	0·3296
" "	0·1996	0·2780	0·2794	0·2845	0·3571	0·3296
" "	0·1996	0·2780	0·2794	0·2844	0·3572	0·3298
" "	0·1996	0·2780	0·2794	0·2845	0·3571	0·3298
" "	0·1996	0·2781	0·2794	0 2844	0·3571	0·3296
" empty coil	0·1986	0·2760	0·2764	0·2804	0.3521	0·3100
" contents (mean)	0·0010	0 00202	0·0030	0·00404	0·00504	0·01968

It is plain that we have in these coils simple means of taking up known amounts of material in solution; and by gentle heating the liquid may be evaporated and the solid material left thinly and uniformly spread, not easily detachable, and so in condition to be acted upon with effect when brought to the flame. The evaporation may be conducted with little danger of loss of material by holding the handle of the coil across the flame with the coil proper at a safe distance outside; but we have generally, and preferably, used a hot radiator over which the coils are exposed, the handles resting upon a flat asbestos ring. The burner which we have used in heating the coils before the spectroscope is of the Muencke pattern and gives a powerful flame 3 cm. wide at its base. We have generally adjusted the flame to a height of 20 cm., and have introduced the coil, after thorough drying, just within the outer mantle, on the side next the spectroscope, with the axis transverse to the slit of the spectroscope and the handle across the body of the flame. In cleaning the coils we have found it convenient to heat them in the flame of an Argand burner of the Fletcher pattern, beneath which is burned, in a small lamp, alcohol containing about a twentieth of its volume of chloroform. The products of combustion of the alcohol and chloroform are conveyed to the interior of the flame above by a glass funnel fitted by a cork to the tube of the Argand burner. This arrangement of apparatus gives a hot colorless flame through which hydrochloric acid is constantly diffused in condition to clean the wires completely and without attention. The spectroscope which we have employed is a well-made single prism instrument provided with a scale, and a movable observing telescope so that different portions of the spectrum may be viewed or cut off at will. The slit is adjustable, but for measuring its width we have been obliged to have recourse to the device of closing it upon wires of known gauge. Our work has been done in the ordinary diffused light of the laboratory, care having been taken to cut off from the room direct sunlight only; but in observing it has been our custom to shield the eye in use as completely as possible with the hand or with a dark handkerchief, and to cover the eye not in use. We have found it desirable to use the scale of the instrument, illuminated to the lowest degree of visibility, to aid the eye in placing barely visible lines.

Upon experimenting with the apparatus described, it was found that the largest coil used was best adapted to our purpose, and, accordingly, in all the experiments made subsequently, and recorded in the following account, coils holding $\frac{1}{50}$ of a gram of water, measuring 2 mm. in diameter by 1 cm. in length, made of No. 28 wire (0·32 mm. in diameter), and wound in about thirty turns, were the ones employed. With these coils and the flame adjusted to a height of 20 cm. we have been able to recognize the presence of potassium, taken in the form of the chloride, in a coil-full of liquid containing 0·00066 grm. of the metal in 10 cm.^{3}, when the slit had a width of 0·18 mm.; and containing 0·0005 grm. in the same volume of solution, when the slit was set 0·23 mm. wide. That is to say, $\frac{1}{750}$ mg. of potassium to the coil-full produces a line distinctly visible with a slit of 0·18 mm., and $\frac{1}{1000}$ mg with a slit of 0·23 mm., and it is evident that this practical method of producing the spectrum of potassium gives results of a delicacy approaching that indicated in the experiments of Bunsen and Kirchhoff.

These determinations were made with pure potassium chloride carefully prepared from the chlorate, but in practical analysis it almost always happens that sodium is also present. Experiments were therefore made to determine the influence of varying amounts of the latter upon the visibility of the potassium line. The dilution of the potassium chloride was adjusted nearly to the last limit of visibility, so that a coil-full of the liquid should contain $\frac{1}{700}$ mg., or $\frac{1}{1000}$ mg. of the element, according as the slit was 0·18 mm. or 0·23 mm. wide; to this solution were added weighed amounts of pure sodium chloride twice reprecipitated and washed by hydrochloric acid; and the spectroscopic tests were carried out as before, the sodium line being kept within the field of view with the potassium line.

Weight of K in a coil-full.	Weight of Na in a coil-full.	Ratio of Na : K.	Width of slit.	Number of trials.	Characteristic of line.
0·0010 mg.	0·0000 mg.	0 : 1	0 23 mm.	3	visible
0·0010 "	0·0020 "	2 : 1	0·23 "	3	visible
0·0010 "	0·0100 "	10 : 1	0·23 "	3	visible
0·0010 "	0·0200 "	20 : 1	0·23 "	3	visible
0·0010 "	0·0400 "	40 : 1	0·23 "	3	visible
0·0010 "	0·0500 "	50 : 1	0·23 "	4	very faint or none
0·0010 "	0 1000 "	100 : 1	0·23 "	3	none
0·0010 "	0·2000 "	200 : 1	0 23 "	3	none
0·0014 "	0·0000 "	0 : 1	0 18 "	3	visible
0·0014 "	0·0560 "	40 : 1	0 18 "	3	visible
0·0014 "	0·0700 "	50 : 1	0·18 "	3	visible
0 0014 "	0·1400 "	100 : 1	0·18 "	2	visible
0·0014 "	0·1400 "	100 : 1	0·18 "	2	none

It is obvious from these results that a considerable amount of sodium may be present in the flame, when the sodium line is in full view in the spectrum, and the slit adjusted to nearly the lowest limit of visibility of pure potassium, without interfering with the appearance of the potassium line, but that a quantity of sodium amounting to a hundred times that of the potassium is sufficient to entirely overpower the spectrum of the potassium. The inference is plain that the proportion of sodium to potassium should not be permitted to reach 100 : 1 when it is desirable to bring out the full delicacy of the spectroscopic test with the sodium line in the field of view. When too great a proportion of sodium is present, its influence may be moderated by throwing the sodium line out of view, if the instrument in use possesses the necessary adjustment; otherwise, it is easy to effect a partial separation of the sodium chloride from the potassium chloride, before bringing the solution to the test, by precipitating with alcohol. Our experience shows that the delicacy of the test for potassium is not impaired materially by such treatment of the mixed chlorides. We found, for example, that 0·0070 grm. of potassium chloride mixed with 0·5 grm. of pure sodium chloride, dissolved in the least amount of water, and extracted carefully by about 7 cm.^{3} of absolute alcohol applied in successive portions, was so completely retained in solution and separated from sodium, that a coil-full taken from the solution diluted to 140 cm.^{3} gave the spectroscopic test for potassium distinctly with the slit at 0·23 mm. In this case, at least, the treatment did not diminish the delicacy of the test; for, a coil-full of the diluted solution could not have contained more than $\frac{1}{1000}$ mg. of potassium, if nothing had been lost. It was found, in like manner, that, by taking pains to evaporate the alcoholic extract, and to dissolve the residue in a drop of water, 0·0001 grm. of potassium originally present as the chloride with 0·5 grm. of sodium chloride, was easily found. By turning the observing telescope so as to cut off as completely as possible the sodium light we were able to detect potassium in four successive tests of a drop of the final solution which was just large enough to fill the coil four times, when the original amount of potassium present with 0·5 grm. of sodium chloride was 0·00001 grm. This is equivalent to detecting $\frac{1}{400}$ mg. of potassium in a drop large enough to fill the coil once. We were assured of the entire absence of potassium from the sodium chloride which we used by the fact that the similar extraction of 1 grm. of the salt by alcohol left a residue which yielded no line of potassium when examined spectroscopically. It is perhaps worth noting in passing that the coil may be made to pick up a drop of a size only sufficient to fill it by simply touching the coil while hissing hot to the drop.

Certain experiments in which the method of manipulation which we have described was applied to the determination of potassium salts other than the chloride indicated that the test is less delicate in the case of the sulphate, and rather more delicate in the case of the carbonate. We were able to find the red line of potassium unmistakably, when only $\frac{1}{2000}$ of a milligram of potassium was introduced into the flame in the form of the carbonate.

The quantitative determination of potassium by the spectroscope has never, so far as we know, been accomplished heretofore. Sodium appears to have been successfully estimated by Champion, Pellet and Grenier* by the use of comparison flames, produced by the aid of complex mechanism, and a spectrophotometer of original construction. Lithium has been determined more simply, Truchot† having been the first to suggest a method of manipulation which was modified by Ballmann‡ and taken up later by Bell§ apparently without knowledge of the previous work on the same line. Truchot's method consists in comparing the duration and strength of the spectral lines developed by exposure to the Bunsen flame of portions taken up in a platinum loop from the test-solution and standard solutions of different strengths. No analytical proofs of the value of the method were given and accuracy was not claimed beyond the recognition of differences of from three to four milligrams in a liter of liquid when amounts not exceeding forty milligrams per liter were compared. Ballmann discards as valueless the observation of the duration of the spectral line, advocates the dilution of the test and standard solutions to the absolute extinction of the line, and employs hollow cones, measuring $2{\cdot}5^{mm}$ by $3{\cdot}5^{mm}$, to carry the liquids to the flame. Bell follows Ballmann's method of diluting the solutions to be compared to a common condition, but takes the vanishing point of the line instead of the point of absolute invisibility and makes his loops of platinum very small. Both Ballmann and Bell were able to estimate thallium similarly, but neither determined potassium, Bell declaring specifically that the method is inapplicable to the handling of that element.

Our success in determining potassium qualitatively by the use of powerful flames and coils of large dimensions was such as to encourage the attempt to apply quantitatively the same method of manipulating; and from certain preliminary experi-

* Compt. Rend., lxxvi, 707.
† Compt. Rend., lxxviii, 1022.
‡ Zeitschr. für Anal. Chem., xiv, 297.
§ Am. Chem. Jour., vii, 35.

ments looking in this direction we found it best, for our purpose at least, to fall back upon Truchot's method of comparing visible lines, rather than to try to fix the vanishing point or the point of extinction of the spectral line. We chose a dilution of the standard solution which corresponds to the presence of $\frac{1}{500}$ mg. of potassium to the coil-full, and set the slit at a width of $0{\cdot}23^{mm}$, having found it most advantageous to work with lines for comparison bright enough to be visible without much effort. Our mode of proceeding is to dilute the test-solution until the line given by the potassium contained in a coil-full is of the same brightness as that given by the same quantity of the standard solution. From the final volume of the test-solution the quantity of potassium present in it is directly calculable; for, since any given volume of the test-solution at its final dilution contains exactly the same amount of potassium as the same volume of the standard solution, we have only to multiply the number expressing the volume in cubic centimeters of the test-solution by the weight in grams of the potassium contained in one cubic centimeter of the standard in order to obtain the weight in grams of potassium in the whole test-solution. We found it convenient to use several coils adjusted to the same capacity, and to clean, fill, dry and ignite them before the spectroscope in the manner previously described. From time to time the capacity of the coils should be readjusted, or else the final comparison tests should be made with a single coil. It is essential that the eye of the observer should be kept as nearly as possible in the same condition of sensitiveness and in the same position in making the comparisons, and to accomplish this end we found it best to hold the eye at the observing telescope during the entire interval between the exposures, to shade it carefully by the hand, or otherwise, to cover the eye not in use, to cut off all direct sunlight from the work-table (though the diffused light of the room is not objectionable), and to light the comparison scale of the spectroscope to the faintest possible visibility in order to fix exactly the position in which the line is to be sought. It is important, too, that the trials of the test and standard should come as closely together as possible in point of time. The observations of a series should be made by the same individual, the preparation and exposure of the wires being made by another. It is not possible to attain the best results in such work single handed. The dilution of the test-solution is made conveniently, and with sufficient accuracy, in $100cm.^3$ cylinders graduated to half cubic centimeters, the mixture being made thorough by passing the solution from vessel to vessel. It is often advantageous to divide a liquid which is to be diluted and to work with aliquot portions, so that it may be possible to retrace a step without trouble in case a portion of the solution has been unwittingly diluted too much; such a mode of proceeding is, of course, necessary when the final dilution must exceed 100 cm^3, unless large graduates are called into use. Excepting the cases of very concentrated solutions, no significant loss of material is occasioned by the filling of the coils, the error thus introduced being trivial in comparison with that inherent in all photometric processes. The following is the record of our experience in the comparison of solutions of pure potassium chloride, the strength of the test solution being unknown to the observer.

EXPERIMENT I.

Volume of test-solution.	Characteristic of line compared with standard.
20 cm^3	stronger
50 "	stronger
100 "	stronger
110 "	stronger
120 "	stronger
150 "	like
200 "	weaker
160 "	weaker
150 "	like

(150 × 0·0001 = 0·0150)

Potassium found	0·0150	grm.
" taken	0·0150	"
Limits on either side	0·0120	"
	0·0160	"
Error	0·0000	"

EXPERIMENT II.

Volume of test-solution.	Characteristic of line compared with standard.
30 cm^3	stronger
60 "	stronger
82 "	weaker
70 "	stronger
76 "	stronger
78 "	stronger
80 "	like

(80 × 0·0001 = 0·0080)

Potassium found	0·0080
" taken	0·0080
Limits on either side	0·0078
	0·0082
Error	0·0000

These results show a degree of accuracy in the process quite unexpected. In the former no attempt was made to approximate as closely as possible to the limits of dilution on both sides of the condition of equal brightness in test and standard, but in the latter great care was taken in this respect and the possible error cannot exceed two and a half per cent of the entire amount of potassium involved.

Experiment III was made to discover the effect of the presence of a reasonable amount of sodium chloride upon the determination of the potassium. To a portion of the solution if pure potassium chloride containing 0·01 grm. of the element was added 0·1 grm. of sodium chloride taken from the salt purified as previously described. This solution was diluted and the comparison made with the standard according to the accompanying account.

EXPERIMENT III.

Volume of the test-solution.	Characteristic of line compared with standard.
25 cm^3	stronger
50 "	stronger
80 "	stronger
90 "	stronger
95 "	stronger
105 "	stronger
120 "	like

(120 × 0·0001 = 0·0120)

Potassium found	0·0120 grm.
" taken	0·0100 "
Error	0·0020 "

The result of this experiment was most surprising; for, instead of diminishing the delicacy of the test we find that the presence of a moderate amount of sodium chloride tends to increase the brilliance of the potassium line. The sodium chloride employed was a part of that prepared and tested as previously described and used in the experiments upon the qualitative determination of potassium. By no possibility could the 0·1 grm. of it taken in the experiment have contained more than 0·000001 grm. of potassium. It is evident, therefore, that the brilliance of the potassium line gained twenty per cent in strength by the influence of sodium chloride amounting to ten times the weight of the potassium present when the effect due to impurity of the salt could by no means exceed a hundredth of one per cent; that is to say, the observed effect is, at the very least, two thousand times greater than that which might have been conceivably produced by contamination of the sodium salt.

In the following experiment the effect of varying amounts of sodium chloride upon the spectrum of the potassium is shown. The sodium line was turned out of the field of view to obviate the dazzling effect of the sodium light, and a solution of potassium chloride containing 0·01 grm. of the element in 100 cm^3. was examined spectroscopically after the addition of successively increasing amounts of sodium chloride, the strength of the line observed being brought into comparison with that produced by similar portions of the potassium solution containing no sodium.

Sodium chloride in a coil-full.	Potassium in a coil-full.	Ratio of NaCl : K	Width of slit.	Characteristic of line compared with standard containing no NaCl.
0·002 mg.	0·002 mg.	1 : 1	0·18 mm.	like.
0·010 "	0·002 "	5 : 1	0·18 "	like.
0·020 "	0·002 "	10 : 1	0·18 "	a little stronger.
0·040 "	0·002 "	20 : 1	0·23 "	much stronger.
0·200 "	0·002 "	100 : 1	0·23 "	very much stronger.
0·400 "	0·002 "	200 : 1	0·23 "	much stronger.
0·600 "	0·002 "	300 : 1	0·23 "	much stronger.

From this it appears that the maximum strengthening effect occurs when the sodium chloride stands to the potassium in the ratio of 100 : 1. The apparent diminution of brilliance when the sodium is increased beyond that proportion is doubtless due to the effect of the strong light diffused through the field of view by the intensely bright sodium flame in spite of the fact that the line itself is cut off from direct vision.

The cause of the brightening effect of the sodium chloride we are inclined to attribute to the chemical action of the sodium dissociated in the flame. The effect of ammonium chloride, and of hydrochloric acid, in destroying the potassium light is well known, and is due, presumably, in very large degree to the prevention of the dissociation of the potassium chloride. The dissociated sodium should naturally by its mass-action reinforce the disintegrating action of the heat upon the molecule of potassium chloride.

It is plain that the complication introduced into the quantitative spectroscopic determination of potassium by the presence of the sodium salt in the test can be obviated if it can be brought about that both the test and the standard solution shall contain the same amount of that reagent. It is a matter of interest, therefore, to discover whether it is possible to match sodium lines of considerable intensity so closely that the quantities of that element in solutions brought into comparison shall be practically equal, and so may be relied upon to give the same strengthening effect to the potassium spectrum. The following statement is the record of an attempt in this direction. The narrower slit was found to be best adopted to the comparison of the sodium lines.

NaCl in a coil-full of new solution.	NaCl in a coil full of standard.	Width of slit.	Characteristic of line as compared with that of standard.
0·010 mg.	0·02 mg.	0·18 mm.	weaker.
0·017 "	0·02 "	0·18 "	weaker.
0·019 "	0·02 "	0·18 "	weaker.
0·020 "	0·02 "	0·18 "	like.

The result shows the possibility of matching the sodium lines with a degree of approximation sufficient for the purpose in view; and, accordingly, a new standard solution was made containing 0·01 grm. of potassium taken in the form of the chloride and 0·1 grm. of sodium chloride in 100 cm^3. and with this new standard the following determinations were made. The experiment was performed in three stages: first, the test solution was diluted until its potassium line matched approximately with that of the standard; secondly, sodium chloride was added to the solution thus diluted until the sodium lines were brought to equality; and, finally, the test solution and the standard were again brought into comparison.

ERRATUM.—In the December number of Volume XLII of this Journal the last seven lines of page 457, printed as a foot note, are to be read with Experiment IV; the five lines immediately preceding the last seven belong with Experiment VI.

EXPERIMENT IV.

Part I. Volume of test-solution.	Part I. Width of slit.	Part I. Characteristic of potassium line as compared with standard.	Part II. NaCl in 100 cm.³ of test-solution.	Part II. Width of slit.	Part II. Characteristic of sodium line as compared with standard.	Part III. Volume of test-solution.	Part III. Width of slit.	Part III. Characteristic of potassium line as compared with standard.
30 cm³.	0·23 mm.	Stronger	0·01 grm.	0·18 mm.	Weaker	108 cm.³*	0·23 mm.	Weaker
70 "	0·23 "	Stronger	0·03 "	0·18 "	Weaker	108 "	0·23 "	Stronger
100 "	0·23 "	Weaker	0·05 "	0·18 "	Weaker			Weaker }
			0·08 "	0·18 "	Weaker	109 "	0·23 "	Stronger }
			0·09 "	0·18 "	Weaker			Like }
			0·10 "	0·18 "	Like			

EXPERIMENT V.

Part I. Volume of test-solution.	Part I. Width of slit.	Part I. Characteristic of potassium line as compared with standard.	Part II. NCl in 100 cm.³ of test-solution.	Part II. Width of slit.	Part II. Characteristic of sodium line as compared with standard.	Part III. Volume of test-solution.	Part III. Width of slit.	Part III. Characteristic of potassium line as compared with standard.
40 cm.³	0·23 mm.	Stronger	0·025 grm.	0·18 mm.	Weaker	160 cm.³	0·23 mm.	Stronger
100 "	0·23 "	Stronger	0·050 "	0·18 "	Weaker	180 "	0·23 "	Stronger
160 "	0·23 "	Weaker	0·085 "	0·18 "	Weaker	190 "	0·23 "	Stronger
			0·100 "	0·18 "	Weaker	200 "	0·23 "	Stronger
			0·110 "	0·18 "	Like	205 "	0·23 "	Weaker
						210 "	0·23 "	Weaker

$$\left.\begin{matrix} 205 \times 0·0001 = 0·0205 \\ 200 \times 0·0001 = 0·0200 \end{matrix}\right\} \text{mean} = 0·02025$$

Potassium found ....0·02025 grm.
" taken ....0·02000 "
Error ....0·00025 " = 1·25 per cent.

EXPERIMENT VI.

Part I. Volume of test-solution.	Part I. Width of slit.	Part I. Characteristic of potassium line as compared with standard.	Part II. NaCl in 100 cm.³ of test-solution.	Part II. Width of slit.	Part II. Characteristic of sodium line as compared with standard.	Part III. Volume of test-solution.	Part III. Width of slit,	Part III. Characteristic of potassium line as compared with standard.
40 cm.³	0·23 mm.	Stronger	0·045 grm.†	0·18 mm.	Weaker	110 cm.³	0·23 mm.	Stronger
80 "	0·23 "	Stronger	0·082 "	0·18 "	Like	120 "	0·23 "	Stronger
100 "	0·23 "	Stronger				130 "	0·23 "	Like
110 "	0·23 "	Like						

* Originally present.

$(130 \times 0·0001 = 0·0130)$

Potassium found ....0·0130 gram.
" taken ....0·0140 "
Error ....0·0010 " = 7 per cent.

† The test-solution having been accidentally over-diluted, its strength was increased by the addition of 0·0010 grm. of potassium and this amount was added in the computation below to that originally in the test-solution.

$(109 \times 0·0001 = 0·0109)$

Potassium found ......0·0109 grm.
" taken ......0·0110 "
Error ....0·0001 " = 0·9 per cent.

EXPERIMENT VII.

PART I.

Volume of test-solution.	Width of slit.	Characteristic of potassium line as compared with standard.
30 cm.³	0.23 mm.	Stronger
90 "	0·23 "	Stronger
100 "	0·23 "	{ Weaker
		{ Like

PART II.

NaCl in 100 cm.³ of test-solution.	Width of slit.	Characteristic of sodium line as compared with standard.
0·05 grm.*	0·18 mm.	Weaker
0·07 "	0·80 "	Weaker
0·09 "	0·18 "	Weaker
0·10 "	0·18 "	{ Like
		{ Stronger
		{ Stronger

PART III.

Volume of test-solution.	Width of slit.	Characteristic of potassium line as compared with standard.
First.		
100 cm.³	0·23 mm.	Stronger
120 "	0·23 "	Stronger
130 "	0·23 "	Stronger
140 "	0·23 "	{ Stronger
		{ Weaker
Second.		
120 cm.³	0·23 mm.	Stronger
140 "	0·23 "	Stronger
150 "	0·23 "	{ Stronger
		{ Weaker
160 "	0·23 "	Weaker

	First.		Second.
	(140 × 0.0001 = 0·0140)		(150 × 0·0001 = 0·0150)
Potassium found	0·0180 grm.		0·0150
" taken	0·0150 "		0·0150
Error	0·0010 "	=7 per cent	0·0000

From these results it is plain that the sodium in test and standard may be matched closely enough to allow a fair approximation to be made in the determination of the potassium. In Experiments IV, V and VI, no readjustment of the percentage of sodium in the final dilution, subsequent to the matching of the sodium lines, was attempted; in Experiment VII this point was looked to, so that in this determination the strength of the sodium was kept equal to that found in the matching process. In Experiments IV and VII, the matching of the sodium in the test-solution against that in the standard proved to have been exact; in V, an excess of 10 per cent was added, and in VI, the point of equality was thought to have been reached while there was still a deficiency of 25 per cent in the sodium chloride of the test-solution.

The error in the determination of the potassium in Experiment VI may, perhaps, be accounted for by the mistake in matching the sodium; that of the first attempt in Experiment VII, we are disposed to attribute to lack of care in keeping the eye of the observer in the most sensitive condition, and of attention to the point of bringing the wires to the plane in quick succession. The largest absolute error met with amounted to one milligram in a total of fifteen. Though not accurate to

* Originally present.

the last degree when large amounts of potassium are to be estimated, the method, we think, offers some advantage without too great sacrifice of exactness in the determination of small amounts. In qualitative work the mode of manipulating described is exceedingly satisfactory. Aside from the practical application of the method the point which has been of greatest interest to us is the development of the fact that the presence of sodium salts in the flame is of direct influence in strengthening the spectrum of potassium.

Art. XLIX.—*The Ultra-Violet Spectrum of the Solar Prominences;* by George E. Hale.*

In various papers published during the past year, I have called attention to some of the advances in our knowledge of the Solar Prominences which might be expected to follow the application of photographic methods to a study of their forms and spectra. A recent number of this Journal, August, 1891, p. 160, contains reproductions of some photographs obtained in the course of my investigations on this subject at the Kenwood Physical Observatory. I am indebted to Professor Lockyer for the use of a measuring machine during a recent visit to London, and I am now able to give my determinations of wave-length for the new prominence lines, and some conclusions to be drawn from them. But perhaps it will first be well to consider for a moment the apparatus and methods at present employed in the work.

