DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Professional Paper 108—F

A FOSSIL FLORA FROM THE FRONTIER FORMATION OF SOUTHWESTERN WYOMING

BY

F. H. KNOWLTON

Published August 22, 1917

Shorter contributions to general geology, 1917

(Pages 73–107)

WASHINGTON
GOVERNMENT PRINTING OFFICE
1917

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A FOSSIL FLORA FROM THE FRONTIER FORMATION OF SOUTHWESTERN WYOMING.

By F. H. KNOWLTON.

INTRODUCTION.

This paper deals with a small but important fossil flora, now known to be of Colorado age, from the vicinity of Cumberland, Lincoln County, Wyo. It was for many years thought to be of Jurassic age, and only within the last decade has its stratigraphic position been established. Although small in number of species, this flora offers information bearing on the physical and climatic conditions that prevailed during early Upper Cretaceous time in this region, and, moreover, it furnishes a series of stratigraphic marks that may be used in the recognition of this horizon elsewhere. It has also a possibly important biologic bearing, for it shows the presence of certain plant types that are now found living in Polynesia. The presence of certain types of insects that lived in and on the plants is shown by their characteristic markings. Finally, this study has a historical and sentimental interest because it is based on material collected on the celebrated Frémont exploring expedition more than 70 years ago and now rediscovered and redescribed.

The fossil plants to be described in this paper were discovered in 1843 by Capt. John C. Frémont, while engaged on an exploring expedition that had for its object the finding of a "new and better road" over the mountains and plains to Oregon and northern California. On August 19, 1843, the expedition turned north from Fort Bridger, on the old Oregon Emigrant Road, and soon passed over Muddy Creek, near the present site of Carter, Uinta County, Wyo. The fossil plants were found somewhat farther north, on Little Muddy Creek, near the present line between Uinta and Lincoln counties. Frémont's description [1] of the discovery of the fossil plants is as follows:

August 19: A few miles from our encampment [of August 18] the road entered a high ridge connecting the Utah with the Mud River chain; and in one of the hills near which we passed I remarked strata of a conglomerate formation. We crossed a ridge of this conglomerate and descended upon one of the heads of Hams Fork, called Muddy, where we made our midday halt. In the river hills at this place I discovered strata of fossiliferous rock having an oolite structure, which, in connection with the neighboring strata, authorize us to believe that here, on the west side of the Rocky Mountains, we find repeated the modern formations of Great Britain and Europe, which have hitherto been wanting to complete the system of North American geology. * * *

In the afternoon we continued our road and, searching among the hills a few miles up the stream and on the same bank, I discovered among alternating beds of coal and clay a stratum of white indurated clay containing very clear and beautiful impressions of vegetable remains. This was the most interesting fossil locality I had met in the country, and I deeply regretted that time did not permit me to remain a day or two in the vicinity. * * * After remaining here only about an hour, I hurried off, loaded with as many specimens as I could conveniently carry.

These plants were referred to James Hall,[1] then paleontologist to the State of New York, who named, described, and figured most of them in an appendix to Frémont's report. Hall also gave the following additional information concerning the locality, evidently derived from Frémont's notes:

Longitude 111°, latitude 41½°, Muddy River: These specimens are of a yellowish-gray oolitic limestone, containing turbo, cerithium, etc. The rock is a perfect oolite and, both in color and texture, can scarcely be distinguished from specimens of the Bath oolite. One of the specimens is quite crystalline, and the oolitic structure somewhat obscure. In this instance the few fossils observed seem hardly sufficient to draw a decisive conclusion regarding the age of the formation; but, when taken in connection with the oolitic structure of the mass, its correspondence with the English oolites, and the modern aspect of the whole, there remains less doubt of the propriety of referring it to the oolitic period. A further collection from this interesting locality would doubtless

[1] Frémont, J. C., Report of the exploring expedition to the Rocky Mountains in the year 1842, and to Oregon and north California in the years 1843–44: Twenty-eighth Cong., 2d sess., House Ex. Doc. 166, p. 131, 1845.

[1] Hall, James, Descriptions of organic remains collected by Capt. J. C. Frémont in the geographical survey of Oregon and north California: Idem, Appendix B, pp. 304–307, pls. 1, 2, 1845.

develop a series of fossils which would forever settle the question of the relative age of the formation.

A few miles up this stream Capt. Frémont has collected a beautiful series of specimens of fossil ferns. The rock is an indurated clay, wholly destitute of carbonate of lime, and would be termed a "fire clay." These are probably, geologically as well as geographically, higher than the oolite specimens, as the rocks at this place were observed to dip in the direction of N. 65° W. at an angle of 20°. This would show conclusively that the vegetable remains occupy a higher position than the oolite. Associated with these vegetable remains were found several beds of coal differing in thickness.

The stratum containing the fossil ferns is about 20 feet thick, and above it are two beds of coal, each about 15 inches. These are succeeded by a bed of sandstone. Below the bed containing the ferns there are three distinct beds of coal, each separated by about 5 feet of clay. Before examining the oolitic specimens just mentioned I compared these fossil ferns with a large collection from the coal measures of Pennsylvania and Ohio, and it was quite evident that this formation could not be of the same age. There are several specimens which I can only refer to the *Glossopteris phillipsii* (see description), an oolitic fossil; and this alone, with the general character of the other species and the absence of the large stems so common in the coal period, had led me to refer them to the oolitic period. I conceive, however, that we have scarcely sufficient evidence to justify this reference; and though among the fossil shells there are none decidedly typical of the oolite, yet neither are they so of any other formation; and the lithological character of the mass is not reliable evidence. Still, viewed in whatever light we please, these fossil ferns must, I conceive, be regarded as mostly of new species and in this respect form a very important addition to the flora of the more modern geological periods.

From the foregoing statement it appears that, although Hall tentatively referred these plants to the Oolite—that is, to the Upper Jurassic—as perhaps the best disposition that could be made under the circumstances, he was by no means certain of their age.

For more than 40 years after these plants were described and figured by Hall they remained in obscurity and practically lost. In 1887 I found some of them, including five of the figured types, in the United States National Museum. They were without adequate labels and were thickly covered with dust and mingled with other material of miscellaneous and unknown origin. How they came into the possession of the National Museum, or where the rest of the collection is—if, indeed, it is in existence—is not now known.

The great interest that attaches to these plants was recognized by me, and as Prof. Leo Lesquereux was at that time engaged in studying and naming the miscellaneous fossil-plant material in the National Museum, they were sent to him for restudy, and his report was published[1] in 1888. Lesquereux changed a number of Hall's generic references—for example, *Sphenopteris* and *Trichopteris* to *Thyrsopteris*—but was evidently somewhat confused by the presence of apparent dicotyledonous leaves, which he forced into or compared with certain genera of ferns and cycads. He referred them to the Jurassic, his statement being as follows: "What seems to me to be conclusive of the oolitic age of the plants is the number of fragments of small ferns referable to the genus *Thyrsopteris*, of which Heer has described a number of species from the Jurassic of Siberia."

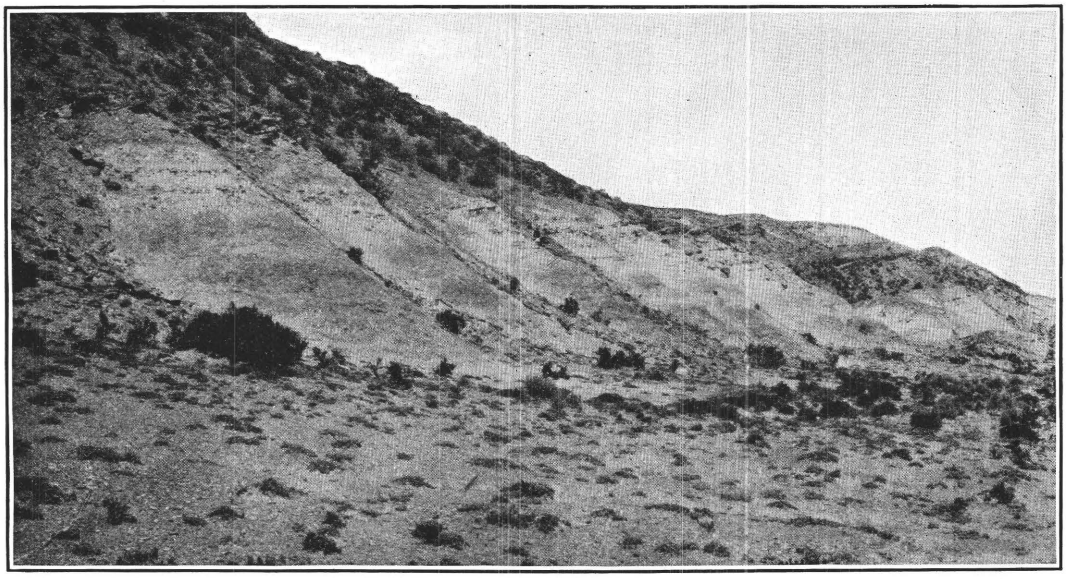
To return to the field relations of these plants, it appears that none of the Government expeditions that operated in this region after the early explorations of Frémont had happened to find the beds containing them, though they are now known to be conspicuous. A. C. Peale, of the Hayden Survey, studied the region a few miles to the north of the Cumberland area during the field season of 1877. He was therefore familiar in a general way with the stratigraphy of this part of Wyoming, and in 1898 he attempted to determine, in the office, from Frémont's account, the locality whence these fossils came but was not able to reach a satisfactory conclusion. The matter then rested for several years, until 1905.

When A. C. Veatch, of the United States Geological Survey, began his study of the coal and oil fields of this general region, Peale called his attention to this unique material and to the desirability of determining the true stratigraphic position of the original locality and of procuring additional collections. From the knowledge Veatch soon acquired of the region, as well as from a careful consideration of the original notes of Frémont and Hall quoted above, the locality that furnished these plants was determined to be on the south bank of Little Muddy Creek, about 1 mile east of the present town of Cumberland. The account of this rediscovery was first given by Veatch[2] in a short article published in June, 1906, and more at length in his formal report[3] on the region in 1907.

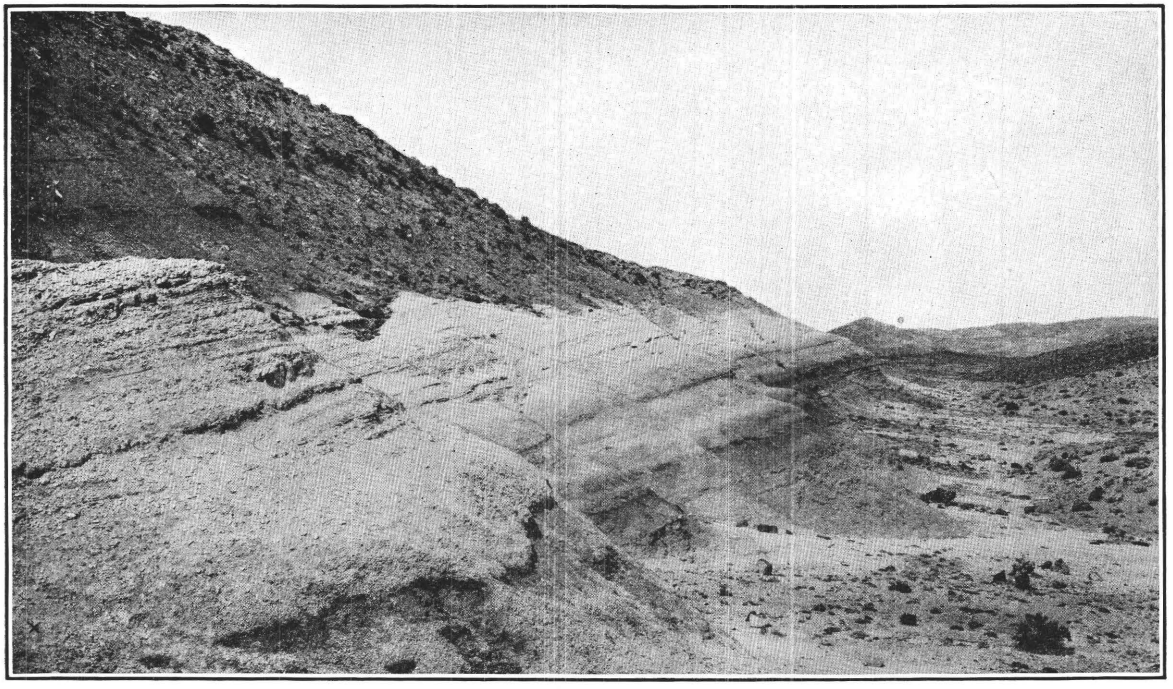
[1] Lesquereux, Leo, Recent determinations of fossil plants from Kentucky, Louisiana, Oregon, etc., with descriptions of new species: U. S. Nat. Mus. Proc., vol. 11, pp. 37, 38, 1888.

[2] Veatch, A. C., Age and type locality of the supposed Jurassic fossils collected north of Fort Bridger, Wyo., by Frémont in 1843: Am. Jour. Sci., 4th ser., vol. 21, pp. 457–460, 1906.

[3] Veatch, A. C., Geography and geology of a portion of southwestern Wyoming: U. S. Geol. Survey Prof. Paper 56, pp. 65–69, 1907.



A. PLANT-BEARING SHALE IN FRONTIER FORMATION, 1 MILE EAST OF CUMBERLAND, WYO.
Photograph by T. W. Stanton.



B. WHITE PLANT-BEARING SHALE IN FRONTIER FORMATION SOUTH OF LITTLE MUDDY CREEK, NEAR CUMBERLAND, WYO.
Probably very near the original Frémont locality. Photograph by T. W. Stanton.

Veatch made a considerable collection of plants on the north side of Little Muddy Creek, in sec. 29, T. 19 N., R. 116 W., and in this collection the matrix, as well as a number of species, are absolutely identical with the original material collected by Frémont and preserved in the United States National Museum. There can be no doubt, therefore, that the beds from which Veatch's collection was obtained are not only at the same horizon but at the same or approximately the same locality as that which furnished the Frémont collection of 1843.

STRATIGRAPHIC RELATIONS.

The plants described in this paper occur in what is now known as the Frontier formation. This formation was named by W. C. Knight [1] in 1902 from the coal town of Frontier, near which the beds are well exposed. It was defined as being "composed of very thick beds of compact sandstone, with shales and coals having an approximate thickness of 2,000 feet." Knight stated that it was characterized by the presence of *Ostrea soleniscus*, a long, slender oyster which has a maximum length of 12 inches, but subsequent study has shown that this species also occurs several thousand feet above the designated top of the Frontier formation.

