4. FLORA OF THE FRUITLAND AND KIRTLAND FORMATIONS.

By F. H. KNOWLTON.

HISTORICAL SUMMARY.

San Juan County, in the extreme northwest corner of New Mexico, comprises but a small portion of the larger more or less clearly defined structural area known as the San Juan Basin. Certain structural elements, particularly the upper series of coal-bearing rocks, form a more or less continuous rim around this basin and dip toward the center, where, however, they are deeply buried.

As the object of the present study is to ascertain the bearing of the fossil plants on the age of this series of coal-bearing and related rocks, it is desirable to give first a brief historical setting for the geologic facts here set forth. It is not necessary in this connection, however, to go further back than the beginning of the time embraced within the history of the so-called "Laramie problem"—that is, to about 1875.

The San Juan district was studied by W. H. Holmes,[1] of the Hayden Survey, during the field season of 1875. The results of his studies of the rocks in the valley of San Juan River are displayed in a generalized section in Plate XXXV of his report. The uppermost member of this section is referred to the Wasatch and is divided into two parts, the lower of which is the Puerco marls of Cope, now included in the Puerco and Torrejon formations. Immediately below the Puerco marls is the so-called "Upper coal group," made up of 800 feet of soft sandstones and marls, which is called Laramie?. This in turn rests on massive sandstone 120 feet thick, called the Pictured Cliffs group, and on the evidence of invertebrates was referred to the Fox Hills unit.

Except for the preparation of a number of economic reports on the coal of this region, little systematic geologic work was done in the region until 1899, when Cross[2] established the units of the Upper Cretaceous section, which subsequently have been so widely identified in Colorado, Wyoming, and Montana. These units, in ascending order, are the Mancos shale, Mesaverde formation, and Lewis shale. Concerning the Lewis shale Cross wrote as follows:

> Above the Mesaverde formation occurs another formation of clay shale, reaching an observed thickness of nearly 2,000 feet, which is very much like the Mancos shale but contains fewer fossils. The only identifiable form thus far found in this shale occurs also in the Mancos shale, so that this division is still apparently below true Fox Hills. This formation is called the Lewis shale.

Continuing, Cross says:

> Still above the Lewis shale is a second series of sandstones, shales, and clays, bearing some resemblance to the Mesaverde formation but differing in detail. The lowest member of this complex is the "Pictured Cliff sandstone" of Holmes's San Juan section, which he placed in the Fox Hills upon the evidence of invertebrate remains. The remainder was referred to the Laramie, but without fossil evidence. The present survey has failed to bring to light valid ground for assigning any of the beds in question to the Laramie, while there is some reason to believe that more than the lower sandstone belongs to the Montana group.

In 1905 Schrader[3] made a reconnaissance examination of the Durango-Gallup coal field in which he adopted the stratigraphic classification established by Cross and described the uppermost coal-bearing sandstone as Laramie?, though he presented no fossil evidence.

In 1906 more detailed examinations were made in the region by Taff and Shaler. Taff[4] studied the Durango coal district, which lies just off the southern foothills of the San Juan and La Plata mountains, and in his report the upper coal-bearing rocks here under consideration were referred without question to the Laramie, though he gave no details as to the reason for this reference. Shaler's report[5] deals with that part of the Durango-Gallup field lying

[1] Holmes, W. H., Geological report on the San Juan district: U. S. Geol. and Geog. Survey Terr. Ninth Ann. Rept., for 1875, p. 241, 1877.

[2] Cross, Whitman, U. S. Geol. Survey Geol. Atlas, La Plata folio (No. 60), 1899.

[3] Schrader, F. C., The Durango-Gallup coal field of Colorado and New Mexico: U. S. Geol. Survey Bull. 285, pp. 241–258, 1906.

[4] Taff, J. A., The Durango coal district, Colo.: U. S. Geol. Survey Bull. 316, pp. 321–337, 1907.

[5] Shaler, M. K., A reconnaissance survey of the western part of the Durango-Gallup coal field of Colorado: Idem, pp. 376–426.

west of longitude 107° 30′. The beds here discussed were also referred by Shaler to the Laramie without qualification, on the basis, it is stated, of fossils studied by T. W. Stanton and F. H. Knowlton, though the evidence is not presented in detail. On looking over the original reports on the plants collected by Shaler and others in this region, I find that they were few and fragmentary collections only, and the tendency was to regard them as mainly older than Laramie.

The status of the "Laramie" in the region under consideration was so well summed up by Lee [1] in 1912 that his statement is quoted entire as follows:

> The "Laramie" formation occurs within the area described in this paper only in the San Juan Basin. It is more than 1,000 feet thick in the southern rim of the basin but is thinner in the eastern rim, probably due to post-Cretaceous erosion. At Dulce it is only 225 feet thick. The formation lies conformably on Lewis shale and probably for this reason more than any other has been called Laramie, although Dr. Cross several years ago called attention to the fact that investigation had "failed to bring to light valid ground for assigning any of the beds in question to the Laramie, while there is some reason to believe that more than the lower sandstone belongs to the Montana group." Since that time a considerable number of fossils, both of invertebrates and of plants, have been collected from these beds in the Durango region. The base of the formation—the Pictured Cliff sandstone—contains marine invertebrates, and the lower part of the coal-bearing rocks above this sandstone contains brackish-water invertebrates, several of which occur in the Mesaverde of other fields. But higher in the formation the rocks contain fresh-water invertebrates which Dr. Stanton regards as Laramie and fossil plants which Dr. Knowlton regards as older than Laramie. The fossil plants have been given in the table * * * and from this table as well as from the accompanying statement by Dr. Knowlton [see below] it will be seen that the flora differs but little from that of the Mesaverde farther to the south. The name "Laramie" is here used for this formation not because the writer wishes to argue for the Laramie age of the rocks, but because the name is in use and because in this paper the writer is intentionally avoiding the introduction of new names for rock formations. It must be noted, however, that while the formation is called "Laramie" it contains a flora which denotes Montana age, having nothing in common with the Laramie flora of the Denver Basin.

The statement by me to which Lee alludes is as follows:

> Near Dulce, N. Mex., and near Durango, Colo., there have been obtained two collections of plants from above the Lewis shale in coal-bearing rocks that have been referred to the so-called "Laramie" of this region. These collections are very full and embrace a number of easily recognized species; hence their identification is satisfactory and complete. These collections prove clearly that these beds do not belong to the Laramie, since, so far as known to the writer, not a single species there present has been found in beds of this age. On the other hand, the plants indicate beyond question that they belong to the Montana, there being, for instance, *Ficus speciosissima*, Ficus sp. (narrow, three-nerved type), Ficus sp., type of *F. lanceolata*, a palm, etc., which link them with the Mesaverde floras to the south and the beds already discussed in the Raton Mesa region. Associated with these, however, and tending to give them a slightly higher position, though still within the Montana, are such forms as Brachyophyllum, Cunninghamites, Geinitzia, Sequoia, etc., all of which are beyond doubt Montana types not found in the Laramie.
>
> A number of collections were made by J. H. Gardner in the Ignacio quadrangle, east of Durango, Colo., from beds regarded as the Laramie of that area. The plants in these collections, almost species by species, are identical with the forms from near Dulce and near Durango, and I have no hesitation in saying that they occupy the same stratigraphic position and are of the same age, viz, Montana.

It now remains to consider certain dinosaur-bearing beds first reported near Ojo Alamo, N. Mex., which may have a bearing on the "Laramie" of the San Juan Basin region. In 1908 James H. Gardner, then of the United States Geological Survey, found reptilian vertebrate remains near the head of Coal Creek, 1 mile southeast of Ojo Alamo, "in variegated sands, shales, and conglomerates, indisputably above the unconformity at the top of the Laramie.[2] These remains were studied by C. W. Gilmore, who states that this fauna "appears to represent a typical fauna of the so-called Laramie or better Ceratops beds."

It appears that dinosaur remains had been known at the Ojo Alamo locality as early as 1902, but it was not until 1904 that a systematic attempt was made to collect them. In this year Barnum Brown, of the American Museum of Natural History, made a reconnaissance trip to the locality and obtained "a small but interesting collection of fossils." These, however, were not described in print until 1910.[3] Concerning the stratigraphic relations of these beds Brown says:

> Less than a mile south of the store at Ojo Alamo the Puerco formation rests unconformably on a conglomerate

[1] Lee, W. T., Stratigraphy of the coal fields of northern New Mexico: Geol. Soc. America Bull., vol. 23, pp. 607–608, 1912.

[2] Gardner, J. H., in Knowlton, F. H., The stratigraphic relations and paleontology of the "Hell Creek beds," "Ceratops beds," and equivalents, and their reference to the Fort Union formation: Washington Acad. Sci. Proc., vol. 11, p. 323, 1909.

[3] Brown, Barnum, The Cretaceous Ojo Alamo beds of New Mexico, with description of the dinosaur genus Kritosaurus: Am. Mus. Nat. Hist. Bull., vol. 28, pp. 267–274, 1910.

that is composed of red, gray, yellow, and white pebbles. The position of these beds is below what may be called the type of the Puerco or basal Eocene. * * * Below the conglomerate there is a series of shales and sandstones, evenly stratified and usually horizontal, in which there is much less cross-bedding than commonly occurs in the Laramie of the northern United States.

The shales below the conglomerates that contain numerous dinosaur and turtle remains I shall designate as the Ojo Alamo beds. They are estimated to be about 200 feet thick, but owing to lack of time I was unable to determine their relations to the underlying formations.

Also in 1910 appeared a paper by Gardner [1] that involved incidentally the beds under discussion. He records the Puerco as resting unconformably on the underlying beds, as Brown had reported, and he states that at Ojo Alamo he "obtained dinosaurs from beds unconformably above the 'Laramie' and below the Wasatch." These beds are, of course, the Ojo Alamo beds of Brown.

From the preceding brief statements it appears that for more than 40 years the upper coal-bearing rocks of the San Juan Basin have been regarded more or less definitely as of Laramie age, though during quite half of this time there has been growing an undercurrent of opinion that the beds may be older than the Laramie. The object of the present study is to ascertain the bearing of the fossil plants on this question, and it may be stated here that the plants appear fully to sustain the opinion that the beds are older than the Laramie.

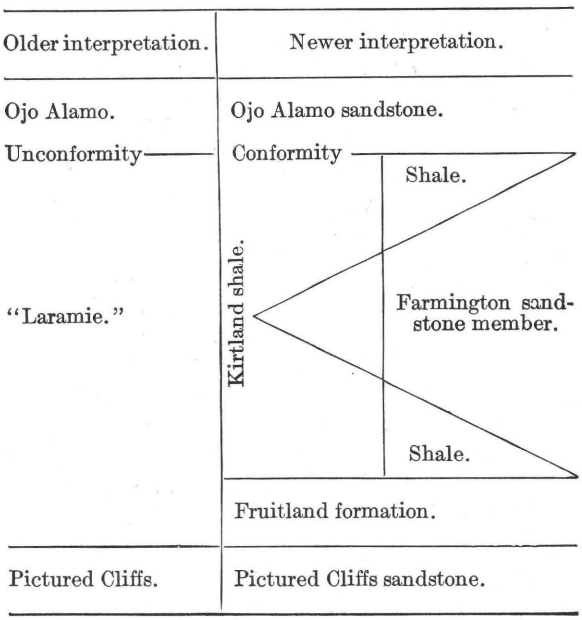
The fossil plants upon which the present report is based were obtained by C. M. Bauer during his geologic studies of the season of 1915 in that portion of the San Juan Basin embraced within San Juan County, N. Mex. The stratigraphic results of his investigations are set forth at length in the paper by Bauer,[2] and in the present connection it is necessary only to give them in brief outline. In that portion of the coal-bearing and associated rocks previously referred to as the "Laramie" of that region Bauer has recognized two lithologic units. The lower of these units, called the Fruitland formation, is about 300 feet thick and includes the coal-bearing beds. Above it is a series of shales, called the Kirtland shale, with an intercalated sandstone, the Farmington sandstone member, and the whole formation has a maximum thickness of nearly 1,200 feet.

[1] Gardner, J. H., The Puerco and Torrejon formations of the Nacimiento group: Jour. Geology, vol. 18, pp. 702-741, 1910.

[2] U. S. Geol. Survey Prof. Paper 98, pp. 274-275 (Prof. Paper 98-P).

Above the Kirtland shale, without observed stratigraphic break, is the Ojo Alamo sandstone, which Bauer thinks should be grouped with the underlying Kirtland and Fruitland formations.