To the eye end of the 12·2 inch equatorial refractor of the Kenwood Observatory a large solar spectroscope is rigidly attached by three steel tubes, and as the spectroscope extends about five feet beyond the focus of the telescope, the declination axis is placed at the center of the combined lengths of the two instruments, in order to reduce the amount of counterbalance required at the object-glass end. The result is very satisfactory, and there can certainly be little fear of flexure in the combination. The whole spectroscope may be rotated by a rack and pinion, so as to make the slit tangential or radial at any point on the sun's limb. The object-glasses of the collimator and observing telescope have 3¼ inches clear aperture, and 42½ inches focal length. The 4-inch Rowland grating is ruled with 14,438 lines to the inch, and as the telescopes make with each other a constant angle of 25°, different orders of

* Read at the Cardiff Meeting of the British Association for the Advancement of Science, August, 1891.

spectra are brought into the field of view by rotating the grating. A diagonal eye-piece at the end of the observing telescope allows the spectrum to be observed after the photographic plate is in position.

In photographing the spectrum of a prominence the following is the ordinary process. Let us suppose that it is desired to use a radial slit, in the H and K region of the spectrum. The C line in the second order is brought into the field, and while observing this line the spectroscope is rotated until the slit is radial at some point on the limb where a prominence is seen. The driving-clock is then started, and the telescope clamped, so that the sun's image is kept as nearly as possible stationary on the slit plate. A small strip of metal, pushed in just behind the slit, excludes the direct solar light, except from a small region near the limb. The whole collimator is next moved by a screw until the slit is brought to the proper focus of the equatorial for K, and the collimator and observing telescope are set at the focus for the same line, the positions being taken from a table of foci, determined by experiment, for the principal lines in the spectrum. After placing the sensitive plate in position, the grating is rotated until the K line in the fourth order is in the middle of the field, the slit is covered, the slide drawn, and the proper exposure given. The exposure of course depends upon the aperture and focal length of the equatorial, the width of the slit, the brilliancy of the grating, the sensitiveness of the plate, etc., but with the ordinary dry plate of sensitometer No. 23 furnished by the Seed Company, and a slit about 0·001 inches wide, I usually find that an exposure of from 20 to 30 seconds gives the best result.

For the first time without an eclipse the prominence spectrum was thus photographed early in April of the present year. The only bright lines then obtained were found to fall nearly at the centers of the dark bands H and K of the solar spectrum, but these were remarkably strong, seeming to fully equal C in intensity, and were present in every prominence photographed. Work was continued on the violet and ultra-violet for some weeks, but, with the exception of some lines which had all the appearance of ghosts of the brilliant H and K reversals, no new lines were discovered until June 23, when an exceptionally bright prominence was found. This gave four lines in the ultra-violet, and the least refrangible of these was found to be double. A line slightly less refrangible than H, nearly but not quite at the position where the first ghost would be expected to fall, was much stronger than any of the other ghosts, and it seemed very possible that it was an independent line. This prominence remained visible for several days, and a number of photographs o. its spectrum were made with both radial and tangential slit.

In reducing the wave-lengths of these lines it might be considered easy to obtain values for a given line agreeing closely in the hundredths place of tenth-meters, but two causes have combined to lessen the accuracy of determinations. The H and K reversals almost invariably show some indications of motion of the prominences in the line of sight, and the consequent distortion renders somewhat difficult the proper setting of the spider line of the measuring machine. Again the plate-holder used was made for another purpose, which required that the plane of the plate should be at right angles to the axis of the observing telescope. As the object-glass of the telescope is corrected for the visual region, it is evident that near K there must be a slight change in focus from one side of the plate to the other, and a small error is thus introduced. It will be seen, however, that the measures are sufficiently accurate to allow very little doubt as to the identity of most of the lines. The fact that the solar spectrum, due to the diffuse light of the atmosphere, is photographed simultaneously with the prominence spectrum, is of great advantage in determining the position of the prominence lines, though it has a corresponding disadvantage in concealing very faint lines, which would otherwise be brought out. The wave-lengths of certain standard lines in the solar spectrum have been taken from the list published by Professor Rowland,* and it has thus been easy to find the wave-lengths of the prominence lines by simple interpolation. The value of the micrometer screw has been determined for several regions on every plate by measuring the positions of properly distributed standard lines, the number of separate settings of the spider line in each case ranging from five to fifteen, depending upon the character of the line measured. In the following table the first column contains the wave-lengths of the ultra-violet prominence lines; the second the positions assigned by Ames to the lines in the hydrogen stellar series; and the third, the wave-lengths of the calcium lines at H and K, which Professor Rowland has been kind enough to furnish in advance of publication. I am informed that they are provisional only, but may be relied on to within 1 or 2 in the last place of decimals. In the case of hydrogen, Ames considers that the error in any wave-length cannot amount to more than 0·05 of a unit,† and my own values for the prominence lines must possess at least an equal degree of accuracy, though I am inclined to believe some of them even more reliable. In the fourth and fifth columns I

* This Journal, p. 182, 1887.

† Phil. Mag., July, 1890, p. 49.

have added Cornu's measures of the hydrogen lines,* and Dr. Huggins' wave-lengths of lines in the hydrogen stellar series,† both reduced to the scale of Rowland's map.

Prominences. Hale.	Hydrogen. Ames.	Calcium. Rowland.	Hydrogen. Cornu.	First Type Stars. Huggins.
3968·56	----	3968·61 (H)	----	----
3933·86	----	3933·80 (K)	----	----
3888.73	----	----	----	----
3970·11(?)	3970·25	----	3969·6	3969·6
3889·14	3889·15	----	3888·5	3888·2
3835·54	3835·6	----	3835·1	3834·6
3798·1	3798·0	----	3797·5	3795·6
3770·8	3770·7	----	3770·0	3768·1
----	3750·15	----	3749·9	3746·1
----	3734·15	----	3734·2	3730·6
----	3721·8	----	3721·1	3717·9
----	3711·9	----	3711·1	3707·9
----	----	----	----	3699·4

Let us first consider the prominence lines which lie near the centers of the broad dark shades at H and K. In his observations of the chromosphere and prominence spectrum at Mount Sherman, in 1872, Professor Young succeeded in seeing these reversals in a number of cases, but the character of the bright lines could not be made out, and it was considered probable that the broad dark bands were included in the reversal, only the brighter central portions, however, being strong enough to affect the eye. We now find, on the contrary, that the substance producing the bright prominence lines may possibly be entirely distinct from that causing the broad bands in the solar spectrum, for though the lines certainly do lie near the centers of the bands, they are narrow and sharp, and it is easily conceivable that their position may be simply the result of chance, though perhaps probability would point the other way. We are hardly in a position to discuss the cause of the unique appearance of the dark H and K bands, but it may be that we may learn something in this connection from Dr. Huggins' important investigations of stellar spectra. It will be remembered by everyone that in his memoir "On the Photographic Spectra of Stars" communicated to the Royal Society in 1880, Dr. Huggins arranged the stars observed in a series, in which the principal criterion of position was the character of the K line. In Arcturus, for instance, this line is broader and more diffuse than in the sun itself, while in Sirius it has narrowed down to

* Journal de Physique, 1886. † Phil. Trans., Part II, 1880, p. 669.

a fine, sharp line. Other stars give intermediate breadths, and in some instances it has entirely disappeared. In the case of H the question is complicated by the fact that hydrogen and calcium possess lines which form a close double at this point, so it is best to consider only K. From the variations of this line it will be seen, apart from the interesting subject of stellar evolution so evidently suggested, that the narrow dark line at the center is very possibly produced by the same substance which, vibrating under different conditions, causes by its absorption the broad dark band.

As the central dark line is known with a high degree of certainty to be due to calcium, it becomes likely that the band is due to the same substance, and as the central dark line of H is also a calcium line, it might perhaps be safe to attribute the H band to the same metal, though in neither case is it well to be too positive in the assertion, for it is somewhat peculiar that the bands and lines appear together in the solar spectrum. If the same substance produces both, and each requires different conditions, possibly of temperature or pressure, for its production, these conditions must presumably exist at different elevations above the photosphere.

The question now arises whether the bright lines in the prominence spectrum agree in position with the dark lines at the center of the H and K bands. Only one or two of my prominence spectra happened to be given the proper exposure to bring out both the bright and dark lines, but in these the coincidence is fairly satisfactory. I have not as yet, however, been able to obtain the wave-lengths of the dark lines in hundredths of a tenth-meter, but Professor Rowland's determinations of wave-lengths for the corresponding calcium lines will answer nearly as well. These have been given in the third column of the table of wave-lengths. It will be seen that in the case of H the prominence line is 0·05 tenth-meters more refrangible, while at K the prominence line is 0·06 tenth-meters less refrangible. Professor Rowland considers his values correct within 1 or 2 hundredths tenth-meters, while the probable errors in the position of the prominence lines, deduced on the assumption of equal weights for the wave-lengths given by each of six plates, are 0·021 and 0·036 tenth-meters for H and K respectively. On the whole, then, there can be little doubt that these prominence lines are due to calcium, and are therefore probably true reversals of the central dark lines of the H and K bands.

It will be of interest next to consider briefly the character of these two prominence lines. In all cases they are quite narrow and sharp, except when motion in the line of sight has produced broadening or distortion. In seven photographs made with a radial slit both lines gradually become narrower as the distance from the limb increases, and have a pointed appearance. This might be due to an actual decrease in the width of the lines, but, as there is usually a certain increase of intensity toward the limb, the effect may be purely photographic. In several plates, however, there is so little change of intensity that the widening can hardly be due to this cause. The arrow-head appearance so frequently seen with the C and F lines, is often shown when the slit is radial. A rather curious appearance has been found on three plates made with radial slit, and in the two which best show the effect there is a very sudden decrease of intensity in the upper part of the lines. Instead of becoming narrower toward the top, the lines seem to expand symmetrically on either side, and the edges become hazy and indistinct. As in the case of the pointed lines, there is also an expansion toward the limb, but here the edges are clearly defined. The arrow-head appearance is shown in two of these plates. With a tangential slit two plates show the lines expanded at the ends, and in one plate they are pointed. Though in most cases the forms of H and K are very similar, there is a single instance where K is shown sharply double in the fainter portions at each end of the line, and at one end the components seem to diverge slightly. That this is not the result of poor focusing is attested by the sharpness of the lines in the background of solar spectrum; at the same time the appearance is hardly that of an ordinary reversal. One further peculiarity will show that it is safest, for the present at least, not to draw any conclusions from such appearances as have been noted. In a certain position of the mirror of the measuring machine the illumination was such that the edges of the radial black lines appeared bright, while the Fraunhofer lines of the solar spectrum were also bright, as with ordinary illumination. One of the negatives, in which H and K were broader and fainter at the top, brought out the effect particularly well. The central dark line extended two-thirds of the distance to the top of the prominence, and in the upper part it was excessively narrow and delicate. Lower down it gradually widened, until at a point very near the limb the widening became much more rapid, and at the limb itself the line was nearly as wide as when seen under ordinary conditions.

A paragraph from Dr. Schuster's report on the results obtained with the spectroscopic cameras at the total eclipse of August 29, 1886, seems to refer to a somewhat similar appearance. Speaking of the photographs of the coronal spectrum, Dr. Schuster remarks:* "A bright line shows black on the negative, and is bounded on both sides by an apparently lighter

* Phil. Trans., vol. clxxx, (1889), (A.), p. 328.

background. This is a well-known contrast effect. The H and K lines, for instance, seem to be surrounded by a lighter band, which follows the contour not only of the lines, but also of the wing by the side of the prominence. If, now, a Fraunhofer line happens to be by the side of a bright line, the contrast is strengthened, and both the bright and the dark lines appear more distinctly than they otherwise would. This is the only simple way in which I can explain some of the appearances of the photographs." The first part of the quotation is all that concerns us at present, for in the negative which I have mentioned as showing this peculiarity particularly well, the Fraunhofer lines are hardly visible above the limb, and none appear within the dark bands at H and K. As Dr. Schuster does not speak of the illumination, I assume that the appearance was generally seen, and this constitutes another point of difference. A penumbra formed by light reflected from the back of the plate would probably extend but little higher than the central line, but in the future plates backed with a dyed collodion film will be employed to obviate any effects of this kind. No entirely satisfactory explanation of the peculiar appearance of these lines has as yet suggested itself.

But on another point there is little room for doubt. The bright H and K lines certainly extend to a very considerable elevation above the sun's limb, and it is extremely probable that calcium is carried to the very top of the highest prominences. With the improved apparatus to be used in a continuation of this research, I hope to be able to ascertain the relative heights of various lines in the prominence spectrum. For instance, while a photograph is being made of H and K, the height of C in the same prominence can be measured with a micrometer. The comparative observations and photographs made up to the present time suggest the belief that calcium attains the highest elevations reached by hydrogen, and the remarkable brilliancy of H and K at the eclipse of 1882 attest the importance of calcium in the prominences. Dr. Schuster is of the opinion that the coronal spectrum contains calcium injected by the prominences, and this may only very gradually descend again to the level of the photosphere.* This supposition seems a very plausible one, and if it be at the same time considered probable that the H and K bands and their central lines are produced by the same substance, the possibility is suggested that the broad dark shades may be caused by the absorption of the cooler vapor at a considerable elevation, while the absorption near the photosphere gives rise to the narrow central lines. This view need not necessarily conflict

* Phil. Trans. vol. clxxx, 1889, (A.), p. 328.

with a belief in a shallow reversing layer, where absorption ordinarily takes place, for the H and K bands are unique in the solar spectrum. It rests, however, on somewhat insecure foundations, and cannot be credited with much weight.

On account of the dark shades at H and K it has proved quite easy to photograph prominence forms with an open slit. With other prominence lines the brilliancy of the background is much increased when the slit is opened, but this is not the case with H and K, and it is often possible to use a slit nearly a quarter of an inch wide. The fourth order spectrum has been employed for this work, and the best results are obtained with an exposure of about one second. It is considered that great advantage will result from a material reduction of this exposure, as the disturbances in our atmosphere have as yet made it impossible to secure the finest details of structure.

It is of interest to note, however, that the first photograph ever taken of the rapid development of a prominence was made in this way by my assistants on July 8, 1891, at 23h. 45m., Chicago M. T. As at first observed through C, the prominence was low, but very bright, and changing rapidly. A great tongue moved rapidly out to an elevation of about 80,000 miles, and at this time the extension was photographed through H and K. In fifteen minutes the prominence had returned to its original form. A reproduction of the photograph is given in the August number of this Journal, and though much has been lost in the printing process, some idea of the actual appearance of the prominence may be gained. A new apparatus for photographing the prominences is now being constructed as the outcome of my investigations on this subject, and this is expected to do away with many of the difficulties previously encountered. It will consist of two curved slits, moved in opposite directions across the ends of the stationary collimator and observing telescope by means of a peculiar form of clepsydra. The sun's image and photographic plate will be stationary, and the apparatus is thus to be constructed on the principle of the second method devised by myself in 1889, but so altered as to avoid the defects of the original scheme.*

Decision must be reserved for the present as to the line at λ 3970·11. The wave-length has been determined from four plates, and its probable error is 0·030, but as the line is not far from where a ghost of H should fall, I cannot be certain that it belongs to the prominence spectrum. At the same time it is

* For previous papers on prominence photography see—Technology Quarterly, vol. iii., No. 4, 1890; Astronomische Nachrichten, Nos. 3006, 3037 and 3053; Sidereal Messenger, June, 1891; This Journal, August, 1891.

very much brighter than any other of the seven ghosts of H and K, and its position with respect to H is not symmetrical with that of the first ghost on the opposite side of this line, while in the case of K the ghosts are very regularly spaced. My assistants report that they were able to *see* H very plainly double in a brilliant metallic prominence observed July 27, and on one or two occasions Professor Young has made out the same thing. The agreement in wave-length with Ames's hydrogen line at 3970·25 is by no means satisfactory, and more observations and measures are required before a conclusion can be reached.

No one can doubt that the next four prominence lines are members of the well-known hydrogen series, for their agreement in wave-length with the values given by Ames is certainly very striking. Cornu's measures show considerable differences, as do also those of Dr. Huggins, but the small dispersion employed by the latter in this investigation must be borne in mind. There can be little question that Ames' wave-lengths are very near the truth, for they almost exactly correspond with those calculated by Balmer's formula. The measures of the prominence lines also serve to confirm them.

The remaining prominence line at λ 3888·73 has not been accounted for. It forms a close double with the hydrogen line at λ 3889·14, and with it attains as great elevations above the limb as those reached by H and K. The character of the lines, however, is quite different, for while the hydrogen line is wider, and slightly diffuse, the line at λ 3888·73 is very narrow and sharp. I have seen no statement that the hydrogen line has shown any signs of duplicity, and, as Mrs. Huggins has had the kindness to examine the corresponding line in some very sharp photographs of steller spectra with the same result, we have reason to consider an independent origin probable.

The results so far obtained can only be regarded as preliminary, for with the improvements now being carried out in the telescope and spectroscope, and the much greater frequency of metallic eruptions as the maximum sun-spot period is approached, it is certainly to be hoped that many more lines will be photographed. The ultra-violet spectra of sun-spots have also been worked upon with some indications of success, and there will evidently be no lack of opportunity in the new and interesting fields thus opened to investigation.

London, August 13, 1891.

Art. L.—*Phonics of Auditoriums;* by Ephraim Cutter, M.D., New York.

Reciprocation of sound.—When two strings of the violin family are tuned in unison, on causing one to sound "the air around it assumes a vibratory movement and this being propagated to the second string causes it to vibrate and emit the same sound or tone because each aerial pulse communicates motion to the second string, and as the movements of both are by the supposition isochronous each succeeding impulse augments the effect of the preceding and this phenomenon is termed the *reciprocation of sound.* Instances have occurred of persons who by modulating their voices, have excited vibrations in glasses so powerful as to overcome the cohesive attraction that held the particles together and consequently break them in pieces."—Bird. Nat. Phil.

An effect of air vibration is seen when a shrill whistle or infant's cry produces a flaring or upward projection of an ordinary gas or oil flame turned on just so as not to blaze. The jet shoots up in long digitations which cease to project when the tone stops.

Green in his History of the English People, vol. i, p. 67, writes of Dunstan the Ecclesiastical statesman: "One morning a lady summons him to her house to design a robe which she is embroidering, and as he bends with her maidens over their toil, his harp, hung upon the walls, sounds without mortal touch, tones which the excited ears around frame into a joyous antiphon." This would be unintelligible but for the "antiphon" which means that he sung and the harp responded.

A thousand years later a Yale student sounding a upper line bass clef 215 vibrations to the second, heard the A string of a 'cello in a distant corner of the room, face to walls, audibly antiphone with the same number of vibrations.

In the case of the two strings vibrating in unison within half an inch of each other it is easy to understand why one string would induce vibrations—from their proximity. But in the last example given there was a distance of 15 to 20 feet between the causal vocal tones and the string A. The other strings G 96·7, D 145 vibrations per second, would not respond when their tones were sung, showing a peculiarity of the A tone vibrations. C 64·5 vibration was too low for the voice. In a church when the pipe F of the subbass sounded the walls and floors would vibrate. Tunes performed in the key of F went with a vim perceptible even to listeners outside.

These examples suffice to show that even musical vibrations act more strongly on the ear and induce objects capable of the same number of vibrations to produce the same musical tone. The size of the auditorium seems to govern this tone, which has been called the key note of the auditorium. Every room has its key note. No one will dispute that music in the key note of the auditorium is more effective than when it is not in that key. An opposite opinion clashes against the above facts. This being so with music, how is it with Phonics?

The differences between music and speech are much less than their joint properties. Both need normal vocal bands. Surgery shows this. A tumor exists which I removed from the vocal bands in 1866. For years before, the patient could not speak nor sing. She could only whisper. In 1891 she speaks and sings.

The same oripulations belong to speech and song. Song prolongs the basic vowel syllable sounds more than speech. These sounds are chiefly formed by the vocal bands alone as the writer since 1862 has shown to himself and others in his own larynx. Speech shortens these sounds. Speech is staccato in music with the rests left out.

The consonants are the same as a general rule in speech and song as to production. Speech and song have pitch, forte and piano.

From this—as Phonics in auditoriums are often a failure, i. e. people can't hear—is there not some remedy by making phonic laws conform to those of music? We think there is and for one thing would suggest *phonics in the key note of the auditorium.*

That is have the pitch of the speaker hold to the key note of the auditorium and vary only as a well regulated song, for example like "Annie Laurie."

The writer has seen this done successfully as follows, in

1. Cincinnati Music Hall, capacity 6000 people, key note F.
2. Prince Albert Memorial Town Hall, Leeds, England.
3. Section rooms of the X International Medical Congress, Berlin, 1890, and other places.

1, 2, 3, were of exceptional difficulty: 1, from its vast size. 2, elegant to the eye but hard for the ear. 3, were picture galleries never intended for the ear.

To find the key note.

Sing the natural scale slowly, *evenly and smoothly*, or play this scale on piano or organ similarly. The note which is most prominent will be the key note.

Those who control auditoriums may employ an expert to do this and post the result. For example, an auditorium of the City Hall at Saratoga Springs was thus tested 1890, and a notice was put up: "The key note of this hall is F."

September, 1891.

Art. LI.—*The Secular Variation of Latitudes*; by George C. Comstock.

[Read at the Washington Meeting of the American Association for the Advancement of Science.]

A possible secular change in the position of the terrestrial pole has long been a subject of discussion among astronomers and physicists, and the history of investigations made in this connection resembles in many respects that of similar researches upon stellar parallaxes. The early investigators expected to find, and announced the actual discovery of, very sensible variations of both kinds while their successors overturned their conclusions and traced their results back to errors of observation. Less than a decade ago a vigorous interest in the matter of latitudes seemed to be aroused by Fergola. A plan for systematic research was proposed and adopted and for a time we appeared to be on the eve of a repetition of the brilliant success attained by Bessel and Struve a half century ago in the determination of parallaxes. But Fergola's plan seems to have been abandoned without a trial and so far as astronomers are concerned these investigations have fallen into abeyance.

But an urgent demand for further research comes now from another quarter. The geologists having tried one by one the various hypotheses which have been advanced to account for the glacial periods have found them successively inadequate and untenable. In the inelegant but expressive language of one of these gentlemen they are "in a hole," and the only escape from the difficulty seems to be through the assumption that the terrestrial pole has wandered widely from its present position during recent geologic time.

I am no geologist, but since my attention was especially directed to the problem in hand by geologists, let me briefly summarize the case from their standpoint. The phenomena of erosion indicate that the last glacial epoch is separated from us in time by a period which is to be measured by thousands of years and probably not a very great number of thousands. At that epoch a certain portion of the earth's surface, including parts at least of Europe and North America, was buried in ice much as the continent of Greenland is now covered by an almost continuous glacier. Only recently has the area covered by the ice been delimited, but as a result of surveys made during the past five or six years it appears that the ancient glacier covered a region approximately bounded by a small circle of the earth whose pole lies somewhere in Greenland and whose angular radius is not far from 35°, *i. e.* the amount of ice present in the northern hemisphere at the time of maximum glaciation was distributed in a manner very different from the present arrangement, and this different distribution will be fully explained by shifting the terrestrial pole from its present position to the center of Greenland. Opposed to this explanation, however, stands the common belief of astronomers that the position of the pole if not absolutely fixed is subject only to very inconsiderable changes.

To guard against any possible misapprehension let it be stated once for all that the questions here raised do not relate to the direction of the earth's axis in space, *i. e.* to the phenomena grouped under the names precession and nutation, but to the position of the points in which the rotation axis intersects the earth's surface.

If any such change in the position of the pole as is supposed above has occurred within recent geologic time it may be fairly presumed that some motion will still remain although nothing can be predicated *a priori* in regard to its amount or direction, and the problem which I have proposed to myself is to determine whether there is any such motion of the pole of sufficient magnitude to be shown by existing astronomical data.

Theoretically there are three classes of observations which may contribute to the solution of the problem: determinations of latitude, of azimuth and of longitude; but for the present at least only the first of these can furnish available data and the amount of satisfactory data of this kind is exceedingly small. I do not wish to enlarge here upon the inherent difficulties which stand in the way of determining a change in the latitude of a given station, but some consideration of them is necessary for the proper appreciation of the conclusions which are subsequently reached.

To take a concrete instance, the following determinations of latitude at Greenwich seem to indicate a progressive change in the position of that observatory:

Date.	Latitude.	Authority.	
1693	51° 28′ 41″·7	Peters.	Flamsteed.
1751	38·72	Auwers.	Bradley.
1826	38·59	Pond.	Gr. Obs. 1834
1838	38·23	Airy.	Gr. Cat. 1860
1845	38·17	"	" " "
1855	38·15	"	" " "
1881	38·07	Christie.	Ten Year Catalogue.
1889	37·95	"	Annual Report.

We have here observations extending over a period of nearly two centuries during which the latitude appears to have diminished very appreciably, but I do not think that such a conclusion can properly be drawn from the data. Dr. Auwers informs me that Bradley's latitude may be anywhere from half a second to a second in error on account of uncertainties inherent in the data, errors of figure and division of the quadrant, errors of the tabular refraction, of the thermometer exposure, etc., and the same may probably be said of Pond's latitude while Flamsteed's is much inferior to either of these. If the several values of the latitude given above had all been derived with the same instrument and by the same method many of these errors would be eliminated from the differences, but in fact five different instruments were employed and the entire apparent variation of the latitude may fairly enough be ascribed to the undetermined errors affecting the results given by these instruments. The same facts obtain for much of the evidence sometimes cited to show a variation of latitude but they are not necessarily true of all of it.