The Frontier formation was further described by Veatch [2] as follows:

> The pronounced sandstone layer or group of sandstone layers, occasionally conglomeratic and containing numerous specimens of the elongate oyster mentioned, produces a pronounced ridge, which was named Oyster Ridge by Hayden in 1872. This name was adopted by the King Survey and used on the maps of that organization. This group of sandstones has therefore been named the Oyster Ridge sandstone member of the Frontier formation. At several places minor sandstones or oyster-bearing ridges occur above the Oyster Ridge sandstone. * * * The Oyster Ridge sandstone is generally about 200 feet thick. Beneath the Oyster Ridge sandstone there are other sandstone layers, which produce pronounced ridges, but these, except near the northern extremity of the map, are definitely separated from and not readily confused with the main Oyster Ridge sandstone. The total thickness of this formation ranges from 2,200 to 2,600 feet. It is exposed along the east side of Mammoth Hollow throughout this area, and on the west side north of Hams Fork and between Little Muddy and Clear creeks. It outcrops west of the great Absaroka fault from the Evanston-Fort Bridger road south to Sulphur Creek.

The stratum that undoubtedly supplied the plants collected by Frémont and that was rediscovered by Veatch is about 1,200 feet below the top of the Oyster Ridge sandstone. It is also below the several minor sandstone ridges mentioned by Veatch. The fossiliferous layer is a hard, brittle white clay only a few inches thick, in the midst of white clay shales, which in the exposure near Cumberland are about 30 feet thick. (See Pl. XXVII.) This almost snow-white band of shales is very conspicuous and may be traced for miles. The layer containing the plants was found to be fossiliferous at nearly every foot of its exposure, and in some places it is literally packed with remains, especially ferns, which, at least at the Cumberland locality, are the dominant types. This great abundance of plants in the bed makes it difficult to procure large or perfect specimens.

AGE OF THE FRONTIER FORMATION.

As already stated the plant-bearing bed discovered by Frémont and now placed in the Frontier formation was tentatively regarded by Hall as of Jurassic age, and this reference was accepted by Lesquereux, who restudied a portion of the original collection in 1888. Long before this date, however, the beds had come to be recognized as belonging to the Upper Cretaceous. Thus, in 1870, when Hayden [3] gave the name Oyster Ridge to the conspicuous sandstone ridge near Sulphur Creek, he said: "It [Oyster Ridge] is composed mostly of gray and yellow-gray sandstone, capped with a calcareous sandstone, filled with a small species of *Ostrea*, and belongs, I think, to the upper portion of the Cretaceous group—probably No. 5." This is a virtual reference to the Fox Hills sandstone, though that term was not actually employed.

Later, however, Oyster Ridge was directly referred to the Fox Hills by both the Hayden and the King surveys, and it is so assigned on the map of this region published by the King Survey.

It is difficult to ascertain just when the Oyster Ridge sandstone and the associated sandstones, shales, and coals of the Frontier formation were first regarded as of Colorado age. At least as early as 1877 Meek [4] described invertebrates that he recognized as of this age,

[1] Knight, W. C., Coal fields of southern Uinta County, Wyo.: Geol. Soc. America Bull., vol. 13, pp. 542-544, 1902.

[2] Veatch, A. C., Geography and geology of a portion of southwestern Wyoming: U. S. Geol. Survey Prof. Paper 56, p. 65, 1907.

[3] Hayden, F. V., Geology of the Missouri Valley: U. S. Geol. Survey Terr., Prel. Rept. for 1870, p. 149, 1871.

[4] Meek, F. B., U. S. Geol. Expl. 40th Par. Rept., vol. 4, pl. 1, p. 143, 1877.

from the vicinity of Sulphur Creek, 3 miles west of Oyster Ridge, where they occur in a heavy sandstone which is the same as the Oyster Ridge sandstone but is in the western limb of the syncline.

This condition was also recognized and briefly alluded to in 1892 by Stanton.[1] In a longer paper published the following year Stanton [2] described a number of the invertebrates from the Sulphur Creek area which he regarded as of undoubted Colorado age.

Although Knight,[3] when he named the Frontier formation, did not definitely fix its age, he took occasion to say that he could "not find a Fox Hills fauna such as is common to the Fox Hills of the eastern part of Wyoming" and, at least by inference, placed it lower than Fox Hills. Veatch [4] also obtained evidence which in his opinion strengthened the reference of the formation to the Colorado. He also mentions the discovery of numerous specimens of *Inoceramus exogyroides*, an invertebrate held to be of Benton age, 3,000 feet above the top of the formation, or approximately in the middle of the overlying Hilliard formation. Mr. Stanton informs me that he has since procured a distinctly Benton fauna from the same sandstone lentil from which Veatch collected, in the Hilliard formation about 3,000 feet above its base. Mr. Stanton has been kind enough to supply the following account of the invertebrates and their occurrence:

The evidence from the invertebrate faunas that the Frontier formation and the lower half of the Hilliard formation are of the age of the Colorado group was presented by Veatch [5] in 1907. Most of the Frontier invertebrates then known came from the upper part of the formation and from localities near the Union Pacific Railroad, 20 to 30 miles south of Cumberland. They include a number of very characteristic Colorado group species, which, in connection with the known stratigraphic relations and the fauna of the underlying beds, justified the reference of the whole Frontier formation, including the plant-bearing bed near Cumberland, to the Colorado group.

Later collections and observations have confirmed and strengthened the evidence for the Colorado age of both the Frontier formation and the lower 3,000 feet or more of the overlying Hilliard formation, and they have a more direct bearing on the age of the plant bed because their relations to it are definitely determined. The white shales associated with the plant bed may be traced along the strike for many miles north and south of Cumberland. To the north they have been recognized near Glencoe, Oakley, and as far as Kemmerer, holding the same position far beneath the Kemmerer coal, which is mined at all these places. Two collections received from the late Robert Forrester have been identified as follows:

120 feet above Kemmerer coal, near Oakley, Wyo.:

Ostrea sp.
Inoceramus related to I. deformis Meek.
Inoceramus sp.
Veniella goniphora Meek.
Baculites gracilis Shumard?
Scaphites ventricosus Meek and Hayden?

Roof of Kemmerer coal, Glencoe mine, Glencoe, Wyo.:

Ostrea sp.
Avicula gastrodes Meek.
Inoceramus labiatus Schlotheim?
Nemodon? sp.
Cardium pauperculum Meek.
Mactra? sp.
Corbula sp.
Melania? sp.
Scaphites ventricosus Meek and Hayden.

All the identified forms in these two lots are characteristic of the fauna of the Colorado group, and most of them in other regions would indicate the upper part of the group, but in this western Wyoming area the Upper Cretaceous sediments are abnormally thick and many species seem to have an unusual vertical range, indicating rapid sedimentation. Thus the sandstone lentils near the middle of the Hilliard formation about 3 miles northwest of Kemmerer, though fully 3,000 feet above the horizon of the two collections last mentioned, still yield a characteristic Colorado fauna. Veatch recorded the presence of *Inoceramus exogyroides* in these lentils and correctly assigned the beds to the Colorado group. In 1913 I collected from these sandstones, which, according to Veatch, lie from 3,000 to 3,800 feet above the base of the Hilliard formation, the following species:

Ostrea soleniscus Meek.
Avicula gastrodes Meek?
Inoceramus umbonatus Meek and Hayden.
Inoceramus exogyroides Meek and Hayden.
Inoceramus cf. I. undabundus Meek and Hayden.
Inoceramus fragilis Hall and Meek?
Cardium pauperculum Meek.
Cyprimeria? sp.
Donax oblonga Stanton.
Tellina? sp.
Mactra emmonsi Meek.
Mactra sp.
Martesia? sp.
Pugnellus fusiformis (Meek).
Placenticeras sp. cf. P. pseudoplacenta Hyatt.

None of the species in this list is known to range above the Colorado group. The first two species of *Inoceramus* are especially abundant and are characteristic of a horizon near the top of the Colorado not far below the Eagle sandstone on Missouri River below Fort Benton, Mont. The *Donax* and the *Pugnellus* are equally characteristic of a sandstone in the Colorado group above the principal coal bed at Coalville, Utah.

[1] Stanton, T. W., The stratigraphic position of the Bear River formation: Am. Jour. Sci., 3d ser., vol. 43, p. 105, 1892.

[2] Stanton, T. W., The Colorado formation and its invertebrate fauna: U. S. Geol. Survey Bull. 106, 1893.

[3] Knight, W. C., Coal fields of Southern Uinta County, Wyo.: Geol. Soc. America Bull., vol. 13, p. 543, 1902.

[4] Veatch, A. C., Geography and geology of a portion of southwestern Wyoming: U. S. Geol. Survey Prof. Paper 56, p. 69, 1907.

[5] Veatch, A. C., op. cit., pp. 66–68, 71, 72.

The evidence of the plants as to the age of the beds containing them was first believed to be in substantial accord with that of the invertebrates. In my report [1] on the plants collected by Veatch I made the following statement regarding their position: "The age, so far as I am able to fix it, is the lower part of the Upper Cretaceous, about the position of the Turonian, possibly a little lower."

The Colorado age of the Frontier formation, as based on stratigraphic position and the evidence of the invertebrates, is here accepted. It is but fair to state, however, that the critical study of the plants does not lend conclusive support to their reference to the Colorado. Inasmuch as practically all the forms are new to science, the interpretation of their bearing on the question of age must be made through their affinities, and these, so far as they can be made out, appear to favor a position stratigraphically higher than the Colorado. This evidence may be briefly reviewed as follows:

The spleenwort (*Asplenium occidentale*) belongs to the same group as and is pretty closely related to an unpublished species from the Farmington sandstone member of the Kirtland shale (Montana group) of San Juan County, N. Mex. The shield fern (*Dryopteris coloradensis*) is strongly suggestive of an unpublished species from the Vermejo formation of the Raton Mesa region of Colorado and New Mexico. The *Anemia* is very closely related to and perhaps identical with a species common in the Eocene of Europe but also reported from the Montana at Point of Rocks, Wyo. Among the dicotyledons, *Cinnamomum hesperium* is hardly distinguishable, except in size, from *Cinnamomum wardii*, from the upper part of the Adaville formation at Hodges Pass, a few miles north of the Cumberland localities. *Dewalquea pulchella* and *Dryandroides lanceolata* are so close to *Dewalquea insignis* and *Dryandroides quercinea*, respectively, from the Upper Senonian of Westphalia, that it is perhaps doubtful if they should be maintained as distinct. *Quercus stantoni* is very similar to *Quercus formosa*, also from the Senonian of Westphalia. *Ficus fremonti* agrees in shape with *Ficus proteoides* Lesquereux, and in shape, size, and nervation with *Ficus lanceolata acuminata* Ettingshausen, as figured by Lesquereux, from the Dakota sandstone. This is the only species that appears to show any special likeness to forms from beds whose position is lower than that assigned to the plant beds at Cumberland.

The foregoing is not the only evidence for assigning the Frontier formation to a position higher than the Colorado, though the additional evidence is not so strong as it was supposed at one time to be. In 1907 A. R. Schultz, of the United States Geological Survey, began an investigation of the coal resources of the so-called Rock Springs dome, about 75 miles east of the Cumberland area. Incidentally to this study Schultz procured a number of very interesting collections of fossil plants, mainly from thin, indurated clay partings in coal. The age of these plants has been fixed as near the middle of the Mesaverde formation (Montana group), in what has been called the Rock Springs coal group. The most abundant plants are ferns of the genera *Gleichenia* and *Anemia*, and the dicotyledons are comparatively few. This flora has a facies strikingly similar to that of the flora from the Frontier formation, and as several species appeared to be in common, I held that the plant-bearing beds at Cumberland and Rock Springs were identical in age. A critical study of the Frontier flora, however, discloses the fact that there are apparently no dicotyledons and few if any ferns common to the two areas.

GENERAL FEATURES OF THE FLORA.

SPECIES NOW RECOGNIZED.

Before proceeding to a discussion of the various aspects of this flora, it will be of interest to present the following complete list of the forms now recognized:

Tapeinidium? undulatum (Hall) n. comb.
Microtaenia variabilis n. gen. and n. sp.
Microtaenia paucifolia (Hall) n. comb.
Dennstaedtia? fremonti (Hall) n. comb.
Dryopteris coloradensis n. sp.
Asplenium occidentale n. sp.
Anemia fremonti n. sp.
Equisetum sp.
Smilax? coloradensis n. sp.
Myrica nervosa n. sp.
Salix cumberlandensis n. sp.
Salix frontierensis n. sp.
Quercus stantoni n. sp.
Ficus fremonti n. sp.
Ficus? sp.
Ficus? sp.
Cinnamomum hesperium n. sp.
Cinnamomum? sp.

[1] Knowlton, F. H., in Veatch, A. C., Age and type localities of supposed Jurassic fossils collected north of Fort Bridger, Wyo., by Frémont in 1843: Am. Jour. Sci., 4th ser., vol. 21, p. 459, 1906.

Dryandroides lanceolata n. sp.
Aralia veatchii n. sp.
Staphylea? fremonti n. sp.
Dewalquea pulchella n. sp.
Phyllites ficifolia n. sp.
Phyllites dentata n. sp.
Phyllites.

LOCALITIES AND COLLECTORS.

1. Probably on the south bank of Little Muddy Creek about 1 mile east of the present town of Cumberland, Wyo. Collected by J. C. Frémont August 19, 1843. Below is a list of the species described by Hall with their present disposition:

Sphenopteris fremonti Hall=Dennstaedtia? fremonti.
Sphenopteris triloba Hall=Microtaenia paucifolia.
Sphenopteris? paucifolia Hall=Microtaenia paucifolia.
Sphenopteris? trifoliata Hall.
Glossopteris phillipsi?=Ficus fremonti.
Pecopteris undulata Hall=Tapeinidium? undulatum.
Pecopteris undulata var.=Tapeinidium? undulatum.
Pecopteris? odontopteroides Hall=Tapeinidium? undulatum.
Trichopteris filamentosa Hall=rootlets of ferns.
Trichopteris gracilis Hall=rootlets of ferns.
Leaf of dicotyledonous plant?=Phyllites fremonti Unger.[1]

2. North branch of Little Muddy Creek 1 mile east of Cumberland, Wyo. Collected by A. C. Veatch August 3, 1906.

Tapeinidium? undulatum.
Dryopteris coloradensis.
Equisetum sp.
Aralia veatchii.
Dewalquea pulchella.

3. Approximately same locality as No. 2. Collected by T. W. Stanton and F. H. Knowlton August 5, 1908.

Tapeinidium? undulatum.
Microtaenia variabilis.
Microtaenia paucifolia.
Dennstaedtia? fremonti.
Asplenium occidentale.
Anemia fremonti.
Ficus fremonti.
Staphylea? fremonti.
Phyllites ficifolia.
Insect mine in leaflet of Staphylea.

4. Mine No. 1, Cumberland, Wyo. Collected by F. H. Knowlton August 6, 1908.

Smilax? coloradensis.

5. About half a mile east of Cumberland, Wyo. Collected by T. W. Stanton and F. H. Knowlton August 5, 1908.

Ficus? sp.
Ficus? sp.
Cinnamomum? sp.

6. About 1 mile east of Cumberland, Wyo. Same horizon as principal Cumberland locality but at a slightly different point. Collected by A. C. Peale August 18, 1909.

Ficus fremonti.
Aralia veatchii.

7. About 1½ miles south of Cumberland, Wyo., in the SE. ¼ sec. 6, T. 18 N., R. 116 W. Same horizon as locality 1 mile east of Cumberland, and probably near the original Frémont locality. Collected by T. W. Stanton September 1, 1913.