A graphic presentation of the older and newer views is given below:



THE FLORA.

The material on which the present report is based comprises 20 collections, of which 15 are from the Fruitland formation, 3 from the Kirtland shale (2 from the extreme top and 1 from the base of the formation), and only 1 from the Ojo Alamo sandstone. The bulk of the material comes from the lower or coal-bearing portion of the section, and much of this is preserved on a red baked shale, indicating proximity to coal.

The material in the single collection from the Ojo Alamo beds is so fragmentary that it can not be identified with satisfaction. It includes portions of a large leaf of unknown affinity, a small willow-like leaf, and a large leaf that appears to be an Aralia of the type of *Aralia notata* Lesquereux, a species very abundant and widely distributed in the Fort Union formation. Nothing like this has been noted in the underlying beds, and to a certain extent it argues for the Tertiary age of the Ojo Alamo beds, though obviously the evidence is not strong. For the present, therefore, the dictum based on the evidence of the fossil vertebrates that these beds can not be separated from the

underlying beds must be accepted, though the writer can not escape the impression that they may ultimately be shown to be of Tertiary age.

Below is a complete list of the forms represented in the collections from the Fruitland and Kirtland formations.

Asplenium neomexicanum Knowlton, n. sp.
Onoclea neomexicana Knowlton, n. sp.
Anemia hesperia Knowlton, n. sp.
Anemia sp.
Sequoia reichenbachi (Geinitz) Heer.
Sequoia obovata? Knowlton.
Geinitzia formosa Heer.
Sabal montana Knowlton.
Sabal? sp.
Myrica torreyi Lesquereux.
Myrica? neomexicana Knowlton, n. sp.
Salix baueri Knowlton, n. sp.
Salix sp. *a* Knowlton.
Quercus baueri Knowlton, n. sp.
Ficus baueri Knowlton, n. sp.
Ficus curta? Knowlton.
Ficus prætrinervis Knowlton.
Ficus leei Knowlton.
Ficus prælatifolia Knowlton, n. sp.
Ficus sp.
Ficus rhamnoides Knowlton.
Ficus squarrosa Knowlton.
Ficus sp.
Ficus eucalyptifolia? Knowlton.
Laurus baueri Knowlton, n. sp.
Laurus coloradensis Knowlton.
Nelumbo sp.
Heteranthera cretacea Knowlton, n. sp.
Pistia corrugata Lesquereux.
Leguminosites? neomexicana Knowlton, n. sp.
Pterospermites undulatus Knowlton.
Pterospermites neomexicanus Knowlton, n. sp.
Pterospermites sp.
Ribes neomexicana Knowlton, n. sp.
Carpites baueri Knowlton, n. sp.
Phyllites petiolatus Knowlton, n. sp.
Phyllites neomexicanus Knowlton, n. sp.
Unassigned plant (a).
Unassigned plant (b).

The above list comprises 40 forms, of which 6 are so fragmentary that they have not been given specific names, 2 have not been assigned, even generically, 16 are regarded as new to science, leaving 16 species known previously in other areas.

Although new species as such have little value in fixing the age of the rocks in which they occur, it not infrequently happens that important and far-reaching conclusions may be drawn from a consideration of their obviously close relation with species whose stratigraphic relations are known. Thus the species described as *Asplenium neomexicanum* is not to be distinguished from the fragment described as Asplenium sp. Knowlton, from the Mesaverde of Dutton Creek, Laramie Plains, Wyo. *Onoclea neomexicana* belongs to a very long lived type, which, it was previously supposed, began in the Fort Union and is still living. The present form carries the type much further back. *Anemia hesperia* is not closely related to any previously described fossil species from this country. *Myrica? neomexicana* is so poorly represented that its generic reference has been questioned, and hence its relationship is obscured. The specimen of *Salix baueri* is also poorly preserved as regards nervation and is of little value in fixing its affinity. *Quercus baueri* is most closely related to an unpublished species from the Vermejo formation of southern Colorado, differing in its slightly smaller size and less prominent teeth. *Ficus baueri* is, in a way, of the type of *Ficus denveriana*, a large Denver species, but it differs very markedly in nervation and is not considered to be closely related to that species. *Ficus prælatifolia* is most nearly related to *Ficus planicostata latifolia*, a form first made known from Black Buttes, Wyo., but later recorded from a number of horizons, including Montana and Laramie. *Laurus baueri* is of the type of *Laurus socialis*, a Tertiary form, but differs in nervation as well as in size. *Heteranthera cretacea* belongs to a living type that has not before been detected in a fossil state. The single minute leaflet described under the name *Leguminosites? neomexicana* is so small and obscure that its affinity can not be established. *Pterospermites neomexicanus* is probably most closely related to *Pterospermites undulata* of Point of Rocks, Wyo. *Ribes neomexicana* is without known close relations among fossil forms. The species of Carpites and Phyllites have been designated by these nondescript names because they are without recognized affiliations.

The species common to the Fruitland and Kirtland formations and the Laramie formation of the Denver Basin are *Sequoia reichenbachi*, *Sabal montana*, *Myrica torreyi*, and *Ficus prætrinervis*. In working up the flora of the Laramie of the Denver Basin of Colorado it has been found that this flora embraces approximately 125 species, of which nine are known to be common to the Montana. As all four of the above-named species are included in the nine common to the Laramie and Mon-

tana, it follows they can not be used as an argument for the Laramie age of the Fruitland and Kirtland formations, because without collateral data it would be impossible to decide their age in the San Juan Basin. As a matter of fact, while these four species are known to occur in the Laramie, their principal distribution is in beds older than Laramie. Thus, *Sequoia reichenbachi* is known to range from the upper part of the Jurassic entirely through the Cretaceous, being perhaps most abundant, at least as regards individuals, in the middle Montana. *Sabal montana* is the principal species of palm in the Montana. *Myrica torreyi* was described originally from Black Buttes, Wyo., but it has since been demonstrated to be most abundant and widely distributed in the Montana. *Ficus prætrinervis* was first found in the Vermejo formation of Colorado and New Mexico, where at certain localities it is exceedingly abundant.

The species common to the Fruitland and Kirtland formations and the Montana group are as follows:

*Asplenium neomexicanum.
*†Sequoia reichenbachi.
*†Sequoia obovata?
*†Geinitzia formosa.
*†Sabal montana.
*†Myrica torreyi.
†Salix sp. *a*.
†Ficus curta?
†Ficus prætrinervis.
†Ficus leei.
*Ficus rhamnoides.
*Ficus squarrosa.
†Ficus eucalyptifolia?
†Laurus coloradensis.
*Pistia corrugata.
*†Pterospermites undulatus.

The species in the above list that are marked with an asterisk (*) are found also in the Montana of Wyoming, mainly at Point of Rocks; those marked with a dagger (†) are found in the Vermejo of Colorado and New Mexico.

Of the 40 forms making up the known flora of the Fruitland and Kirtland formations, 16 have been found in other areas, and the above list brings out the fact that no less than 15 of these forms are known to occur in the Montana. A further analysis of the list shows that 12 of the 15 forms occur in the Vermejo formation of Colorado and New Mexico, 10 occur in the Mesaverde, or rocks of about this age, in Wyoming and elsewhere, and 6 species are common to both these areas. On the basis of this showing the conclusion seems justified, therefore, that the Fruitland and Kirtland formations are of Montana age.

Family POLYPODIACEÆ.

Asplenium neomexicanum Knowlton, n. sp.

Plate LXXXIV, figures 5–9.

Asplenium sp. Knowlton, U. S. Geol. Survey Bull. 163, p. 20, pl. 3, fig. 11, 1900.

Frond at least firm in texture; outline of whole frond not known but apparently simple or once forked, base abruptly rounded and slightly cordate, apex abruptly narrowed to an acuminate point; margin finely toothed, the teeth small and apparently spinose; stipe slender, its length not known but at least 6 centimeters; nervation very distinct, consisting of a rather strong midvein and numerous veins at an angle of emergence of about 45°, usually forking at or very near the base and occasionally once above, the veins or nearly all of them entering the teeth; sori long, narrowly linear, attached to the upper side of the veins.

This very interesting species is represented by about a dozen fragments, five of which are here figured. Although none is of sufficient completeness to show the outline of the whole frond, they include parts that give what seems to be a fairly complete knowledge of its appearance. Two examples (figs. 8 and 9) show the configuration of the base and a portion of the slender stipe, and two (figs. 5 and 6) show the apical portion, figure 5 being particularly complete to the tip. It appears that as a rule the rachis forks at an angle of approximately 45° a very short distance above the base of the frond, producing two broad, probably short, obtusely pointed lobes. In the specimen shown in figure 8 (right-hand leaf), however, there is no evidence of forking within its preserved length of 5 centimeters, and whether it was forked at a still higher point or was entire can not be determined. The marginal teeth may be noted at a number of points in the specimens figured but are especially distinct in figure 6.

The nervation is very distinct and is well shown in all the specimens. Most of the nerves fork at the base and some of them also above the middle, but here and there one may be noted that is simple and unforked throughout. Most of the nerves enter the teeth.

Several of the specimens, notably those illustrated in figures 7 and 9, show the fruit, though this fact was not detected until it was pointed out by W. R. Maxon, of the United States National Museum, to whom the specimens were shown. The sori are apparently somewhat immature, being very long and narrowly linear, hardly more than doubling the normal thickness of the vein.

This species undoubtedly is most nearly related to *Asplenium hemionitis* Linné, now living in Spain, Portugal, and the adjacent Atlantic islands. *A. hemionitis* is usually five-lobed, having a large triangular acute terminal lobe and two shorter similar acute lateral lobes which are bluntly or sometimes acutely lobed at the base; the basal sinus is deep and rounded, and the basal lobes overlap the stipe.

Occurrence: Kirtland shale, 3 inches below base of Ojo Alamo sandstone, 1½ miles east-northeast of Pina Veta China, San Juan County, N. Mex. Lot 40 (6966).

Onoclea neomexicana Knowlton, n. sp.

Plate LXXXIV, figures 1, 2.

Size and outline of whole frond unknown, though evidently it was rather large and at least bipinnatified; main rachis thin, ridged; pinnæ apparently alternate, rather widely spaced, apparently connected by a broad wing; pinnæ short, broad, deeply cut into several lobes, those near the base rather obtuse and provided with a few teeth, the outer lobes acute and entire; nervation very strongly marked, reticulated throughout, the reticulations or areas inclosed by the veins somewhat irregular but in general about four times longer than broad.

The available material representing this form is so scanty and imperfectly preserved that ordinarily to attempt a characterization of it would hardly be worth while, but it is so clear as far as it goes that it can undoubtedly be recognized if found in the future, and moreover it furnishes a valuable biologic step in the interpretation of the geologic history of this genus. As may be seen from the figures, which represent all but a few inconsequential fragments, it is impossible to form any adequate idea as to the size of the whole frond, as there is no means of knowing what part of the frond is represented. So far as can be made out the pinnæ are alternate, a considerable distance apart, and apparently connected by a broad wing. The best-preserved pinna was about 4.5 centimeters long and at least 2.5 centimeters wide. It is cut into four or more lobes having rather large teeth. The other figured specimen is probably the tip of a pinna, but it may be the extreme tip of the whole frond. It is cut into large, sharp-pointed lobes.

The nervation, as may be seen from the figures, is very distinct. It is completely anastomosing, the inclosed areas being somewhat irregular, though in general they are three or four times longer than broad. No trace of the fruiting frond was detected.

This species is undoubtedly most closely related to the living *Onoclea sensibilis* Linné, which, so far as can be determined, has also been found abundantly and widely distributed, in a fossil state, in the Fort Union formation. The fossil form, under the name *Onoclea sensibilis fossilis*, was first described and figured by Newberry[1] from specimens obtained at Fort Union, on Yellowstone River near the Montana-North Dakota line. This form and *Onoclea neomexicana* are so close together that with the material available it is not easy to point out essential differences between them. It appears, however, that in *Onoclea neomexicana* the pinnæ are shorter and relatively more deeply cut into lobes, which are themselves more or less toothed. The nervation is more completely reticulated throughout than in *Onoclea sensibilis fossilis*, but more and better preserved material must be available before it will be possible to determine definitely its distinctness or identity.

Occurrence: Kirtland shale, 3 inches below base of Ojo Alamo sandstone, 1½ miles east-northeast of Pina Veta China, San Juan County, N. Mex. Lot 40 (6966).

Family SCHIZIACEÆ.

Anemia hesperia Knowlton, n. sp.

Plate LXXXIV, figure 3.

