QE
1
J57
no.4

UC-NRLF
B 3 766 822

CES
Y

Berkeley
LIBRARY OF THE UNIVERSITY OF CALIFORNIA

CONTRIBUTIONS TO THE PALEOBOTANY OF PERU, BOLIVIA AND CHILE

THE JOHNS HOPKINS UNIVERSITY
STUDIES IN GEOLOGY

No. 4

EDITED BY
EDWARD BENNETT MATHEWS

CONTRIBUTIONS TO THE PALEOBOTANY OF PERU BOLIVIA AND CHILE

FIVE PAPERS
BY
EDWARD W. BERRY

BALTIMORE
THE JOHNS HOPKINS PRESS
1922

J57
no. 4

EARTH
SCIENCES
LIBRARY

PRESS OF MEYER & THALHEIMER
BALTIMORE, MD

CONTRIBUTIONS TO THE PALEOBOTANY OF PERU, BOLIVIA AND CHILE

By Edward W. Berry

Contents

677360

CARBONIFEROUS PLANTS FROM PERU *

By Edward W. Berry

Introduction

Just south of the port of Pisco the peninsula of Paracas, celebrated in the War of Independence, juts out into the Pacific, forming a bold wind and wave-swept headland (Lat. 13° 55′ S., Long. 76° 33′ W.). It is about 220 km. south of Callao and 25 km. southwest of the port of Pisco, and is of great geological interest since it is largely made up of continental Carboniferous sediments and constitutes one of the very few deposits of this character in South America, and the only known occurrence of rocks of this age on the West Coast of South America.

The outcrop of coal bearing rocks on Paracas was discovered by F. C. Fuchs, who published a brief account [1] of it in 1900. Fuchs made a considerable collection of the fossil plants, which are now in the Museum at Lima, where I had the privilege of seeing them. He identified the following forms: *Calamites Suckowii, Sphenopteris Hartlebenii, Lepidodendron Sternbergii, Sigillaria tessellata, Stigmaria ficoides* and *Baiera pluripartita,* and considered the deposit to be of Upper Carboniferous age.

The true *Sphenopteris Hartlebenii* of Dunker which has since been referred to *Ruffordia Gœpperti* is a characteristic species of the Wealden, and the Paracas form which Fuchs thought represented this species is *Palmatopteris furcata* a rather widespread Carboniferous fernlike plant of the sphenopterid group. Fuchs' *Baiera pluripartita* is not a Baiera

---

* George Huntington Williams Memorial Publication No. 15. An abstract of this paper was printed in Amer. Jour. Sci., vol. 3, pp. 189-194, March, 1922.

[1] Fuchs, F. C. Nota sobre el terreno carbonífero de la península de Paracas. Bol. de Minas Industria y Construcciones, tomo 16, No. 7, Lima, 1900.

but a species of the genus Eremopteris, his Sigillaria I was unable to identify from an inspection of the material and as there are no true Sigillarias in my collections I cannot say whether his specific name is correct or not. His Lepidodendron is not *Lepidodendron Sternbergii* but represents both of the species recorded from this locality in the present paper. His Calamites and Stigmaria appear to be correctly determined.

The scarcity of coal at tidewater on the West Coast aroused a great local interest in Fuch's discovery, pertenencias were quickly taken out and much money was spent in putting down concrete lined shafts and in diamond drilling although the complete section is admirably exposed along the south shore of the peninsula. Prospecting has not resulted in economic development, since the coal seams are thin and the coal contains a prohibitive percentage of ash.

Subsequently Fuchs gave a brief account of the geology of this general region in his paper on the copper deposits around Ica and Nazca.[2] In this report he considers that the Carboniferous at Paracas is continuous to the eastward beneath the Pleistocene and recent deposits that form most of the surface of the country in the belt lying between the igneous rocks of the Western Range of the Andes and the present coast, i.e., the Pampa de Condar, Pampa de Chunchanga, Pampa de Pisco and Tablazo de Ica. Another account of the Paracas Carboniferous without, however, adding anything to our knowledge concerning it, was published by Dorca in 1909.[3]

Steinmann, who did not visit Paracas, saw Fuchs' collection at the Cuerpo de Ingenieros de Minas in Lima. In a short note published in 1910 he makes the interesting gener-

---

[2] Fuchs, F. G., La Región Cuprífera de los Alrededores de Ica y Nazca. Cuerpo de Ingenieros de Minas, Bol. 29, Lima, 1905.

[3] Dorca, I. R., Estudio sobre los Yacimientos Carboniferos de Paracas. Bol. Soc. Ingenieros, vol. 11, pp. 104-130, Lima, 1909.

alization that the plant bearing Carboniferous in South America is Lower and the invertebrate bearing Carboniferous is Upper in age.[4] He states with his usual assurance that the Paracas forms represent

Archæocalamites radiatus
Lepidodendron cf. Veltheimi
Lepidodendron cf. Volkmanni
Sphenopteris affinis = S. furcata
Rhodea filifera
Rhabdocarpus

None of these forms are represented in the large collections which I made at Paracas, nor did I see any of them in the Fuchs collection.

Finally in 1917 in Lisson's admirable compilation of Peruvian fossils[5] the two species *Lepidodendron rimosum* and *Lepidodendron obovatum* are listed, the determinations being by the late Professor Zeiller, and the age is given as Westphalian. Both of these species are represented in my collections.

DESCRIPTION OF THE SECTION

The question of the age of the Paracas deposits and their relation to the widespread Carboniferous limestones of the Andes is one of great importance. It was apparently some conversation with Señor Bravo, the Director of the Cuerpo de Ingenieros de Minas regarding the Paracas continental Carboniferous that was the basis for the beautiful diagrams of the relations of land and sea during Carboniferous time published by Bowman,[6] which he unfortunately located at Pacasmayo which is 805 km. north of Paracas in a region of crystalline rocks.

---

[4] Geol. Rundschau, Bd. 1, p. 50, 1910.

[5] Lisson, C. I., Edad de los Fósiles Peruanos y Distribución de sus Depósitos en Toda la Republica, pp. 20-21, Lima, 1917.

[6] Bowman, I., The Andes of South America, p. 19.

There was not time for a detailed study of the Carboniferous of Paracas since the peninsula is a practically uninhabited desert. The wide and desert coastal plain, interrupted only by the irrigated valley of Ica, that extends from the igneous foothills of the Western Range to the ocean, consists of wind blown sands, desert pavement gravel and paper shales. Similar deposits form the neck of the Paracas peninsula, which is thus the result of the block faulted Carboniferous and apparently bears no relation to westerly spurs from the Andes or igneous intrusions in the Coastal Plain.

Following is a measured section of the easternmost fault block and was repeated in the next block to the southwest. The horizons from which fossil plants were collected are indicated and there is no chronologic change in the flora from top to bottom although fossil plants are more varied in the lowermost horizon.[7]

	FEET
Thin to heavy bedded rather coarse greenish-gray sandstone....	13
Greenish-gray massive and cross-bedded sandstone with varying amounts of shaly intercalations with Lepidodendron. (N. 21 E, 26 E)........	75
Dark shale with sandstone layers less than a foot in thickness..	55
Sandstone with a shale parting in the middle........	35
Sandy and somewhat carbonaceous fossiliferous shale........	80
Sandy shale (tunnel)........	22
Massive sandstone passing into thin-bedded sandstone along the strike. (N. 9 E, 25 E)........	30
Massive greenish-gray somewhat arkosic sandstone........	15
Thin-bedded sandstone........	10
Thin-bedded sandstone with dark shale (no coal) toward the top (tunnel in shale)........	32
Alternating sandy and carbonaceous shale with 6 inch coal at top, abundantly fossiliferous (tunnel)........	38
Massive greenish-gray somewhat arkosic sandstone........	20
Shale carbonaceous above, sandy below (N. 20 E, 25 E) (tunnel)	10
Greenish-gray sandstone, thin-bedded above........	5
Gray shale........	2
Interbedded thin sandstones and shales........	3

---

[7] Section measured by Dr. Joseph T. Singewald, Jr.

Shale	1
Gray arkosic sandstone	5
Sandy shale	18
Thin-bedded sandstone and sandy shale with more massive sandstone at base	70
Dark carbonaceous shale with 2 to 3 inches of coal at top, abundantly fossiliferous (N. 5 E, 25 E) (tunnel)	18
Massive greenish sandstone	15
Sandy shale	13
Total	585

Pleistocene

Section repeated by faulting to the southwest.

The materials are relatively coarse throughout and would seem to indicate rapid deposition. Between 53 and 54 per cent of the total thickness is described as sandstone, which is often coarse and arkosic. Of the 273 feet described as shale 192 feet is distinctly sandy, so that less than 14 per cent of the total thickness, including the so-called coal seams, is fine grained shale and even the coal contains much silty impurities. No underclays with rootlets, or upright stems were observed and the coaly layers have every appearance of having been formed of drift material, which also appears to have been the case in the probably contemporaneous and very similar continental Carboniferous examined on the Copacabanya Peninsula on Lake Titicaca in Bolivia.

AGE OF THE FLORA

The flora comprises the following forms:

1. Palmatopteris furcata (Brongn.).
2. Eremopteris whitei Berry.
3. Eremopteris peruianus Berry.

Arthrophyta—Calamariaceæ.

4. Calamites suckowii Brongn.
5. Calamostachys sp.

Lepidophyta Lepidodendrales—Lepidodendraceæ.

6. Lepidodendron rimosum Sternb.
7. Lepidodendron obovatum Sternb.
8. Lepidophyllum sp.
9. Lepidostrobus sp.
10. Stigmaria sp.
11. Knorria sp.

It is thus extremely limited, although some of the elements are exceedingly common and this is especially true of *Palmatopteris furcata, Eremopteris whitei, Calamites suckowii* and *Lepidodendron rimosum.* I imagine that the coarseness of the sediments and the apparent drifting of the material is mainly responsible for the absence of a more representative flora. Thus the present collections contain no traces of Sigillaria, Cordaites, Sphenophyllum, calamite foliage, nor of any Neuropterids, Pecopterids, Alethopterids or Lonchopterids. It is this feature of the flora which is undoubtedly responsible for the opinion of Steinmann, quoted on a preceding page, that the Paracas flora is of Lower Carboniferous age.

A somewhat similar situation is furnished by the flora of the Kuttung series of New South Wales, where the so-called Rhacopteris flora appears to be wholly lacking in Neuropteris, Alethopteris and Pecopteris. Walkom, however, and quite rightly I believe, correlates this Kuttung flora with the Westphalian stage of the European section.

The nearest known occurrence of marine Carboniferous is at Huanta, Dept. of Ayacucho 277 km. N.E. of Paracas. The only known outcrop of the marine Carboniferous west of the Western Range is at Cotahuasi, Dept. of Arequipa. This is about 150 km. inland from the present coast and about 395 km. S.E. of Paracas.

Continental Carboniferous, mostly of unknown age, is more widely distributed in South America than has been suspected. Thus there are some continental sediments in the lower part of the section on the Copacabanya peninsula, and Titicaca Island, at the Cerro de Lacctacucho, Sicuani, Dept. of Cuzco, at the Pongo Mainique on the Urubamba, Dept. of Cuzco. Steinmann (Geol. Rundschau, Bd. 2, pp. 50-51, 1910) records Lepidodendron and *Rhacopteris inæquilatera* Göppert from near Huichaycota on the Rio Huallaga in the Eastern Range 1 km. south of Huánuco in the Department of that name. In the same publication similar deposits, said to contain *Archæocalamites radiatus* and *Lepidodendron* cf. *Volkmanni* are recorded from Retamito, which is between San Juan and Mendoza in the Argentine Cordillera.

I think that there can be no doubt that the Paracas Carboniferous is younger than the Dinantian stage of the European section and that it corresponds to the Westphalian stage. The marine Carboniferous of the Andes is usually considered to be of Uralian age, that is to say Stephanian in terms of the continental section. Whether or not the marine series represents more than Uralian has not yet been definitely determined. The finding of one at least of the Paracas plants in the lower part of the section on the Copacabanya peninsula, Bolivia, several hundred feet below the fossiliferous limestones would lead to the inference that the Paracas plant bearing Carboniferous is older than the bulk of the marine Andean Carboniferous and especially the highly fossiliferous portion of the latter.

DESCRIPTION OF THE FOSSIL PLANTS

Genus PALMATOPTERIS Potonié

Like the majority of forms treated systematically by Potonié, his *Palmatopteris furcata* is composite and his synonymy cannot therefore be relied upon. However, I believe it to be a desirable practise to break up the unwieldly form-genus Sphenopteris whenever this is possible, and therefore adopt Palmatopteris for these Peruvian remains, which are exceedingly common in the Paracas deposits. Despite their abundance they are usually very much broken up, a reflection of the coarse nature of the shales. At times large slabs are covered with the small broken pinnæ of this species.

Palmatopteris furcata (Brongniart)

PLATE I—Figs. 1-3

Sphenopteris furcata Brongniart, Hist. végét. foss., p. 179, pl. 49, figs. 4, 5, 1829.

Sternberg, Versuch, vol. 2, fasc. 5-6, p. 58, 1833.

Lindley & Hutton, Fossil Flora, vol. 3, pl. 181, 1836.
Sauveur, Végét. foss. terr. houil. Belg. pl. 18, figs. 1, 2, 1848.
Weiss, Aus d. Steink. p. 13, pl. 12, fig. 74, 1882.
Potonié, Zeits. Deutsch. Geol. Gesell., vol. 43, p. 756, 1892.
Frech, Lethæa geogn., vol. 2, pt. 1, pl. 50a, fig 2, 1899.
Kidston, Proc. York. Geol. & Poly. Soc., vol. 14, pp. 191, 209, 1901; Trans. Roy. Soc. Edinb., vol. 50, pt. 1, p. 83, 1914.
Arber, Quart. Jour. Geol. Soc. Lond., vol. 59, p. 13, pl. 2, fig. 3a, 1903.
Kidston, Mém. Musee Roy. Hist. Belg., vol. 5, p. 19, 1911.

Hymenophyllites furcatus Gœppert, Syst. fil. foss., p. 259, 1836.
Geinitz, Vers. Steinfl. in Sachsen, p. 17, pl. 24, fig. 10, 1855 (not figs. 8, 9, 11).
Roehl, Foss. Fl. Steink. Form. Westph., p. 66, pl. 15, fig. 12, 1869.

Rhodea furcata Presl in Sternberg, Versuch, vol. 2, fasc. 7-8, p. 110, 1838.

Diplothmema furcatum Stur, Culm Fl. pt. 2, p. 230, 1877.
Zeiller, Végét. foss. terr. houil., p. 45, pl. 162, fig. 3, 1880.
Stur, Carbon Fl. Schatz, Schichten, p. 299, pl. 28, figs. 2, 3, 1885.
Zeiller, Fl. foss. Bass. houil. Valenc., p. 147, pl. 4, figs. 5, 6; pl. 5, fig. 4, 1886.

Sphenopteris trichomonoides Brongniart, Hist. végét. foss., p. 182, pl. 48, fig. 3, 1829.

Hymenophyllites obtusilobus Gœppert, Syst. fil. foss., p. 257, 1836.

Diplothmema geniculatum Stur, Carbon Fl. Schatz. Schichten, p. 297, pl. 28, fig. 1, 1885.

Palmatopteris furcata Potonié, Ueber einige Carbonfarne, pt. 3, p. 1, pl. 1, tf. 1, p. 3, 1892; Lehrbuch, p. 136, fig. 127, 1899; Abbild. u. Beschr. foss. Pfl. Lief, 2, No. 21, (part) 8pp, 1 pl. figs. 1-3, 1904 (not figs. 4, 5).
Gothan, Oberschles. Steinkohlenfl. Teil 1, p. 77, pl. 16, figs. 1, 2, tf. 5, 1913.
Zeiller, Fl. foss. bass. d'Héraclée, p. 28, 1899.

Sphenopteris Hartlebenii Fuchs (not Dunker), Bol. de Minas Ind.y Const. tomo 16, No. 7, p. 50, 1900.

Sphenopteris affinis Steinmann (not L & H), Geol. Rundschau, Bd. 1, p. 50, 1910.

Potonié includes *Sphenopteris alata* Brongniart (*Hymenophyllites Graudini* Gœppert), *Sphenopteris spinosa* Gœppert, *Trichomanes Brongniartii* Ettingshausen, *Sphenopteris palmata* Schimper (Diplothmema Stur) in this species and considers that Calymmotheca Stur represents the fertile forms.

It is possible, as Kidston remarks (Cat. Pal. Plants, p. 81, 1886), that *Sphenopteris membranacea* Gutbier is only a varietal form of Brongniart's species, which has been identified from a large number of European localities. Brongniart's type material came from Newcastle, England, Charleroi, Belgium and Saarbrucken, Germany.

Potonié considers *Sphenopteris royi* Lesquereux[8] as a probable North American occurrence of this species, but it is obviously different. Both are characteristic of the Pottsville formation of the Appalachian coal basin of North America and in the uppermost Pottsville they approach very closely to one another and possibly intergrade.[9]

Steinmann's *Sphenopteris affinis* recorded from Paracas is this species in all probability. *S. affinis* Lindley & Hutton, which is the same as *S. linearis* Brongniart, is, except for its Calymmatotheca fructifications, a Diplothmema. It is a characteristic type of the Lower Carboniferous of Europe. While this species is variable as to size it appears to me to be different from the Paracas material.

Fuchs called this form *Sphenopteris Hartlebenii* a Wealden species of Dunkers, since transferred to the genus Ruffordia by Seward.

Genus EREMOPTERIS Schimper

[Traité Pal. Végét., t. 1, p. 416, 1869]

This genus was proposed by Schimper, the type being the *Sphenopteris artemisiæfolia* of Sternberg from the English Coal Measures. The question of demarcation between *Eremopteris, Rhacopteris* and other genera that might be mentioned is particularly puzzling and probably insoluble.

Schimper was also responsible for the name Rhacopteris, the type and only species enumerated by him being based on

---

[8] Coal Fl., vol. 3, p. 768, pl. 104, figs. 7-10, 1884.

[9] White, D., 20th Ann. Rept. U. S. Geol. Surv., pt. 2, p. 882, 1900.

the *Asplenites elegans* of Ettingshausen, a species often referred to Eremopteris. This latter is a form characteristic of the Westphalian stage and the fact that the later described species referred to Rhacopteris are especially characteristic of the Culm (Dinantian and Mississippian) and some of them approach Archæopteris in form and venation, has resulted in giving the name Rhacopteris a chronologic significance which obscures rather than elucidates the floral history of the Carboniferous.

Rhacopteris was characterized as having simply pinnate forked fronds with trapezoid or rhomboid pinnules with lobed margins, and is supposed to be more typical of the Lower (Culm) than of the Upper (Pennsylvanian) Carboniferous. I know of no evidence to indicate that the supposed Rhacopteris frond is other than a single pinna of an Eremopteris frond. Most of the attempts at a systematic arrangement are highly artificial, notably that of Potonié as elaborated in Engler and Prantl. The truth is that our information is as yet too incomplete to permit of a satisfactory delimitation of the overlapping generic terms now in use.

Lesquereux, in his study of American Carboniferous floras used Eremopteris in a rather broad way and in this he was followed by White. I regard this as the most logical treatment and consider Eremopteris as suitable for most of the series of forms, largely intermediate in both form and chronologic occurrence between Triphyllopteris and Mariopteris. For example the present *Eremopteris peruianus* is very similar to the *Rhacopteris transitionis* (Ettingshausen) Stur from the Upper Culm of Moravia. It is almost equally close to *Eremopteris crenulata* Lesquereux from the Westphalian of Alabama. The second species of Eremopteris enumerated by Schimper, namely, *E. Neesii* came from the Bohemian Permian and Zeiller subsequently transferred it to Callipteris.

Eremopteris peruianus sp. nov.

PLATES II and III

Description.—Frond habit unknown since the material is all fragmentary, possibly tripinnate. Pinnæ large with a stout flexuous axis giving off alternately obovate pinnules which vary from a nearly entire, typically Rhacopteris-like form, to others that approach Sphenopteris in both lobation and venation. Certain smaller pinnules figured, which were found detached and are therefore not positively ascertained to belong to this species are entire, the distal rounded margin with rounded teeth and the venation flabellate. Others are bilobate and of intermediate character. Both of these would, I imagine, be unhesitatingly referred to Rhacopteris. As previously mentioned their relationship to this species is assumed and not proven. On the other hand I have brought together on one plate, enlarged sketches of pinnules all of which come from a single pinna. Although these show the same general facies, throughout they differ considerably in the degree of lobation and depth of the intervening sinuses, ranging from forms with 4 palmate, nearly equal lobes, to forms with as many as 7 subequal divisions, and showing every gradation between these two extremes. The texture is coriaceous and the venation is largely immersed in the frond substance, but is Sphenopterid rather than Archæopterid in character. Similar variations are seen in the forms variously referred by authors to Sphenopteridium, Cyclopteris, etc.

In this form the pinnules are much coarser than in the associated *Eremopteris whitei* and the proximal part of the frond is believed to be missing. As previously mentioned there is great similarity to part of the material referred to *Rhacopteris transitionis* (Ettingshausen) Stur[10] from the Upper Culm of Moravia and also to *Eremopteris crenulata*

---

[10] Stur, D., Culm Flora, vol. 1, p. 77, pl. 8, figs. 5-7, 1875 (Abh. k. k. geol. Reichsanstalt, Bd. 8).

Lesq.[11] which comes from the Alabama Coal measures (Westphalian).

The species appears to be unlike previously known forms and I have ventured to describe it as new. It is not at all uncommon in the Paracas outcrop.

Eremopteris whitei sp. nov.

PLATE IV

Eremopteris elegans Lesquereux, Coal Flora, p. 294, pl. 53, fig. 7, 1880 (not Gutbier, Ettingshausen or Schimper).

This form, which is not uncommon at Paracas, appears to be identical with the material described by Lesquereux from the Pottsville formation of Pennsylvania and Illinois and referred to the European species variously named *Sphenopteris asplenites* by Gutbier.[12] *Asplenites elegans* by Ettingshausen[13] and *Rhacopteris elegans* by Schimper.[14] The American form is entirely distinct from the European. No complete material of the Paracas species is available but from the disposition of the three stout stipes shown in the specimen figured it would seem that the frond was very large and quadri-pinnate. The stipes are stout, longitudinally channeled and not winged. The pinnæ are linear oblong, their divisions or pinnules are oblique, oblong or rhomboidal in form, narrowed to the somewhat decurrent base, deeply pinnately cut by narrow sinuses into cuneate divisions which are rounded or sub-crenate distad. The venation is flabellate and largely immersed in the thick substance of the lamina.

In the size of the frond and stoutness of the stipe the present species is reminiscent of *Eremopteris bilobata* White, but the pinnules are different in form. I have not seen actual specimens of Lesquereux's types and it may be that the Par-

---

[11] Lesquereux, L., Coal Flora, vol. 1, p. 292, pl. 53, figs. 1, 2, 1880.

[12] Geinitz, H. B., Verst. Steink. Sachsen, p. 17, pl. 24, fig. 6, 1855.

[13] Ettingshausen, C., Abh. k. k. Geol. Reichs. Bd. 1, Ab. 3, No. 4, p. 14, pl. 3, figs. 1-3; pl. 4, 1852.

[14] Schimper, W. P., Traité Pal. Végét. tome 1, p. 482, 1869.

acas material represents a distinct species, but in any case the two occurrences represent closely related forms. Bodenbender[15] in 1902 recorded a *Rhacopteris Szajnochai* on the authority of Kurtz from a Glossopteris assemblage in the Carpinteria region of Western Argentina. What this last may represent I do not know.

Genus CALAMITES Suckow

Calamites suckowi Brongniart

PLATES V, VI, VII

Calamites Suckow, Acad. Elect. Theodoro-Palatinæ, vol. V, p. 355, pl. XVI, Fig. 2; pl. XIX, Fig. 8, 9, 1784.

Calamites Suckowii Brongniart, Hist., I, p. 124, pl. XV, Fig. 1-6, pl. XVI, Fig. 1?, 2-4, 1828.

Sternberg, Versuch, II, Fasc. 5-6, p. 49, 1833.
Gutbier, Abdr. u. Vers. d. Zwick. Schwarzkohl., p. 17, pl. II, Fig. 1 (non Fig. 2), 1835.
Sauveur, Végét. foss. terr. houil. Belgique, pl. III; IV, Fig. 1, 2; pl. XI, Fig. 3, 1848.
Brown, Lethæa geog., vol. I, p. 101, pl. VI, Fig. 1, 1851.
Geinitz, Steinkf. Sachsen, p. 6, pl. XIII, Fig. 1, 3, 5, 6, (4?), 1855.
Dawson, Acad. Geol., 2e, p. 195, Fig. 39, p. 442, Fig. 163A^2, A^4, p. 478, 1868.
Röhl, Foss. Fl. Steink. Westf., p. 9, pl. I, Fig. 6; pl. II, Fig. 2, 1869.
Weiss, Foss. Fl. jüngst. Steink. u. Rothl., p. 117, pl. XIII, Fig. 5, 1871.
Feistmantel, Verst. Böhm., p. 102, pl. II, Fig. 3, 4; pl. III, Fig. 1, 2; pl. IV, Fig. 1, 2; pl. V; pl. VI, Fig. 1, 1874.
Weiss, Steink.—Cal., pt. I, p. 123, pl. XIX, Fig. 1, 1876; pt. II, p. 129, pl. II, Fig. 1; pl. III, Fig. 2, 3; pl. IV, Fig. 1; pl. XVII Fig. 5, 1884.
Römer, Lethæa geog., vol. I, p. 144, pl. I, Fig. 1, 1879.
Grand 'Eury, Fl. Carb. Dept. Loire, p. 14, pl. I, Fig. 1-6, 1877.
Zeiller, Vég. foss. terr. houil., p. 12, pl. CLIX, Fig. 1, 1880.
Weiss, Aus d. Steink., p. 10, pl. VII, Fig. 43, 1882.
Renault, Cours. bot. foss., vol. II, p. 159, pl. XXIV, Fig. 3-5, 1882.
Zeiller, Fl. foss. Bass. houil. Valenc., p. 333, pl. LIV, Fig. 2-3; pl. LV, Fig. 1, 1886.

---

[15] Bodenbender, Bol. Acad. Nac. Ciencas Cordoba, vol. 17, 1902.

Stur, Calam. Schatz. Schicht., p. 145, pl. III, Fig. 3-5, Fig. 5-6; pl. XVI, Fig. 1, 2 (non pl. 1, Fig. 3; pl. IX, Fig. 2; pl. XIV, Fig. 1), 1887.

Toula, Die Steinkohlen, p. 202, pl. V, Fig. 1, 2, 9 (non Fig. 26), 1888.

Renault, Fl. foss. terr. houil. Commentry, p. 385, pl. XLIII, Fig. 1-3; Pl. XLIV, Fig. 4, 5, 1890.

Hofmann and Ryba, Leitpflanzen, p. 24, pl. I, Fig. 6, 1899.

Potonié, Landschaft, p. 27, Fig. 17, 1899.

Zeiller, Eléments paléob., p. 149, Fig. 149, 1900.

Scott, Studies, p. 15, Fig. 2, p. 16, Fig. 3, 1900.

Kidston, Proc. Yorksh. Geol. and Poly. Soc., vol. XIV, p. 200, 202, 215, 225, pl. XXX, Fig. 1; pl. XXXV, Fig. 3, 1901.

Zeiller, Blanzy et Creusot, p. 126, pl. XXXVII, Fig. 1, 1906.

Sterzel, Baden, p. 429, pl. XVIII, Fig. (?1) 2 (non pl. XIX, Fig. 1), p. 506, pl. XXXI, Fig. 2, pl. XXXII, Fig. 1, p. 549, p. 702, pl. LVII, Fig. 1 bei A, Fig. 2-5, pl. LVIII, Fig. (?1) 2, 3, pl. LIX, Fig. 1, 1907.

Zalessky, Donetz I, Domherr, p. 363, Fig. 1, 2, 1907.

Zalessky, Dombrowa, pp. 17, 51, Fig. 4, 1907.

Renier, Méthodes, p. 41, Fig. 16, 1908.

Schuster, Saarbr. Sch., p. 229, Textbeil. L, Fig. 1, 2, 1908.

Scott, Studies 2e., p. 17, 18, Fig. 2, 3, 1908.

Arber, Fossil plants, pl. p. 52, 1909.

Renier, Paléontologie, pl. 43, 1910.

Jongmans, Karbonfl. West-Europas, p. 164, fig. 137-142, 1912.

Kidston, Cat. Pal. Plants, p. 24, 1886; Trans. Roy. Soc. Edinb., vol. 50, pt. 1, p. 117, 1914.

Lesquereux, Coal Flora, p. 20, pl. 1, figs. 3, 4, 1880.

Jongmans, Fl. Carb. Netherlands Atlas, pl. 39, figs. 2, 3; pls. 82, 83, 84, 85, 86, 87; pl. 88, figs. 2, 3; pl. 89; pl. 90, fig. 2; pl. 136, figs. 2, 3; pl. 137, figs. 1, 2; pl. 138, fig. 1, 1915.

Kidston, Végét. Houil. Belge, p. 113, 1911.

Sterzel, Fl. Rothl., p. 87, pl. 10, fig. 1, 1893.

Andrae, Neues Jahrb., 1864, p. 164; Jahrb. Naturw. Ver. Halle, p. 119, 1859.

Brongniart, Prodrome, p. 37, 1828.

Boulay, Recher. Pal. Végét., p. 7, 1880.

Fontaine & White, Perm. Fl., p. 35, 1880.

Zeiller, Fl. foss. bass. Héraclée, p. 59, 1899.

Arber, Phil. Trans. Roy. Soc., Lond., vol. 202 B, p. 241, 1912.

Calamites æqualis Sternberg, Versuch, II, Fasc. 5-6, p. 49, 1833.

Calamites Artisii Sauveur, Végét. foss. terr. houil. Belg., pl. VII, Figs. 1, 2, 1848.

Calamites nodosus Sauveur, (non Schlotheim) ibid., pl. XII, Fig. 3, 1848.

Calamites approximatus Feistmantel, (non Schlotheim) Verst. Böhm., p. 106, pl. VI, Fig. 2; pl. VII, Fig. 1-2, 1874.

Calamites cannæformis Lebour, (non Schlotheim) Illustr. Fossil Pl., pl. I, 1877.

Calamites irregularis Achepohl, Niederrh. Westf. Steink., p. 89, pl. XXVIII, Fig. 2, 1882.

Calamites approximatiformis Stur, Culm-flora, II, p. 202, pl. IV, Fig. 7; pl. V, Fig. 4, 1877.

Calamites Haueri Stur, Culm-flora, II, p. 89, (195), Textfig. 19, 20, pl. II, Fig. 7; pl. V, Fig. 2, 3*a*, *b*, 1877.

Calamites Seward, Fossil Plants, p. 323, Fig. 82, 1898.

? *Calamites decoratus* Artis, Antedil. Phyt. pl. XXIV, 1825.

Calamites decoratus Brongniart, (pars) Hist., I, p. 123, pl. XIV, Fig. 1, 2 (non Fig. 3-4), 1828.

? *Calamites Steinhaueri* Brongniart, Hist., I, p. 135, pl. XVIII, Fig. 4, 1828.

? *Calamites Voltzi* Brongniart, Hist., I, p. 135, pl. XXV, Fig. 3, 1828.

? *Calamites cannæformis* Brongniart, Hist., I, pl. XXI, Fig. 4, 1828.

Calamites L. and H., Fossil Flora, pl. LXXVIII (vergl. Kidston, Proc. Roy. Phys. Soc. Ed., vol. X, p. 364, 1890-'91).

This wide ranging species is abundant in both large and small examples at Paracas and occurs also in the lower part of the section on the Copacabanya peninsula, Bolivia. It undoubtedly represents what Steinmann called Archæocalamites and suggests that this author's Archæocalamites from other localities in South America may represent true Calamites. Stems of this sort have little that is truly specifically characteristic, but the vascular alteration at the nodes proves it to be a true Calamites and the infra nodal canals and character of the ribbing invite comparisons with this classic species, which had a wide geological and geographical range.

Genus CALAMOSTACHYS Schimper

Calamostachys sp.

The Paracas material contains several fragmentary specimens of a poorly preserved calamite fructification belonging to the genus Calamostachys. The material is too poor for proper identification or illustration.

Genus LEPIDODENDRON Sternberg

Lepidodendron rimosum Sternberg

PLATE VIII

Lepidodendron rimosum Boulay, Terr. Houil. Nord. France, p. 37, 1876.
Brongniart, Prodrome, p. 86, 1828.
Dawson, Acadian Geol. 2nd ed., p. 487, 1868.
Quart. Journ. Geol. Soc., Lond., vol. XXII, p. 161, pl. IX, fig. 42, 1866.
Canadian Nat., vol. VIII, p. 450, 1863.
Foss. Plants of Lower Carb. Canada, p. 37, 1873.
Etheridge, Cat. Australian Fossils, p. 31, 1878.
Ettingshausen, Steinkf. v. Radnitz, p. 56, 1854.
Grand 'Eury, Flore Carbon Dép. Loire, p. 139, 1877.
Lesquereux, Coal Flora, p. 393, pl. LXIV, fig. 11, 1880.
Geol. of Pennsyl., vol. II, p. 874, 1858.
Morris, Trans. Geol. Soc., Lond., 2nd ser., vol. V, p. 488.
Renault, Cours Botan. Foss., p. 15, pl. V, figs. 6, 7, 1882.
Roehl, Foss. Fl. Steinkf. Form. Westph., p. 132, pl. VIII, fig. 1, pl. X, fig. 2, 1869.
Sauveur, Végét. Foss. Belgique, pl. LXII, fig. 1, 1848.
Sternberg, Vers. I, fasc. 1, pp. 21, 23, pl. X, fig. 1, 1820; fasc. 4, p. XI, 1826.
Unger, Synop. Plant Foss., p. 131, 1845.
Genera et Species, p. 257, 1850.
Neues Jahrbuch, p. 608, 1842.
Fischer, in Potonié, Abbildungen und Beschreibungen foss. Pflanzen, Lief 4, 1906.
Sagenaria rimosa Bronn, Index Palaeont., p. 1106, 1848.
Eichwald, Lethæa Rossica, vol. 1, p. 125, pl. VII, fig. 7, 1860.
Feistmantel, Zeitsch. Deut. Geol. Gesell., vol. XXV, p. 595.
Vers. Böhm. Kohlenab., p. 210, pl. XLVIII, fig. 1, pl. XIX, fig. 1, 1875.

Jahrb. k. k. Geol. Reichsanst., vol. XXII, p. 293.
Steinkohl. u. Perm.—Ablager, p. 92, 1873.
Geinitz, Vers. Steinkf. Sachsen, p. 35, pl. III, figs. 13-15, pl. IV, fig. 10 (excl. pl. II, figs. 1, 4, pl. X, fig. 2?), 1855.
Geibel, Deutschl. Petrefacten, p. 81, 1852.
Sternberg, Vers. fasc. II, p. 180, pl. LXVIII, fig. 15, 1821.

Lepidodendron fusiforme Ettingshausen, Steinkf. v. Radnitz, p. 55, 1854.
Grand 'Eury, Flore Carbon. Dép. Loire, p. 139, 1877.
Schimper, Traité Paleont. Végét., vol. II, p. 33, 1872.
Unger, Genera et Species, p. 257, 1850.

Sagenaria fusiformis Corda, Flora d. Vorwelt, p. 20, pl. VI, 1848.
Feistmantel, Vers. Böhm. Kohlenab., p. 212, pl. XLVIII, fig. 2, 1875.
Giebel, Deutschl. Petrefacten, p. 81, 1852.

Lepidodendron selaginoides ? Lindley and Hutton, Foss. Flora, vol. I, pl. XII, 1831; vol. II, pl. CXIII, 1834.
Heer, Fl. Foss. Helv., lief. 1, p. 37, pl. XVI, fig. 6 (fig. 7?), 1877.

Lycopodites selaginoides Feistmantel, Vers. Böhm. Kohlenab., p. 184, pl. XXX, figs. 3, 4, pl. XXXI, 1875.

Lepidostrobus Lycopodites Feistmantel, Vers. Böhm. Kohlenab., p. 184, 1875.

Lepidodendron dubium Wood, Trans. Amer. Phil. Soc., vol. XIII, p. 344, pl. VIII, fig. 4.

Sagenaria dichotoma Geinitz, Vers. Steinkf. Sachsen, pl. III, fig. 11, 1855.

Lepidodendron undulatum Roehl, Foss. Fl. Steinkf. Form. Westph., p. XXXII, fig. 1, 1869.

Lepidodendron caudatum ? Roehl, Foss. Fl. Syeinkf. Form. Westph., pl. VIII, fig. 7, 1869.

Aspidiaria undulata ? Geinitz, Vers. Steinkf. Sachsen, p. 37, pl. III, fig. 17, 1855.

? Lepidodendron Pictoense Dawson, Acadian Geol. 2nd ed., p. 454, 487, fig. 169*a*, 1868.
Quart. Journ. Geol. Soc., Lond., vol. XXII, p. 160, pl. IX, fig. 37, 1866.
Canadian Nat., vol. VIII, p. 449, 1863.
Foss. Plants of Lower Carb., Canada, p. 37, 1873.
Schimper, Traité Paleont. Végét., vol. II, p. 29, 1872.

? Lepidodendron plicatum Dawson, Quart. Journ. Geol. Soc., Lond., vol. XXII, p. 162, pl. IX, fig. 38, 1866.
Schimper, Traité Paleont. Végét., vol. II, p. 29, 1872.

Lepidodendron simplex Lesquereux, Geol. Survey of Illinois, vol. II, p. 454, pl. XLV, fig. 5, 1866.

Lepidodendron King, Edinb. New Phil. Journ., vol. XXXVI, pl. V, fig. 3.

Lepidodendron dissitum, Sauveur, Végét. Foss. Belgique, pl. LIX, fig. 3; pl. LXI, fig. 6, 1848.

Lepidodendron elegans ? Sauveur, Végét. Foss. Belgique, pl. LIX, fig. 4, 1848.

Phytolithus (*cancellatus*) Martin, Petrificata Derbiensia, pl. XIII, fig. 3, 1809.

This well known species, of which I have cited a considerable bibliography, is common at Paracas. There is considerable variation in the closeness or remoteness of the long narrow bolsters. Those in which these are well spaced often show the characteristic longitudinally wrinkled epidermis.

That the spacing is largely a matter of age is shown by those specimens where the bolsters are closely spaced frequently having the narrow, linear lanceolate leaves still attached.