Tapeinidium? undulatum.
Myrica nervosa.
Salix cumberlandensis.
Salix.
Quercus stantoni.
Ficus fremonti.
Cinnamomum hesperium.
Dryandroides lanceolatum.
Phyllites dentata.
Phyllites.

8. About 1 mile east of Oakley and 3 miles southeast of Kemmerer, Wyo., in the SW. ¼ sec. 3, T. 21 N., R. 115 W. Collected by T. W. Stanton September 2, 1913.

Ficus fremonti.
Quercus stantoni.
Fragments of dicotyledons, not determinable.

BIOLOGIC ASPECTS OF THE FLORA.

The known flora from the Frontier formation near Cumberland embraces 25 forms, of which 7 are ferns, 1 an *Equisetum*, 1 a monocotyledon (*Smilax*), and the remaining 16 dicotyledons. As regards the relative abundance of the different types, it is probable that the ferns outnumber the other forms by perhaps two to one. Several of the dicotyledons are based on single specimens, but there is hardly a piece of matrix without fragments of ferns.

The first four species of ferns enumerated in the list on page 77 possess great biologic interest. They form a natural group that, from their peculiar and well-marked type of

[1] This is apparently not from the Frontier formation but probably from the Green River formation 40 or 50 miles east of the Cumberland locality. (See p. 94.)

fructification, marks them as being undoubtedly davallioid—that is, clearly allied to the group of mainly tropical ferns of which the genus *Davallia* is the central form. They are entirely unlike anything now living in the New World and appear to find their closest relatives among species now living in Polynesia. Thus the *Tapeinidium*, although far from being conspecific with any living form of the genus, appears to be most closely related to *Tapeinidium pinnatum* (Cavanilles) C. Christensen, a species widely dispersed in Malaysia and Polynesia. The two species called *Microtaenia* are so wholly unlike any living or fossil form known that it has been necessary to create a new genus for their reception. They are very abundant in individuals, showing that they formed a well-established element in the Frontier flora. The species referred to *Dennstaedtia* is not so well established as either of the first three forms in the list and is based on a few fragments that may possibly represent an extreme modification of *Microtaenia paucifolia*. The genus *Dennstaedtia* is a large group comprising more than 60 species. They are of wide, mainly tropical distribution, only one species (*D. punctilobula*), the so-called hay-scented fern, inhabiting North America; this species is quite unlike the fossil form under discussion.

The single species of shield fern (*Dryopteris*) is of an ordinary type, but the spleenwort (*Asplenium occidentale*) belongs in the group of living species of which *A. hemitonites* Linné is the type. *Anemia* is also a large genus of almost exclusively tropical American forms, only two inhabiting the United States—one in peninsular Florida, the other in southern Texas and extending into adjacent parts of Mexico.

The horse-tail (*Equisetum* sp.) is so poorly represented that it has little value beyond indicating the presence of this type of vegetation.

The smilax, the only form referred to the monocotyledons, is based on a single specimen and is of doubtful biologic value.

The dicotyledons are represented by a number of well-known types. They include a coriaceous-leaved waxberry (*Myrica*), two willows (*Salix*), and a small-leaved oak (*Quercus*), all of which are very modern in appearance. The named species of fig (*Ficus fremonti*) is so placed on account of its general resemblance to and affinity with certain described fossil species, and not on account of its relationship with living members of the genus. *Ficus* is a vast, mainly tropical group comprising over 600 species. The named form referred to *Cinnamomum*, the well-known cinnamon tree, is of the type of an unidentified living species from China. The genus is not now a native of the New World, its center of distribution being tropical and subtropical portions of southeastern Asia. The species of *Dryandroides*, if correctly placed, is of importance as showing the presence of the Proteaceae in this country during early Upper Cretaceous time, but it is so fragmentary that I can not be certain of its position.

PHYSICAL AND CLIMATIC CONDITIONS INDICATED.

From the facts now available it appears unquestionable that at least the major portion of the Frontier formation was laid down in fresh water. This is proved by the numerous, thick, and widespread beds of coal it contains. The coal swamps of that epoch, which must have been of wide extent and long duration, might well have been and doubtless were but little above sea level, for sandstones containing oysters occur both below and above certain of the coal beds, showing slight oscillation that permitted the access of at least brackish water. No strictly marine organisms are known. About 1,000 feet below the top of the formation there are several thick beds of unios which indicate that the water at that time was fresh. There is nothing in the flora to indicate that any of its members required or indeed could tolerate a saline habitat; on the contrary, they could have found a congenial home only in or near fresh-water swamps and forests.

The climate during Frontier time appears to have been tropical or subtropical, as is shown in a number of ways. Thus, one of the most abundant of the ferns (*Tapeinidium*) was indeterminate in growth, a condition that could survive to the extent here indicated only in the absence of frosts. The most abundant elements in this flora are the ferns, and of these the davallioid forms (*Tapeinidium*, *Microtaenia*, and *Dennstaedtia*), to which may be added the *Anemia*, all call for a tropical or

subtropical habitat. The spleenwort (*Asplenium*), if its affinity has been correctly interpreted, likewise calls for at least a subtropical setting, as does the single shield fern (*Dryopteris*). The smilax is too incompletely known to permit a generalization concerning its climatic environment, though it must have been as warm as warm temperate and might well enough have been still warmer. The waxberry (*Myrica*), the oak (*Quercus*), and the willows (*Salix*), on the other hand, might not be out of place in a temperate region, but the figs (*Ficus*) and the cinnamon trees (*Cinnamomum*) certainly required a tropical or subtropical location.

EVIDENCE OF INSECTS IN FRONTIER TIME.

An interesting though very meager fragment of information concerning the insect life of Frontier time has resulted from this study. Evidence of the presence of insects was noted on two leaves. One of these leaves (see Pl. XXXV, fig. 5), now named *Ficus fremonti*, was found by Frémont and is fortunately one of those in the collection of the United States National Museum. This specimen was figured by Hall,[1] who noted the presence of a cluster of circular bodies on one side of the leaf. He was uncertain as to the nature of these bodies, and as he had referred the leaf to *Glossopteris phillipsi*, a fern, he suggested that they might possibly represent the fruiting stage, though he adds: "This structure is so partial that it can only with doubt be referred to the fructification of the plant; and it is not improbable that the same may be some parasitic body or the eggs of an insect which have been deposited upon the leaf." This specimen was shown to Dr. August Busck, of the Bureau of Entomology, who at once recognized these circular bodies as an undoubted insect egg mass, probably of a microlepidopterous insect.

The other specimen, shown in Plate XXXIII, figure 5, is a leaflet of *Staphylea? fremonti* in which a symmetrically looping mine has been made in the leaf substance by an insect larva. This Dr. Busck pronounced also to be the work of a microlepidopter, possibly belonging to the genus *Phylloenistis*. The mine appears to increase slightly in size from the apex of the leaflet toward the base, the exit being the basal margin next to the midrib. The work of this Frontier insect is absolutely similar in character to that of forms now living, a fact which would seem to indicate that the habits of life have persisted with no observable change from middle Cretaceous time to the present.

[1] Hall, James, in Frémont, J. C., Report of the exploring expedition to the Rocky Mountains in the year 1842, and to Oregon and North California in the years 1843–44: Twenty-eighth Cong., 2d sess., House Executive Doc. 166, pl. 2, figs. 5b, 5c, 1845.

THE FLORA.

Family POLYPODIACEAE.[2]

Tapeinidium? undulatum (Hall) Knowlton, n. comb.

Plate XXVIII, figures 1–4.

Pecopteris undulata Hall, in Frémont, Report of the exploring expedition to the Rocky Mountains in 1842, etc., Appendix B, p. 306, pl. 1, figs. 1a, 1b, 1845.

Pecopteris undulata Hall, var., idem, p. 306, pl. 1, figs. 2, 2a, 2b.

Pecopteris? odontopteroides Hall, idem, p. 306, pl. 1, figs. 3, 4.

Outline and habit of whole frond not known but presumed to be simply pinnate, lanceolate in outline, gradually narrowed to the apex (base not seen); rachis strong, ridged, in places slightly winged; pinnae numerous, at right angles to the rachis, sessile, linear in general outline, sharp-pointed at apex, cut in varying degree into numerous rounded, slightly oblique or fan-shaped lobes which are entire or slightly erose-dentate; the lobes decrease in size apically, becoming merely undulations, the tip being almost or quite entire; upper pinnae reduced in size, with undulate or almost entire margins; nervation of pinnae consisting of a very strong, grooved midvein, the lobes provided with a thin, delicate midvein and usually about three pairs of once-forked veins.

This species is exceedingly abundant, probably the most abundant plant found in these beds, as there is hardly a piece of matrix that does not contain a fragment. In spite of its abundance, however, it is very rarely that specimens of considerable size and completeness are procured. It was apparently very brittle and easily broken up before it was entombed. The most complete example thus far found is that shown in figure 3, which has a preserved length of 12 centimeters but was undoubtedly considerably longer than this when perfect. The

[2] In the study of the ferns, especially the first four species, I have had the benefit of the assistance and critical judgment of Mr. W. R. Maxon, of the United States National Museum. My thanks are due to Mr. Maxon for detecting and pointing out affinities and interrelationships that would otherwise have been overlooked.

width, of course, varies according to the position in the frond, the maximum width being 6 or 8 centimeters. In the upper part of the frond the pinnae are continuous, but in the middle and lower parts some of them are separated by a distance of once or twice their width.

An interesting feature connected with the manner of growth in this fern is that it appears to be indeterminate in growth—that is, the apical bud continued active and the frond continued to grow indefinitely. This is a condition not unknown among living ferns, though its recorded occurrences are not numerous. It is presumed to occur, at least to a noticeable degree, only in ferns of a tropical habitat, where absence of frost would permit the delicate growing tip to survive.

It has been difficult to place this fern biologically, and for information and advice concerning its position I am greatly indebted to Mr. W. R. Maxon, of the United States National Museum. It has, at least superficially, some features of resemblance to *Gleichenia*, such as the size and shape of the pinnae and the thin right-angled insertion on the rachis, but on closer inspection it is seen that the lobes or segments of the pinnae are really oblique or somewhat unequal-sided. The forked veins also exclude the present form from *Gleichenia*.

In habit this form somewhat approaches certain species of *Dryopteris*, but, all things considered, its characteristic features appear to be davallioid and to approach most closely those of *Tapeinidium*, a small genus of fern species of pinnate form, mainly natives of the Polynesian Islands.

Although Hall described this fern under two specific names and one varietal name, the distinctions are based mainly on size and it is not believed that they can be maintained. Thus the type of his *Pecopteris undulata* (his Pl. I, fig. 1a) is evidently a segment from the middle part of a large frond, where the pinnae are separated by a considerable interval, as shown in Plate XXVIII, figures 1 and 4. Hall's *Pecopteris? odontopteroides* (his Pl. I, figs. 3, 4) is based on small pinnae with undulate or slightly cut margins that can be duplicated in the upper portion of the frond shown in Plate XXVIII, figure 3. The form described by Hall as a variety of *Pecopteris undulata* (his Pl. I, fig. 2) is also a segment from the middle or lower part of a very large frond, and the pinnae, although broader than any others noted, are not cut so deeply by the lobes as many smaller ones. If it has been correctly drawn, however, it appears to be slightly different from the normal forms, but even so it is hardly entitled to separate recognition. The other specimens referred to this variety (Hall's Pl. I, figs. 2a, 2b) are clearly segments with nearly entire pinnae from near the apex of a frond of the normal type.

The nervation of the pinnules shown by Hall in his Plate I, figures 1b and 2a, is incorrect, as the lateral nerves are shown as simple and unforked, although he describes the veins in the text as forking. As may be seen from the enlargement shown in figure 2a, the nervation consists of a thin, delicate midvein and two or three pairs of once-forking veins.

The only specimen of the original Frémont collection known to be extant is one of the types of *Pecopteris? odontopteroides*, figured by Hall in his Plate I, figure 4. It is No. 30848 of the United States National Museum collections.

Occurrence: Frontier formation, about 1 mile east of Cumberland, Wyo. Collected originally by J. C. Frémont August 19, 1843. Subsequently collected by A. C. Veatch in 1906 and by F. H. Knowlton and T. W. Stanton in 1908.

Genus MICROTAENIA[1] Knowlton, n. gen.

Small davallioid, pinnate herbaceous ferns, with close, linear, acute pinnules; lower pinnules barren, entire or slightly crenulate-margined; middle pinnules incompletely fertile; upper ones more completely or wholly fertile, reduced, becoming undulate, then cut nearly to the midvein into sharp-pointed lobes; sori large, terminal, somewhat elongate, occupying the whole of the tips of the lobes.

Type, *Microtaenia variabilis*.

Microtaenia variabilis Knowlton, n. sp.

Plate XXIX, figures 1–4a.

Size and shape of whole frond unknown but apparently at least bipinnate, the divisions (frond ?) lanceolate in outline, narrowed at base, acutish at apex; rachis slender, distinctly sulcate; segments or pinnules numerous, approximately at right angles to the rachis, close to

[1] From μικρος, small, and ταινια, Latin taenia, a ribbon, in allusion to the narrow, ribbon-like pinnules.

distant, linear and grasslike in shape, slenderly acuminate at apex, truncate or very slightly heart-shaped or halberd-shaped at base, closely sessile; lower barren pinnae entire or very slightly undulate; middle pinnules incompletely fertile, the fertile portion reduced, cut nearly to the midvein into sharp-pointed lobes; sori terminal or elongate, occupying nearly the whole outer part of the lobe; nervation of pinnules obscure, consisting of a very strong, sulcate midvein and apparently delicate, once-forked lateral veins which are at a low, almost right angle with the midvein.

This very strongly marked type is represented by a large number of specimens, some of which, it will be seen, are exceptionally well preserved. In spite of the profusion of specimens, however, none are so complete as to give incontestable evidence as to the size and shape of the whole frond, though it appears to have been at least bipinnate. The two largest segments preserved, shown in figures 1 and 2, are from the lowest portion of the frond, but neither quite reaches the base. They are narrowly lanceolate in outline, narrowing below to their point of attachment. Another specimen not figured shows that the apex also narrows and becomes acutish. The largest of the segments has a preserved length of 10 centimeters and a maximum width of about 4 centimeters. Its full length was probably not less than 15 or 18 centimeters.

The pinnules are all approximately at right angles to the rachis. In the specimen shown in figure 2, which must be very near the base of the frond, the pinnules are close together, but in the upper portion they become more distant, and in the specimen shown in figure 1 they are separated by more than the width of the pinnules. In other specimens, such as those shown on the left of figure 2 and in figure 4, the pinnules are separated by two or three times their width. The pinnules clearly are more distant in the middle and upper portions, where the frond is becoming fertile.