To obtain a reliable indication of a change in latitude we must compare determinations made at a sufficient interval of time by the use of the same instrument and the same methods, or we must compare determinations made by methods which are practically free from systematic error, such as are furnished by the zenith telescope and the prime vertical transit. The results furnished by these instruments depend upon the adopted star places, but by using only observations of the same stars made at different epochs the change of latitude may be made to depend solely upon the proper motions of the stars and the residual error in these proper motions may be almost indefinitely diminished by increasing the number of stars employed. I assume that absolute determinations of latitude instead of being the only data from which a motion of the pole can be concluded are in the present state of practical astronomy decidedly inferior to differential determinations for this purpose. If these principles are applied to the data collected by Fergola and presented to the International Geodetic Association assembled at Rome they will be found to exclude nearly every case of supposed variation, although the general agreement of the data in indicating a progressive diminution of European latitudes must still remain a very striking fact.

Of all the cases in which an apparent variation of an absolute latitude is shown, the one least open to adverse criticism seems to be the discussion of the latitude of Pulkowa published by Nyrén, see *Die Polhöhe von Pulkowa* and *Observations de Poulkova*, vol. xiv. There are here two independent series of observations made with the vertical circle, the results of the first of which, observations of Polaris, are shown in the following table:

Latitude of Pulkowa. Polaris Observations.

Date.	Observer.	Latitude.	No. of Obs.
1843	Peters.	59° 46′ 18″·73 ± 0·″013	371
1866	Gyldén.	18·65 ± ·014	236
1872·5	Nyrén.	18·50 ± ·014	155
1882·0	Nyrén.	18·40 ± ·010	184

The first three of these values are taken from Nyrén's paper on the latitude of Pulkowa, the last one is derived by myself from the data given at *p.* [50] of the volume of Pulkowa observations cited above, after correcting the individual results there given for the periodic variation of the latitude (Küstner) by means of the formula

$$-0.''26 \sin(\odot - 47^\circ)$$

derived from meridian circle observations at the Washburn Observatory and confirmed by the special observations made at Berlin, Potsdam and Prague to determine the existence of a periodic variation. If this correction were omitted the value of the latitude for 1882·0 would be increased 0″·04. A graphical treatment of these data indicates an apparent diminution of the latitude amounting to 0″·005, six inches, per annum.

To this it has been objected by Bruns (V. J. S. vol. xxv, p. 15) that such a conclusion presupposes that the difference between the tabular refractions employed and the true refraction at the time of observation is the same for the several epochs and that this assumption requires confirmation. This confirmation is afforded by an investigation by Nyrén contained in vol. xiv above cited. From a discussion of the observations of 127 stars north of +45° declination, not including Polaris, treating the latitude and a correction to the assumed refraction as unknown quantities he finds for the epochs,

1846 (?) Latitude = 59° 46′ 18″·66
1866 " 18·546
Annual variation, −0″·006

This astonishingly close agreement between the results of two independent series of observations will probably suffice to establish the constancy of the refraction at Pulkowa during this period. The corrections to the tabular refractions for the two epochs differ by less than their probable errors.

There is available another series of Pulkowa observations by which to test the reality of the apparent change of latitude. I have compared the declinations of fourteen stars observed with the prime vertical transit by both Oöm and Nyrén, the epochs of their respective observations being in the mean 1862 and 1881. Auwers has published proper motions for all of these stars save one for which I adopt Nyrén's value and comparing the declinations observed at the two epochs I find for the variation of the latitude between 1862 and 1881 −0″·12, or Annual Variation −0″·006, agreeing exactly with the result furnished by the vertical circle. I very much regret that I have not had access to the results of observations made with the prime vertical transit during the years 1840–1860 by W. Struve. I have, however, compared the declinations of the three stars most frequently observed during this period, which are discussed in Nyrén's paper *Bestimmung der Nutation der Erdachse*, with Nyrén's observations with the same instrument. From 375 observations of these stars at the mean epoch 1846 combined with 113 observations at the epoch 1881 using Auwers' proper motions I find

Annual variation of latitude, −0″·094.

Each star shows a diminution of the latitude. These results derived from two different instruments and from different series of observations with these instruments seem to me inexplicable on any other hypothesis than that of a change of latitude and I adopt as the rate of variation at Pulkowa −0″·006 per annum.

I know of no other European observatory at which a variation of latitude can be established in an equally satisfactory manner and the only one to which reference seems required is Königsberg. Two careful determinations of the latitude of the Repsold meridian circle have been made with the following results:

Date.	Observer.	Latitude.
1843·5	Bessel.	54° 42′ 50″·56 ± 0″·03
1887·0	Rahts.	50·43 ± ·04

No investigation of a possible change in the amount of the refraction between the two epochs appears to have been made, but in spite of this defect the precision of the observations and the care with which the instrumental errors were investigated together with the Pulkowa results in regard to the refraction seem to entitle these determinations to some consideration. I therefore adopt for Königsberg

Annual variation of latitude , −0″·003.

Turning now from European to American observatories we find a very different set of values. I shall first consider the latitude of the Washburn Observatory at Madison, Wis., as determined from observations of fundamental stars made with the Repsold meridian circle. In the reduction of the observations the latitude is made to depend upon the declinations of these stars as given in the *Berliner Jahrbuch* and observations on opposite sides of the zenith were combined in such a way as to eliminate the errors of the instrument and of the refraction tables. The results of separate years are given in the following table:

Meridian circle latitudes of Madison.

Date.	Obs'r.	Latitude.	Ann. var.	Lat. 1890·0*
1883·8	T.	43° 4′ 36″·45 ± 0″·14	+0″·06	36″·70
84·5	H. and C.	36·49 ± 0·04	+ ·05	36.72
85·5	H. C. and U.	36·54 ± 0·04	+ ·04	36·72
87·2	U. and L.	36·61 ± 0·04	+ ·11	36·72
88·6	B.	36·76 ± 0·03	+ ·05	36·82
89·6	B. and E.	36·81 ± 0·03	− ·11	36·83
90·2	B. and E.	36·74 ± 0·06		36·73

It should be said in regard to these values that the observations of each year except the first and last are distributed through the whole circuit of twenty-four hours of right ascension and are sufficiently numerous to furnish a good representation of the system of declinations adopted as fundamental. The latitudes thus derived are affected with whatever constant error inheres in the declination system and in the instrument itself, but since we are here concerned only with variations of latitude constant errors are of no consequence and we may therefore neglect the absolute value of the latitude and inquire what interpretation is to be placed upon its apparent annual increase.

I do not think that it will be seriously maintained by any competent critic that this variation is due to error in the star places for, the same stars being observed year after year, this would imply that the mean of the proper motions of some hundreds of fundamental stars is in error to the amount of 0″·06.

The variation may be due to accidental error of observation, but the uniform progression and the small probable errors of the results render this hypothesis somewhat improbable.

No correction for flexure has been applied to the observations and it may be supposed that the variation is due to a progressive change in the flexure constants. Nearly forty years ago W. Struve adopted this as the explanation of an apparent annual variation of 0″·06 in the latitude of Dorpat.

* Computed with the finally adopted elements of the motion of the pole.

But in the present case the sine flexure is eliminated by giving equal weight to the observations of stars on opposite sides of the zenith in the reduction of each night's work, and the cosine flexure is commonly supposed to be eliminated from the mean of observations made Circle W. and Circle E.

I know of no other reasonable hypothesis to adopt in this connection except that of an actual change in the latitude, but before coming to any conclusion it will be well to consider another set of latitude determinations which are available. The latitude of Madison was first determined in 1873 by officers of the U. S. Coast Survey, employing the Talcott method, and since that date five other determinations have been made by the same method. The final results of these determinations are contained in the following table:

Date.	Obs'r.	No. of Obs.	No. of Pairs.	Seconds of Lat.	Periodic Term.	Corrected Latitude.
1873·62	B.	60	12	36″·24 ±0″.05	+0″.15	36″·39
81·64	C.	26	16	36·58 ± ·13	+ ·17	36·75
84·50	C. & H.	72	11	36·98 ± ·08	— ·03	36·95
89·33	T.	84	15	37·36 ± ·14	— ·23	37·13
90·50	T.	53	11	37·17 ± ·09	— ·03	37·14
91-50	C.	49	13	37·21 ± ·06	— ·02	37·19

The latitudes determined in 1884, '90 and '91 are from observation of substantially the same pairs of stars, the other latitudes are from other stars but all of the declinations employed have been taken either directly from the Berliner Jahrbuch or from a discussion of the data contained in modern catalogues of precision reduced by the application of systematic corrections to the system of Pub. XIV, *Astron. Gesell.* While the star places thus determined doubtless admit of further improvement, it seems to me highly improbable that any one of the above latitudes can be altered in this way by so much as 0″·1 and they must therefore be considered as representing the relation of the latitude at the epochs of observation to the system of declinations of the Berliner Jahrbuch within the limits of the accidental error of observation and such systematic error as may affect determinations of this kind.

I have applied to the observed latitudes the correction for periodic variation

$$-0''\cdot 26 \sin(\odot + 73^\circ)$$

and have obtained by a graphical treatment of the corrected results the

$$\text{Annual variation of latitude} = +0''\cdot 043$$

agreeing more closely than could be expected with the variation indicated by the meridian circle, while the several latitudes from which the annual variation is derived show the following astonishingly close agreement when reduced by it to a common epoch:

Date.	Latitude. 1890·0.	Weight.	*v.*
1873·6	43° 4′ 37″·10	4·0	−0″·03
81·6	37·11	0·6	− ·02
84·5	37·19	1·6	+ ·06
89·3	37·16	0·5	+ ·03
90·5	37·12	1·2	− ·01
91·5	37·13	2·8	·00

Since these two independent and dissimilar series of observations indicate the same variation of the latitude I conclude that this variation is real and I adopt for Madison

$$\text{Annual variation of latitude} = +0''{\cdot}043$$

If such a variation as this is actually in progress it must affect other latitudes and it should be recognized at every American observatory at which there is a series of latitude determinations extending over a considerable number of years. Unfortunately very few such series of observations have been published, the Naval Observatory at Washington being almost the only institution from which the requisite data can be obtained. The observations made here with the mural and transit circles have been discussed recently by Prof. Hall (A. J., No. 224) who concludes that "there is no proof of a secular change in the latitude." So far as this conclusion relates to the meridian instruments of the observatory I concur in it, but Prof. Hall includes in his discussion a comparison of the declinations of α Lyræ determined with the prime vertical transit in the years 1845, '48 and 1862–'67, and with reference to these observations I dissent from his conclusion and wish to present in some detail the evidence furnished by this instrument which on account of its extreme precision and its freedom from systematic error seems entitled to far more confidence than can properly be accorded to the meridian instruments. I must here acknowledge my indebtedness to the Superintendent of the Naval Observatory, Capt. F. W. McNair, U. S. N., who has placed at my disposal the manuscript results of unpublished observations made with this instrument in the years 1882–'84.

I have collated all the observations of α Lyræ, including fifty-eight made in the years 1846–'50, but omitted from Prof. Hall's data; have compared them with Auwers' declination of the star carried back to the epochs to which the observations were reduced and from this comparison and a similar comparison with Boss's declination I have derived the following values of the latitude:

		Seconds of Latitude.		Ann. Var.	
Epoch.	No. of Obs.	Auwers.	Boss.	Auwers.	Boss.
1847·2	192	37″·26	37″·64		
				+0″·050	+0·031
1864·5	436	38·13	38·17		
				+ ·041	+ ·018
1883·5	123	38·90	38·51		

The progressive character of the results is here unmistakable and the Madison variation is confirmed. But in order that my conclusions may not be open to the objection of resting upon an assumed proper motion of a single star, I have derived a value of the latitude for the several epochs from all of the observations of fundamental stars (*Berliner Jahrbuch*) which are available for this purpose with the following result:

Epoch.	No. of Stars.	No. of Obs.	Seconds of Lat.	Ann. Var.
1847·0	41	461	37″·31 ± 0″·03	
				+0″·047
1864·5	1	436	38·13 ± ·06	
				+0·037
1883·5	9	306	38·83 ± .05	

Auwers' proper motions have been employed in this comparison, but it should be stated here that there is some uncertainty in regard to the proper motions employed by the observers in reducing the observed declinations to a mean equinox, since the printed volumes contain no indication of these. It is stated in connection with the mural circle observations that the proper motions there employed for this purpose were taken from the Nautical Almanac for 1848, and I have assumed that the same practice prevailed with the prime vertical transit and have corrected the printed results by the product of the difference between these proper motions and those of Auwers, multiplied by the time interval between the date of observation and the equinox to which the observations were reduced. There is probably a certain amount of error introduced by this process into the latitude for 1847 but its total amount must be exceedingly small since in no case were the observations reduced to an equinox more than five years removed from the date of observation.

The data furnished by the prime vertical transit may be presented in another form which eliminates the declinations of the stars and involves only their proper motions. There are nine stars common to the observations of 1847 and 1883 which are also contained in Auwers' Fundamental Catalog. A comparison of the corrections to Auwers' declinations furnished by the observations of 1847 and 1883 is contained in the following table in the preparation of which I have assumed that the earlier observations were reduced with sufficiently accurate values of the proper motions to require no further correction. The error of this assumption will in some measure tend to counterbalance the error made above in the same connection.

Correction to Auwers' δ.

Star.	1847.	Obs.	1883.	Obs.	1847–1883.
κ Androm.	+1″·09	17	−0″·14	28	+1″·23
Gr. 1450	+1·12	2	+0·69	24	+0·43
10 Leo. Min.	+1·49	2	+0·16	10	+1·33
31 Leo. Min.	+1·79	5	−0·31	23	+2·10
17 H. Can. Ven.	+1·79	3	−0·15	13	+1·94
π Herculis	+1·49	5	+0·18	28	+1·31
ϑ Herculis	+1·78	3	−0·26	19	+2·04
α Lyræ	+1·52	192	−0·10	123	+1·62
10 Lacertæ	+1·34	8	−0·12	38	+1·46

This comparison may be interpreted as indicating either that the latitude of Washington changed to the amount of 1″·5 between 1847 and 1883 or that Auwers' proper motion of each of these nine stars is too great and that the mean value of this error is 0″·041. I do not at present see how to draw any other conclusion and of the two the former appears to me the more probable especially as it is confirmed by the Madison observations. I therefore adopt for Washington

Annual variation of latitude , +0″·042

I have searched diligently for other American data to compare with the above but I have found nothing which certainly contravenes it and but little which confirms it. A comparison of the latitudes determined at Annapolis by Chauvenet in 1853 and by Brown in 1883 indicates an increase of the latitude by 1″·0 between these dates, but it is questionable if the observations are comparable.

The results at Cambridge are conflicting as is shown in the following table taken from vol. xvii of the Annals of the Harvard College Observatory, excepting the result for 1845 which I have derived from a rediscussion of the original data contained in Peirce's memoir on the Latitude of Cambridge.

Date.	Latitude.	Method Employed.
1845·0	42° 22′ 47″·00±0″·19	Prime Vertical Transit.
55·8	47·61± ·08	Zenith Telescope.
85·8	47·64± ·02	Almucantar.

In my judgment no conclusion can be drawn from these numbers until the relative errors of the several methods have been more closely investigated than has yet been done. For the present the only available data seems to be contained in the following table:

Station.	Longitude.	Ann. Var. of ϕ.	Weight	No. of Determin's.	Comput'd Ann. Var.
Pulkowa	$-30°·3$	$-0''·006$	4	3	$-0''·007$
Königsberg	$-20·5$	$-0·003$	1	1	$-0·000$
Washington	$+77·0$	$+0·042$	4	1	$+0·044$
Madison	$+89·4$	$+0·043$	4	2	$+0·041$

The longitudes are reckoned from Greenwich.

I have made a least square solution of these data to determine the most probable direction and amount of motion of the pole and find a motion of 0″·044 along the meridian 69° west of Greenwich. The last column of the table above contains the values of the annual variation at the several stations computed from these elements.

If the elements of the motion of the pole thus derived are even a rough approximation to the truth they furnish valuable indications of the methods by which our knowledge may be extended. In the first place European observatories cannot be expected to show any considerable change of latitude. Observations made there will be chiefly valuable for determining the direction of motion of the pole and for this purpose a careful comparison of the older latitudes with modern determinations is much to be desired. In particular the latitude determinations made at Dorpat by W. Struve in 1824 and 1827 with the meridian circle and prime vertical transit are for this purpose probably the most valuable data not yet utilized. I have endeavored to compare these with similar modern determinations by Schwarz and Renz but the printed results of the later determinations, at least so far as I have access to them, do not furnish sufficient data for the purpose. In America the older latitudes of the Coast Survey could very profitably be rediscussed and compared with redeterminations at such stations as can now be identified. A redetermination of the latitude of Cambridge with both the prime vertical transit and the zenith telescope seems especially desirable and the Asiatic stations occupied by the American Transit of Venus parties in 1874 can be made to furnish most valuable data, since their latitudes should now be three quarters of a second less than in 1874.

I wish now to consider briefly a plan for the systematic investigation of the motion of the pole. For the present it seems best not to attempt the absolute determination of latitudes for this purpose on account of their great liability to systematic error but rather to rely upon differential methods.

These methods as commonly applied require an accurate knowledge of the declinations and proper motions of the stars but it is perfectly feasible to eliminate both declinations and proper motions and leave the resulting variation of latitude almost if not quite free from systematic error. To illustrate, suppose two stations to be selected as nearly as possible on the same parallel of latitude, one in longitude 70° west of Greenwich and the other 110° east and let the latitudes of the stations be simultaneously determined by zenith telescope observations of the same pairs of stars. The difference of the latitudes of the stations thus determined is entirely independent of the star places, and I know of no source of systematic error by which this difference can be affected except possible personal peculiarities of the observers which can be eliminated by an interchange of observers if this should be thought desirable. The periodic variation of the latitude would be eliminated from the mean of observations made at epochs six months apart. An annual motion of the pole of 0″·045 will alter the difference of latitude of these stations by twice this amount per year giving a change in the difference of latitude amounting to 1″ in eleven years, a quantity which cannot possibly escape careful observations with the zenith telescope or prime vertical transit. If similar observations be conducted near the meridian 20° east of Greenwich they will furnish the best attainable data for determining the direction of motion of the pole. The execution of this program, which can be effected within a dozen years, will add more to our knowledge of the variation, or possible permanence, of terrestrial latitudes than can be furnished by all the astronomical observations that have hitherto been made. By a proper selection of stations it will even be possible within a year or two to test the results above obtained. The following pairs of stations approximately satisfy the conditions above indicated and in addition possess the great advantage that at each one of them a good value of the latitude was determined by the Talcott method prior to 1875:

Vladivostok,	Lat. 43° 6′·6	Peking,	Lat. 39° 54′·3
Madison, Wis.	43 4·6	Columbus. O.	39 57·7

Nagasaki,	Lat. 32° 43′·4
Macon, Ga.	32 50·4
San Diego, Cal.	32 43·1

If these stations can now be reoccupied the simultaneous determination of latitudes at the two stations composing a group will furnish the beginning of the program above indicated while the latitudes thus derived will be immediately available for comparison with the earlier determinations. I know no reason to suppose that the determinations of latitude already made at the other stations are less precise than that at Madison and a rediscussion of this determination has shown that by the aid of improved star places the latitude referred to Auwers' declination system is determined for the epoch 1873 with a probable error of 0″·05. If the same degree of precision obtains at the other stations a new set of determinations in 1892 would furnish for a single pair of stations a value of the annual motion of the pole with a probable error of only 0″·003.

But little difficulty will be experienced in securing new determinations at the American stations. I will myself become responsible for the observations at Madison, and it is probable that upon a proper presentation of the case being made to the Superintendent of the Coast and Geodetic Survey the observations at Columbus and Macon or San Diego will be undertaken by that organization. To secure the reoccupation of the Asiatic stations, however, is a very different matter, for which concerted action of some kind will probably be necessary, and it is with a view to securing such action that I present this paper to the Section for discussion.

ART. LII.—*On the Capture of Comets by Planets, especially their Capture by Jupiter*; by H. A. NEWTON.

[Continued from p. 199, Sept., 1891.]

30. IF there are assumed to be n comets equably distributed in each unit of the space near and through which a planet is moving, and if these comets are all assumed to be moving in parabolas about the sun with the velocity v, having also their directions of motion equably distributed, then the number that are moving from quits lying within an element dS of the surface of the celestial sphere will be $\frac{nd\text{S}}{4\pi}\cdot$ Let v_0 be the common velocity of these comets relative to the planet. Then suppose that a spherical surface S′ is described with a radius r' about the planet as center; r' being small relative to the sun's distance, yet not so small as to forbid the omission of the planet's perturbing action so long as the comet is without the surface S′. In each unit of time out of these comets directed from the element dS of the celestial sphere there would pass nearer than r' to the planet $n\frac{d\text{S}}{4\pi}.\,\pi r'^2 v_0 = \frac{1}{4} n v_0 r'^2\, d\text{S}$

comets if unperturbed. Evidently an equal number cross the surface S′ entering the sphere in each unit of time.

If now ω be the angle which the comet's unperturbed motion is making with the planet's motion, and if v_1 or its equal $v/\sqrt{2}$, be the planet's velocity in its orbit about the sun, then $v_0^2 = \frac{1}{2}v^2[3-2\sqrt{2}\cos\omega]$. The element dS may be taken to be the elemental zone between the two small circles whose common pole is the planet's quit, and whose distances from the planet's quit are ω and $\omega+d\omega$. Then $d\text{S} = 2\pi\sin\omega\, d\omega$. The number of comets entering S′ in a unit of time with quits within that elemental zone will be

$$\tfrac{1}{4}nv_0r'^2\times 2\pi\sin\omega\, d\omega = \frac{\pi nvr'^2}{2\sqrt{2}}(3-2\sqrt{2}\cos\omega)^{\frac{1}{2}}\sin\omega\, d\omega.$$

The integral of this,

$$\frac{\pi nvr'^2}{2\sqrt{2}}\int_0^\pi (3-2\sqrt{2}\cos\omega)^{\frac{1}{2}}\sin\omega\, d\omega = \tfrac{7}{6}\pi nvr'^2,$$

expresses the total number of comets that, under the hypotheses that have been made, would in a unit of time enter the sphere S′.

31. If we compare the two expressions obtained in Arts. 27 and 30 we find that the number of comets which, in a given period of time come nearer to the sun than r is to the number that (unperturbed) come nearer to the planet than r' as $6r^2$ is to $7r'^2$. The factor $\frac{7}{6}$ expresses the increase of numbers caused by the planet's motion in its circular orbit. The value of r', as has been said, must not be too small, nor yet must it be very large.

32. In order to determine the number N of comets which in a unit of time will have their periodic times reduced below a given period we may make use of the isergonal curves represented in Figs. 2–18. Although the diagrams were not constructed to exhibit the motions of the bodies, yet they may be utilized for that purpose. Let OH be the tangent to the planet's orbit, O the place of the planet considered at rest, and let the plane HOE contain the shortest line d between the two orbits. This d will be the abscissa of the point at which the comet's unperturbed orbit will cut the plane. The ordinate of the same point, produced if necessary, will be the projection of the comet's path upon the plane HOE, and the comet's path makes with the plane the angle θ. The velocity of the comet perpendicular to the plane will be $v_0\sin\theta$. By reason of the hypothesis that the comets are equably distributed, the points of intersection with the plane HOE will be equably distributed over the plane. Hence the number of

comets whose quits are in the element dS of the celestial sphere and that will pass the planet in a unit of time in such a way as to have their periodic times reduced below a given period will be equal to the area inclosed in the corresponding isergonal curve multiplied by the velocity perpendicular to the plane, $v_0 \sin\theta$, and by the factor $\frac{ndS}{4\pi}$. If @ is the semi-major axis of the orbit for the limiting periodic time, the area of the corresponding isergonal curve will be (Art. 17).

$$\frac{\pi}{\sin\theta}\left(\frac{4m^2@^2}{s^2}-\left(\frac{2m@\cos\theta}{s}-\frac{mr}{s^2}\right)^2\right).$$

For dS we may, as before, take $2\pi\sin\omega\, d\omega$, and we shall then have

$$\mathrm{N}=\frac{\pi n}{2}\int v_0\sin\omega\left[\frac{4m^2@^2}{s^2}-\left(\frac{2m@\cos\theta}{s}-\frac{mr}{s^2}\right)^2\right]d\omega.$$

The integration must extend through the positive values of the quantity in square brackets beginning at $\omega=0$. [In case $\omega=0$ gives a negative value for the quantity in square brackets we must integrate between the two values of ω corresponding to the zero value of the bracketed quantity.] We may make S the independent variable by the equations $sds=\sqrt{2}\sin\omega\, d\omega$, $v_0\sqrt{2}=sv$, and $2s\cos\theta=1-s^2$.

These give:

$$\mathrm{N}=\tfrac{1}{4}\pi nm^2v\int\left[4@^2-\left(\frac{@-r-@s^2}{s}\right)^2\right]ds.$$

33. If now we require the number of comets which in each unit of time shall pass the planet in such way as that they shall have after the passage respectively less than one-half, once, three-halves, and twice, the planet's period of revolution, we may place $@=r\mathrm{T}^{\frac{2}{3}}$, and make T equal successively to $\frac{1}{2}$, 1, $\frac{3}{2}$, and 2, and compute in each case the vâlue of N as given in the last article. The results are found to be πnm^2r^2v multiplied severally by the coefficients 0·139, 0·925, 1·875, and 2·943.