Fronds presumably dimorphous; sterile frond roughly deltoid, 2.5 centimeters long, 3 centimeters broad, dipinnate, the rachis slender, pinnæ three or four pairs, alternate, lanceolate, decreasing toward the apex; pinnules confluent, cuneate, erose-dentate at apex; nerves few, slender, at an acute angle, once or twice forked; fertile frond not known.

[1] Newberry, J. S., New York Lyceum Nat. Hist. Annals, vol. 9, p. 30, 1868; U. S. Geol. Survey Mon. 35, p. 8, pl. 23, fig. 3; pl. 24, figs. 1–5, 1898.

The little specimen figured is all that was found of this form. It represents the upper portion of the frond, but whether it is the whole frond or a mere fragment can not be determined. From its apparent affinities it seems probable that the species was dimorphous, and that this specimen is only the sterile portion, the fertile frond remaining unknown.

Anemia hesperia finds its closest affinity with the living species of the group including *Anemia wrightii* Baker, *Anemia cicutaria* Kunze, and *Anemia cuneata* Kunze. These are all natives of Cuba and are found growing in crevices of rocks along shaded rivers.

Occurrence: Fruitland formation, about 10 miles south of Jewett and 2½ miles east of Chaco River, San Juan County, N. Mex. Lot 14 (6947).

Anemia sp.

Plate LXXXIV, figure 4.

The genus Anemia is very widely distributed both areally and vertically, but it rarely happens that specimens are well enough preserved to convey any adequate knowledge of the whole frond. The present material is so fragmentary that it does not admit of satisfactory identification. The specimen figured is sufficient to show clearly that it belongs to this genus, but beyond that no judgment can be ventured. It was evidently a large species, with pinnæ cut deeply into deltoid, very finely toothed lobes. The nervation is of the usual type.

Occurrence: Fruitland formation, 30 miles south of Farmington and 1 mile east of reservation line, San Juan County, N. Mex. Lot 76 (6953).

Family PINACEÆ.

Sequoia reichenbachi (Geinitz) Heer.

Araucarites reichenbachi Geinitz, Charakteristik der Schichten und Petrefacten des sächsisch-böhmischen Kreidegebirges, pt. 3, p. 98, pl. 24, fig. 4, 1842.

Sequoia reichenbachi (Geinitz) Heer, Flora fossilis arctica, vol. 1, p. 83, pl. 43, figs. 1d, ab, 5a, 1868.

Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 6, p. 51, pl. 1, figs. 10–10b, 1874; U. S. Geol. Survey Mon. 17, p. 35, pl. 2, fig. 4, 1892.

The collections contain a few poorly preserved examples that are merely of sufficient value to indicate the presence of this widely spread species.

Occurrence: Fruitland formation, 30 miles south of Farmington and 1 mile east of reservation line, San Juan County, N. Mex. In clinker above highest coal. Lot 75 (6956).

Sequoia obovata? Knowlton.

Sequoia obovata Knowlton, U. S. Geol. Survey Prof. Paper 101, p. —, pl. 30, fig. 7 (in press).

Sequoia brevifolia Heer, Lesquereux, U. S. Geol. and Geog. Survey Terr. Bull., vol. 1, p. 365 [1876]; Ann. Rept. for 1874, p. 298 [1876]; Tenth Ann. Rept., for 1876, p. 500 [1878]; U. S. Geol. Survey Terr. Rept., vol. 7, p. 78, pl. 61, figs. 25–27, 1878.

Knowlton, U. S. Geol. Survey Bull. 163, p. 27, pl. 4, figs. 1–4, 1900.

In the present collections from the San Juan Basin is a single small, poorly preserved specimen that is clearly a Sequoia and from the few leaves retained appears to belong to this species. That this may be so is rendered likely by the fact that characteristic and well-identified specimens have previously been collected in this same region.

Occurrence: Fruitland formation, Hunters Wash, 30 miles south of Farmington and 1 mile east of reservation line, San Juan County, N. Mex. Lot 78 (6952).

Geinitzia formosa Heer.

Plate LXXXV, figure 3.

Geinitzia formosa Heer, Kreideflora von Quedlinburg: Schweiz. Gesell. Neue Denkschr., vol. 24, p. 6, pl. 1, fig. 9; pl. 2, 1871.

Newberry, U. S. Geol. Survey Mon. 26, p. 51, pl. 9, fig. 9, 1876.

Knowlton, U. S. Geol. Survey Bull. 163, p. 28, pl. 5, figs. 1–2, 1900; U. S. Geol. Survey Prof. Paper 101, p. —, pl. 31, figs. 1–3 (in press).

The figured specimen is a fragment of a branch of considerable size showing leaf bases and traces of the leaves. It is of somewhat doubtful validity in this connection.

Occurrence: Fruitland formation, 17 miles south of San Juan River and 2 miles east of Rio Chaco, San Juan County, N. Mex. Lot 26 (6949).

Family PONTEDERIACEÆ.

Heteranthera cretacea Knowlton, n. sp.

Plate LXXXV, figure 5.

Leaf evidently thick in texture, elliptical or very slightly ovate-elliptical, abruptly narrowed or rounded to a very narrow, short basal portion, rounded and slightly pointed at apex; three nerves arise in the basal portion of the blade or petiole, one passing up the center of the blade and the other two dividing the space

between the first and the margin; from these three arise several others of equal strength, there being altogether 10 or 12, close, parallel, and all curving around to and apparently entering the tip; no other nervation discernible.

This curious little leaf is absolutely perfect except a minute portion of the tip. It is about 22 millimeters long including the narrow basal portion or petiole, which is 3 millimeters in length and 15 millimeters wide. It is almost elliptical, though it is perhaps 1 millimeter broader in the lower portion than in the upper. There are 11 or 12 nerves, only three of which arise in the basal portion, the others arising from them and all running into the tip.

The genus Heteranthera is a small one, comprising about nine species, two of which occur in tropical Africa and the others in America. Only three species are found in the United States. They are herbs growing in mud or shallow water, with creeping, ascending, or floating stems and petioled leaves which may be cordate, ovate, oval, reniform, or even grasslike. Of the three United States species the one most similar to the present form is *Heteranthera limosa* (Swartz) Willdenow, the smaller mud plantain, which ranges from Virginia to Kentucky and Missouri, south to Florida and Louisiana, and thence throughout tropical America. The living species bears numerous oval or ovate leaves 1.5 to 2.5 centimeters long on petioles 5 to 12 centimeters long. The several nerves all arise from or near the top of the petiole and arch around to the tip.

It will be noted that the fossil form agrees closely with this living species, the leaf being more nearly elliptical or ovate-elliptical and more abruptly pointed at the apex. The nerves as they pass from base to apex are very similar in both forms, but in the fossil leaf they do not all arise from the top of the petiole, as apparently they do in the living species. It is believed that the generic reference can hardly be questioned.

This species undoubtedly resembles and indeed may be identical with a little leaf from Point of Rocks, Wyo., which was referred by Lesquereux [1] to *Lemna scutata* Dawson and which I afterward,[2] probably incorrectly, regarded as merely a small leaf of *Pistia corrugata* Lesquereux. The leaf from Point of Rocks is much smaller than the leaf here described and is more nearly circular, but the "petiole" and the disposition of the nerves is much the same in both. It is certainly clear that the present leaf, as well as the one from Point of Rocks, is not the same as the type specimens of Dawson's *Lemna scutata*, and it is also reasonably certain that the present leaf can not belong to the genus Lemna.

Occurrence: Fruitland formation, Coal Creek, 35 miles south of Farmington and 1 mile east of reservation line, San Juan County, N. Mex. Lot 81 (6955).

[1] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7, p. 102, pl. 61, fig. 5 [not fig. 3], 1878.

[2] Knowlton, F. H., U. S. Geol. Survey Bull. 163, p. 31, 1900.

Family ARACEÆ.

Pistia corrugata Lesquereux.

Plate LXXXV, figure 4.

Pistia corrugata Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1874, p. 299 [1876]; U. S. Geol. Survey Terr. Rept., vol. 7, p. 103, pl. 61, figs. 1, 3, 4, 6, 7, 9–11, 1878.

Knowlton, U. S. Geol. Survey Bull. 163, p. 31, 1900.

One of the collections from the San Juan Basin contains a single example with its counterpart that undoubtedly belongs to *Pistia corrugata* as described by Lesquereux from specimens collected in the Montana group at Point of Rocks, Wyo. As may be seen from the figure, it is considerably broken and adds little or nothing to our knowledge of the species. It is about the same as the specimen shown in figure 7 of Lesquereux's plate in volume 7 of the Hayden Survey reports, in that it appears to be attached to the side of the thick stem, though it is perhaps really terminal and has been distorted in position during entombment. There appears to be a mass of rootlets by the side of the base, but these are so matted and compressed that their character can not be made out. The nervation is the same as that figured by Lesquereux, namely, an indeterminate number of veins arising in the base of the blade and spreading out and variously anastomosing above, producing very irregular polygonal meshes.

Pistia corrugata is said to be very abundant at Point of Rocks, Wyo., Lesquereux describing it as "covering by itself only large surfaces of shale." It was also found in beds of similar age at Superior, Wyo., by Schultz in 1907, in beds believed to be of Mesaverde age in the

Wind River Basin by Woodruff in 1909, and in the Judith River formation along Milk River, Mont., by Pepperberg in the same year. The questionable reference to this species of the specimens collected in 1908 near Alesua Mountain, N. Mex., by Gardner is now rendered more probably correct by the evidence of the present specimen.

The genus Pistia has had a very interesting geologic history. It is represented in the living flora by a single variable and widely distributed species (*Pistia stratioles* Linné). It is mainly tropical, ranging in this country from Florida to Texas and thence through the West Indies, Mexico, and Central America to Paraguay and Argentina. In Africa it ranges from Natal to Senegambia and Nubia, and thence to Madagascar and the Mascarene Islands. In Asia it is found throughout the East Indies and thence to the Philippines.

Of the four or five fossil species recognized, three are found in North America. The oldest of these is *Pistia nordenskiöldi* (Heer) Berry,[1] which occurs in the Magothy formation of Maryland and very abundantly in the Black Creek formation (Turonian) of North Carolina. It was first described by Heer[2] under the name *Chondrophyllum nordenskiöldi*, from specimens found in the Atane beds of Greenland.

The next species in point of age is *Pistia corrugata* Lesquereux, which has already been discussed.

The youngest American fossil form is *Pistia claibornensis*, from the Claiborne group (middle Eocene) of Georgia, recently described by Berry.[3] This differs markedly from the other forms by its obovate shape and strongly retuse apex.

The only accepted European fossil species is *Pistia mazeli* Saporta and Marion,[4] which occurs in the lignites of Furvean (Provence), France, and is of approximately the same age as *Pistia corrugata*. *Pistia mazeli* appears to be most closely related to the living form; in fact in the figures of the two species given side by side by Saporta and Marion it is almost impossible to note marks of distinction. In some ways it appears that the Claiborne species (*Pistia claibornensis*) is most closely related to *Pistia mazeli*, except that it is more retuse at the apex. However, its full character has not yet been made out, as it still depends on a single example in which little of the nervation has been retained.

The other two species (*Pistia corrugata* and *Pistia nordenskiöldi*) are themselves closely related and are also close to the living species, the main difference being their larger size and more anastomosing nerves.

The significant point brought out by this discussion is the fact that this peculiar plant, now so widely distributed over both hemispheres, was established in essentially its present form in late Cretaceous time, and even then occurred in both hemispheres. It is rather remarkable that so little has been ascertained regarding its Cenozoic history, in view of the great number of localities that have been investigated, yet the evidence that it must have persisted with very little change is brought out by the above exposition.

Occurrence: Kirtland shale, 1¼ miles northeast of Pina Veta China, San Juan County, N. Mex. Lot 96 (6965).

Family PALMACEÆ.

Sabal montana? Knowlton.

Plate LXXXV, figure 2.

Sabal montana Knowlton, U. S. Geol. Survey Prof. Paper 101, p. —, pl. 32, fig. 3 (in press).

Sabalites grayanus (Lesquereux) Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 7, p. 112, pl. 12, fig. 1 [not pl. 12, fig. 2], 1878.

Most fossil palms are very difficult to identify and as a consequence are more or less unsatisfactory as stratigraphic criteria. The leaves are commonly of very large size and it is difficult to procure specimens that are anywhere near perfect, essential characters being in many specimens lacking or obscure. A specimen perhaps no larger than one's hand from a leaf that was possibly 5 or 6 feet in diameter can not fail to convey a very inadequate idea of its character, particularly the range in individual variation, and it is not at all improbable that too many species have been established.