Most of the barren pinnules are entire or nearly so, as shown, for instance, in figure 1, but a tendency to variation is constantly manifest. Thus, in figure 2, which to all intents and purposes is about the same as figure 1, the pinnules show a decided tendency to be undulate margined and some of them to become distinctly lobed near the tips. In the fragmentary specimen on the left of the stone shown in figure 2 the exceedingly long, narrow pinnule is lobed up to the point where it becomes fertile, as are the other, broken pinnules, though the undulate lobed to strongly cut fertile portions are well shown in figure 3. None of these pinnules is completely fertile, each having a short barren, undulate-lobed portion near the base. In the specimen shown in figure 4a the whole of the pinnule has become fertile.

The sori are perhaps best shown in figure 3. They are seen to be terminal and somewhat elongate and to occupy the whole of the tips of the lobes.

The relationships of this fern are not easy to determine. That it is extremely variable in a number of particulars has been brought out in the above discussion. In certain specimens in which the barren pinnules are more or less undulate lobed this species appears to approach what is here called *Tapeinidium? undulatum*. Some specimens of that species have pinnules only slightly lobed and are almost impossible to distinguish from the present form. The character of the midvein is exactly the same in both forms—that is, it is strong and deeply sulcate, thus producing the appearance of two lines when seen from the upper side of the pinnule.

So far as can be learned by study of the figures given by Hall and such of the original material as is now accessible, Frémont did not collect specimens of *Microtaenia variabilis* unless the fertile upper portion of Hall's *Sphenopteris triloba* (his Pl. II, fig. 2) is an isolated fragment of a pinnule.

Occurrence: Frontier formation, 1½ miles east of Cumberland, Wyo. Collected by F. H. Knowlton and T. W. Stanton August 5, 1908.

Microtaenia paucifolia (Hall) Knowlton, n. comb.

Plate XXX, figures 1, 2.

Sphenopteris? paucifolia Hall, in Frémont, op. cit., Appendix B, p. 304, pl. 2, figs. 1, 1a, b, c, d.
Sphenopteris? trifoliata Hall, idem, pl. 2, fig. 2.

Similar in general effect to the type species but evidently more finely divided, probably tripinnatified, the rachis much more slender; complete barren pinnules not seen; basal barren portion of fertile pinnules strongly undulate

lobed; fertile pinnules very short, with only two or three lobes on each side; sori terminal, occupying the whole of the tip.

There is more or less uncertainty regarding the status of this form. It is represented by only four or five very fragmentary specimens, all of which show the fertile pinnules but give very little evidence regarding the barren portions. In the first place, it appears to be more finely divided than *M. variabilis*, as shown in one of Hall's figures (his Pl. II, fig. 1) of *Sphenopteris? paucifolia*, though none of the recent specimens is sufficiently complete to show this feature. The specimen shown in Hall's figure is certainly tripinnatified, with the pinnules short and very much reduced.

The only evidence regarding the character of the barren pinnules is shown in figure 2, where the basal portions of three or four of the lower pinnules are seen to be undulate lobed before they pass into the deeply lobed, fertile portion.

The specimen named *Sphenopteris triloba* by Hall is probably only a smaller and more reduced state of *S. paucifolia* in which the fertile lobes are reduced to three. It may be that the pinnules are broken at the tips, but as the specimen is not now known to be extant, it is impossible to settle this point.

In the upper portion of Hall's figure 2 he shows the axis apparently passing into a fertile portion (enlarged in his fig. 2d), but this portion is only accidentally in that position and has no organic connection with the rest of the specimen. It appears to be an isolated fragment of a fertile pinnule of *M. variabilis*.

Occurrence: Frontier formation, 1½ miles east of Cumberland, Wyo. Collected by F. H. Knowlton and T. W. Stanton August 5, 1908.

Dennstaedtia? fremonti (Hall) Knowlton, n. comb.

Plate XXX, figure 5; Plate XXXI, figure 1.

Sphenopteris fremonti Hall, in Frémont, op. cit., Appendix B, p. 304, pl. 2, figs. 3, 3a.

Size and shape of whole frond unknown but probably at least tripinnate or tripinnatified; main rachis exceedingly strong, ridged; pinnae approximately at right angles to the rachis, linear or lanceolate, with the secondary rachis sulcate; pinnules rather remote, subovate, somewhat decurrent at base, about three or four lobed; sori large, terminal on the tips of the lobes.

This form is represented by so few and so fragmentary specimens that it must stand as insufficiently characterized. The most important features that can be made out are the exceedingly thick main rachis; small, few-lobed pinnules; and rather large, terminal sori.

As regards the probable affinity of this form the best that can be said is that it is undoubtedly a davallioid fern, which as a matter of convenience is tentatively referred to the genus *Dennstaedtia*.

Occurrence: Frontier formation, about 1 mile east of Cumberland, Wyo. Collected by J. C. Frémont August 19, 1843, and by F. H. Knowlton and T. W. Stanton August 5, 1908.

Dryopteris coloradensis Knowlton, n. sp.

Plate XXX, figures 3, 4.

Outline of whole frond not known but evidently of large size and at least bipinnatified; rachis strong, round; pinnules at an angle of about 30°, alternate, rather remote, linear-lanceolate, acuminate at apex, broadest at base, sessile, cut more than half the distance to the secondary rachis into numerous close, slightly scythe-shaped, obtusely pointed, or somewhat acute lobes; small upper lobes entire, larger lobes uneven or in places sharply serrate; secondary rachis slender; nervation of the lobes consisting of a thin, slightly flexuose midvein and five or six pairs of delicate, once-forked veins, the fork occurring just above the midvein; fructification not seen.

This form is represented by several pieces, two of the most complete of which are figured. From the presence of large pieces of stems intermingled with the fronds and presumed to belong with them, it is assumed that this fern was probably of large size, but the direct evidence is only sufficient to say that it is at least bipinnatified. Under the circumstances measurements are of comparatively little value, though it may be stated that the pinnules range from 5 or 6 to 10 centimeters or more in length and from 8 to 18 millimeters in width.

Occurrence: Frontier formation, about 1 mile east of Cumberland, Wyo. Collected by A. C. Veatch in 1906.

Asplenium occidentale Knowlton, n. sp.

Plate XXXI, figures 2–5.

Although this form is represented by a large number of specimens, they are all so fragmentary and disconnected that it is impossible to gain an adequate conception of the frond as a whole. Under the circumstances it seems best simply to figure a number of the best-preserved fragments and describe them as fully as possible, but to leave to the future its definite allocation. It was evidently a fern of considerable size, as may be seen from the example shown in figure 4. This has a preserved length of 7 centimeters and a width of 3.5 centimeters but was probably considerably larger. The margin is undulate-lobed and has a few fine, sharp teeth. The apex in other specimens is shown to be strongly toothed. The nervation consists of a very stout midvein and strong veins that arise at an angle of probably 40° but curve outward until they are nearly at right angles to the midvein. The veins fork usually very close to the midvein and once or twice above.

The specimen shown in figure 2 consists of two pinnules attached to a minute piece of the rachis. Each is rounded on the lower side, so that they produce together a deeply heart-shaped base. The tip of the left-hand pinnule shows the strong teeth above mentioned.

In figure 5 two examples are shown; the lower is about the size of the one last described, the upper much smaller. The margin of the upper one is strongly undulate-toothed, becoming in the upright segment almost lobed. The nervation is of the same character as that in the large example (fig. 4), described above, except that there is usually only one fork in the nerves and this is near the midvein.

On account of the uncertainty attending the assignment of this form it is obviously unwise to attempt comparisons with either living or fossil species. It is placed in the genus *Asplenium* on the ground of its resemblance—fancied or real—to the living *Asplenium hemionites* Linné, but more complete material will be necessary before its status can be fixed. It is believed, however, that enough of it is here described and figured to permit its subsequent recognition, not only in the Frontier formation but elsewhere.

Occurrence: Frontier formation, 1 mile east of Cumberland, Wyo. Collected by F. H. Knowlton and T. W. Stanton in 1908.

Family SCHIZAEACEAE.

Anemia fremonti Knowlton, n. sp.

Plate XXXI, figure 6; Plate XXXII, figures 1–3.

Outline of whole front not known; stipe long, slender, dichotomous; frond bipinnate, possibly tripinnate; pinnae narrowly deltoid; pinnules arising at an acute angle, linear-lanceolate, sessile and decurrent or lower ones nearly free; pinnules cut, especially near the base, into deep, sharp-toothed, entire, forward-pointing lobes, which decrease apically so that the terminal fourth is entire or merely crenulate; middle and upper pinnules becoming more and more entire toward the apex, which is only crenulate; nervation rather sparse, at a very acute angle, nerves once or twice forked; fertile frond not found.

This species is represented by a large number of specimens, but unfortunately all are so fragmentary that it is impossible to make out the shape and size of the whole frond. Some evidence to show that the frond was very large and several times compounded is afforded by the presence of certain fragments disposed in such a way on the matrix as to suggest the possibility of their organic connection, but no such union has been seen. A dichotomous branching of the slender rachis, such as is shown in figure 3, is all the branching that has been observed. The longest segment of rachis observed (fig. 3) is 6 centimeters long but was certainly considerably longer when perfect. The best-preserved pinna, shown in figure 1, is 14 centimeters long, of which at least 2 centimeters is made up of secondary rachis. It is approximately 6 centimeters broad between the tips of the lower pinnules. The manner and extent of the marginal cutting of the pinnules is so well shown in the figure that it is not necessary to describe them at greater length.

This species is exceedingly close to *Anemia subcretacea* (Saporta) Gardner and Ettingshausen,[1] a species that was described from specimens obtained in the Eocene travertines of Sézanne and was subsequently found to be abundant in the Eocene of Bournemouth, England. The present form appears to differ slightly in its broader pinnae, generally less sharply cut pinnules, and more erect nervation, but at best the difference is not great.

Gardner and Ettingshausen referred Lesquereux's *Gymnogramma haydenii*,[2] from the divide

[1] Gardner, J. S., and Ettingshausen, Constantin von, Monograph of the British Eocene flora, vol. 7, p. 45, pls. 8, 9, 1880.

[2] U. S. Geol. Survey Terr. Rept., vol. 7, p. 59, pl. 5, figs. 1–3, 1878.

between the headwaters of Snake River and Yellowstone Lake, to their *Anemia subcretacea*, and in this reference Lesquereux concurred. The specimen shown in figure 3 of Lesquereux's plate is considerably like the specimens from Cumberland, but those shown in the other figures are quite different.

At one time Newberry was of the opinion that he had found *Anemia subcretacea* at a number of localities, as Point of Rocks, Wyo. (Montana), Erie, Colo. (Laramie), and Bellingham Bay and Carbonado, Wash. (Eocene), but in his formal report[1] he inclined to regard them as representing a well-marked, robust variety. This work was edited by Hollick, who substituted the name *Anemia perplexa* for the reason that *A. subcretacea* was considered nomenclatorially untenable. The specimens figured by Newberry are very unlike the present species, and furthermore, it would seem to be wise not to regard them as identical with the European form.

A fine large species of *Anemia* from the Raton formation of Colorado is described by me in a paper now in press,[2] but it is quite different from *Anemia gracillinea*.

Fragmentary specimens of *Anemia* have been found at many localities in the Rocky Mountain region, ranging in age from early Montana to Laramie, but none of them appear to agree very closely with the present species.

Occurrence: Frontier formation, 1 mile east of Cumberland, Wyo. Collected by F. H. Knowlton and T. W. Stanton in 1908.

Family EQUISETACEÆ.

Equisetum sp.

Plate XXXIII, figure 6.

The collection made near Cumberland by Veatch contains a single specimen with its counterpart that apparently represents the underground stem of an *Equisetum*. It is about 9 centimeters long, has a maximum diameter of nearly 1 centimeter, and is more or less constricted or cut up into short segments 10 to 15 millimeters in length. It is irregularly ridged or wrinkled longitudinally but otherwise has no marks or features of diagnostic value.

Beyond the fact of attesting the presence of vegetation of this type in the Frontier formation this specimen is of little value, as it could probably not be recognized or discriminated if found elsewhere. For this reason there is little use in attempting comparisons with described species, though incidentally it may be compared as being similar in type to *Equisetum prelaevigatum* Cockerell (*E. laevigatum* Lesquereux[3]), from the Denver formation of Colorado.

Occurrence: Frontier formation, north side of Little Muddy Creek, about 1 mile east of Cumberland, Wyo., in sec. 29, T. 19 N., R. 116 W. Collected by A. C. Veatch in 1905.

Family SMILACEÆ.

Smilax? coloradensis Knowlton, n. sp.

Plate XXXIII, figure 1.

Leaf small, membranaceous, regularly elliptical, abruptly rounded below to a very slightly heart-shaped base, apex destroyed but apparently rather obtusely pointed; three-ribbed from base, the midrib slightly the stronger, lateral ribs passing up nearly or quite to the apex, each with several branches on the outside which join and produce a semblance of an additional rib on each side; no secondaries observed on the midrib, but a few strong nervilles between the ribs; fine nervation not retained.

The specimen figured is all that was found of this form. It is about 5 centimeters long and 3.5 centimeters wide. The nervation is so poorly preserved that hardly anything but the main ribs is retained. It is for this reason that the generic reference has been questioned, though it has the size, shape, thickness, and, so far as can be made out, the essential nervation of certain living forms of the genus. More and better material will be necessary to settle the matter fully.

Occurrence: Frontier formation, dump of mine No. 1, Cumberland, Wyo. Collected by F. H. Knowlton August 5, 1908.

Family MYRICACEÆ.

Myrica nervosa Knowlton, n. sp.

Plate XXXIV, figure 1.

In the small collection obtained about 1½ miles south of Cumberland, Wyo., there are a number of fragmentary leaves of *Myrica*. The

[1] Newberry, J. S., The later extinct floras of North America: U. S Geol. Survey Mon. 25, p. 4, 1898.

[2] Lee, W. T., and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, p. 285, pl. 54, fig. 2 (in press).

[3] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7, p. 68, pl. 6, fig. 6, 1878.

nervation is very distinct and characteristic, and although the specimens are so much broken that the size and shape can not be fully made out, it seems best to put the form on record so that it may be looked for in the future.

This species is narrowly lanceolate, probably acuminate at base and apex, and has perfectly entire margins. The length was apparently 8 or 9 centimeters and the width about 2 centimeters. The leaf substance is thick and leathery, as shown by the wrinkled appearance of the leaves. The midrib is exceedingly strong. The secondary nervation is thin and irregular, at an angle of 50° or more, much curved upward, each principal nerve arching just outside the margin and producing an intramarginal "stitch." There are numerous intermediate secondaries which pass up and join the bows of the larger nerves, or disappear in a network of nervilles. The finer nervation produces a network of irregular areas.

This species is, in a way, of the type of *Myrica torreyi* Lesquereux, of the Montana group and slightly younger horizons. It differs markedly from that species, however, in its smaller size, entire instead of serrate margins, and secondaries of two sizes, the larger ones forming the intramarginal vein. The nervation is also at a more acute angle than in *M. torreyi*.

Occurrence: Frontier formation, 1½ miles south of Cumberland, Wyo., in the SE. ¼ sec. 6, T. 18 N., R. 116 W. From same horizon as plant beds 1 mile east of Cumberland. Collected by T. W. Stanton September 1, 1913.

Family SALICACEAE.