34. By comparing the results of Arts. 27 and 33, and making the assumptions of Art. 26, we have the proposition, that *the number of comets which in a given period of time pass their perihelia nearer to the sun than a given planet, is to the number of comets whose periodic times are reduced by the perturbing action of the planet so as to be less severally than one-half, once, three halves, and twice, the periodic time of the planet, as unity is to the square of the mass of the planet multiplied severally by* 0·139, 0·925, 1·876 *and* 2·943.

35. If Jupiter is the planet, $m = \frac{1}{1050}$, and we may express these ratios as

1 000 000 000 : 126 : 839 : 1701 : 2670.

That is, assuming the hypotheses of Art. 26, and regarding the planet as without dimension so as to intercept any comets, *if in a given period of time a thousand million comets come in parabolic orbits nearer to the sun than Jupiter,* 126 *of them will have their orbits changed into ellipses with periodic times less than one-half that of Jupiter;* 839 *of them will have their orbits changed into ellipses with periodic times less than that of Jupiter;* 1701 *of them will have their orbits changed into ellipses with periodic times less than once and a half times that of Jupiter; and* 2670 *of them will have their orbits changed into ellipses with periodic times less than twice that of Jupiter.*

36. Another and perhaps a more important inquiry is this, what effect have the perturbations of the planet in bringing or not bringing the comets to move in the same direction that the planet is moving after the comets have by perturbation had their periodic times largely reduced. For simplicity and as a special example I shall consider the action of Jupiter only, and also only his action upon those comets whose periodic times are reduced to be less than Jupiter's period, the original orbits of the comets being parabolic. In other words, how many of the 839 comets which are reduced (Art. 35,) to have periodic times less than Jupiter's period will after perturbation have goals distant less than 15°, 30°, 45°, etc., severally from Jupiter's goal?

37. Let BA, Fig. 19, be drawn to represent v_1 and CA to represent $v_1\sqrt{2}$. With A as a center and AB and AC as radii describe the semicircumferences BLO and CHG. Let the angle BAH be made equal to ω and BH be drawn; then HA will represent the comet's velocity about the sun, BA the planets velocity about the sun, and therefore HB the comet's velocity v_0 in its orbit about the planet before perturbation. About B as center describe the semicircumference KHT. Since the relative velocity after as well as before perturbation is equal to HB, therefore the velocity of the comet about the sun after perturbation will evidently be represented by a line drawn from some point in the semicircumference KHT to A. If the velocity is increased the new velocity will be represented by a line to A from some point in the arc KH, if diminished by a line to A from some point in the arc HT. If the new velocity is less than the planet's velocity, and so the new cometic period less than the planet's period, the new velocity will be represented by a line to A from some point in the arc ET.

If in a diagram constructed for $\omega = \mathrm{BAH}$ the isergonal curve be drawn for $@ = r$, those comets for which d and h represent points within that isergonal curve will after perturbation have velocities represented by lines drawn from points in ET to A, while comets for which d and h represent points outside that isergonal curve will after perturbation have directions of motion represented by lines drawn to A from points in EHK.

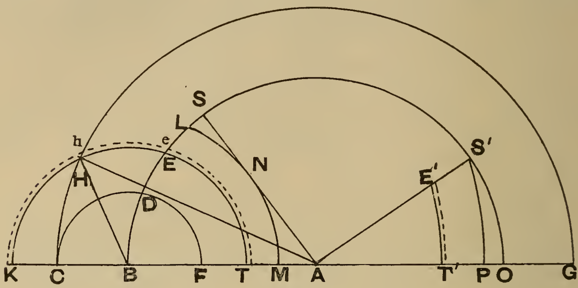


Fig. 19.

The number of comets having motions represented by lines to A from points in ET will be proportional to the area of the isergonal curve $@ = r$. Let the angle BAS represent a limiting value ω'' of distance of quits of comets from Jupiter's quit after perturbation. The comets which are thus limited and at the same time have $@ < r$ will be moving in lines directed to A from points in the area bounded by the straight lines SA and AF, and the arcs FD and DS. Let ω receive an increment $d\omega = \mathrm{H}h$ and let a new semicircumference be drawn with Bh as radius. To the elemental arc Hh will correspond the elemental area along the semicircumference KET. If ET lies wholly in SAFD the number of comets that pass the planet in a unit of time having initial angles of direction with Jupiter's motion between ω and $\omega + d\omega$ will be equal to the area of the isergonal curve for $@ = r$ multiplied by the elemental number $\frac{1}{2}n \sin \omega d\omega$, and by the relative velocity $v_0 \sin \theta$ of the comet perpendicular to the isergonal area. If the area of the isergonal curve be represented by $\Phi s^2 \sin \theta$, then this product will be

$$\frac{\Phi}{s^2 \sin \theta} \cdot v_0 \sin \theta \cdot \frac{n \sin \omega d\omega}{2} = \frac{nv}{4} \Phi ds.$$

since $\sqrt{2}v_0 = sv$, and $\sqrt{2} \sin \omega d\omega = sds$.

38. This expresses the elemental number of comets corresponding to the elemental area Te. The integral of this expression, that is, $\frac{1}{4}nv\int \Phi ds$, so taken as to cover the area

AFDS will give the number of comets which in a unit of time will pass the planet in such a way as to have $@<r$ and $\omega'<$BAS. When the elemental area does not extend from the arc DS to the line BA, the area of another appropriate isergonal curve is to be used in determining Φ.

By Art. 17 we have

$$\Phi = \pi m^2\left[4@^2-\left(\frac{@-r-@s^2}{s}\right)^2\right].$$

For the elemental areas of the surface AFDS which end on the arc DS we make $@=r$, and let Φ_0 be the resulting value of Φ; then $\Phi_0 = \pi m^2r^2(4-s^2)$.

For elemental areas that end on the radius AS the values of $@$ on that line are functions of s. To compute them let v' be the comet's velocity in its orbit about the sun, and hence equal to the distance of the point on AS from A; then, by the triangle of velocities

$$v_{,}^2+v'^2-2v'v_{,}\cos\omega''=v_0^2=s^2v_{,}^2.$$

Again by the laws of gravitation,

$$v'^2=\left(2-\frac{r}{@}\right)v_{,}^2.$$

Hence

$$s^2=3-\frac{r}{@}-2\sqrt{2-\frac{r}{@}}\cos\omega'',$$

or

$$\frac{@}{r}=\frac{3-s^2-2\cos^2\omega''\pm2\cos\omega''(s^2-\sin^2\omega'')^{\frac{1}{2}}}{9-8\cos^2\omega''-6s^2+s^4}.$$

Let Φ' and Φ'' be the two values of Φ obtained by substituting in Φ these values of $@$, Φ'' representing the value for the point nearer to A.

39. If $\omega''=90°$, and therefore $\cos\omega''=0$, we have along the limiting line, the two values of $@$ equal, hence

$$\frac{@}{r}=\frac{1}{3-s^2},\ \text{and}\ \Phi'=\frac{s^2-1}{s^2(3-s^2)^2},$$

so that the number of comets having quits less than 90° from Jupiter's quit and $@<r$ is

$$\frac{nv}{4}\int_{\sqrt{2}-1}^{\sqrt{2}}\Phi_0 ds-\frac{nv}{4}\int_1^{\sqrt{2}}\Phi' ds=\frac{\pi nvm^2r^2}{4}\left[\int_{\sqrt{2}-1}^{\sqrt{2}}(4-s^2)ds-4\int_1^{\sqrt{2}}\frac{(s^2-1)\,ds}{s^2(3-s^2)}\right]$$

$$=\frac{\pi nvm^2r^2}{12}(7+\sqrt{2})=\cdot7012\ \pi nvm^2r^2.$$

Since the whole number of such comets is (Art. 33) equal to $\cdot925\ \pi nvm^2r^2$, the number of comets the distance of whose quits from Jupiter's quit is between 90° and 180° is ·224 $\pi n v m^2 r^2$. The number of the comets for which @$<r$ that have inclinations to the ecliptic less than 90° is to the number that have inclinations greater than 90° as 701 is to 224. *Of the* 839 *comets spoken of in Art.* 36, 203 *will after perturbation have retrograde motions, and* 636 *will have direct motions.*

40. If ω'' is less than 90° the expression to be integrated in order to cover the area SAFD will be

$$\int_{\sqrt{2}-1}^{\sin\omega''} \Phi_0 ds + \int_{\sin\omega''}^{2\sin\frac{1}{2}\omega''} (\Phi_0 - \Phi')\, ds + \int_{\sin\omega''}^{1} \Phi'' ds.$$

If ω'' is greater than 90° the corresponding expression becomes

$$\int_{\sqrt{2}-1}^{2\sin\frac{1}{2}\omega''} \Phi_0 ds - \int_{1}^{2\sin\frac{1}{2}\omega''} \Phi''\, ds.$$

As the value of @ introduces into Φ' and Φ'' only one radical in s, and that a radical of the second degree, these integrations are possible. Finite summation is however more convenient. Computing the values for each interval of 15° we construct the following table. The first column indicates the interval in values of ω''; the second column gives that coefficient of $\frac{1}{4}\pi n v m^2 r^2$ that must be used to obtain the number of comets which in a unit of time will pass perihelion nearer than Jupiter's distance to the sun, shall also have their periodic times reduced to be less than Jupiter's period, and shall also leave Jupiter's vicinity so that the distance between the quits of the two bodies is between the two values in column I; the third column indicates the distribution of the 839 comets of Art. 36 through the twelve zones.

TABLE III.

Limiting values of ω''.	Coefficient of $\frac{1}{4}\pi n v m^2 r^2$.	No. out of 839 comets.
From 0° to 15°	26	6
From 15° to 30°	401	91
From 30° to 45°	751	170
From 45° to 60°	670	152
From 60° to 75°	548	124
From 75° to 90°	443	101
From 90° to 105°	296	67
From 105° to 120°	235	53
From 120° to 135°	162	37
From 135° to 150°	99	23
From 150° to 165°	50	11
From 165° to 180°	16	4

We see also from the last column of this table that of the 839 comets under consideration 267 have quits less than 45°

from Jupiter's quit, while only 38 of them have quits within 45° of Jupiter's goal.

41. Table III gives the distribution of the comet quits relative to Jupiter's quit. It may also be used to determine how many of the comets whose orbits are thus changed shall have an inclination to the plane of Jupiter's orbit less than a given angle.

Let the angle be 30°. Let Q be Jupiter's quit on the celestial sphere, Q′ the comet's quit and S the sun's position as seen from Jupiter. Then in the triangle QQ′S put ω'' for QQ′ the distance of the quits. The side QS = 90°, and QSQ′ will be the inclination of the orbits. Represent this angle by i and the angle Q′QS by η. Then $\sin\eta = \cot\omega'' \cot i$.

Let two small circles be drawn about Q at distances ω'' and $\omega''+d\omega''$ then if $d\omega''$ be made 15° the numbers in the second or third columns of table III indicate how many quits are in the several zones of 15° on the celestial sphere. These may be distributed at smaller intervals than 15° by known processes. All the quits that lie in the lune between two semicircles drawn through S so as to make angles of 30° with QS will evidently have orbits inclined less than 30° to Jupiter's orbit. From $\omega'' = 0$ to $\omega'' = 30°$ all the quits are included in the lune. From $\omega'' = 30°$ to $\omega'' = 90°$ we compute η from the equation $\sin\eta = \cot\omega'' \cot 30°$; then the portion of the quits in any elemental zone that fall in the lune is to the whole number of quits in that elemental zone as this value of η is to 90°. These may be summed by finite summation, and the result is that among the 839 comets 257 would move in orbits inclined less than 30° to the orbit of Jupiter

42. If a like summation be made for the equal lune that contains Jupiter's goal we find 51 to be the number out of the 839 comets which move in orbits inclined more than 150° to Jupiter's orbit. That is, *somewhat more than five times as many of these comets move in direct orbits inclined less than 30° to Jupiter's orbit as move in retrograde orbits inclined less than 30° to Jupiter's orbit.*

43. The comet has been thus far considered as approaching Jupiter while moving in a parabolic orbit about the sun. If the comet however is moving in any other orbit, and it passes near to the planet, the result of the planet's perturbing action will in general be quite similar to the result when the orbit is parabolic, the other circumstances of the approach being assumed to be alike in the two cases.

44. These are perturbations during one transit past the planet. But the comet, unless the orbit is further changed by another planet, must return at each revolution to the place where it

encountered Jupiter. At some time Jupiter will be nigh that place nearly at the same time as the comet, and the comet will suffer a new, and perhaps a large perturbation. Its period will again be changed, being shortened or lengthened according as the comet passes before or behind the planet. This process will be repeated again and again, since after any number of encounters the new orbit of the comet will still pass near to the orbit of the planet.

This repeated action makes it possible to have an orbit shortened in period by several passages near to Jupiter instead of its being done at one passage. A much larger proportion of comets than 839 out of 1,000,000,000 might therefore have their periodic times reduced below the period of Jupiter.

45. If the comet's orbit is largely inclined to the ecliptic and hence its motion makes a large angle with that of Jupiter the diagrams figs. 10–18 show that there is nearly an even chance that the velocity will be increased or diminished. A considerable fractional part of the whole number of such comets will at each passage be thrown out of the solar system altogether, or thrown into such long orbits that they will return only at very great intervals of time. This class of comets cannot be therefore regarded as permanent members of the family of short period comets, except such of them as happen to come so near to other planets as to have their orbits changed in such wise that they do not have thereafter the near approach to Jupiter's orbit. But when an orbit is greatly inclined to the plane of the solar system the comet passes through the plane in general at a considerable angle and the chance of coming close to another planet is relatively small.

46. On the other hand all the comets which after perturbation are moving in orbits somewhat but not greatly inclined to the ecliptic are liable to meet, in fact are sooner or later almost certain to meet other planets in such a way as to suffer perturbations that will prevent future close encounters with Jupiter. After such changes those comets must be regarded as tolerably permanent members of the solar system.

47. Comets that have motions not greatly inclined to Jupiter's motion are, as figs. 2 and 4 show, more likely in subsequent passages near to Jupiter to have their periodic times shortened than lengthened. On the contrary those passing in nearly opposite direction to Jupiter's motion will as figs. 3, 5 and 7 show, be much more likely to have their periods lengthened than shortened.

All these causes combine and work together to the one end that those comets which are changed by the perturbing action of Jupiter, or other planets, from parabolic orbits of every possible inclination to the ecliptic into short period ellipses and become permanent members of the solar system, will as a rule (but with exceptions) move in orbits of moderate inclination to the ecliptic, and with direct motions.

We know as a fact that most short period comets do move in orbits having small inclinations and direct motions, while long period and parabolic comets move at all possible inclinations to the ecliptic. If the short period comets have been changed by Jupiter and other planets from parabolic orbits, the preceding investigation shows why their orbits have now small inclinations to the ecliptic, and the comets themselves have direct motions.

ART. LIII.—*Distribution of Titanic Oxide upon the surface of the Earth;* by F. P. DUNNINGTON, University of Virginia, Charlottesville, Va.

AT the Ann Arbor meeting of the Association for the Advancement of Science in 1885, I read a short paper* which considered the occurrence of titanic oxide in considerable amount in certain soil of Albemarle Co., Va.; and in an article published† in 1888, by Mr. J. F. McCaleb and myself, we presented estimations of this substance in sixteen specimens of soil from scattered points of the United States.

In view of the unfrequent mention of this element as a constituent of rocks and the very rare mention of its occurrence in soils, I have endeavored to secure samples of soil and some rocks from points scattered over the earth's surface; and, including the before mentioned sixteen, I herewith present the results of examining eighty specimens.

The method employed in the recent determinations is the following: weigh into a platinum crucible one gram of the powdered sample, ignite, again weigh, then moisten with water and add 2 or 3 c.c. of hydrofluoric acid,‡ gradually heat to dryness, add about 7 grams of sodium acid sulphate, gradually heat to low redness for 1 or 2 hours, cool, digest in 5 per cent diluted sulphuric acid for several hours, filter, to filtrate§ add about 1 c.c. of hydrogen peroxide solution and compare the color so produced with one similarly obtained from a standard solution of titanic oxide.

* Proc. A. A. A. S., xxxiv, 132. † American Chem. Jour., x, 36.

‡ This acid was used before seeing the article of Dr. Noyes in Jour. Anal. Chem., v, 39.

§ Method of A. Weller: Berichte d. deutsch. chem. Gesell., xv, 2592.

To present a more satisfactory comparison with the amount of titanic oxide in the rocks, the percentage on the ignited soil is given together with that on the air-dried soil.

Nos. (1) to (12) are all from Albemarle Co, Va. (1) is dark red clay, from Carter's mountain, farm of Rev. J. T. Randolph being the soil from which was formed a fulgerite (?) which first drew my attention to this occurrence of titanic oxide. (2), deep red clay, one mile south of (1). (3), red clay, one mile north of (1). (4), red clay, one-half mile west of (1). (5), light red sand, one mile northwest of (1). (6), red bottom soil, one and one-half miles northwest of (1). (7), white micaceous soil, near McCormick Observatory, University Va., and three miles west of (1). (8), near chemical laboratory of University Va. (9), mica schist, one-half mile north of (8). (10), deep red clay, ten miles southwest of (1). (11), red clay ten miles west of (1). (12), Diorite, the rock which is most common in the above locality.

Nos. (13) to (17) are from other points in Virginia: No. (13), is deep red clay from farm of Mr. J. Shelton, Lowesville, Nelson Co. No. (14) a dark gray clay from swamp on Rappahannock River in Stafford Co. No. (15), a gray sandy loam, near Williamsburg, James City Co. No. (16), a yellow clay, per Mr. F. P. Brent, Onancock Creek, Accomac Co. No. (17), white sea sand, from Virginia Beach, Princess Anne Co. The percentage of titanic oxide found in these respectively is as follows:

	Air-dried.		Air-dried.		Air-dried.	Ignited.
(1)	5·42	(7)	0·77	(13)	1·87	
(2)	1·45	(8)	2·86	(14)	0·88	
(3)	2·73	(9)	1·14	(15)	0·49	0·50
(4)	2·73	(10)	1·86	(16)	0·80	0·84
(5)	0·33	(11)	1·51	(17)	0·07	0·07
(6)	1·73	(12)	1·15	Average	1·57	

Nos. (18) to (40) are from other portions of the United States. No. (18), a light brown loam, per Dr. A. C. Hopkins, Charlestown, W. Va. No. (19), a gray loam, per Mr. J. W. Rinehart, Foote, Mineral Co., W. Va. No. (20), pale red loam, a "limestone soil" per Mr. C. C. Councilman, Worthington's valley, Baltimore Co., Md. No. (21), a gray yellow loam, per Dr. Simon Gage, Cornell University, N. Y. No. (22), a gritty yellow loam, per Dr. F. P. Venable, Chapel Hill, N. C. No. (23), a light yellow clay, 1 foot deep, per Mr. R. M. Cooper, near Black River, Sumter Co., S. C. No. (24) a gray clay per Dr. P. S. Baker, over Carboniferous Limestone, Greencastle, Ind. No. (25) a gray clay, per Dr. W. A. Noyes,* Terra Haute, Ind. No. (26), a deep orange clay sub-soil per Prof. C. E. Wait, Knoxville, Tenn. No. (27), a pinkish china clay from a 10-foot seam, and No. (28), a coarse gray clay from an 18 foot seam, both per Mr. W. R. Searcy, Tuscaloosa, Ala. No. (29), a heavy gray clay, per Mr. A. P. Wright, River bottom soil, Bolivar Co., Miss. No. (30), light red surface loam and No. (31), a gray sub-soil, both per Mr. Thos. Dunnington, Pine Bluff, Ark. No. (32), a brown clay, 6 feet deep, per Prof. W. H. Echols, Rolla, Mo. No. (33), a pale gray loam, per Dr. F. W. Traphagen, Deer Lodge, Montana. No. (34), a gray alkaline soil, from Truckee Valley, Nevada. No. (35), a yellow surface clay, per Dr. Masser, Los Angeles, Cal. No. (36), a brown clay, 3 feet deep, per Prof. H. E. Storrs, Los Angeles, Cal. Nos. (37) to (40) were sent by Prof. E. W. Hilgard, Berkeley, Cal. No. (37), upland red loam Station No. 1226, from Yuba River near Smartsville. No. (38), yellow gray Mesa soil, Station No. 1281, from Chino Ranch Station, San Bernardino Co. No. (39), "Red Mountain Land," Station No. 188, from a vineyard in Sonora Co. No. (40), a red loam, Station No. 1110, Thermolite Colony, Butte Co.

The percentage of titanic oxide found in these respectively is as follows:

	Air-dried.	Ignited.		Air-dried.	Ignited.		Air-dried.	Ignited.
(18)	0·83	0·88	(26)	0·46	0·50	(34)	0·57	
(19)	0·88	0·98	(27)	1·01	1·12	(35)	0·72	0·82
(20)	1·17	1·26	(28)	0·67	0·76	(36)	0·49	0·53
(21)	0·55	0·58	(29)	0·46	0·61	(37)	0·77	0·85
(22)	0·49	0·55	(30)	0·52	0·62	(38)	0·72	0·75
(23)	0·57	0·61	(31)	0·60	0·62	(39)	4·93	6·05
(24)	0·71	0·76	(32)	0·57	0·65	(40)	0·90	0·97
(25)	0·58	0·62	(33)	0·44	0·50	Average	0·85	0·98

Nos. (41) to (45) are from Oceanica and Asia. Nos. (41) to (45) were sent by Prof. A. B. Lyons, Oahu College, Hawaii, Sandwich Islands. No. (41), a dark brown loam. No. (42), a yellow brown loam. No. (43), a yellow brown loam. No. (44), a brown clay. No. (45), a gray brown loam. No. (46), a light gray china clay and No. (47), a gray china clay, both per Miss Mildred Page, Tokio, Japan. No. (48), a piece of a gray brick from the Great Wall of China, per Rev. Collins Denny. No. (49), a pink clay and No. (50), a yellow loam subsoil from the bank of the Yellow River, and No. (51) a fine yellow silt from the old bank of the Yellow River. The three last specimens were sent by Dr. Edgar Woods, Tsing-Kiang-Pu, China. No. (52), light red pottery, from Kurrachee, Sind, India. No.

* Dr. Noyes writes that he has recently found from ·5 to 4· per cent of titanic oxide in a number of minerals from Arkansas.

(53), dark brown crucible clay and No. (54) red furnace clay; both from Tumkur, India. The three last specimens were sent by H. B. M's Secretary for India. No. (55), gray loam from the shore of the Sea of Galilee, Palestine, per Rev. Collins Denny, of Vanderbilt University.

The percentage of titanic oxide found in these respectively is given below, and in making an average the specimens (41) to (45) are counted as one.

	Air-dried.	Ignited.		Air-dried.	Ignited.		Air-dried.	Ignited.
(41)	4·43	5·25	(47)	0·40	0·50	(53)	0·62	0·73
(42)	2·40	3·37	(48)	0·55	0·55	(54)	0·28	0·30
(43)	2·25	3·11	(49)	0·58	0·68	(55)	1·80 (?)	1·90
(44)	4·00	4·64	(50)	0·60	0·65	Average	0·90	1·18
(45)	2·78	3·37	(51)	0·54	0·56			
(46)	0·70	0·80	(52)	0·69				

Nos. (56) to (72) are soils from Europe.—Nos. (56) to (62) are from Russia and were sent by Prof. Nich, Menschutkin, Kaiser. University, St. Petersburg. No. (56) is a yellow sandy loam, "Souglinok," from Borovitsky, Novgorod. No. (57), dark gray loam, Prof. Docoutschaeff's type, "Solonetz" (barren black earth), Prilouky, Poltava. No. (58), brown gray loam, forest soil, Zenkovsky, Poltava. No. (59), dark gray loam, "Tschernosem," (black earth), Prilouki, Poltava. No. (60), sandy black earth, "Tschernosem," Zenkovetsky, Polkava. No. (61), black earth, "Tschernosem," Balashoff, Saratoff. No. (62), black earth, "Tschernosem," Zoubrilovka, Saratov. No. (63), white porcelain clay from Halle, Prussia. No. (64,) white porcelain clay from St. Yrieux near Limoges, France. No. (65), yellow gray loam from Florence, Italy, per Dr. C. L. Minor, of New York. Nos. (66) to (72) are from Great Britain and were collected for me by Prof. W. G. Brown, of Lexington, Va. No. (66) black garden soil, Kensington, London. No. (67), dark gray loam from coast near Brighton. No. (68), gray loam, Liverpool. No. (69), gray sandy loam, Donington, Lincolnshire. No. (70), gray sandy loam, Cambridge. No. (71), brown yellow clay, Inversnaid, Loch Lomond, Scotland. No. (72), brown clay, under Forth bridge, N. Queensferry.