The specimen under consideration is a case in point. It is a fragment, only about 10 centi-

[1] Berry, E. W., Torrey Bot. Club Bull., vol. 37, p. 189, pl. 21, figs. 1–15, 1910.

[2] Heer, Oswald, Flora fossilis arctica, vol. 3, p. 114, pl. 30, fig. 4b; pl. 32, figs. 11, 12, 1874.

[3] Berry, E. W., U. S. Geol. Survey Prof. Paper 84, p. 137, pl. 26, figs. 1–2, 1914.

[4] Saporta Gaston, and Marion, A. F., L'évolution du règne végétale, Phanérogames, vol. 2, p. 37, figs. 114c, 114d, 1885.

meters long, from some portion of the blade showing the petiole, or its prolongation, and the attachment of numerous rays. It appears to be from the under side of the leaf, but it is impossible to determine the length of this prolongation of the petiole or to estimate the number of rays with any degree of accuracy. It seems to belong to what has been named *Sabal montana*, as based on a considerable number of examples rather widely scattered through the several Montana localities, but on the other hand it is hardly to be distinguished from *Geonomites ungeri* Lesquereux,[1] a species supposed to be confined to the Raton and allied Eocene formations. *Geonomites ungeri* was established on a mere fragment from the middle of a leaf that was obviously of considerable size, and there is no means of knowing the size and configuration of the petiole, the number of rays, etc., and consequently there is no way to compare it with leaves referred to *Sabal montana*, in which these features are known. However, until more definite information is available the San Juan specimen may stand as *Sabal montana?*.

Occurrence: Fruitland formation, 18 miles south of San Juan River and 4 miles east of Chaco River, San Juan County, N. Mex. Lot 28 (6961).

Sabal? sp.

Plate LXXXV, figure 1.

The specimen here figured is the only one of its kind observed in the collections. It is a mere fragment from what apparently was a very large leaf, but it lacks so many essential features that it has seemed unwise to give it a specific name. When compared with the specimen figured as *Sabal montana?* it is seen to be very different, the prolongation of the rachis being especially strong and the rays very large at the point of their attachment. But the size of the leaf, the length of the rachis, and the number and configuration of the rays are unknown, and this fragment simply serves to call attention to the presence in these beds of a large palm.

Occurrence: Fruitland formation, just across San Juan River from Fruitland, about half a mile above the bridge, San Juan County, N. Mex. Lot 3 (6957).

[1] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7, p. 118, pl. 11, fig. 2, 1878.

Family MYRICACEÆ.

Myrica torreyi Lesquereux.

Plate LXXXVI, figure 1.

Myrica torreyi Lesquereux, U. S. Geol. and Geog. Survey Terr. Sixth Ann. Rept., for 1872, p. 392 [1873]; U. S. Geol. Survey Terr. Rept., vol. 7, p. 129, pl. 16, figs. 3–10, 1878.
Ward, U. S. Geol. Survey Sixth Ann. Rept., p. 551, pl. 40, fig. 4, 1886; Bull. 37, p. 32, pl. 14, fig. 5, 1887.
Knowlton, U. S. Geol. Survey Bull. 163, p. 34, pl. 6, figs. 1–3, 1900.
Cockerell, Colorado Univ. Studies, vol. 7, p. 150, 1910.

Only a few fragments of this species were found, but it is so well marked that these are sufficient to attest its presence in these beds.

Occurrence: Fruitland formation, 30 miles south of Farmington and 1 mile east of reservation line, San Juan County, N. Mex. Lot 75 (6956).

Myrica? neomexicana Knowlton, n. sp.

Plate LXXXVI, figures 2–4.

Leaves small, deltoid in general outline, apparently truncate at the base and obtusely pointed at the apex; with at least 9 and probably as many as 11 or 13 lobes, the basal pair cut deeply or nearly to the midrib, becoming almost separate, others only slightly cut and in upper portion probably reduced to merely strong undulations; lobes obtuse, entire or more commonly strongly and obtusely toothed; nervation pinnate, the midrib being relatively strong; secondaries as many as the lobes, at a low angle of emergence, craspedodrome, ending in the lobes; finer nervation abundant and very irregular.

Although there are several specimens that obviously belong together they are so fragmentary that the species is very inadequately represented. It is roughly triangular or deltoid, and was at least 4 centimeters in length and very probably was considerably longer. The width at base was certainly over 4 centimeters, and if there was an additional free or nearly free lobe, its width must have been 6 centimeters or more.

Three specimens have been figured. In that shown in figure 3 the lobes are nearly or quite entire, but in the somewhat larger leaf shown in figure 2 the lobes are irregularly and obtusely toothed. The specimen shown in figure 4 is evidently the basal lobe of the leaf, but whether it belonged to a larger leaf

or is another nearly detached lobe below the one shown in figure 2 is of course quite impossible to determine. Except for its close resemblance to the lower lobe like that in figure 2, this specimen might be considered an individual leaf, but it is broken on the upper side near the base, where it was undoubtedly connected to the other part of the blade.

Owing to the fragmentary nature of these specimens this generic reference is more or less uncertain. In some respects they are of the character of certain species of Myrica, such, for instance, as *Myrica alkalina* Lesquereux,[1] from the Green River formation of Wyoming, but they differ markedly in many essential particulars.

Occurrence: Kirtland shale, 3 inches below base of Ojo Alamo sandstone, 1½ miles northeast of Pina Veta China, San Juan County, N. Mex. Lot 40 (6966).

Family SALICACEÆ.

Salix baueri Knowlton, n. sp.

Plate LXXXVI, figures 7, 8.

Leaves small, of firm texture, narrowly elliptical-lanceolate, about equally narrowed to both base and apex; margin entire; midrib relatively very thick; other nervation obscure or wanting.

This little species is represented in the collections by some half dozen specimens, three of which are here figured. They are small leaves 3 or 4 centimeters in length and about 14 millimeters in greatest width. They are preserved on a very coarse grained matrix which has obscured or obliterated nearly all traces of nervation except the very thick midrib. An occasional secondary appears to be at an angle of about 45° and much curved upward near the margin.

These little leaves are so obscurely preserved that their full character can not be made out, and they are consequently of comparatively little stratigraphic value. They are of about the same size and shape as specimens of *Salix integra* Göppert from Black Buttes, Wyo., as figured by Lesquereux,[2] but the absence of most of the nervation makes it impossible to compare them satisfactorily with this species.

Occurrence: Fruitland formation, 10 miles south of San Juan River and 4 miles east of Chaco River, San Juan County, N. Mex. Lot 16 (6958).

Salix sp. *a* Knowlton.

Plate LXXXVI, figure 9.

Salix sp. *a* Knowlton, U. S. Geol. Survey Prof. Paper 101, p. —, pl. 38, fig. 1 (in press).

The collection contains a number of willow leaves that are indistinguishable from a form described and figured from the Vermejo formation of the Raton Mesa region. The leaf figured here, which is one of the best, is about 8 centimeters in length and 1.8 centimeters in width. It has a very thick midrib and only faint indications of secondaries, which appear to be close, parallel, and at an angle of about 45°. It is so indistinctly preserved that it has not been thought desirable to give it a specific name.

Occurrence: Fruitland formation, 10 miles south of San Juan River and 4 miles east of Chaco River, San Juan County, N. Mex. Lot 16 (6958).

Family FAGACEÆ.

Quercus baueri Knowlton, n. sp.

Plate LXXXVI, figures 5, 6.

Leaf small, of coriaceous texture, ovate-elliptical, about equally rounded to both base and apex; margin provided with relatively strong, rather obtuse teeth; midrib very strong; secondaries about four pairs, strong, alternate, craspedodrome, terminating in the teeth; finer nervation obscure.

The specimen here figured is nearly perfect and is 3.5 centimeters long and 2 centimeters wide. It was evidently a rather thick and coriaceous leaf, as is attested both by its thick nervation and by its general appearance.

This species has some resemblance to an unpublished species of Quercus from the Vermejo formation but differs in its slightly smaller size and less prominent teeth.

Occurrence: Fruitland formation, from clinker above highest coal bed, 30 miles south of Farmington and 1 mile east of reservation line, San Juan Basin, N. Mex. Lot 75 (6956).

[1] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 8, p. 149, pl. 45A, figs. 10–15, 1883.

[2] Idem, vol. 7, p. 167, pl. 21, figs. 1, 2, 1878.

Family MORACEÆ.

Ficus baueri Knowlton, n. sp.

Plate LXXXIX, figure 2.

Leaves of medium size and firm texture, ovate, rather abruptly rounded to the apparently truncate base, acuminate at apex; midrib strong, straight; secondaries three or four pairs, very remote, alternate, at an angle of 45°, strong below, much thinner and almost disappearing above, probably camptodrome; nervilles thin, very obscure, oblique to the midrib; finer nervation not retained.

The specimen figured, although it lacks a considerable portion of the leaf, is sufficient to give a good idea of this species. It is very regularly ovate, about 115 centimeters in length and 7 centimeters in greatest width, which is above the middle of the blade. It is remarkable for its strong midrib and its few, remote, alternate secondaries.

This species is in a way of the type of *Ficus denveriana* Cockerell,[1] a well-known Denver species. It differs markedly in nervation, however, as it has only three or four pairs of very remote secondaries, while the Denver form has not less than ten or twelve pairs of relatively close parallel secondaries. The manner in which the secondaries reach the margin is also very different in the two forms, and hence they can not be considered as at all closely related.

Occurrence: Fruitland formation, in clinker above highest coal bed, 30 miles south of Farmington and 1 mile east of reservation line, San Juan Basin, N. Mex. Lot 75 (6956).

Ficus curta? Knowlton.

Plate LXXXVIII, figure 3.

Ficus curta Knowlton, U. S. Geol. Survey Prof. Paper 101, p. —, pl. 42, fig. 5 (in press).

The type of this species comes from the Vermejo formation of the Canon City coal field, Colorado, and is described and figured in the report cited.

The specimen here figured lacks most of the margin, but so far as can be made out it appears to agree with the leaf from Colorado.

Occurrence: Fruitland formation, 30 miles south of Farmington and 1 mile east of reservation line, San Juan County, N. Mex. Lot 75 (6956).

Ficus prætrinervis Knowlton.

Ficus prætrinervis Knowlton, U. S. Geol. Survey Prof. Paper 101, p. —, pl. 41, figs. 1–4; pl. 42, fig. 1 (in press).

The types of this species come from the Vermejo formation of the Raton Mesa region of Colorado and New Mexico and are described and figured in the report cited. It is a well-marked and exceedingly abundant form in the Vermejo formation and appears to be also abundant and well defined in the San Juan Basin.

Occurrence: Fruitland formation, 30 miles south of Farmington and 1 mile east of reservation line, San Juan County, N. Mex. Lots 75 (6956) and 78 (6952).

Ficus leei Knowlton.

Plate XC, figure 2.

Ficus leei Knowlton, U. S. Geol. Survey Prof. Paper 101, p. —, pl. 39, figs. 1–6; pl. 40, figs. 1, 2 (in press).

The types of this fine species come from the Vermejo formation of the Raton Mesa region of Colorado and New Mexico and are described and figured in the report cited. It is one of the most abundant and well-marked forms of the Vermejo formation.

Ficus leei is also fairly abundant in the San Juan Basin, though the leaves are somewhat smaller than the average size of those from the type area, but they do not otherwise differ.

Occurrence: Fruitland formation, Amarillo Canyon, 10 miles south of San Juan River and 4 miles east of Chaco River, N. Mex., lot 16 (6958); 30 miles south of San Juan River and 4½ miles east of reservation line, San Juan County, N. Mex., lot 74 (6963). Kirtland shale; 1½ miles northeast of Pina Veta China, San Juan County, N. Mex., lot 40 (6966).

Ficus prælatifolia Knowlton, n. sp.

Plate LXXXVII, figure 4.

Leaves large, broadly ovate, truncate or slightly heart-shaped at base, probably obtuse above; nervation strongly three-ribbed from the top of the petiole, the midrib stronger, with several pairs of subopposite secondaries high up above the base; lateral ribs with six or

[1] A new name for *Ficus spectabilis* Lesquereux, which proved to be preoccupied. See U. S. Geol. Survey Terr. Rept., vol. 7, pl. 33, figs. 4–6, 1878.

seven secondary camptodrome branches on the outside; nervilles numerous, strong, mostly unbroken.