Salix cumberlandensis Knowlton, n. sp.

Plate XXXVIII, figure 3.

Leaf firm in texture, lanceolate, 8 centimeters long, 2 centimeters wide, abruptly rounded below to the short, thick petiole, broadest at and below the lower third of the blade, whence it is gradually narrowed to the slenderly acuminate apex; margin finely and evenly crenate throughout; midrib very thick, especially below; secondaries strong, 16 or more pairs, alternate, emerging at an angle of 30° or 35°, much curved upward and apparently effused near the margin; finer nervation not retained.

This handsome little species is represented only by the very perfect example figured. It is well marked by its narrowly oblong-lanceolate outline, abruptly rounded base, finely crenulate margin, and numerous strong, apparently camptodrome secondaries.

Occurrence: Frontier formation, 1½ miles south of Cumberland, Wyo., in the SE. ¼ sec. 6, T. 18 N., R. 116 W. From same horizon as the plant beds 1 mile east of Cumberland. Collected by T. W. Stanton September 1, 1913.

Salix frontierensis Knowlton, n. sp.

Plate XXXV, figure 4a.

Leaf small, apparently rather thick, elliptical lanceolate, broadest at a point below the middle, whence it rounds rather abruptly to the short, thick petiole; apex destroyed but apparently acuminate; margin perfectly entire; midrib very strong for a short distance, then much thinner; secondaries 10 or 12 pairs, very thin and delicate, curved upward, camptodrome; finer nervation obscure.

The little leaf figured is unfortunately the only one of this kind noted in the collection. It was about 3.5 centimeters long and 1.3 centimeters wide; the petiole is about 3 millimeters long.

Occurrence: Frontier formation, 1½ miles south of Cumberland, Wyo., in the SE. ¼ sec. 6, T. 18 N., R. 116 W. From same horizon as plant beds 1 mile east of Cumberland. Collected by T. W. Stanton September 1, 1913.

Family FAGACEAE.

Quercus stantoni Knowlton, n. sp.

Plate XXXIII, figures 2–4.

Leaves membranaceous, rather broadly lanceolate, long, wedge-shaped at base, much more abruptly narrowed above to an obtusely acuminate apex; margin entire below, coarsely few-toothed or lobed above, the teeth separated by shallow sinuses, sharp, mucronate-tipped; petiole strong, at least 1.5 centimeters long; midrib very strong below, not much thinning above; secondaries about 10 or 12 pairs, mainly alternate, at an angle of 45°, running nearly straight to the teeth below, slightly curved upward above; nervilles numerous, strong, irregular, finer nervation forming a coarse, irregularly quadrangular network.

This species is represented by nearly a dozen specimens, none of which, however, is complete. The length, including the petiole, must have been at least 10 or 12 centimeters and the width between 3 and 4 centimeters. The

species is well marked by the long, wedge-shaped base, more obtuse apex, and coarse marginal teeth or lobes, which are all mucronate-tipped, thus indicating that it is a member of the black-oak group. In figure 3 is shown a cluster of three leaves that were probably attached to the same branch, though the actual union is not shown. The best preserved of these gives a very satisfactory view of the lower half of the blade, with its strong petiole and mucronate teeth. In figure 2 is shown a very complete apical portion of a leaf of the same size as the one in figure 3. The basal portion of another well-preserved leaf is seen in figure 4.

Among fossil species of *Quercus* the present species is rather closely related apparently to a number from the Senonian of Haldene, Westphalia, as described by Hosius and Von der Marck.[1] It is perhaps nearest to *Quercus formosa*, from which it differs in being broader and in having larger, sharper, mucronate-tipped teeth. From *Quercus sphenobasis* it differs in its fewer, larger teeth and fewer secondaries.

Occurrence: Frontier formation, 1½ miles south of Cumberland, Wyo., in the SE. ¼ sec. 6, T. 18 N., R. 116 W. From same horizon as plant beds 1 mile east of Cumberland. Collected by T. W. Stanton September 1, 1913.

Family MORACEAE.

Ficus fremonti Knowlton, n. sp.

Plate XXXIV, figures 4–6; Plate XXXV, figures 4c, 5.

Glossopteris phillipsii? Brongniart. Hall, in Frémont, op., cit., Appendix B, p. 305, pl. 2, figs. 5, 5a–c. Lesquereux, U. S. Nat. Mus. Proc., vol. 11, p. 37, 1888.

Leaves small, very thick and coriaceous, narrowly lanceolate, broadest below the middle, whence they narrow below to a rather long, wedge-shaped base and above to a very long, narrow acuminate apex; margin perfectly entire; petiole short (1 centimeter), relatively strong; midrib very strong; secondaries immersed in the substance of the leaf and indistinct, numerous, at an acute angle, camptodrome; finer nervation obscure.

This form is represented by 25 or more specimens, few of which are perfect. It is a small, very narrowly lanceolate leaf, 6 to 8 or 9 centimeters long and 1 to 2 centimeters wide, with a petiole 1 centimeter or slightly over in length. It is especially distinguished by its long, narrowly acuminate apex.

The species here called *Ficus fremonti* has had a most interesting history. It was first collected by Frémont in 1843 and was identified by Hall as *Glossopteris phillipsii*, for the reason, he adds, that Brongniart's species afforded "the only description and figure accessible to me to which this fossil bears any near resemblance." Examination of Brongniart's figure [2] shows that this form certainly does resemble it so far as size and shape go but is totally different in nervation. *Glossopteris phillipsii* has of course a pteroid nervation with close, parallel, forking veins, but the secondary nerves in the leaves here described, as may be seen from the figures, are distinctly those of a dicotyledon.

Fortunately, two of the original Frémont specimens (Hall's figs. 5 and 5b) are preserved in the United States National Museum and are shown here (Pl. XXXIV, fig. 6; Pl. XXXV, fig. 5). These leaves passed under Lesquereux's eye, and although he lists them under *Glossopteris phillipsii* he makes the following statement: [3] "This is remarkably similar in form of leaves and nervation to *Glossochlamys transmutans* Gardner and Ettingshausen (British Eocene flora, pl. 3, fig. 3; pl. 12, fig. 8). The specimens of Frémont show indistinctly nervilles between the lateral nerves composing irregular, square meshes."

The figures of *Glossochlamys transmutans* given by Gardner and Ettingshausen show that to all intents and purposes this form is a dicotyledon, and in fact these authors admit that Saporta, whom they consulted, objected to the reference of this fossil to a fern, and Heer stated flatly that "it is not a fern, but a leaf of a dicotyledon." There can be absolutely no question about it—the leaves under consideration belong to a dicotyledon and have nothing to do with ferns.

It was largely on the basis of Hall's identification of these leaves as *Glossopteris phillipsii* that the beds were referred to the Jurassic. On this point Hall says: "The geological position of the fossil is so well ascertained to be the schists of the upper part of the Oolitic period

[1] Hosius, A., and Von der Marck, W., Flora der westfälischen Kreideformation: Palaeontographica, vol. 26, p. 164 [40], pl. 31, fig. 81, 1880.

[2] Brongniart, Adolph, Histoire des végéteaux fossiles, p. 225, pl. 61 bis, fig. 2, 1828.

[3] Lesquereux, Leo, Recent determinations of fossil plants from Kentucky, Louisiana, * * * : U. S. Nat. Mus. Proc., vol. 11, p. 37, 1888.

that, relying upon the evidence afforded by a single species, we might regard it as a strong argument for referring all the other specimens to the same geological period."

Ficus fremonti agrees very well in shape with *Ficus proteoides* Lesquereux,[1] from the Dakota sandstone of Kansas, but the latter is a much larger leaf and has a more open nervation. In shape, size, and nervation it is even closer to *Ficus lanceolata acuminata* Ettingshausen, as figured by Lesquereux,[2] from the Dakota sandstone of Kansas. This species, however, is somewhat longer and broader and has the nervation more regular and at a less acute angle of divergence.

As stated on page 80, one of the original specimens figured by Hall showed on one side of the leaf round bodies which have now been identified as the egg mass of an insect, probably a microlepidopterous insect. It is shown in figure 5 of Plate XXXVI.

Occurrence: Frontier formation, about 1 mile east of Cumberland, Wyo. Originally collected by J. C. Frémont August 19, 1843; subsequently found at or near the same place by F. H. Knowlton and T. W. Stanton in 1908.

Ficus? sp.

Plate XXXV, figure 1.

A small collection made from a rather coarse-grained shaly sandstone about 300 feet above the main plant locality east of Cumberland contains a number of fragmentary leaves that seem to belong to *Ficus*, but there are little more than outlines to afford basis for a judgment. The leaf shown in figure 1 is one of the best preserved of these specimens. It is ovate, with an abruptly rounded truncate base, probably obtusely acuminate apex, and entire margins. The length was about 10 or 11 centimeters and the width nearly 5 centimeters. Even the primary nervation is so obscure that it is made out with difficulty. It consists of a fairly strong midrib and apparently a strong rib or secondary arising near the base and passing up for a long distance, but it is more or less uncertain.

This form is so obscure that it is of little value, and except for the desirability of enumerating all the plants present in this region, it might well be discarded. It simply calls attention to the presence of a large leaf whose more definite placing must be left to the future.

Occurrence: Frontier formation, mine No. 1, half a mile east of Cumberland, Wyo. Collected by T. W. Stanton and F. H. Knowlton in 1908.

Ficus? sp.

Plate XXXIV, figures 2, 3.

The collection obtained half a mile east of Cumberland contains a number of narrow leaves that are included here only on the ground that it seems desirable to enumerate everything known from this general region. They are preserved in a coarse-grained sandstone that has obscured most of the characteristic features—in fact, about all that can be made out is the outline and the thick midrib. They are narrowly lanceolate leaves that are rather abruptly rounded to the base and apparently long acuminate at the apex. The length is about 10 centimeters and the width a little over 2 centimeters. The midrib is strong, and there is some slight indication of secondary branches, but they are very uncertain.

This form might be compared with a number of long, narrow-leaved species of *Ficus* or certain entire-leaved species of *Salix*, but absence of essential features makes definite comparisons of little value.

Occurrence: Frontier formation, half a mile east of Cumberland, Wyo. Collected by F. H. Knowlton and T. W. Stanton August 5, 1908.

Family LAURACEAE.

Cinnamomum hesperium Knowlton, n. sp.

Plate XXXVIII, figure 2.

Leaf semicoriaceous or finer in texture, narrowly lanceolate, broadest near the middle, whence it narrows in almost the same degree to both base and apex; length 7 centimeters including the petiole, which is about 8 millimeters long; width about 13 millimeters; petiole relatively short, stout; midrib very strong below, becoming much thinner in the upper half of the blade; lateral ribs at an acute angle, arising at a point about 5 millimeters above the base of the blade, passing up and joining the lowest pair of secondaries near or above the middle, each with two or

[1] Lesquereux, Leo, Flora of the Dakota group: U. S. Geol. Survey Mon. 17, p. 77, pl. 12, fig. 2, 1892.
[2] Idem, p. 85, pl. 13, fig. 4.

three secondary branches on the outside; secondaries on the midrib three pairs, alternate, lowest arising far below the middle of the blade, arching upward and running along near and gradually lost in the margin; nervilles obscure, apparently close, parallel, unbroken, and at right angles to the ribs and secondaries.

This species is represented only by the example figured, which fortunately is practically perfect, so that its characters can be made out with certainty. It is with much hesitation described as new. At one time it was identified with a specimen from Hodges Pass, Wyo., described and figured by Ward [1] under the name *Cinnamomum lanceolatum* (Unger) Heer but later given the name *C. wardii* Knowlton [2] on the ground that it was not conspecific with the European species. Except in the matter of size these two leaves are undoubtedly close. Thus, *C. wardii* is 15 centimeters long and 2.5 centimeters wide, *C. hesperium* is 6 centimeters long and 1.4 centimeters wide. There are also other slight differences. In *C. wardii* the base is more obtuse and rounded, the lateral ribs at a less acute angle and without outside secondaries, and the secondaries on the midrib are closer and more numerous, but these are all comparatively unimportant divergences that might possibly break down if a series was available for comparison instead of a single leaf of each form.

The leaf found near Cumberland, Wyo., is also strikingly similar in size, shape, and general appearance to *Cinnamomum salicifolium* Staub,[3] from the well-known Tertiary beds at Sotzka, in Styria, but here again there are noticeable slight differences. Thus there are no outside secondaries on the lateral ribs, and the secondaries on the midrib are more numerous and confined to the upper half or upper third of the leaf.

Cinnamomum salicifolium was segregated by Staub from *C. lanceolatum* (Unger) Heer, on the basis of its generally narrower shape, higher secondaries, etc., but the difference is not great.

The geologic horizon at which the leaf *C. wardii* was found is more or less in doubt. The specimen was supposed by Ward to be from beds of Laramie age as then interpreted, but the work of Veatch appears to place it in the upper part of the Adaville formation of the Montana group, or nearly 10,000 feet above the horizon which supplied the Cumberland leaf. The species was not found in any of the recent collections made in this general region.

Although these two species (*C. wardii* and what is here called *C. hesperium*) are undoubtedly close together, the best that can be done under the circumstances, considering the differences in size and nervation already pointed out, as well as the apparent disparity in age, is to regard them as distinct until additional material can be obtained.

Occurrence: Frontier formation, 1½ miles south of Cumberland, Wyo., in the SE. ¼ sec. 6, T. 18 N., R. 116 W. Same bed as plant locality 1 mile east of Cumberland. Collected by T. W. Stanton September 1, 1913.

Cinnamomum? sp.

Plate XXXV, figure 2.

There are in the collection several very fragmentary leaves that appear to belong to the genus *Cinnamomum*, though they are obscure at critical points. The one figured is ovate-lanceolate and has a rounded wedge-shaped base and an acuminate apex. The length is 9 centimeters and the width a little less than 5 centimeters. The midrib is strong; the lateral ribs are somewhat thinner and pass up nearly to the apex. There are several secondary branches on the outside of the lateral ribs, but otherwise the nervation can not be made out.

Occurrence: Frontier formation, half a mile east of Cumberland, Wyo. Collected by F. H. Knowlton and T. W. Stanton August 5, 1908.

Family PROTEACEAE.

Dryandroides lanceolata Knowlton, n. sp.

Plate XXXIV, figure 7.

Leaves coriaceous, narrowly lanceolate, base not seen but apparently rather abruptly narrowed to a short, wedge-shaped basal portion, prolonged above into a very long, acuminate apex which is minutely emarginate at the tip; margin in lower and middle portions distinctly toothed, the teeth sharp pointed, separated by very shallow sinuses; margin in upper portion

[1] Ward, L. F., Synopsis of the flora of the Laramie group: U. S. Geol. Survey Sixth Ann. Rept., pl. 46, fig. 12, 1886.

[2] Knowlton, F. H., A catalogue of the Cretaceous and Tertiary plants of North America: U. S. Geol. Survey Bull. 152, p. 69, 1898.