The percentage of titanic oxide found in these respectively is as follows:

(56)	0·54	0·57	(62)	0·56	0·73	(68)	0·41	0·46
(57)	0·40	0·43	(63)	0·03	0·03	(69)	0·45	0·49
(58)	0·60	0·70	(64)	0·015	0·017	(70)	0·50	0·53
(59)	0·32	0·34	(65)	0·53	0·62	(71)	0·85	0·89
(60)	0·58	0·66	(66)	0·21	0·27	(72)	2·36	2·52
(61)	0·63	0·79	(67)	0·46	0·52	Average	0·54	0·62

This wide distribution of titanic oxide naturally suggests the examination of the rocks themselves. I have so far been able to examine only the following typical rocks, the localities of which have furnished also the samples for analyses already published: (73), Trachyte, Kühlsbrunnen. (74), Trachyte. (75), Trachyte, Drachenfels. (76), Hornblende andesite, Wolkenburg. These four were from the Siebengebirge. (77), Gabbro, Radauthal, Harzburg.* (78), Melaphyr, Ilmenau, Schneidemuller-berg. (79), Melaphyr, Plauenschen Grunde, near Dresden. (80), Nosean phonolite, Castle Olbrück, Laacher See. These afford the following:

	TiO_2 mentioned in published analysis.			TiO_2 found.
(73)	none	Zirkel, II,	p. 181	0·22
(74)	none	"	p. 182	0·86
(75)	0·38	"	p. 181	0·64
(76)	none	"	p. 212	1·14
(77)	none	"	p. 116	0·10
(78)	0·89	"	p. 55	1·01
(79)	trace	Zirkel I,	p. 584	0·36
(80)	none	"		0·18
	Average			0·56

While the frequent association of titanium with iron (as indicated by the color after ignition), in these soils points to menaccanite as a source of the titanic oxide; yet the considerable amount of this substance in some of the clays and rocks containing little iron suggests that it may also result from titanite which has been observed† to be widely distributed in igneous rocks.

In conclusion I desire to thank those who have assisted me in this work by supplying the desired specimens.

Sept., 1891.

ART. LIV.—*Notes on a Missouri Barite;* by C. LUEDEKING and H. A. WHEELER.

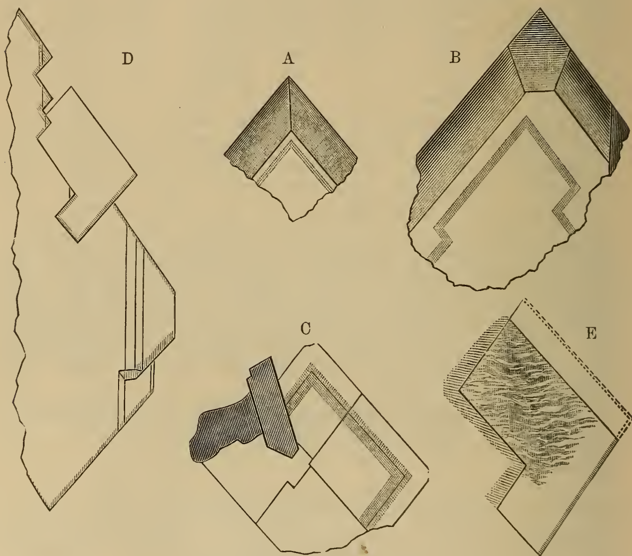
A VARIETY of barite is found in Pettis County, Mo., that presents peculiar chemical and crystallographic characteristics. It occurs in clusters of simple and compound crystals that individually are quite perfect and which vary in size from 10 to 200^{mm} in length by 1 to 30^{mm} in thickness and are of tabular habit. The peculiarity of the crystals is the occurrence of

*I find in Bischoff III, page 467: Gabbro from Rodanthal bei Steinbruch, contains TiO_2—1·75 per cent.

† Dana's System of Mineralogy, p. 389.

white to yellowish thin bands in an otherwise normal colorless barite, and analysis shows that these bands consist of a mixture of the sulphates of barium and strontium with slight amounts of calcium and ammonium.

Two distinct types of the banded crystals occur, of which one type (A, B) is found near Smithton, while the other type (C, D, E) is found at Sedalia, both localities being within seven miles of each other in Pettis Co., Mo. They occur in clay associated with galena in the lead-bearing magnesia limestone series of Missouri, which latter in that locality usually has barite very abundantly associated with the lead ores.



The crystal, A, consists of the right rhombic prism, beveled by the right rhombic pyramid and truncated by the basal pinacoid; another crystal, B, is in addition modified by the macro- and brachydomes, which, like the pyramid, have very low values for the coefficient of the vertical axis. All the faces of the modifications of the A and B forms of crystals, except the basal pinacoid, are coated with an opaque white variety of barite, next to which is a colorless band followed by a narrow white band, the body of the crystal being clear and colorless. The inner white band is from 0·5 to 1·0^{mm} wide and persistently occurs in all the Smithton specimens that have been examined in relatively the same position with respect to the development of the crystal, whether large or small in size. The white coating that fringes the crystals is usually superficial, as it most frequently is found to be underlaid by a clear wine-colored ground mass; in some crystals however the opaque matter entirely replaces this latter.

The simple tabular crystal C has a clear colorless interior inclosed within a subtransparent wine-colored band $1{\cdot}5^{mm}$ in width, that is adjoined by a white opaque band $0{\cdot}5^{mm}$ in width; both of these bands are parallel to the prismatic faces as likewise the cleavage crack shown in the drawing. The outer edge of this crystal is transparent but has the slight bluish tinge indicative of strontium.

The twinned group of crystals shown in D have the edges of the right rhombic prism modified by either one, two or three modifications of the macrodome, and truncated as usual by the basal pinacoid; in this type only the faces of the prism are coated with the opaque white barite, the rest of the material consisting of clear colorless and essentially pure barite. The thickness of this coating is variable on different faces of the prism, being appreciably greater on the upper face in some and on the lower face in other crystals and varying from 0·2 to $2{\cdot}2^{mm}$ in thickness; but in every case the opaque barite is only found on the prismatic faces.

The crystal E is a member of the same cluster of crystals from which D was taken. It consists of only the simple rhombic prism which is thinly fringed with white barite, but on one of the basal faces is a series of irregular lines of a fine white pulverulent material that suggests the deposition of a sediment on an inclined surface. A subsequent deposition of clear barite has preserved this pulverulent matter *in situ*.

An analysis of the white barite showed it to be somewhat variable in composition, but the following gives its general character.

Barium sulphate	87·2	per cent.
Strontium sulphate	10·9	"
Calcium sulphate	0·2	"
Ammonium sulphate	0·2	"
Water	2·4	"
	100·9	

The occurrence of ammonium sulphate in barite is quite novel. The amount seems to be somewhat greater in the yellow than in the white variety by about 0·1 per cent and is always very small, and occasionally scarcely appreciable. The isomorphism of ammonium sulphate, mascagnite, with barite is worthy of notice.

When the powdered white or yellow material is heated in a closed tube an appreciable sublimate of ammonium salts is obtained and at the same time an empyreumatic odor is noticeable. It was thought that perhaps the sublimate might be due to the decomposition of nitrogenous organic matter by the heat employed. That this was not the case was proved by the fact that it was possible by cold extraction with water to obtain very decided Nessler reactions for ammonia. It is therefore assumed by the writers that the ammonium occurs as mascagnite in association with the other sulphates.

Specimens of these Pettis Co. barites were sent to Mr. F. W. Clarke, of the chemical department of the U. S. Geological Survey, and were kindly examined by Dr. W. F. Hillebrand, who confirms the presence of ammonia. Mr. J. S. Diller, of the U. S. Geological Survey, also examined them microscopically and finds that the opacity is probably due to the presence of myriads of cavities which seem to be filled with air.

We wish to herewith express our thanks to these gentlemen, as well as also to Dr. Hambach of St. Louis and Mr. Sampson of Sedalia for samples furnished.

Art. LV.—*The Contraction of Molten Rock*; by C. Barus.

At the request of Mr. Clarence King I made the following volume measurements on a sample of diabase which he furnished. In the method employed, both the contraction of the rock and of the vessel containing it, were measured simultaneously, and cooling was conducted so slowly that the viscosity of the latter remained indefinitely high relatively to the former, throughout. Four series of data are in hand, the last two of which are full and satisfactory. Thus if 3α be the mean coëfficient of actual volume expansion (or contraction), and 3β be the actual volume decrement on solidifying, where both 3α and 3β are referred to the unit of volume of solid rock at zero centigrade, I found in the third series between 0° and 1000°, $3\alpha = 250/10^7$; between 1100° and 1500°, $3\alpha = 470/10^7$; at 1095°, $3\beta = +39/10^3$; and in the fourth series, similarly, $3\alpha = 250/10^7$, $3\alpha = 468/10^7$, $3\beta = +34/10^3$, respectively. Fusion of igneous rock (diabase) is therefore not only quite normal in type, but sharp at a definite melting point. Thus the volume increments $(v_t - v_0)/v_0$, at consecutive temperatures, t, during contraction of the originally liquid mass were found to be, for instance (fourth series): 0·0771 at 1421°, 0·0760 at 1388°, 0·0730 at 1319°, 0·0721 at 1305°, 0·0661 (sticky) at 1190°, 0·0652 (very sticky) at 1163°, ·0628 at 1112°, falling off eventually to 0·0285 at 1093°, 0·0223 at 914°, 0·0202 at 855°, etc. Conversely since sudden bulk contraction is a criterion for solidifying point, these results lead to sharp values for this datum.

Finally, the density of the original (cold) rock was 3·0178 (four measurements) and the density of the (cold) glass after fusion 2·717 (three measurements). Now I have been at considerable pains to show that the chemical equilibrium of a substance (solid or liquid) varies with pressure. Since, therefore, the glass obtained by fusion is permanently homogeneous in character, structural rock texture is due to pressure; i. e. pressure induces a redistribution of molecules, such that the smallest specific volume possible under the given conditions may result. Hence it is permissible to conceive a solution-fusion mechanism, in virtue of which, by the mere act of pressure, volume changes of an order of even 13 per cent may present themselves.

Art. LVI.—*Notes on Michigan Minerals*;* by A. C. Lane, H. F. Keller and F. F. Sharpless.

Contents: 1. Chloritoid [L. and K.] § 1. Historical introduction. 2. Summary of results. 3. Physical characters. 4. Chemical analysis. 5. Paragenesis. 6. Comparison with previous results.

2. Grünerite [L. and S.] § 1. Historical introduction. 2. Physical characters, 3. Chemical characters. 4. Comparison with other ferromagnesian monoclinic amphiboles.

3. Riebeckite [L.] § 1. Occurrence and optical character.

1. Chloritoid.

§ 1. This mineral has been known to occur in the Upper peninsula of Michigan for some years. It was first described, so far as we know, by Wadsworth† as occurring at Humboldt. It may be found about one thousand feet S. of the station of the D. S. S. and A. R. R., and occurs in scales 2^{mm} to 4^{mm} broad. It also occurs at points east and west in the same range, e. g. the Fitch Mine, S. 24, T. 47, R. 28, and from S. 29, T. 47, R. 26. Recently we have found it, in dark green

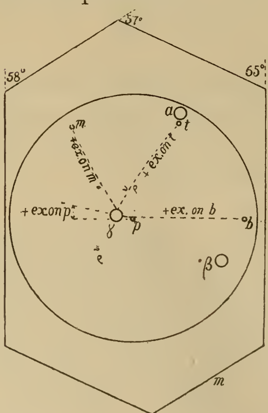
* From the laboratory of the Michigan Geological Survey, with the permission of M. E. Wadsworth, State Geologist.

† Bull. Mus. Comp. Zool., vol. vii, 1880, p. 45.

plates several centimeters broad and up to 4^{mm} thick at the Champion Iron Mine. As it was so very large, not very impure, and extremely like the masonite from Natick village, Warwick township, R. I., it seemed worth while to examine it both chemically and optically. The results have brought out some new facts, which we feel justified in giving now, since previous data have been neither complete nor accordant, even though we hope to continue our investigations into the chloritoid group.

§ 2. We may summarize our results as follows. All the Michigan chloritoids, as well as the masonite, a chloritoid from Pregratten, one from Leeds, Canada, and one from the Apennines, appear to be optically the same. They have the usual trichroism and are pronouncedly triclinic. The axis of mean elasticity (β) is inclined some 20° to the basis (001), so that of the twin lamellæ parallel to the basis, which commonly occur in three sets, that one has the greatest angle of extinction which is most blue in color. The horizontal dispersion is strong. Fig. 1 shows the lateral cleavages, and a stereographic projection on the basis of the orientation of the optical axes.

All the chloritoids that we have tested, i. e. those from Champion, Pregratten and Natick contain constitutional alkali. In this respect, as otherwise in qualitative composition they resemble hornblendes of like pleochroism. Ottrelite from Ottrez seems to be optically as well as chemically different, and less pleochroic.



§ 3. The detailed description of the Champion chloritoid is as follows: H. 6·5. Sp. G. 3·552. Cleavage basal, perfect, but often warped. One lateral cleavage (t) and traces of two or three others can be seen. The color is dark green, almost black to the naked eye. It is decidedly brittle.

The measurements given below, used in constructing fig. 1, were mainly made with the microscope. To a few of the better determined ones we append the probable error [P. E.]. The material is not suited for exact determinations.

The $\angle\ bpt$ = the $\angle$ between the traces on the basis of the two lateral cleavages nearest to the two directions of extinction.

$= 65°·1$ [P.E. $= 0°·088$]

tpm $= 57°·3$

tpb $= 57°·6$ [P.E. $= 0°·374$]

p : *t* (? the best cleavage)	$= 80°\frac{1}{2} \pm 2°\frac{1}{2}$	(cleavage faces)
: *b* ?	$= 83\frac{1}{2}° \begin{smallmatrix} +4° \\ -7° \end{smallmatrix}$	" "
: *m* ?	$= 84° \begin{smallmatrix} +10 \\ -10 \end{smallmatrix}$	" "

These angles from the basis to the lateral cleavage were taken with a reflection goniometer. The lateral faces gave only a "schimmer."

The sense of the angle from *p* to *t*, *m* and *b*, is still uncertain, i. e. it is possible, though not probable, that one or more of them may be on the other side of *p*. The angle from the negative extinction to the trace of *b*, in basal sections, is 14° [P.E. = 0°·42]. The angle from the positive extinction to the trace of *t* should be, by calculation 11°. Certain observations give 12°·3. The directions of extinction in basal cleavage fragments vary from being nearly parallel to the trace of *t*, to being nearly perpendicular to the trace of *b*, which last position agrees best with the observations of previous writers. This variation is doubtless due to superposed twinned lamellæ. The thinner fragments which have least signs of twinning, i. e. sharpest extinctions and purest pleochroism, give an extinction angle about as drawn.

For *t*, i. e. in cleavage bits that have a strong pleochroism, blue to yellow, and appear to be parallel to *t*, the extinction angle against the trace of *p* averages 18°·6, but there is a strong dispersion of the extinction; ex. $\rho <$ ex. v. Values as high as 21° occur often. Such cleavage fragments are very frequent.

In cleavage bits that are apparently parallel to *b*, and have a pleochroism from green to yellow, the extinction angle is almost inappreciable. A section artificially cut nearly perpendicular to *p* and parallel to *m* (probably) gave an extinction angle of 8°. The best cleavage follows *t*, the next *b*, a very poor one *m*, and there seem to be traces of a cleavage perpendicular to *b*.

The refraction by the de Chaulnes method is about 1·75, the bi-refraction, judging from the brightest polarization colors, about 0·007, not above that of quartz. [According to Lacroix it is 0·015, but doubtless it varies with the ratio of Mg : Fe.]

In convergent light the positive acute bisectrix emerges doubly obliquely, i. e. so that when the cross is formed, neither arm passes exactly through the center of the field of view.

The arm corresponding to the plane $\gamma\beta$ lies nearest the center. The *real* obliquity of γ appears to be about 17°. The direction of γ from the center of the field of view, i. e. the normal to *p*, makes an angle of about 150° with the direction of β; i. e. $\gamma\ p\ \beta = 150°$ circa. The optical angle does not appear large. [According to Lacroix it is 45°.]

From the double obliquity of the axial image it follows that the position of formation of a cross by closing in of the hyperbolas, which occurs approximately when β is in the direction of one of the principal planes of the nicols, will *not* be a position of extinction. The angle to be turned varies but is always noticeable. The formation of the cross is almost exactly parallel to the trace of *t*, and makes an angle against the direction of extinction of from 8° to 11°. The axial image is of course liable to disturbance from the twinning.

The direction of γ from the normal to *p* also seems to make an angle of about 80° with the trace of *b*, (in the sense opposite to that of the angle *bt*?).

These data harmonize fairly, but not absolutely, and it must be remembered that the directions of extinction do not pass exactly through γ. By *every* indication, however, γ lies within the small circle marking its position.

The pleochroism is as usual:—γ, yellow; β, blue, (not so far as I have noticed reddish); α, green. This so far as color is concerned is precisely that of certain hornblende, approaching glaucophane, which occurs in the crystalline schists and has a cellular structure [e. g. specimen No. 11270 of the Mich. Geol. Survey.] The pleochroism of such hornblende has also been noted by Lacroix. Moreover, such hornblendes like chloritoid contain alkali as well as Fe, Mg, Al_2, Fe_2 and Si.

Transverse sections of the plates of chloritoid frequently show twinned lamellæ parallel to the basis, though this Champion chloritoid has sometimes thick untwinned plates. In such cases, as might be expected if the twinning was according to Tschermak's law for the micas, there are three sets of lamellæ, with different extinction angles. The larger extinction angles are in those lamellæ where the pleochroism is most purely blue in one direction,—that near to β. The other lamellæ where the change of color is from green to yellow have far smaller extinction angles. When one set of lamellæ have a very large extinction angle, the other two sets have generally quite small angles.

§ 4. The analysis of the carefully selected material gave the following results:—

		Mol. ratio.	
SiO_2	24·29	·4048	
TiO_2	0·28	·0035	
Al_2O_3	34·00	·3333	·3992 (Al_2O_3, Fe_2O_3)
Fe_2O_3	10·55	·0659	
FeO	20·51	·2850	·3432 (FeO, MnO, MgO, CaO)
MnO	trace	——	
MgO	1·29	·0430	
CaO	0·61	·0152	
K_2O	0·97	·0103	·3906 (K_2O, Na_2O, H_2O)
Na_2O	0·35	·0059	
H_2O	6·75	·3744	
Sum	99·60		

From these figures we deduce the formula $H_{16}Fe_7Al_{16}Si_8O_{55}$ or $8H_2O·7FeO·8Al_2O_3·8SiO_2$, which is nearly identical with that now generally accepted for sismondine.* It will be observed, however, that the composition of our mineral, as we have determined it, differs from the published analyses of the latter in two respects: the iron is largely in the ferric condition, and alkalies occur in notable quantity. Since the microscopic examination of the material revealed only traces of sericite, and the magnetite had been carefully extracted with the magnet, it is evident that the ferric oxide as well as the alkalies are essential constituents of this chloritoid. The ferric oxide without doubt replaces part of the alumina, while the alkalies, it may be assumed, are substitutes for some of the hydroxyl-water. We have reason to believe that alkalies have been overlooked in many of the former analyses of chloritoid and the allied species. An examination of the masonite from Natick, for instance, showed them to be present to upwards of two per cent—the soda predominating—and a qualitative test disclosed small amounts of both potash and soda in the Pregratten occurrence. The titanic acid in our analysis was doubtless contributed by a slight admixture of ilmenite or rutile.

§ 5. Now, comparing our data with those generally given, we find that all authorities agree,—first, in the pleochroism; secondly, that γ is the positive acute bisectrix; thirdly, that there is a marked dispersion, $\rho<\nu$. Lacroix also mentions the horizontal dispersion. There is a decided difference, however, as to the direction of the axes of elasticity, γ, β and α. It is perhaps worth noting that in Rosenbusch's "Microscopic Physiography" there is a statement on page 494, that in masonite the pleochroism of α is blue and β green. This is

* Groth, Tabell. Uebersicht, 3 ed., p. 118.

not true and we are told to strike it out in the errata, but the statement may have arisen from the fact that β is at a much greater angle to the basal cleavage than α, as we believe that Sanger was still at work on the chloritoids when he was interrupted by his last illness, and never put his work in final shape. For, as we have seen in our material, sections which show a change from blue to yellow are those which have the greatest extinction, whereas according to the orientation given in the Physiography they should have no angle of extinction. The ottrelite from Ottrez, however, shows no marked difference of color in the different twin lamellæ parallel to the basis. Lacroix merely remarks that the extinctions are longitudinal but much dispersed.

The triclinic character of chloritoid seems assured, for: (1), sections showing the pleochroism of β and γ, i. e. perpendicular to α, have a large and dispersed angle of extinction. Consequently if monoclinic, α must be parallel to the orthodiagonal $\bar{b}$, inasmuch as β and γ are inclined to the basal cleavage. Then lateral cleavage fragments showing the pleochroism from blue to yellow should also exhibit the directly perpendicular emergence of a negative bisectrix. This is not the case.

(2.) The lateral cleavages have not a corresponding symmetry.

(3.) In a monoclinic mineral the emergence of an axial image from a fragment due to a solitary perfect cleavage cannot be doubly oblique, but when the axial image is in the shape of a cross, one arm must pass through the center of the field of view. Or, which amounts to the same thing, when the mineral is in the position of extinction with parallel light, on changing to convergent light, without disturbing the mineral, the axial image must be that of a cross with one bar extending directly across the field of view. In this case, although the possible effect of twinning makes observations on basal sections the least trustworthy, it is nevertheless pretty certain that the above condition is not fulfilled.

The various apparent lateral cleavage lines are numerous. Lacroix gives a third cleavage bisecting the acute angle between the two better ones, while Rosenbusch describes it as bisecting the obtuse angle. Traces of both seem to occur, or rather it seems as if lines corresponding both to "druckfigur" and "schlagfigur" occurred. Obviously however in crystals made up of twin lamellæ as these so often are, cleavage lines are liable to pass, or be imposed, from one lamella to the next at an angle of about 60° from their proper direction.

§ 6. The discussion of the paragenesis and occurrence must be left till later. Suffice it to say that the Champion chloritoid occurs in a schist which bears a general resemblance to the schist famous for its large pseudomorphs of chlorite after garnet. The most abundant impurities are ilmenite and magnetite. Rutile, quartz and sericite are much less common. The analyzed material was examined under the microscope and, though not absolutely pure, was but slightly contaminated. The chloritoid is evidently averse to enclosing the brown mica and chlorite which also occur in the rock and they occur only at its very margins. All the Michigan chloritoids, so far as yet known, occur in altered arkoses or similar rocks, in one case both in the cement and in the basic and acid pebbles of a conglomerate.

2. Grünerite [L. and S.]

§ 1. There is a peculiar amphibole, associated with certain iron ores of Lake Superior, which has been called both actinolite and anthophyllite. The latter name is due to Brush* who rightly recognized that it was essentially a silicate of Fe and Mg. He was followed by Brooks and Julien.† On the other hand Wichman‡ and Wadsworth§ rightly recognized that it was not orthorhombic, and referred it to actinolite. They were followed by Van Hise,‖ while C. F. Wright in some of his work called the rock in which the amphibole occurs an anthophyllo-actinolite schist.

§ 2. It is in reality a ferro magnesian monoclinic amphibole, corresponding closely to the description of grünerite given by Lacroix¶. The strong refraction, like that of epidote, is noticeable, not only in the thin section but in the hand specimen, which has in consequence a peculiarly high silky luster. It is much greater than that of common blue green hornblende or actinolite, but less than that of garnet, and by de Chaulnes' method is 1·7. The bi-refraction is also strong. It varies in specimens from different localities, but is always stronger than that of actinolite and does not differ markedly from that of the talc into which the mineral readily changes, so that $\gamma-\alpha$ is always $>0{\cdot}030$.

The polysynthetic twinning parallel to (100) is commonly well marked, and with the strong optical powers distinguishes it at a glance from actinolite. A striation parallel to $(10\bar{1})$, which should be more properly (001)**, is in one case developed. The mineral is colorless or slightly greenish or brownish, but

* Rep. Mich. Geol. Survey, I, p. 114. † Idem, II, p. 24.
‡ Report Wis. Geol. Survey, III, p. 604.
§ Notes on the Geol. of the Iron and Copper Districts of Lake Superior, p. 47, *et passim.*
‖ This Journal, xli, 1891, pp. 119 and 131.
¶ Lévy et Lacroix, "Minéraux des Roches," 1889.
** G. H. Williams, this Journal, xxxix, 1890, p. 352.

never more than faintly pleochroic. The angle from $c:\chi$ is between 15° and 20°. We endeavored to get the curve of the extinction angles in the prismatic zone, by revolving a fiber in Nachet's "cuve goniometrique" filled with mono-brom-naphthalin. Owing to the twinning the results were not satisfactory but in a general way the curve starting from a 0° extinction at 010 rose with an initial slope of about 0·7 until perpendicular to the cleavage faces the extinction was nearly 20°. After that it varied but little.

From these observations* and from the relative retardations of pinacoidal sections as manifested in their polarization, values of $-2V$ between 50° and 80° are deduced. The specific gravity of a specimen contaminated with quartz alone was found to be 3·2 to 3·3.

§ 3. The purest material at hand in sufficient bulk for analysis seemed to be some from the Champion Mine, after removing all the iron oxides from it. Unfortunately the crushing of a larger amount for analysis introduced unexpected impurities. The mineral is changed to talc in spots, and there was some entangled quartz though apparently not enough to account for the high percentage of SiO_2.

The following analysis which was made on material first treated with the magnet to remove magnetite, and then briefly with HCl to remove martite and hematite, has therefore merely a qualitative value, but shows very clearly by the absence of lime that the mineral is not actinolite.