This species is represented by a number of examples, one of the best of which is figured. It was probably not less than 13 or 14 centimeters in length and about 9 centimeters in width, but the exact length can only be inferred. It was conspicuously longer than broad. The strong, three-ribbed nervation and other details are well shown in the figure.

This form appears to be most closely related to *Ficus planicostata latifolia* Lesquereux[1] (later called *Ficus latifolia* (Lesquereux) Knowlton), which was described originally from specimens collected at Black Buttes, Wyo., but has since been discovered at a number of other localities. If only the basal portion was present it would be extremely difficult to distinguish the San Juan leaf from the previously named species, but the shape of the whole leaf is very different. Thus, in *Ficus planicostata latifolia* the blade is very much broader than long, but in the one under consideration the reverse is true.

Occurrence: Fruitland formation, 30 miles south of Farmington and 1 mile east of reservation line, San Juan County, N. Mex. Lot 75 (6956).

Ficus sp.

Plate LXXXIX, figure 1.

The single much-broken specimen figured is the only one noted. It is a rather large leaf (about 12 centimeters long and 6.5 centimeters wide) elliptical-ovate, with apparently a slightly heart-shaped base, and entire margin. The entire upper part is missing. The nervation consists of a rather slender midrib and an unknown number of thin, remote, alternate secondaries, the lower of which has several tertiary branches on the lower side. None of the finer nervation is retained, owing to the coarse-grained matrix.

This form is so poorly preserved that it is hardly worth while to institute comparisons between it and various named species.

Occurrence: Fruitland formation, Amarillo Canyon, 10 miles south of San Juan River and 4 miles east of Chaco River, San Juan County, N. Mex. Lot 16 (6958).

[1] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7, p. 202, pl. 31, fig. 9, 1878.

Ficus rhamnoides Knowlton.

Plate LXXXVII, figure 3.

Ficus rhamnoides Knowlton, U. S. Geol. Survey Bull. 163, p. 47, pl. 10, figs. 1–3; pl. 11, fig. 1, 1900.

This species was described originally from specimens found in the Montana group at Point of Rocks, Wyo. The specimen figured here, although lacking all the lower half of the leaf, agrees in every particular with the original specimens.

Occurrence: Fruitland formation, 13 miles south of San Juan River and 1 mile east of Chaco River, San Juan County, N. Mex. Lot 23 (6960).

Ficus squarrosa? Knowlton.

Plate LXXXVI, figure 10.

Ficus squarrosa Knowlton, U. S. Geol. Survey Bull. 163, p. 45, pl. 8, fig. 2, 1900.

The single example figured is referred with doubt to this species. It is a much smaller leaf than the type but does not appear to differ essentially otherwise. It is so poorly preserved, however, that it seems best to question the full identification.

Occurrence: Fruitland formation, 30 miles south of Farmington and 1 mile east of reservation line, San Juan County, N. Mex. Lot 76 (6963).

Ficus sp.

Plate LXXXVIII, figure 1.

Leaf large, apparently nearly circular in general outline, rather broadly heart-shaped at base, probably rounded above; nervation strongly marked, consisting of seven ribs from the top of the petiole, the central or midrib slightly the stronger, with two pairs of opposite, remote secondaries, other ribs (three on each side) about equally dividing the broad blade into four areas, the inner pair of ribs joining the lower secondaries of the midrib; the lower ribs with tertiary branches on the outside which join by a series of broad loops just inside the margin; nervilles numerous, very strong, mainly broken; finer nervation producing quadrangular areolæ.

This form is undoubtedly very well marked, but unfortunately it lacks nearly all the margin except at the base and for a distance of some 4 centimeters above it. This leaf was probably 11 or 12 centimeters long and hardly less than

12 centimeters broad. The rather deeply heart-shaped base, seven strong ribs, strongly looping tertiaries, and strong, broken nervilles would make it easy of recognition though it lacks so much of the blade.

This leaf suggests at once *Ficus wardii* Knowlton,[1] from the Montana group at Point of Rocks, Wyo. That species, however, is smaller and has a shallower heart-shaped base and only five instead of seven ribs. The lower or outer ribs in *Ficus wardii* have numerous regular, parallel tertiary branches quite unlike the tertiaries in the present form. These characters should make it easy of recognition in the future.

Occurrence: Fruitland formation, 30 miles south of Farmington and 1 mile east of reservation line, San Juan County, N. Mex. Lot 75 (6956).

Ficus eucalyptifolia? Knowlton.

Plate LXXXVII, figures 1, 2.

Ficus eucalyptifolia Knowlton, U. S. Geol. Survey Prof. Paper 101, p. —, pl. 44, figs. 1, 2 (in press).

The types of this species come from the Vermejo formation of Rockvale, Colo., and are described and figured in the report cited. The San Juan Basin material embraces a number of leaves that appear to belong to this species, but as they are rather poorly preserved it has seemed best to question the reference. They are, so far as can be made out, of the same size and shape as the types, but the nervation, with the exception of the strong midrib, is obscure. The secondaries appear to be very thin, evenly spaced, and parallel, but their termination near the margin can not be seen.

Occurrence: Fruitland formation, 13 miles south of San Juan River and 1 mile east of Chaco River, San Juan County, N. Mex. Lot 23 (6960).

Family LAURACEÆ.

Laurus baueri Knowlton, n. sp.

Plate LXXXIX, figure 5.

Leaf evidently of thick texture and probably evergreen, lanceolate, narrowed in about equal degree to the wedge-shaped base and apparently acuminate apex (actual base and apex not preserved); margin entire, provided with a thick "cord" which makes the actual margin; midrib relatively thick, straight; secondaries very thin, alternate, at an angle of 30° or 40°, much curved upward and disappearing just inside the margin or each joining by a series of very thin loops to the one next above; nervilles all very much broken and irregular and forming different-sized areolæ.

The example figured is the only one observed. It is a narrowly lanceolate, slightly unequal-sided leaf about 9 centimeters long and a little over 2.5 centimeters wide. It is remarkable in that the margin is formed by a thick fibrous "cord" nearly 1 millimeter in width, which otherwise resembles a secondary branch. The midrib is very thick for the size of the leaf, but the secondaries are thin and delicate. The actual leaf substance is retained as a thin membranaceous carbonaceous film, which shows all the details of the nervation as completely as could be seen in a living leaf. When this carbonaceous film is removed it is found that the details of nervation are very faintly impressed on the matrix. It seems probable, from the thick midrib, the woody marginal "cord," and the faintly impressed secondaries, that the leaf was originally thick and coriaceous and not unlikely was evergreen.

This species is of the general type of certain of the leaves referred by Lesquereux[2] to *Laurus socialis*, a well-known Tertiary form. It differs from that species, however, in its larger size, fewer secondaries, which curve upward for a longer distance, and above all in the presence of the marginal "cord."

Occurrence: Fruitland formation, 2 miles east of Chaco River, San Juan Basin, N. Mex. Lot 14 (6948).

Laurus coloradensis Knowlton.

Plate LXXXVIII, figures 4, 5.

Laurus coloradensis Knowlton, U. S. Geol. Survey Prof. Paper 101, p. —, pl. 45, fig. 3 (in press).

The type of this species comes from the Vermejo formation at Rockvale, Colo., and is described and figured in the report cited. The two leaves here figured are somewhat smaller than the type but do not appear to differ essentially in any other particular.

Occurrence: Fruitland formation, 13 miles south of San Juan River and 1 mile east of Chaco River, San Juan County, N. Mex. Lot 23 (6960).

[1] Knowlton, F. H., Flora of the Montana formation: U. S. Geol. Survey Bull. 163, p. 48, pl. 9, fig. 1, 1900.

[2] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7, p. 213, pl. 36, figs. 1–4, 7, 1878.

Family NYMPHÆACEÆ.

Nelumbo sp.

Plate LXXXVI, figure 11.

The San Juan Basin collections include the specimen here figured, which appears to belong to Nelumbo. It is a fragment from near the central part of what was a perfoliate leaf of considerable size, though none of the margin is now retained. The leaf was at least 12 centimeters in diameter and very likely was nearly twice this size. It was evidently very thick, as is proved by the fact that the ribs seem deeply embedded in the leaf substance—so deeply, in fact, that it is impossible to determine their exact number, though there were apparently as many as 18 or 20. There is also evidence that some of them were unforked. None of the other details can now be made out.

It is hardly worth while to attempt comparisons between this and described species of the genus, as so many of its characters are obscure or missing. It appears, however, to be of the type of the common living *Nelumbo lutea* (Willdenow) Persoon, the water chinkapin of lakes and streams.

Occurrence: Fruitland formation, 30 miles south of Farmington and 1 mile east of reservation line, San Juan County, N. Mex. Lot 76 (6953).

Family MIMOSACEÆ.

Leguminosites? neomexicana Knowlton, n. sp.

Plate XC, figures 3, 4.

Leaflet minute, about 11 millimeters in length and 5 millimeters in width, ovate-lanceolate, rounded and apparently truncate at base, acuminate at apex; midrib very thick for the size of the blade; secondaries extremely thin, about four pairs, alternate, camptodrome, each joining the one next above and forming a bow far inside the margin; finer nervation not retained.

It must be confessed that this leaflet is of little stratigraphic value, its main interest being in the evidence it affords of the presence of vegetation of this type in these beds. It is so very small and on the whole so poorly preserved that comparisons with other forms referred to this type will not be attempted.

Occurrence: Kirtland shale, 1½ miles northeast of Pina Veta China, San Juan County, N. Mex. Lot 40 (6966).

Family STERCULEACEÆ.

Pterospermites undulatus Knowlton.

Plate XC, figure 5.

Pterospermites undulatus Knowlton, U. S. Geol. Survey Bull. 163, p. 67, pl. 16, fig. 3; pl. 17, fig. 2; pl. 18, fig. 4, 1900.

The example figured, which unfortunately is much broken, appears to be referable to this species. It is of about the average size of those from Point of Rocks, Wyo., and with the exception of being a little more rounded below does not differ essentially.

Occurrence: Fruitland formation, 30 miles south of Farmington and 1 mile east of reservation line, San Juan County, N. Mex. Lot 75 (6956).

Pterospermites neomexicanus Knowlton, n. sp.

Plate XC, figure 6.

Leaf evidently thin in texture, ovate, abruptly truncate and slightly heart-shaped at base, acuminate at apex; margin entire below, becoming slightly undulate in the middle and few-toothed in the upper third, the teeth small, sharp, pointing outward, and separated by very shallow sinuses; midrib slender; secondaries about four pairs, subopposite, remote, the lower pair arising near the top of the petiole, with five or six branches on the lower or outer side, the lowest with several tertiary camptodrome branches on the lower side; upper secondaries simple or occasionally branched; nervilles few, irregular; finer nervation not retained.

This leaf is regularly ovate, about 8 centimeters long and 5.5 centimeters wide at the broadest point, which is just below the middle. It is otherwise distinguished by its few secondaries and by the margin entire below and undulate and finely toothed above.

Occurrence: Fruitland formation, 30 miles south of Farmington and 1 mile east of reservation line, San Juan County, N. Mex. Lot 75 (6956).

Pterospermites sp.

Plate LXXXIX, figure 3; Plate XC, figure 1.

One of the collections contains a fragment of a very large leaf that apparently belongs to the genus Pterospermites. It could hardly have been less than 18 centimeters in length and was at least 14 centimeters in width. It

was apparently broadly ovate, rounded at the base, with the margin strongly undulate-toothed, both the teeth and the sinuses separating them being rounded. The secondaries are strong, occasionally forked, approximately parallel, and craspedodrome. Nervilles rather scattered, somewhat irregular but usually unbroken. Finer nervation producing an irregularly quadrangular mesh.

Associated in the same collection is the specimen shown in figure 1, which represents the basal portion of a large leaf that is probably the same species as that shown in Plate LXXXIX, figure 3. It is deeply heart-shaped at the base. The midrib is very strong, and the secondaries are at a very low angle. The petiole is preserved for a length of 1.5 centimeters and is very thick and strong.

This leaf, which is obviously too much broken to admit of satisfactory diagnosis, appears to be congeneric with *Pterospermites undulatus* Knowlton,[1] from Point of Rocks, Wyo., but it was much larger and has a more markedly undulate margin. The secondaries appear to emerge from the midrib at a lower angle than in the Point of Rocks form, but this point is obscure. The finer nervation is about the same in both forms.

Occurrence: Kirtland shale; 1½ miles northeast of Pina Veta China, San Juan County, N. Mex. Lot 40 (6966).

Family GROSSULARIACEÆ.

Ribes neomexicana Knowlton, n. sp.

Plate LXXXIX, figure 4.