Lepidodendron obovatum Brongniart

PLATE I—Fig. 5

Lepidodendron obovatum Brongniart, Prodrome, p. 86, 1828.
  Ettingshausen, Steinkfl. Radnitz, p. 54, 1854.
  Fontaine & White, Permian Fl., p. 17, 1880.
  Lesquereux, Geol. Pa., vol. 2, p. 874, 1858.
  Lindley & Hutton, Foss. Fl., vol. I, pl. 19 bis, 1832.
  Owen, Geol. Surv. Wis., p. 99, pl. 6, fig. 2, 1852.
  Renault, Cours. Bot, foss., p. 13, pl. 6, fig. 5, 1882.
  Roehl, Foss. Fl. Steink. Westph., p. 129, pl. 6, fig. 1; pl. 8, fig. 8b; pl. 29, fig. 15, 1869.
  Sternberg, Versuch., fasc. 1, pp. 20, 23, pl. 6, fig. 1; pl. 8, fig. 1a, 1820; fasc. 4, p. X, 1826.
  Zeiller, Végét. foss. terr. houil., p. 108, 1880.
  Kidston, Cat. Pal. Pl., p. 149, 1886.
  Fischer, in Potonié, Abbildungen und Beschreibungen foss. Pfl. Lief 3, 1905.
  Zeiller, Foss. Fl. bass. Héraclée, p. 73, pl. 6, fig. 11.
  Kidston, Trans. Roy. Soc., Edinb., vol. 50, pt. 1, p. 134, 1914.
Sagenaria obovata Bronn, Index Palaeont., p. 1106, 1848.
  Feistmantel, Vers. Böhm. Kohlenab., p. 204, pl. 38, figs. 1-4, 1875.

This characteristic Westphalian species is considerably less common at Paracas than is *Lepidodendron rimosum.* It requires no extended comment.

Genus LEPIDOPHYLLUM Brongniart

Lepidophyllum sp.

The leaves of a Lepidodendron, probably *Lepidodendron rimosum* are not uncommon at Paracas.

Genus LEPIDOSTROBUS Brongniart

Lepidostrobus sp.

PLATE I—Fig. 4

A characteristic Lepidodendron cone, too poor for identification or description, is present in the Paracas collection and is shown on the accompanying plate.

Genus STIGMARIA Brongniart

Stigmaria sp.

Characteristic, but poorly preserved, remains of Stigmaria are not uncommon at Paracas.

Genus KNORRIA Sternberg

Knorria sp.

Lepidophyte material in the Knorria stage of preservation is not uncommon at Paracas.

PLATE I

Figs. 1-3. Palmatopteris furcata (Brongniart).

Fig. 4. Lepidostrobus sp.

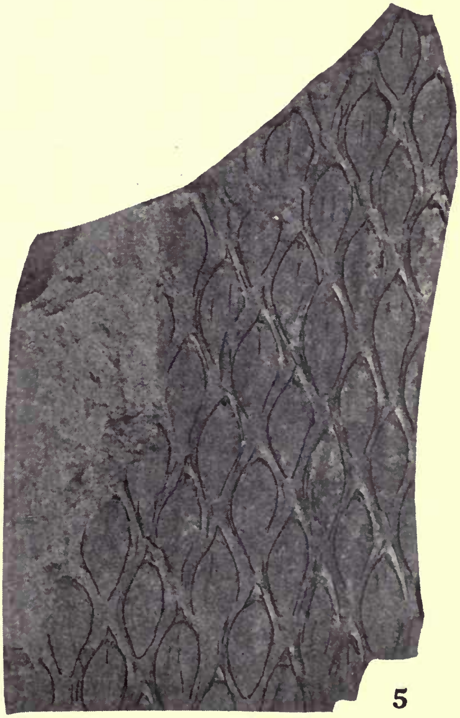
Fig. 5. Lepidodendron obovatum Sternberg.

1

2

3

4



5

Palmatopteris furcata (Brongn.).
Lepidostrobus sp.
Lepidodendron obovatum Sternb.

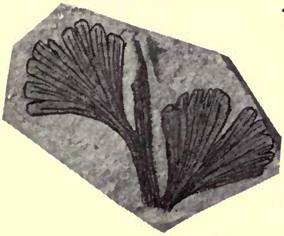
Plate II

Figs. 1-3. Eremopteris peruianus Berry.

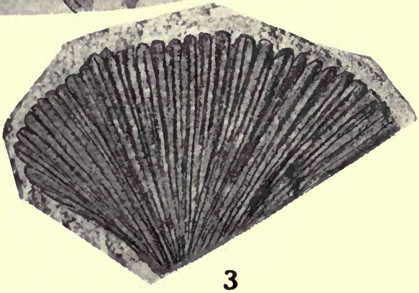
Fig. 2. Two pinnules, nat. size.

Fig. 3. Another form of pinnule, X 3.

1



2



3

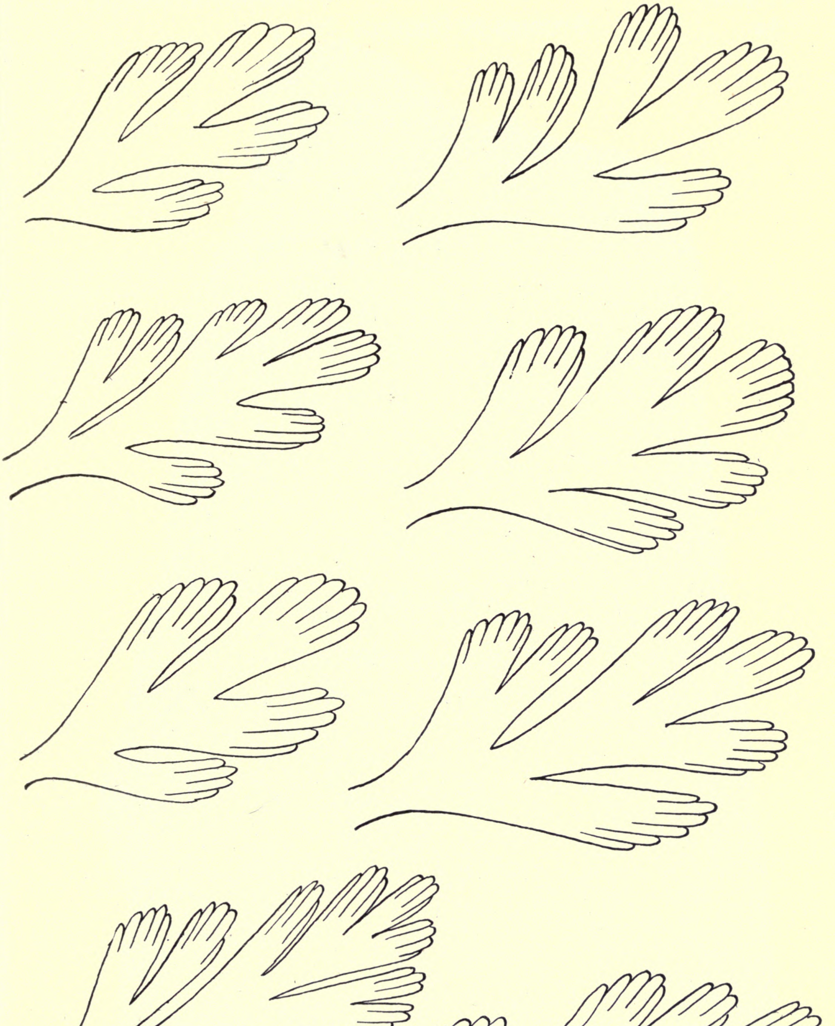
Eremopteris peruianus sp. nov.

UNIV. OF

PLATE III

Enlarged pinnules of Eremopteris peruianus Berry showing some of the variations.

Plate III



Eremopteris peruinus sp. nov.

PLATE IV

Eremopteris Whitei Berry.

Eremopteris whitei sp. nov.

PLATE V

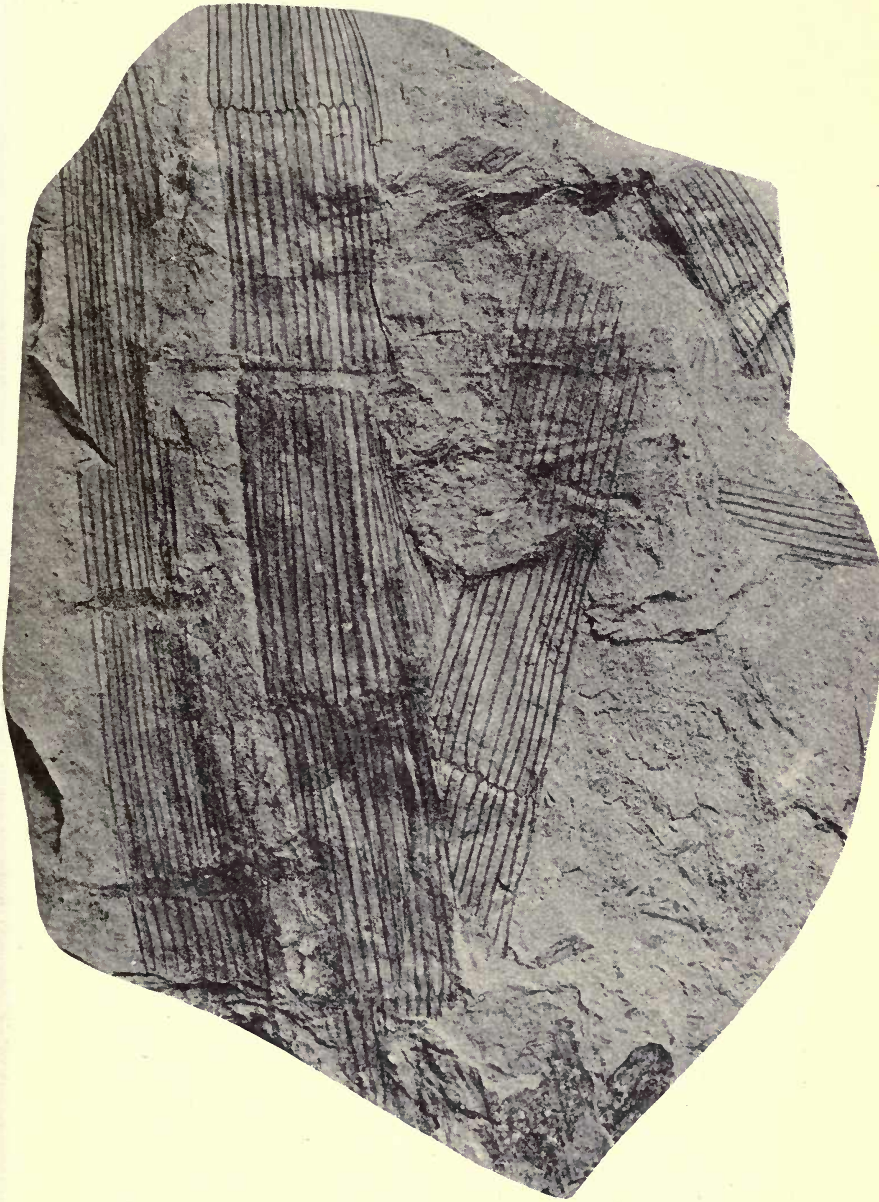
Calamites Suckowii Brongniart.

Calamites Suckowii Brongn.

UNIV. OF CALIFORNIA

PLATE VI

Calamites Suckowii Brongniart.

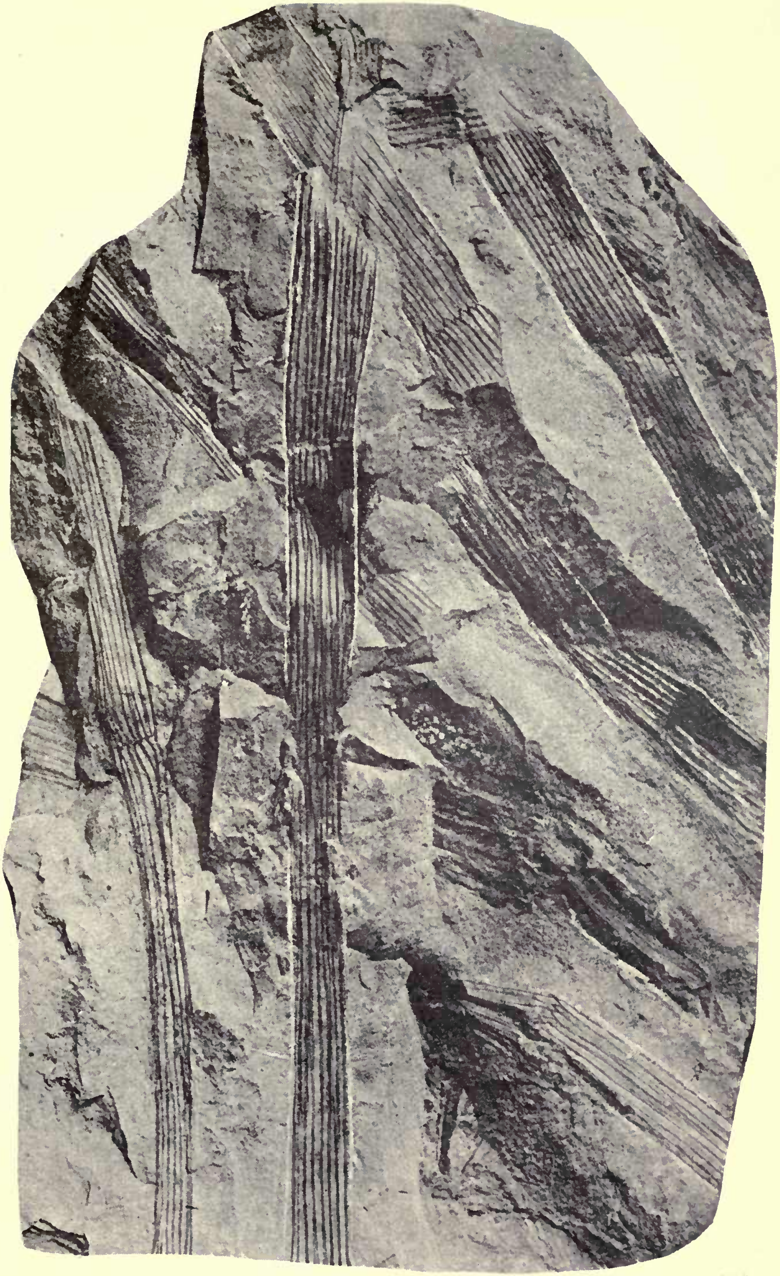


Calamites Suckowii Brongn

UNIV. OF CALIFORNIA

PLATE VII

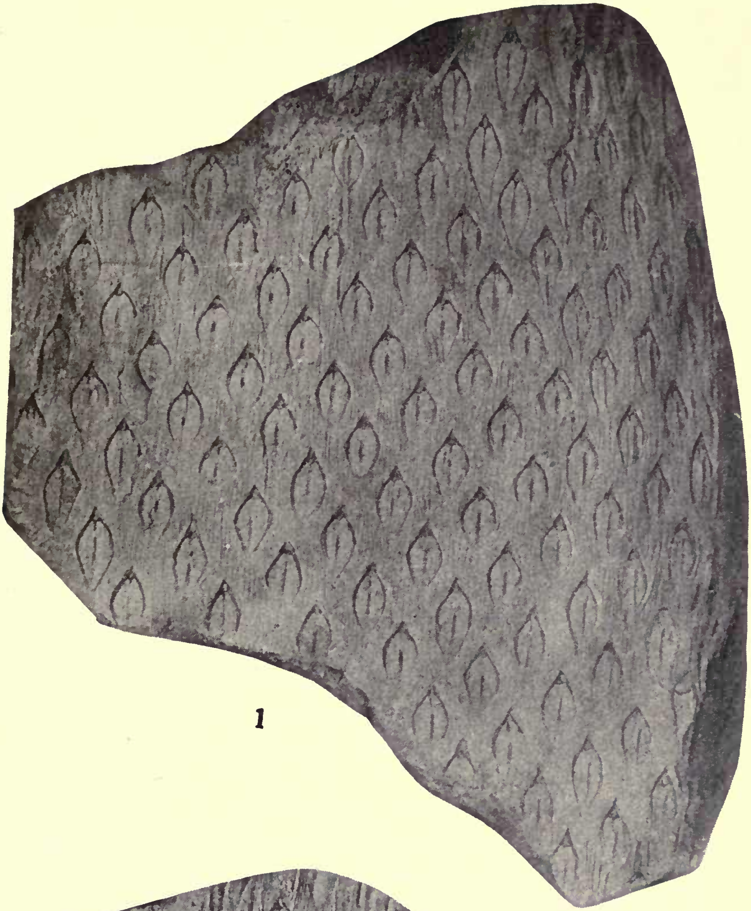
Calamites Suckowii Brongniart.



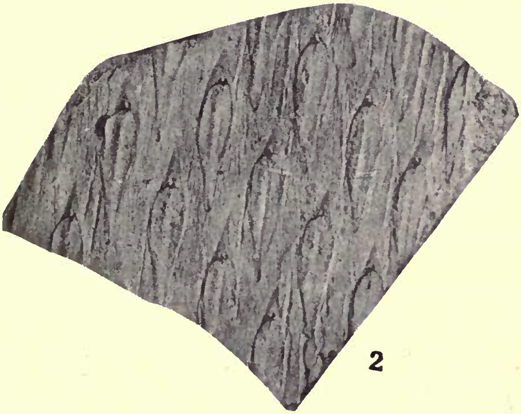
Calamites Suckowii Brongn.

PLATE VIII

Figs. 1-3. Lepidodendron rimosum Sternberg, showing variations and an enlarged bolster.



1



2

3

Lepidodendron rimosum Sternb.

THE MESOZOIC FLORA OF PERU *

By Edward W. Berry

Distribution and Character of the Mesozoic Rocks

Mesozoic rocks are very widespread in Peru and are especially prominent in the Cordillera Occidental, especially between latitudes 5° and 13° South. Beyond this the enormous amount of volcanic material almost entirely masks the sedimentary rocks, but the presence of Cretaceous limestones at Sta Lucia identical in character with those farther north suggests similar conditions beneath the great volcanic field of Southern Peru. These rocks probably also continue northward across Ecuador and tie up with the Mesozoic series in the Columbian Andes, and all are a part of the Mediterranean, Urgonian or Comanchean province of the Western Hemisphere. Most of the Jurassic and Cretaceous horizons are represented, but the details are still obscure despite the extensive recent contributions of Steinmann and Lisson to the paleontology of the beds of these ages in Peru.

The question of Mesozoic climates, particularly the great latitudinal range of the so-called Wealden flora gave an enhanced interest to the excellent sections of Mesozoic to be found near Lima and admirably described by Señor Lisson.[1]

Through the courtesy of Señor Jose Bravo, the genial director of the Cuerpo de Ingenieros de Minas the Williams Expedition was enabled to study and collect from the section exposed on San Lorenzo Island.

This island, to which the port of Callao owes its harbor, is about 10 km. long from northwest to southeast, about one-third that width, and about 5 km. off La Punta. It rises to a maximum height of 1,326 feet and consists entirely of Mes-

---

* George Huntington Williams Memorial Publication No. 16.

[1] Lisson, Carlos I., Contribución a la Geologia de Lima y sus Alrededores. Lima 1907.

ozoic rocks which dip about 25° West of South and represents the remnants of the southwestern limb of a considerable anticline.

The fossil plants from San Lorenzo occur on the eastern coast at the Caleta del Paraiso where they were first noted by Naumann[2] who described the following forms based on collections made by Steinmann, who incorrectly gives the locality as Presos: *Weichselia mantelli, Equisetites Lyelli, E. peruanus, Otozamites Gœppertianus, Zamiostrobus crassis, Z.affindex* and *Rhynchogoniopsis neocomiensis.* Subsequently Zeiller[3] reported on a collection made from this locality by Capt. Berthon, the complete account of which was published in 1914.[4] Zeiller's determinations comprise

Sphenopteris Berthoni
Ruffordia Gœpperti
Cladophlebis cf Browniana
Weichselia peruviana
Podozamites sp.
Otozamites Neumanni
Cycadolepis (?) Bonnieri
Antholithus sp.

The only other systematic account of Mesozoic fossil plants from Peru is a short appendix to Hauthal's travels in Bolivia and Peru by Salfeld.[5] This records a number of poorly defined plants from Huallanca and Lima. There are several references to fossil plants in the Bulletins of the Bureau of Mines of Peru, that by Lukis in Bol. 64 containing figures of several forms from the coal measures of Huayday, Department Libertad. There is considerable overlapping and confusion in these various contributions—that by Zeiller being much the most scholarly and valuable.

---

[2] Naumann, R., Neues Jahrb. Beil. Bd. 24, pp. 74-87, pl. 1, 2, 1907.

[3] Zeiller, R. Comp. Rend. Acad. Sci., tome 150, pp. 1488-1490, 1910.

[4] Zeiller, R., Revue Générale de Botanique, tome 25 bis, pp. 647-674, pl. 20-21, 1914.

[5] Salfeld, H., Gesell. Erdkunde Leipzig, Bd. 7, pp. 211-217, 1911.

Undoubtedly there is a splendid flora hidden in the Mesozoic rocks of Peru which would repay the work of experienced collectors, but the localities are so remote and difficult of access that it will doubtless be many years before we can hope to know much about it. My own collections are limited to a small amount of material from Piñonate near Lima, a large collection from Caleta de Paraiso on San Lorenzo Island and three specimens from Jatunhuasí, Department Junin obtained from Señor Bravo.

An attempt is made in the following pages to sum up our present knowledge of the Peruvian Mesozoic flora. With the exception of Salfeld previous contributors have accepted without question the Wealden or Neocomian age of these various plant-bearing outcrops. According to the determinations of Lisson the plant beds at Piñonate and Paraiso lie between marine Portlandian and marine Valanginian. It may be again emphasized that the term Wealden is not a satisfactory chronologic term since the name, even in Europe, connotes a type of deposition of no exact time value and its application in various other parts of the world is most unfortunate. Certainly the flora from Peru contains nothing that conclusively proves its Neocomian age. Most of the discovered forms are distinctly Jurassic types which brings up the old question of the lack of a decisive paleobotanical boundary between the Jurassic and Lower Cretaceous that has been raised in so many other regions. My own conclusion is that it would be nearer the true facts to refer these Peruvian plant-bearing beds to the Portlandian stage rather than perpetuate the indefinite term Wealden.

The lithology of the plant-bearing beds on San Lorenzo Island is especially interesting and I append the following notes on the lithology kindly furnished by Dr. M. I. Goldman, the well-known authority on the study of sediments.

"In the *hand specimen* a light colored, pearl-gray shale, hard, with a rather soapy feel, probably due to the film of gypsum that occurs along bedding planes throughout the specimen.

"In *thin section* rather sandy and full of small accretions of tiny, hematite spherules, which were very probably originally sulfide (pyrite). In one place a lamina of gypsum parallel to the bedding appears in the thin section. There are hints of extensive silicification, but I cannot prove it; the hardness of the shale makes it most probable.

"I would conclude that this was originally a carbonaceous sulfidic (pyritiferous) shale, which for some reason (perhaps because it was adjacent to a plane of tectonic movement?) has been the locus of active water circulation which has oxidized the carbon and sulfide originally present, formed gypsum by means of sulfuric acid derived from the sulfide and produced extensive silicification."

ANALYSIS OF THE FLORA

An analysis of the previous and present contributions results in the following list of generic plant types from the Mesozoic of Peru:

Equisetites
Tæniopteris
Ruffordia
Filicites
Cladophlebis
Sphenopteris
Weichselia
Klukia
Otozamites
Zamiostrobus
Cycadolepis
Podozamites
Thuites
Brachyphyllum
Antholithus

The majority are poorly characterized and those which are not are the Ruffordia, Weichselia, Klukia and the two species of Otozamites. All of these genera except Klukia are represented in the English Wealden, only Ruffordia is represented in the Potomac flora of the eastern United States. None are certainly represented in the Neocomian of Japan or the Uitenhage series of South Africa or the Knoxville of Pacific North America.

Considering the list as a whole their affinities are about equally divided between Upper Jurassic and Neocomian. The nearest Lower Cretaceous floras are those of North America and these are rather different from the Peruvian flora. The nearest Upper Jurassic flora is that of Graham Land monographed by Halle.[6] This is extensive and well preserved flora with a notable display of Otozamites and, except for the absence of Weichselia which is so abundant in the Peruvian flora, it contains nearly all of the types represented in that flora.

When a representative flora shall have been collected from the Mesozoic rocks of Peru it will doubtless be easy to determine its exact age and the impressions derived from a consideration of the meager list of forms at present known may be entirely invalidated. In themselves, however, they impress me as more strongly late Jurassic than Lower Cretaceous in their facies.

Description of Fossil Plants

Genus Equisetites Sternberg

Equisetites Lyelli Mantell (?)

Equisetites Lyelli Neumann, Neues Jahrb. Beil. Bd. 24, pp. 77, pl. 1, fig. 2, 1907.

This rather common Neocomian species of Equisetum was fully discussed by me in 1911 to which reference is here made,[7] since it seems undesirable to seriously consider the

---

[6] Halle, T. G., Wiss. Ergeb. Schwed. Sudpolar-Exped. 1901-1903, Band 3, Lief 14, 1913.

[7] Berry, E. W., Maryland Geological Survey, Lower Cretaceous, p. 311, pl. 41, figs. 7, 8, 1911.

specimen which Neumann referred to this species and which is probably nothing but a fragment of a stipe of Weichselia, although this has not been definitely demonstrated to be the case.

The Neumann material was collected by Steinmann on San Lorenzo Island among the profuse remains of Weichselia and has not been reported from any other Peruvian locality.

Equisetites sp.

PLATE II—Fig. 4

A single specimen of a sheath of some species of Equisetales is contained in the small collection from Jatunhuasi, Department of Junin. It is of considerable interest in showing the undoubted presence of plants of this order in the Mesozoic flora of Peru.

Genus TÆNIOPTERIS Brongniart

Tæniopteris sp.

Tæniopteris sp., Salfeld, Gesell. Erdkunde Leipzig, Bd. 7, p. 213, pl. 3, fig. 3, 1911.

This appears to be correctly referred to Tæniopteris although it might represent the impression of the lower surface of a Nilsonia frond. No Peruvian material, aside from this fragment from Huallanco, Department Huanuco,, is known.

Genus RUFFORDIA SEWARD

Ruffordia Gœpperti (Dunker) Seward[8]

Ruffordia Gœpperti Zeiller, Revue Gén. Bot., tome 25 bis, p. 7, pl. 20, fig. 2, 1914.

Apparently correctly determined material from Piñonate represent this widespread and wide ranging Lower Cretaceous type.

---

[8] For discussion and synonymy see Berry, E. W., Maryland Geological Survey, Lower Cretaceous, p. 31, pl. 23, figs. 3, 4, 1911.

Genus FILICITES Schlotheim

Filicites ellensis Salfeld

Filicites (Alethopteris?) ellensis Salfeld, Gesell. Erdkunde Leipzig, Bd. 7, p. 214, pl. 3, figs. 1, 2, 1911.

It is impossible from either the description or figures of this form to get any idea of its relationship. It came from Huallanca in the Department of Huanuco, and probably represents Cladophlebis or Matonidium.

Genus CLADOPHLEBIS Brongniart

Cladophlebis sp. Salfeld

Cladophlebis sp. cf. *Coniopteris arguta* L & H Salfeld, Gesell. Erdkunde Leipzig, Bd. 7, p. 214, pl. 3, fig. 4, 1911.

This fragment, which Salfeld compared with Coniopteris, does not appear to possess decisive characters, at least these cannot be made out from the published account or figure. Material was from Huallanca, Dept. Huanuco.

Salfeld also recorded two *Sphenopteris* sp. one of which he compared with Coniopteris and the other with Cladophlebis. Since neither are described or figured they are best ignored.

Genus SPHENOPTERIS Brongniart

Sphenopteris Berthoni Zeiller

Sphenopteris Berthoni Zeiller, Revue Gén. Bot., tome 25 bis, p. 5, pl. 20, figs. 1, 1a, 1914.

This form is fully described and figured by Zeiller, but its precise botanical position is uncertain. Although depreciating the use of the Paleozoic form-genus Sphenopteris for entirely unrelated Mesozoic ferns, no better disposition can be made of it. It came from Caleta del Paraiso on the Island of San Lorenzo, but is not contained in my collections from that locality. It is somewhat suggestive of the genus Acrostichopteris Fontaine, which is a common element in the Potomac group of the eastern United States.

Genus WEICHSELIA Stiehler

Weichselia peruviana (Neumann) Zeiller

PLATE I, PLATE II—Figs. 1, 2

Weichselia mantelli Bravo (non Brongniart) Bol. Cuerpo Ing. d. Minas, No. 35, pp. 109-110, 1906.

Equisetites peruanus Neumann, Neues Jahrb. Beil. Bd. 24, p. 78, pl. 2, figs. 1, 2, 1907.

Weichselia Mantelli Neumann (non Brongniart), Idem., p. 74, pl. 1, figs. 1a, b.

Pecopteris weichselia Lukis, Bol. Cuerpo Ing. d. Minas, No. 64, plate facing page 18, 1908.

Weichselia reticulata Zeiller, Compt. Rendus, tome 150, p. 1488, 1910.

Weichselia (?) cf. *Mantelli* Salfeld, Gesell. Erdkunde Leipzig, Bd. 7, p. 214, 1911.

Weichselia peruviana Zeiller, Revue Gén. Bot. tome 25 bis, p. 10, figs. D, D2, Empl. 21, figs. 2-13, 1914.

? *Weichselia mantelli* Schlagintweit, Centralb. Min. Geol. & Pal. Nos. 19-20, pp. 315-319, 1919.

This species has been rather fully described by Zeiller (op. cit.) and it would seem that the characters disclosed are sufficient to warrant its specific segregation from *Weichselia reticulata,* or *mantelli* as many prefer to call it.

These features have been observed only in the material from near Lima but in view of the great abundance of Weichselia at many localities in Peru all of which appear to be of approximately the same age, the probability is all in favor of these occurrences representing a single species, and I have treated them as such in the accompanying citations of synonymy and occurrences.

Material collected by me from Piñonate and San Lorenzo is in form of impressions and the venation is seldom clear.

Material from Jatunhuasi has the very thick pinnules preserved and when these break away from the shale the venation is very distinct on the impressions of the under side of the pinnules. The veins aside from mid-vein are thin but the pinnule substance is arched in areolæ, giving impressions the appearance of inordinately stout veins.

The reflexed basal pinnules figured by Zeiller in material from Piñonate were observed in several specimens from San Lorenzo where the impressions are of the upper side of the frond. Where the opposite surface is preserved the rachis entirely obscures this arrangement. From the large amount of material from Peru that I have seen it seems probable that this reflexion of the basal pinnules of the ultimate pinnæ is a constant feature.

The pinnæ in the South American form are not inclined to the rachis and if the venation of a pinnule from Bernissart, Belgium figured by Seward actually depicts the course of the veins, it is considerably different from what obtains in *Weichselia peruviana.* There is also considerable difference of opinion regarding the specific identity of the European material referred to *Weichselia reticulata,* both Nathorst and Gothan differing from Seward in his treatment of this form.

There is also some difference of opinion as to the botanical position and habit of Weichselia. Bommer considers the pinnæ to have been palmate which is not borne out by the South American material. Gothan suggested a dune habitat, I suspect because of the frequent occurrence of the European form in sandstones. The South American species is excessively abundant and is almost invariably found in shales and these are often in a non-sandy region where there is no lithologic evidence of dune structures, or any probability that dunes had ever been present.

Weichselia reticulata has been recorded in Europe and Asia from a number of horizons ranging in age from the Purbeckian to the Senonian, and is not, as at present understood, any more characteristic of Neocomian time than it is of Barremian or Aptian time.

The genus is curiously absent from the Mesozoic floras of North America, only one occurrence, namely in the Black Hills, being known, and it is by no means certain that these scraps from the Fuson formation of eastern Wyoming really represent this species. It may be suggested that the *Gleichenia* (?) *Gilbert-Thompsoni* Fontaine[9] from the Knoxville beds of California may represent Weichselia.

Bommer concluded[10] from his study of *Weichselia reticulata* from Bernissart that the primary pinnæ where digitate from the top of a common stipe. He says that the structure of the petiole and stem, the mode of division of the frond and what is known of the synangia, offer analogies with the existing Matoniaceæ and Marattiaceæ. Zeiller although agreeing in general with Bommer's conclusions gives evidence that is fairly conclusive that in the Peruvian species the fronds were tripinnate. More recently Florin[11] has studied specimens of *Weichselia reticulata* preserved in the Paleobotanical section of the Stockholm Museum. He describes the stomata which indicate xerophytic conditions and are more like those of gymnosperms than those of ferns although they are not unlike those of the existing fern genus Niphobolus Kaulfuss a tropical member of the Polypodiaceæ abundant in the Indo-Malayan but also represented in South America.

The last author makes some comparisons with Thinnfeldia and concludes that the question as to whether Weichselia is a fern, pteridosperm or cycadophyte cannot be definitely settled until we have more complete information regarding the fructifications. There is certainly nothing in the superficial appearance of the sori of *Weichselia peruviana* to suggest that the plant is not a true fern.

Occurrence in Peru—Jatunhuasi and Vilca near Moya in the Department Junin; Conocpata in the Department of An-

---

[9] Fontaine, W. M., Mon. U. S. Geol. Surv., vol. 48, p. 232, pl. 66, fig. 11, 1905.

[10] Bommer, C., Bull. Soc. Roy. Bot. Belg., tome 47, pp. 296-304, pl. 1, 1910.

[11] Florin, R., Svensk. Botanisk Tidsskrift, Bd. 13, hft. 3-4, pp. 305-312, figs. 1-5, 1919.

cash; Trujillo and Huayday in the Department of Libertad; Huallanca in the Department of Huanuco; Caleta del Paraiso, Island of San Lorenzo, Piñonate and Lima, in the Department of Lima.

Family SCHIZÆACEÆ

Genus KLUKIA Raciborski

Klukia Zeilleri sp. nov.

Cladophlebis (*Klukia*) cf. *Browniana* (Dunker) Zeiller, Revue Gén. Bot. tome 25 bis, p. 7, figs. A, B, C, pl. 21, fig. 1, 1914.

This form, which came from Piñonate, Department of Lima, is admirably described by Zeiller. The character of the sporangia, with complete apical annulus, stamp this form as a member of the family Schizæaceæ.

Various authors have argued from the unfortunate association of these fertile specimens from Peru with the name *Cladophlebis Browniana* that this large Mesozoic genus should be referred to that family, when all it proves is that the genus Cladophlebis is a composite one. What is identified as *Cladophlebis Browniana* from the Potomac group of the eastern United States[12] has entirely different fertile pinnules and suggests its reference to the family Polypodiaceæ. In neither case can it be absolutely proved that these forms are the same as the European material referred to that species.

The proper course, it seems to me, in connection with this Peruvian form, is to refer it to the genus Klukia in accordance with Zeiller's researches and I have renamed it as a slight token of esteem to the memory of that eminent paleobotanist.

It may be noted that Klukia is distinctly a Jurassic type.

---

[12] Berry, E. W., Maryland Geological Survey, Lower Cretaceous, p. 243, pl. 29, figs. 1, 2, 1911.

CYCADOPHYTA

Genus OTOZAMITES Braun

[in Münster, Beitr. Petrefact. hft. 6, p. 36, 1843]

This form genus, proposed by Braun in 1843, was diagnosed in the following terms: Leaves pinnate, pinnæ alternate and approximate, auriculate, and attached by a portion of the base; veins radiating from the point of attachment to the margins of the segments.

Its proposer included in it *Odontopteris falcata* Sternberg, *Filicites Bucklandi* var *Brittanica* of Brongniart and *Zamites brevifolius,* the first two being forms which Morris in 1841 had assigned to the genus Ptilophyllum. Brongniart (Tableau p. 61) adopted Braun's genus and pointed out that it corresponded to Otopteris Lindley & Hutton.

There was at that time much difference of opinion as to whether these forms were cycads or ferns and even as recently as 1895 Seward deems it necessary to remark (Jurassic Fl. pt. 2, p. 59) that we know very little regarding the exact botanical position of the genus. If by this is meant that its exact relations to other frond genera of the Mesozoic cycadophytes is not definitely determined, the statement is undoubtedly true. No competent student would at the present time deny that it was a cycadophyte.

The question of the auriculate base something not seen in recent cycads is one that is not always easy to determine in forms with such thick stipes and overlapping pinnæ preserved as impressions, except in cases where the preservation is unusually good. Brongniart suggested Sphenozamites for forms of the same general type as Otozamites but lacking auricules, and this genus has been rather generally adopted. Bornemann published an amplified and amended diagnosis of Otozamites in 1856 in which he emphasized the distal auricles which are exaggerated in some species, his definition demanding the attachment of the pinnæ near their proximal basal border, a variable and untenable category.

Schenk who discussed some of these forms at length was at first disposed to consider them as ferns, as did also Brongniart, but subsequently referred them to the Cycadaceæ. Schimper at first adopted Otopteris but subsequently substituted Otozamites. Saporta also discusses the genus at length and more recently Seward has given an excellent account of it.

As at present understood it may be defined as follows: Fronds pinnate, elongate. Pinnæ varying in form from long narrow linear lanceolate to elliptical or nearly orbicular. Stipe stout, bearing the pinnæ on its upper (ventral) margin. Pinnæ not attached by the whole base, more or less auriculate varying from rounded basal margins to conspicuously auriculate, the distal lobe frequently much more prominent than the proximal lobe and always more or less overlapping on the stipe. Pinnæ may be closely spaced, imbricated or more or less remote. The area of attachment is more or less broad and several bundles enter from the stipe, these fork in the basal portion of the pinna and diverge in a flabellate manner terminating in the distal margins. As a rule branching is not obvious although it is sometimes present higher up in the pinnæ. The veins are numerous thin and closely spaced; their arrangement varies greatly with the form of the pinnæ. In long narrow forms like *Otozamites Neumanni* they are practically parallel with one another and the lateral margins and unbranched, scarcely if at all distinguishable from some forms of Zamites, whereas in short, elliptical, auriculate pinnæ, especially when the area of attachment is restricted, they are conspicuously flabellate.

As will be realized from the foregoing the generic limits are difficult to define and still more difficult to apply in practice. There is a natural amount of variation within the different species so that the specific limits are also often difficult to establish, particularly when dealing with poorly preserved or fragmentary material.

Zigno long ago (1885) figured an Italian Jurassic Otozamites in close association with a Williamsonia fructification and Wieland has brought to light many similar associations so that one is perhaps justified in referring the genus to the order Williamsoniales. The structure of the epidermis was partially described by Schenk[13] and more fully by Thomas and Bancroft.[14] The epidermal cells have sinuous walls and the stomata, which appear to be confined to the lower surface of the pinnæ, have guard cells with hemispherical or fusiform thickened patches like those of some Zamites pinnæ. In *Otozamites Feistmanteli* Zigno, Thomas and Bancroft found about 100 stomata per square millimeter which formed almost continuous rows between the veins.

In describing material it is important to discriminate between the upper and under surface of the frond which may show considerable differences due to the size of the midrib and the position of the pinnæ, and the latter also show considerable variation in form and orientation according as they represent basal, medial or apical portions of the frond.

Many species have been referred to Otozamites and this type is very abundant from the late Triassic through the Jurassic and sparingly in the early Lower Cretaceous.