SiO_2	76·32
Al_2O_3	0·56
Fe_2O_3	0·99
FeO	6·96
MgO	12·47
CaO	----
$(Na,K)_2O$	*tr.*
H_2O	2·80
Sum	100·20

The alteration to talcose matter is strictly pseudomorphic and follows lines of alteration parallel to the polysynthetic twinning (100). It must be quite extensive. The mineral is in small fibers, associated with quartz and iron ores, commonly

*It may be shown, starting from Lévy's equation 3, p. 20, that $\cos^2 V(\sin\chi+1)=\cos^2\theta(\sin\chi-1)-1$, when V is half the optical angle, $\theta=\angle\frac{1}{c}:a$, and χ the angle from the plane (010) to the prismatic plane in which the angle of extinction first becomes equal to θ. We may also show that $\cos^2 V(\tan\theta+\cot\theta)=\tan\theta+$ (initial steepness of curve of extinctions, i. e., $\frac{dy_0}{dx_0}$)

magnetite. Garnet, common blue green hornblende and brown mica are associated with it at times, marking stages of transition to ordinary hornblende schist.

§ 4. Judging from some slight variation in the optical properties of different occurrences, it seems likely that they are not chemically identical. We really need one general name for all monoclinic ferromagnesian amphiboles, without regard to varieties differing merely in the ratio of Mg : Fe. To amphiboles of this kind the names antholite, kupfferite, silfbergite, cummingtonite and grünerite have been applied. The first name, antholite, has been used also for anthophyllite and is confined by Dana to the very magnesian varieties. Typical kupfferite seems to be chromiferous, but otherwise practically the same as antholite, though its physical relations to the amphiboles have not been determined so far as we know. Silfbergite* has 8·39 per cent MnO, as well as 30·49 per cent FeO, and 8·74 per cent MgO. The name cummingtonite was given by Dewey† to a mineral from Cummington, Mass., which he supposed to be a kind of epidote. There are two minerals from Cummington which have been taken for it, as the original description is not very explicit. The one is a ferromagnesian monoclinic amphibole in truth, with only a mere trace of MnO, as we have personally found. This we also find to be very much like our mineral but larger and coarser. It agrees in luster, color, brittleness and specific weight, 3·2. The mineral associations, optical properties and frequent twinning are also similar. It has been analyzed by Smith and Brush.‡

The other mineral is a manganese mineral akin to rhodonite. It has been analyzed by Muir§ and the name is used in this latter sense by Rammelsberg, Groth and other writers up to the present day.

With grünerite‖ there is physically the closest agreement. Grünerite however is supposed to contain only about 1 per cent MgO, and to be somewhat heavier, perhaps also more birefractive.

What the average ratio of Mg : Fe in the Michigan amphiboles under consideration is,—they are of widespread occurrence, and what their relations to kupfferite, etc., are questions that require work upon a large range of authentic material to settle. It seems indeed possible, in view of the tendency to repeated twinning parallel to 100, that anthophyllite may be

* This Journal, xxvi, p. 157. † This Journal, viii, 1824, p. 59.

‡ This Journal, xvi, 1853, p. 48. § Thomson's Mineralogie, vol. i, p. 493.

‖ The diaeresis which strictly should be over the *u* is dropped by Rammelsberg, Tschermak, Naumann, Zirkel, Groth and Chester, and sometimes by Lévy and Lacroix and Max Bauer, while Dana, Lapparent, Descloizeaux and Ramsay retain it.

due to such molecular or submicroscopic twinning, for such a structure would produce a rhombic symmetry. Then anthophyllite and grünerite would be related, as orthoclase (submicroscopic microcline) and albite, or the two kinds of natrolite.

Considering the unfortunate ambiguity of the word cummingtonite, its hitherto more imperfect optical description, and the greater length of the word, it seems preferable to denote the allied Michigan amphiboles as grünerite, pending further investigation. Inasmuch as they are concomitants of the iron ores, it seems the more proper to lay stress on the $Fe_4Si_4O_{12}$ molecules.

3. Riebeckite or Crocidolite. [L.]

Our knowledge of this group of amphiboles is rapidly increasing, but it has not yet been so frequently observed that a new occurrence is devoid of interest. I have observed it as a secondary fibrous growth on the primary hornblende of a syenite.* It occurs much as those fibers do, that we often see in more basic rocks growing out from patches of uralite into the adjacent feldspar, and it is worth noting that uralite patches are often most bluish at the margin. The growths I have noticed answer precisely to those described by Cross,† and verify his observations, as I can testify from a personal examination of his sections, which he kindly afforded me. The vertical axis and orientation are parallel to those of the original hornblende, but the angle of the + extinction is very large, somewhere about 75°, above, to the front, so that as Cross notes the nearest extinction is on the other side of the vertical axis from that of common hornblende. The pleochroism is,— α blue to greenish blue; β violet or reddish blue; γ yellow. The bi-refraction is weak. The fibers are often separated from the dark green hornblende by a sharp crystallographic line. At other times they seem to mingle and compensate, forming an isotropic band.

Michigan Mining School, Houghton, May 23d, 1891.

* No. 583 of the Mich. State Coll.; 325 paces N., 975 paces W., of the S.E. corner of Sec. 17, T. 49, R. 25.

† This Journal, xxxix, 1890, p. 359.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On Two new Modifications of Sulphur.*—Engel has observed that if one volume of solution of sodium thiosulphate, saturated at the ordinary temperature, be poured with continual agitation into two volumes of a solution of hydrochloric acid, saturated at 25°-30° and cooled to about 10°, sodium chloride is precipitated, and the resulting thiosulphuric acid is so stable that the liquid can be filtered. At first the filtrate is colorless, but it soon becomes yellow, the intensity of the color increasing gradually, and sulphurous oxide being evolved. If now, after the liquid has become deep yellow in color, but is still entirely transparent, it be agitated with its own volume of chloroform, the chloroform removes the yellow color; and on being allowed to evaporate, deposits orange-yellow crystals of sulphur, quite different from the octahedral variety. Friedel describes them as rhombohedral showing the cross and rings of uniaxial crystals in polarized light. The rhombohedron is very obtuse, *pp* (normal) $=40° 50'$. These crystals have a density of 2·135, greater than that of octahedral sulphur. At first they are transparent but in three or four hours they pass into an amorphous insoluble form. They fuse below 100°, passing into the pasty condition and becoming partially soluble in carbon disulphide. If, however, the solution of thiosulphuric acid in hydrochloric acid be allowed to stand, the sulphur separates as a yellow flocculent precipitate, completely soluble in water. The solution is yellow, but decomposes rapidly, yielding the ordinary pasty sulphur of the thiosulphates. The original precipitate also agglomerates and passes into the same insoluble form, without evolution of hydrogen sulphide. These varieties of sulphur are probably polymerized atomic forms.—*C. R.*, cxii, 866; *J. Chem. Soc.*, lx, 976, Sept. 1891. G. F. B.

2. *Chemistry of the Carbon compounds or Organic Chemistry;* by Victor von Richter, University of Breslau. Authorized translation by Edgar F. Smith, University of Pennsylvania. Second American from the Sixth German edition. 12mo, pp. 1040. Philadelphia, 1891. (P. Blakiston, Son & Co.).

The new edition of this excellent text-book will be very acceptable to students of Organic Chemistry. The introduction contains much new and valuable matter upon the later physical and chemical methods of fixing the mass as well as the structure of the molecule, the sections on stereochemical theories and the tautomeric theory being noteworthy. In the special part, Class I is devoted to the Fatty bodies or the Methane derivatives and Class II to the Benzene derivatives. The new edition shows a large introduction of new matter, the chapter on the carbohydrates having been re-written, the sections relating to the tri-, tetra- and penta-methylene series greatly enlarged, and the whole brought up to date. Dr. Smith's translation is clear, accurate and in every way admirable. The volume as it now stands seems to us one of the best and most complete text-books in the English language. We regret sincerely the recent death of its distinguished author, who has done so much in his text-books to present the science of chemistry in a compact and yet comprehensive form. G. F. B.

3. *A System of Inorganic Chemistry;* by WILLIAM RAMSAY, Ph.D., F.R.S., Professor of Chemistry in University College, London. 8vo, pp. xvi, 700. Philadelphia, 1891. (P. Blakiston, Son & Co.).—The system of classification adopted in this book is somewhat remarkable. "After a short historical preface the elements are considered in their order; next their compounds with the halogens, including the double halides; the oxides, sulphides, selenides and tellurides follow next, double oxides, such as sulphates, for example, being considered among the compounds of the simple oxides with the oxides of other elements; a few chapters are then occupied with the borides, carbides and silicides and the nitrides, phosphides, arsenides and antimonides; and in these the organo-metallic compounds, the double compounds of ammonia, and the cyanides are considered; while a short account is given of alloys and amalgams." Special chapters are appended treating of spectrum analysis and of the periodic law; the former chapter considering also the chemistry of the rare earths. Since the author tells us that "no systematic text-book has been written in English with the periodic arrangement of the elements as a basis," his attempt to supply this deficiency in the present volume has resulted in the above classification. He criticises as ancient and arbitrary the electrochemical line of demarcation between metals and non-metals, and says that too great importance has hitherto been assigned to the distinction between acid hydroxides and basic hydroxides. Moreover, the chemistry of text-books he thinks has almost always been influenced by commercial considerations. While the absolute classification according to the periodic law here adopted brings out prominently the quantitative affiliations of the elements, yet their qualitative relations are well nigh lost sight of. Moreover, the above mentioned arrangement of chemical compounds would seem likely to be confusing to the student. Of course the author's reputation is a guarantee of the accuracy and clearness of statement of the book. Moreover, its mechanical execution is excellent, and its size convenient. G. F. B.

4. *An Introduction to the Mathematical Theory of Electricity and Magnetism;* by W. T. H. EMTAGE, M.A., Examiner in the School of Natural Science, Oxford. 12mo, pp. viii, 228. Oxford, 1891 (Clarendon Press). This little book supplies a want which has long been felt for a text book treating the mathematical theory of electricity within a compass suited to the brief course generally available. It is clearly written, accurate and follows the best methods. G. F. B.

5. *Chapters on Electricity:* An introductory text-book for students in College; by SAMUEL SHELDON. pp. 351–452. New York, 1891. (Charles Collins and the Baker & Taylor Co.).—These chapters on Electricity are reprinted from the new (fourth) revised edition of Olmsted's Natural Philosophy. They give a concise and systematic statement of the most essential principles and phenomena in the subjects of Electricity and Magnetism as now understood. The treatment is of necessity very brief but if supplemented by the illustrations and explanations of the class-room, the book should give the average student a satisfactory elementary knowledge of his subject.

6. *Apparent change in electrochemical equivalent of copper.*—Certain observers have maintained that the electrochemical equivalent of copper changes with the density of the current per square millimeter of the surface of the electrodes. J. VANNI shows that the conditions of acidity of the bath produce the discordant results obtained by previous observers. When sulphuric acid is present in excess, the electrodes are attacked. By making a normal solution with a definite proportion of free sulphuric acid, concordant results can be obtained with a copper voltameter. The author gives results of his experiments and shows that the deposition of copper can be employed with great exactness to measure electrical currents if the proper care is taken in forming a normal solution without too much acidity.—*Ann. der Physik und Chemie*, No. 10, 1891, p. 214, 221. J. T.

7. *Electrolytic generation of Gas in a closed space.*—M. CHABRY of the Société de Biologie has succeeded in obtaining by this means a pressure of 1200 atmospheres. The electrolyzed liquid was a 25 per cent soda solution. The current had a strength of 1½ amperes and was very constant during the experiment.—*Nature*, Oct. 15, 1891. J. T.

8. *Upon the damping of electrical oscillations.*—An important paper on this subject has been written by V. BJERKNES. The author discusses the mathematical theory and shows that the multiple resonance discovered by Sarasin and de la Rive can be explained by the phenomena of damping. Their results are therefore in accord with the experiments of Hertz. The author expresses his obligations to the work of Poincaré (Électricité et Optique, II, Paris, 1891).—*Ann. der Physik und Chemie*, No. 9, 1891, pp. 74–101. J. T.

9. *Velocity of Electrical waves in solid insulators.*—AVONS and RUBENS in a previous article (Wied. Ann., vol. xlii, p. 582, 1891), described a method of measuring electrical waves in dielectrics, which was an extension of Hertz's method. Its peculiarity consisted in the employment of a bolometer instead of an electric spark for the observation of maxima and minima of oscillations. They have extended their work to an investigation of Maxwell's law connecting the dielectric constant with the index of refraction of the dielectric, and find a very satisfactory agreement between his theory and their experiments. Maxwell's

law is $n^2 = \mu$ where n = index of refraction and μ = dielectric constant.

The results of the authors are embodied in the following table (λ is wave length).

Dielectric.	μ	$\sqrt{\mu}$	n $\lambda = 6m$	n $\lambda = 6 \cdot 10^{-7}m$
Fluid paraffine	1·98	1·41	1·47	1·48
Cooling paraffine	2·08	1·44	1·48	bis
Solid paraffine	1·95	1·40	1·43	1·53
Glass I	5·37	2·32	2·33	1·51
Glass II	5·90	2·43	2·49	1·53
Castor oil	4·67	2·16	2·05	1 48
Olive oil	3 07	1·75	1·77	1·47
Xylol	2·35	1·53	1·50	1·49
Petroleum	2·07	1·44	1·40	1·45

—*Ann. der Physik und Chemie*, No. 10, 1891, pp. 206–213.

J. T.

II. Geology.

1. *On the British Earthquakes of 1889;* by C. Davison, of King Edward's High School, Birmingham, (Geol. Mag., viii, 1891.) —The more important conclusions of Prof. Davison's paper are presented in the following citations from pages 10, 20 and 28.

I believe we may, with some probability, conclude: (1) that the Edinburgh earthquake was caused by a slip of the fault marked BB on the map, at a spot vertically below the position indicated for the epicentrum, and therefore not far from the middle of the fault, where, probably, the throw is a maximum and where earthquake-action has been most frequent or most intense; (2) that, on account of the simple character and short duration of the disturbance, the horizontal length of the fault over which the slip took place was very short, possibly less than a mile; (3) that the slip of the downthrow side was downward or that of the upthrow side upward, resulting, in either case, in an increase of the throw of the fault in the neighborhood of the seismic focus; and (4) that, while the region of maximum slip, the focus of the earthquake proper, was probably at a depth of several (perhaps about 8) miles, the slip extended upwards to within a short distance of the surface, this part of the slip-area being the focus of the sound-vibrations.—p. 10.

In both the Edinburgh and Lancashire earthquakes, the shock and sound, we have reason to believe, were caused by slipping along well-known faults, the foci of the sounds being nearer the surface than the foci of the corresponding shocks. In both, also, the area over which the slip took place must have been very limited in extent: and, while the amount of the slip may have been greatest near the center of the Lancashire area, it must certainly have died away toward its upper and lateral margins.

Now, the seismographic records recently obtained by Prof. Milne and others in Japan show that earthquakes usually begin with a series of tremors very small in amplitude and very rapid in period, from six to eight occurring every second, but becoming slower before the shock takes place. These may last for many seconds or even several minutes. Following, and continuous with them, come the sensible vibrations, of larger amplitude and longer period, about three to five occurring in every second. One or more of these, attaining a still greater amplitude and longer period, of one or two seconds each, constitute what are generally known as the principal shock or shocks. The earthquake closes with vibrations of smaller amplitude, but which have a period so long that no record of them can be obtained. The earliest tremors, on the other hand, are not registered on account of the smallness of their amplitude, and, in all probability, as Prof. Milne suggests, the "minute movements which have been recorded are the continuation of still smaller and more rapid movements which . . . . have never yet been rendered visible." It is to these supposed rapid vibrations which form the front portion of an advancing earthquake, that Prof. Milne attributes the origin of the earthquake-sounds. We may conclude from these observations that, initially at any rate, the period of the vibrations increases and decreases with the amplitude.

Now, from different parts of the area over which a fault-slip takes place, there must proceed vibrations differing greatly in amplitude, and therefore also in period. From the central portions of the slip-area will come, as a rule, the vibrations of largest amplitude and longest period; while, from the margins there will proceed minute vibrations of a period so short that they may be perceptible only as sound. The position of the line separating the marginal and central parts of the slip-area will depend only on the amplitude of the vibrations corresponding to the period of the lowest sound that can be heard; it will not at all depend on the amount of the slip at the center of the area, *i. e.* it will be independent of the *intensity* of the shock.—p. 10. This theory explains (1) the fact that the sound-area is not concentric with the disturbed area, and the sound-focus is nearer the surface than the rest of the seismic focus; (2) the fact that, in great earthquakes, the sounds are heard only within a comparatively small area immediately surrounding the epicentrum.—pp. 20, 21.

With one possible exception (that of Ben Nevis), the earthquakes of 1889 are typical examples of British shocks—they occurred in districts where earthquakes are rarely felt, and their disturbed areas are circular or only slightly elliptical in form. Turning to a more distinctly seismic area, Switzerland for example, we find that the disturbed areas are often extremely elongated, the longer axes being parallel to those of the neighboring Alpine chain; earthquakes are more frequent, their intensity, as a rule, is greater, and much larger areas are disturbed. Different stages in the geological history of a district are characterized by different kinds of earthquakes. The Alpine system is not yet old, fault-formation is still in progress, and the fault-slips are long and frequently recurring. In Great Britain, we meet with a later stage. Fault-formation in our seismic area is more advanced, and slipping takes place so slowly and over distances so short, that our earthquakes are rare and the areas disturbed by them more or less circular in form.

Every stage in the process, however, requires investigation, and that of which our British earthquakes are witness is certainly deserving of attentive study. Unattractive though it may be at first sight, the epoch immediately preceding the death of a mountain-chain, is at least as interesting to the geologist as the more vigorous periods of origin and growth.—pp. 28, 29.

2. *On the Formation of Graphite in Contact-metamorphism.*—Graphite is found naturally in various Archean rocks. Generally it occurs in beds or pockets, in gneiss, mica slate, clay slate, granular limestone, etc.; whence is obtained most of that used in the arts. Besides this, a second mode of occurrence of graphite, which is of great interest, is that in which in certain Archean rocks it replaces either wholly or partially, the mica. Graphite-mica-schists are known, and also graphite-gneisses, in which the scales of mica in ordinary mica-schists and gneisses are partly or wholly replaced by scales of graphite; and a schistose rock called graphite-schist exists which consists substantially of graphite and quartz. Even more noteworthy is the occurrence of graphite scales in granite, in place of the usual mica scales. Beck and Luzi have now observed the occurrence of beautifully crystallized graphite in strata which have been metamorphosed by contact with eruptive rocks, and have proved that these graphite crystals have originated in the amorphous coaly substance existing originally in the clay slates and quartzose schists. In the Pirna and Kreischa sections in Saxony, there are upper Silurian clay slates and quartz schists which are very rich in carbon particles; these slates and schists lying partly within the region of contact with granite and syenite. Now it is within this contact-region as the authors have shown, that these strata have been converted into rocks rich in graphite. For the examination, they used a very rich chiastolite slate and a graphite-quartzite. The former occurs in layers in the highly metamorphosed upper Silurian grauwacke of Burkhardtswalde. The latter is a genuine contact rock in the immediate vicinity of the granite and occurs in the Röhrsdorf valley near Kreischa. Both these rocks have come from the original quartz-schist, their structure and composition alike showing them to be true contact-products. In the chiastolite slate, the graphite has taken the place of the finely divided coaly substance easily combustible in the Bunsen flame previously existing in the quartz-schist. Isolated from the rock, it appeared as completely opaque irregular masses dark gray in color and having a metallic luster, and from 0·003 to 0·02 mm. in diameter; the carbon particles in the un-

altered schists not being over 0·001 mm. in diameter. Moreover, well defined single graphite crystals were observed having a hexagonal contour. The Röhrsdorf quartzite is still richer in graphite, and it is more beautifully crystallized. The rock itself is seen under a magnifier to consist essentially of a mixture of quartz and graphite, the latter feeling greasy to the touch and giving a metallic streak. Some of the crystals were 0·3 mm. in diameter. On chemical analysis, the chiastolite graphite gave 98·84 per cent carbon and 0·21 per cent. hydrogen ; the quartzite-graphite 99·94 per cent carbon and 0·05 per cent hydrogen. In amount the quartzite contains about 2 per cent of the graphite, its density being from 2·62 to 2·637.—*Ber. Berl. Chem. Ges.*, xxiv, 1884, June, 1891. G. F. B.

3. *Geological Survey of Alabama*, E. A. SMITH, State Geologist. *Report on the Coal Measures of the Plateau region of Alabama*, by HENRY MCCALLEY, including a report *on the Coal Measures of Blount County*, by A. M. GIBSON. 238 pp. 8vo, with a map of the Coal-fields and two geological sections across the Plateau region.—The Coal-measures of all the Plateau region, about 4500 square miles in area, are here described except those of the Warrior Coal-field which were reported upon in 1886. The region is one of broad gentle undulations in the bedding, and is divided by wall-sided valleys which are cut down to the Subcarboniferous and inferior strata. The coal beds belong for the larger part to the lower part of the coal-measures and the most productive bed, the Main Etna, 2 to 5 feet thick, is below the Lower Conglomerate or Millstone Grit. Under this there are four other beds separated by 20 to 100 feet of shale. The Subcarboniferous beds, below the coal-measures, consist of a limestone, the probable equivalent of the Chester group, resting on shales and sandstone, in all perhaps 1000 feet in thickness, and underneath these, about 400 feet of cherty or siliceous limestones. All there is of Devonian in Alabama is a stratum of Black shale not over 10 or 15 feet thick.

4. *Geological Survey of Missouri, Bulletin No. 5*, ARTHUR WINSLOW, State Geologist. 86 pp., 8vo.—This Report contains a paper by ERASMUS HAWORTH, on the age and origin of the crystalline rocks of Missouri, and another by G. E. LADD, on the clays and building stones of certain western central counties tributary to Kansas City. Mr. Haworth concludes that the rocks of the iron region, granite and "phorphyry," are of igneous origin, and this makes the iron ore deposits also igneous. As stated in the Preface to the Report, Pumpelly, in his survey of the region, decided that the rocks and ore were metamorphic.

5. *Geological Survey of Georgia.* First Report of Progress, 1890–91, by L. W. SPENCER, State Geologist. 128 pp. 8vo.—This report, after observations on the topography of the State, treats of the Cretaceous and Tertiary formations, presents briefer notes on the older strata, and gives some account of phosphate beds and other mineral materials of economic value.

6. *Geological facts on Grand River, Labrador;* by AUSTIN CARY. The following note is to be added to the sentence on p. 421 (line 14 from top) in the November number.

"Our measurements proving worthless on account of the difficulties under which they were taken, the smallest estimate made by the party on the spot was given. A measurement since made by Mr. Henry G. Bryant, of Philadelphia, makes the height of the fall 316 feet, from which the height of the basin wall will not much vary."

The adjective "gneissic" in line 14 of p. 420 should be erased, as the nature of the rock was not positively determined.

7. *Index to the known Fossil Insects of the World, including Myriapods and Arachnids;* by S. H. SCUDDER. Bull. U. S. Geol. Surv., No. 71. 744 pp. Washington, 1891.—Contains exact references, arranged chronologically under each species, to all the scientific publications where fossil insects are described and figured, with the locality and horizon of each. The catalogue is divided into the sections, Paleozoic, Mesozoic, and Cenozoic, and the classes and species appear alphabetically under the various orders. An index of generic names completes the work.

8. *Stones for Building and Decoration;* by GEORGE P. MERRILL. 453 pp., 8vo. New York, 1891. (John Wiley & Sons).—There are few subjects of more general interest and about which it is at the same time more difficult to obtain precise scientific information than that of Building Stones. Mr. Merrill's excellent volume, therefore, fills an important gap and should be highly valued by a wide range of readers. The book is divided into four parts of which the first gives a concise account of the minerals entering into building stones, the physical and chemical properties of the stones and their distribution in the United States. The second part, comprising the greater part of the volume (pp. 45–312), takes up in succession the various kinds of rocks and gives an account of the prominent quarries and quarry regions in the successive states arranged alphabetically with brief remarks upon those of abroad. The other parts give the methods of quarrying and dressing stone, the machines employed, a discussion of the effect of weathering, and so on; also appendices presenting in tabular form the physical and chemical characters of the stones in use, prices, etc. The book is well illustrated and the whole forms a more than usual attractive and interesting volume.

9. *Manganese; its uses, ores and deposits;* by R. A. F. PENROSE, Jr. 642 pp., 8vo. Little Rock, 1891, being vol. I of the Annual Report of the Geological Survey of Arkansas for 1890, J. C. Branner, State Geologist.—The subject of manganese has received exhaustive treatment by Dr. Penrose. The volume has a wide scope and covers, first, a discussion of the nature of early uses of manganese; second, the modern uses of manganese; third, the manganese industry in this country and Canada; fourth, a general account of the ores of manganese and fifth,

a detailed description of the manganese deposits of Arkansas, followed by those of other parts of the country. The final chapter deals with the origin, and chemical and geological relations of manganese deposits. An examination of the volume shows that the author has done his work with great thoroughness and the large amount of new matter relative to hitherto little known deposits with the numerous analyses, etc., give the work a high value in addition to that which it has as a convenient digest of what was before known on the subject.

III. Botany.

1. *Botanic Gardens in the Equatorial Belt and in the South Seas.* (Fifth paper.)—In all the gardens hitherto referred to in this series, it is not unusual to meet with plants from different parts of Japan. The southern portions of Japan have contributed plants which thrive, or, at least, can be made to grow even in the warmer gardens of the tropics, while in the hill gardens of the tropics are found certain species from the colder regions of the Empire. It may therefore not be out of place for this series to close with a short sketch of a visit to Japan on my way home. The spring was far enough advanced to give me a glimpse of some of the most interesting vernal species, but not sufficiently so to present the Pæonies, one of the specialties of Japan, at their best.