Leaf small, firm in texture, broader than long, three-lobed, the lateral lobes strongly toothed (central lobe much broken); base truncate or very slightly heart-shaped; nervation not well retained, consisting at least of a fairly strong midrib and two lateral ribs that arise at or near the base and supply the lateral lobes, each apparently with several branches on the outside that end in the marginal teeth.

This little leaf, the only one of its kind in the collections, is broadly ovate in general outline, about 2 centimeters long and nearly 3 centimeters broad. It appears to be rather deeply three-lobed, and each of the lateral lobes is provided with five or six strong pointed teeth. The middle lobe is so much broken that its exact shape can not be made out, though it was doubtless toothed like the others.

Occurrence: Fruitland formation, 10 miles south of San Juan River and 4 miles east of Chaco River, San Juan County, N. Mex. Lot 16 (6958).

INCERTÆ SEDES.

Carpites baueri Knowlton, n. sp.

Plate LXXXVIII, figure 2.

Fruit spheroidal, about 11 by 13 millimeters in short and long diameter, much compressed; surrounded by an exocarp fully 1 millimeter thick; "stone" deeply sulcate at one end but not otherwise marked.

The example figured is the only one found in the collections and consequently its exact character is difficult to determine; in fact, it is impossible to be certain of its orientation. The sulcation on one side is probably opposite the point of attachment. The nature of the outer covering is difficult to interpret. It could hardly have been fleshy, as it is so uniform in thickness and so distinct, and probably it was an exocarp similar to that in certain species of Carya. The inner portion, or "shell," is without markings except the deep furrow on one side. It is perhaps needless to add that its affinity is not known.

Occurrence: Fruitland formation, Coal Creek, 35 miles south of Farmington and 1 mile east of reservation line, San Juan County, N. Mex. Lot 81 (6955).

Phyllites petiolatus Knowlton, n. sp.

Plate XCI, figure 3.

Leaves small, membranaceous in texture, elliptical-lanceolate, long wedge-shaped at base, apparently narrowly acuminate at apex; margin perfectly entire; petiole very strong, more than 2.5 centimeters in length; midrib very strong below, becoming thin in the upper third of the leaf; secondaries four pairs, alternate, at an angle of about 50°, each running up for a long distance and disappearing in or near the margin or joining the secondary next above; nervilles numerous, very thin, mainly unbroken, at right angles to the secondaries; finer nervation obscure.

[1] Knowlton, F. H., U. S. Geol. Survey Bull. 163, p. 67, pl. 17, fig. 2, 1900.

The leaf figured is the best one observed. It is about 7 centimeters long and slightly over 2 centimeters in width, the petiole, as already stated, adding at least 2.5 centimeters to the total length. This species may be known by its elliptical-lanceolate shape, long wedge-shaped base, long, thick petiole, and only four pairs of alternate secondaries.

Occurrence: Fruitland formation, 30 miles south of Farmington and 1 mile east of reservation line, San Juan County, N. Mex. Lot 75 (6956).

Phyllites neomexicanus Knowlton, n. sp.

Plate XCI, figure 2.

Leaf small, rather thick in texture, slightly obovate-elliptical, rather abruptly wedge-shaped at base, apparently rounded and rather obtuse above; margin entire; midrib relatively strong; secondaries about five pairs, subopposite, remote, at an angle of about 50°, somewhat turned upward, camptodrome or just barely reaching the margin; nervilles mainly unbroken, somewhat oblique to the secondaries.

This little leaf is 6.5 centimeters in length and 3 centimeters in width just above the middle.

Occurrence: Fruitland formation, 30 miles south of Farmington and 1 mile east of reservation line, San Juan County, N. Mex. Lot 75 (6956).

Unassigned plant (a).

Plate XCI, figures 4–9.

In one of the collections there are several specimens of a plant whose exact affinity has not been ascertained. The most complete example, shown in figure 8 (enlarged in fig. 9), is pinnate, with several narrowly lanceolate fern-like "pinnæ," about 15 millimeters long and 5 millimeters broad, with two close rows of small, scythe-shaped organs (pinnules or leaflets). Some of the little "pinnules" (see fig. 4) are short-petioled; others are nearly or quite sessile below, becoming confluent above. In the upper portion of some of the "pinnæ" the "pinnules" are set so closely that the blades distinctly overlap.

The nervation of the "pinnules" is peculiar. A single vein arises from the petiole at the lower margin of the blade and forks just above its point of origin; the lower branch usually traverses the length of the blade and occasionally branches or forks, and the upper one distinctly forks once or twice into equal branches entirely after the manner of a fern.

The size and general appearance of this little plant, as well as the shape and close overlapping of many of the foliar organs ("pinnules" or "leaflets"), are somewhat suggestive of Selaginella, but if it were of that genus it should belong to a type in which there should be present two other rows of minute scalelike leaves, and nothing of the kind has been detected. Moreover, the nervation does not agree with the nervation of Selaginella.

On first inspection it suggested *Selaginella falcata* Lesquereux,[1] from Point of Rocks, Wyo., but closer study shows that the "leaves" are much broader in the present material and have a quite different nervation.

The pinnate arrangement of the narrow "pinnæ," the appearance of the "pinnules," and above all the forking nervation suggest a small delicate fern of the asplenoid type, but Mr. W. R. Maxon, to whom the specimen was shown, is quite certain it is not a pteridophyte.

Considering these uncertainties as to its affinities, I will not venture to place it biologically until more and better material is available.

Occurrence: Kirtland shale, 1½ miles northeast of Pina Veta China, San Juan County, N. Mex. Lot 43 (6965).

Unassigned plant (b).

Plate XCI, figure 1.

In one of the collections of red baked shale there is a specimen that is worthy of brief mention, although it is very fragmentary and hence difficult of allocation. It consists of a fragment of a stem about 4 centimeters in length and about 4 millimeters in diameter. It bears apparently opposite or subopposite leaves, whose sheathing bases cover the stem for a considerable distance below each node. The leaves are lanceolate and slightly constricted at the base and presumably acute at the apex, though no tips are preserved. The leaves are retained for a length of about 1.5 centimeters, but may well have been many times this length. They are unkeeled and pro-

[1] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7, p. 46, pl. 61, figs. 12–15, 1878.

vided with numerous close, fine, parallel veins with cross veinlets.

The affinity of this plant has not been determined. The leaves with their sheathing bases suggest a sedge, but this is hardly more than a suggestion, for they do not agree with the combined characters of this group. The plant is evidently a monocotyledon and in general appearance somewhat resembles some of the leafy-stemmed forms of Cypripedium or Habenaria, but this resemblance is perhaps hardly more than superficial, and the fact remains that the specimen is too fragmentary to permit complete identification.

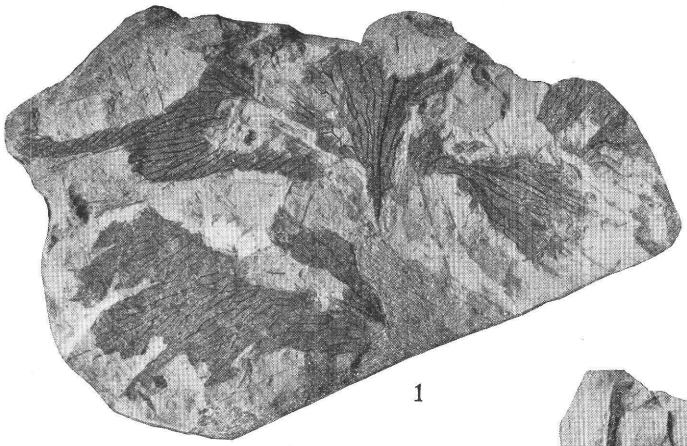
Occurrence: Fruitland formation, 30 miles south of Farmington and 1 mile east of reservation line, San Juan County, N. Mex. Lot 75 [6956].

PLATES LXXXIV-XCI.

PLATE LXXXIV.

Page.

FIGURES 1, 2. *Onoclea neomexicana* Knowlton 332
3. *Anemia hesperia* Knowlton 332
4. Anemia sp 333
5–9. *Asplenium neomexicanum* Knowlton 331



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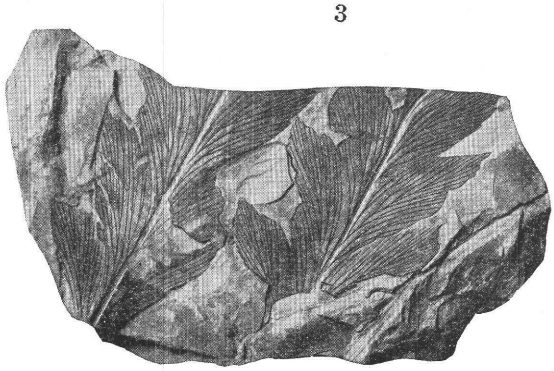

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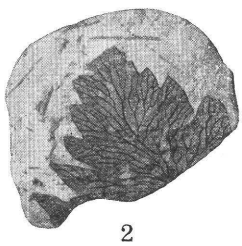

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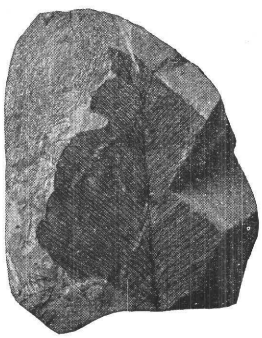

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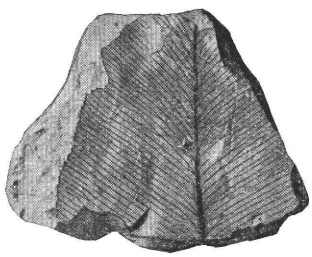

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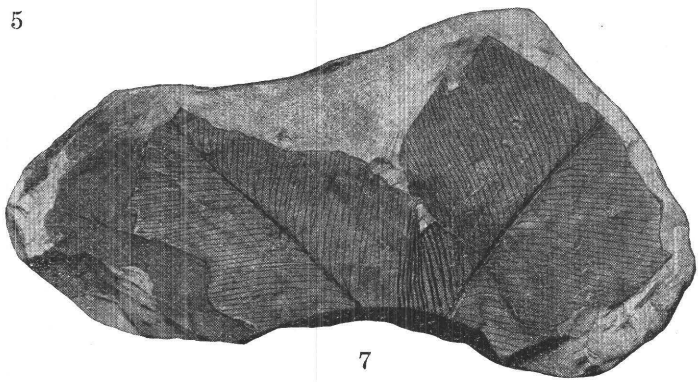

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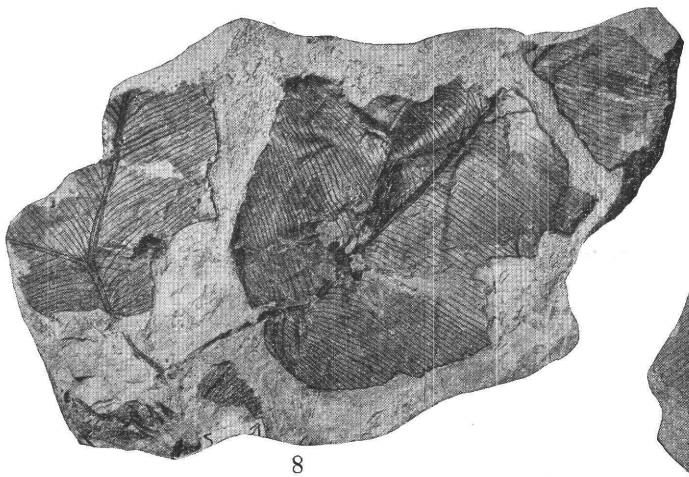

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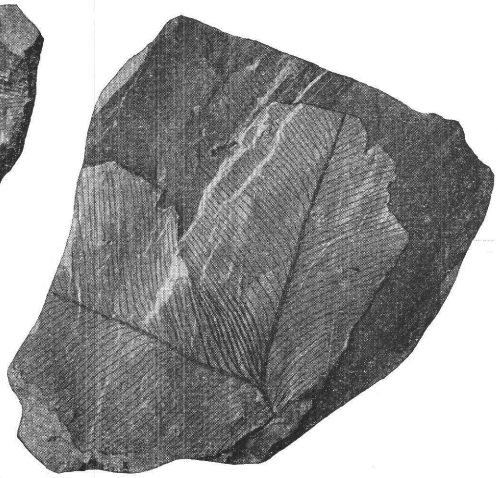

9

FLORA OF THE FRUITLAND AND KIRTLAND FORMATIONS.