Otozamites is very poorly represented in North America and chiefly in rocks of older Mesozoic age. Thus four species have been recorded from the Triassic, two from the Lower, one from the Middle and one from the Upper Jurassic. None are known from the Lower Cretaceous of North America even from beds such as the Knoxville and the Morrison which at times have been considered Jurassic. The genus is not represented in the older Potomac formations of the East Coast in the assemblage which contains very many Wealden and Neocomian ferns, cycads and conifers. Sim-

---

[13] Schenk, A., Würzb. Naturwiss. Zeits. Bd. 6, p. 10, pl. 34, fig. 7, 1867.

[14] Thomas, H. H., and Bancroft, N., Trans. Linn. Soc., vol. 8, pt 5, p. 186, pl. 19, figs. 3, 4, 1913.

ilarly the genus is absent from the Lower Cretaceous of Portugal. Arber (1917) comments on absence of Otozamites from Neocomian flora of New Zealand although he records Ptilophyllum which is of doubtful generic distinctness. Ptilophyllum has also been recorded from Patagonia by Halle (1913, p. 34, pl. 3, f. 1-12) in association with Marchantites, Nathorstia, Gleichenites, Cladophlebis, Ruffordia, etc., from Upper Jurassic or Lower Cretaceous.

Kuntz in 1901 recorded 4 species of Otozamites from the Lias of Piedra Pintada, northern Patagonia: Wieland in 1916 describes 17 species of Otozamites from Lias of southern Mexico: and Halle in 1913 recorded 4 forms from Graham Land.

Otozamites peruvianus Salfeld

PLATE III

Otozamites Goeppertianus Neumann (non Dunker), Neues Jahrb. Beil. Bd. 24, p. 82, pl. 2, fig. 3, 1907.

Zamites (*Otozamites?*) *peruanus* Salfeld, Gesell. Erdkunde Leipzig, Bd. 7, p. 215, pl. 3, fig. 5, 1911.

Glossozamites Hauthali Salfeld, Idem., fig. 6.

Otozamites Neumanni Zeiller, Revue Gén. Bot. tome 25 bis, p. 19, pl. 20, figs. 3, 4, 1914.

Pinnate fronds of apparently large size, the longest fragment collected measuring 27 cm. in length and 15 cm. in width and showing no approach to either end. Simple pinnate. Coriaceous in texture. Stipe stout, about 6 mm. in diameter in the laminar region. Pinnæ alternate relatively narrow and elongate, linear lanceolate, the tips narrowed curved upward slightly, the wider ones roundly pointed, attached to the upper margin of the stipe by about half their width, the distal side of the base wider than the proximal and slightly auriculate, the latter rounded. Veins thin and close, immersed in the leaf substance, parallel except at the base. The pinnæ form angles of about 70° with the stipe, they are slightly sigmoid curving outward and then upward, the larger are 8 cm. in length by 11 mm. in maximum width, the smaller are 6.5 cm. in length by 6 mm. in maximum width: they are closely spaced but do not overlap: they do not decrease regularly in width from below upward, although they are prevailingly wide toward the base of specimen and narrower higher up. In the specimen figured the base appears to represent the medium portion of a frond and shows well the variation in width of the pinnæ.

I found this species to be rather abundant at Caleta Paraiso on San Lorenzo Island and succeeded in collecting more complete material than had hitherto been found. The species was first noted by Neumann who identified it as *Otozamites Gœppertianus* (Dunker)[15] a common form in the Neocomian of England and Germany and one which has been referred successively to the genera Pterophyllum, Zamites and Dioonites. Zeiller in his admirable[16] account of the plants collected on San Lorenzo by Capt. Berthon pointed out the distinctness of the Peruvian form which had also been noted by Salfeld in discussing the flora of Huallanca.

The specimen which Salfeld figures from Huallanca and renames *Glossozamites* (?) *Hauthali* is much less like what Neumann identified as *Otozamites gœppertianus* than is the form which Salfeld described as the new species *Otozamites peruanus.* Both are, I believe fragments of the same species, and I have adopted the last as the proper name for this species, after changing the spelling to the proper form.

This species is very abundant at Caleta de Paraiso and I have several fine specimens of various sizes. It is also found at Huallanca and Huayday.

Otozamites Zeilleri sp. nov.

PLATE II—Fig. 3

Description.—Fronds simple pinnate, elongate, the fairly complete material indicating a length of about 30 cm. ex-

---

[15] Seward, A. C., Wealden Flora, pt. 2, p. 70, pl. 1, figs. 1, 2, 1895.

[16] Loc. cit.

clusive of petiole, and a maximum width of 5.5 cm. Stipe stout, somewhat curved. Pinnæ coriaceous, alternate, relatively short and broad, elliptical in general form, somewhat unsymmetrical, with broadly rounded tips and slightly auriculate base which overlaps the upper side of the stipe and renders the exact area of attachment obscure. The pinnæ are slightly ascending diverging from the stipe at wide but slightly varying angles. The margins are entire, full and evenly rounded and the proximal margins are usually fuller and more rounded and the distal margins straighter although these characters are not constant. The pinnæ vary in size from a length of 2.75 cm. and a maximum width of 1.4 cm. in the median region of the frond to a length of 1.5 cm. and a maximum width of 8.5 mm. in the lower part of the frond. They are closely placed and their margins usually overlap slightly. The veins are thin, numerous, close set and immersed; they diverge from the area of attachment and doubtless fork in the basal region but throughout most of their length to the margins they are straight and approximately parallel.

This species is very close to the Wealden species *Otozamites Klipsteinii* (Dunker) Seward[17] in its general aspect but is smaller and the pinnæ are shorter and more ovate. It is still more like the incomplete form from the Jurassic of Oregon described by Fontaine as *Otozamites oregonensis*[18] and may be identical with that imperfectly known species. It is something like *Otozamites obtusus* (*ooliticus* Seward)[19] but has larger relatively wider and less auriculate pinnæ. Other similar forms are *Otozamites beani* (Lindley & Hut-

---

[17] Seward, A. C., Wealden Fl. pt. 2, p. 60, pl. 1, figs. 3, 4; pl. 7, 1895.

[18] Fontaine, W. M., Mon. U. S. Geol. Surv., vol. 48, p. 150, pl. 38, figs. 13, 14, 1905.

[19] Seward, A. C., Jurassic Fl. pt. 1, p. 218, pl. 1, fig. 1; pl. 2, fig. 2, 1900.

ton) and *Otozamites molianus* Zigno,[20] as well as other widespread and abundant Jurassic types, all of which serve to strengthen the impression that this South American occurrence is Jurassic rather than Lower Cretaceous.

Zamiostrobus crassus (L & H) Gœppert?

Zamiostrobus crassus Neumann, Neues Jahrb. Beil. Bd. 24, p. 83, pl. 2, fig. 5, 1907.

This object may represent a part of a cycadophyte cone but it does not appear to me to be identical with the European Wealden form with which Neumann identified it and probably represents a fragment of a large branch of a Brachyphyllum. The material came from San Lorenzo Island.

Genus CYCADOLEPIS Saporta

Cycadolepis sp.

Rhynchogoniopsis neocomiensis Neumann, Neues Jahrb. Beil. Bd. 24, p. 86, pl. 1, fig. 3, 1907.

This supposed fruit from San Lorenzo Island which Neumann made the basis of a new carpological genus is contained in my collections and is nothing other than a cycadophyte conescale.

Cycadolepis Bonnieri Zeiller

Zamiostrobus aff *index* Saporta, Neumann, Neues Jahrb. Beil. Bd. 24, p. 84, pl. 2, fig. 4, 1907.

Cycadolepis (?) *Bonnieri* Zeiller Revue Gén. Bot. tome 25 bis, p. 22, fig. G, pl. 20, fig. 5, 1914.

This form from San Lorenzo Island is fully discussed by Zeiller and undoubtedly represents, as my own material shows, cone scales of some cycadophyte, the markings on the scales corresponding in my material to what appears to be the areas of attachment of pollen sacs.

---

[20] Zigno, A., Fl. foss. form. Oolith., vol. 2, p. 92, pl. 35, figs. 1-3; pl. 36, figs. 1-5, 1885.

Podozamites sp. Zeiller

Podozamites sp., Zeiller, Revue Gén. Bot. tome 25 bis, p. 19, fig. F, 1914.

What appears to be a pinnule of Podozamites and one readily associated with the widespread *Podozamites lanceolatus* L. & H. is present on San Lorenzo Island and at Piñonate. It is doubtfully represented at Jatunhuasi, Dept. Junin.

Genus THUITES Sternberg

Thuites leptocladoides sp. nov.

PLATE II—Figs. 5, 6

Pagiophyllum sp. cf. *cirinicum* var *uncinatum* Salfeld, Gesell. Erdkunde Leipzig, Bd. 7, p. 217, 1911.

Based upon a slender twig with short stout bluntly pointed falcate leaves, broadly united to the axis and slightly decurrent, opposite, and arranged in two cycles. The twig is about 3 mm. in diameter and the leaves are about 2 mm. long and approximately circular in cross section.

The material is altogether inadequate for a proper description but the form and arrangement of the leaves is so characteristic that additional material should be readily recognizable. The type comes from Jatunhuasi in the Department of Junin.

The form from Huallanca, Dept. Huanuco which Salfeld listed as *Pagiophyllum* cf. *cirinicum* var *unicinatum* Saporta is neither described nor figured but from the comparison suggested it is probably an occurrence of this species of Thuites since it is often not easy to distinguish between a cyclic and spiral phyllotaxy and Pagiophyllum often looks superficially much like Thuites.

This form is exceedingly close to *Thuites leptocladus* described by Saporta[21] from the Upper Jurassic of Portugal and were it not for the remoteness of the two occurrences I would be inclined to consider them identical. I have perpet-

---

[21] Saporta, G. de., Fl. Foss. Port. p. 55, pl. 5, figs. 12-16, 1894.

uated this resemblance in the specific name chosen for the Peruvian form. There is also considerable resemblance to *Thuites meriani* Heer[22] of the Kome beds of Greenland.

The genus Thuites was proposed by Sternberg in 1823 and six species ranging in age from Jurassic to Tertiary were enumerated at that time. The type was *Thuites cupressiformis* Sternberg from the Jurassic of Scania—a not very characteristic form which has also been referred to Caulerpites. Thuites has been widely used for vegetative twigs, particularly those from the Mesozoic, which agree in habit with those of Thuja and other genera of the Cupressinaceæ. Seward[23] made the proposal that the term Thuites be restricted to those specimens with a demonstratable close affinity with the existing Thuja, thus limiting it to a few Tertiary species, and proposed the form-genus Cupressinocladus for sterile vegetative shoots with the general habit of branching and the cyclic more or less appressed leaves of the recent Cupressinaceæ.

It would be most desirable to distinguish in our classification between ascertained and possible relationships but it seems to me that the author fools nobody but himself in trying to go beyond the facts and as a form genus Thuites means something which every student understands and which is neither more or less than Cupressinocladus means. Professor Seward has confessedly little use for taxonomic codes or the so-called laws of priority, and although I fully sympathize with this point of view it is purely a matter of expediency and does not harmonize very well with the rather numerous ill advised terms which this author has seen fit to propose entirely ignoring the fact that a name is after all merely a name and not a description or tag of relationship.

---

[22] Heer, O., Fl. Foss. Arct. Bd. 3, ab. 2, p. 73, pl. 16, figs. 17, 18, 1873.

[23] Seward, A. C., Fossil Plants, vol. 4, pp. 303, 305, 1919.

Genus BRACHYPHYLLUM Brongniart

Brachyphyllum Pompeckji Salfeld

Brachyphyllum Pompeckji Salfeld, Gesell. Erdkunde Leipzig, Bd. 7, p. 216, pl. 4, fig. 5, 1911.

Widdringtonia or *Moriconia* Lukis, Bol. Ing. d. Minas del Peru, No. 64, plate facing page 18, 1908.

The genus Brachyphyllum aside from certain indefinite forms of late Paleozoic age extends throughout the Mesozoic. The form from Peru which Salfeld referred to this species is not entirely typical if one may judge from his figure, having keeled pointed and imbricated leaves. It is more like the genus Echinostrobus of Schimper, but as this is not always clearly distinguishable from Brachyphyllum the present species may stand as named by Salfeld. It comes from the coal measures of Huallanca, Department of Huanuco and according to Salfeld is represented by the specimen from Huayday, Department of Libertad, figured by Lukis.

Antholithus sp. Zeiller

Antholithus sp., Zeiller, Revue Gén. Bot. tome 25 bis, p. 24, fig. H, 1914.

An incomplete fragment, interpreted as part of an inflorescence possibly of a Williamsonia, is recorded from Piñonate.

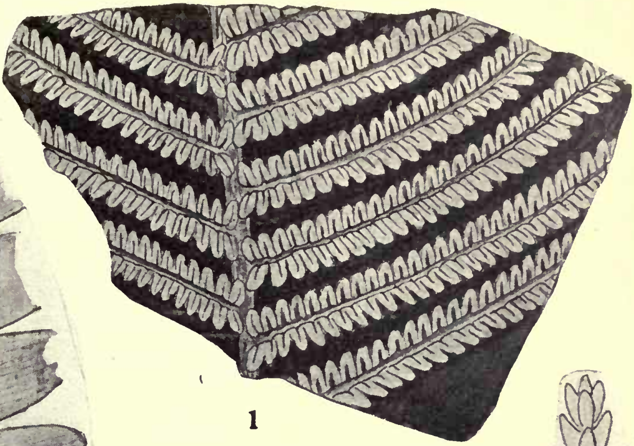
PLATE I

Weichselia peruviana (Neumann) Zeiller from San Lorenzo, ¾ nat. size. Under side of frond.

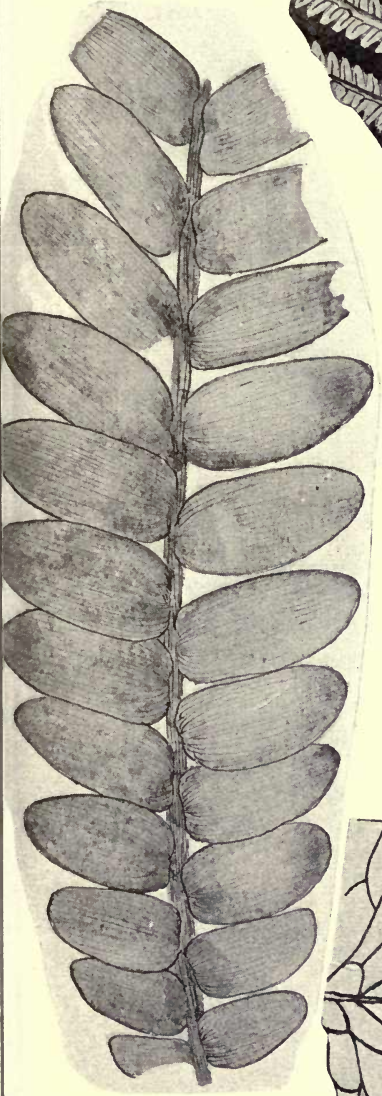
UNIV. OF
CALIFORNIA

PLATE II

Figs. 1, 2. Weichselia peruviana (Neumann) Zeiller.
  Fig. 1. Upper side of frond showing reflexed basal pinnules.
  Fig. 2. Pinnule showing venation, X 14.
Fig. 3. Otozamites Zeilleri Berry.
Fig. 4. Equisetites sp.
Figs. 5, 6. Thuites leptocladoides Berry. Fig. 6 enlarged 3 times.



1

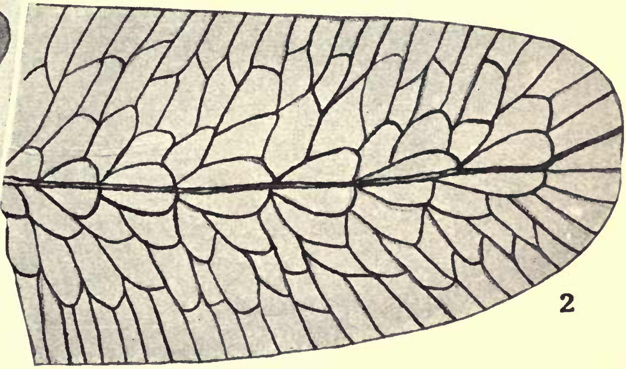


3

4

5

6

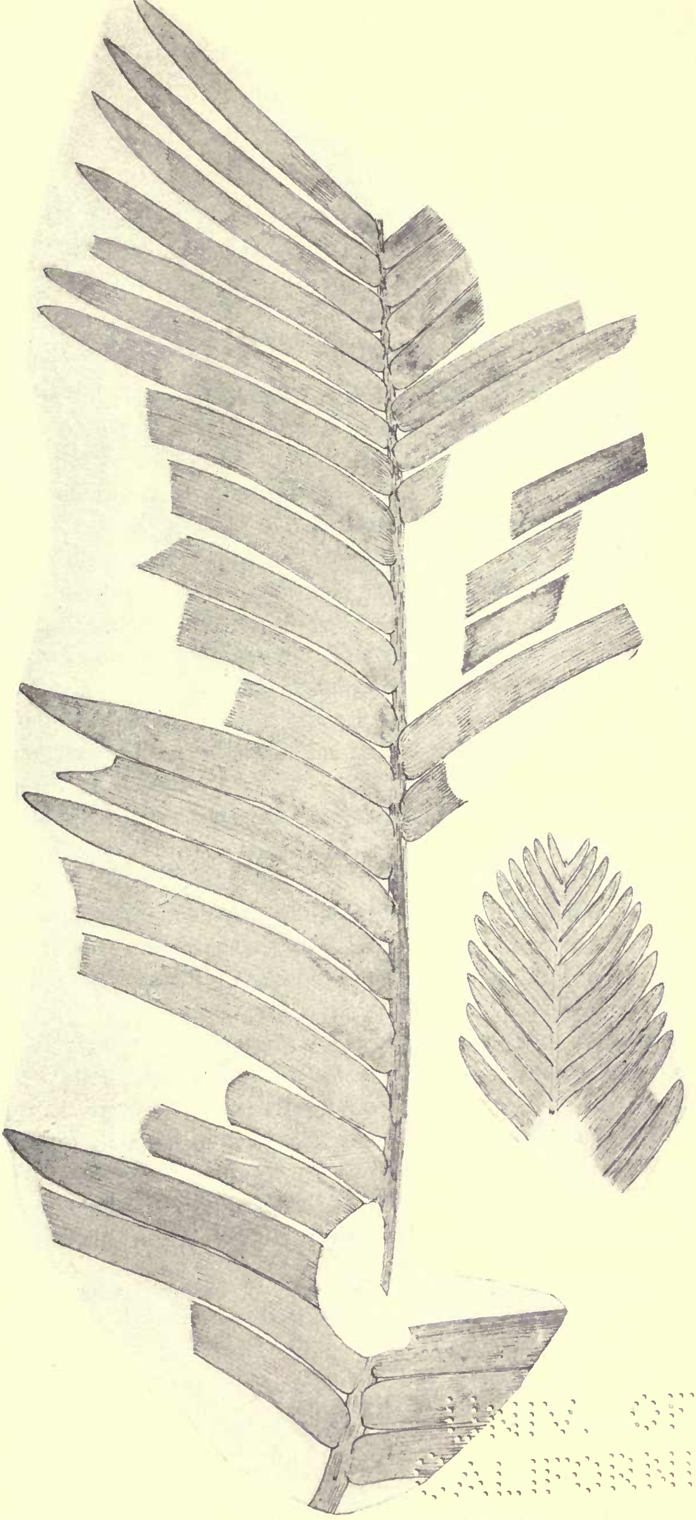


2

UNIV. OF CALIFORNIA

PLATE III

Otozamites peruvianus Salfeld, 8/11 nat. size.



UNIV. OF
CALIFORNIA

THE FLORA OF THE CONCEPCION—ARAUCO COAL MEASURES OF CHILE *

By Edward W. Berry

Introduction

The only steam coal on or near tidewater along the western coast of the Pacific south of Puget Sound in the State of Washington is in the region around Coronel Bay a short distance south of Concepcion, Chile. Mining in the latter region is therefore an old and exceedingly profitable industry, although it is not so important a factor in maritime trade as it was when the main lanes of travel were around the southern end of South America, as they were before the Panama Canal was opened. The former importance of Coronel as a port is perhaps conclusively shown by the fact that drinks demanded by the officers and sailors of all maritime races can still be mixed at the bar of the small but excellent hotel in that city.

Detailed geological information of the region has accumulated very slowly. General observations go back to the date of Darwin's voyage, and Pissis as early as 1873 published a geological map of the whole of Chile, which naturally is very much generalized. d'Orbigny, Darwin, Marcou, and more recently Nogués,[1] supposed that the ammonite bearing Upper Cretaceous of this region passed into the Tertiary without a break. Even Philippi, who recognized the Upper Cretaceous of Quiriquina Island, lists (1887) 13 species common to the Cretaceous and Tertiary. The credit for showing the unconformity between Cretaceous and Tertiary and the description of the Cretaceous faunas belongs to Steinmann.[2] Doubtless the old and erroneous tradition is responsible for such correlations as DeLapparent's prob-

---

* George Huntington Williams Memorial Publication No. 17.

[1] Nogués, A., Bol. Insp. Jeografiá i Minas 1907, p. 121.

[2] Steinmann, G., Neues Jahrb. Beil. Bd. 10, p. 1, 1895.

ably Sparnacian age of the Coals, and Russell's statement[3] that they are to be correlated with the Chico-Tejon beds of California, a similar mistake that we owe originally to Gabb.

Within the last decade much detailed and reliable information upon this, as well as other regions in Chile, has been published by Dr. J. Brüggen, Professor in the University at Santiago and geologist to the Ministry of Industries and Public Works.[4] There is much information still lacking because of lack of detailed geologic work and the secretiveness of some of the native coal companies. One is especially anxious to know the exact position of the coals of Concepcion and Arauco with relation to the lignites farther south between Temuco and Puerto Montt, on the Island Chiloe and at Punta Arenas on the Straits of Magellan. I am convinced that the coals of Concepcion and Arauco are different in age from the lignites of Punta Arenas, but until the age of the latter is conclusively determined the larger questions of former plant distribution and Antarctic relations cannot be settled.

The sole previous contributor to the paleobotany of the district is Hermann Engelhardt who in an elaborate paper published in 1891 and a shorter one in 1905, described over 100 species of fossil plants, chiefly from Lota and Coronel.[5] He emphasizes the resemblance of the fossil flora to the existing flora of eastern Peru, Brazil and the Antilles, and is inclined to consider it insular, pre Miocene and pre Andean.

---

[3] Russell, A., Trans. Inst. of Mining Engineers, vol. 38, pp. 29-82, 1909.

[4] Brüggen, J., Bol. Soc. Nacional de Minería, ser. 3, vol. 25, pp. 6-29, 49-84, 1913. (Also published separately.)

Idem., pp. 459-512. (Also published separately.)

Brüggen, J., La Formacion de los Carbones de Piedra i especialmente de los Chilenos. 39 pp. Santiago, 1916.

[5] Engelhardt, H., Abh. Senck. Naturf. Gesell., Bd. 16, pp. 629-692, pl. 1-14, 1891: Abh. Naturw. Gesell. Isis in Dresden, 1905, pp. 69-82, pl. 1.

The great bulk of the species recorded from this region as noted above have been identified by Engelhardt. He deserves great credit for the vast amount of recent material which he evidently consulted in reaching his identifications, which, except for a tendency to multiply species, are usually to be relied upon. His descriptions are brief and he does not fully discuss the comparative relations of the forms, nor is any very satisfactory attempt made to formulate the conclusions which may be legitimately deduced from such a study, and which are the real results that make paleontological science really worth while.

For this reason it has seemed profitable to assemble this flora in one paper and discuss its bearing upon botanical and geological history as fully as the facts warrant, even though my own collections add few new species to the flora. I had hoped before visiting the region that it would be possible to make detailed studies of the stratigraphic position of the invertebrates and florules associated with the different coal seams, but I found that such an investigation to yield the desired facts would have to be continued over months if not years.

Such a study must wait until it can be solved by local scientists. Eventually no doubt the coal companies will realize the necessity of employing geologists as well as mining engineers. Meanwhile there are the admirable geological studies of Brüggen for this district, already mentioned, which constitute a basis for future more detailed work. It may well be doubted if the seams of the different collieries can ever be satisfactorily correlated except by paleontological and especially paleobotanical methods, and even this method may fail since in some places the coals lack underclays and roofing shales and are hence without identifiable plants, as was particularly the case at Colico.

I have had the advantage of personally collecting the material and studying its relations to the marine fossiliferous horizons. I have also visited the three main botanic provinces of Chile, namely the northern coastal and interior deserts, the sclerophyllous woodlands of central Chile and the southern rain forests, as well as the coastal, mountain, interior valley and plateau, and montaña regions of Peru and Bolivia. I have also seen something of the tropical rain forest in Panama and the Antilles and on the eastern slopes of the Andes, and collected or studied fossil plants from all of these regions, having approached the subject after fifteen years study of the fossil floras of the Cretaceous and Tertiary of the States bordering the Gulf of Mexico.

This wearisome summary is not given from any motive of egoism, but in an effort to justify and fortify the conclusions that I have drawn from this exceedingly interesting Miocene flora in southern Chile.

PRESENT CLIMATE AND FLORA OF CHILE

The combination of exceedingly high mountains overhanging a meridianal coast, crossing the zone of trade winds and extending southward to the "roaring forties" gives the whole West Coast of South America a seemingly anomalous climate. Chile is no exception to the other West Coast countries in this respect. Its ribbon-like form extending from 17° to 56° South Latitude and its mainland width nowhere exceeding 228, and in places narrowing to less than 50 miles, renders it unique among the countries of the world. Physiographically Chile may be divided into three meridianal regions—the Andes, the Longitudinal Valley, continued northward as the nitrate pampas and submerged south of Puerto Montt, and the Coast Range.

Climatically it may be roughly considered as comprising: (1) the Coastal desert which extends from the ocean to the crest of the Andes and from the Peruvian boundary to Coquimbo: (2) the agricultural region extending from Coquimbo to Llanquihue: and (3) the rain forest region extending from about latitude 41° southward.

The desert region includes spurs and irregular lateral ranges enclosing saline plateaus near the main range, the plateaus sloping gradually seaward and partially bounded along the coast by the low coast range from which the descent beneath the waters of the Pacific is rapid.

This region is rainless and consequently barren and without vegetation except in the region of melted snow of *los Andes* and in some small river valleys where irrigation is possible. At Coquimbo the mean annual temperature is 59.2° F. and the rainfall 1½ inches. Central Chile, or the region from Coquimbo to Llanquihue, shows but a slight lowering of temperature and a gradual increase in rainfall as one proceeds southward. Hence it constitutes a rich agricultural country and supports a varied vegetation. Most of the peculiar genera of temperate South American plants belong to this province.

Southern Chile not only exhibits a striking contrast to the northern desert region but an almost equally sharp contrast to the corresponding latitudes in Argentina on the other side of the Andes, resulting from the combination of prevailingly westerly winds and high mountains. In the absence of the latter the climate of both would be similar.

South of the Rio Bio Bio the rain forest flora gradually replaces that of the central region. Its most prominent elements are the Chilean pine (*Araucaria imbricata*) and the evergreen beech (*Nothofagus*).

Peculiar elements are the Alerce (*Fitzroya*), the Chiloé and Chilean cypress (*Libocedrus* and the winters bark (*Drimys*)—all relics of earlier geological periods.[6]

The only meteorological records for the region from which the fossil plants come are in the admirable series published

---

[6] Neger, F. W., Die Vegetations verhaltnisse im nördlichen Araucarien (Flussgebiet des Rio Bio Bio) Engler's Jahrbücher, Bd. 23, 1896.

Skottsberg, C. V., Die Vegetations verhaltnisse langs der Cordillera de los Andes S. von 41° S. Br.: Ein Beitrag zur Kenntnis der Vegetation in Chiloe, West-Patagonien, den Andinen, Patagonien und Feuerland. Bot. Ergeb. Schwed. Exped. nach Patagonien und dem Feuerlande 1907-1909. 366 pp. Stockholm, 1916.

by the *Instituto Central Meterológico y Geofísico de Chile* for Concepcion (Lat. 36° 50′ Long. 73° 03′). Concepcion is situated within the coal field, and leaf bearing sandstones outcrop within the city limits, but the only recognizable plant collected at this locality was a species of *Sabalites*. The determinable plant remains all come from slightly farther south. For the years 1912 to 1915 inclusive the mean annual temperature at Concepcion averaged 56.25° F., the absolute maximum was in March, 1912, when the thermometer reached 98.25° F., and the absolute minimum was in July of the same year when it sank to 28.4° F.

There is no snowfall, but much rain. During these years the fewest number of days with rain was 89 in 1912 and the greatest was 135 in 1914. The annual rainfall during this period averaged 54.4 inches, but showed considerable annual variation, from 44 inches in 1912 to 66.9 inches in 1914. The winds are almost exclusively from the north, south and west.

It is very obvious that the fossil flora recorded from the coal measures could not exist under the existing climatic conditions—the fact that the present flora of the region contains no elements common to the fossil flora is an ample demonstration of this conclusion. The rainfall is ample and extremes of cold are rare, but the prevailing cloudiness inhibits sufficient sunshine, the summer temperatures are not high enough, and the growing season is too short.

GEOLOGY OF THE REGION

Nogués[7] in 1907 divided the sedimentary formations of the Concepcion-Arauco region into three groups—the Quilacoya, Arauco and Malleco groups. The first he considered Cretaceous, the second Cretaceous to Eocene and comparable with the so-called Laramie and the Chico-Tejon of western North America, and the third Upper Miocene.

---

[7] Nogués, A., La formacion lignitífera del sur de Chile, 1895.

These are the divisions quoted by Russel in his account of the Coal fields of Chile (op. cit.). As Brüggen points out these divisions have little if any basis in fact. Machado[8] in 1912 adopts much the same divisions which he calls the Quiriquiniano, Lautariano (Lota, Coronel) and Lebusiano (Arauco) stages.

The oldest known rocks in the region are highly metamorphosed sedimentaries now altered to mica schists, sericite and biotite gneiss, phyllites, grauwackes, etc. These are of the greatest interest since at various places in the Bio Bio valley they contain black schists, arkosic quartzites and anthracitic streaks, of considerable thickness. Between Talcamávida, Gomero and Buenoraqui these contain fossil plants. From this region Brüggen has recorded[9] *Cladophlebis, Tæniopteris, Sagenopteris, Zamites, Williamsonia, Ginkgo* and *Equisetites*. These determinations are sufficiently reliable to prove that their age is either Jurassic or Lower Cretaceous and this raises the question if the similar metamorphic rocks of the Coast Range in other regions may not be as young as Jurassic or Lower Cretaceous instead of being very old, as they have frequently been considered.

The intrusive rocks are andesitic and granodiorites, and they are, in part at least, more recent. Following these older Mesozoic rocks after a considerable interval of time had elapsed, possibly representing the whole of the Lower Cretaceous and the earlier part of the Upper Cretaceous, are a series of conglomerates and highly fossiliferous sandstones of Senonian age. The most recent studies of this fauna, which has been found on Quiriquina Island, at San Vicente, Lirquen and Colico, are by Steinmann[10] and Wilckens.[11] Brüg-

---

[8] Machado, M. R., El carbon de Chile i su distribucion jeográfica. Bol. del Museo Nacional de Chile IV, 1912.

[9] Brüggen, J., Bol. Soc. Nacional de Minería, 3d ser. vol. 25, pp. 19-20, 1913.

[10] Steinmann, G., Neues Jahrb. Beil. Bd. 10, pp. 1-106, 1895.

[11] Wilckens, O., Idem., Beil. Bd. 18, pp. 181-284, 1904.

gen has recorded plant remains associated with *Inoceramus* in a clay lens in the upper part of the Upper Cretaceous near Colico, but I did not succeed in locating this outcrop. The succeeding Tertiary is everywhere unconformable upon the Upper Cretaceous or older rocks. It consists of a basal conglomerate of varying thickness overlain by a thick and highly variable series of shales and sandstones with coal seams, and some marine intercalations below the coal carrying species of *Fusus, Turritella, Nucula, Lutraria*, etc. The coal free portion varies from 146 to 325 feet in thickness and is overlain by from 300 to 750 feet of shales, sandstones and grits with several seams of workable coals. These vary in thickness and appear to be at very discordant levels in the various mines. The more important have received names and most mines work an "Alta" seam but this is probably not the same seam in the different mines. In fact one gets the impression that the coal seams of workable size are not continuous but much restricted in areal extent. The sandstones are prevailingly greenish in tint and crossbedding is frequent. This is borne out to a certain extent by drill cores examined at Colico where a short distance from the present mine the drill had penetrated 1,100 feet of essentially uniform grits without encountering either shales, coal, or marine fossils. A good idea of the detailed variations of the Tertiary section for comparison with the above can be obtained from the Coronel section described in 1870 by Lebour and Mundle.[12]

A fauna of the same general facies as that below the coals, but more abundant, is found in intercalated lenses through a considerable thickness in the superior non coal bearing part of the section. This fauna, comprising species of *Nucula, Mytilus, Solen, Tellina, Limopsis, Glycimeris, Panopea, Venus, Pinna, Dentalium, Oliva, Cassis, Natica, Fusus, Cancellaria, Bulla*, etc., is in the main the so-called Navidad fauna that has been recorded from numerous localities along the Chilean coast. It is clearly Miocene in age but in its entirety

---

[12] Lebour and Mundle, Geol. Mag. dec. I, vol. 7, pp. 499-509, 1870.

is undoubtedly mixed with forms from other horizons. The supposed Pliocene marine faunas are found north of Arauco. They are distinctly modern Pacific in facies and have been correlated with the Coquimbo-Caldera beds described by Steinmann and Möricke, which occur farther northward along the Chilean coast.

Their present position might be taken as indicative that they are older than the late Pliocene Cape Fairweather beds of Patagonia which have been involved in the Andean uplift, in which case they are properly called Pliocene. I have no opinion to offer, but am inclined to doubt that they are so old, because in northern Peru the basis for marine Pliocene seems to me to rest entirely upon mixed collections of Miocene and Pleistocene fossils.

The coal measures are much faulted and the dips are discordant and in the present state of our knowledge do not disclose any major structural units.

THE FOSSIL FLORA

The present collections, as previously mentioned, are not extensive. Much of the plant bearing material is in a sandstone which does not preserve details. The shales, although containing an abundance of leaf impressions are very brittle and slack a great deal—this was notably the case at the Puchoco mine. Another obstacle to the securing of good material is that the two most extensive workings, namely those at Lota and Coronel, now dump their waste directly into the Pacific, so that this rich collecting ground is not available. If there were anyone on the ground on the lookout for good material as in the case of the German engineers that obtained the collection studied by Engelhardt, very extensive and excellent collections could be made, as the measures are in place crowded with plants.

The present collection includes the following species arranged by localities:

Arauco Mine, Curanilahue
Anona coronelensis Engelhardt
Cassia gardneri Berry
Cassia oxleyi Berry
Cyathoides thyrsopterioides Berry
Lecythis nereifolia Engelhardt
Phœbe elliptica Engelhardt
Thouinia philippii Engelhardt
Zamia tertiaria Engelhardt

Rios Mine, Curanilahue
Araucaria araucoensis Berry
Myrcia reticulato-venosa Engelhardt
Sequoia chilensis Engelhardt

Puchoco Mine near Coronel
Cassia longifolia Engelhardt
Hoffmannia protogæa Engelhardt
Sequoia chilensis Engelhardt

Concepcion
Sabalites ochseniusi (Engelhardt)

Lota
Anona speciosa Engelhardt
Araucaria araucoensis Berry
Cassia longifolia Engelhardt
Coussarea membranacea Engelhardt
Cyathoides thyrsopterioides Berry
Gœppertia engelhardti Engelhardt
Gœppertia ovalifolia Engelhardt
Laurophyllum actinodaphnoides Engelhardt
Mallotus (?) platanoides Engelhardt
Myrcia reticulato-venosa Engelhardt
Nectandra chilana Berry
Thouinia philippii Engelhardt
Triumfetta miocenica Berry
Sapindus acuminatus Engelhardt
Sequoia chilensis Engelhardt

Before discussing the character of the flora I give in this place a revised systematic list of the known species:

Algæ
Chondrites subsimplex Lesq. (?)

Pteridophyta—Filicales
    Blechnum antediluvianum Engelhardt
    Cyathoides thyrsopterioides Berry
    Pteris Cousiniona Engelhardt
    Pecopteris Buhsei Engelh. (cf. Gleichenia)
    Adiantites Borgoniana Engelhardt

Gymnospermæ—Cycadaceæ
    Zamia tertiaria Engelhardt

  Gnetaceæ (?)
    Ephedra sp. (doubtful)

  Coniferæ
    Sequoia chilensis Engelhardt
    Araucaria araucoensis Berry

Monocotyledonæ—Arecaceæ
    Sabal Ochseniusi Engelhardt
    Iriartites sp., Berry

Dicotyledonæ—Piperales—Piperaceæ
    Artanthe geniculatoides Engelhardt

  Urticales—Moraceæ
    Coussapoa ? quinquenervis Engelhardt

  Santales—Loranthaceæ
    Psittacanthus crassifolius Engelhardt
    Antidaphne ? lotensis Engelhardt

  Ranales—Anonaceæ
    Anona coronelensis Engelhardt
      Myristicaceæ
    Myristica ? fossilis Engelhardt

  Rosales—Cæsalpiniaceæ
    Cassia longifolia Engelhardt
    Cassia gardneri Berry
    Cassia oxleyi Berry

  Rosales—Papilionaceæ
    Desmodium obliquim Engelhardt
    Copaifera reticulata Engelhardt
    Leguminosites erythrinoides Engelhardt
    Leguminosites copaiferæoides Engelhardt

  Geraniales—Erythroxylaceæ
    Erythroxylon Reichei Engelhardt
      Rutaceæ
    Zanthoxylon inæquabile Engelhardt
        tenuifolium Engelhardt

Ticorea fœtidoides Engelhardt
Pilocarpus Saavedrai Engelhardt
Erythrochiton grandifolium Engelhardt
    Meliaceæ
Moschoxylon falcatum Engelhardt
        tenuinerve Engelhardt
    Vochysiaceæ
Vochysia dura Engelhardt
    Euphorbiaceæ
Omphales ficiformis Engelhardt
Tetraplandra longifolia Engelhardt
Aleurites (?) platanoides Engelhardt

Sapindales—Ilicaceæ

Ilex subtilinervis Engelhardt
    Celastraceæ
Maytenus araucensis Engelhardt
        magnoliæfolia Engelhardt
    Sapindaceæ
Sapindus acuminatus Engelhardt
Thouinia Philippii Engelhardt

Malvales—Tiliaceæ

Triumfetta irregulariterserrata Engelhardt
Triumfetta miocenica Berry
    Bombacaceæ
Empedoclea repando—serrata Engelhardt
Bombax firmifolium Engelhardt (?)
Bombaciphyllum opacum Engelhardt (?)