From Woosung it is a run of less than two days to the straits at Shimonoseki, where the ship enters the Inland Sea. The descriptions of this famous sheet of water do not do justice to its extraordinary picturesqueness. The shores and the water, with their ever changing scenes of interest, keep every passenger attentively employed in forming contrasts between these and similar scenes in other countries. It was worthy of note that travelers who had passed many times over this sea, did not appear to have exhausted their enthusiasm in regard to its beauty in any way. The older travelers were the most eager to point out to the novices the more striking features and combinations.

On the northern shore, we could frequently see the preparations made for extending the railroad, and catch now and then a view of a rigid line of rail contrasting strangely with the general air of the place. There is absolutely nothing which can fairly be called picturesque in or around the railroad stations,—except the people.

The port of Kobe is reached in twenty hours from the southern entrance to the sea. Hyogo, or Hiogo (pronounced by the natives almost as if written Shyogo), lies on the opposite side of the river, Minato-gawa, and is the native part of the double town. Together, the two towns occupy about three miles along the shore and are alike fortunate in having a charming range of hills behind to increase their attractiveness. The tourist loses no time in leaving his ship for the walk or the jinrickisha ride up the most easily accessible of these hills, and here the native vegetation and cultivated land are on every side. Bright green fields of barley and golden fields of rape-plants appear as if planted solely for decorative purposes, so completely do they adjust themselves to the tone of the landscape. The angular conifers seem far more irregular and picturesque than even the most contorted on our Atlantic coast. It is instructive to correct, or at least check, this impression by a strict comparison of photographs of trees having somewhat similar port. On the Maine coast one can find specimens of *Pinus rigida* and even battered examples of *Pinus Strobus* which are quite as grotesque as any which grow naturally in Japan, but it is out of the question to find in America miles after miles of trees which do not regard the proprieties of growth. And further, in Japan, when by the skillful lopping off of a branch here or there, the grotesque effect can be heightened in a tree near a dwelling, or plainly in sight of one, such artistic pruning is pretty apt to be done.

It may be said once for all that the Japanese give a naturalist to understand that he is heartily welcome to examine their plants to any extent, and even the poorest classes take pleasure in affording such information regarding their plants as may be in their power. All are very lenient in regard to what might strictly be called trespassing on private grounds. Time did not permit me to visit any of the gardens in Kobe, for it was desirable to reach Tokio in the height of the Cherry-blossom season, then so close at hand. Reserving the railroad ride for another occasion, we went by steamer to Yokohama, the principal port of Japan, and did not again arrive in the vicinity of Kobe until some weeks after. By that time the spring transformation was complete. The trees then had much the appearance of ours in the Atlantic states, in June.

Yokohama offers to the botanist some profitable excursions within the treaty limits, where one can travel without a passport. By courtesy, the Japanese government permits foreigners to pass and repass, on certain definite and yet very generous lines. Obedience to local laws, and strict regard to the limitations of the passport, cover all the requirements, for comfortable botanizing or collecting. There are nineteen fixed routes which cover all the more interesting places in the empire, and for each of these routes one passport is demanded. It is obtained on application to the American Consul at any of the treaty ports, who transmits the request to the American Legation at the capital, Tokio, where the American Minister procures the documents from the foreign office. The passport, of which I made use, permitted me to travel from Yokohama to Nikko and vicinity by rail; thence by regular routes to Kozuke, Shinano, Musashi, Sagami, Kai, Suruga, and Totomi to Nagoya, Kioto, and Kobe, with permission to visit Nara, *en route*. This passport was required only at the railway stations and at the hotels and inns, but was not asked for on any walk or short excursion. These facts are mentioned here, merely to remind intending tourists that no obstacles are now thrown in the way of any one desirous of exploring the Empire. In fact, it may be said, that it is not unusual to find even in out of the way places, people who are anxious to give any assistance in their power in the way of collecting, and of preparing desirable specimens. The means of communication have been so much improved of late years that a tourist can go by rail from Kobe, skirting the base of Fuji, to Yokohama, with great comfort; or he can reach Nikko and the northern port of the lower island with great facility. At any of the points designated in the passport, the tourist can find a convenient center for local exploration.

In Yokohama itself there is no Botanic Garden, but there are good opportunities in and around the city for examining Japanese horticulture. Some of the establishments are large and well organized, and carry a very heavy stock, while some of the smaller ones are interesting on account of their specialties. Few cultivated plants possess more interest than the dwarfed trees found in the larger Japanese Gardens and frequently used as house decorations. The extravagant claims made as to the great age of some of them cannot of course be established by satisfactory evidence, or, for that matter, successfully contested by skeptics. In no case of a potted commercial plant did I hear a greater antiquity claimed than six hundred years; but it is said that in some of the gardens of the nobles, plants much older than this can be found. Dwarfed trees are pointed out in one of the larger gardens in Tokio, which are claimed to go nearly up to the age of a thousand years. After one has carefully examined the very slight growth made each year and has noted the extraordinary painstaking and skill with which every needless bud has been removed, it seems almost ungracious to refuse to accept the unwritten history. The methods by which plants are dwarfed has been clearly explained in many works, and generally with correctness, but a brief mention of the practice in commercial gardens may be useful.

First of all, good subjects for experimenting are selected, and, from the outset, these are placed under favorable conditions for slow development. All buds which can be spared are taken off with great care, and the root-system is brought within as narrow compass as possible. In a few of the cases which were shown me by the nurseryman who gave me instruction, the amount of root-surface retained was ludicrously inadequate to supply the most moderate demands of a healthy plant. And, yet, the plants in question were sufficiently vigorous to present an unfailing crop of bright foliage every year. The buds are reduced in number beyond what one might regard as safe limits for a healthy plant, and thus the dwarfed plant, crippled above and below, becomes almost a pathological specimen. But experience shows abundantly, that the few phytomera which are left, are ample to protect the organism against ordinary perils. The prices asked for the best specimens varied from forty to one hundred dollars, (Mexican), these plants being thrifty, clean, picturesque, and very old, say from two to three hundred years. Dwarfed flowering plants, such as cherries, magnolias, and the like, varying from fifteen to fifty years, could be had for about thirty dollars. These prices differ widely in different places, and it is impossible to state any averages.

Larger trees pruned into flat shapes, and encouraged to grow only horizontally, are common, and are among the most interesting specimens of topiary work in the world. The most remarkable one likely to be seen by the tourist is that at Lake Biwa, about ten miles from Kioto. Here at Karasaki, near Otsu, is the immense and very old Pine tree, which is trained horizontally, and extends over a considerable area, with its flat branches supported on pillars and poles. Japanese traditions assign to this tree an exceedingly great age. It should be said in passing, that the practice of training also fruit trees on flat trellises is much in vogue. It imparts to the trees, when one looks down on them from a slight elevation, precisely the impression that they are vines of some sort, grown for shade rather than for fruit. Good examples of this method are to be seen near Yokohama.

At the time of my visit to Tokio, the cherry-blossoms were in perfection. In certain parts of the city and the suburbs the streets were thronged by Japanese who were enjoying the profusion of delicate coloring which clothed the leafless trees. The blossoms most in favor were the pink cherries and the pure white plums. The term "pink," usually and naturally applied to the cherry blossoms of Japan, does them injustice : the tint is rather that of the most delicate "rose-madder." After seeing the blossoms at Uyeno, one cannot wonder that these trees are chosen with which to surround the temples and decorate the approaches to them.

It was my privilege, through the courtesy of Mr. Edwin Dun, Chargé d'Affaires, of the United States, to be present at a reception given by the Emperor and Empress, in one of the Imperial gardens. The cherry-blossoms were here the most interesting horticultural feature ; the *Wisterias* were not yet in full bloom, but their very long pendant racemes showed to what a degree of perfection this plant has been brought.

The Botanical Garden in Tokio had just passed out of the charge of Professor Yatabe, well-known to many American botanists, and his successor had hardly yet taken his place. But I was able to make a careful examination of the whole establishment, and received from those in control every attention. Facilities were placed at my disposal for making my short stay as profitable as possible.

The Garden is at a considerable distance from the University, to which it is made tributary for purposes of instruction. It struck me that there was abundant evidence of a lack of funds for the proper care of the garden : retrenchment has been carried too far in this interesting place. The collection of plants illustrative of systematic botany is large, and many of the specimens well-grown. This seemed to be particularly true of the foreign species. There were excellent examples of trained trees, and in some parts of the grounds, the characteristic landscape gardening had yielded good results. The management of the conifers was especially noticeable.

A small fee is charged for admission to the garden. The grounds are said to be much frequented at certain times. On the occasion of my visit, there were few visitors : this was probably due to the fact that the exhibition of blossoming trees in the vicinity of the temples was far finer in every respect, than that which the garden could present.

A careful search through various horticultural establishments, as well as my study of the Imperial garden at Chokubutsu, has satisfied me that there are many more attractive plants yet to be brought from Japan to our country. Most of them, to be sure, have been already noticed in the horticultural journals, but they have not received the attention which they deserve. Some of the dwarfed flowering shrubs and trees would certainly prove most acceptable for house decoration, while the early flowering trees of large size merit a thorough trial in the middle States of our Union.

Answering a question which has been often asked, it will be well to mention the ease and rapidity with which a tourist can visit the famous locality, Nikko. Of the temples there it is not necessary to speak, but the groves of conifers which surround them must be alluded to. These are of great size and of symmetrical port. Many of them are arranged effectively in and around the temple grounds, but those which are of highest interest are the magnificent specimens which constitute the miles upon miles of shaded avenues. This locality which formerly required a long and tedious jinrickisha ride, can now be reached in less than a day's journey from Tokio. In closing, it must be confessed that the new railroads in Japan, which it may well be claimed have destroyed much of the peculiar charm of the Empire, have rendered accessible to many naturalists, localities which otherwise they could not have found time to study.

In bringing to an end this short series of sketches of a long journey, I must be pardoned for calling attention again to the extraordinary fact that the newly settled countries of the South Seas and the newly awakened people of the Orient have hastened to provide themselves with appliances for research and instruction in Natural History on a scale which should put to blush some of our communities. There is, as we have seen in earlier numbers of this series, hardly a large town in Australasia which does not possess a good Botanic Garden or a Natural History Museum, or both. Even in places which do not have a Botanic

Garden, properly so-called, there is, as in Dunedin, in New Zealand, and Geelong, in Victoria, a public garden, in which a good deal of attention is given to the exhibition of native plants.

Can there be any valid excuse urged by the young and flourishing cities of our own country for not providing for the public, these simple and useful means for popular instruction?

To serve as a basis for comparison with our own communities, it is thought best to subjoin a few statistics relative to population taken from Hübner's Statistische Tabellen. The figures apply to the towns and cities of which mention has been made in the sketches.

Melbourne and suburbs	410,000
Sydney	357,000
Adelaide	128,000
Auckland	57,000
Dunedin	46,000
Christchurch	45,000
Brisbane	74,000
Wellington	28,000
Hobart	25,000
Geelong	21,000

These figures, which are only approximate, correspond very nearly to those given in the latest Australian Year-Book (1890) accessible to me. Hübner's data are preferred, because the year-book does not add in the population of the suburbs of some of the cities. In fairness, these should be included.

It would seem that many of our American cities and towns have much to learn from these smaller communities in the islands of the South Seas. G. L. G.

IV. Miscellaneous Scientific Intelligence.

1. *Analysis of the water of the Salt Lake, Aliapaakai, on Oahu, Hawaiian Islands;* by Prof. Lyons of Oahu College (Daily Pacific Comm. Advertiser of Oahu, Oct. 8, 1891).—The salt lake of Oahu is situated near the sea-level, on the south side of the island, in a basin made of a combination of shallow craters of basaltic tufa. It is described by J. D. Dana in his Expedition Report, p. 245, and his work on Volcanoes, p. 297. Its position may be seen on the map of Oahu, Plate IV of volume xxxvii (1889) of this Journal. In dry seasons the bottom of the lake is covered with a deposit of crystallized salt. The water is saturated brine, yet it differs much in composition from the brine obtained by evaporating to saturation ordinary sea-water. The difference is strikingly shown on mixing the two clear fluids, when a copious deposit immediately forms of sulphate of lime, so that the mixture almost solidifies. The specific gravity of the water, even at a temperature of 80° F. is 1,256. The water of the Dead Sea is considerably lighter, its specific gravity having been found by

different observers to range from 1·13 to 1·24. The results of the analysis are given below, together with comparative figures showing the composition (average of several analyses) of the water of the Dead Sea and that of concentrated sea water from Kakaako salt works. The figures represent in each case the quantity in grains of the ingredient contained in one wine gallon of the water :

	Salt Lake. Grains.	Dead Sea. Grains.	Concentrated Sea Water. Grains.
Chloride of sodium	6,989	5,137	13,239
Chloride of calcium	7,742	2,077	absent
Chloride of magnesium	7,790	8.235	3,779
Bromide of magnesium	99	208	57
Sulphate of magnesium	absent	absent	2,478
Sulphate of calcium	34	58	22
Chloride of potassium	156	736	534
Total solids	22,810	16,451	20,109
Weight of one gallon (approximate)	73,044	68,900	72,180

The most remarkable peculiarity of the water is the excessive quantity of calcium chloride, the large amount of magnesium chloride and the absence of magnesium sulphate. Part of the lime as well as the magnesia may have been supplied by the tufa ; but there is a ledge of coral-reef rock on one side.

2. *National Academy of Sciences.*—The following is a list of papers accepted for reading at the meeting of the Academy held at New York, Nov. 10–12 :

G. L. Goodale: Some aspects of Australian vegetation. The nomenclature of vegetable histology.

C. S. Hastings: Certain new methods and results in optics.

T. C. Mendenhall: Exhibition of the new pendulum apparatus of the U. S. Coast and Geodetic Survey, with some results of its use. The use of a free pendulum as a time standard

E. D. Cope: Degenerate types of scapula and pelvic arches in the Lacertilia.

T. B. Osborne: The proteids or albuminoids of the oat-kernel—second paper.

C. S. Peirce: Astronomical methods of determining the curvature of space.

J. A. Allen: Geographical variation among North American birds, considered in relation to the peculiar intergradation of *Coloptes Auratus* and *C. Cafer.*

S. C. Chandler: The variation of latitude.

S. H. Scudder: The Tertiary Rhynchitidæ of the United States.

O. N. Rood: A color system.

J. K. Rees: Preliminary notice of the reduction of Rutherford's photographs.

H. A. Rowland: The application of spectrum analysis to the analysis of the rare earths, and a new method for the preparation of pure yttrium.

Theo. Gill: A nomenclator of the families of fishes.

A. A. Michelson: Measurement of Jupiter's satellites by interference.

W. K. Brooks: The follicle cells of Salpa.

3. *The Metal Worker:* Essays on House Heating by steam, hot water and hot air with introduction and tabular comparisons. Arranged for publication by A. O. Kittredge. New York. 288 pp. 8vo. 1891 (David Williams).—This volume contains a number of essays by a variety of writers called out by a series of prize competitions established by "The Metal Worker"

in 1888. They discuss, from a thoroughly practical standpoint, the various forms of heating in use with illustrations, tabular statements of cost and so on and thus give the reader a wide range of information on a subject of prime importance.

The Four Rocks, with Walks and Drives about New Haven; by James D. Dana. 120 pp. 8vo, with 7 plates. New Haven, Sept. 1891. (E. P. Judd)—This little book contains the author's paper in the early part of this volume, and also eighty pages of instructions. geological notes, etc., with regard to walks and drives within twenty miles of New Haven.

Copernic et la découverte du Système du Monde, par Camille Flammarion. 250 pp. 12mo. Paris (Marpon et Flammarion).

Systematic list of the British Oligocene Eocene Mollusca of the F. E. Edwards Collection in the British Museum, by R. B. Newton, F.G.S. 366 pp. 8vo. London, 1891.

Transactions of the Kansas Academy of Science, vol. xii 1889–90. Topeka, 1890.—Prof. S. W. Williston gives figures of the complete skull and a cervical vertebra of his new Cretaceous Plesiosaur (Cimoliosaurus Snowii) from the Niobrara Cretaceous of Western Kansas, on pp. 174, 176.

Stratigraphy of the Bituminous Coal Field of Pennsylvania and West Virginia by I. C. White. 212 pp. 8vo, with a map and sections. U. S. Geol. Survey Bulletin, No 65, Washington, 1891.

The Mediterranean Naturalist, a monthly Journal of Natural Science, edited by J. H. Cooke, F.G.S., at Malta.—No. 1 of this monthly of 12 to 16 pages was issued June 1, 1891. Price 5 shillings a year. Address. the editor at the Lyceum, Malta. In number 2, a paper on the geology of the Malta Islands by the editor is commenced.

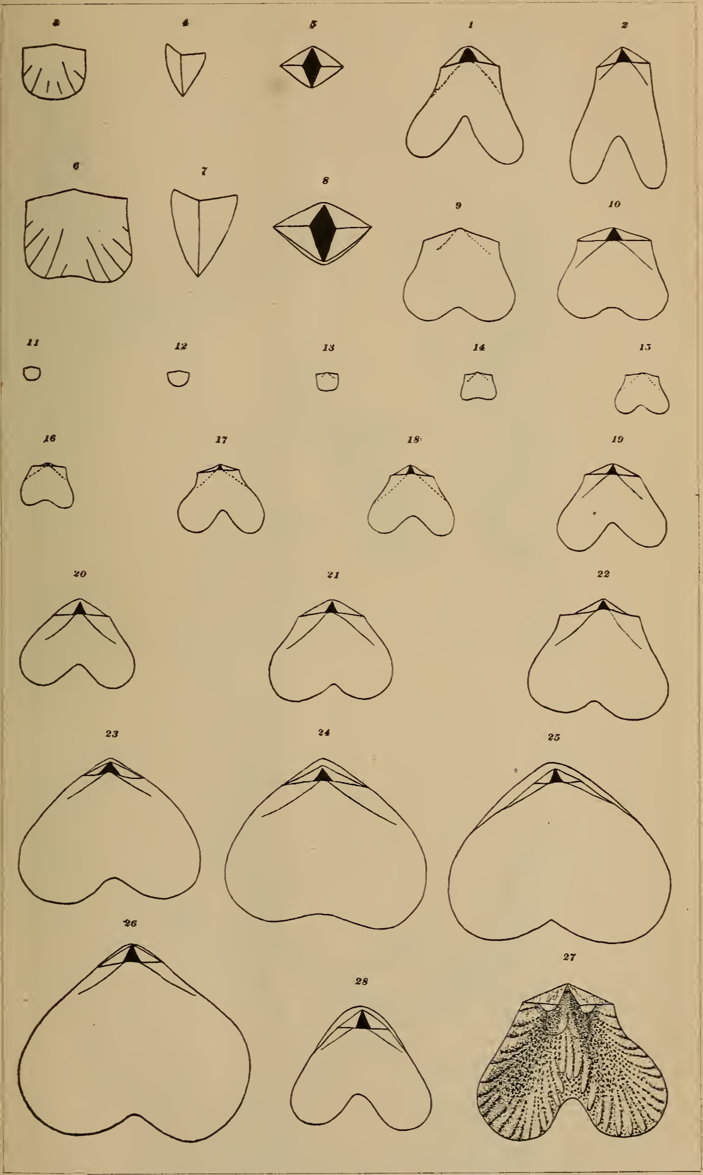
Progress Report on Irrigation in the United States, under the direction of the Secretary of Agriculture; Artesian underflow and Irrigation Investigation, Part I by R. J. Hinton. 338 pp. 8vo; Part II, with maps and profiles, by E. S. Nettleton, Chief Engineer of the Investigation. Washington, 1891.

OBITUARY.

J. Francis Williams, Assistant Professor of Geology and Mineralogy in Cornell University, died at Ithaca, N. Y., on November 8th, of malarial fever. He was but twenty-nine years of age, but had already done some excellent scientific work and his life, thus prematurely closed, gave promise of being highly useful and successful. For the past year he had been a teacher at Clark University in Worcester, Mass., and under the direction of the University he had spent considerable time in the survey of Arkansas, collecting materials for a report on the petrography of the State, which is now ready for publication. Articles by him upon some Arkansas minerals have been published in the numbers of this Journal for December, 1890, and July, 1891. At the time of his death he had hardly more than entered upon his new duties at Cornell, but his loss is deeply felt there, as well as in circles where he was better known.

INDEX TO VOLUME XLII.*

* This Index contains the general heads BOTANY, CHEMISTRY, GEOLOGY, MINERALS, OBITUARY, and under each the titles of Articles referring thereto are mentioned.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WEST ROCK
Judges Cave
Wilmot Brook
WHITNEY PEAK
WEST RIVER
WESTVILLE
INDIAN HEAD
SNAKE ROCK
QUINNIPIAC RIVER
EAST HAVEN
Allingt
41° 20′
41° 19′
41° 18′
63
62
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PLATE II
NEW HAVEN REGION
BEFORE 1640
1 Inch = 2 miles Heights above mean tide level. Areas of trap colored red.
WEST RIVER
WESTVILLE
Wilmot Brook
Judges Cave
WEST ROCK
MILL ROCK
BEAVER HILLS
BEAVER POND MEADOWS
SACHEMS RIDGE
MILL ROCK
Whitneyville
WHITNEY PEAK
EAST ROCK
INDIAN HEAD
SNAKE ROCK
MILL RIVER
QUINNIPIAC RIVER
NEW HAVEN IN 1638
CHAPEL STREET
COLLEGE STREET
STATE STREET
West Cr.
East Cr.
NEW HAVEN BAY
Allingtown
EAST HAVEN
41° 19′
41° 18′
72° 56
72° 55


EAST ROCK
NEW HAVEN
(NOW A CITY PARK)
Scale 1 inch = 800 feet
Heights reckoned from High Tide
INDIAN HEAD
310
185
SNAKE ROCK
200
160
COLD SPRING
CANNER
ORANGE ST.
ST.
ST.
HEMLOCK ST.
SYCAMORE ST.
STATE ST.
C''
C'
D
E


EAST ROCK
NEW HAVEN
(NOW A CITY PARK)
Scale 1 inch = 800 feet
Heights reckoned from High Tide
S Sandstone outcrop
S′S″ Sandstone in fragments
A A′ Northern Trap-mass
B B′ East Rock Trap-mass
C C′ Indian Head Trap-mass
D D′ Snake Rock Trap-mass
W H Whitney Ridge and Dike
Q Present condition of the Rock at its S S W Angle
E English Drive
F Farnam Drive
H Refreshment House
M Soldiers Monument
QUARRY CORNER.
LAKE WHITNEY
MILL ROCK
WHITNEYVILLE
WHITNEY PEAK
WHITNEY AVE.
BURNS ST.
RIVER
ROCK LANE
EVERIT ST.
MILL
PARK BOUNDARY
EAST ROCK
INDIAN HEAD
SNAKE ROCK
COLD SPRING ST.
CANNER ST.
ORANGE ST.
HEMLOCK ST.
SYCAMORE ST.
STATE ST.

View of East Rock from the southwest, near Orange Street Bridge.

(From a photograph.)

Profile view of columns, East Rock, near the house on the brow of the Rock in Plate IV.
(From a photograph.)