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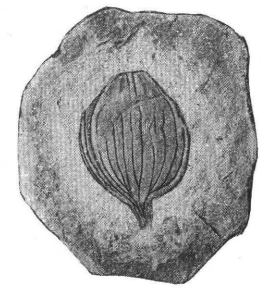

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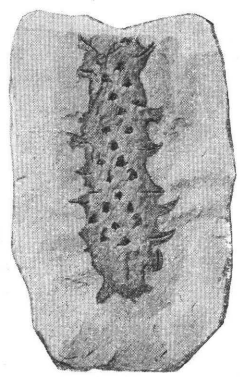

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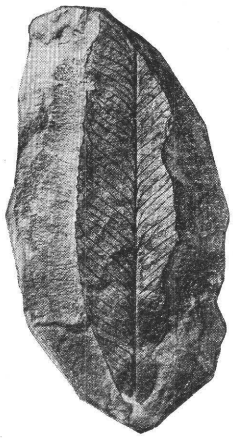
FLORA OF THE FRUITLAND AND KIRTLAND FORMATIONS.

PLATE LXXXV.

PLATE LXXXVI.



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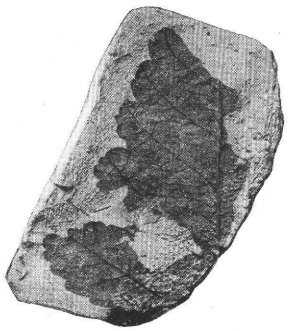

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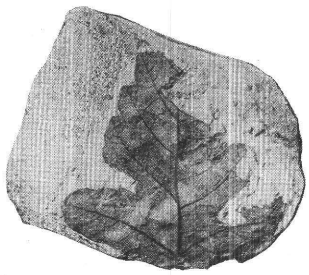

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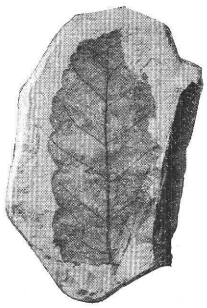

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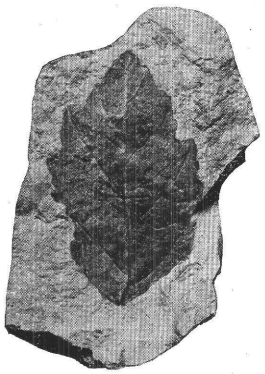

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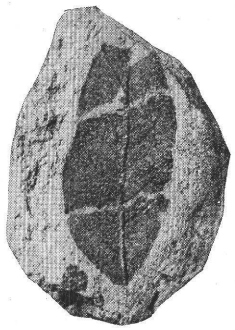

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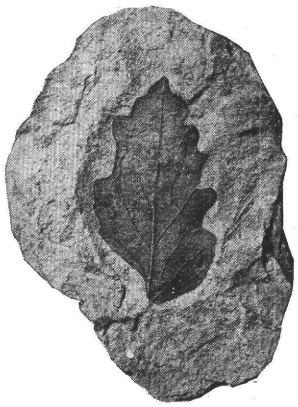

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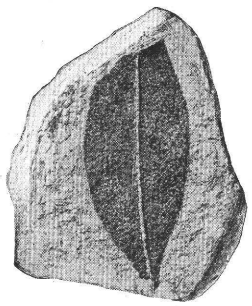

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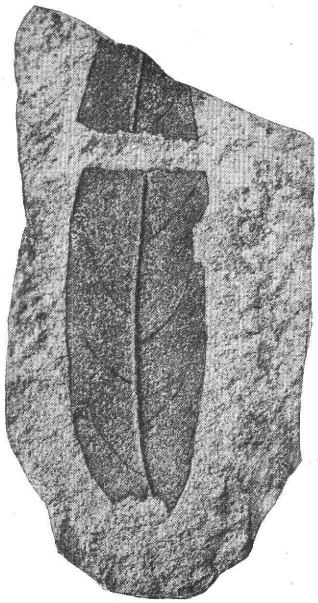

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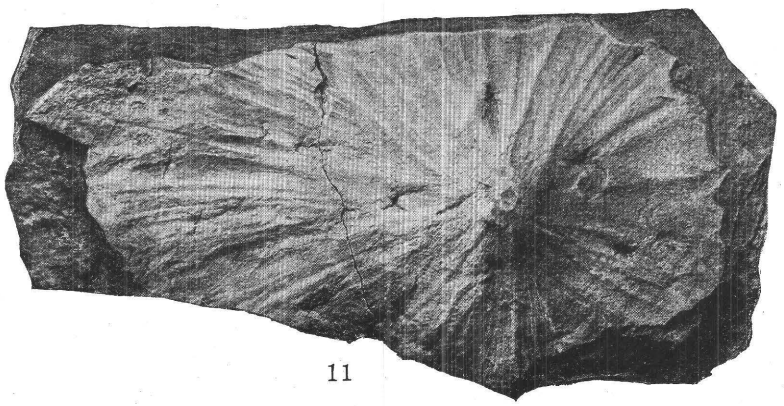

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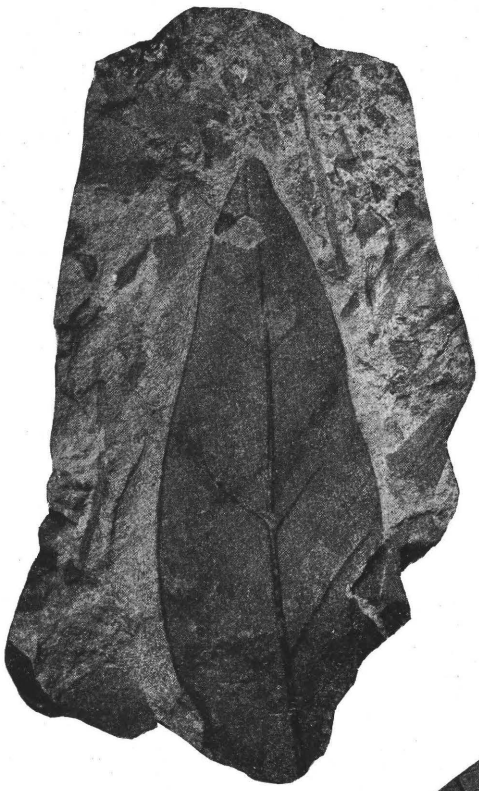
FLORA OF THE FRUITLAND AND KIRTLAND FORMATIONS.



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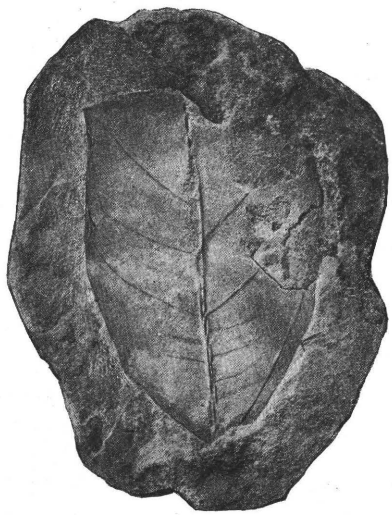

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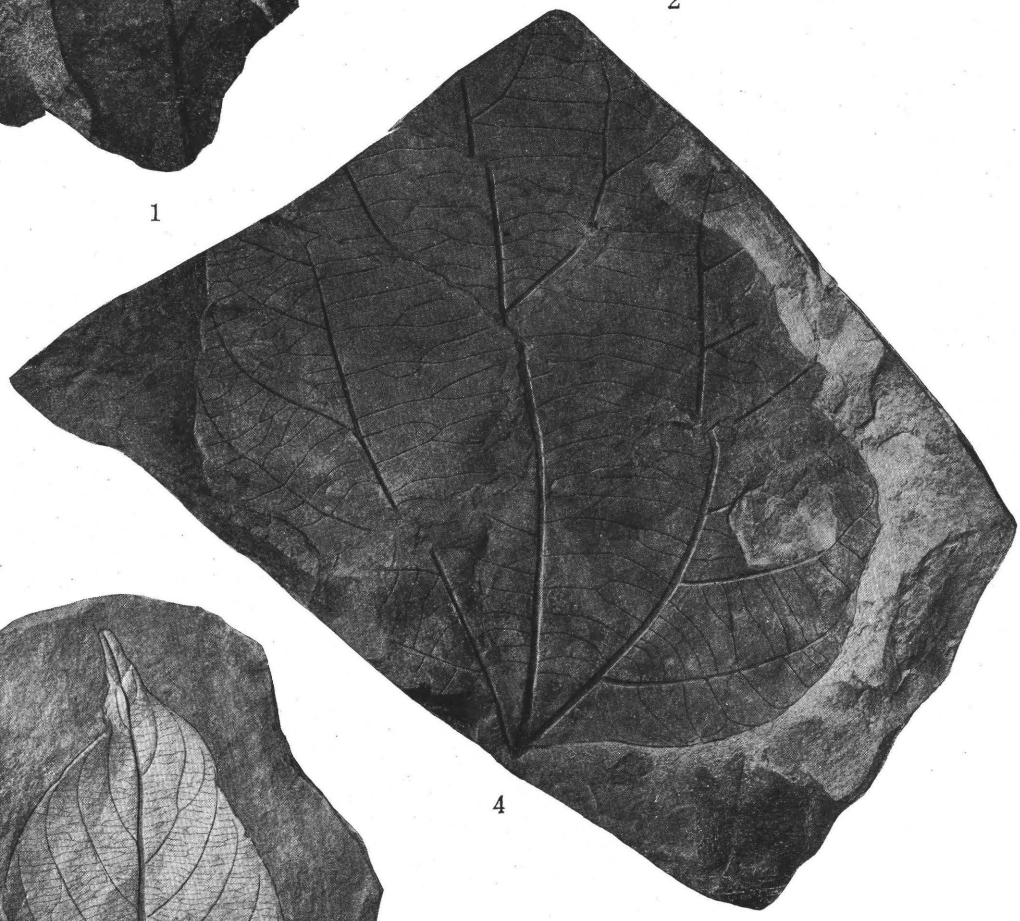

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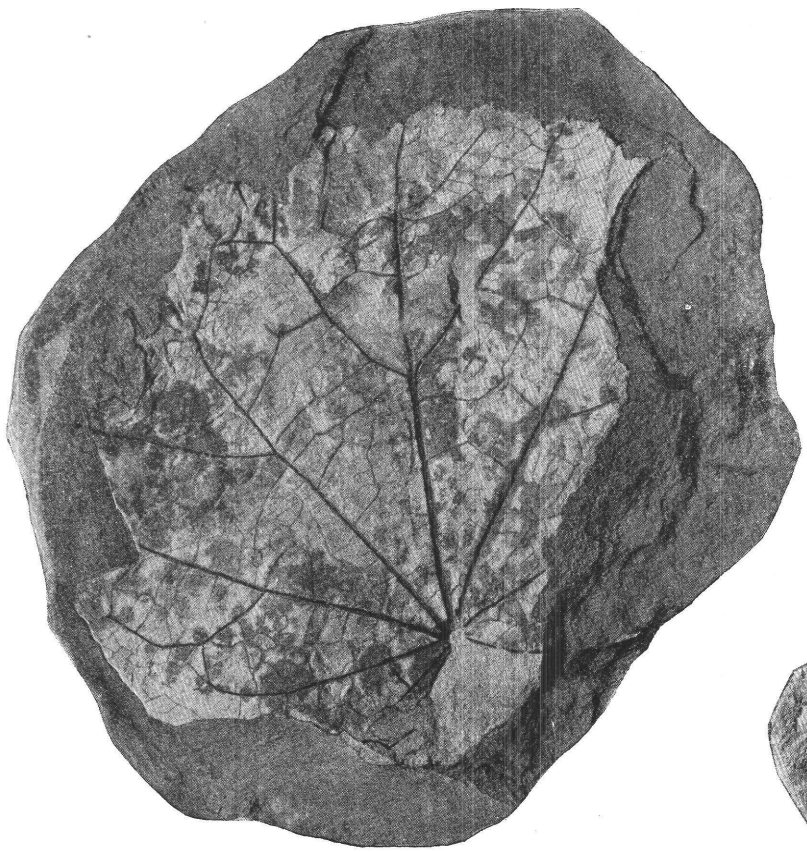
FLORA OF THE FRUITLAND AND KIRTLAND FORMATIONS.

PLATE LXXXVII.

PLATE LXXXVIII.