Parietales—Dilleniaceæ

Doliocarpus oblongifolia Engelhardt
        (?) serrulata Engelhardt
Tetracera elliptica Engelhardt
        rhamnoides Engelhardt
    Ochnaceæ
Ouratea (Gomphia) firmifolia Engelhardt
Flacourtiaceæ
Patrisia eocenica Engelhardt
Casearia oliganthoides Engelhardt
        spinulosa—serrata Engelhardt
        piparoides Engelhardt
Banara Cuadræ Engelhardt
Lætia transversinervis Engelhardt

Thymeleales—Lauraceæ
- Persea macrophylloides Engelhardt
  - microphylla Engelhardt
- Phœbe lanceolata Engelhardt
  - elliptica Engelhardt
- Acrodiclidium oligocænicum Engelhardt
- Gœppertia ovalifolia Engelhardt
  - spectabilis Engelhardt
  - Engelhardti Berry
- Camphoromoea speciosa Engelhardt
- Ampelodaphne grandifolia Engelhardt
- Mespilodaphne longifolia Engelhardt
- Laurophyllum actinodaphnoides Engelhardt
- Nectandra chilana Berry

Myrtales—Combretaceæ
- Combretum oblongifolium Engelhardt

Lecythidaceæ
- Lecythis neriifolia Engelhardt

Myrtaceæ
- Psidium membranaceum Engelhardt
- Myrcia deltoidea Engelhardt
  - nitens Engelhardt
  - reticulato—venosa Engelhardt
  - costatoides Engelhardt
- Myrciaria acuminata Engelhardt
- Myrciophyllum ambiguaeoides Engelhardt

Primulales—Myrsinaceæ
- Ardisia crassifolia Engelhardt

Ebenales—Styracaceæ
- Styrax coriacea Engelhardt
  - glabratoides Engelhardt

Gentianales—Apocynaceæ
- Thevetia angustifolia Engelhardt
- Allemanda crassostipitata Engelhardt
- Hæmadictyon tenuifolium Engelhardt
- Apocynophyllum chilense Engelhardt

Polemoniales—Boraginaceæ
- Cordia pulchra Engelhardt

Bignoniaceæ
- Tecoma serrata Engelhardt
- Bignonia gigantifolia Engelhardt

Rubiales—Rubiaceæ
- Coussarea membranacea Engelhardt
- Psychotria grandifolia Engelhardt
- Gouatteria tenuinervis Engelhardt
- Hoffmannia protogæa Engelhardt
- Sabicea (?) elliptica Engelhardt

Incerate sedis
- Phyllites coccolobæfolia Engelhardt cf. Coccoloba fagifolia Jacq.
- Phyllites aspidospermæoides Engelhardt cf. Aspidosperma tomentosa Mart.
- Phyllites alsodeiæoides Engelhardt cf. Alsodeia macrocarpa Aubl.
- Phyllites triplarioides Engelhardt cf. Triplaris americana Aubl.
- Phyllites saураujæoides Engelhardt cf. Saurauja montaña Seeman
- Phyllites repandus Engelhardt
- Phyllites acutoserratus Engelhardt
- Phyllites ternstrœmiæoides Engelhardt cf. Ternstrœmia dentata Sw.
- Phyllites banisteriæoides Engelhardt cf. Banisteria blanchetiana Juss.
- Carpolites cycæformis Engelhardt
- Carpolites guilielmæoides Engelhardt

ANALYSIS OF THE FLORA

The supposed alga, *Chondrites subsimplex* Lesquereux, which Engelhardt records may be at once dismissed as worthless. It is not the same as the object described by Lesquereux and is not algal in nature, but merely a fragment of a stem of some unknown plant.

The ferns comprise the following 5 forms:

Gleicheniaceæ (?)
- Gleichenia (?) buhsei (Engelhardt) Berry

Cyatheaceæ
- Cyathoides thyrsopterioides Berry

Polypodiaceæ
- Blechnum antediluvianum Engelhardt
- Pteris cousiniona Engelhardt
- Adiantites borgoniana Engelhardt

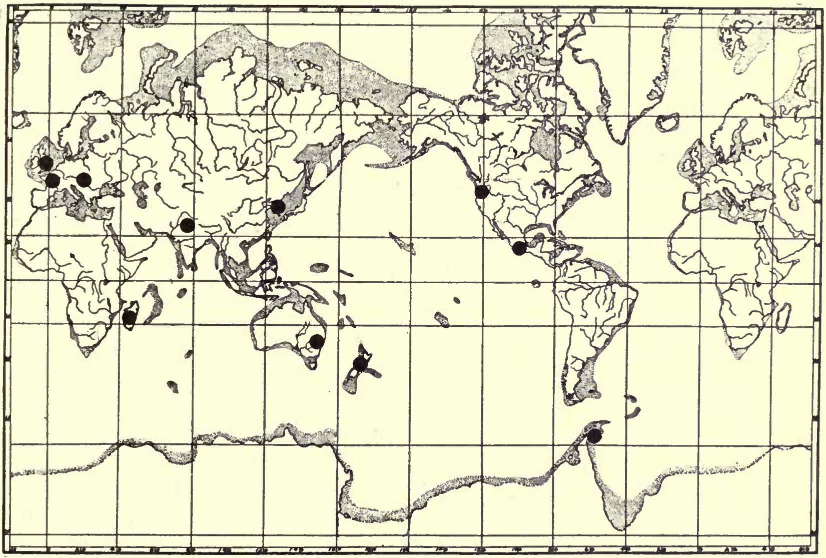


Fig. 1. Jurassic occurrences of Araucaria.

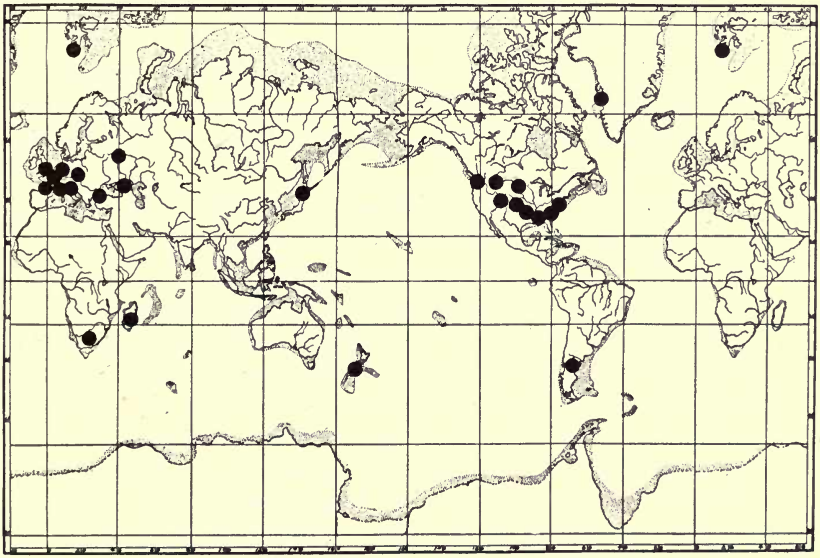


Fig. 2. Cretaceous occurrences of Araucaria.

They are of exceeding interest but are unfortunately represented by a scanty amount of material, that of the Pteris being the most extensive and satisfactory. The Gleichenia (referred to Pecopteris by Engelhardt) is represented by a single specimen which fails to show the dichotomous habit and is to that extent inconclusive. The pinnæ are Gleichenoid but the veins are simple and possibly may be more properly referable to the Cyatheaceæ.

The Cyathoides presents remarkable similarities to the monotypic Thyrsopteris of the Juan Fernandez islands. The family includes the existing tree ferns of South America which are particularly prominent in the rain forests of the montaña country from Bolivia northward. The Blechnum has been compared with the existing *Blechnum longifolium* H.B.K., which ranges from the Antilles and Central America in the rain forest country to the Amazon basin, and the montaña of eastern Peru. There are a large number of existing, mostly tropical, species, and the genus is well represented and confined in South America to the same general region as *Blechnum longifolium.*

The Adiantites is represented by rather dubious material that suggests the existing *Adiantum macrophyllum* Sow., which ranges from Central America to eastern Peru and Brazil.

The Pteris is well preserved and very similar to the existing *Pteris grandifolia* Linné, with a range simliar to the preceding.

Cycads are not common fossils in Tertiary deposits anywhere and it is therefore important to verify Englehardt's reference of a scrap to the genus *Zamia* by the discovery of abundant and well preserved material at Curanilahue. Zamia is the dominant existing cycad genus of the Western Hemisphere with upwards of two score species ranging from peninsular Florida and Mexico to Brazil and Bolivia. It is probably not related to the older fossil forms of the genus Zamites, but evidently had a more extensive range in the

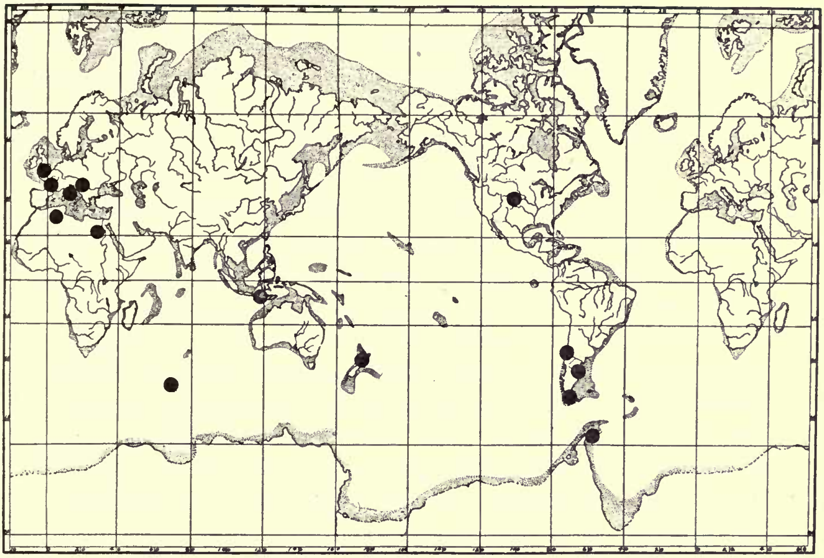


Fig. 3. Tertiary occurrences of Araucaria.

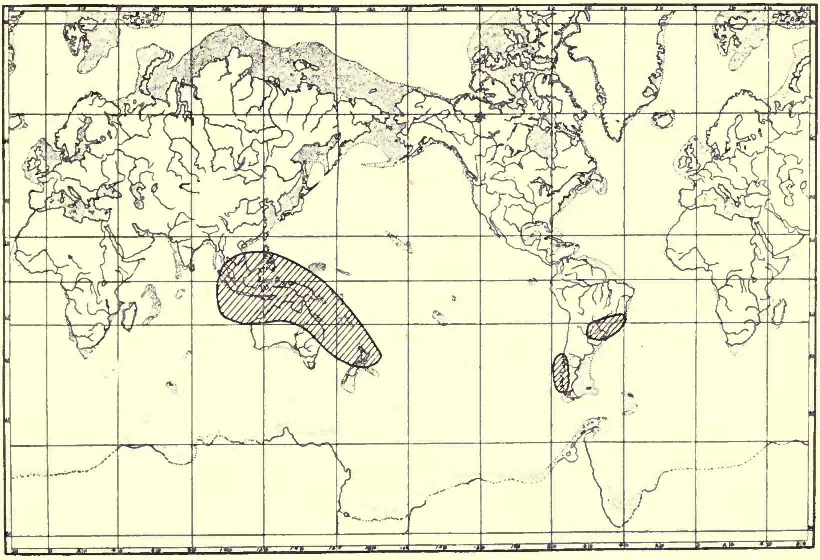


Fig. 4. Recent area of distribution of Araucaria.

Tertiary than at present since it is found in the Eocene of the Mississippi embayment as far north of its existing range as this Chilean occurrence is south of it.

The fragment which Engelhardt refers to the Gnetalean genus Ephedra and compares with the existing *Ephedra americana* H. B. and *Ephedra triandra* Tul. is altogether doubtful and I cannot regard it as proving the occurrence of this genus in the Chilean fossil flora.

The two species of Coniferales recorded, namely *Sequoia chilensis* and *Araucaria araucœnsis* are conclusive representatives of the genera Sequoia and Araucaria and it would be spectacular to find forms, which in the existing flora are separated by 75° of latitude, associated in southern Chile, were it not for the fact that both genera are today represented by what might be termed living fossils—the circumscribed descendants of once cosmopolitan types. I was disposed to consider the Sequoia as probably a Taxodium until I had seen the actual specimens. I found it abundant at Coronel, Lota and Curanilahue and satisfied myself that it was a Sequoia, which thus represents the farthest known southern occurrences of authentic specimens of that interesting genus.

The Araucaria is represented by abundant and conclusive material not greatly different from existing species. In trying to picture the ecology and affinities of this fossil flora both of these genera may be safely ignored since both represent relics of other and earlier days, survivals whose physiological requirements cannot be measured by comparisons such as can be instituted among the much younger dicotyledons of this flora. The geologic history of Sequoia has been summarized in previous publications[13] and need not be repeated in the present connection. The history of the Araucariales has also been discussed[14] and I have plotted the

---

[13] Berry, E. W., Pop. Sci. Monthly, vol. 67, pp. 465-474, 1905. Nat. Hist., vol. 20, pp. 152-155, 1920.

[14] Berry, E. W., Bull. Torrey Bot. Club, vol. 35, pp. 249-260, 1908.

records of Jurassic, Cretaceous and existing Araucariaceæ on the accompanying sketch maps which bring out clearly that Araucaria first becomes obvious in the geological record in late Jurassic times, became cosmopolitan during the Cretaceous, and more restricted in very recent times.

The described collections contains but a single monocotyledon—a fan palm described from Coronel and also found at Concepcion in a sandstone ledge beneath the Normal School. The University collection at Santiago, however, contains a magnificent specimen of a feather palm, presumably an Iriartites, from Curanilahue. Both of these are well to the southward of the existing southern limits of the Palm family. The statement is frequently made that palms extend to 37° South. I did not see any south of 34° and very sparingly in this latitude, although they are cultivated farther south. As Schimper appropriately remarks, however, it is a common error to suppose that palms are necessarily a prominent constituent of modern tropical rain forests in either the New or Old worlds.

The great bulk of the known fossil flora consists of dicotyledons. These represent about 100 species in about 65 genera, 39 families, and 24 orders. There are 15 species of Gamopetalæ as against about 85 Choripetalæ.

The following are the largest alliances:

Leguminosæ 7 spp., Rutaceæ 5 spp., Dillenaceæ 5 spp., Flacourtiaceæ 6 spp., Lauraceæ 14 spp., Myrtaceæ 7 spp., Apocynaceæ 4 spp., Rubiaceæ 5 spp., thus showing that the lower Miocene flora of South America was as distinctively South American in its facies as is the existing flora. The following genera are represented by two or more species: Anona, Cassia, Zanthoxylon, Moschoxylon, Maytenus, Bombax, Triumfetta, Doliocarpus, Tetracera, Casearea, Persea, Phœbe, Gœppertia, Myrcia and Styrax. The largest of these is Myrcia with 4 species.

The order Piperales and the family Piperaceæ is represented by a single species referred to Artanthe, a subgenus of Piper, often given generic rank. The material on which the fossil record was based is scanty and does not merit the attempt to identify it, much less to definitely assign it to Artanthe, although one would expect the Piperaceæ to be represented in this fossil flora. The present record does not, however, satisfy this expectation.

The Urticales, the first order of Dicotyledonæ to be considered, is represented by a single, somewhat doubtfully determined species which Engelhardt refers to Coussapoa and compares with the existing *Coussapoa asperifolia* Trécul of the Guayana region. The genus Coussapoa comprises about 15 existing species of Central and northern South America which have very characteristic leaves both as regards form and venation. The Chilean record is extremely inconclusive. Three fossil species rest upon more satisfactory evidence. These occur in the Miocene of the foothills of the Sierra de Merida in Venezuela, in the Miocene of southern Mexico, and in the Pliocene of the Sierra de Cochabamba in Bolivia.

Strangely enough, the genus Ficus, so abundantly represented in the existing flora of tropical South America, and present in most Tertiary floras, is apparently absent from the Chilean Miocene. I can scarcely account for this except by falling back on the imperfection of the geologic record and assuming that Ficus will eventually be discovered in this flora as a result of future exploration.

Other families which are absent and which one would expect to find represented are the Musaceæ, Sapotaceæ, Melastomataceæ, Malpighiaceæ, Trigoniaceæ and Anacardiaceæ, all of which are prominent at the present time in the South American tropics and many of which are already known in the few South American Tertiary floras that have been described.

The order Santalales is represented by the family Loranthaceæ with two species in the genera Psittacanthus and Antidaphne. The former which is similar to the existing

P. robustus Martius of Brazil, is not otherwise known in the fossil state. The genus contains about 50 existing species confined to the American tropics. The latter, a very doubtful determination, has been compared with the existing *A. viscoidea* Pœpp. which ranges from Costa Rica to Peru. The genus has few existing species which center in Colombia and eastern Peru.

The order Ranales is represented by two nominal species of Anona, which, if Engelhardt's figures are reliable, undoubtedly represent a single species of this genus. The fragment referred to Myristica is valueless as proof of the occurrence of that genus in Chile, but like so many paleobotanical records it is of geological importance since identical remains occur in the Ecuadorian Andes.

The family Anonaceæ is a large one in the modern flora with about two-thirds of its 750 existing species confined to the Old World. The family is evidently an old one despite the paucity of its geological record. The genus Anona with about 70 existing species, nearly all of which are confined to the American tropics, stands in close relationship to this ancient cosmopolitan type. That it originated in America appears reasonably certain from general considerations and from its presence in the Upper Cretaceous of North America. It is the one genus in the family fairly represented in the fossil record, with about a score of species. The Chilean forms have been compared with the existing *Anona montaña* Martius, *A. sphærica* Duch., and *A. furfuraceæ* St. Hil., all tropical forms of Brazil. The fossils are, however, equally close to various leaves of "chiromoya" observed in Peru and Bolivia, and one is warranted in saying that the "chiromoya" was a member of the Miocene flora of southern Chile.

The order Rosales is represented by 7 species all of which belong to the two leguminous families—the Cæsalpiniaceæ and Papilionaceæ. The family Mimosaceæ is unrepresented, in fact the number of leguminous forms known from this flora is surprisingly small and is, I believe, no indication of the actual living assemblage, but largely a result of the prevailing coarseness of the sediments. Muds deposited in quiet coastal waters like the lagoons along the lower Eocene coast of the Mississippi embayment are the materials in which great quantities and varieties of leguminous leaflets are preserved. An apt illustration of the influence of the matrix is obtained by comparing the synchronous fossiliferous beds at Corocoro and Potosi in Bolivia. The former are coarse and contain few recognizable species, the latter are fine grained and contain an astonishing variety of mostly small leguminous leaflets.

The family Cæsalpiniaceæ is represented in the fossil flora of Chile by the abundant pods of one species and the leaflets of two species of the large genus Cassia. The Papilionaceæ comprise species of Copaifera, Desmodium and two that are referred to the form-genus Leguminosites but are suggestive of Erythrina and Copaifera. The latter genus with about a score of existing species is mostly American but is sparingly represented in the African tropics. The nearest existing species to Chile are in the lower montaña country of Bolivia, but the genus is represented in the Pliocene deposits of that country at both Corocoro and Potosi.

The order Geraniales is rather well represented by the families Erthroxylaceæ, Rutaceæ, Meliaceæ, Vochysiaceæ and Euphorbiaceæ. The first by a single species of Erythroxylon from Curanilahue. The material is fragmentary but the venation appears to represent this genus, which has nearly one hundred existing species largely confined to the American tropics, but represented from tropical Africa through Asia to northern Australia. The fossil species closely simulates an existing Brazilian one.

The Rutaceæ is one of the large families in this flora with representatives of the four genera Zanthoxylon, Ticorea, Pilocarpus and Erythrochiton. The first with two species, which have been compared with the existing *Z. sprucei* Engler of eastern Peru and Brazil, and *Z. aromaticum* of Colombia and the Antilles, are types often referred to the allied genus Fagara. The genus Ticorea, a small existing genus of Guiana is represented by a species that is named in allusion to its resemblance to the existing *Ticorea fœtida* Aublet. The material referred to Pilocarpus is not extensive but shows characteristic venation features. The present species is close to the existing *Pilocarpus pauciflorus* of Brazil, and a second fossil species occurs in the Pliocene of Bolivia. The genus contains about 15 existing species of shrubs and small trees with even pinnate leaves confined to tropical South America and mainly Brazilian. So far as I know it does not occur in the montaña country of Peru and Bolivia at the present time, although it is found in the Pliocene of the latter country.

The genus Erythrochiton comprises a few existing species of small trees ranging from southern Mexico through eastern Peru and Bolivia to southern Brazil. The fossil species, which is represented by a small amount of characteristic material, is close to the existing *Erythrochiton brasiliense* Nees and Martius, which is a common form in eastern Bolivia.

The Meliaceæ is represented by two species of Moschoxylum, a genus sometimes made a subgenus of Trichilia, with about 60 existing species of the tropics of America and Africa, chiefly the former. The fossil species are compared with the existing *Moschyxlum swartzii* Jussieu and *M. hirtum* Sowerby of the Antilles and northern South America.

The family Vochysiaceæ is exclusively South American and tropical with slightly over 100 existing species. Engelhardt has referred a somewhat inconclusive form from Chile to Vochysia, comparing it with the existing *Vochysia elliptica* Martius. The genus has about 55 modern species of shrubs or trees with coriaceous leaves, and its center of occurrence is in the Amazon Valley.

The family Euphorbiaceæ is represented by three genera—each with a single species. The first *Omphalea ficiformis*

Engelhardt although much like the existing *Omphalea diandra* Linné of the region from the Antilles to Brazil and eastern Peru, is based upon material which is not conclusive. The genus comprises about a dozen tropical American species, mostly shrubby climbers. The second, *Tetraplandra longifolia* Engelhardt is represented by well characterized material similar to the modern Brazilian *Tetraplandra Leandri* Baillon. The genus, which is shrubby, contains only the last and one other existing Brazilian species. It is not at all certain that the fossil should not be referred to the allied genus Mabea Aublet, which it much resembles, and which contains about 16 existing species of trees and shrubby climbers of the Brazilian—Guiana region. The third species is referred by Engelhardt with a query to the oriental genus Mallotus and compared with the existing *Mallotus oreophilus* Müller, *paniculatus* Müller and *albus* Müller. That it does not represent a species of this genus is I think obvious. It is undoubtedly euphorbiaceous but finds its closest allies in certain existing South American tropical species of Aleurites, Jatropha and Manihot.

The order Sapindales contains five Chilean fossil species representing the families Ilicaceæ, Celastraceæ and Sapindaceæ. The first is referred to the genus Ilex and is of doubtful value. The second is represented by two nominal species of Maytenus neither of which is very convincing. The third is represented by what appears to be a correctly identified species of Sapindus, and a species of Thouinia close to the existing *Thouinia decandra* H & B of Central America. The latter genus contains about 15 existing species of shrubs and trees of the Central American region. The fossil material is abundant and well characterized and should probably be referred to the genus Allophylus Linné (Schmidelia Linné) which is common to all the tropics, with about half of the existing 100 species American.

The order Malvales is represented by two species of Tiliaceæ referred to the genus Triumfetta and three species of

Bombacaceæ referred to Bombax and Bombaciphyllum. The two species of Triumfetta are closely related and may represent the variants of a single botanical species with leaves like those of the existing *Triumfetta longicoma* St. Hil. of the Amazon basin. The modern genus, with numerous small forms, is found in both tropics, and the hypothesis is here advanced that these fossil forms should be referred to the form-genus Grewiopsis and the latter considered as ancestral to the modern species of Triumfetta, Grewia, etc.

Of the 3 species referred to the Bombacaceæ, *Bombax playense* Engelhardt appears to be correctly determined, and the other two are questionable. The first suggests the modern *Bombax glaucescens* Swartz of Brazil, and other South American forms. To the same species should probably be referred the Chilean fossil described by Engelhardt as *Empedoclea repando-serrata.* Leaves of this type are known from the Upper Cretaceous, and occur in the Tertiary of both Europe and North America, being variously referred to Bombax, Bombaciphyllum, Bombacites and Chorisia. They unquestionably represent this family which was found in the Mediterranean region of both the Old and New World during the older Tertiary, and from this stock the existing species have been derived.

The family Bombacaceæ consists of about 20 genera and 125 existing species, all tropical and the majority American. The genus Bombax has about 50 existing species, all large tropical trees and all American except a single African species, a second Australian and about half a dozen southern Asiatic forms, all of which are the living witnesses of the former range of the genus as outlined above.

The order Parietales is represented by the families Dilleniaceæ, Ochnaceæ, and Flacourtiaceæ. After removing the Empedoclea and referring it to Bombax, as suggested in a preceding paragraph, the Dilleniaceæ contains 4 fossil Chilean forms, two of which are referred to Doliocarpus and 2 to Tetracera. These all appear to be authentic identifications.

Doliocarpus has not otherwise been recorded as a fossil but leaves of this type present in the Eocene of the Southern United States have been referred to the form genus Dillenites. The latter are abundant and characteristic.

Doliocarpus has about 20 existing species confined to the South American tropics and mostly Brazilian. The allied genus Tetracera is probably descended from the same Dillenites stock. Tetracera contains numerous species of trees and lianas of all tropical lands, largely represented in the Amazon basin.

The family Ochnaceæ is represented by a single species of Ouratea similar to the Brazilian species *Ouratea multiflora* Pohl. The genus has about 120 existing species, 90 of which occur in the American tropics and the balance in the corresponding part of the Old World. The family is a small one of 17 genera and about 210 species, mostly trees. There are 125 species and 9 peculiar genera, three of which are monotypic, in the American tropics, and 82 species and 6 peculiar genera in the Oriental tropics. The genera Ouratea and Sauvagesia are common to both. The former is represented by distinct subgenera in the two regions and the latter comprises herbaceous or ericaceous like shrubs and probably is modern. The family evidently has a geological history, but is practically unrepresented in the known geological record.

The family Flacourtiaceæ is a rather large one in the modern flora with over 500 species in 70 or more genera, largely wanting in the known geological record. It has no living species in North America or Europe and is mainly tropical in its habitat, although not strictly so, and many species are montane forms. The family is represented by 6 species of the genera Banara, Patrisia, Casearia and Lætia in the Chilean fossil flora. The Banara is very similar to *Banara nitida* Spruce of eastern Peru and belongs to a genus with about 18 existing species ranging from the Antilles and Mexico to Bolivia and southern Brazil. The 3 species of Casearia are closely related to existing Brazilian forms. The genus is widely distributed and fully half of its 120 modern species are American and the majority are Brazilian.

The Patrisia represents a genus with about 10 existing species in the South American tropics, and the Lætia, which is close to the existing *Lætia coriacea* of Brazil and Guiana, represents a genus with about 10 modern species of the Antilles, Central America and northern South America. All of the genera except Banara belong to the largely American subfamily, the Casearieæ, which Warburg considers to have evolved from the Old World Flacourtieæ. This seems a very doubtful filiation to me.

It is a matter of some surprise that the family Ternstrœmiaceæ is unrepresented in the Chilean flora and in this connection it may be noted that of the 9 species of Phyllites described by Engelhardt *Phyllites ternstrœmæoides* is the only one that merits a more definite generic reference. It is very similar to the existing *Ternstrœmia dentata* Swartz of northern South America and very likely represents this otherwise unrepresented family.

The next order, the Thymeleales, is represented solely by the important family Lauraceæ, which many authors refer to the order Ranales. The Lauraceæ of the Chilean fossil flora comprise 9 genera and 14 species and it is hence by far the largest family present. This South American abundance is closely parallel in the modern distribution of the family. Thus Grisebach records but 28 Lauraceæ from the British West Indies, Hemsley but 36 for Mexico and Central America, whereas there are over 350 species in the Brazilian flora. The tribes Eusideroxyleæ, Apollonieæ, Laureæ and Cassytheæ are unrepresented in the present fossil flora and the tribe Litseæ only doubtfully by the form named *Laurophyllum actinodaphne,* which suggests the genus Actinodaphne.

The tribe Cinnamomeæ, which embraces fully half of the 1000 existing species of Lauraceæ, and which is found on all of the continents except Europe, but is chiefly South American and Asian, is also the largest in this fossil flora with 8 of the 14 recorded species of the family. Two are referred to Persea and are close to existing East Peruvian and Brazilian forms. Two are referred to Phœbe and are similarly close to forms of the Upper Amazon basin. Two are referred to Nectandra or Nectandrophyllum with similar relationships, one to Mespilodaphne and one to Camphoromœa, both related to existing Brazilian species. For the guidance of readers I may state that I recognize the genera Mespilodaphne and Camphoromœa, although some systematists, notably Pax, submerge them in the unnatural genus Ocotea Aublet.

The tribe Acrodiclidieæ, which is confined to Central and South America in the existing flora, except for the single genus Endiandra R. Brown with less than a score of forms ranging from the East Indies to Australia, is represented in the Chilean Tertiary by a species of Acrodiclidium close to an existing Brazilian form. The tribe Cryptocaryeæ, which occurs on all of the continents except Europe, is represented by 3 species of Gœppertia (referred to the genus Aydendron by Pax) and one of Ampelodaphne, all close to existing Brazilian species, in fact these two genera are confined to tropical America in the modern flora.

It is perhaps unnecessary to discuss the fossil records of the foregoing genera of Lauraceæ since they are largely obscured by the paleobotanical use of Laurus as a form-genus. Many go back to the late Cretaceous and others appear in the early Tertiary, and several were once cosmopolitan. The family appears to have been of northern origin and its range has recently been discussed by me in another place.[15]

---

[15] Berry, E. W., U. S. Geol. Surv. Prof. Paper 91, pp. 115-118, 1916.

The order Myrtales is an extensive one with about 335 genera and nearly 8,000 existing species segregated in 11 families—the bulk of the species belonging to the ancient families Myrtaceæ and Melastomataceæ. There are 3 families and 9 or 10 species in the Chilean fossil flora. The Combretaceæ is represented by extremely doubtful material referred to Combretum and so far as it goes comparable with the existing *Combretum laxum* Aublet of the Antilles, Central America and tropical South America.

The family Lecythidaceæ has a species of Lecythis close to the existing *Lecythis spruceana* Berg of the Amazon basin. The genus, which has about 40 existing species, belongs to the tribe Lecythidoideæ with 10 genera and about 185 existing species, all found exclusively in the South American tropics.

The large family Myrtaceæ, whose history I have discussed recently in another place [16] is represented by 7 species of which 1 is referred to Psidium, 4 to Myrcia, 1 to Myrciaria and 1 to Myrciophyllum. The modern species of Psidium number over 100 and range from the Antilles and Mexico to Uruguay. The fossil form is close to *Psidium polycarpon* Lamb which ranges from southern Mexico to Trinidad and Brazil. The three species of Myrcia are close to existing Brazilian species. The genus is very large with an extended geological history which goes back to the Upper Cretaceous, and it stands close to the ancestral stock of the family. It was apparently cosmopolitan in the earlier Tertiary and still contains upward of 450 species confined to the tropical American region.

The genus Myrciaria is very close to Myrcia and of doubtful distinction as a term applied to a fossil form. It contains about 60 existing species ranging from Antilles to Peru and Brazil. Were I describing these forms *de novo* I would refer both Myrciaria and Myrciophyllum to the genus Myrcia.

---

[16] Berry, E. W., Bot. Gaz., vol. 59, pp. 484-490, 1915.

The Gamopetalæ which furnish representatives of but 5 orders, have the three orders Gentianales, Polemoniales and Rubiales fairly well represented, whereas the two orders Primulales and Ebenales are scantily represented, although both are important in the existing flora of the American tropics.

The order Primulales, or Myrsinales as it should be called, since the Myrsinaceæ are much more ancient than the Primulaceæ, has but a single species of Ardisia in the Chilean flora. This is represented by incomplete material which as far as it goes is comparable to the leaves of the existing *Ardisia ambigua* Martius of the Amazon basin. The genus contains over 200 existing species and is found in both the oriental and occidental tropics, and as would be expected, about 20 fossil species are known from North America, Europe and Asia.

The Ebenales with 4 families and over 1,000 existing species has two species of Styrax of the family Styracaceæ in the Chilean flora, and no traces have been discovered of the families Sapotaceæ or Ebenaceæ—the two big families of the order, and both with a geological history going back to Upper Cretaceous times. This is especially strange in the case of the Sapotaceæ which should have been present in such an association as that found in the Chilean coal measures, and which is found fossil in the Tertiary of Bolivia as well as elsewhere in South America.

The fossil forms of Styrax are comparable with existing Brazilian species. The genus has about 60 existing species and a considerable number of fossil ones which serve to explain the otherwise inscrutable disconnected range of the modern forms.

The order Gentianales is represented by the single family Apocynaceæ with 4 species in as many genera. All have been compared with existing species of the Amazon basin, which they closely resemble. The genus Thevetia, with few species, is still confined to the region between Mexico and

Paraguay. The genus Allamanda with about a dozen species ranges from Central America to Brazil. The genus Hæmadictyon, or Prestonia to give it Robert Brown's name, has between 30 and 40 climbing species in the country between Mexico and Rio de Janeiro. The form referred to Apocynophyllum is compared with existing Brazilian species of Tabernamontana, a large modern genus found in both tropics. Apocynophyllum is a form-genus for members of this family whose generic affinity is not certainly established, and consequently a large number of fossil species are known.

The order Polemoniales is represented by a form referred to Cordia of the family Boraginaceæ and by species of Tecoma and Bignonia of the family Bignoniaceæ. Although the material is scanty in the case of the first of these I see no reason for questioning these determinations. Cordia is a large genus of shrubs or trees with upward of 250 existing species in the warmer regions of both hemispheres, more than half being American. It is present in the Upper Cretaceous and earlier Tertiary of southeastern North America, but is sparingly represented in the known geological record. It is still present in the montaña and elsewhere in eastern Bolivia.

Tecoma has 80 existing species in the region between New Jersey and Argentina, most of which are found in the tropical portion of this area. The genus is scarcely known fossil. The Chilean species is close to the wide ranging *Tecoma stans* Jussieu, which is abundant in eastern Bolivia. Tecoma is abundant in the lower valleys of the western Andes in central Peru and is thus one of the few genera of the Chilean flora that still persists west of the Cordillera, at least in the region south of Ecuador.

This, however, is without other meaning than that the peculiar climate from Tumbez southward to Coquimbo resulting from the uplift of the Andes has made this coastal strip uninhabitable for the normal flora of those latitudes.

Bignonia has few existing species, which occur in the area between the Antilles and Mexico and Argentina.

The sole family of the Rubiales present in this fossil flora is the Rubiaceæ, with 5 species referred to as many genera. Of these I regard the form referred to Sabicea as entirely unreliable. The others, although represented by a scanty amount of material, are exceedingly like the recent species with which they have been compared. The genus Coussarea embraces about 40 existing Brazilian species of shrubs or trees and the fossil is close to *Coussarea nodosa* Müller of Brazil. The genus is represented in eastern Bolivia.

The Chilean species referred to Psychotria and close to the existing *Psychotria grandis* Swartz of the American tropics, is notable in that indistinguishable remains occur in the lower Eocene coastal region of the southern United States and thus may indicate a considerable migration southward during the Eocene and Oligocene, although this lacks confirmatory evidence from the other members of the two fossil floras. The genus Psychotria is a large one with several hundred existing species in the tropics of America, Africa, Asia and the East Indies, thus indicating a considerable, even if unknown, geological history. Psychotria is common in eastern Bolivia and is especially prominent in the northern Santa Cruz Sierra.[17] The genus Hoffmannia with a score of existing species ranges from the Antilles and Central American to Brazil.

In addition to the determined species Engelhardt has recorded two forms of Carpolithus and 9 species of Phyllites, the specific names of the latter suggesting affinities with existing members of the families Polygonaceæ, Apocynaceæ, Violaceæ, Dilleniaceæ, Malpighiaceæ and Ternstrœmiaceæ. As previously mentioned these are all represented by scanty and imperfect material and I do not regard any but the last as worthy of record. The others may represent these

---

[17] Herzog, T., Engler's Jahrb., Bd. 44, p. 393, 1910.

families or they may equally well represent something else. Such material should generally be thrown away rather than described unless it is likely to possess stratigraphic value—it certainly possesses no botanical value.

Well preserved material from Coronel is identified by Engelhardt as a species of Bennetia S. F. Gray.[18] Bennetia, more properly Saussurea De Candolle, is a genus of herbaceous Compositæ with about 125 existing species, the vast majority of which are confined to Alpine situations in the Northern Hemisphere. So far as I know the genus does not occur in South America, nor is it likely to occur fossil either there or elsewhere. I regard the fossil as a slightly more prominently toothed leaf of *Thouinia philippii* Engelhardt.

Without taking the space to summarize the foregoing enumeration it is obvious that this fossil flora is a consistent unit, overwhelmingly American and subtropical in its facies, totally lacking any discordant or exotic members. This alone would serve to place it in the later rather than the earlier half of the Tertiary. Although found on the present Chilean coast it lacks any conclusive evidence that its original environment was coastal—it is certainly not a strand flora, but of a subtropical rain forest assemblage. The number of toothed leaves suggest upland but this is not borne out by the intercalated marine beds, unless the leaves came from the upland. The sediments are of a character, however, that render such a supposition hardly probable.

ENVIRONMENT INDICATED

It would be a tedious repetition or rephrasing of what has already been written in the section of this paper entitled Analysis of the Fossil Flora to comment at length on the most closely related existing forms, and the climate and environment that they indicate. There are, however, certain

---

[18] Abh. Senck. Naturf. Gesell., Bd. 16, Hft. 4, p. 655, pl. 12, fig. 3, 1891.

general considerations that demand formulation and certain qualifications that are often lost sight of in discussions of this sort.

The fossil flora contains no elements of the existing flora of Central Chile, but in every case its elements are represented by modern species of tropical South America east of the Andes, and in the main of forms dwelling in the Amazon basin, especially toward the Peruvian part of the basin, and extending southward into eastern Bolivia. Does this mean a tropical climate in southern Chile during the Miocene corresponding to that at present in eastern Peru or around the headwaters of the Rio Chapare in Bolivia, and what is a tropical climate? Naturalists use these terms in a qualitative rather than a quantitative sense, and generally very loosely. The statement that the climate of our own western early Tertiary or that of Alaska and West Greenland was tropical or subtropical is hackneyed and yet it is, I believe, far from the truth.

Although the Chilean fossil forms are most like those of the existing upper Amazon rain forests, there are wanting certain elements that would render such a deduction of past conditions conclusive. It is true many of these elements, such as epiphytes for example are not likely to take their share in the fossil record, but on the other hand it is scarcely realized to what an extent the flora of the tropics pushes into the temperate zone or up into the mountains where environments are favorable. Ficus and Cinnamomum may indicate tropical climate or they may indicate conditions not more tropical than the present climate of Georgia or Florida. Some tropical plants undoubtedly cannot exist except in torrid lowlands, but the vast majority of the forms belonging to so-called tropical genera that occur in fossil floras, belong to old and large genera with a very considerable range of adaptability. In the case of the Chilean fossils, although their immediate existing analogues are often lowland tropical forms, nearly all of these genera contain species that are not strictly confined to that environment.