[3] Staub, Moriz, Die Geschichte des genus *Cinnamomum*, p. 65, pl. 12, figs. 7–14, 1905.

undulate and finally entire; midrib very strong; secondaries numerous (probably at least 15 pairs), alternate, at an angle of 35° or 40°, considerably curved upward, entering the teeth or arching and each joining the secondary next above and sending a short, outside branch to the tooth; secondaries in the narrowed, entire apical portion of the blade arching upward for a considerable distance and disappearing in or near the margin; nervilles numerous, mainly broken and at right angles to the secondaries.

The portions of the two leaves shown in figure 7 are all that has been observed of this well-marked form. It is not possible to ascertain the exact length, but it could hardly have been less than 11 or 12 centimeters. The greatest width is slightly less than 2 centimeters.

The large segment referred to this species is certainly very oaklike in appearance, but the long, slenderly acuminate apical portion is much less so, and it seems best referred to the genus *Dryandroides*. It is, for instance, very similar to *D. quercinea* Velenovsky,[1] from the Cretaceous of Bohemia. It is, however, a larger, longer leaf, with a narrower apical portion, fewer lower teeth, and fewer secondaries at a more acute angle.

Dryandroides quercinea has been reported by Hollick[2] from the Magothy formation at Gay Head, Marthas Vineyard, Mass., but this reference depends on two fragmentary leaves and is open to some question.

The only other species of *Dryandroides* tentatively accepted as North American was described by Lesquereux[3] under the name *Quercus cleburni*. It comes from Black Buttes, Wyo., and is very different from the present form; in fact, it is doubtful if it should be placed in *Dryandroides*.

Occurrence: Frontier formation, 1½ miles south of Cumberland, Wyo., in the SE. ¼ sec. 6, T. 18 N., R. 116 W. From same horizon as plant bed 1 mile east of Cumberland. Collected by T. W. Stanton September 1, 1913.

[1] Velenovsky, J., Die Flora der böhmischen Kreideformation: Beitr. Paläontologie Oesterr.-Ungarns u. des Orients, Band 3, Heft 1, p. 33 (8), pl. 10 (2), 1883.

[2] Hollick, Arthur, The Cretaceous flora of southern New York and New England: U. S. Geol. Survey Mon. 50, p. 60, pl. 8, figs. 18, 19, 1906.

[3] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7, p. 154, pl. 20, fig. 2, 1878.

Family RANUNCULACEAE?

Dewalquea pulchella Knowlton, n. sp.

Plate XXXVI, figures 1–3; Plate XXXVII, figures 1–3.

Leaves of medium or small size, palmately decompound, the segments usually five but occasionally six in number; petiole extremely long, much longer than the longest foliar segment, splitting at top into two nearly equal branches, one of which usually gives rise to two and the other to three segments, though the middle segment in a five-parted leaf may be nearly or quite free; segments all narrowly linear-lanceolate, of approximately the same size, the other segments slightly inequilateral, the middle one in some leaves slightly smaller than the others, all long and very narrowly wedge-shaped at base, acuminate at apex; margin of segments usually entire for a short distance at the base, thence strongly and sharply serrate; midrib strong, straight; secondaries obscure owing to the thickness of the leaf substance, numerous, apparently subopposite, at an angle of about 40°, slightly curved upward, all but the lower ones craspedodrome and ending in the marginal teeth; finer nervation not retained.

This splendid species is represented by nearly twenty specimens, six or seven of which have been figured. In none of the specimens are all the segments preserved entire, but some are nearly perfect, and hardly any of them is so fragmentary as not to show the manner in which the segments arise from the top of the petiole. Apparently in a majority of the leaves of this genus from other areas, as described, the segments are so broken and detached that it becomes a matter of difficulty to interpret them satisfactorily. The leaves here described, however, are so well preserved that there can be absolutely no question as to their being congeneric with the type and typical species from European deposits, from which the genus was first made known.

The present leaves are rather small compared with those of typical members of the genus. None of the segments exceed 8 or 9 centimeters in length and 1.5 centimeters in width, and apparently most of them are only 6 or 7 centimeters long and 1 centimeter or less in width. The segments are cut so deeply that they are

almost free, and there is very little evidence of their being unequal-sided at the base. In only one specimen, that shown in Plate XXXVI, figure 3, is there six segments, all the remainder having five very symmetrically spaced divisions.

The petiole, which is preserved entire in several specimens, is extremely long and slender. In the leaf shown in Plate XXXVII, figure 2, for instance, it is nearly 5 centimeters long and probably exceeds the length of the segments. The average length is about 4 centimeters.

This species is very closely related to *Dewalquea insignis* Hosius and Von der Marck,[1] from the Upper Senonian of Westphalia—so closely related, in fact, that it would perhaps do no great violence to call them the same. The present form differs from the Westphalian species in its generally smaller size, longer petiole, usually fewer segments with much larger, sharper teeth, and, so far as can be made out, fewer, more curved secondaries. These, however, are all minor differences that might well be covered by individual variation; but in consideration also of the difference in geographic and stratigraphic position, it is perhaps as well to consider the Wyoming form under another name.

Dewalquea insignis was recorded by Heer [2] from both the Atane and Patoot beds of Greenland, and by Hollick [3] from the Cretaceous of Staten Island, but as Berry [4] has recently pointed out, "both these determinations are based upon fragments of single leaves and are, in the writer's judgment, entirely untrustworthy."

The genus *Dewalquea* was established by Saporta and Marion [5] in 1874, and was based on two species (*Dewalquea haldemiana* and *D. aquisgranensis*) from the Senonian of Westphalia, sent to them by Debey under the manuscript names *Araliophyllum* and *Grevillea*, and one (*D. gelindensis*) collected by themselves from the Paleocene of Gelinden, Belgium. Since that date 10 additional species, all from the Upper Cretaceous, have been named by different authors. Of these one (*D. grönlandica* Heer) is from the Patoot and Atane beds of Greenland, two (*D. dakotensis* Lesquereux and *D. primordialis* Lesquereux) from the Dakota sandstone of Kansas and Minnesota respectively, one (*D. trifoliata* Newberry) from the Raritan formation of New Jersey, and one (*D. smithi* Berry) from the Tuscaloosa formation of Alabama and the Black Creek formation (Middendorf arkose member) of South Carolina.

Of the Greenland and American species all but one (*D. smithi* Berry)[6] have leaves with only three segments or leaflets and are very unlike *D. insignis* or *D. pulchella*. The species described by Berry is a very handsome one; the leaves have five segments which are from 8 to 16 centimeters in length and sharply serrate, and the lateral segments are curiously unequal-sided at the base. This is undoubtedly a *Dewalquea*, but it is very distinct from the species here described.

The systematic affiliations of the genus *Dewalquea* are still more or less obscure. As may be inferred from the names suggested by Debey, he regarded it as belonging either in the Araliaceae or in the Proteaceae, but when Saporta and Marion established the genus they took occasion to review the matter with great care, and after comparing it with several genera such as *Aralia*, *Ampelopsis*, and *Arisaema* (a monocotyledon of the family Araceae) concluded that it had the greatest affinity with the tribe Helleboreae of the family Ranunculaceae. The Helleboreae in the living flora are herbaceous, but Saporta and Marion state that the presence of a Cretaceous or early Eocene shrubby ancestor would be quite in accord with the evolutionary history of some other groups.

Although these authors pointed out the reasons opposing the reference of *Dewalquea* to the Araliaceae, such a reference seems to the writer to be entitled to further consideration. It is, for instance, difficult to escape the conviction that certain leaves from the Dakota sandstone referred to *Aralia* may well have been ancestral to leaves of *Dewalquea* of the type of *D. insignis*, *D. pulchella*, etc. Take, for example, the species described by

[1] Hosius, A., and Von der Marck, W., Die Flora der westfälischen Kreideformation: Palaeontographica, vol. 26, p. 172 (48), pl. 32, figs. 111–113; pl. 33, fig. 109; pl. 34, fig. 110, 1880.

[2] Heer, Oswald, Flora fossilis arctica, vol. 6, Abt. 2, p. 86, pl. 25, fig. 7, pl. 33, figs. 14–16, 1882; vol. 7, p. 37, pl. 58, fig. 3; pl. 62, fig. 7, 1883.

[3] Hollick, Arthur, The Cretaceous flora of southern New York and New England: U. S. Geol. Survey Mon. 50, p. 106, pl. 8, fig. 24, 1906.

[4] Berry, E. W., The Upper Cretaceous and Eocene floras of South Carolina and Georgia: U S. Geol. Survey Prof. Paper 84, p. 42, 1914.

[5] Saporta, Gaston de, and Marion, A. F., Essai sur l'état de la végétation à l'époque des marnes heersiennes de Gelinden: Acad. roy. Belgique Mem. cour. et des sav. étrang., vol. 37, p. 55, 1874.

[6] Berry, E. W., op. cit., p. 41, pl. 8, figs. 3–9 (restoration, fig. 1 in text).

Lesquereux[1] as *Aralia wellingtoniana*. This is a medium-sized leaf with five deeply cut, sharply serrate lobes in which the secondary nervation is close, parallel, and craspedodrome in the upper portions. If the separation of these lobes were continued a short distance until the lobes were nearly or quite free, though still showing the method of origin from the branches of the petiole, a palmately decompound leaf would result that seemingly would be a *Dewalquea*. A further step in this process is shown in one of the Dakota leaves figured by Lesquereux[2] under the name *Aralia saportanea* var. *deformata*. Here the central lobe is reduced and cut almost to the base. The lateral lobes are also deeply cut and the margin below the major fork of the petiole is reduced to a very narrow web. A very slight continuation of this lobing would make these segments free or at least cut them to the branches of the petiole. Hence it seems to the writer a less violent assumption to derive the decompound, coriaceous-leaved species of *Dewalquea* from an equally coriaceous deeply lobed *Aralia* of the type above indicated than to suppose them to be the Cretaceous ancestors of the living herbaceous Helleboreae.

Occurrence: Frontier formation, 1 mile east of Cumberland, Wyo., in sec. 29, T. 19 N., T. 116 W. Collected by A. C. Veatch in August, 1905.

Family ARALIACEÆ.

Aralia veatchii Knowlton, n. sp.

Plate XXXVI, figure 4; Plate XXXVII, figure 4; Plate XXXVIII, figure 1; Plate XXXIX.

Aralia cf. *A. saportana* Lesquereux. Knowlton, in Veatch, Am. Jour. Sci., 4th ser., vol. 21, p. 459, 1906.

Outline of whole leaf not known, but clearly a leaf of large size and firm texture; palmately three-lobed and, presumably at least, five-lobed, the central lobes lanceolate, slenderly acuminate at apex, slightly contracted at the base; margin conspicuously toothed, the teeth sharp pointed, separated by shallow sinuses; lateral lobes at an angle of about 45° with the middle lobe and separated from it by a deep narrow sinus, margin entire below, becoming toothed above like the central lobe; nervation of lobes consisting of a very strong midrib and 12 or 14 pairs of fairly strong secondaries which emerge at an angle of 45° or 50°, are nearly straight, and end in the marginal teeth; nervation of lateral lobes similar, but secondaries more curved upward and camptodrome in the lower untoothed portion; finer nervation consisting of numerous strong nervilles, which are irregular and in places broken, and finer quadrangular areas.

The above description is in the main drawn from the specimen shown in Plate XXXVI, figure 4, which is the best one available. It consists of a nearly perfect central lobe and a small portion of one lateral lobe, the two being separated by a deep, narrow sinus. It is impossible to ascertain the size of this leaf when it was perfect, or to determine whether it had more than three lobes. It must have been 17 or 18 centimeters long and presumably 20 centimeters or more broad between the tips of the lateral lobes. From its analogy with a species to which it is presumed to be related, it is thought probably to have been five-lobed, but this is not known.

If I am correct in referring the other specimens here figured (Pl. XXXIX) to *Aralia veatchii*, the whole leaf was much larger than the dimensions given above. Thus, the specimen shown in Plate XXXVIII, figure 1, could hardly have been less than 20 centimeters in length and 7 or 8 centimeters in greatest width. In Plate XXXIX there are portions of three leaves or, more properly, lobes, which, while not now in actual organic connection, are so placed as to lend support to the idea that this was a huge five-lobed leaf. The central lobe, if it is such, was about 20 centimeters long and 7 centimeters wide, and the other was about 16 centimeters long and 6 centimeters wide. Both of these are more elliptical-lanceolate in shape than that shown in figure 1, and the margin is less sharply toothed. The fragment of a leaf given in Plate XXXVII, figure 4, is quite distinctly undulate-toothed. The nervation, however, is practically the same in all the specimens figured under this name, and this is one of the strong reasons for considering them all as conspecific.

There seems to be little or no doubt as to the propriety of referring these leaves to the genus *Aralia* on the basis of their resemblance to leaves from different horizons that have been so regarded. One of the species that is perhaps nearest to the present species, as exemplified in Plate XXXVI, figure 4, is *Aralia saportanea*

[1] Lesquereux, Leo, The flora of the Dakota group: U. S. Geol. Survey Mon. 17, pl. 22, fig. 2, 1891.
[2] Idem, pl. 23, fig 1.

Lesquereux,[1] from the Dakota sandstone of Kansas. The Dakota species is a smaller form and has the lateral lobes at a much more acute angle, the margins less conspicuously toothed, and the secondaries more curved upward, but they may well enough have belonged to the same genus.

Occurrence: Frontier formation, north side of Little Muddy Creek, about 1 mile east of Cumberland, Wyo., in sec. 29, T. 19 N., R. 116 W. Collected by A. C. Veatch in 1905.

Family STAPHYLEACEAE?

Staphylea? fremonti Knowlton, n. sp.

Plate XXXII, figures 4, 5; Plate XXXIII, figure 5.

Leaves trifoliolate, the leaflets petioled, all arising from the same point at the top of the main petiole; leaflets all of about the same size, elliptical-lanceolate, broadest near or just below the middle, whence they are gradually rounded or narrowed to the wedge-shaped base and to an acuminate apex; margin of leaflets perfectly entire; midrib exceedingly strong, straight; secondary nervation obscured by the thick substance of the leaflet; secondaries emerging at a low angle, close, nearly parallel, camptodrome, arching, and apparently joining well below the margin; finer nervation not discernible.

This beautiful species is represented by the two specimens figured, as well as their counterparts and a number of detached leaflets. They have a thick general petiole of unknown length but at least 1 centimeter long. Standing on the top are the petioles of the leaflets, each of which is from 5 to 8 millimeters in length. The petiole of the middle leaflet is uniformly a little shorter than the lateral one. The leaflets are 3.5 to 4 centimeters long and about 12 millimeters wide. The leaflets are very thick in texture and, with the exception of the extremely strong midrib, the secondary nervation has been observed in only one or two leaflets. Here it is seen to be thin, close, nearly parallel, and arching some distance below the margin.

There is some uncertainty as to the propriety of this generic reference. These leaves appear to be close enough to the living *Staphylea trifolia* Lesquereux to warrant their being considered as congeneric with it, though there are some differences. Thus, in the living form the lateral leaflets are sessile and the central one is short-stalked, whereas in the fossil form the central leaflet has a markedly shorter stalk than the lateral ones. The margin in the living leaf is finely, sharply serrate, but in the fossil leaf it is entire. Again, the texture in *S. fremonti* was evidently much thicker than in *S. trifolia*. The shape, size, and nervation are approximately the same in both forms.