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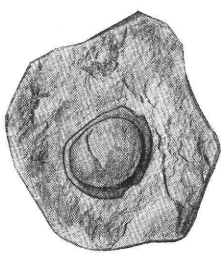

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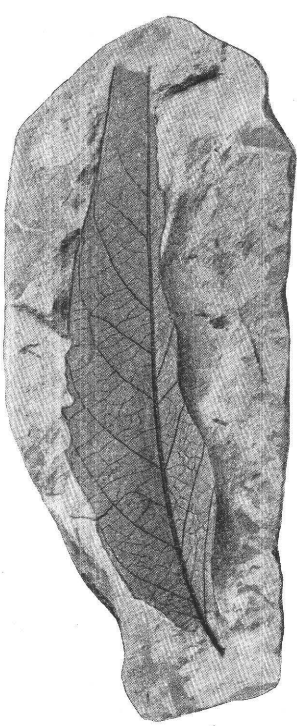

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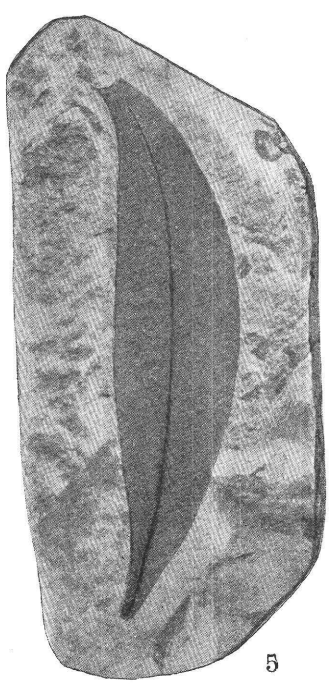

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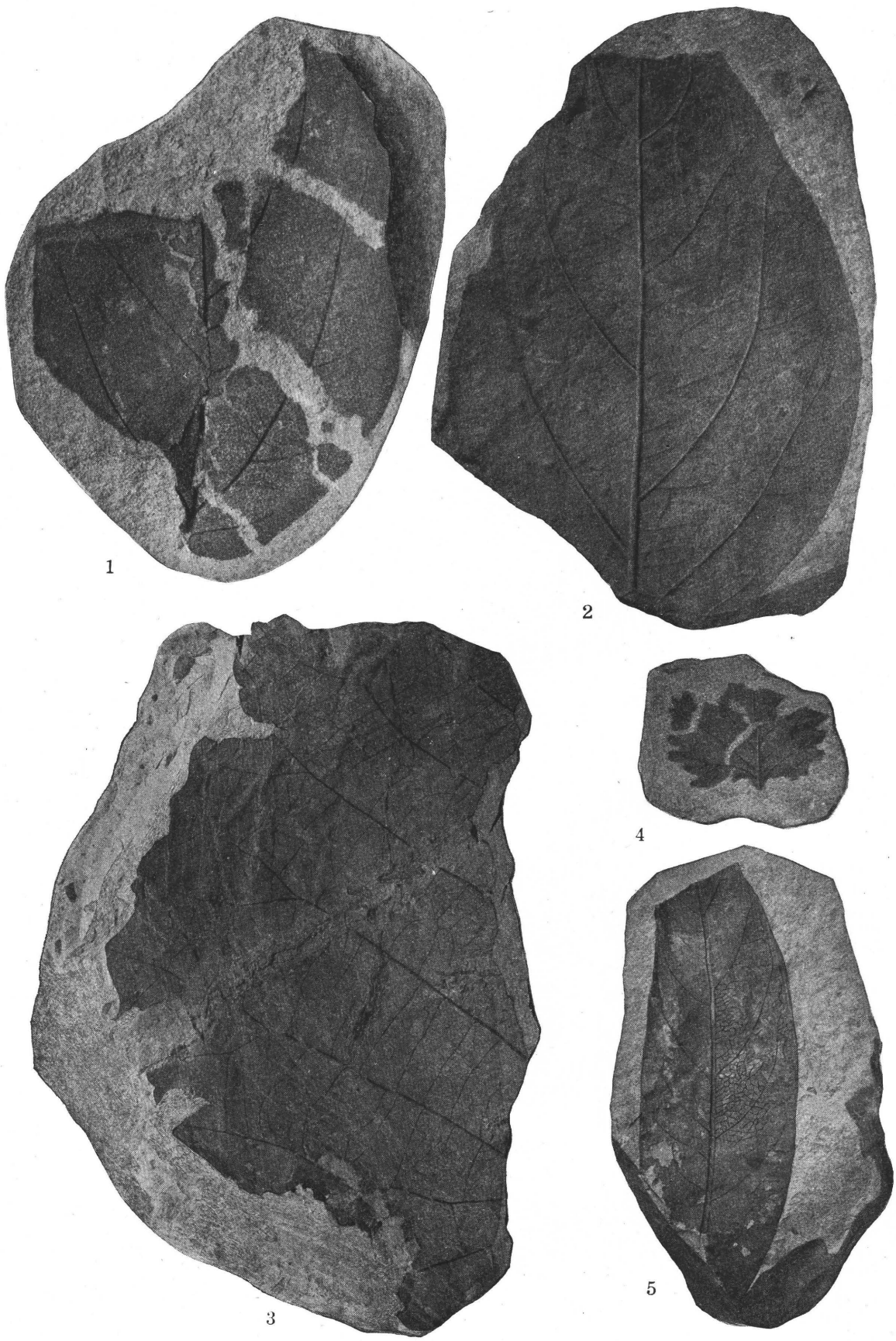
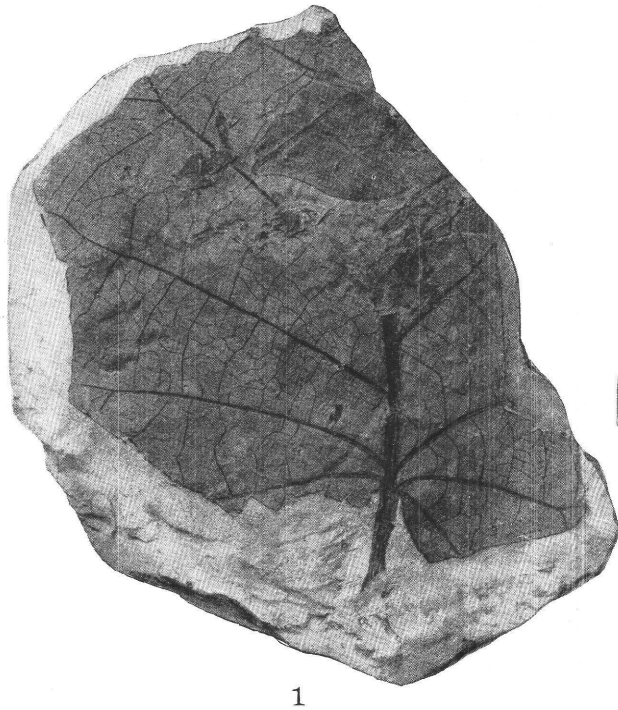
FLORA OF THE FRUITLAND AND KIRTLAND FORMATIONS.



FLORA OF THE FRUITLAND AND KIRTLAND FORMATIONS.

PLATE LXXXIX.

PLATE XC.



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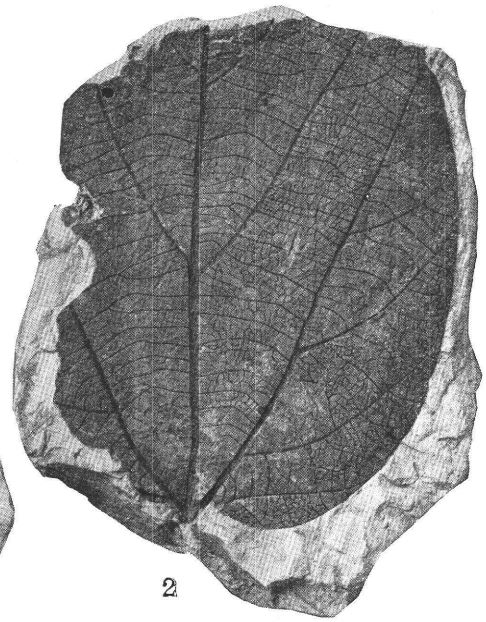

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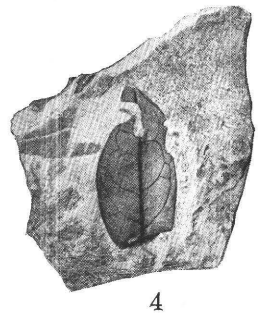

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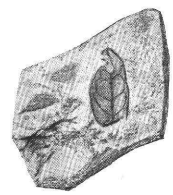

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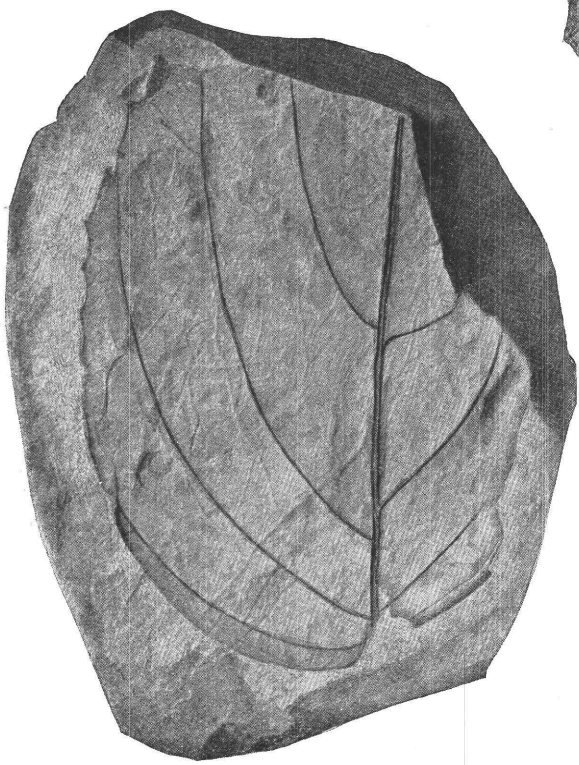

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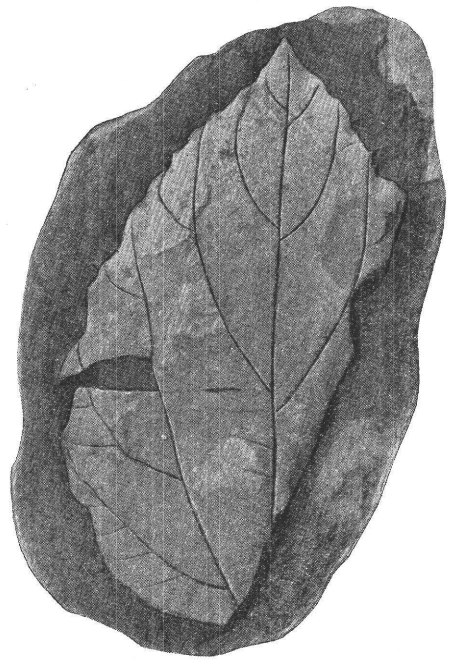
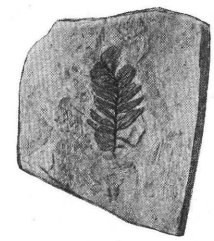


6

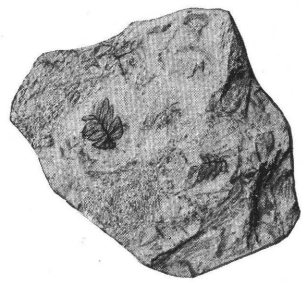
FLORA OF THE FRUITLAND AND KIRTLAND FORMATIONS.

1



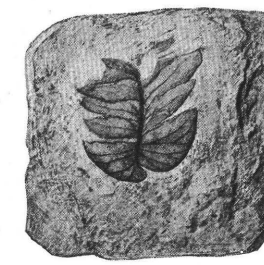
4

5

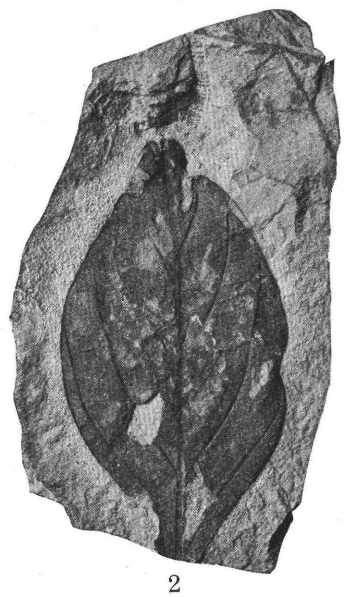


6

3



7



2

9

FLORA OF THE FRUITLAND AND KIRTLAND FORMATIONS.

PLATE XCI.