384.5
366
363
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Oa 382.8
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O 380.4
396
384.1
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400
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L 387.6
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J 397.7
II 400.2
I 401.3
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100
80
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40
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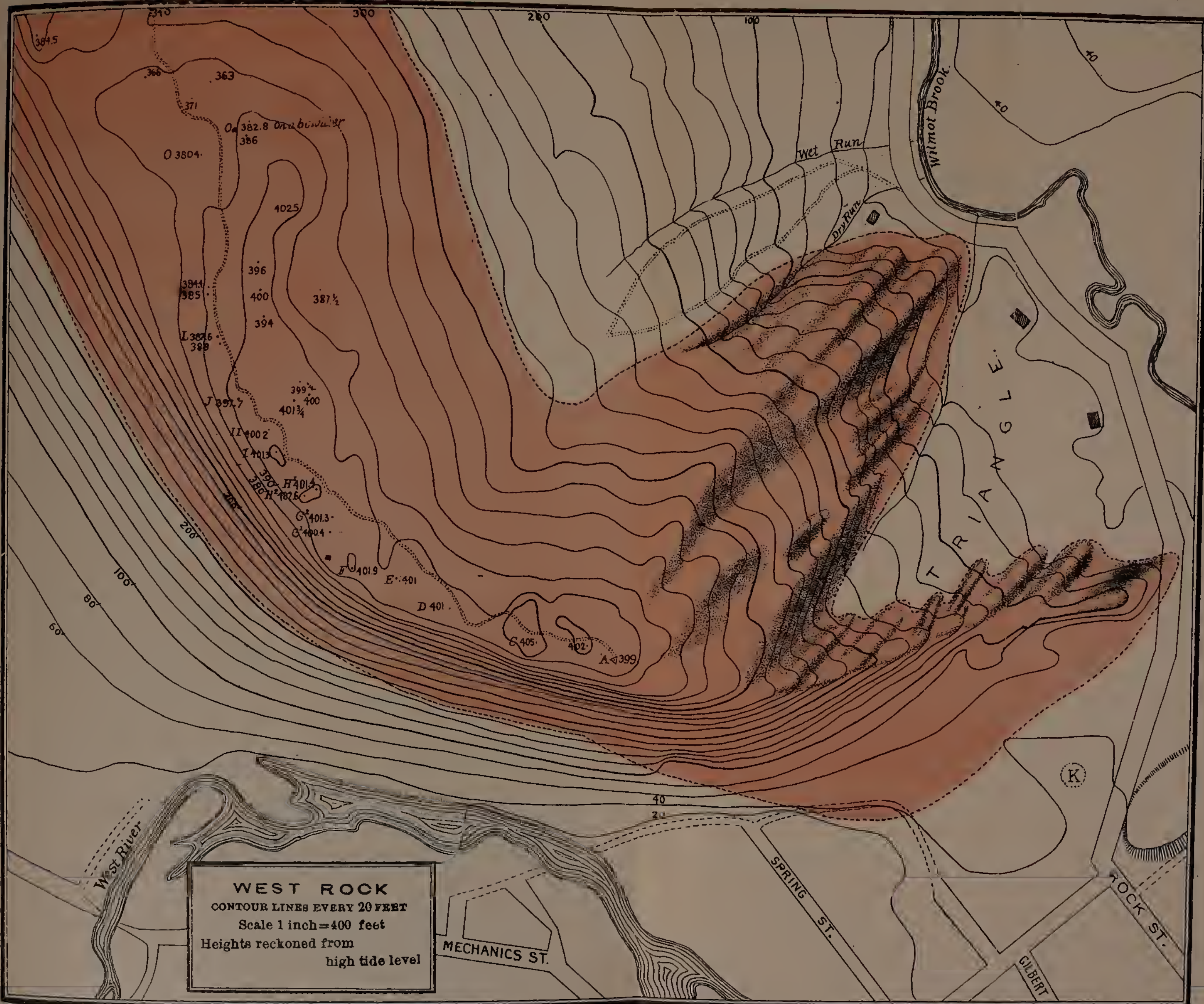
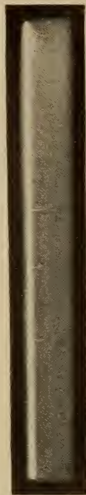
West River
ROCK ST.
GILBERT
WES
CONTOUR
Scale
Heights rec


WEST ROCK
CONTOUR LINES EVERY 20 FEET
Scale 1 inch=400 feet
Heights reckoned from
high tide level
Wilmot Brook
Wet Run
Dry Run
TRIANGLE
West River
MECHANICS ST.
SPRING ST.
ROCK ST.
GILBERT
K

View of the south front of West Rock, showing the trap of the outflow overlying upturned sandstone for a distance of 550 feet. (From a photograph.)



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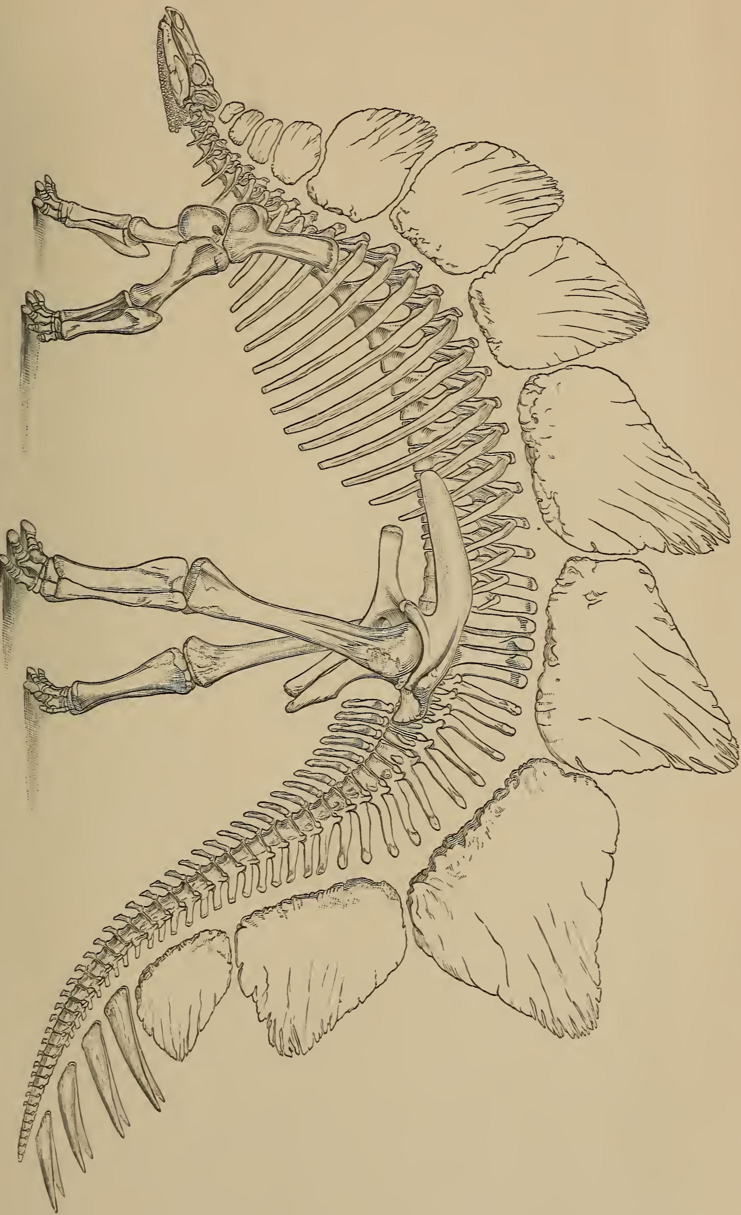
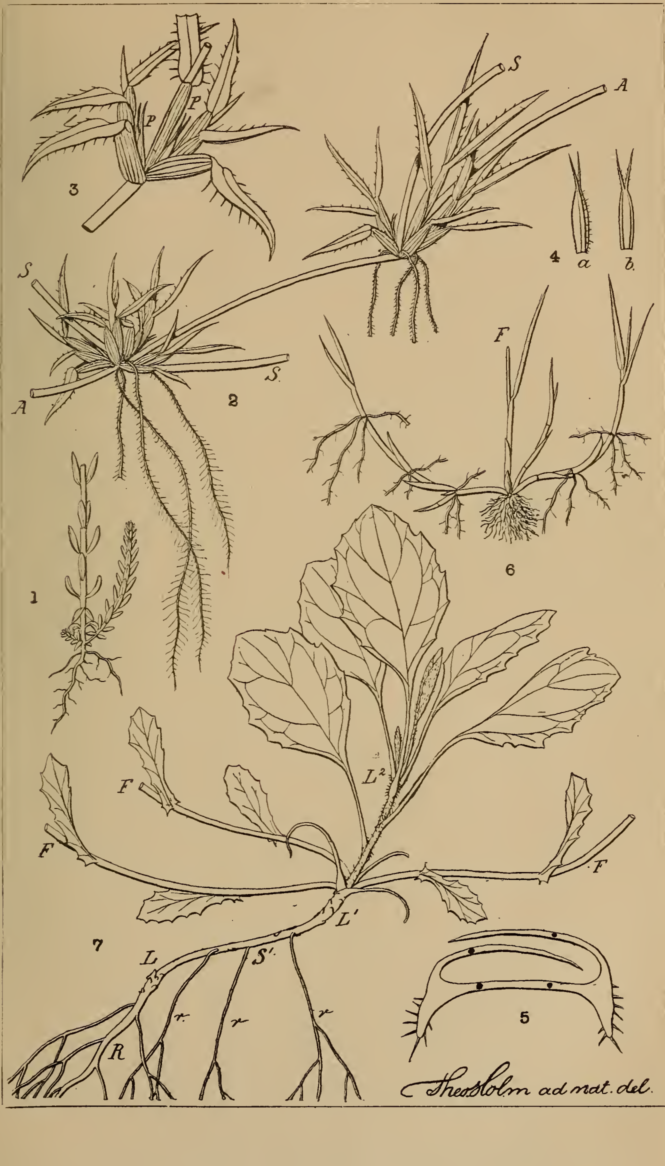


Restoration of STEGOSAURUS UNGULATUS, Marsh. One-thirtieth natural size.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Theo Holm ad nat. del.

Plate XII.

Procamelus,

·s.
Iyracodon,

itanops, Titano-
Elotherium.

m, Palæosyops,
s.

ngulates,

, Dryptosaurus.
n, Selenacodon,
opteryx.

ornis.
us, Tylosaurus.
urs.

rus, Diplodocus,
urus. Mammals,
Ctenacodon.

mmosaurus.

odonts),

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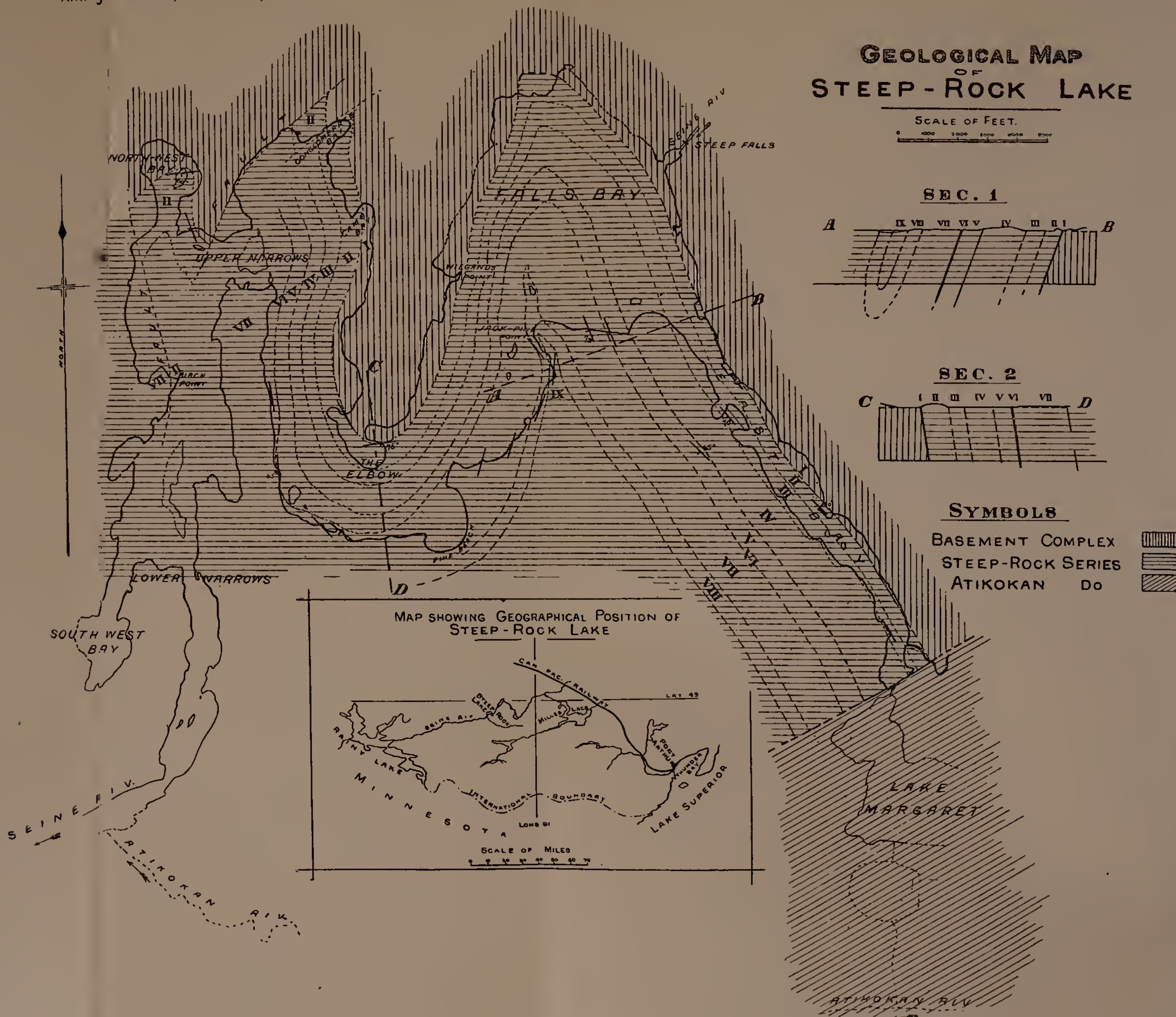
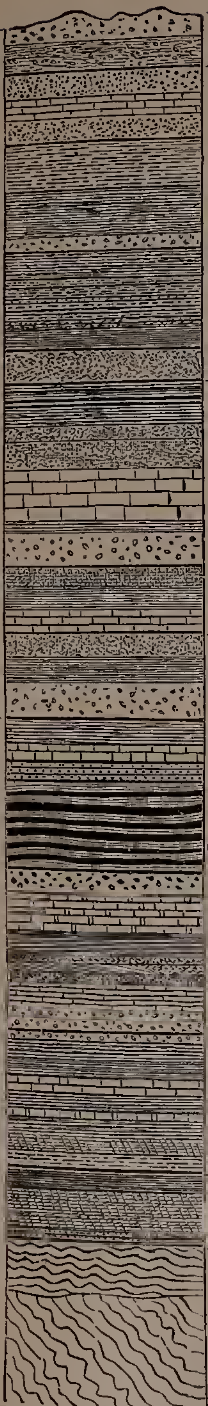
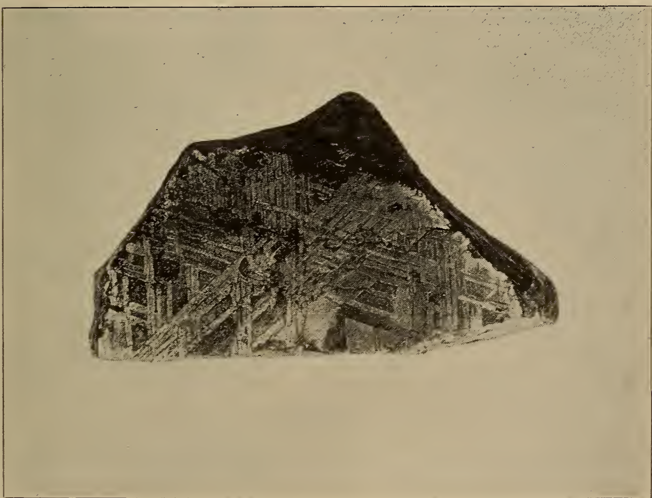

Geological Map of Steep-Rock Lake
Scale of Feet.
Sec. 1
A
B
Sec. 2
C
D
Symbols
Basement Complex
Steep-Rock Series
Atikokan Do
North
North-West Bay
Upper Narrows
Falls Bay
Steep Falls
Birch Point
The Elbow
Lower Narrows
South West Bay
Seine Riv.
Atikokan Riv.
Lake Margaret
Map showing Geographical Position of Steep-Rock Lake
Can. Pac. Railway
Lat 49
Rainy Lake
Minnesota
International Boundary
Long 91
Lake Superior
Scale of Miles



Era	Period		Beds	Vertebrates
Cenozoic.	Recent.			Tapir, Peccary, Bison, Llama.
	Quaternary.			*Bos, Equus, Megatherium, Mylodon.*
	Tertiary	Pliocene.	Equus Beds.	*Equus, Tapirus, Elephas.*
			Pliohippus Beds.	*Pliohippus, Tapiravus, Mastodon, Procamelus, Aceratherium, Bos, Morotherium.*
		Miocene.	Miohippus Beds.	*Miohippus, Diceratherium, Thinohyus.*
			Oreodon Beds.	*Oreodon, Eporeodon, Hyænodon, Hyracodon, Moropus.*
			Brontotherium Beds	*Brontotherium, Brontops, Allops, Titanops, Titanotherium, Protoceras, Mesohippus, Elotherium.*
		Eocene.	Diplacodon Beds.	*Diplacodon, Epihippus, Amynodon.*
			Dinoceras Beds.	*Dinoceras, Tinoceras, Uintatherium, Palæosyops, Orohippus, Hyrachyus, Colonoceras.*
			Heliobatis Beds.	*Heliobatis, Amia, Lepidosteus.*
			Coryphodon Beds.	*Coryphodon, Eohippus,* Lemurs, Ungulates, Tillodonts, Rodents, Serpents.
Mesozoic.	Cretaceous.		Laramie Series, or Ceratops Beds.	*Ceratops, Triceratops, Hadrosaurus, Dryptosaurus.* Mammals, *Cimolomys, Dipriodon, Selenacodon, Nanomys, Stagodon.* Birds, *Cimolopteryx.*
			Fox Hill group.	
			Colorado Series, or Pteranodon Beds.	Birds with Teeth, *Hesperornis, Ichthyornis.* Mosasaurs, *Edestosaurus, Lestosaurus, Tylosaurus.* Pterodactyls (*Pteranodon*). Plesiosaurs.
			Dakota Group.	
	Jurassic.		Atlantosaurus Beds, Baptanodon Beds. Hallopus Beds.	Dinosaurs, *Brontosaurus, Morosaurus, Diplodocus, Stegosaurus, Camptonotus, Allosaurus.* Mammals, *Dryolestes, Stylacodon, Tinodon, Ctenacodon.*
	Triassic.		Otozoum, or Conn. River, Beds.	First Mammals (*Dromatherium*). Dinosaur Footprints. *Anchisaurus, Ammosaurus.* Crocodiles (*Belodon*).
Paleozoic.	Permian.		Nothodon Beds.	Reptiles (*Nothodon, Sphenacodon*).
	Carboniferous		Coal Measures, or Eosaurus Beds.	First Reptiles (?) *Eosaurus.*
			Subcarboniferous, or Sauropus Beds.	First known Amphibians (Labyrinthodonts), *Sauropus.*
	Devonian.		Dinichthys Beds.	*Dinichthys.*
			Lower Devonian.	
	Silurian.		Upper Silurian.	
			Lower Silurian.	First known Fishes.
	Cambrian.		Primordial.	
	Archæan.		Huronian.	No Vertebrates known
			Laurentian.	

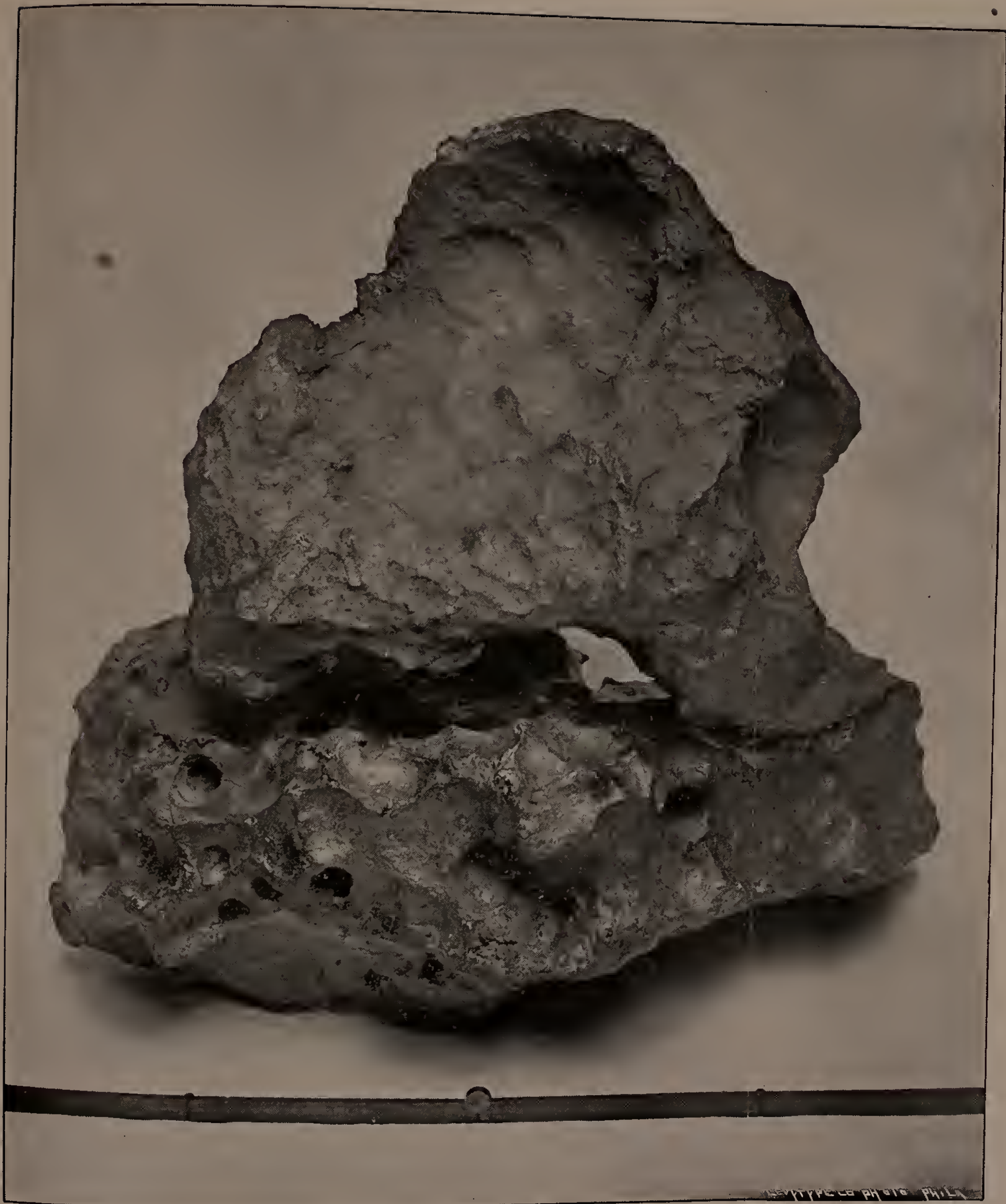
Section to illustrate Vertebrate Life in America.



TONGANOXIE METEORITE.

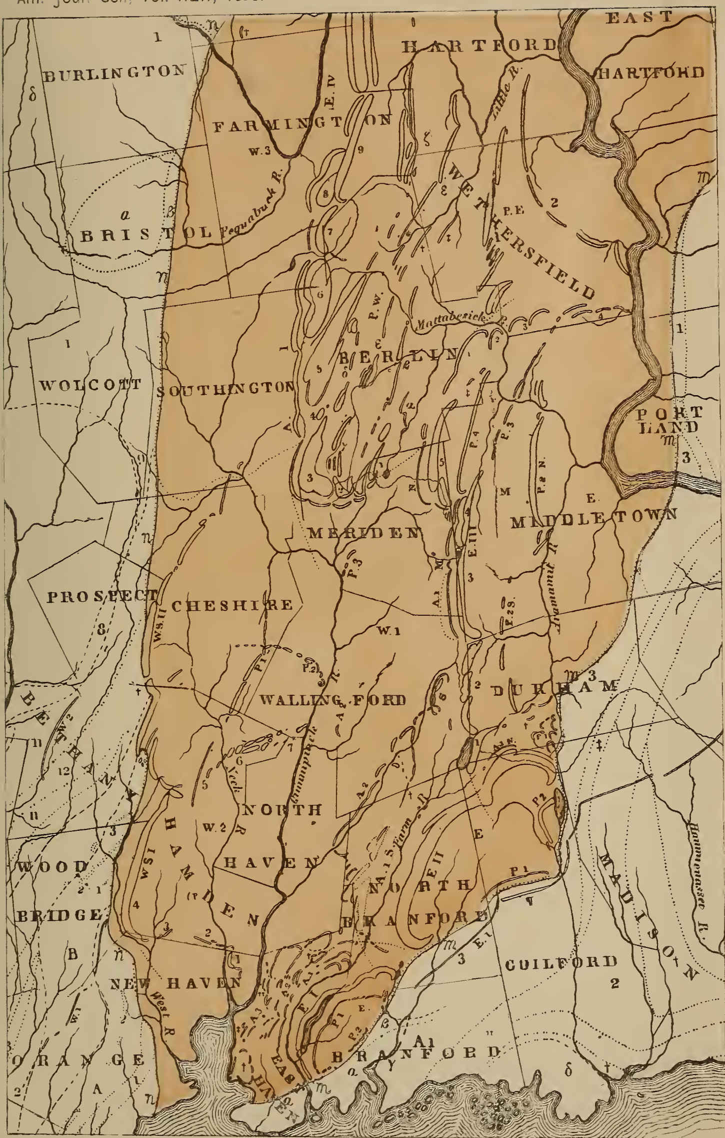
FIG. I.—Five-twelfths natural size.
FIG. II.—Etched surface, reduced one-fifth.

Meteoric Ir
Larger mas



Meteoric Iron, collected near Cañon Diablo, Arizona, June, 1891.
Larger mass weighing 201 lbs., completely perforated in three places.

Polished Surface of Meteoric Iron from Cañon Diablo, Arizona, showing Widmanstättian figures. A small black diamond is shown protruding near one side of the central black cavity, at D; a circle of scratches made by small loosened diamonds can be seen near this spot.


BURLINGTON
FARMINGTON
HARTFORD
EAST HARTFORD
BRISTOL
WETHERSFIELD
Pequabuck R.
Mattabesick R.
Little R.
WOLCOTT
SOUTHINGTON
BERLIN
PORTLAND
MERIDEN
MIDDLETOWN
PROSPECT
CHESHIRE
WALLINGFORD
DURHAM
NORTH HAVEN
HAMDEN
WOODBRIDGE
NORTH BRANFORD
MADISON
Hammonasset R.
GUILFORD
NEW HAVEN
West R.
ORANGE
BRANFORD
EAST HAVEN

CONTENTS.

SCIENTIFIC INTELLIGENCE.