It was at first thought possible that the leaves under consideration might be congeneric with *Dewalquea trifoliata* Newberry,[2] from the Raritan formation of New Jersey, especially in view of a statement made by Berry[3] to the effect that "it is remarkable that where this genus has been found in abundance, two species are usually described—one entire and one with toothed margins," the inference being that both forms probably grew on the same plant. This condition can not be true in the present instance, for the leaves under discussion are clearly trifoliolate, while in *Dewalquea* the leaf is merely palmately decompound.

One of the leaflets (Pl. XXXIII, fig. 5) shows a mine made in the leaf substance by an insect larva. (See p. 80.)

Occurrence: Frontier formation, 1 mile east of Cumberland, Wyo. Collected by F. H. Knowlton and T. W. Stanton in 1908.

Unknown systematic position.

Phyllites ficifolia Knowlton, n. sp.

Plate XXXV, figure 3.

The leaf figured is all that was noted of this form. It was evidently a leaf some 15 or 18 centimeters in length and about 6 centimeters in width. It appears to have been elliptical-lanceolate, very gradually narrowed at the base, and presumably acuminate at the apex. The margin is indistinct. There is some evidence to show that there were a few low teeth, but this is not certain. The midrib was relatively strong. The secondaries, of which there were probably about a dozen pairs, were alternate, at an angle of 35° or 40°, remote in the middle of the blade, somewhat curved upward, and presumably camptodrome. None of the finer nervation can be made out.

This is probably a *Ficus*, but in the absence of definite knowledge concerning certain of the essential characters it seems best to leave its allocation to further and better material.

[1] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 8, p. 61, pl. 8, fig. 1, 1883.

[2] Newberry, J. S., The flora of the Amboy clays: U. S. Geol. Survey Mon. 26, p. 129, pl. 22, figs. 4–7, 1895.

[3] Berry, E. W., The Upper Cretaceous and Eocene floras of South Carolina and Georgia: U. S. Geol. Survey Prof. Paper 84, p. 42, 1914.

Occurrence: Frontier formation, 1 mile east of Cumberland, Wyo. Collected by F. H. Knowlton and T. W. Stanton in 1908.

Phyllites dentata Knowlton, n. sp.

Plate XXXIV, figure 8.

The example figured is all that was found of this form. It is a segment apparently from the middle portion of a narrowly lanceolate leaf of membranaceous texture. It was acuminate at the apex, but the base is not known. The margin is provided with numerous low, sharp-pointed teeth. The nervation consists of a rather strong midrib and several pairs of alternate thin secondaries which arise at a low angle and arch and join well inside the margin, sending branches from the outside to the marginal teeth. There are a few intermediate secondaries. The nervilles are numerous, rather strong, and usually broken, forming irregular areas.

This leaf, although a mere fragment, is so entirely distinct from any other form found in these beds that it merits recognition.

Occurrence: Frontier formation, 1 mile east of Cumberland, Wyo. Collected by F. H. Knowlton and T. W. Stanton in 1908.

Phyllites sp.

Plate XXXV, figure 4b.

The basal portion of the leaf here figured seems to represent a very distinct form that can probably be recognized if found in the future. It appears to have been ovate, the base at first abruptly rounded, then projected downward into a wedge-shaped portion. The rather slender, curved petiole is apparently complete. The margin is entire. The nervation consists of a rather slender midrib, a pair of very slender secondaries just above the basal margin of the blade, and a pair of opposite secondaries some distance above the base. These upper secondaries, or perhaps "ribs," have branches on the outside that curve upward along and perhaps end in the margin. These "ribs" do not join with the midrib where they come into contact with it but are distinct and run down along the midrib almost to the base of the leaf. The finer nervation can not be made out with certainty.

Occurrence: Frontier formation, 1½ miles south of Cumberland, Wyo., in the SE. ¼ sec. 6, T. 18 N., R. 116 W. From same horizon as plant beds 1 mile east of Cumberland. Collected by T. W. Stanton September 1, 1913.

FORMS EXCLUDED FROM THIS FLORA.

Genus TRICHOPTERIS.

Trichopteris filamentosa Hall, in Frémont, op. cit., Appendix B, p. 306, pl. 2, fig. 6, 1845.

Trichopteris gracilis Hall, idem, p. 307, pl. 1, fig. 5.

This genus with two species was established by Hall, but clearly the forms are only rootlets of ferns.

Phyllites fremonti Unger.

Phyllites fremonti Unger, Genera et species plantarum fossilium, p. 503, 1850. Leaf of a dicotyledonous plant (?) Hall, in Frémont, op. cit., Appendix B, p. 307, p. 2, fig. 4, 1845.

There is much doubt about the propriety of including this species in the present flora. It was placed by Hall at the end of the description of this flora, with the following remarks:

> Locality in the neighborhood of the specimens containing the preceding fossils and regarded by Capt. Frémont as belonging to the same formation. The rock containing them is a soft or very partially indurated clay, very unlike the hard and brittle mass containing the other species.

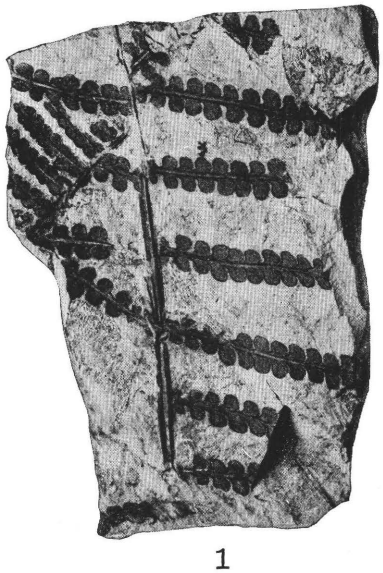
The probability that it did not come from the vicinity of the Cumberland locality is further strengthened by the chance statement "Fr. Aug. 17, and No. 201 of collection," which appears to mean that it was collected on Friday, August 17, whereas the others are recorded under the date of August 19. Frémont's itinerary for the earlier date [1] indicates that on that day the expedition encamped on Blacks Fork of Green River, some 40 miles east of the locality reached on August 19. In the low hills bordering the stream he found "strata containing handsome and very distinct vegetable fossils." This locality is presumably in the Green River formation, and if the above reasoning is correct, it appears to dispose of the reference of this species to the Colorado flora under consideration. The type specimen is now lost, and hence it is impossible to study the matrix in which it was preserved.

This leaf was named and described by Unger as *Phyllites fremonti*, from Hall's figure, and Unger fell into the usual error of ascribing it to Oregon, as the expedition went to "Oregon and north California." The above history has been given at some length for the purpose of setting forth the unsatisfactory status of this species and thus preventing future misunderstanding.

[1] Frémont, J. C., op. cit., p. 130.

PLATES XXVIII–XXXIX.

PLATE XXVIII.



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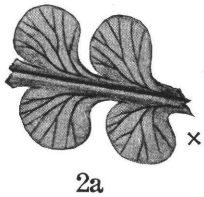

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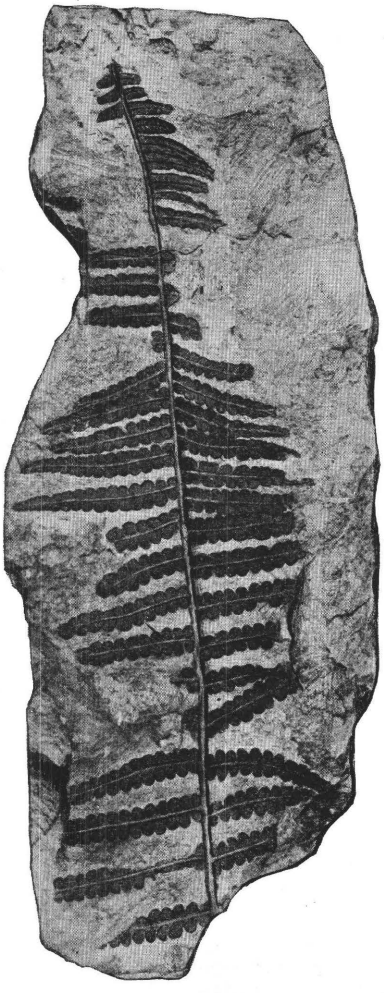

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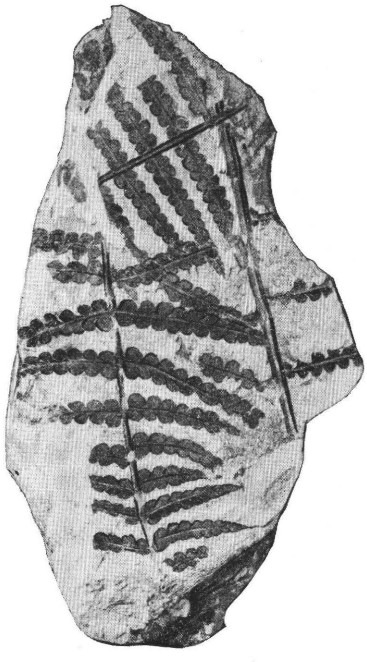

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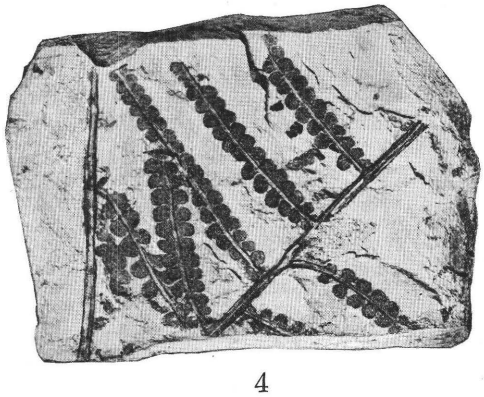

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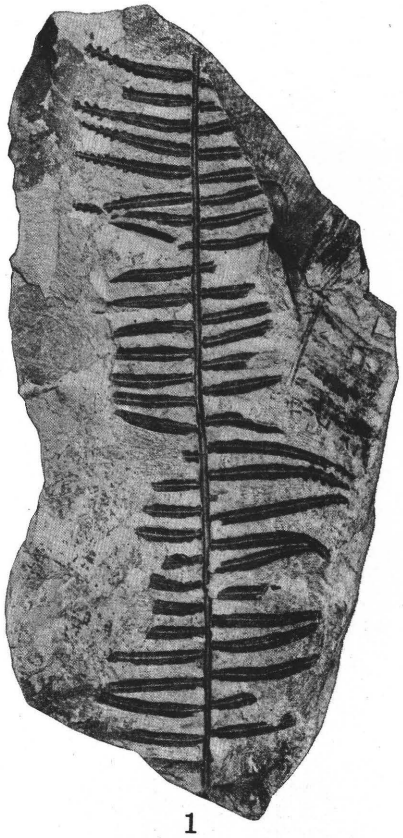
FOSSIL FLORA FROM THE FRONTIER FORMATION.



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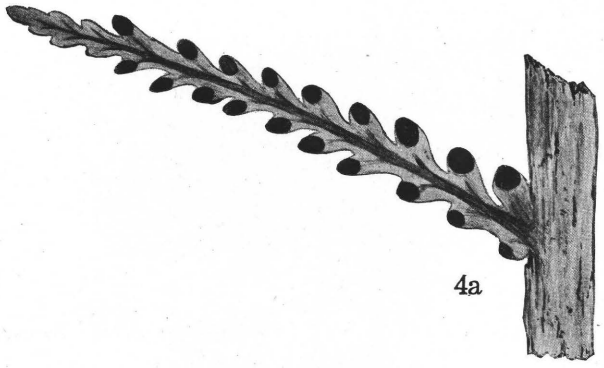

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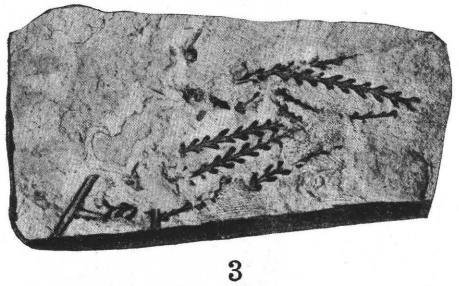

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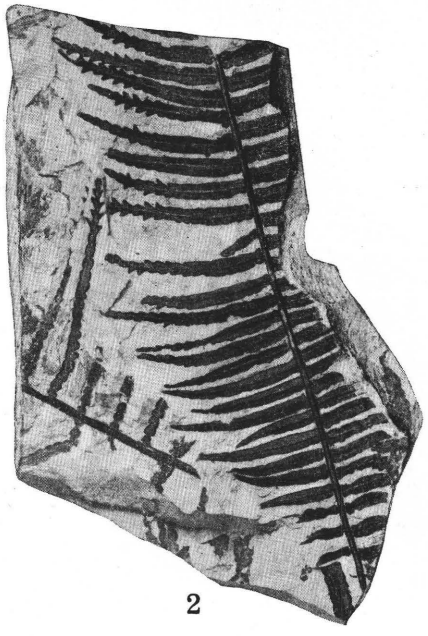

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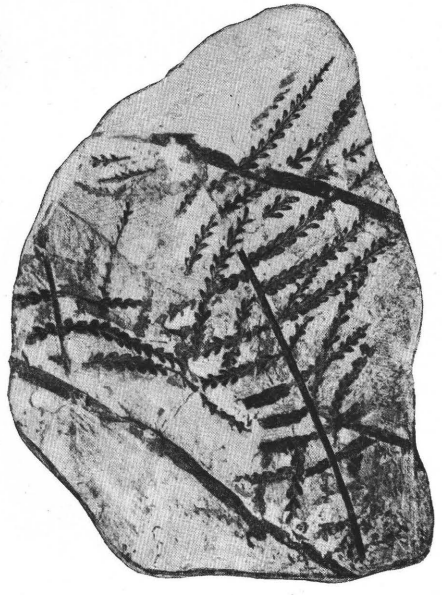

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FOSSIL FLORA FROM THE FRONTIER FORMATION.