The modern Amazon basin flora, for example, presses upward into the eastern Andes, where the limiting factors seem to be precipitation, and ultimately of course temperature, to a degree that is amazing when seen for the first time. The transition upward in the montaña zone is gradual, certain types drop out, the same as they do in tracing the montaña flora southward in Bolivia beyond the equatorial zone. The modern field botanist would not be misled, but the closet botanist, as well as the paleobotanist, would be, and it would be easily possible to collect scores of species in the Yungas of Bolivia at an altitude of 8,000 feet in latitude 20°, that would be pronounced lowland tropical.

Humboldt's classical zones of altitudinal vegetation may hold good in the Eucadorian Andes, although I much doubt it—they certainly do not hold in Peru or Bolivia where many so-called tropical forms reach altitudes of over 11,000 feet.

The montaña flora of eastern Peru and Bolivia continues southward to about 25° South, with the dropping out of some forms and reduction in the number of lianes and epiphytes, and this so-called tropical forest continues on southward with some modifications along the Andes into the Argentine provinces of Oran and Tucuman to between 27° and 28° South. The flora of the latter region, although different in many features, is the nearest geographical approach of a similar modern flora to the Chilean region.

This flora contains such types as Machærium, Myrsine, Chorisia, Nectandra, Cupania, Cedrela, Acacia, Eugenia, Terminalia, Schmidelia, Ruprechtia, Erythroxylon, Randia, Pisonia, Canavalia, Desmodium, Heteropteris, Serjania, etc. —the last four being lianes.

Ecologists will think of many limiting factors other than those of mean annual temperatures and rainfall, which are the two that seem most obvious, for example low maximum summer temperatures because of cloudiness may be an important

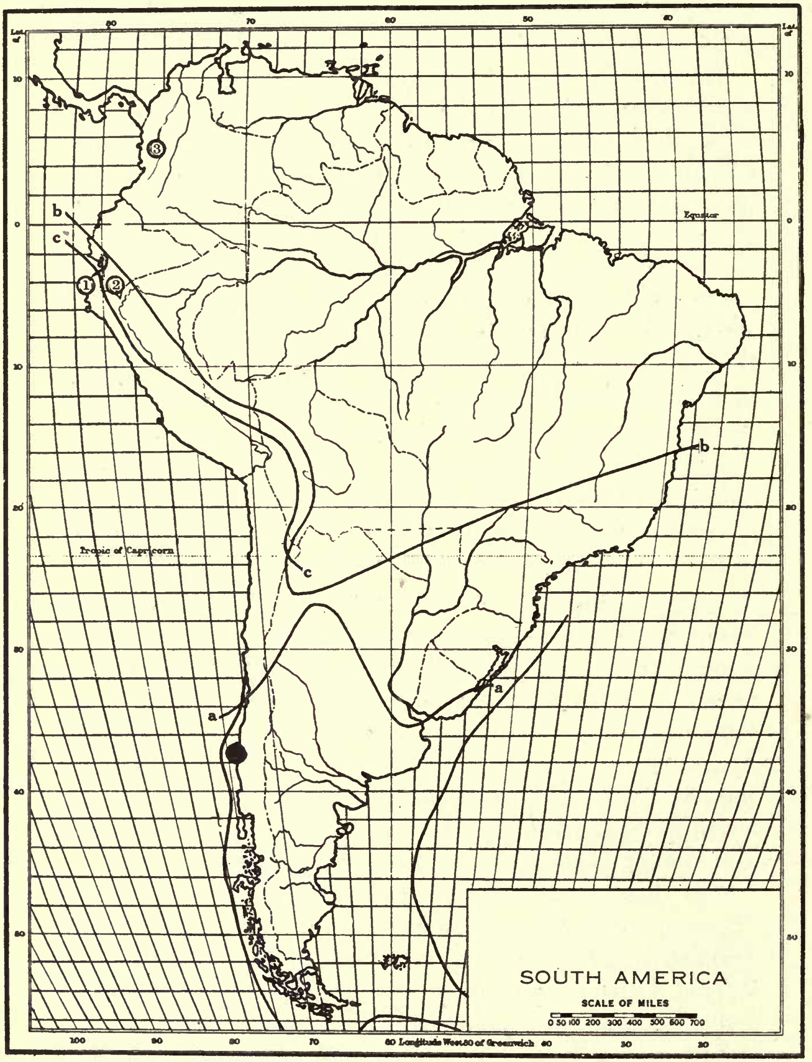


Fig. 5. Sketch map of South America showing the location of the Miocene coal fields of Chile (solid black circle), and the location of known fossil floras of approximately the same age.

1. near Tumbez, Peru.
2. Lota and Tablayacu, Ecuador.
3. Cauca Valley, Colombia.

a-a. Present southern limit of palms.

b-b. Approximate western and southern limits of Zamia, Iriartea, Bactris, Euterpe, Chamadorea and Triplaris.

c-c. Approximate western and southern limits of Podocarpus, tree ferns, Myricaceæ, Proteaceæ, Cunoniaceæ, Coriariaceæ, Melastomataceæ, Lauraceæ, Myrtaceæ, Guttiferæ, Sapotaceæ, etc.

The small scale of the map and the absence of detailed information over large areas renders these lines very inexact, but sufficient to bring out certain general relations, which is all that is intended.

The probable outline of the southern coasts if the present sea-bottom were raised to the 550 fathom line is shown. The major part of this submerged area is within the 100 fathom line.

factor, and recent experiments have shown that many plants will not seed under conditions of abnormally continued lighting. Again the amount of precipitation is within certain limits less important than its seasonal distribution. This is the main reason our own western prairies are treeless.

We may have in the equatorial zone every stage of transition from evergreen rain forest through monsoon forests, savanna, thorn forest, bush, grassland to desert, in response to the gradually diminishing amount of rainfall during the wet season.

It seems obvious in the case of the Chilean Miocene flora that the prevailing winds were, as at present, from the Pacific, hence there is little question regarding the abundant precipitation at that time and if the fossil plants failed to show this the sediments would, for they indicate an abundant run off.

The remaining question is one of altitude and temperature. Obviously the coal beds were deposited near sea level—the intercalation of marine beds indicates this. Certain of the seams have every appearance of having had an allocthonous origin, but if the materials had come from the upland they would have carried so much in addition to vegetable débris, that there would have been no coal seam. I therefore conclude that the flora was a lowland flora. On the other hand it is distinctly not a littoral flora, although it may have flourished along a coast. Nor is it a swamp flora. I would especially emphasize this total lack of predominantly palustrine facies, since Brüggen in a recent paper on the formation of coal with special reference to this region, seems to think that the flora described by Engelhardt was a swamp flora. Regarding the temperature indicated I can only feel sure of two general conclusions, namely that at the time it flourished there was never frost in that region and second that the climate was very much warmer and with more sunshine than at the present time.

The accompanying sketch map shows the location of the Chilean fossil flora and of other fossil floras of similar age in Peru, Ecuador and Colombia. It also shows the present southern limit of palms and the approximate western and southern limits of Zamia, Iriartea and various other equatorial types that occur in this fossil flora. The lines of the East and West coast show the approximate shape of the southern part of the continent if the present sea bottom were raised to the 550 fathom line and the outline would be little altered if this elevation were to only the 100 fathom line, since the major part of the area is within the 100 fathom line. That it is not entirely conjectural to suppose that there has been this relatively recent coastal subsidence is indicated by the disappearance beneath the Pacific of the Chilean Coast Range from Latitude 42° southward, and the flooding of the great longitudinal valley that formerly existed between this range and the Andes.

Most of the Andean region throughout its whole extent in South America was covered by the sea during the Upper Cretaceous. It is possible but has not been demonstrated that the areas of crystalline schists in the Coast Range may have existed as mountains in earlier geologic times, although doubt is thrown upon this possibility by the occurrence of Mesozoic plants in the metamorphic series of the Bio Bio valley. The land appears to have extended westward beyond the present coast of this region during the earlier Tertiary (Eocene-Oligocene), and there is some evidence of a similar land mass farther north. The latter, however, appears to have antedated the radiation of the Angiosperms.

The confessedly slender evidence, since it is based upon a single locality in northern Peru[19] and the fossil flora in the Arauco region of Chile, indicates that as late as the early Miocene the flora of the Amazon Basin extended westward across the present site of the Andes to the Pacific coast. There apparently were no mountains high enough or continuous enough to modify the climate as it is modified today in coastal South America between Tumbez and Coquimbo. The fossil flora of the Arauco region in Chile shows that an essentially similar flora extended southward along the West Coast, with some modification resulting from the higher latitude, at least as far as latitude 40° South.

This lower Miocene flora was essentially modern in its main attributes and it would be exceedingly interesting, if only sufficient evidence was available, to attempt to portray the biological changes brought about by the gradual elevation of the mighty Cordillera in a region of tropical, subtropical and warm temperate lowland forest such as that of Miocene Peru and Chile.

It seems to me that it is safe to postulate, at least for later Tertiary times, that the atmospheric circulation as governed by the distribution of land and water and areas of high and low barometric pressure, was essentially the same as it is at the present time. The vast quantities of volcanic dust in the Miocene and later formations of Patagonia furnish the proof,

---

[19] Berry, E. W., Proc. U. S. Natl. Mus., vol. 55, pp. 279-294, pls. 14-17, 1919.

if proof be necessary, that the prevailing winds of those times were westerly as they are today. .

What is more interesting they show that there was abundant volcanic activity in the Miocene. This in itself would seem to indicate the presence of mountains such as have not been demonstrated in the Andean region farther north. Some further evidence on this point is furnished by a consideration of the contemporaneous climate of Patagonia. The time has perhaps not yet arrived for a precise evaluation of the climatic conclusions to be derived from the wonderful assemblage of mammals described by Professor Scott from the Santa Cruz beds of Argentina. It is a great pity that the contemporaneous flora of that region has not been discovered. The Santa Cruz vertebrates predominate in plains types, the discovered birds are flightless forms, and no snakes, crocodiles or tortoises have been found. The arboreal forms are limited, but include tree porcupines, and there were hosts of ground sloths. This evidence may all be negative, but it seems plausible to suppose that the country was a plains or savanna country lacking forests except in scattered clumps and along streams. Hence the precipitation was less than in the corresponding region of Chile, although the evidence that the climate of Patagonia at that time was more genial than at present is overwhelming and everywhere admitted.

If the Patagonian climate was drier than that of Chile in Miocene time, and the available evidence points in that direction, the only plausible explanation is the presence of an intervening mountain chain that also contained the volcanoes that were the source of the ashes so much in evidence in southern Argentina. The Miocene climate did not, however, furnish the extreme contrast that the present climate of Patagonia and southern Chile exhibits and both the Chilean fossil flora and the Patagonian fossil vertebrates are in concordance in proving that at that time more genial climatic conditions prevailed far to the southward of their existing limits.

I would estimate the Chilean fossil flora as indicating a change from the present climatic conditions corresponding to from 10° to 12° of latitude at sea level. Thus if the region around Antafogasta, Chile was not rainless at the present time and supported a humid flora appropriate to its latitude I would expect to find a flora comparable with that found fossil in Chile growing for 2 or 3 degrees north and south of that place. Ignoring the complications due to the climatic changes that resulted from the elevation of the Andes, this suggests that the secular change of climate since lower Miocene time was sufficient to cause this flora to withdraw northward some 10 degrees nearer the equator.

It may be, however, that there has been no secular change, and that the indicated difference may be due entirely to changes in level and the consequent altered distribution and proportions of land and water, and the effects of these changes on atmospheric and oceanic circulation.

AGE OF THE DEPOSITS

It seems probable that the term Navidad beds should be dropped from the literature, certainly its application to beds at numerous scattered localities as is done by Möricke is entirely unwarranted. The so-called Navidad fauna is extensive, but probably a mixture of more than one horizon, as Ortmann and others have suspected. It has been described principally by Philippi[20] and Möricke.[21] It is said to show closer relationships with the Tertiary faunas of Europe than with the corresponding faunas of Australia and New Zealand, although it contains some elements common to the latter. No adequate comparisons have ever been made with the corresponding faunas of the Antilles and North America.

---

[20] Philippi, R. A., Die tertiaren und quartaren Versteinerungen Chiles. Leipzig, 1887.

[21] Möricke, W., Versteinerungen der Tertiarformation von Chile. Neues Jahrb. Beil. Bd. 10, pp. 548-612, pls.

Before discussing the age of the plant beds, I wish to refer to the so-called Patagonian beds of southern Argentina, the marine fauna from which has been admirably described by Ortmann.[22] This fauna has been satisfactorily shown to be of lower Miocene age, and while the Australian and New Zealand element is more pronounced than in the Navidad beds, nevertheless the Patagonian has, out of a total fauna of 175 species, 34 that are identical with and 15 additional that are closely allied with Navidad species. Ortmann quite rightly concludes that the Patagonian is synchronous with at least a part of the series referred to the Navidad. Two of the Chilean species are common to the lower Miocene Heath stage [23] of northern Peru and there are an additional number of closely related species in the latter, according to Grzybowski, but both the determinations and horizon of this author are questionable.

A more comprehensive study of the lower Miocene fauna of Northern Peru by Spieker in No. 3 of these Studies, discusses fully the few relationships and many differences between the Navidad fauna and that of the same age in Peru, and suggests the presence of an intervening Pacific land mass to account for the lack of intermigration between the two areas.

Whether the Chilean fauna be regarded as lower or middle Miocene it is evidently undoubted Miocene and very probably earlier Miocene. I see no reason for not correlating it with the Burdigalian stage of European geology and with the Patagonian beds of Argentina. The fossil flora is more remote from fossil floras of known age to afford as satisfactory data for its correlation. It is in my judgment not appreciably older than the associated fauna. A feature of great interest is the presence of a more northern element

---

[22] Ortmann, A. E., Tertiary Invertebrates. Princeton Exped. to Patagonia, vol. 4, pp. 45-332, pls. 11-39, 1901-1906.

[23] Grzybowski, J., Neues Jahrb. Beil. Bd. 12, pp. 610-664, pls. 15-20, 1899.

which invaded south-eastern North America as early as the Eocene. This element includes the genera Zamia, Anona, Myristica, and representatives of the families Papilionaceæ, Bombacaceæ, Lauraceæ, Myrtaceæ, Boraginaceæ, and Rubiaceæ. Compared with the known fossil floras from other parts of South America, it contains 3 species in common with that found in the Loja basin of Ecuador, 2 species in common with that found in Colombia, and 2 species in common with that described recently from Peru. When compared, on the other hand, with the geographically much less remote flora found in the Magellanian beds along the straits of that name and on Tierra del Fuego, it is found to have nothing in common with the latter except a single species of Flabellaria, about which Dusén expresses the opinion that it could not have come from the Magellanian beds, and in this Dusén appears to be perfectly justified. It appears to me that the Chilean flora is younger than the floras known from farther south.

In conformity with the conclusions of invertebrate paleontology as expressed by Steinmann, Möricke, Ortmann, and others, and from a consideration of the flora found in these beds, I would confirm the lower Miocene age of a part at least of what goes under the name of Navidad beds and I would consider them as representing the Burdigalian stage and possibly the older Aquitanian stage as well, since transgression was continuous in Europe from the one to the other, as it was also in the Canal Zone. The presence of some of the mollusca of the Navidad beds in the Magellanian Oligocene may indicate that a part of the former is still older than Aquitanian, but this I greatly doubt, since the facts can be explained by intermigrations of the forms better than by postulating contemporaneity. The facies of the flora appears to be slightly older than the previously mentioned fossil floras from Colombia, Ecuador and Peru, and it may well fall within the Aquitanian, but it is surely not so old as Eocene, as Steinmann and De Lapparent suggest, nor is it as old as the Fagus flora of the Straits of Magellan and Tierra del Fuego, which I have considered as Lower Oligocene in age.

Windhausen[24] has recently described the hitherto unknown (wrongly correlated) transgression of what he calls the San Jorge formation, which in the early Eocene flooded the east coast of southern Argentina and penetrated northwesterly up the Roca Valley. I mention this admirable contribution in the present connection, since it has a bearing on the age and antecedent history of the Magellanian beds.

At Punta Arenas and elsewhere along the Straits of Magellan and at various localities in Tierra del Fuego a series of sandy lignitic beds have been described by Ortmann, Hatcher, Nordenskjold, and others, which are of the greatest interest to paleobotanists because of the remarkable flora contained near their base. The section somewhat abbreviated, is as follows:

1. Sands, lignitic sandstone, and conglomerate = horizon V of Hatcher = Patagonian formation of Ortmann = Burdigalian.
2. Sandstones with lignite beds and fossil plants = horizon IV of Hatcher = Upper lignites or Punta Arenas coal = Miocene Araucaria beds of Dusén = Aquitanian.
3. Sandstone with oyster beds = horizon III of Hatcher = Oligocene.
4. Sandstones with fossiliferous calcareous lenses = Oligocene.
5. Fossiliferous beds = horizon II of Hatcher = Oligocene.
6. Sand and sandstone with fossiliferous calcareous concretions and fossil plants = horizon I of Hatcher = Oligocene Fagus zone of Dusén = Oligocene.
7. Lignitic shales = Lower lignites of Hatcher = Oligocene (?).

This section presents the record of a minor oscillation of the strandline with continental deposits passing into lagoonal, and these into littoral and shallow-water marine, and then

---

[24] Windhausen, A., The problem of the Cretaceous-Tertiary boundary in South America and the stratigraphic position of the San Jorge formation in Patagonia. Am. Jour. Sci. (IV), vol. 45, 1918, pp. 1-53.

gradually shallowing and perhaps becoming emergent during the Aquitanian, followed by a marked transgression in the Burdigalian. At present our chief interest centers in the Fagus zone and its flora. This flora, as described by Dusén,[25] consists of 29 species, of which the Flabellaria, previously mentioned as doubtful, is the only one that occurs in the Tertiary floras already enumerated from South America. The particular facies of this flora is furnished by the abundance of Fagaceæ. This family is represented by two species of Fagus and by 13 species or varieties of Nothofagus. This flora is certainly older than those already mentioned and it is as certainly Tertiary in age. It unquestionably had its beginnings in the Northern Hemisphere and has also been found to be represented at somewhat similar horizons in Australia, New Zealand, and Antarctica. That it did not migrate into Patagonia from North America appears to be probable from the total absence of any definite ancestral assemblage in the abundantly fossiliferous Upper Cretaceous or Eocene of the latter continent from which it seems probable that it could have been derived. Nor are any traces of it found at more northern localities in South America. The explanation seems to be that it reached southern South America from the opposite direction, namely Antarctica.

A very interesting Tertiary flora has been recently described[26] from the border of the Antarctic continent on Seymour Island, off the east coast of Graham Land. This flora contains a large element of subtropical or warm temperate types like those found today in southern Brazil, and another large element of forms suggestive of the existing temperate flora of southern Chile and Patagonia, and including species of Fagus and Nothofagus like those found in Patagonia, Chile, Australia, and New Zealand. Dusén,

---

[25] Dusén, P., Ueber die tertiare Flora der Magellanslander Svenska Exped. till Magellanslanderna, Band 1, pp. 87-107, pls. 8-13, 1899.

[26] Dusén, P., Uber die Tertiare Flora der Seymour-Insel. Wiss. Ergeb. Schwed. Südpolar-Exped., Band 3, 27 pp., 4 pls., 1908.

ignoring the usually mixed climatic character of early Tertiary floras, and the association of tropical and temperate types under favorable conditions of humidity, and basing his conclusions on the broken character of the fossil remains of these temperate types, reaches the conclusion that the temperate and the subtropical elements were contemporaneous, but that the latter were coastal forms under a subtropical climate, while the former grew in the vicinity at elevations which he suggests amounted to 6,500 feet or more, and were brought by streams to the littoral basin of sedimentation. If this is true, it indicates a considerable mountain chain of the Andean type forming the axis of Graham Land at that time as it does at present. The only evidence bearing on the age of the folding, which may really have little bearing on the time of elevation, is the presence at Hope Bay, on Graham Land, of an extensive late Jurassic flora [27] found in continental beds which are involved in this folding. Dusén concludes that this Tertiary Antarctic flora is older than that of the Fagus zone of the Magellanian beds but this can not be considered as proven.

Poorly preserved mollusks associated with the plants are considered by Wilckens to represent what he calls the Patagonian molasse, but since the latter is more or less composite, as Windhausen [28] has shown, and includes faunal elements belonging to the lower Eocene San Jorge formation as limited by the latter author, the evidence for the correlation adopted by Andersson[29] can not be said to be conclusive. The presence of Zeuglodon vertebræ, described from this locality by Wiman, should probably be considered as evidence of upper Eocene age. I would therefore dissent from Wilcken's conclusions that this plant-bearing sandstone is

---

[27] Halle, T. G., The Mesozoic flora of Graham Land. Swedish South Polar Exped. 1901-1903, Band 3, lief 4, 123 pp., 9 pls. 1913.

[28] Op. Cit.

[29] Andersson, J. Gunnar, On the geology of Graham Land. Bull. Geol. Inst. Upsala., vol. 7, pp. 19-71, pls. 1-6, 1906.

upper Oligocene or lower Miocene in age and would consider this flora as probably of upper Eocene age and the flora of the Chilean coal measures, as previously stated, lower Miocene in age and corresponding to the Aquitanian or Burdigalian stages of Europe.

NEW OR NOTEWORTHY SPECIES

Pteridophyta

Class LEPTOSPORANGIATÆ

Order POLYPODIALES

Family CYATHEACEÆ

Genus CYATHOIDES Berry, gen. nov.

Cyathoides thyrsopterioides Berry, sp. nov.

PLATE I—Figs. 1-3

These fragments undoubtedly belong to the family Cyatheaceæ. Since, however, the different members of the family show much convergence in foliar characters, and the tribes are differentiated upon soral and sporangial features not preserved in the fossil, it becomes impossible to reach a conclusive opinion as to their generic allocation. In so far as the meager material permits a judgment the fossil agrees more closely with the genus Thyrsopteris than with the other genera of the family, but in the absence of fruiting material I hesitate to go beyond recognizing this resemblance in the specific name chosen for the species, since Thyrsopteris is now monotypic and confined to the Juan Fernandez islands, and most of the fossil forms that were formerly referred to this genus are now regarded as being based upon too slender evidence. Moreover other genera of Cyatheaceæ are abundant in South America at the present time, particularly in the "montaña" country of the eastern Andean slopes and these, apriori, would be more likely to occur in the Tertiary flora of southern Chile when the climate was warmer than it is at present.

Although Saporta and others have referred Tertiary ferns to Gœppert's genus Cyatheites this genus was based on Carboniferous and older Mesozoic forms of varied relationships and certainly not related to the present species, so that this very appropriate generic name is not available. The generic term Cyatheopteris of Schimper was based upon a European lower Triassic specimen of a trunk, similarly unrelated to the present species.

Cycadophyta

Order CYCADALES

Family CYCADACEÆ

Genus ZAMIA Linné

Zamia tertiaria Engelhardt

PLATE VIII—Fig. 4; PLATE II—Figs. 1-3

Zamia tertiaria Engelhardt, Abh. Senck. naturh. Ges. Bd. 16, p. 646, pl. 2, fig. 16, 1891.

"Monokotyler Blattrest" Engelhardt, Idem., p. 686, pl. 1, fig. 4.

Description.—Leaflets of variable size, prevailingly large, lanceolate and inequilateral in outline. Apex and base equally acuminate, the apex somewhat more extended than the base which has a blunt articular surface about 2 mm. in width. Texture coriaceous, the very numerous parallel veins being immersed in the substance of the lamina. Length in the collected material ranging from 8 cm. to 18 cm., averaging about 13 cm. Maximum width, in the middle region or slightly below, ranging from 1.2 cm. to 3 cm., indicating large leaves with numerous, rather close set pinnules.

Although no complete leaves were seen, the shales were sometimes packed with the pinnules, which were apparently not firmly attached to the rachis. Since, however, the materials that made up the coal seams was drifted material it is not surprising that the leaves are broken up. In several instances fragments were found showing the pinnules in normal orientation. One such specimen is figured where the rachis is still imbedded in the matrix and 2 or 3 pinnules on each side are folded back with their ends broken off.

It is rather singular that with the small amount of material at his disposal Engelhardt should have recognized as representing a Zamia the small fragment figured by him and should have failed to recognize the relationship of the larger specimen which he refers to and figures as a fragment of a monocotyledonous leaf. This will account for the fact that Engelhardt compared the species with the existing *Zamia integrifolia* Ait. of Florida and the Antilles, when it actually is much more similar to several existing South American species. Engelhardt's type is given as from Coronel but since it came from the Cousino workings it is obviously from the locality referred to as Lota in the present paper. Remains of cycad pinnules are apparaently rare in the vicinity of the coal seams exploited at Coronel and Lota for the Engelhardt collections contained only the fragments figured and I saw none at either place. Farther south at the mines of the Arauco Company at Curanilahue cycad remains are exceedingly abundant and in places the shales are packed with their detached pinnules. There can be no question of their identity and it is interesting to find them associated with Tertiary palms and araucarians at 37½° south latitude.

The genus Zamia, which probably includes forms not at all genetically related to the fossil species referred to Zamites, comprises about 35 existing species ranging from peninsular Florida, Mexico and the Antilles through northern South America and along the eastern Andean slopes to about the latitude of northern Chile. (The geographically nearest form to the fossil that I know of comes from the Velasco Hill country in eastern Bolivia.) It is the dominant existing cycad genus of the Western Hemisphere. Its range during the Tertiary was apparently more extended than it is at the present time since species have been found north of the existing range in the Eocene of the Mississippi embayment and much to the southward in this Chilean occurrence. These facts are shown on the accompanying sketch map (Fig. 5). Another fossil species from South America was recorded by Krasser[30] from the Pliocene of Bahia, Brazil.

Coniferophyta

Order ARAUCARIALES

Family ARAUCARIACEÆ

Genus ARAUCARIA Jussieu

Araucaria araucœnsis Berry, sp. nov.

PLATE III—Figs 1-4

Sequoia spp., Engelhardt, Abh. Naturw. Gesell. Isis in Dresden, Heft 2, p. 69, pl. 1, figs. 2-8, 1905 (not fig. 3).

Description.—Terminal leafy twigs. Leaves flat, unkeeled, ovate lanceolate and inequilateral in outline, ranging in length from 6 mm. to 15 mm., and in maximum width, from 2.5 mm. to 5 mm., sharply but not cuspidately pointed, narrowing to the sharply reflexed and somewhat expanded decurrently sheathing base. The leaves are not crowded on the twigs and the decurrent bases are long. While the arrangement is clearly seen to be spiral the habit is distichous and the twigs are distinctly bifacial. The leaf substance is thick and coriaceous and the veins are numerous simple and parallel and immersed in the leaf substance, which is transformed in the fossils to a lignitic sheet.

This, in all of its characters, is obviously a species of Araucaria of the Columbea section of that genus, differing from the modern forms in the somewhat smaller size and less crowded arrangement of the leaves. It appears that Engelhardt had received specimens from Curanilahue of this species which he failed to recognize, referring them to Sequoia and figuring them with a midrib or midrib-like keel. I am sure that these specimens are the same as mine, the parallel veins being obscure in the thick lignified leaves.

---

[30] Krasser, F., Sitz. k. Akad. Wiss. Wien, Bd. 112, ab. 1, p. 853, 1903.

It is of considerable interest to find that Araucaria was abundantly represented in the Tertiary deposits of Chile in a region adjoining that in which it still makes one of its greatest existing displays. It is also of interest to see that in the Tertiary flora of Chile it is associated with palms and cycads and a variety of other plants of warmer latitudes and not present in recent times in or near the Araucarian forests. Nor has their modern compatriot, the evergreen beech (Nothofagus) been found in the coal measures of Coronel, Lota and Curanilahue, although still farther to the southward Dusén has described both genera from what are probably somewhat older deposits. Quite different species from this general region are *Araucaria nathorsti* Dusén [31] from Punta Arenas, Chile and *Araucaria imponens* Dusén [32] from Seymour Island, Graham Land, and furthermore Gothan has described [33] the wood of an Upper Cretaceous or Tertiary species from Seymour Island as *Araucaria pseudoparenchymatosum*.

The present fossil species comes from Curanilhue and Lota. The past and present geographical distribution is summarized on the maps forming Figs. 1 to 4.

Angiospermophyta

Order ROSALES

Family CÆSALPINIACEÆ

Genus CASSIA Linné

Cassia longifolia Engelhardt

PLATE V—Figs. 2, 3

Cassia longifolia Engelhardt, Abh. Senck. Naturf. Gesell. Bd. 19, pp. 19, 24, pl. 2, figs. 14-16, 1895.

Description.—Leaflets sessile, somewhat variable in size, oblong elliptical and somewhat inequilateral in outline. Apex

---

[31] Dusén, P., Svenska Exped. till Magellanslanderna, Bd. 1, p. 105, pl. 12, figs. 1-13, 1899.

[32] Dusén, P., Wiss. ergeb. Schw. Südpolar-Exped. 1901-1903, Bd. 3, Lief 3, p. 11, pl. 1, figs. 16, 17, 1908.

[33] Gothan, W., Idem., Lief 8. p. 10, pl. 1, figs. 1-3, 12-16, 1908.

and base about equally rounded, the base more inequilateral than the apex. Margins entire. Texture subcoriaceous. Midrib stout and prominent, usually somewhat curved. Secondaries numerous, closely spaced, relatively stout, camptodrome. Length ranging from 2 cm. to 3 cm., averaging 2.5 cm. Maximum width ranging from .75 cm. to 1.1 cm.

The present characteristic species was described by Engelhardt from Loja and Tablayacu, Tertiary coal basins in the south Ecuadorean Andes. It is closely simulated by the leaflets of the existing *Sweetia lentiscifolia* Sprengel, *Cassia spectabilis* D. C. and *Cassia excelsa* Schrad. Although its positive generic determination is doubtful it undoubtedly represents a leguminous form most closely allied to existing species of the Amazon basin which penetrated as far south as southern Chile in the early Miocene. These leaflets are not uncommon at Lota and Coronel.

Cassia Oxleyi Berry, sp. nov.

PLATE V—Fig. 1

Description.—Leaves pinnately compound. Leaflets small, elongate elliptical in general outline, widest in the middle and narrowing equally to the rounded tip and the inequilateral base, petiolulate, margins entire, evenly rounded. Texture subcoriaceous. Petiolule stout, 2 mm. or less in length. Midrib stout. Secondaries stout, about 6 alternate and equally spaced pairs diverge from the midrib at angles of about 45 degrees, pursue rather straight ascending courses two-thirds of the distance to the margins where they sweep upward in an open camptodrome loop. Tertiaries mostly obsolete. Named for Mr. Oxley the efficient and hospitable manager of the Arauco Company.

These little leaflets are, in my judgment clearly referable to Cassia. They are of a type very frequent in fossil floras of the Tertiary in all parts of the world and could be matched by Eocene or Miocene or Pliocene forms from remote regions, so that little is to be gained by extending comparisons among fossil forms, and the same is true among the existing forms of a genus so large as is Cassia, among which numerous South American species resemble it closely, as for example *Cassia lævigata* Willd. and *Cassia stipulacea* Ait.

Fig. 6. Restoration of lower Miocene Cassia from Chile, ½ nat. size. Restoration based on the leaflets of Cassia oxleyi and the associated pods of Cassia Gardneri.

These leaflets, presumably because of their more perishable nature, are much rarer than the pods with which they are associated. The latter are exceedingly common but beyond finding the two in association in the same hand specimen no evidence of their identity is available. I have consequently described the leaflets and pods under distinct specific names, although I have combined them in the accompanying restoration.

Cassia has between 300 and 400 existing species, found in the warmer temperate and tropical regions of all the continents and especially abundant in tropical America. Their place of origin is unknown, since they make their appearance in the Upper Cretaceous almost simultaneously in New Zealand, Australia, Bohemia, Saxony, Greenland, the Atlantic Coastal Plain, and the Dakota sandstone of the Rocky Mountain province. More than 100 fossil species are already known. The Eocene distribution sheds no light on the early history of the genus, for species occur in such widely separated regions as North America, Europe, and Australia. There are numerous Oligocene and Miocene species, the Oligocene records being confined to Europe and Africa and the Miocene records being confined to Europe and America. Cassia was abundant along the shores of the Pliocene Mediterranean of Europe, and 4 species are recorded from South American beds which are thought to be of Pliocene age. Pleistocene species are recorded from Maryland, and also from the East Indies (Java), where they are associated with *Pithecanthropus erectus* Dubois. One fact is certain—the genus has been a part of the American flora since the dawn of the Upper Cretaceous, and has probably been present in South America since the dawn of the Tertiary. The present species along with its associates is indicative of warmer climatic conditions than prevail at the present time in southern Chile.

Arauco mine, Curanilahue.

Cassia Gardneri Berry, sp. nov.

PLATE V—Figs. 5, 6

Description.—Small elliptical, tardily dehiscent or indehiscent, few or single seeded, pods. These pods are flat and of a coriaceous consistency. They may be almost circular in outline or may taper proximad and be slightly pointed distad. They are borne on stout curved stalks up to a centimeter in length and contain several flat seeds. They are distinctly margined all around and the surface is slightly corrugated and marked with a conspicuous network of transverse veins. They range in length from 2 cm. to 3.5 cm. and in maximum width from 1.5 cm. to 2.25 cm. The species is named for Mr. Gardner the hospitable mine manager of the Arauco Company.

This is a characteristic type of legume strikingly like many fossil and recent species of Cassia, Lonchocarpus, Dalbergia, etc. The pods resist maceration well and are very abundant in the Curanilahue beds, although not seen at the other localities. The possibility of their representing the same botanical species as the associated leaflets described as *Cassia oxleyi* has already been mentioned. Since this cannot be demonstrated it seems preferable to keep the two distinct, although they are combined in the restoration. They may also be compared with the pods of various members of the tribe Dalbergieæ, especially the genera Dalbergia, and Lonchocarpus both of which are so abundant both as trees and lianes in tropical South America.

Order SAPINDALES

Genus SAPINDUS Linné

Sapindus acuminatus Engelhardt

Sapindus acuminatus Engelhardt, Abh. Senck. Naturf. Gesell., Bd. 16, Heft 4, p. 670, pl. 9, fig. 10, 1891.

The present collections show that these leaflets had stout curved petioles 7 mm. in length.

Order MALVALES

Family TILIACEÆ

Genus TRIUMFETTA Linné

Triumfetta miocenica Berry, sp. nov.

PLATE IV—Fig. 5

Leaves broadly ovate and somewhat inequilateral in general outline, widest below the middle, and narrowing upward to the acuminate tip. Base rounded. Margins evenly serrate, fuller on one side and straighter on the other. Midrib stout. Secondaries about 5 opposite to alternate camptodrome pairs, the basal pair stoutest and somewhat more ascending than the others and giving off on the outside a series of camptodrome tertiaries. Remaining tertiaries percurrent. Length about 8 cm. Maximum width about 4.75 cm.

This species, obviously new, greatly resembles a number of existing species of Triumfetta of the South American tropics. It is, unfortunately represented by a scanty amount of material from the mine dumps at Lota. It is referred to the genus Triumfetta with considerable hesitation and it would, perhaps, have been better to describe it as a species of Grewiopsis and consider the latter genus as the original and more or less cosmopolitan stock from which the different existing members of the subfamily Grewieæ were derived. The existing species of Grewia, upward of 100 in number and very similar to the present fossil are all old world forms of Africa, Asia and Australia. The existing species of Triumfetta, about three score in number, are herbs or shrubs of the tropics of both hemispheres, and undoubtedly derived from Grewiopsis like ancestors, as is indicated not only by their characteristics but by their geographical distribution, and the reduction in size and herbaceous form of many of them. The genus is practically unrecognized in the fossil state, although a second species has been described from these same beds by Engelhardt.

Order THYMELEALES

Family LAURACEÆ

Genus NECTANDRA Roland

Nectandra chilana Berry, sp. nov.

PLATE V—Fig. 8

Nectandrophyllum B, Engelhardt, Abh. Senck. Naturf. Gesell., Bd. 16, Hft. 4, p. 655, pl. 3, fig. 3, 1891.

Complete material identical with the fragments recorded from Lota by Engelhardt were collected from the mine dumps at Lota and prove to represent a new species of Nectandra, as Engelhardt suspected. It may be described as follows:

Leaves of medium size, oblong ovate or obovate in general outline, widest in the middle. Apex obtusely pointed. Base cuneate. Margins entire, somewhat irregularly and slightly undulate. Length about 10.5 cm. Maximum width about 3.8 cm. Petiole short and stout, expanded proximad, about 5 mm. in length. Midrib stout, prominent on the lower surface of the leaf, somewhat flexuous. Secondaries stout, prominent, variable in spacing, calibre, and course; four to six pairs diverge from the midrib at irregular intervals, the second or third one may be more prominent and ascending but none merit being classed as lateral primaries; all are camptodrome, and the tertiaries are largely immersed in the substance of the leaf.

This species appears to be common at Lota and is readily distinguished from the other rather numerous species of Lauraceæ that have been described from the Tertiary coal measures of Chile. It is very close to a number of existing species of Nectandra of the tropics of South America.

Genus GŒPPERTIA Nees

Gœppertia Engelhardti Berry, sp. nov.

PLATE IV—Fig. 3

Leaves of medium size, oval in general outline, widest at or slightly above the middle, with full rounded entire margins narrowing about equally distad and proximad. Apex broadly cuneate pointed. Base slightly more extended than the apex, about equally cuneate pointed or slightly narrower. Texture subcoriaceous. Length about 10 cm. Maximum width about 4.4 cm. Petiole short and stout, about 5 mm. in length. Midrib stout, curved, prominent on the lower surface of the leaf. Secondaries fairly stout; the basal pair diverge from the midrib at considerable but unequal distances above the base and are hence not opposite; their angle of divergence is less than is the case with the balance of the secondaries and a wide interval separates them from the secondaries next above; they pursue regularly curved ascending courses subparallel with the lower lateral margins and are eventually camptodrome above the middle of the leaf. A very slight enlargement and development of these would make the leaf have distinctly tripalmate venation. The remaining secondaries, numbering 4 or 5 alternate pairs are generally confined to the upper half of the leaf; they diverge at wider angles and are shorter and more curved and likewise camptodrome. The tertiaries are well marked, forming marginal arches without, and mostly transversely percurrent nervilles within, the secondaries.

This new species is named in honor of Herman Engelhardt, the pioneer student of South American Tertiary floras. It is not common in my limited collections but this is without significance. It is clearly distinct from the two species of Gœppertia already described from these beds by Engelhardt. The genus comprises about 50 species in the existing flora and is confined to the tropical and subtropical regions of South America where there is an abundant rainfall. The genus is sometimes, as by Pax, made a section of the South American genus Aydendron Nees, and the two are doubtfully distinct. They are also closely allied to Cryptocarya R. Brown whose range includes southern Asia, Africa and Australia, with about one-fourth of the existing two score species South American.

It may perhaps be questioned whether it is possible to differentiate these genera in the Tertiary, and the widest ranging genus Cryptocarya may be considered as representing the cosmopolitan ancestral stock from which the localized genera of the tribes Cryptocaryeæ and Acrodiclidieæ were derived. The present fossil species was collected at Lota.

Gœppertia ovalifolia Engelhardt

PLATE V—Fig. 7

Gœppertia ovalifolia Engelhardt, Abh. Senck. Naturf. Gesell., Bd. 16, Hft. 4, p. 652, pl. 3, figs. 8, 9b; pl. 4, fig. 9; pl. 5, fig. 4, 1891: Idem., pl. 14, fig. 10.

Leaves ovate in general outline, somewhat variable in both form and size. Widest below the middle, tapering upward to a narrow extended acuminate tip or rather abruptly and bluntly pointed. Base narrowly or broadly cuneate, the narrower forms slightly decurrent. Margins entire, somewhat irregularly undulate in nearly all of the specimens collected. Texture coriaceous. Length 10 cm. to 13 cm. Maximum width 3.5 cm. to 5.25 cm. Petiole short and stout. Midrib stout, prominent on the lower surface of the leaf. Basal secondaries opposite or subopposite, stouter than the upper secondaries, parallel with the lower lateral margins, invariably suprabasilar, generally sufficiently developed to merit the term lateral primaries, camptodrome at or above the middle of the leaf, separated by a considerable interval from the secondaries next above. Remaining secondaries 3 or 4 subopposite to alternate, remotely spaced, camptodrome pairs. The tertiaries are mostly obsolete on the upper surface of the leaf but fairly well defined on the lower surface; they form marginal abruptly camptodrome arches within the margins and are mostly percurrent within the secondaries.

This well marked species was described by Engelhardt from abundant material from Coronel, and a single fragment from Lota (op. cit. pl. 14, fig. 10) which he failed to recognize. I found it common at Lota. It greatly resembles *Camphoromoca speciosa* Engelhardt from Coronel, as well as existing species of Camphoromoea. It is also similar to the fossil forms of the Northern Hemisphere which paleobotanists invariably refer to the allied genus Cinnamomum, which in the existing flora is confined to the Old World. It is also very similar to several existing species of Gœppertia, particularly *Gœppertia sericea* Nees.

I regard the present species, as well as the two additional species recorded from Chile as undoubtedly representing the genus Gœppertia. Whether or not some of the North American forms described as Cinnamomum should be referred to Gœppertia and Camphoromoea I am not able to determine. It would seem that these genera should have reached North America along with the numerous Central and South American Lauraceous types during the Tertiary. On the other hand the identity of Cinnamomum seems to be firmly established in some cases and it may be that the latter represents the original cosmopolitan type from which these other genera diverge in the South American region. Systematists do not recognize any such relationships but the Lauraceæ are notably difficult and it may be doubted if the last work has been said upon this subject, certainly the treatment of the family by Pax in Engler and Prantl is about as unsatisfactory as can well be imagined.

Genus LAUROPHYLLUM Gœppert

Laurophyllum actinodaphnoides Engelhardt

Laurophyllum actinodaphnoides Engelhardt, Abh. Senck. Naturf. Gesell. Bd. 16, heft 4, p. 654, pl. 4, figs. 3, 4, 1891.

The present collections show that these leaves had a stout petiole, 1.5 cm. in length.

Order MYRTALES

Genus MYRCIA De Candolle

Myrcia reticulato-venosa Engelhardt

Myrcia reticulato-venosa Engelhardt, Abh. Senck. Naturf. Gesell. Bd. 16, heft. 4, p. 680, pl. 8, fig. 1, 1891.

The present collection shows that these leaves reached dimensions of 12 cm. in length by 2 cm. in maximum width.

UNIV. OF
CALIFORNIA

PLATE I

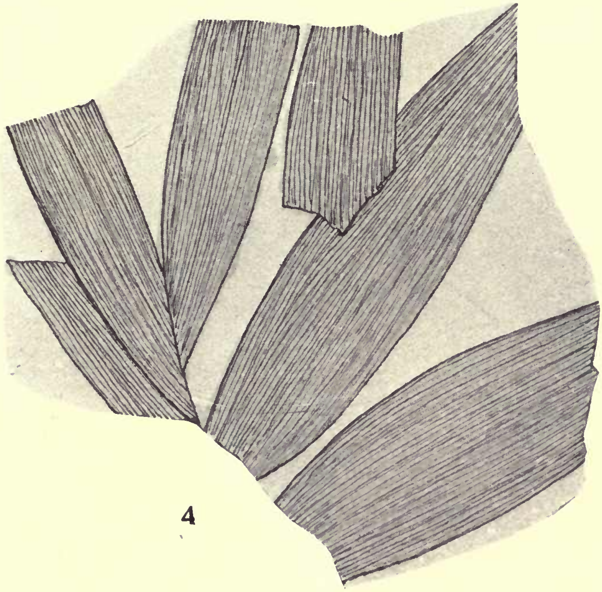
Figs. 1-3. Cyathoides thyrsopterioides Berry, n. sp.......Arauco Mine, Curanilahue. Figs. 2 and 3 enlarged.

Fig. 4. Zamia tertiaria Engelhardt......Arauco Mine, Curanilahue.

1

2

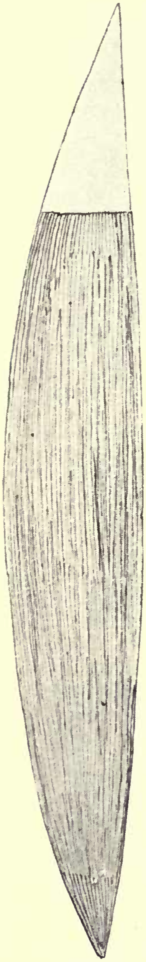
3

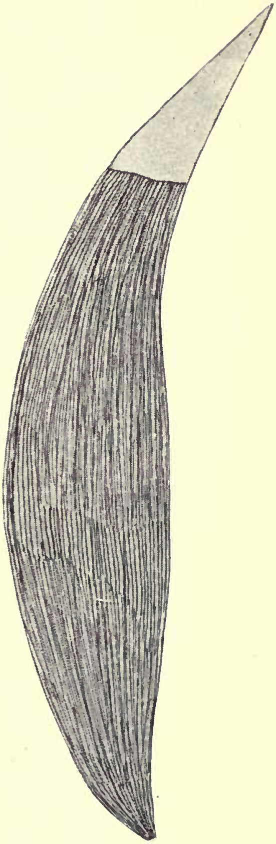


4

Plate II

Zamia tertiaria Engelhardt......Arauco Mine, Curanilahue.





UNIV. OF
CALIFORNIA

PLATE III

Figs. 1-4. Araucaria araucoensis Berry, n. sp.
Figs. 1-3. Rios Mine, Curanilahue.
Fig. 4. Lota.

1

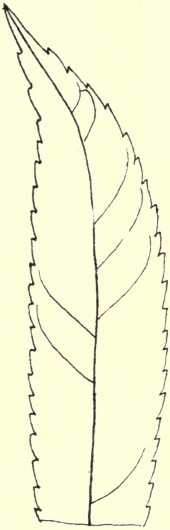
2

3

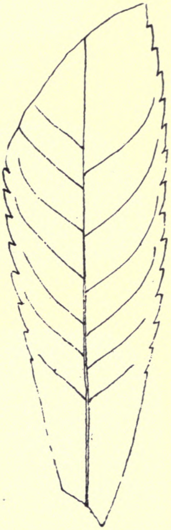
4

PLATE IV

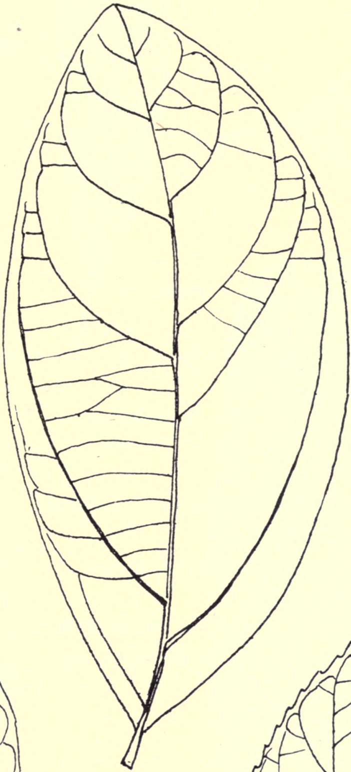
Figs. 1, 2. Thouinia philippii Engelhardt .... Lota.
Fig. 3. Gœppertia engelhardti Berry, n. sp. .... Lota.
Fig. 4. Anona speciosa Engelhardt .... Lota.
Fig. 5. Triumfetta miocenica Berry, n. sp. .... Lota.



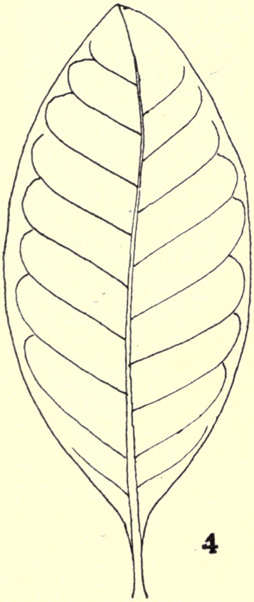
1



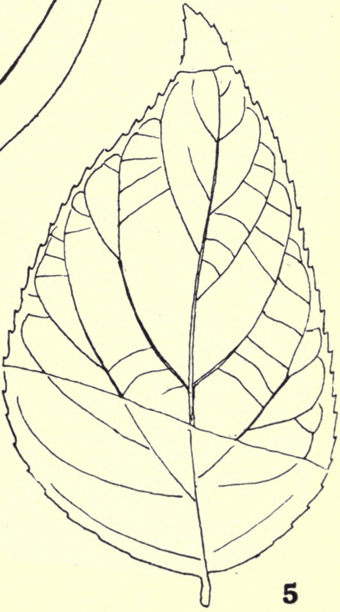
2



3



4



5

PLATE V

Fig. 1. Cassia oxleyi Berry, n. sp. .... Arauco Mine, Curanilahue.

Figs. 2, 3. Cassia longifolia Engelhardt....
  2. Puchoco Mine, Coronel.
  3. Lota.

Fig. 4. Hoffmannia protogæa Engelhardt .... Puchoco Mine, Coronel.

Figs. 5, 6. Cassia gardneri Berry, n. sp. .... Arauco Mine, Curanilahue.

Fig. 7. Gœppertia ovalifolia Engelhardt .... Lota.

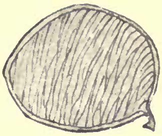
Fig. 8. Nectandra chilana Berry, n. sp. .... Lota.

1

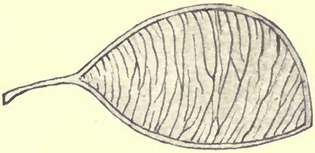
2

3

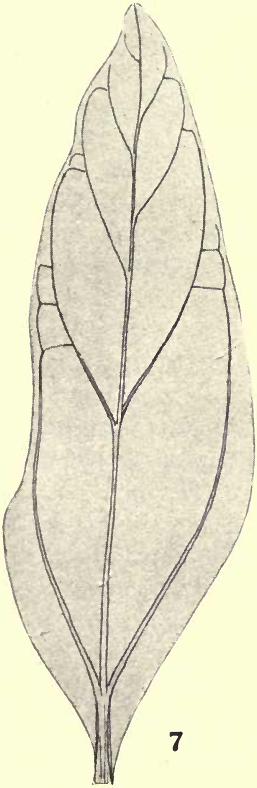
4



5



6



7

8

PLIOCENE FOSSIL PLANTS FROM EASTERN BOLIVIA *

By Edward W. Berry

Description of the Region

The present contribution is devoted to the description of late Tertiary basin deposits northeast of Cochabamba, Bolivia, and to the discussion of the remains of a subtropical flora contained in these deposits, now 11,800 feet above sea level, and its bearing on the age and amount of uplift of the Andes in this region.

In a region without fuel such as is the Bolivian Andes, considerable local interest was aroused by the discovery some years ago, of lignite at the locality in question, and my trip was made possible through the courtesy of Señor Enrique Salinas, the owner of the property, and Señor Donato Cornejo of Cochabamba, who entertained me for two nights at his finca at Palca, in the mountains only a league from the locality. It is a great pleasure to record the hospitality and assistance received in this most delightful section of Bolivia.

The Eastern Andes, or Cordillera Oriental, in Bolivia is dominated by that unsurpassed series of peaks along its western border from Sorata (Illampu) on the north to Illimani on the south, which, commonly known as the Cordillera Real, and well meriting the term Royal, rise to heights of between 20,000 and 22,000 feet. Although this range borders the Bolivian high plateau or altaplanicie on the east it forms the divide. Only a single river, the La Paz, takes its origin on the western slopes of this mighty mountain pass and passes through it to join the Amazon system.

The boundary between mountains and high plateau is continued southward from the Cordillera Real by the Quimsa Cruz and Frailes which constitute the divide. East of the

---

* George Huntington Williams Memorial Publication No 18.

divide the broken Andean ranges fan out and cover an area of about twenty-four square degrees, reaching eastward to Santa Cruz de la Sierra, about 250 miles from the western border of the eastern ranges. Although the mountains are somewhat less impressive in this last region than habit leads one to expect in the Andes, many of the peaks rise above 15,000 feet and several go two or three thousand feet higher. The enclosing rampart of this mountain mass is formed by the Sierra de Cochabamba on the northeast and the Sierra de Misiones on the east.

Cochabamba the Sierra, and Cochabamba the second city of Bolivia, both derive their name from the Cochabamba basin, the name being a partial Spanish corruption of the Indian Cocha or lake and pampa or flat, an interesting etomology for what appears to have been a late Tertiary lake now drained by the Rio Grande. Systematic exploration should eventually bring to light some traces of a Tertiary mammalian fauna in this region, which must have been a garden spot in late Tertiary times.

The rim of the basin north of Cochabamba over which the route to the plant locality passes is made up almost exclusively of rocks of Silurian age, although inconsiderable dark unfossiliferous shales observed northeast of the pass may be Devonian. The divide itself is a bold mass of Bilobites sandstone, reached by painfully slow mule-back over a poor trail that crosses from the plain over the immense detrital fans that skirt the mountains, and switchbacks up the lateral spurs, necessitating a five hours ride to cover the four leagues from the town to the pass.

Some distance below the pass on the south side a compact yellowish sandstone was found to be sparingly fossiliferous, containing Silurian forms of Orthis and other brachiopods. This observation is of importance as giving a clue to the age of the identical sandstones north of the pass and underlying the Tertiary. The geographical relations and something of the geology are shown on the accompanying sketch map

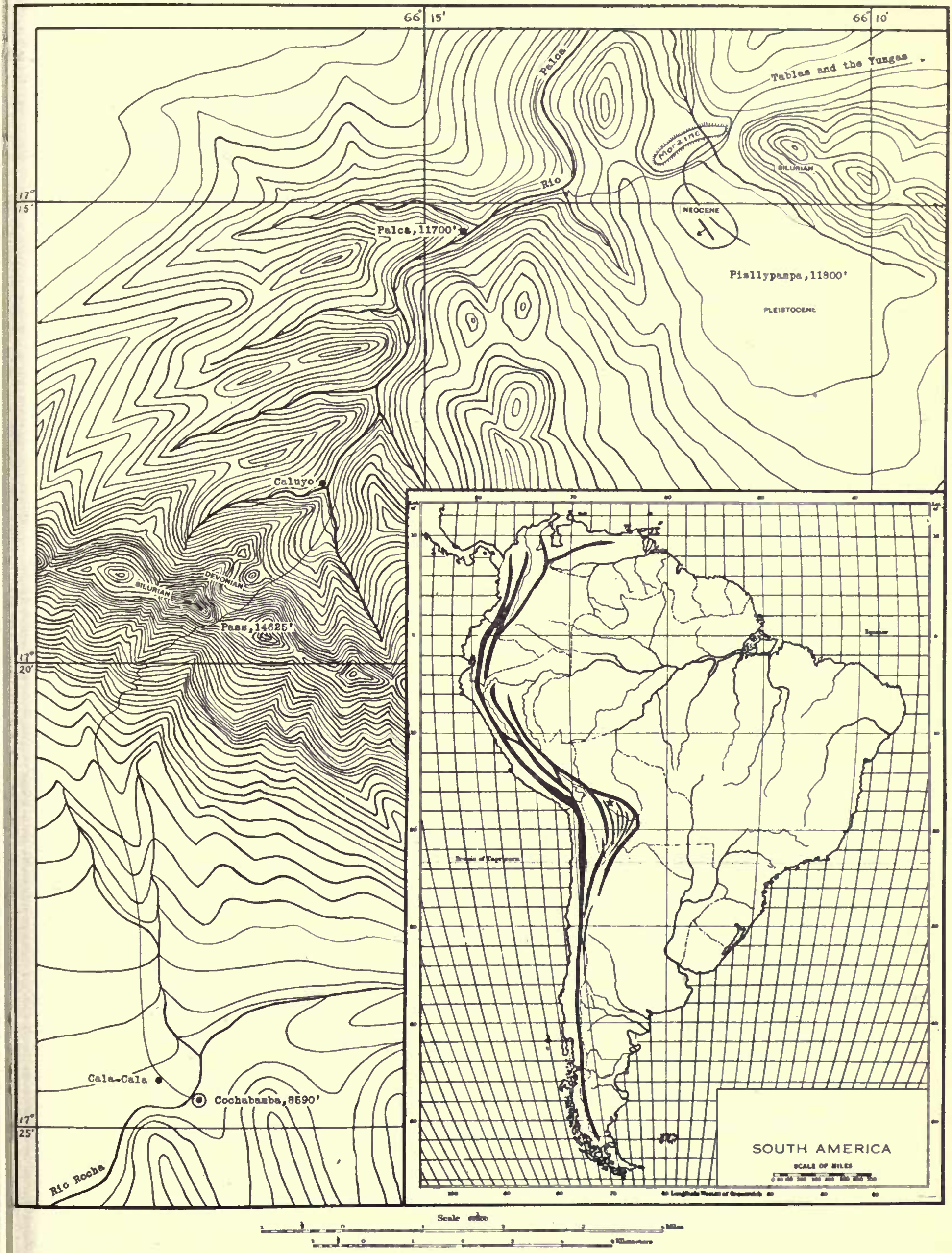


Fig. 1. Sketch map of Pisllypampa region and inset showing its location with respect to Andean tectonic lines.

(Figure I). The trail descends to the northeast down the valley of the Rio Palca, which river eventually reaches the Amazon via the Mamore and the Madeira. Slightly over a mile below Palca the trail leaves the valley and ascends to the pampa of Pisllypampa, which owes its origin to a symmetrical terminal moraine that blocked the outlet of the valley and formed the basin, in fact this whole region is beautifully glaciated above 11,000 feet.

Pisllypampa is about two miles wide by three miles in length, rising rather rapidly to the bordering peaks, especially to the southeast. It lies at an altitude of 11,800 feet, and is about 12 miles northeast of Cochabamba in an airline, although it is just twice that distance by the trail, and is a hard day's journey riding up, although only about half as long returning.

The country rock is a yellowish sandstone, probably of Silurian age. East of the pampa it dips steeply to the northeast. West of the pampa it dips moderately to the southwest, and in the Palca valley just south of Palca it is nearly horizontal. The Tertiary outcrops in a limited area along a small quebrada in the western part of the pampa, presumably abutting against the Silurian bedrock within a quarter of a mile. It strikes North 30 degrees West, and dips to the southwest from 18 to 25 degrees. There are no traces of Tertiary deposits along the more easterly and larger stream.

It seems obvious that the Tertiary deposits were once more extensive, and represent wind blown, flood plain and small lake deposits, the major portion of which were subsequently removed by glacial erosion. If then the contained flora can furnish consistent evidence regarding the age of the deposits and the physical conditions at the time of entombment, it will give a conclusive answer to the question as to when the uplift occurred and its probable amount. Before discussing this evidence it would be well to describe the deposits somewhat more fully.

After the discovery of the lignite, mining claims or pertenencias were taken out and eight short drifts from the stream level and one vertical shaft from the pampa surface were opened, but at the time of my visit these were filled with water to stream level, and as the drifts followed down the dip, a very limited section was available for study. I was fortunate, however, in having as a guide Señor Serepio of Cochabamba, who had originally discovered the outcrop and who had been in charge of it during the development, so that I was thus enabled to get data which I regard as fairly reliable regarding the total thickness of the deposit.

The section is as follows:

Recent or Pleistocene.	FEET
1. Cobbly wash	2
Pliocene.	
2. Compact buff tuff with fossil plants	8
3. Similar material in thin seams alternating with lignitic layers usually 1 to 2 inches but sometimes 4 inches in thickness	4
4. Brownish-buff, laminated, water laid clay with matted layers of mostly large leaf impressions	4
5. Lignitic seam, consisting of irregular bands up to 8 or 10 inches in thickness, with clay partings	3
6. Beneath the water the guide reported definitely an argillaceous layer immediately below the second lignite bed (No. 5)	4
7. Third lignite bed	3
and more vaguely several still lower lignitic seams separated by rather uniform thicknesses of clay or tuff.	

The Tertiary materials have then, a maximum thickness of 30 feet and a possible thickness of twice that amount. Stratum No. 2 was recognized as probably a tuff or ash and stratum No. 4 appeared to be a clay. When studied in the laboratory hand specimens of the former appeared so light that they were carefully examined for diatoms without positive result. They were, however, seen to consist of tiny needles and angular particles of an isotropic material which is obviously volcanic glass, and similar volcanic material in lesser proportions is present in the so-called clay. Traces of vegetation, aside from the layers of lignite with sticks and branches, are present throughout the section in so far as it was exposed, but the collected material came almost entirely from stratums No. 2 and No. 4.

In the former the leaves are imbedded at all angles and degrees of curvature, and were evidently covered by wind blown volcanic ashes when still dry and curled. In the latter the percentage of volcanic ashes is much smaller, the leaves are matted in layers parallel to the bedding planes, and the material is laminated and obviously water laid, in the quiet waters of what was either a permanent or seasonal lake. After an analysis of the flora I will have something to say regarding the climate and other physical conditions.

Regarding the source of the volcanic ashes it may be noted that the Eastern Andes offer a striking contrast to the Western Andes. I know of no volcanic peaks, or effusive, or fragmental igneous rocks in the Eastern Andes of Bolivia. The Western Andes on the other hand constitute one of the most impressive volcanic regions of the world throughout almost their whole extent, and the Mesozoic sediments which enter so largely into their composition, are almost thoroughly masked by tuffs, ash beds, and lava flows. Many of the cones have only recently become extinct and many others are still feebly active. It seems conclusive that the ash beds found in the Eastern Andes at this and other localities in Bolivia came from eruptions in the Western range, where the nearest volcanoes to Pisllypampa are 250 miles to the west of that place.

THE FLORA AND ITS ENVIRONMENTAL CONDITIONS

The distribution of land and water during the late Tertiary could not have been sufficiently divergent from the present geographic pattern to have altered the atmospheric circulation, which, if it is different today in this region, as seems improbable, is the result of orogenesis. The ashes that came to rest at Pisllypampa need not have come from the nearest volcano but may have come from the Chilean volcanoes if the winds were southwesterly or from the Peruvian volcanoes if they were northwesterly. These winds would presumably be dry winds on reaching the Cochabamba region since I should say that some sort of a divide antedates the time of deposition of these deposits, and the moisture bearing winds were the easterly trades as they are at the present time.

Hence Pisllypampa was, in Pliocene time, a region with a wet summer and a less wet but not cold winter season, the former extending approximately from September to May. That the ash beds alternating with the lignite seams do not indicate consecutive seasons is shown by the thickness of the lignite which could scarcely have accumulated during a single summer. I regard the deposit as one of many years growth, the wind-blown ash beds indicating volcanic eruptions in the Western or Chilean Andes at intervals and when the prevailing winds were favorable for transportation to Pisllypampa. The ash in the waterlaid materials is easily explained by reworking during which it was more or less masked by silt and vegetable debris. It seems obvious also that there were no high peaks in the vicinity at this time in the Pliocene, but that the topography was one of maturity, otherwise there would be some trace of pebbles or gravel or sandstone, or resistant rock minerals, all traces of which appear to be entirely absent.

Our knowledge of the existing flora of Bolivia east of the Andes and in the sub-andean ranges is very incomplete. d'Orbigny's Voyage dans l'Amerique Meridionale contains many botanical observations and there is the Flora Crucena published by Peña at Sucre in 1901. Weddell described many plants from this region as a result of his Cinchona studies during the first half of the nineteenth century, and the enumeration of the Rusby and Bang collections resulted in extensive lists of species.

The only modern ecological treatment of this flora is in the important paper by Herzog[1] published in 1910. This has proved to be very helpful, but Herzog's stay in the country was short and the identified material which he collected included only about 600 species of vascular plants, which probably represent less than 10 per cent of the whole flora. Moreover he did not visit the most interesting part of Bolivia, namely the Yungas, lying east of the Cordillera Real and north of the Sierra de Cochabamba, which is the region of most importance in studies of the Tertiary floras of the Andean region.

The systematic enumeration of the Rusby and Bang collections contains a wealth of information, but the arrangement is systematic and not geographical, the localities are not given with sufficient precision, nor are the altitudes reported in many instances, so that in the particular features most significant for an interpretation of the Pisllypampa fossil flora, the data are wanting.

The total number of recognizable forms at Pisllypampa is limited to 20 species. It is unfortunately true that in collecting from difficult and inaccessable localities such as Pisllypampa one is very much limited for time and the collections will be as a rule correspondingly poor. At the same time, in describing materials from such remote Andean localities that may never be visited again, it has seemed important not to ignore the most fragmentary material if it was at all capable of yielding any information. This is my reason for attempting the identification of some specimens, which, if they had come from the United States, I would have lain aside and waited for subsequent collections of more complete material.

The twenty species recognized include three ferns, two monocotyledons and fifteen dicotyledons. The most abundant individually are the fern species of Goniopteris, the moraceous species of Coussapoa and the fruits of Saccoglot-

---

[1] Herzog, T., Pflanzenformationen Ostbolivias. Engler's Bot. Jahrb. Bd. 44, pp. 346-405, 1910.

tis. The three ferns represent the two families Polypodiaceæ and Gleicheniaceæ, and all three are familiar types of the Yungas region of Bolivia at the present time. The monocotyledons represent the two striking and familiar types of the South American tropics—the wild banana (Heliconia) and the Iriartea palm (Iriartites).

The dicotyledons comprise the eight orders Urticales, Chenopodiales, Ranales, Rosales, Geraniales, Thymeleales, Myrtales and Ebenales, and possibly the Sapindales. The largest of these orders is the Rosales with four species of Mimosaceæ and Cæsalpiniaceæ and the Geraniales with one species each of the four families Rutaceæ, Burseraceæ, Humiriaceæ and Meliaceæ. There are two species of Sapotaceæ and one each of the families Moraceæ, Nyctaginaceæ, Anonaceæ, Lauraceæ, Myrtaceæ, and possibly the Sapindaceæ.

The genera of dicotyledons represented are Coussapoa, Pisonia, Anona, Cassia, Pithecolobium, Pilocarpus, Saccoglottis, Protium, Mespilodaphne, Myrcia, Sideroxylon, Chrysophyllum, and Cedrela or Sapindus. All of these are characteristic forms of the warmer parts of South America. The fossil flora is essentially modern in facies and typically South American. The accompanying table shows the most closely related existing species with their occurrence and habitat.

The modern species most similar to the fossil forms where these can be definitely ascertained and located geographically, occupy regions where the rainfall varies between 20 and 80 inches per annum. The majority of these exist under conditions approaching this maximum more nearly than the minimum. This is shown not only by the genera that are represented, but by the individual character of the leaves, some of which are large in size and mesophytic in structure, thus denoting humid conditions. Moreover they are nearly all types which extend to regions which experience a summer and fall rainy season, and a dry winter and spring during which many of the trees shed their leaves. Great observed variation in this respect depends upon the particular situation and topography. Thus east of Cochabamba in the Sierras, leaf fall is noticeable in the winter season, whereas north of Cochabamba in the true Yungas the valleys were humid and moist and largely evergreen during the winter that I visited them. Under the last mentioned conditions the prominent elements in the vegetation with the possible exception of the palms, reached notably higher altitudes than was the case east of Cochabamba.

There is probably no region where detailed studies of the relations of life to the climatic and topographic environment would prove more interesting and instructive than east of the Cordillera Real in Bolivia. With such a body of facts available for comparison it would be possible to attain a much greater degree of precision in the interpretation of the fossil floras of the Andes.

There can be no question but that the closest approach to the botanical character of the present fossil flora and to the climatic environment under which it existed are to be found at the present time in the Yungas north of Cochabamba at altitudes under about 5,000 feet. The annual precipitation is something that cannot be precisely evaluated since the question of humidity is a modifying factor of such great importance. The bulk of the fossil plants represent modern forms which extend from the moist tropical lowlands into the humid mountain valleys where rain may not fall from April to September. I should say that those found fossil at Pisllypampa indicate humidity and a consequent growing season throughout at least nine months of the year, and an annual precipitation of between 40 and 80 inches.

AGE OF THE FLORA

There is no direct method of determining the precise age of the Pisllypampa flora. The deposits in their stratigraphic position are post Silurian and preglacial. The fact that the deposits are largely volcanic ash stamps them rather definitely as having been formed at some time in the late Tertiary.

The flora itself, in its close relationship with that still existing at lower and more humid levels in the same general region, also points to a relatively modern age.

There are three known Pliocene floras in Bolivia for comparison. These are the partially described floras found at Potosi and at Corocoro,[2] and a third of limited extent and described in the following contribution. Earlier South American fossil floras are those from the Miocene of Chile,[3] Peru,[4] Ecuador,[5] Colombia [5] and Venezuela.[6]

The last five floras just mentioned are of slight value since all are considerably older than the Pisllypampa flora. The most important for comparative purposes are those of Potosi and Corocoro. The latter contain a large number of types that are closely related to existing forms of the Amazon Basin and montaña zone of the sub-andean slopes, more particularly among the Leguminosæ. They abound in forms with compound leaves of small leaflets, and clearly denote somewhat different climatic conditions from those indicated by the Pisllypampa plants. In my preliminary account of the Potosi and Corocoro floras my conclusions, which were based upon the extant botanical literature and before I had seen the region, are subject to certain modifications resulting from my field studies, and these will be fully discussed in a separate contribution.

The Potosi and Corocoro floras denote more arid, or at least drier, conditions than does the Pisllypampa flora—not of course the aridity and cold of present day Potosi, but con-

---

[2] Berry, E. W., Proc. U. S. Natl. Mus., vol. 54, pp. 103-164, pls. 15-18, 1917.

[3] Engelhardt, H., Abh. Senck. Naturf. Gesell., Bd. 16, pp. 629-692, pls. 1-14, 1891.

[4] Berry, E. W., Proc. U. S. Natl. Mus., vol. 55, pp. 279-294, pls. 14-17, 1919.

[5] Engelhardt, H., Abh. Senck. Naturf. Gesell., Bd. 19, pp. 1-47, pls. 1-9, 1895.

[6] Berry, E. W., Proc. U. S. Natl. Mus., vol. 59, pp. 553-579, pls. 107-109, 1921.

ditions more like those found at the present time east of Cochabamba at elevations below 6,000 feet. From a consideration of all of the available facts I conclude that the Pisllypampa flora is of Pliocene age and probably slightly older than that found at Potosi. The difference in age I regard as slight, and the observed differences in the two floras are those that can be almost entirely explained by slight differences in altitude and somewhat greater differences in humidity.

A flora of about the same age as that of Pisllypampa is known from several localities in the state of Bahia, Brazil. This was partially worked up by Ettingshausen, but never completed.[7] Considerable collections made from these localities by Branner and others are being elaborated by Hollick and the present writer, but this work has not progressed far enough for discussion, although there are some similarities shown to the Pisllypampa flora despite their geographical remoteness.

AMOUNT OF ANDEAN UPLIFT INDICATED

If the Pliocene age of the Pisllypampa flora is established, as I regard it, and it can be determined within reasonably accurate limits what is the upper limit of range of an almost identical modern plant assemblage, the result will be a fairly reliable measure of the amount of uplift to the present altitude of 11,800 feet since some time in the Pliocene.

A consideration of the accompanying table shows that altitudinal information is lacking in the case of eight of the twenty species, and this information is inexact in the case of six additional forms. There are, however, no forms represented which normally reach great altitudes, except the cassias which could equally well represent low bushes of high altitudes or bushes of arid climatic conditions or trees of

---

[7] Krasser, F., Sitz. k. k. Akad. Wiss. Wien, Bd. 112, pp. 852-860, 1903.

Fossil species	Existing species	Habitat	Upper limit of altitude
Goniopteris cochabambensis	Goniopteris (Dryopteris) spp.	montaña of Peru and Bolivia	7500 ft. (?)
Filicites elaphoglossoides	Elaphoglossum villosum	Ditto	8800 ft. (?)
Gleichenia pectinata fossilia	Gleichenia pectinata	Yungas of Bolivia	7000 ft.
Heliconia tertiaria	Heliconia spp.	Ditto	7000 ft.
Iriartites boliviensis	Iriartea spp.	Ditto	5200 ft.
Coussapoa pliocenica	Coussapoa spp.	Ditto	(?)
Pisonia pliocenica	Pisonia spp.	Ditto	(?)
Anona cochabambensis	Anona acutiflora	Brazil	(?)
Pithecolobium palcanum	Pithecolobium spp.	Yungas of Bolivia	4875 ft. (?)
Cassia pisllypampensis	Cassia spp.	Ditto	9000 ft.
Cassia coriacea	Cassia spp.	Ditto	9000 ft.
Cassia palcana	Cassia spp.	Ditto	9000 ft.
Pilocarpus bolivianus	Pilocarpus spp.	Matto Grosso, Brazil	(?)
Protium fossilium	Protium heptaphyllum	Venezuela to Paraguay	(?)
Saccoglottis tertiaria	Saccoglottis, Humiria & Vantanea	Amazon basin	not far above sea level
Mespilodaphne boliviana	Mespilodaphne spp.	Ditto	(?)
Myrcia pliocenica	Myrcia spp.	Ditto	5000 ft.
Sideroxylon pliocenicum	Sideroxylon spp.	Brazil	(?)
Chrysophyllum crassum	Chrysophyllum spp.	Ditto	(?)
Undetermined	Cedrela spp., Sapindus spp.	Yungas of Bolivia	2500 ft. (?)

lowland warm humid regions. Since all of the other members of this flora belong to the last type of plant association, it is to be presumed that the same is true of the cassias.

There are then no montane types represented, although most of the forms are what a modern botanist would call sub-andean—meaning thereby the belt of country with warm temperatures and a heavy rainfall that is characteristic of the eastern slopes of the Cordillera Oriental from central Bolivia northward, and which goes by the name of the montaña, of which geographic belt the Bolivian Yungas are a special province.

All of the Pisllypampa species are types that it would be perfectly proper to designate as tropical. There is, however, nothing to prevent such an assemblage of tropical types from being perfectly at home in the sub-tropical altitudinal zone. The determination of the probable upper limit of the latter zone and the difference between it and 11,800 feet will give the minimum amount of change of level that has occurred at Pisllypampa since the fossil flora was buried by the volcanic ash.

Commencing with Humboldt's classic zones of vegetation I think that botanists have rather generally underestimated the ability of most plants to live at high altitudes where temperatures were not absolutely prohibitive and where moisture or wind become the important limiting factors.[8] Certainly in the Bolivian Yungas such types as Heliconia, Melastomataceæ, Piperaceæ, etc., extend much higher than I expected to find them. The only conspicuous forms that seemed to me to fail to surge upward were the palms, and I would be inclined to attach considerable weight to the presence of the latter at Pisllypampa as indicative of an al-

---

[8] I have found the discussion of zones in Chapman's "The Distribution of Bird-Life in Colombia" the most satisfactory and instructive of any contributions, either general or special, that I have consulted. Bull. Am. Mus. Nat. Hist., vol. 36, 1917.

titude of not over about 5,000 feet.[9] This elevation also corresponds approximately to the present upper limit in this latitude of Pithecolobium, Sapindus, Myrcia and Coussapoa. Saccoglottis, so far as I know, does not reach this altitude. Moreover all of the Pisllypampa forms are lowland tropical types that reach to these altitudes under favorable environmental conditions and which are normally present in great force at much lower levels.

It seems to me therefore, that the indicated change of level since this fossil flora was living could not have been less than 6,500 feet, and that there is no negative evidence that it may not have been as much as 9,000 feet.

DESCRIPTION OF THE FOSSIL PLANTS

Phylum Pteridophyta

Class LEPTOSPORANGIATÆ

Order POLYPODIALES

Family POLYPODIACEÆ

Genus GONIOPTERIS Presl

Goniopteris cochabambensis Berry, sp. nov.

PLATES I and II

Fronds of large size, probably bipinnate; with a stout, prominently winged rachis at least 5 mm. in maximum width. Pinnæ alternate, shortly stipitate, linear-lanceolate in outline; at least 15 cm. in maximum length and 1.5 cm. to 2 cm. in maximum width. Pinnæ pinnatifid, separated by acute sinuses reaching from 1/2 to 2/3 of the distance to the rachis, into inequilateral segments which vary from a broadly rounded to a more or less conical shape, the latter appearance heightened by the more or less revolute margins. Margins entire. Texture coriaceous, resulting in the venation appearing much stouter than it really is in the material preserved as

---

[9] I have found low palms such as Geonoma and Chamædorea somewhat higher than 5000 feet in the Yungas.

impressions. Well marked slightly curved lateral veins diverge from the stout, margined midvein of the pinnæ alternately, at obtuse angles (approximately right angles), and terminate at the tips of the bluntly pointed, pinnatifid segments, of which they constitute the midribs. These give off alternately, and approximately equally spaced, sub-parallel veinlets, which are curved and invariably simple. There are from 12 to 15 pairs of these veinlets in the sterile pinnæ; their spacing diminishes regularly toward the tip of the segment and all but the basal two or three pairs terminate in the free margin of the segment. The two or at most three basal pairs are slightly more curved than the rest and unite with the corresponding two or three basal pairs from the subjacent and superjacent lateral segments to form a short straight ray which terminates at the head of the sinus that separates the segment from its adjacent fellows. The fertile pinnæ are somewhat narrower than the sterile, relatively shorter and broader, with more conical pinnatifid divisions, separated by sinuses extending about half way to the rachis. The venation is identical with that of the sterile pinnæ but the veins are fewer in number (8 to 10 pairs). Each veinlet bears about half way between its base and apex a relatively large circular sorus. The sori decrease in size distad and are situated nearer the base of the veinlet, so that the curved line of sori form one arc of a lens which is a counterpart of the arc formed by the margin of the segment.

The present form is a type that agrees in most particulars with various Tertiary species which have been referred by paleobotanists to the more or less interrelated and synonymous genera Lastrea, Phegopteris and Goniopteris. It is a type met with in existing, mostly tropical ferns, that are variously segregated or aggregated in the genera Lastrea, Nephrodium, Phegopteris, Polybotrya and Dryopteris (Aspidium). The existing species of Dryopteris number, according to Christensen, upwards of one thousand species, which this author segregates in ten subgenera. Most of these are, in my judgment, of generic rank, and the present fossil species appears to be referable to the ninth of Christensen's groups—the genus Goniopteris of Presl.

The genus Goniopteris comprises about 60 existing species, largely confined to the American tropics, but said to be sparingly represented in Africa, Asia and Australia. Among previously described fossil forms the present species appears to be most similar to *Goniopteris claiborniana* Berry [10] from the late middle Eocene of Mississippi and Louisiana (Yegua formation), differing in the degree of incision of the margin and in the less complex venation, but identical in general form, habit, winged rachis, etc. The Bolivian species is, however, thicker textured. Entirely too little is known of the ferns of the eastern Bolivian lowlands or of the upper Amazon basin to enable me to make proper comparisons with the existing species in those regions, but I have not the slightest doubt that species, closely similar to the fossil, are present in the well watered and lower montaña country east of the present Andes, as I know that they are present in that general region.

The following are some of the existing species that are very similar to the fossil: the common *Dryopteris patens* (Desv.), widespread in the American tropics; *Dryopteris riparium* (Mor.), *Dryopteris gonylodes* (Schk.), *Dryopteris monostichum* (Kunze), *Phegopteris brachyodes* Mett., and *Phegopteris tetragona* Mett., all forms of the South American equatorial region. Other existing species in that region are probably closely related, since I have made no extended search in herbaria, nor have I sought to correct the obsolete nomenclature in the case of the forms cited. The fossil also resembles somewhat *Hemitelia grandifolia* Sprengel of the Antilles, northern Andes and northern Brazil in the form of the pinnæ and position of the sori, differing in venation in not having anastomosis confined to the extreme base of the

---

[10] Berry, E. W., Bull. Torr. bot. Club, vol. 44, pp. 331-335, pl. 22, 1917.

segments. The present species is exceedingly abundant in the wind-blown material. Fertile pinnæ are much less common than the sterile, and the relation of this æolian material to the waterlaid leaf-bearing clay is not certainly determinable since the material was collected from dumps of the old prospects which were flooded at the time of my visit. It appears to have come from below the upper lignite and to have had waterlaid material both above and below it.

Genus FILICITES Schlotheim

Filicites elaphoglossoides Berry, sp. nov.

PLATE VI—Fig. 4

This occurrence is based upon a tiny fragment of a simple pinnule or frond, evidently linear in form, with a stout midvein, entire margin, and numerous thin parallel straight simple lateral veins which diverge from the midvein at wide angles. In the absence of more complete material it is out of the question to attempt the generic determination of this fossil scrap, and it is therefore referred to the old form-genus Filicites proposed by Schlotheim.

There are a number of existing genera that suggest comparisons, namely Blechnum, Lomaria, Gymnogramme, Elaphoglossum, etc. Even with more complete material it would probably be impossible to determine which genus the fossil represented unless fructifications were preserved. Analogies suggest the genus Elaphoglossum Schott. as the most likely and this suggestion is embodied in the specific name chosen. The fossil suggests *Elaphoglossum simplex* of Brazil and *E. villosum* of Peru. The Modern species are numerous (the genus Acrostichum of authors) and are wide spread in rain forest regions of the tropics and subtropics. They are mainly American and occur also in the humid forested region of the northern Andes, and in the montaña zone of the Eastern Andes. In Peru *Elaphoglossum Jamesonii* attains altitudes of 8,800 feet, but theoretically at least the upper limit of the genus should be somewhat lower than this in the Yungas region of Bolivia.

Order GLEICHENIALES
Family GLEICHENIACEÆ
Genus GLEICHENIA Smith
Gleichenia pectinata fossilia Berry, var. nov.

PLATE VI—Figs. 1, 2

I only succeeded in finding a single pinnule of this fern and therefore can say nothing conclusive regarding the habit, nor of its positive relationship with the existing and wide ranging *Gleichenia pectinata* Presl[11] of South America. In size, general form and venation the fossil pinnule is absolutely identical with the pinnules of the existing species, as may be seen in the accompanying figures. The pinnule is 17.5 mm. in length by 3 mm. in maximum width, entire margined, and bluntly pointed. The margins are slightly revolute, and the pinnule was borne at nearly right angles to the rachis. The midvein is relatively very stout and prominent, and curves upward slightly distad. It gives off alternately about 20 to 22 well marked veins which immediately fork once and then proceed straight to the margins. Exact data relative to the geographical and altitudinal range of the existing species are incomplete. I have collected it in the Yungas region of Bolivia in the narrow moist valleys at altitudes slightly over 7,000 feet and within 9 miles of the iceclad peaks of the Cordillera Real.

Angiospermophyta
Class MONOCOTYLEDONÆ
Order SCITAMINALES
Family MUSACEÆ
Genus HELICONIA Linné
Heliconia tertiaria Berry, sp. nov.

PLATE III—Fig. 1

Leaves of relatively small size, oblong in form, slightly tapering to the acute tip, rounded truncate at the base, of a

---

[11] This variable species is now commonly referred to the genus Dicranopteris Bernh.

coriaceous texture, and with an entire margin except where mechanically split. Indicated length about 33 cm. Maximum width, which is below the middle of the leaf, about 7.5 cm. Midrib stout, circular in cross section, prominent on the under side of the leaf. Venation of closely spaced, relatively stout, simple laterals, which diverge from the midrib at angles of about 75 to 80 degrees, and proceed with but slight curvature to the lateral margins. Petiole presumably long and stout.

This well marked species is unfortunately represented by a single specimen which was somewhat broken in transit. It occurs in the water laid part of the section and obviously represents a leaf of Heliconia—the American wild banana. The relationship is clear and I can see no reason for using the generic term Musaphyllum, which latter is open to objection in this connection since it indicates or at least suggests an unwarranted degree of affinity to the existing genus Musa which is not borne out by the geological history of the family.

This is another one of the species found fossil at this locality that serves to ally this fossil flora with the existing Yungas flora of eastern Bolivia. I did not penetrate far enough toward the Amazon plain to observe the changes in flora below elevations of 5,000 feet, nor are travellers' accounts detailed enough to be of much value. The geologic interest centers in the possible upper limits of the tropical and sub-tropical forest. In the humid valley of the Rio Undavi I found Heliconia associated with tree ferns, peppers, gleichenias and giant cannas up to elevations of 7,000 feet. Weberbauer gives 5,850 feet as the upper limit of Heliconia in southern Peru, which is nearer the equator. This may be an excessively low figure but on the other hand warm types, for some unknown reason, appear to range to greater elevations in the Yungas than they do farther north. Heliconias are commoner, however, at somewhat lower levels than those cited above so that in the latitude of Pisllypampa one would

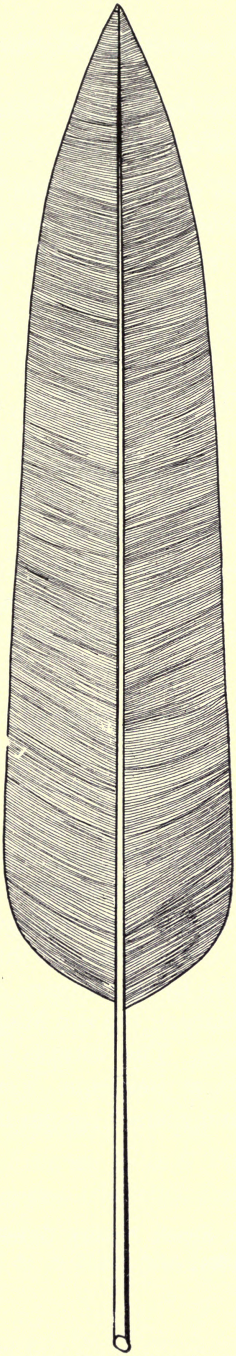


Fig. 2. Heliconia tertiaria Berry, Pisllypampa, **Bolivia.**

perhaps be justified in considering about 5,500 feet as an average for the normal upper limit.

The genus Heliconia contains between 30 and 40 existing species which are confined to the American tropics, where they range from the West Indies to Brazil, being especially common in the rain forests of Central America and in the montaña region of the Eastern Andes from the Yungas of Bolivia northward to the Caribbean. Fossil Musaceæ have been invariably referred to the genus Musaphyllum since Gœppert proposed that name in 1854 for a fossil form from the Tertiary of the Island of Java. Over a dozen fossil species have been recorded, of which the majority are from European localities. These appear to represent the genus Musa, which appears to have invaded Europe from Central and Eastern Africa during Oligocene times and continued their existence on the former continent to the close of Miocene times.

Fossil forms that have been referred to Musaphyllum are widely distributed in the present Rocky Mountain region of North America in the earlier Eocene although none have as yet been detected in the Tertiary deposits of the Atlantic or Gulf Coastal Plain. I consider that these North American forms probably represent the genus Heliconia, which in addition to the present fossil species I have recently recorded from the Miocene of Costa Rica. A third fossil species of Heliconia is represented by the remains described by Engelhardt[12] from the Tertiary of the Rio Magdalena in Colombia as *Musaphyllum elegans*. This form is also present in probably Miocene deposits at Betijoque, Venezuela, and represents a much larger and coarser species than the form under discussion.

---

[12] Engelhardt, H., Abh. Senck. Naturf. Gesell., Bd. 19, p. 25, pl. 4, figs. 1-3; pl. 5, fig. 1, 1895.

Order ARECALES

Family ARECACEÆ

Genus IRIARTITES Berry

Iriartites boliviensis Berry, sp. nov.

PLATE III—Fig. 2

This species is based upon the broken rays of a feather palm and scarcely deserves to be dignified with a specific name. Since, however, it is distinct from the other known species of Iriartites, and comes from so remote a region that more complete material can scarcely be expected to turn up in the future, it is deemed less clumsy to name it than to be obliged to refer to it as Iriartites sp. It may be partially described as follows: Rays linear-lanceolate, long and relatively narrow—the widest seen not being over 3.2 cm. in width. Keels not especially prominent, traversed by a relatively thin primary vein. Lateral veins thin but prominent, closely spaced, parallel, about four to a millimeter. Some of these laterals appear to have been slightly stouter than others but this may be due entirely to the preservation, since in the impressions the interspaces simulate coarse veins. Texture coriaceous. The remains are common enough throughout the clays, but are much broken. They afford the evidence of a perfectly logical element in the plant association found fossil at this locality, and one that is of importance in any discussions of the environment in which this flora lived.

The genus Iriartites was established for the remains of a palm found in the Miocene of northern coastal Peru a short distance south of Tumbez.[13] The only other known species is based upon characteristic Iriartea-like fruits from the Gatun formation (Miocene) of the Panama Canal Zone. The existing genus Iriartea Ruiz & Pavon, which gives its name to the fossil genus Iriartites, contains an unknown

---

[13] Berry, E. W., Proc. U. S. Natl. Mus., vol. 55, p. 285, pl. 14, 1919.

number of species ranging from Costa Rica through Colombia over the Orinoco and Amazon basins and extending southward east of the Andes along the headwaters of the Amazon system to Bolivia. It is common in the Yungas region and elsewhere in eastern Bolivia.

D'Orbigny many years ago described the magnificent palms in the Yuracare country around the headwaters of the Rio Chapare and Rio Chipiriri, some 150 kilometers northeast of Cochabamba, or about 75 miles northeast of Pislly-pampa. These occur at elevations of from 3,000 to 5,000 feet and comprise Iriartea along with other palms, and such other genera as Erythrochiton, Heliconia, Costus, Schmidelia, Erythrina, Psychotria, Cordia, Ficus, Hiraea, Pithecolobium, Blechnum, and various additional Leguminosæ and Lauraceæ. Eastward from Cochabamba the country is at present somewhat drier than to the northward, and in the former region one encounters what is largely brush vegetation on the mountains and forest in the valleys below about 5,200 feet. *Iriartea exorrhiza* and *Iriartea phæocarpa* are not uncommon below this altitude in the country between Cochabamba and Santa Cruz de la Sierra.

A magnificent but undescribed fossil species of Iriartites occurs in the lower Miocene (coal measures) of southern Chile (Concepcion-Arauco district).

Order URTICALES

Family MORACEÆ

Genus COUSSAPOA Aublet

Coussapoa pliocenica, Berry, sp. nov.

PLATES IV and V

Leaves ranging from small to large size, ovate-cordate in general outline, widest medianly, tapering upward to the bluntly pointed tip and downward to the cordate and often slightly perfoliate base. Margins entire, slightly undulate in the apical half of the leaf. Texture coriaceous, the lower surface appearing as if villous in life. Length ranging from 2.5 cm. to 16 cm. Maximum width ranging from 1.9 cm. to 10 cm. These leaves are very common at Pisllypampa and the usual size is about 13 cm. in length by 8.5 cm. in maximum width. The extremes of size as given above are considered as variants, or in the case of the very small forms as juvenile or reduced leaves in proximity to floral organs. Petiole stout, its length undeterminate, forming an angle with the lamina. Midrib stout, prominent on the lower surface of the leaf. A lateral primary diverges from the midrib on either side at the extreme base at an angle of about 60 degrees, curving immediately upward and ascending rather straightly to, or slightly above the middle of the leaf, where it joins a lateral branch from the lowest secondary. Secondaries stout and prominent, 6 or 7 opposite to alternate pairs diverge from the midrib at regular intervals, at angles of about 50 to 55 degrees, curving upward, sub-parallel, abruptly camptodrome close to the margins. There is a considerable interval between the basal primaries and the lowermost secondaries. The lateral primaries send off on the outside at regular intervals sub-parallel secondaries which are abruptly camptodrome close to the margins. The basal secondaries send off laterally near their tips, three or four similar camptodrome tertiaries. The normal tertiaries, which are prominent on the lower surface of the leaf, are at approximately right angles to the veins which they connect; they are simple or branched, at regular closely spaced intervals and are rather straight except in the sinuses formed between the secondaries and the midrib, where they are more curved; they are connected by thin, irregularly inosculating nervilles—the venation as a whole being characteristic of this genus.

I have figured several of the smaller leaves of this species. These may be short and broad, or longer and narrower without, however, departing from the general facies of the species.

These leaves are exceedingly abundant in matted layers in the water laid part of the section, and are exceedingly well characterized. I saw very many exceedingly handsome and complete specimens that I was unable to bring away with me because of the friable nature of the material. Other genera that have leaves which approach the fossil more or less closely are Gouania of the Rhamnaceæ, Lühea of the Tiliaceæ, and Hura of the Euphorbiaceæ, as well as other genera that it is needless to mention. None of these, however, are close enough to be considered in detail and the majority have toothed margins. I mention Gouania in particular since Engelhardt has referred to it [14] two species from the Miocene of Santa Ana in the Magdalena valley of Colombia. These have a very similar venation to that of the present species, as is true of a number of other existing Rhamnaceæ, but are smaller leaves with toothed margins. This resemblance to the smaller leaves of *Coussapoa pliocenica* is heightened by the tendency of the latter to break along the veins around the margins and thus to simulate toothing. The Pisllypampa leaves are, however, entirely distinct from those of Gouania.

The genus Coussapoa contains about 15 existing species of shrubs or trees that are confined to the Central and South American tropics. It is rather poorly represented in American herbaria, consequently I am unable to indicate the existing species that is most similar to the fossil. The Central American species that I have seen have pinnate secondaries, but certain South American forms are said to have basal lateral primaries, and they are incipiently developed in the only additional fossil species of Coussapoa which I described recently [15] from the Miocene of Venezuela. Engelhardt in

---

[14] Engelhardt, H., Abh. Senck. Naturf. Gesell., Bd. 19, pp. 33, 34, pl. 4, figs. 4-7, 1895.

[15] Berry, E. W., Proc. U. S. Natl. Mus., vol. 59, p. 563, fig. 2, pl. 108, figs. 1-4, 1921.

1891 referred[16] a fossil leaf from the lower Miocene of Coronel, Chile, to this genus but the material is very inconclusive and his identification is hence of doubtful validity. Typical forms are also present in the upper Miocene of the Isthmus of Tehuañtepec in southern Mexico, which will be described in the near future.

Order CHENOPODIALES

Family NYCTAGINACEÆ

Genus PISONIA Linné

Pisonia pliocenica Berry, sp. nov.

PLATE VIII—Fig. 1

Leaves of medium size, elliptical or obovate in general outline, shortly pointed or rounded at the apex, slightly decurrent at the base, widest in the middle, one side of the lamina often slightly wider than the other. Margins entire. Texture coriaceous. Length about 5 cm. Maximum width about 2.75 cm. Petiole relatively long, stout, curved, about 1.3 cm. long. Midrib stout, prominent on the lower surface of the leaf, slightly curved. Secondaries thin, about five opposite to alternate pairs diverge from the midrib at angles of from 45 to 50 degrees, and are camptodrome. The tertiaries are thin and partially immersed in the leaf substance, but are well marked, forming an open mesh internally, and characteristically disposed arches in the marginal region.

The present species is exceedingly like the existing widely distributed strand plant, *Pisonia aculeata* Linné. It is also very close to a number of other existing species which have been described from Brazil, but with an undetermined range. Among previously described fossil forms the present species

---

[16] Engelhardt, H., Abh. Senck. Naturf. Gesell., Bd. 16, p. 649, pl. 3, fig. 2, 1891.

approaches closely to *Pisonia eocenica* Ettingshausen[17] which is a common form in the Oligocene and Miocene of Europe.

The number of fossil forms of Pisonia now known is considerable. The genus appears in the Upper Cretaceous of both North America and Europe. There are three well marked species in the lower Eocene and one in the upper Eocene of southeastern North America. In Europe there are two Oligocene and four Miocene species and there is an American lower Miocene form found in Florida.

The existing species are numerous and occur in all the tropics. *Pisonia aculeata* is a strand plant but most of the species are largely represented in forests of the monsoon type. *Pisonia hirtella* H.B.K. ranges from Mexico to northern Argentina, others occur in Colombia. South of Ecuador the genus is confined to the region east of the Andes. The Eupisonia section of the genus, comprising shrubs and trees with elliptical coriaceous leaves, is largely developed in the Guiana highlands and in Brazil, *Pisonia nitida* Martius, *laxiflora* Martius, etc. The Pisllypampa fossil very probably represents this section of the genus.

Order RANALES

Family ANONACEÆ

Genus ANONA Linné

Anona cochabambensis Berry, sp. nov.

PLATE VIII—Fig. 4

Leaves of medium size, ovate in general outline, with a rounded base and a cuspidate apex. Margins entire, full and evenly rounded. Texture subcoriaceous. Length about 10 cm. Maximum width, in the lower half of the leaf, about 4.1 cm. Midrib stout, prominent on the under side of the leaf. Secondaries stout, regularly spaced, diverging from the midrib at wide angles, pursuing straight, subparallel

---

[17] Ettingshausen, C., Tertiarflora von Haering, p. 43, pl. 11, figs. 1-22, 1855.

courses, and abruptly camptodrome close to the margins. The tertiaries are immersed in the leaf substance.

Among existing species seen the present fossil is most like *Anona acutiflora* Martius of eastern Brazil, but this is without especial significance. The genus is large and is at present confined almost exclusively to tropical and subtropical America. The Chirimoya in numerous varieties is widespread in cultivation both in the montaña country and in the deeper inter-Andean valleys of Peru and Bolivia. I have seen it in gardens, as near Araca, Bolivia, at altitudes of 10,725 feet. Weberbauer gives its upper limit in Peru as 5,850 feet, which seems to me to be too low. There are other species of Anona in the Bolivian Yungas at present as in the past. It is rather curious that the characteristic seeds have not been preserved with the other forest litter at Pisllypampa. The present species is unfortunately represented by a scanty amount of material.

Order ROSALES

Family MIMOSACEÆ

Genus PITHECOLOBIUM Martius

Pithecolobium palcanum Berry, sp. nov.

PLATE VI—Figs. 7, 8

Leaflets sessile, nearly equilateral and broadly obovate in outline, with a rounded apex and a cuneate base. Margins entire, evenly rounded. Texture sub-coriaceous. Length about 3 cm. Maximum width, in the median region of the leaflet, about 1.5 cm. Midrib stout, prominent on the lower surface of the leaflet, slightly curved. Secondaries stout, largely immersed in the leaf substance; they are somewhat irregularly spaced, diverge from the midrib at angles of 45 degrees or slightly more, are relatively straight except in the marginal region, where they are camptodrome. What is discernable of the tertiary areolation is shown in the accompanying sketch twice natural size.

A considerable number of fossil species of Pithecolobium have been described within the past few years. The existing species number well over one hundred, all confined to the tropics, and many of them large trees widely planted for shade. Three-fourths are American, although there are about twenty forms known from tropical Asia, and a few in tropical Africa and Australia. In the present montaña region of eastern Bolivia the upper limit of their range appears to be about 1,500 meters, at which altitude one or more species are found along the head waters of the Rio Chapare, a few miles northeast of Pisllypampa, but at a much lower level, and also throughout the valleys in the Sierras between Cochabamba and Santa Cruz de la Sierra.

A distinct and somewhat smaller species is represented in the Pliocene tuffs at Potosi, Bolivia, and a second South American fossil species has been described by Engelhardt[18] from the Miocene of Colombia.

Family CÆSALPINIACEÆ

Genus CASSIA Linné

Cassia pisllypampensis Berry, sp. nov.

PLATE VI—Fig. 6

Leaflets sessile, inequilateral, obovate in form, widest above the middle. Apex rounded, mucronate. Base bluntly pointed. Margins entire. One side of the lamina is full and evenly rounded and the other is narrow and relatively straight margined. Texture coriaceous. Midrib mediumly stout, curved proximad. Secondaries thin, immersed; about six pairs diverge from the midrib at angles of about 50 degrees, ascending subparallel, and but slightly curved, ultimately camptodrome. Tertiaries obsolete.

This leaflet may be matched by various existing South American species, in fact I collected a species with similar

---

[18] Engelhardt, H., Abh. Senck. Naturf. Gesell., Bd. 19, p. 37, pl. 3, fig. 21, 1895.

leaflets at considerable elevations in eastern Bolivia which Dr. Britton considered as probably new to science. The genus is a large one in the existing flora, with upwards of 400 described species, and probably many additional and still to be described. It is found in the warmer temperate and tropical regions of all of the continents, and is especially abundant in tropical America. The Bolivian species are numerous, and several extend upward to altitudes of 11,000 feet in favorable situations in the montaña valleys.

There are also many described fossil species dating from the late Upper Cretaceous to the present. The Cassia pod associated with this and the following species of leaflet although described under a separate name, may represent the fruit of this or the following species.

Cassia coriacea Berry, sp. nov.

PLATE VI—Fig. 5

Leaflets small, sessile, elliptical in form, nearly equilateral in outline, about equally rounded at the apex and base. Margins full, evenly rounded. Texture extremely thick and coriaceous. Length about 1.75 cm. Maximum width, in the median part of the leaflet, about 1.25 cm. Midrib stout, prominent, curved. Secondaries few, stout, remote; four or five camptodrome pairs diverge from the midrib at wide angles. The tertiaries are obsolete.

Only a single specimen was collected of this characteristic species which is entirely distinct from the other forms found at this locality. There is considerable resemblance to the Pliocene leaflets from Potosi, Bolivia, described by Engelhardt[19] as *Cæsalpinia gmehlingi,* but the two are not identical. The present fossil is similar to the leaflets of several existing species of Cassia of a variety of habitats.

---

[19] Engelhardt, H., Sitz. Naturw. Gesell., Isis in Dresden, 1894, abh. 1, p. 9, pl. 1, fig. 29.

Cassia palcana Berry, sp. nov.

PLATE VI—Fig. 11

A single broken pod of what is apparently some species of Cassia was collected at this locality and this may represent the fruit of one or the other of the preceding species based upon leaflets. This pod may be matched by those of numerous existing species in this same general region. It is linear lanceolate in form, strongly compressed, prominently margined, of resistant consistency, and prominently cross veined. It was probably long stalked and presumably pendulous, and is much like an unidentified existing species which I collected in eastern Bolivia. Length about 7 cm. Maximum width 12 mm.

Order GERANIALES

Family RUTACEÆ

Genus PILOCARPUS Vahl

Pilocarpus bolivianus Berry, sp. nov.

PLATE VI—Figs. 9, 10

The leaves in this genus may be reduced to one or two leaflets but are prevailingly even pinnate. The present fossil species was apparently of the last type. The leaflets are elliptical in general outline, widest in the middle and rapidly narrowing both distad and proximad to the equally pointed apex and base. Margins entire, full and evenly rounded. Texture coriaceous. Length about 7 cm. Maximum width about 3.75 cm. Petiolule wanting. Midrib stout and prominent, slightly curved. Secondaries stout and prominent, sub-parallel and camptodrome; 5 or 6 pairs diverge from the midrib at angles of over 50 degrees, they are at first relatively straight and then curve rapidly upward. The tertiaries are thin, but well marked on the under side of the leaflet, forming an open, prevailingly quadrangular areolation.

Only a single other fossil species of Pilocarpus is known and it comes from the lower Miocene of Coronel, Chile. It is somewhat similar to this Bolivian species, but is relatively narrower and longer, as well as older. It is quite probable that this Pliocene Bolivian species marks a stage in the withdrawal of the genus from the Pacific coast of South America which was brought about by the elevation of the mountains in the late Tertiary.

The existing species of Pilocarpus number about fifteen, and are small trees or shrubs, largely confined to the eastern provinces of Brazil, although one species reaches northward as far as Cuba, another to Colombia and a third extends southward as far as Uruguay. A fourth is present in the Brazilian provinces of Matto Grosso and Cujaba. How far toward the headwaters of the Amazon the genus may be represented at the present time is not known.

Family BURSERACEÆ

Genus PROTIUM Burm.

Protium fossilium Berry, sp. nov.

PLATE VII—Fig. 5

Leaflets medium sized, ovate in general outline, widest below the middle, tapering upward and acuminate tipped. Base abruptly cuneate-rounded, slightly decurrent. Margins entire, obviously, but not markedly indulate. Texture subcoriaceous. Length about 10 cm. Maximum width about 2.5 cm. These leaflets are distinctly inequilateral, especially proximad—the outer basal margin being twice as far from the midrib as the inner, and rounded although the latter is almost straight. Petiolule wanting. Midrib thin, prominent, straight. Secondaries well marked, numerous, at regular intervals and subparallel except in the constricted base on the inner (upper) side of the lamina; they diverge from the midrib at wide angles, and are camptodrome in the marginal region.

The present specimen is obviously the leaflet of a compound leaf and I have compared it with various Leguminosæ, Simarubaceæ, Sapindaceæ, Meliaceæ, etc., families likely dividuals have been found growing in southern Trinidad. The tree has never been recorded from Colombia, Central America, or the Pacific Coast, but I collected characteristic fruits in the sea drift of Panama Bay, so that this species evidently grows somewhere in the Pacific water-shed of Central or northern South America.

Their presence in the latter region and the finding of this well marked fossil species in the Pliocene of Bolivia suggests an American origin for the family, and that the single west African coastal species reached that region either by means of the equatorial counter current, or before the continental outlines had assumed their present form. As I have pointed out on a former occasion, there are a number of distributional facts which suggest that Guppy, in his admirable studies on distribution, has underestimated the possibilities of this line of travel. Although the main equatorial current might be expected to carry coastal types from the Old to the New World I see slight evidence of this having taken place, and there is considerable evidence of dispersal in the opposite direction. If the present Atlantic currents preclude effective dispersal in the tropics from west to east, then we are forced to assume that the late Tertiary oceanic circulation differed from its present arrangement.

The fruits of *Saccoglottis tertiaria* are present in the Pislly-pampa deposits in considerable abundance and in a good state of preservation. In so far as their reference to the Humiriaceæ is concerned they are identified with absolute certainty and they offer a striking contrast to the conditions that prevail today on this bleak and treeless pampa, 11,800 feet above sea level.

Order THYMELEALES

Family LAURACEÆ

Genus MESPILODAPHNE Nees

Mespilodaphne boliviana Berry, sp. nov.

PLATE VIII—Fig. 3

Leaves of large size, lanceolate in general outline, widest in the middle and acutely pointed at both ends, with entire margins and a coriaceous texture. Length about 14 cm. Maximum width about 3.25 cm. Petiole missing. Midrib stout, prominent on the under side of the leaf. Secondaries stout, about nine pairs; they diverge from the midrib at angles of about 45 degrees, sweep upward in long ascending sub-parallel curves, ultimately losing their individuality in gradually diminishing arches parallel with the margins. The tertiaries are immersed in the leaf substance.

This species, which is obviously new, is clearly lauraceous, and appears to me to represent the genus Mespilodaphne, although there is a possibility of it representing the allied genus Nectandra. It is unfortunately represented by a scant amount of material so that a final conclusion on this point is not possible.

There are a number of closely comparable existing forms in the flora of the upper Amazon basin. The genus, although represented in the modern flora of Africa, is largely American and appears to have originated in the Western Hemisphere.

Order MYRTALES

Family MYRTACEÆ

Genus MYRCIA De Candolle

Myrcia pliocenica Berry, sp. nov.

PLATE VII—Figs. 3, 4

Leaves of medium size, lanceolate in general outline, slightly falcate, widest in the middle and about equally acuminate at both the apex and base. Margins entire, slightly revolute. Texture coriaceous. Length 8 cm. to 9 cm. Maximum width about 1.75 cm. Midrib stout, prominent below. Secondaries stout, numerous, diverging from the midrib at angles of about 55 to 60 degrees, straight, their tips joined by a conspicuous marginal vein close to the margins. Tertiaries well marked on the under side of the leaf, forming an inosculating and distinctly myrtaceous areolation.

dividuals have been found growing in southern Trinidad. The tree has never been recorded from Colombia, Central America, or the Pacific Coast, but I collected characteristic fruits in the sea drift of Panama Bay, so that this species evidently grows somewhere in the Pacific water-shed of Central or northern South America.

Their presence in the latter region and the finding of this well marked fossil species in the Pliocene of Bolivia suggests an American origin for the family, and that the single west African coastal species reached that region either by means of the equatorial counter current, or before the continental outlines had assumed their present form. As I have pointed out on a former occasion, there are a number of distributional facts which suggest that Guppy, in his admirable studies on distribution, has underestimated the possibilities of this line of travel. Although the main equatorial current might be expected to carry coastal types from the Old to the New World I see slight evidence of this having taken place, and there is considerable evidence of dispersal in the opposite direction. If the present Atlantic currents preclude effective dispersal in the tropics from west to east, then we are forced to assume that the late Tertiary oceanic circulation differed from its present arrangement.

The fruits of *Saccoglottis tertiaria* are present in the Pislly-pampa deposits in considerable abundance and in a good state of preservation. In so far as their reference to the Humiriaceæ is concerned they are identified with absolute certainty and they offer a striking contrast to the conditions that prevail today on this bleak and treeless pampa, 11,800 feet above sea level.

Order THYMELEALES

Family LAURACEÆ

Genus MESPILODAPHNE Nees

Mespilodaphne boliviana Berry, sp. nov.

PLATE VIII—Fig. 3

Leaves of large size, lanceolate in general outline, widest in the middle and acutely pointed at both ends, with entire margins and a coriaceous texture. Length about 14 cm. Maximum width about 3.25 cm. Petiole missing. Midrib stout, prominent on the under side of the leaf. Secondaries stout, about nine pairs; they diverge from the midrib at angles of about 45 degrees, sweep upward in long ascending sub-parallel curves, ultimately losing their individuality in gradually diminishing arches parallel with the margins. The tertiaries are immersed in the leaf substance.

This species, which is obviously new, is clearly lauraceous, and appears to me to represent the genus Mespilodaphne, although there is a possibility of it representing the allied genus Nectandra. It is unfortunately represented by a scant amount of material so that a final conclusion on this point is not possible.

There are a number of closely comparable existing forms in the flora of the upper Amazon basin. The genus, although represented in the modern flora of Africa, is largely American and appears to have originated in the Western Hemisphere.

Order MYRTALES

Family MYRTACEÆ

Genus MYRCIA De Candolle

Myrcia pliocenica Berry, sp. nov.

PLATE VII—Figs. 3, 4

Leaves of medium size, lanceolate in general outline, slightly falcate, widest in the middle and about equally acuminate at both the apex and base. Margins entire, slightly revolute. Texture coriaceous. Length 8 cm. to 9 cm. Maximum width about 1.75 cm. Midrib stout, prominent below. Secondaries stout, numerous, diverging from the midrib at angles of about 55 to 60 degrees, straight, their tips joined by a conspicuous marginal vein close to the margins. Tertiaries well marked on the under side of the leaf, forming an inosculating and distinctly myrtaceous areolation.

This is a well marked form, of which the thick leaf substance has slacked and become dissipated since the collection was made. Represented by a scant amount of material.. It is of a type usually referred by paleobotanists to the allied genera Eucalyptus or Myrtus, in which so many species from the Upper Cretaceous to the present have been placed, and it is not very different from the widespread *Eucalyptus oceanica* Unger of the European Tertiary. I have compared it with all of the existing genera of Myrtaceæ and have come to the conclusion that it is indubitably a species of Myrcia. Among the existing species of this genus it is close to *Myrcia rostrata* De Candolle and *Myrcia acutata* Berg, both species of tropical Brazil, as well as to other existing species of the Amazon basin.

About 150 fossil forms have been referred to the Myrtaceæ, one-third at least having been described as species of Eucalyptus. At least half of these forms occur in the Cretaceous of all parts of the world, but especially throughout the Northern Hemisphere. They are especially well represented in North America, and the possibility that they are ancestral forms of Myrcia or Eugenia has already been pointed out.[20] Upwards of a score of fossil forms have been definitely referred to Myrcia. These include an Upper Cretaceous, six lower Eocene and a lower Oligocene species from the Mississippi embayment region. There are several in the Oligocene of Europe, one in the Miocene of Ecuador, several in the lower Miocene of Chile and one in the Pliocene of eastern Brazil.

The genus Myrcia is considered to comprise more than 400 existing species, and although this number may be too large, it is nevertheless one of the most important genera of American Myrtaceæ. It ranges from the West Indies and Mexico to Uruguay and Chile, and most of the species are massed in the South American tropics. There are several species in the

---

[20] Berry, E. W., Bot. Gaz., vol. 59, pp. 484-490, 1915.

Yungas of Bolivia a short distance northeast of Pisllypampa at lower elevations, as well as in the Sierra valleys between Cochabamba and Santa Cruz.

Order EBENALES

Family SAPOTACEÆ

Genus SIDEROXYLON Linné

Sideroxylon pliocenicum Berry, sp. nov.

PLATE VII—Figs. 1, 2

Leaves of mediumly large size, elliptical in general outline, widest in the middle and narrowing regularly to the shortly (abruptly) and equally acute apex and base. Margins entire, full and evenly rounded. Texture coriaceous. Surface polished. Length about 10 cm. Maximum width about 4.4 cm. Midrib stout, prominent on the lower surface of the leaf. Secondaries stout, prominent on the lower surface of the leaf, although more or less immersed in the leaf substance; fifteen or 16 sub-opposite to alternate pairs diverge from the midrib at wide angles of about 65 to 70 degrees; they are sub-parallel, at first straight, curving upward somewhat toward the margins, and eventually camptodrome. The tertiaries are well marked on the under side of the leaf, consisting of inosculating nervilles sub-parallel with the secondaries, forming irregular, laterally elongated meshes.

The venation is generally characteristic, as may be seen by comparing it with such remote forms as *Sideroxylon costatum* (De Candolle) Bentham & Hooker of Norfolk Island, and *Sideroxylon mastichodendron* Jacquin of southern Florida, the Bahamas and the Antilles. The present fossil is quite similar to *Sideroxylon putterlicki* Unger from the Miocene of Croatia, but is slightly more elongate and with closer spaced secondaries.

The genus Sideroxylon includes between 80 and 90 existing species of the tropical and sub-tropical regions, the majority of which (all but about 15) are Old World forms.

Engler segregates them in ten unnatural sections with impossible names. Their distribution includes tropical and South Africa, Madeira, Madagascar, Mauritius and Bourbon; India to Australia; New Zealand and Norfolk Island; the Sandwich Islands; southern Florida, the Bahamas and Antilles, and tropical South America to southwestern Brazil.

The genus is one of great interest since its distribution not only suggests antiquity, which is borne out by what little is known of the geological record, but also suggests that the genus represents at the present time the survivors of one of the formerly cosmopolitan and synthetic types of the family. The fossil record of forms specifically assigned to the genus Sideroxylon is meager, although other genera of Sapotaceæ, and particularly the form-genus Sapotacites, go back to Upper Cretaceous times.

The oldest forms referred to Sideroxylon are two species from the lower Eocene of the Mississippi embayment region.[21] There are four recorded species from the Oligocene of Central and southern Europe, and two or three species from the Miocene of southern Europe. The Bolivian fossil species, although fragmentary, is well marked.

Genus CHRYSOPHYLLUM Linné

Chrysophyllum crassum Berry, sp. nov.

PLATE VII—Fig. 6

Leaves of medium to small size, symmetrical-oval in outline, widest in the middle, narrowing equally distad and proximad. Base broadly cuneate. Apex abruptly acuminate. Margins entire, full and evenly rounded. Texture polished and coriaceous. Length about 6 cm. Maximum width about 3.2 cm. Petiole missing. Midrib stout and prominent. Secondaries mediumly stout, but largely immersed in the leaf substance and not nearly so prominent as might be inferred from the way they are outlined on the photograph; they

---

[21] Berry, E. W., U. S. Geol. Surv. Professional Paper 91, pp. 334-335, pl. 99, fig. 4; pl. 100, fig. 8, 1916.

diverge from the midrib at wide angles, averaging about 70 degrees, pursue rather straight outward courses, and are camptodrome in the marginal regions they are numerous, parallel, and approximately equally spaced. The tertiaries are obsolete by immersion.

This fossil species resembles a number of existing forms of Chrysophyllum in fact it is about the same size and shape as the only tropical American species of this genus that reaches Florida—namely *Chrysophyllum oliviforma* Lamarck. It differs from this species in the more numerous and more widely divergent secondaries.

I was at first disposed to compare this fossil form with the genus Clusia of the Guttiferæ, which is also abundant in tropical South America and ranges up the eastern Andean slopes to altitudes of 3,100 meters. Clusia leaves are still thicker than those of Chrysophyllum and tend to be larger, widest above the middle, and with blunt or rounded tips. The venation also shows differences.

The genus Chrysophyllum, with between 50 and 60 existing species, is tropical or sub-tropical, most of its forms being American, although it is represented in tropical Africa, southern Asia, Australia, and the Sandwich Islands, and in all tropical countries by the cultivated star apple, *Chrysophyllum cainito* Linné, a native of the West Indies. Ten fossil forms have been referred to this genus, all of which come from the European Tertiary except one, a not very convincing form, described by Engelhardt[22] from the Cenomanian of Saxony, a species from the Miocene of Colombia described by the same author,[23] and a third species described by the writer from the lower Eocene of the Mississippi embayment region.[24]

---

[22] Engelhardt, H., Naturw. Gesell. Isis in Dresden, Sitz. 1891, abh. 7, p. 98, pl. 2, fig. 15.

[23] Engelhardt, H., Abh. Senck. Naturf. Gesell., Bd. 19, p. 31, pl. 5, fig. 7, 1895.

[24] Berry, E. W., U. S. Geol. Surv. Prof. Paper 91, p. 335, pl. 100, fig. 7, 1916.

UNDETERMINED LEAFLET

PLATE VIII—Fig. 2

The fragment figured lacks diagnostic characters but it seems desirable to include it from among the many fragments that have been ignored in the present account of this flora, since it apparently represents a leaflet of a pinnate form that suggests either Sapindus or Cedrela. The leaflet is entire margined, coriaceous in texture, markedly inequilateral and conspicuously falcate-lanceolate in outline, with a sessile base, stout midrib, and immersed venation.

Species of Sapindaceæ are very common in the monsoon region of Bolivia, but I do not have any exact details regarding the range of Sapindus in this region. There are numerous existing species of Sapindus, and the wide ranging *Sapindus saponaria* occurs along streams in the Lomas region of coastal Peru and in the interandine valleys of that country. In Bolivia it is recorded by Herzog from altitudes up to 2,275 feet in the Santa Cruz Sierras east of Cochabamba, and it is also present northeast of Pisllypampa in the Rio Chimore country at low altitudes.

The genus Cedrela (Meliaceæ) comprises about ten existing species of large trees of the American tropics, ranging from Mexico southward to eastern Peru and Brazil. It is doubtless present in the existing flora of the Bolivian Yungas, although I know of no such records, and may be represented by the present fossil leaflet.

PLATE I

Goniopteris cochabambensis Berry.

Plate I

UNIV. OF
CALIFORNIA

PLATE II

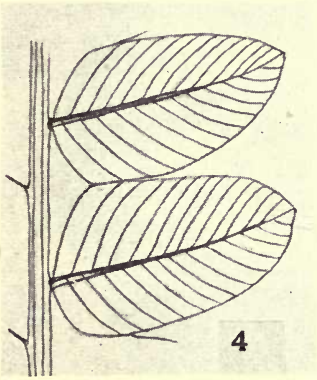
Goniopteris cochabambensis Berry.

Fig. 3. Showing fertile pinnæ.
Figs. 4, 5. Sterile and fertile segments, X 4.


1


2


3


4

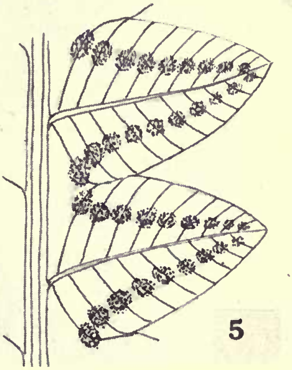
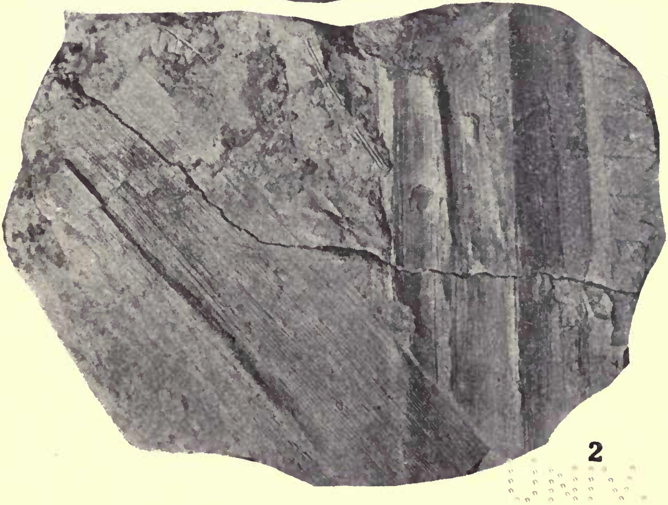

5

PLATE III

Fig. 1. Heliconia tertiaria Berry.
Fig. 2. Iriartites boliviensis Berry.

1



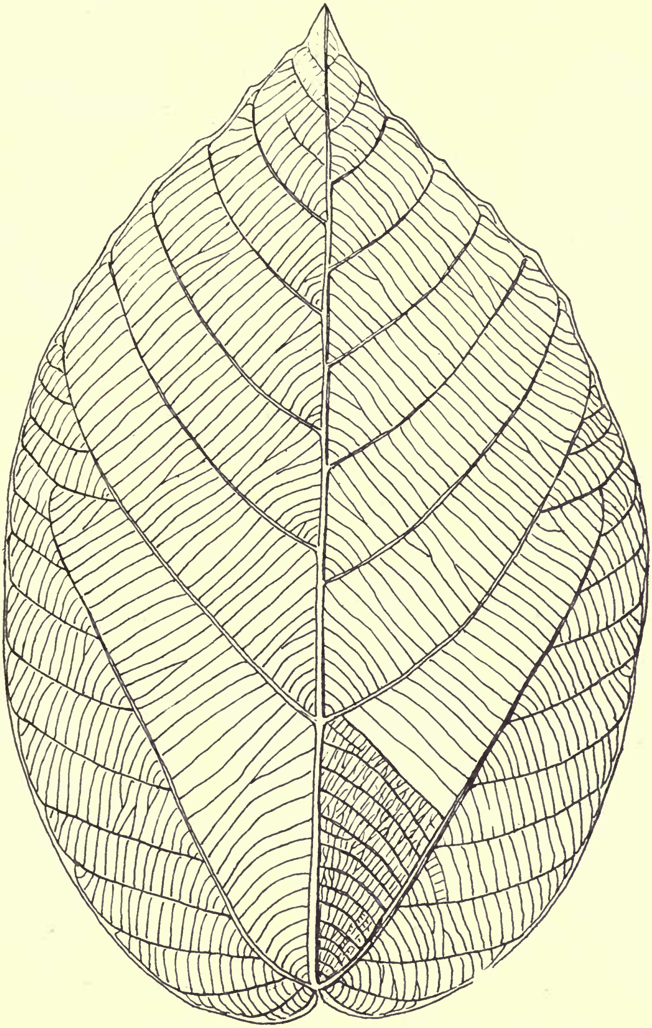
2

PLATE IV

Showing variations in leaves of Coussapoa pliocenica Berry.

PLATE V

Restoration of leaf of Coussapoa pliocenica Berry.

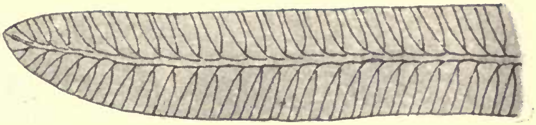


UNIV. OF
CALIFORNIA

PLATE VI

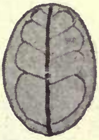
Figs. 1, 2.	Gleichenia pectinata fossilia Berry. Fig. 2. Enlarged twice to show venation.
Fig. 3.	Pinnule of Gleichenia pectinata Presl from the Yungas of Bolivia for comparison with fossil.
Fig. 4.	Filicites elaphoglossoides Berry, X 2.
Fig. 5.	Cassia coriacea Berry.
Fig. 6.	Cassia pisllypampensis Berry.
Figs. 7, 8.	Pithecolobium palcanum Berry. Fig. 8. Restoration enlarged to show venation.
Figs. 9, 10.	Pilocarpus bolivianus Berry. Fig. 10. Restoration, nat size, to show venation.
Fig. 11.	Cassia palcana Berry.

1



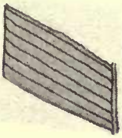
2

3

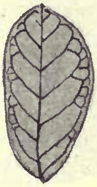


5

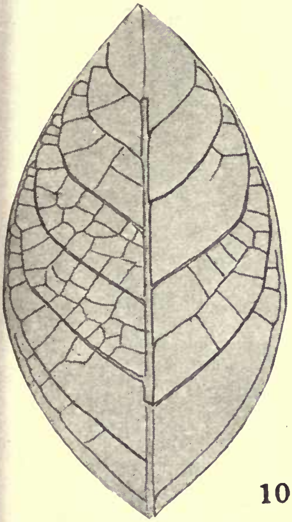
7



4

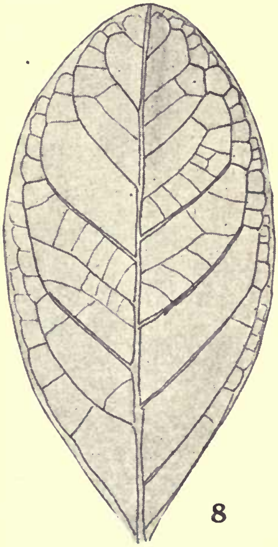


6

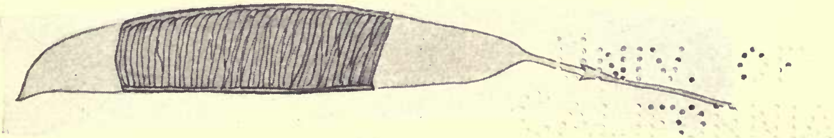


10

9



8

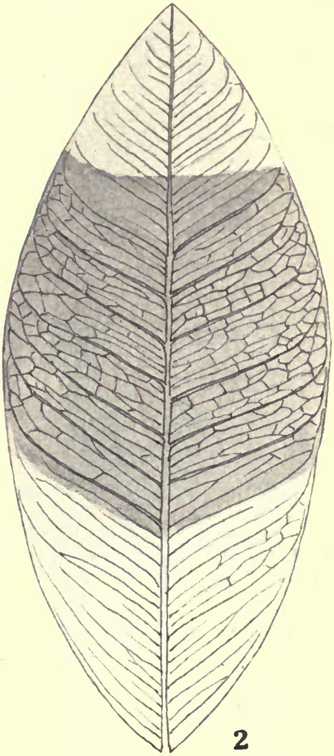


11

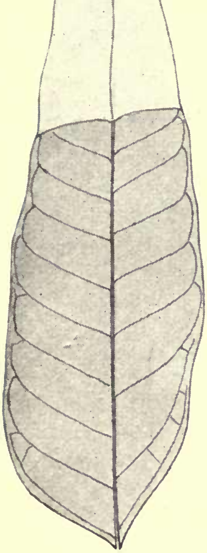
PLATE VII

Figs. 1, 2. Sideroxylon pliocenicum Berry.
Fig. 2. Restoration to show venation.
Figs. 3, 4. Myrcia pliocenica Berry.
Fig. 4. Restoration to show details of venation.
Fig. 5. Protium fossilium Berry.
Fig. 6, Chrysophyllum crassum Berry.


1


2


3


5

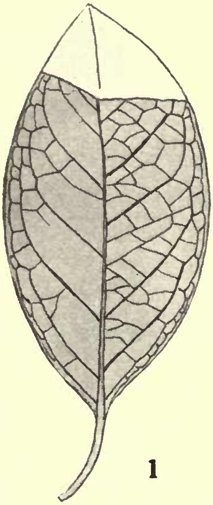

4


6

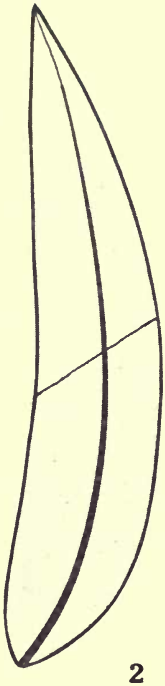
UNIV. OF

PLATE VIII

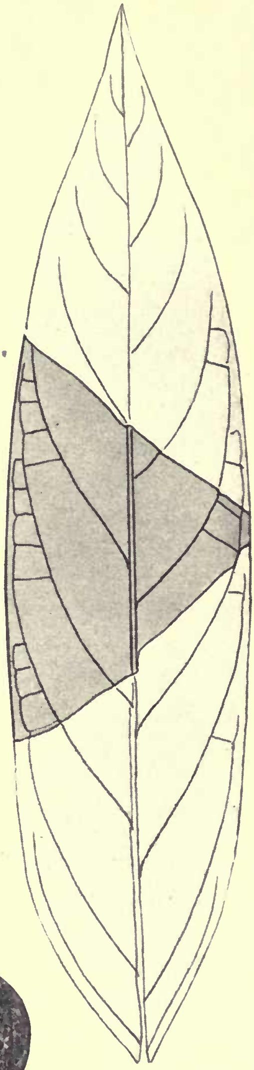
Fig. 1.	Pisonia pliocenica Berry.	
Fig. 2.	Undetermined leaflet, Sapindus or Cedrela.	
Fig. 3.	Mespilodaphne boliviana Berry.	
Fig. 4.	Anona cochabambensis Berry.	
Figs. 5-11.	Saccoglottis pliocenica Berry, all nat. size.	
	Figs. 5-7.	Lateral views of fruits lacking sarcotesta, showing resin cavities.
	Fig. 8.	Apical view of same showing resin cavities and outlines of seeds.
	Fig. 9.	A fruit retaining considerable of the sarcotesta.
	Fig. 10.	Seed in tangential view.
	Fig. 11.	Seed in side view.



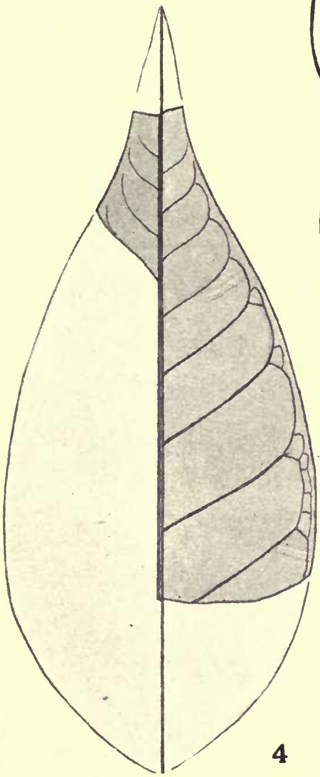
1



2



3



4

5

10

11

6

9

8

7

LATE TERTIARY PLANTS FROM JANCOCATA, BOLIVIA *

By Edward W. Berry

Description of the Locality

The fossil plants that form the basis of the present contribution were collected by M. Roman Kozlowski, formerly director of the Escuela de Ingenieros at Oruro, Bolivia. They were obtained at an altitude of about 12,675 feet on the Cerro Jancocata which is approximately 12 km. southeast of the town of Santiago in the province of Pacajes, the most westerly province of the Department of La Paz, Bolivia. This locality is 135 km. southwest of La Paz, 75 km. almost due west of Corocoro, and 445 km. northwest of Potosi.

The plant horizon is at (a) in the accompanying view of the locality and the section may be described as follows: The total thickness exposed is about 100 meters. The lower part consists of reddish clays with gypsum concretions, alternating with gray clays and some calcareous layers, the whole entirely unfossiliferous. The upper part of the series is predominately a kaolinized andesitic tuff, with some beds of sand and conglomerate. About midway in the upper part of the section is the white plant bearing tuff. The beds are all gently folded and were evidently deposited subsequent to the main folding of the Andes, although probably before the major elevation of the ranges. They are widely distributed in the provinces of Pacajes and Carangas and are considered to be fluvio-lacustrine by Kozlowski, although probably the more general term continental would be more appropriate.

The Jancocata beds are in part the equivalent of the so-called Mauri volcanic series of Douglas [1] and they may represent the uppermost of the three series at Corocoro named by

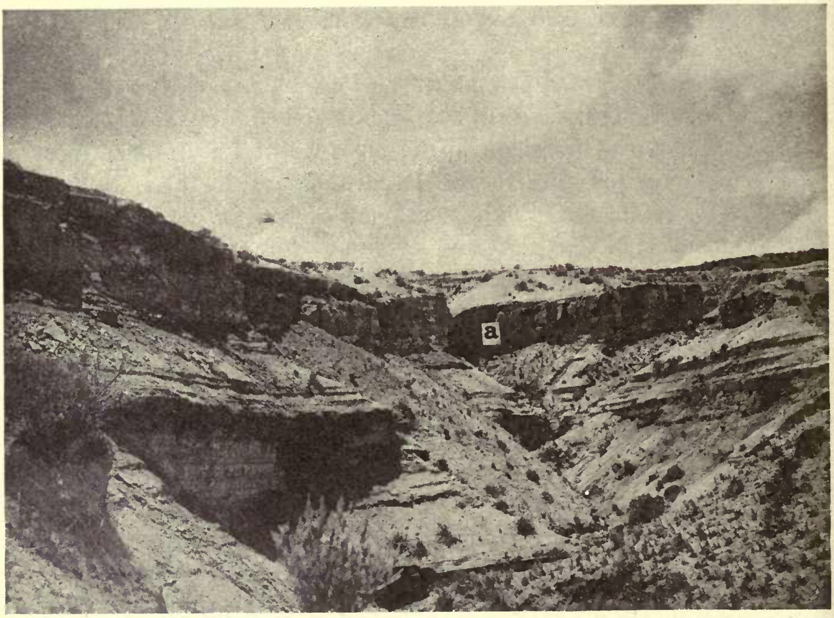
---

* George Huntington Williams Memorial Publication No. 19.

[1] Douglas, J. A., Quart. Jour. Geol. Soc., Lond., vol. 70, p. 23, 1914.

Singewald and Berry[2] the Desaguadero series. I saw no evidence of the former greater extent of Lake Titicaca in this region, although this is not improbable. The only raised strand lines that I saw anywhere in Bolivia were in the marginal hills of the Cordillera east of Lake Poopo.

I regard the Jancocata plant horizon as of approximately the same age as the beds near the Desaguadero River in the vicinity of Ulloma about 85 km. southeast of Jancocata, from which a considerable mammalian fauna has been described.[3]



Cerro Jancocata, Dept. La Paz, Fossil plant locality.

---

[2] Singewald & Berry, Johns Hopkins Studies in Geology, No. 1, p. 49, 1922.

[3] Philippi, R. A., Zeits. Deutsch. Geol. Gesell., Bd. 45, pp. 87-96, 1893. Pompeckj, J. P., Palæontographica, Bd. 52, 1905. Sefve, I., Geol. Inst. Univ. Upsala Bull., vol. 12, pp. 205-256, 1914; vol. 13, pp. 61-92, 1915.

This includes *Mastodon bolivianus, Megatherium sundti, Scelidotherium bolivianum, Macrauchenia ullomensis, Hippidium nanum* and *Parahipparion bolivianum.* The altitude of the Ulloma beds, which Pompeckj illadvisedly christened the Punaschichten, is 12,350 feet.

Sundt considered that the high plateau of Bolivia, the altaplanicie, had once been occupied by an immense lake extending from Cuzco, Peru to Lipez in southern Bolivia, formerly draining into the Pacific, but subsequently into the Atlantic through the cutting back of the La Paz River. There is not a particle of evidence for this interpretation.

AGE AND ENVIRONMENT OF THE FLORA

The time has not yet arrived when it is possible to make positive correlations throughout Bolivia. Many isolated facts are significant but as yet admit of only tentative conclusions. It is clear that in late Tertiary time the land was much nearer sea level than it is today and that the climate was very different from what it is at the present time. Plants are reported from Chacarilla from a horizon that corresponds to a part of the Pliocene series at Corocoro, and 50 km. southeast of that place and 25 km. east of Ulloma. Vertebrates belonging to the so-called Plio-Pleistocene fauna are of widespread occurrence, both on the high plateau and in both the Eastern and Western Andes, and there is a thick series of continental Pliocene in the region between Santa Cruz de la Sierra and Tarija, Bolivia and northwestern Argentina, which contains fossil plants like those found at Potosi, and which are more or less involved in the Andean structures. It seems obvious that these very widespread and enormously thick series of continental beds are all of nearly the same age, and are the direct result of faulting and uplift, which appears to have extended from Pliocene to Recent times.

The fossil plants from Jancocata comprise but nine determinable species, a much too limited number upon which to base sweeping conclusions. They include a fern, a reed-like grass, an alder, two aborescent Rosaceæ, three Leguminosæ, and a member of the family Melastomataceæ. They thus represent 9 genera, 7 families and 5 orders. Their exact age is a matter of some doubt. All are closely related to still existing species of South America found at the same or lower levels. Consistent with the opinion expressed in a preceding paragraph they may be called Pliocene, belonging toward the close of that period. It should be borne in mind, however, that there is no adequate evidence of a definite Pleistocene period in South America which was coterminous with the Pleistocene of the Northern Hemisphere, so that it might perhaps be better to state the age of the Jancocata plants as Plio-Pleistocene.

Although this flora is so limited it is definite enough in the evidence which it furnishes that it antedated the present climatic cycle in Bolivia. About the only existing aborescent forms in the Titicaca basin are the small scrubby wild-olive, so-called (Buddleia, Loganaceæ) and the keñua (*Polylepis racemosa*), and it is obvious that these fossils indicate a wetter climate than that of the present. This conclusion is reinforced by the lack of similarities between the fossils and the chaparral of the Chaco of eastern Bolivia where grow such things as Aspidosperma, Acacia, Prosopis, Capparis, etc. Every one of the allies of these fossil species occurs under more humid conditions, the majority in the more humid valleys of the montaña zone, although some are lowland types.

It may be considered established that at Jancocata in late Pliocene time there was more humidity and a greater rainfall—the abundance of grass fragments is a further confirm-ation of this conclusion. The question of change in altitude between then and now is more obscure. The Pteris, Phragmites, Alnus, Osteomeles and Polylepis all range upward to 10,000 feet or more where there is sufficient humidity, and the upper limit of two of these, namely the Osteomeles and the Polylepis is still higher. On the other hand the Calliandra, Cæsalpinia and Melastomites are similar to Amazon basin types, although all three range upward in the wet montaña zone that skirts the Eastern Andes and constitutes the Yungas of Bolivia. The Cassia could belong in either of the two foregoing categories. The upper limit of range of all of these forms is not necessarily a measure of the altitude of the fossils, since all of their existing relatives find their optimum conditions considerably below their upper limits. There appears to have been some elevation since this fossil flora was living, but this may be only apparent, and it seems possible that with the Eastern Andes much lower than at present there would have been sufficient moisture in the plateau region for this flora to have existed without any great change of level.

The present study shows a close correlation with the presence of large extinct herbivorous mammals in this region and largely confirms the surmise of Pompeckj, who, from a study of the mammals inferred the presence of more moisture and a more abundant vegetation at the time they flourished than at present. He, however, referred to it as a steppe climate. It was still more genial than that term usually connotes. The Pliocene Altaplanacie may legitimately be pictured as having an abundant rainfall with abundant grasses and trees, and in every way suitable for sustaining the large mammals which we know inhabited it.

DESCRIPTION OF THE FOSSIL PLANTS

Phylum Pteridophyta

Class LEPTOSPORANGIATÆ

Order POLYPODIALES

Family POLYPODIACEÆ

Genus PTERIS (authors)

Pteris pacajensis Berry sp. nov.

PLATE I—Figs. 7, 7a

I use the generic term Pteris in a somewhat generalized sense, fully realizing that the existing forms formerly referred to Pteris have been segregated into a number of genera. It seems highly undesirable to attempt anything more with fossil forms like that under consideration than to indicate the general affinity by the use of the older and broader generic term. The present material, which is limited, may be described as follows:

Pinna divided to within about 1 mm. of the rachis into remote, lanceolate segments. These make an angle of about 60 to 70 degrees with the rachis, and are separated by wide, evenly rounded and nearly equilateral sinuses. Rachis stout, prominent. Lobes about 1.25 cm. in length and 2.5 mm. in maximum width. Midveins stout, sending off at acute angles numerous laterals, some of which are simply once forked and others are connected by cross veinlets to form a netted venation of the type known as "dictyopteroid." There are a few simple or furcate veins in the wings that connect the lobes at the base of the sinus, but this region is so narrowed in the present material that it is largely without veins and the lobes are to all intents pinnules. Possibly in more proximal parts of the frond the lamina may have been wider. The lateral veins run directly to the margins, which are entire, and at their tips they are conspicuously expanded and show every indication of the former presence of marginal sori.

There are a considerable number of existing species of the South American region that are very similar to this fossil form, as for example, *Pteris polyphylla* (Presl) and *Pteris deflexa* Link of the Brazilian area, or *Pteris coriacea* Desv. of Peru. The last two have what Ettingshausen called the "Alethopteris" venation, namely with furcate laterals. The first has what this author called the "dictyopteris composita" venation, and is hence most like the fossil form. In some respects the latter is intermediate in character, the simplification of the venation being due to the narrowing of the lobes and the great depth of the intervening sinuses. The fossil is somewhat smaller than the existing *Pteris polyphylla,* with deeper sinuses, but is otherwise very similar to it.

I do not know the upper limits of range of the most similar modern members of the genus, but the genus occur in equatorial South America up to altitudes of 10,000 feet where the humidity is sufficient, and possibly still higher.

The present species, which is obviously new, is named in allusion to the Bolivian province in which it was found.

Phylum Angiospermophyta
Class MONOCOTYLEDONÆ
Order POALES
Family POACEÆ
Genus PHRAGMITES Trinius
Phragmites sp.

Striated stem fragments and broken leaves are not uncommon in the tuffs at Jancocata. They are obviously too incomplete to warrant specific diagnosis, but are of interest as indicative of the presence of a large reed-like grass in this flora. They appear to be most similar to the existing *Phragmites vulgaris,* whose upper limit in Peru, according to Weberbauer, is 3,000 meters. Other Poaceæ or Cyperaceæ that reach comparable altitudes in the existing flora of Bolivia are the Totora, *Scirpus riparius* Presl, of Lake Titicaca and the swamps along the Desaguedero River (upper limit 4,000 meters), the Chusquea (Bambuseæ) of the Chaco country of eastern Bolivia (upper limit of 3500 meters), and the Cortaderia (Festuceæ, upper limit 4000 meters). The present climate at Jancocata is too dry for any of these.

I have recorded a very similar Phragmites from Potosi[4] and at the latter locality there are also many grass leaves (Poacites) and awned scales (Festuca).

Class DICOTYLEDONÆ

Order FAGALES

Family BETULACEÆ

Genus ALNUS Linné

Alnus preacuminata Berry, n. sp.

PLATE I—Fig. 6

It is scarcely possible to frame a diagnosis of the incomplete material to which I am giving the above name. I have compared the material with all of the vegetation which exists at the present time on the altaplanicie of Bolivia without result, and it might, without any great stretching of the facts be called *Alnus jorullensis, Alnus mirbelii* or *Alnus acuminata.* To avoid the nomenclatorial tangle in which these modern species appear to be involved my course appears to be the most desirable.

The alder, generally of large size, is not uncommon in the mountain valleys of Peru and Bolivia where there is sufficient moisture. I have no measure of this but noted the presence of Alnus in the Araca valley at 10,000 feet. What is called *Alnus mirbelii* Spach is cultivated at 13,000 feet at Sacaba. What is called *Alnus acuminata* H. B. K., grows naturally at Cotana, Bolivia at 8,000 feet, and a specimen from the last locality bearing this name in the Bang collection from Bolivia (No. 1893) is identical with the fossil.

---

[4] Berry, E. W., U. S. Natl. Museum Proc., vol. 54, p. 122, pl. 15, fig. 5, 1917.

Order ROSALES

Family ROSACEÆ

Genus OSTEOMELES Lindley

Osteomeles kozlowskiana Berry sp. nov.

PLATE I—Figs. 4, 4a

Leaves of small size, obovate or broadly spatulate in general outline, widest in the middle, broadly rounded at the apex, and decurrent at the base to the short and stout petiole. Margins entire below, with a few crenate teeth apically. Texture subcoriaceous. Length about 8 mm. Maximum width about 6 mm. Lamina broader on one side than on the other, and the base also somewhat inequilateral. Petiole stout, about 1.5 mm. long. Midrib relatively very stout, prominent on the under side of the leaf. Secondaries relatively stout; about 5 pairs diverge from the midrib at angles of about 45 degrees, pursue relatively straight, subparallel courses and are abruptly camptodrome close to the margins. Tertiaries percurrent.

This characteristic little leaf is typical of the genus Osteomeles, or Hesperomeles as it is sometimes called. The genus contains about a score of existing species the majority of which are unarmed or spinescent shrubs of the Cordillera region of South America where they range from Central America southward to Bolivia. Among these the fossil appears to be most similar to *Osteomeles intermedia* Pittier which was described recently [5] from the Cordillera de Santa Marta in Colombia from an altitude of 8937 feet, and to *Osteomeles obovata* Pittier from the Irazu volcano in Costa Rica from an altitude of 9750 feet. Too little is, however, known of the occurrence of the genus in the mountains of Peru and Bolivia to attach any particular importance to this similarity of the fossil species to these existing forms from so much farther north. *Osteomeles pernettyoides* (Wed-

---

[5] Pittier, H., Cont. U. S. Natl. Herb., vol. 20, pt. 3, p. 107, 1918.

dell) Decaisne appears to be the commonest known species in Peru and Bolivia. It has larger and pointed leaves, and reaches altitudes of between 11,000 and 12,000 feet in the Cordillera Real of Bolivia.

A second fossil species, not far removed from the Jancocata form is not uncommon in the Pliocene deposits at Corocoro and Potosi, Bolivia. It is closer to the existing *Osteomeles cuneata* (Lindley) Decaisne of this same region than is *Osteomeles kozlowskiana.* The latter is named in honor of Señor Roman Kozlowski, who has done so much to advance our knowledge of the geology of Bolivia.

Genus POLYLEPIS Ruiz & Pavon

Polylepis tomentellafolia Berry sp. nov.

PLATE I—Figs. 1, 1a

Although I do not have the entire leaves, the great similarity of the fossil to the leaflets of the existing *Polylepis racemosa* Ruiz & Pavon leads me to regard the present specimen as representing a detached leaflet of a fossil form that is related to this common Andean tree of the present day. It may be characterized as follows: Leaflets small, sessile, ovate or narrowly elliptical in outline, widest medianly, with a rounded tip and a cuneate base. Margins entire below, prominently crenate above. Texture subcoriaceous. Length about 14 mm. Maximum width about 6 mm. The species is based upon the single known specimen which is figured on the accompanying plate and this may well represent the minimum rather than the average size. Midrib stout, prominent on the under side of the leaflet. Secondaries well marked, about six pairs, diverging from the midrib at acute angles, and camptodrome. Nervilles percurrent.

This well marked little leaflet is similar to those of the existing *Polylepis racemosa* Ruiz & Pavon, a rosaceous tree that is very characteristic of the Western Andes in southern Peru up to elevations of 14,625 feet. I do not recall seeing it in Bolivia south of Lake Titicaca except in the Araca region but the lessened rainfall may cause it to be rarer toward the southern limit of its range and its upper limit of growth should also be somewhat lower than in Peru. My own observations are too fragmentary to be worth much in this connection.

In extreme southern Peru and in the Titicaca Basin, that is to say, in the northern part of the *altiplanicie, Polylepis racemosa* is largely, if not entirely, replaced by *Polylepis tomentella* Weddell, a characteristic trifoliate shrubby species, whose leaflets are even more similar to the fossil form. A third similar species is *Polylepis incana* which is characteristic of the Sierras east of Cochabamba around Duraznillos at altitudes of between 8,000 and 9,000 feet.

The genus Polylepis contains about fifteen existing species which are confined to the Andean region of equatorial South America, where they range from Venezuela and Colombia southward to northern Chile and Argentina, and hitherto unknown in the fossil state.

As the fossil is a form not markedly different from a still existing species in the same region it suggests that at the time these sediments were deposited the altitude was not very different from what it is in the present habitat of the genus. This conclusion requires modification, however, when the associated plants are taken into consideration and will be discussed in the section of the present contribution devoted to the analysis of the fossil flora.

The only fossil plant from other regions that resembles the present species is *Raphiolepis indica* Lindley an existing Rosaceous form of southern Asia which Marty[6] has identified from the Mio-Pliocene of Central France.

---

[6] Marty, P., Revue Général Botanique, tome 32, p. 24, pl. 12, fig. 5, 1920.

Family MIMOSACEÆ

Genus CALLIANDRA Bentham

Calliandra jancocatana Berry, n. sp.

PLATE I—Fig. 3, 3a

Leaflets small, ovate in outline, markedly inequilateral, bluntly pointed at the apex, broadly and very inequilaterally rounded at the base. Margins entire, full and evenly rounded. Texture coriaceous. Length about 1 centimeter. Maximum width about 4 millimeters. Midrib stout, slightly curved. Secondaries thin; those in the narrower half of the lamina diverging at wide angles and camptodrome; those in the wider half of the lamina are somewhat less regular, occasionally inosculating and the lowermost is somewhat stouter and ascending at least half way to the tip.

The present species shows considerable similarity to *Calliandra obliqua* Engelhardt which is common at Potosi and Corocoro.[7] The Jancocata plant appears, however to represent a distinct but closely related species. It is also something like *Enterolobium grandifolium* which is found fossil at both Potosi and Corocoro.[8] The modern species of Calliandra number over one hundred varieties of shrubs and small trees, largely confined to the humid tropics of South America. The genus is represented in the montaña country of Bolivia, but does not extend westward beyond the sub-andean slopes of the Cordillera Real.

Family CÆSALPINIACEÆ

Genus CASSIA Linné

Cassia altœnsis Berry sp. nov.

PLATE I—Fig. 2

Small, ovate, compressed, few seeded, ligneous pods, about 2.5 cm. to 3 cm. in length, and 2 cm. in maximum width,

---

[7] Berry, E. W., Johns Hopkins Studies in Geology, No. 1, p. 97, pl. 4, 1922.

[8] Idem., p. 98, pl. 7, fig. 16.

rounded distad and bluntly pointed at the base. Conspicuously margined along one border and prominently marked by forking and anastomosing cross veins.

This form suggests a variety of genera of the leguminous alliance, notably Lonchocarpus, Dalbergia and Copaifera, and it may possibly represent one of these genera, since it is more ligneous than is usual in Cassia. It is, however, similar in appearance to the pods of certain existing species of Cassia, and is also very close to numerous Tertiary pods from the Chilean Miocene, the North American Eocene, and Tertiary horizons elsewhere, which have been referred to this genus. For this reason I refer it tentatively to that large and diversified genus.

There are two types of leguminous leaflets associated with these pods at Jancocata, and it is quite possible that the pods represent the fruit of one or the other of the species based upon leaflets, but this cannot be determined.

Cassia altœnsis constitutes a well marked type and is one that is unlike anything at present known from the Pliocene deposits at Corocoro or Potosi in Bolivia. This, however, argues little, since a great variety of leguminous leaflets are present at these two localities and fruits are very scarce and represent but two leguminous forms.

Genus CÆSALPINIA Linné

Cæsalpinia jancocatana Berry, n. sp.

PLATE I—Figs. 5, 5a

Leaflets ovate-elliptical in outline, markedly inequilateral; with a broadly rounded, sessile base, and a somewhat narrowed rounded tip. Margins entire, full and evenly rounded. Texture sub-coriaceous. Length about 1.25 centimeters. Maximum width about 8 millimeters. Midrib very stout, conspicuously curved. Secondaries thin, about 7 pairs diverge from the midrib at wide angles and are camptodrome. Tertiaries as shown in the accompanying enlarged drawing (Fig. 5a).

This species is quite similar to *Cæsalpinia gmehlingi* Engelhardt from Potosi, Bolivia,[9] but is more inequilateral and more coriaceous. The two are probably closely related. It is also much like the existing *Cæsalpinia floribunda* Tul. of the Amazon basin.

The genus is abundantly represented in the fossil record from the Upper Cretaceous onward, and the two score or more recent species are found in the tropics of both hemispheres, and are especially well represented in the Amazon basin and in the valleys of the eastern Andean slopes.

Order MYRTALES

Family MELASTOMATACEÆ

Genus MELASTOMITES Unger

Melastomites sp.

PLATE I—Fig. 8

Fragments of a lanceolate leaf about 3 to 3.5 centimeters in length and 1 centimeter in maximum width almost certainly represent a fossil species of this family. The texture is subcoriaceous, and there are 5 relatively stout, acrodrome primaries connected by thin transverse nervilles.

The presence of a member of this family at Jancocata throws an interesting light on the physical conditions at the time the fossil species lived. The Melastomataceæ is a large, prevailingly American family, of distinctly humid climate types and almost strictly tropical in its distribution. There are between 2,000 and 2,500 species in the existing flora of the western hemisphere, chiefly in the Antilles, Central and tropical South America, especially in the Amazon basin. In Bolivia species occur abundantly in the montaña country, but do not, as far as I know, occur west of the divide of the Eastern Andes. Nothing similar has thus far been discovered in the Pliocene floras of Potosi or Corocoro.

---

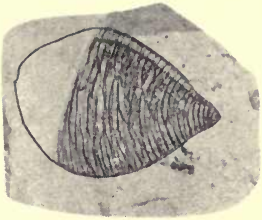
[9] Berry, E. W., U. S. Natl. Museum Proc., vol. 54, p. 141, pl. 16, fig. 14, 1917.

EXPLANATION OF PLATE

Figs. 1, 1a. Polylepis tomentellafolia Berry
Fig. 2. Cassia altœnsis Berry.
Figs. 3, 3a. Calliandra jancocatana Berry.
Figs. 4, 4a. Osteomeles kozlowskiana Berry.
Figs. 5, 5a. Cæsalpinia jancocatana Berry.
Fig. 6. Alnus preacuminata Berry.
Figs. 7, 7a. Pteris pacajensis Berry.
Fig. 8. Melastomites sp.

1

1a



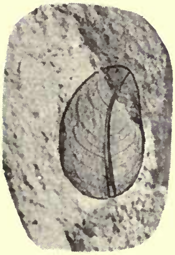
2

3

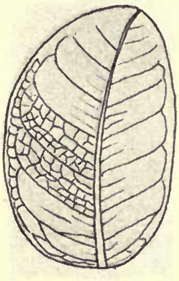
3a

4

4a



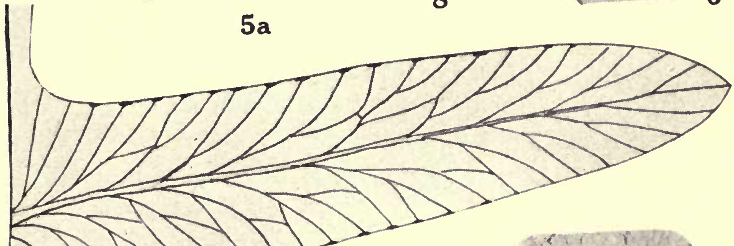
5



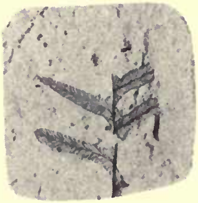
5a

8

6



7a



7

Jancocata, Bolivia.

RD

RETURN TO → **EARTH SCIENCES LIBRARY**
230 Earth Sciences Bldg. 642-2997

~~LOAN PERIOD 1~~ ~~14 DAYS~~	2 **7 DAYS**	3
4	5	6

ALL BOOKS MAY BE RECALLED AFTER 7 DAYS
Books needed for class reserve are subject to immediate recall

DUE AS STAMPED BELOW

~~OCT 17 1983~~ FEB 06 1984		

UNIVERSITY OF CALIFORNIA, BERKELEY
FORM NO. DD8, 7m, 12/80 BERKELEY, CA 94720
Ⓟs

-260

C033218881