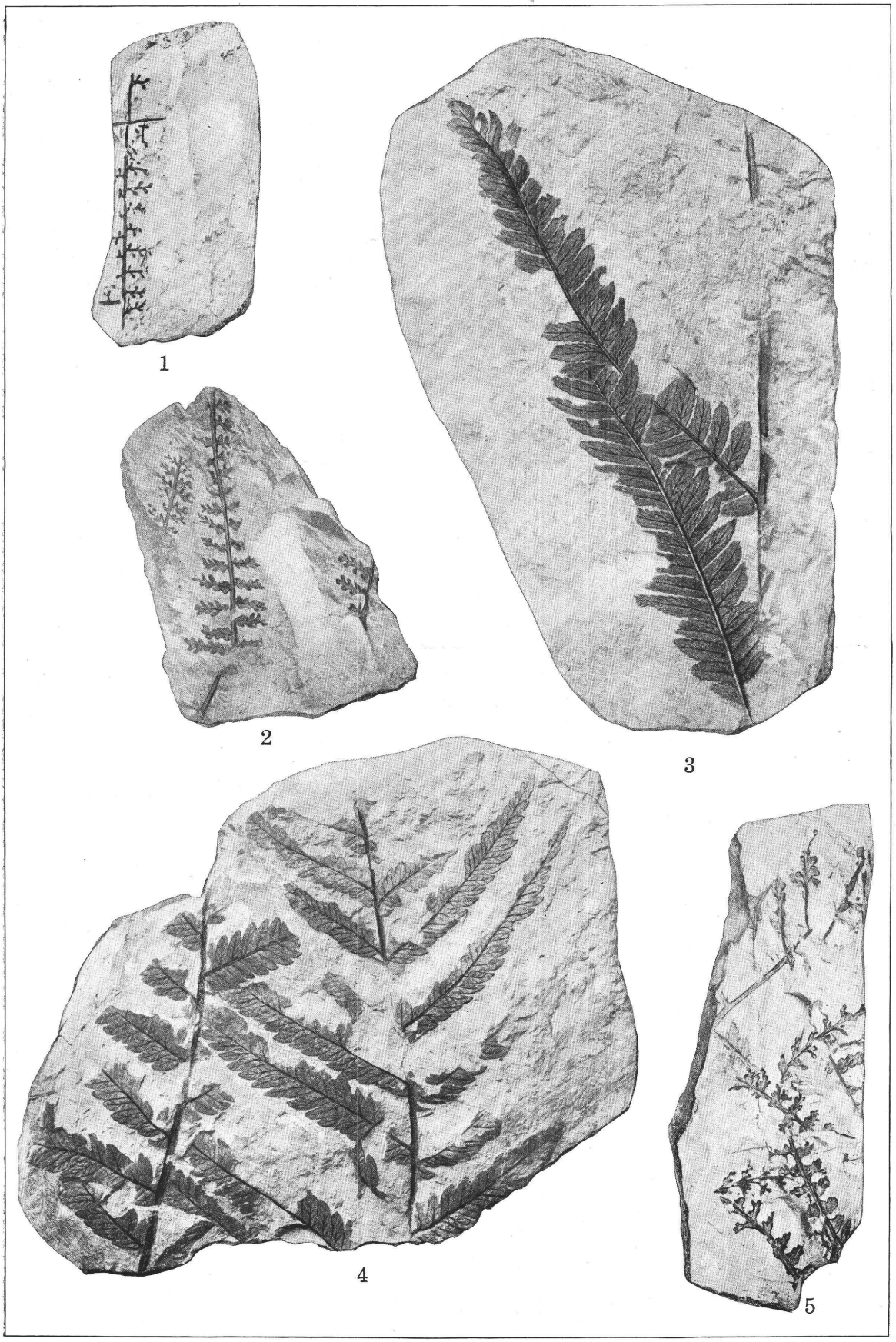
PLATE XXIX.

Page.

FIGURES 1–4. *Microtaenia variabilis* Knowlton, n. sp. 81

4a. Uppermost pinnule in figure 4, enlarged three times to show nervation and sori 81

PLATE XXX.



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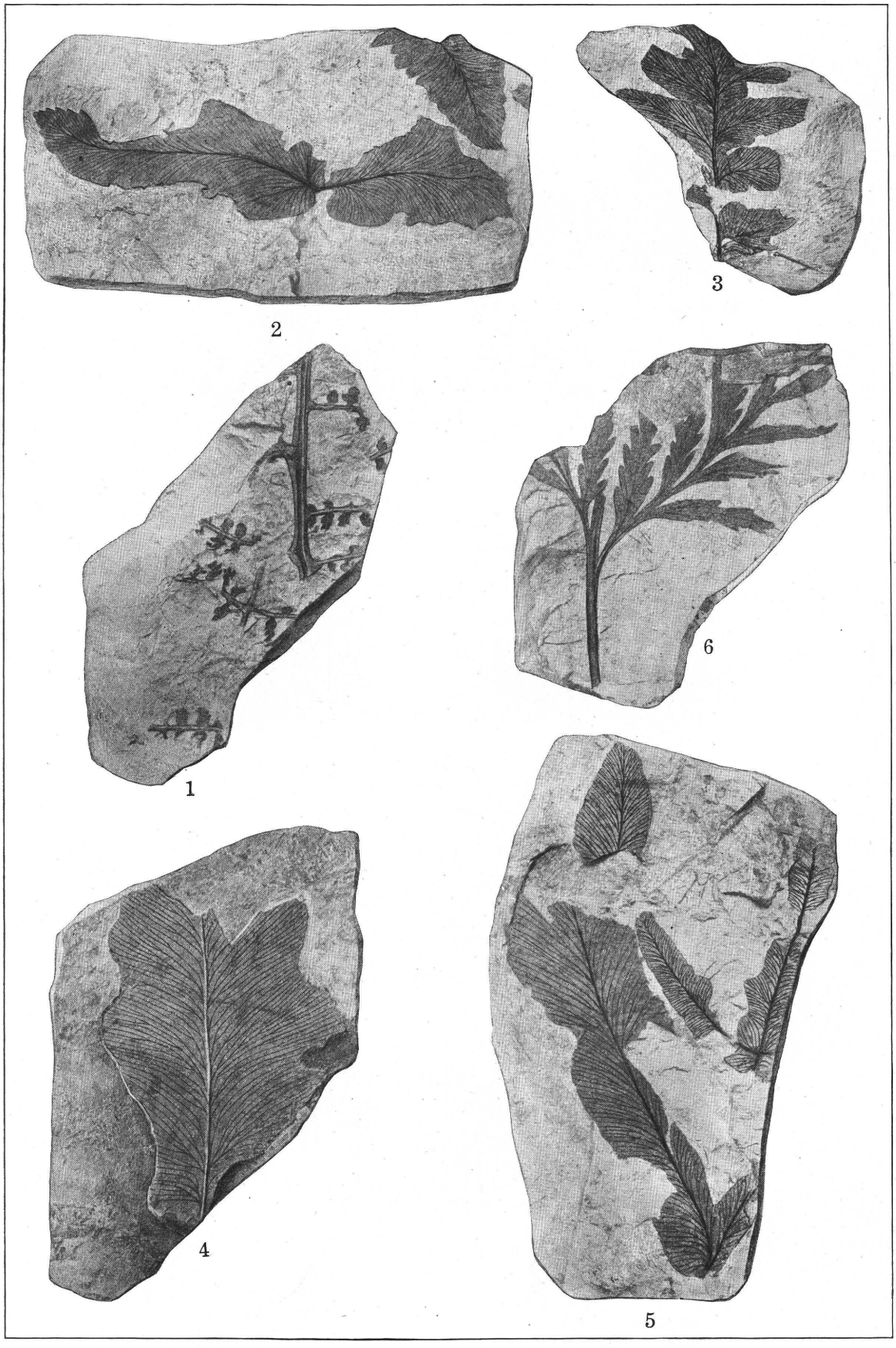


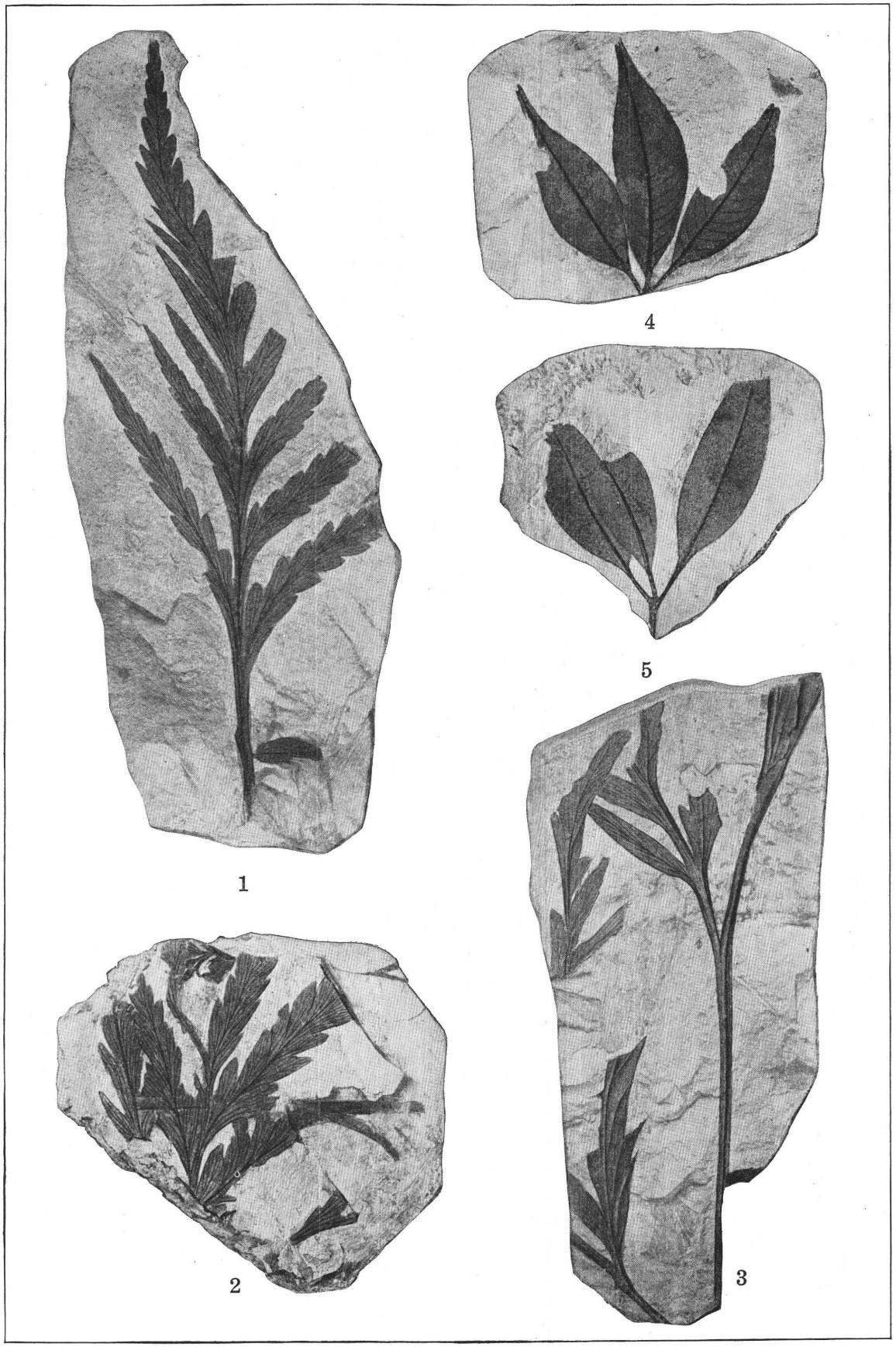
FOSSIL FLORA FROM THE FRONTIER FORMATION.

PLATE XXXI.

PLATE XXXII.

Page.

FIGURES 1–3. *Anemia fremonti* Knowlton, n. sp..... 84
4, 5. *Staphylea? fremonti* Knowlton, n. sp..... 93



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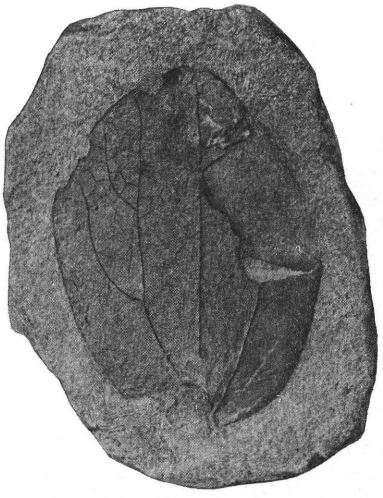

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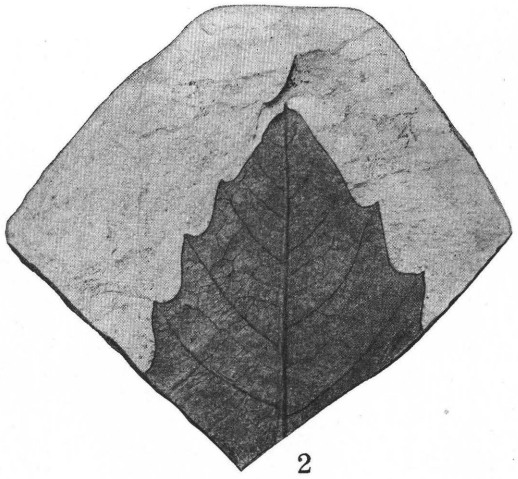

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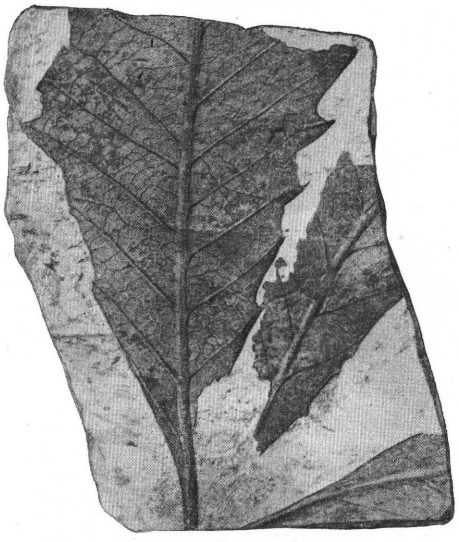

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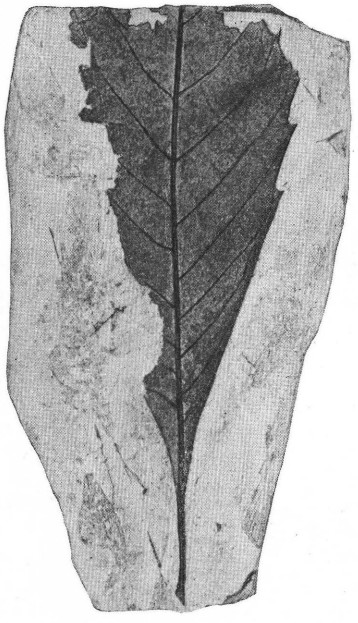

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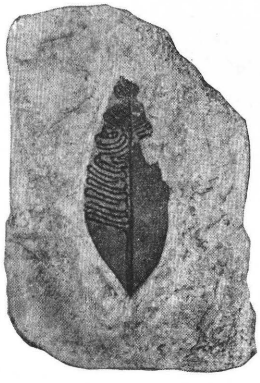

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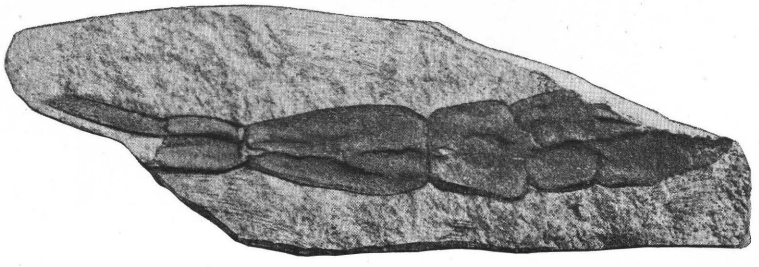

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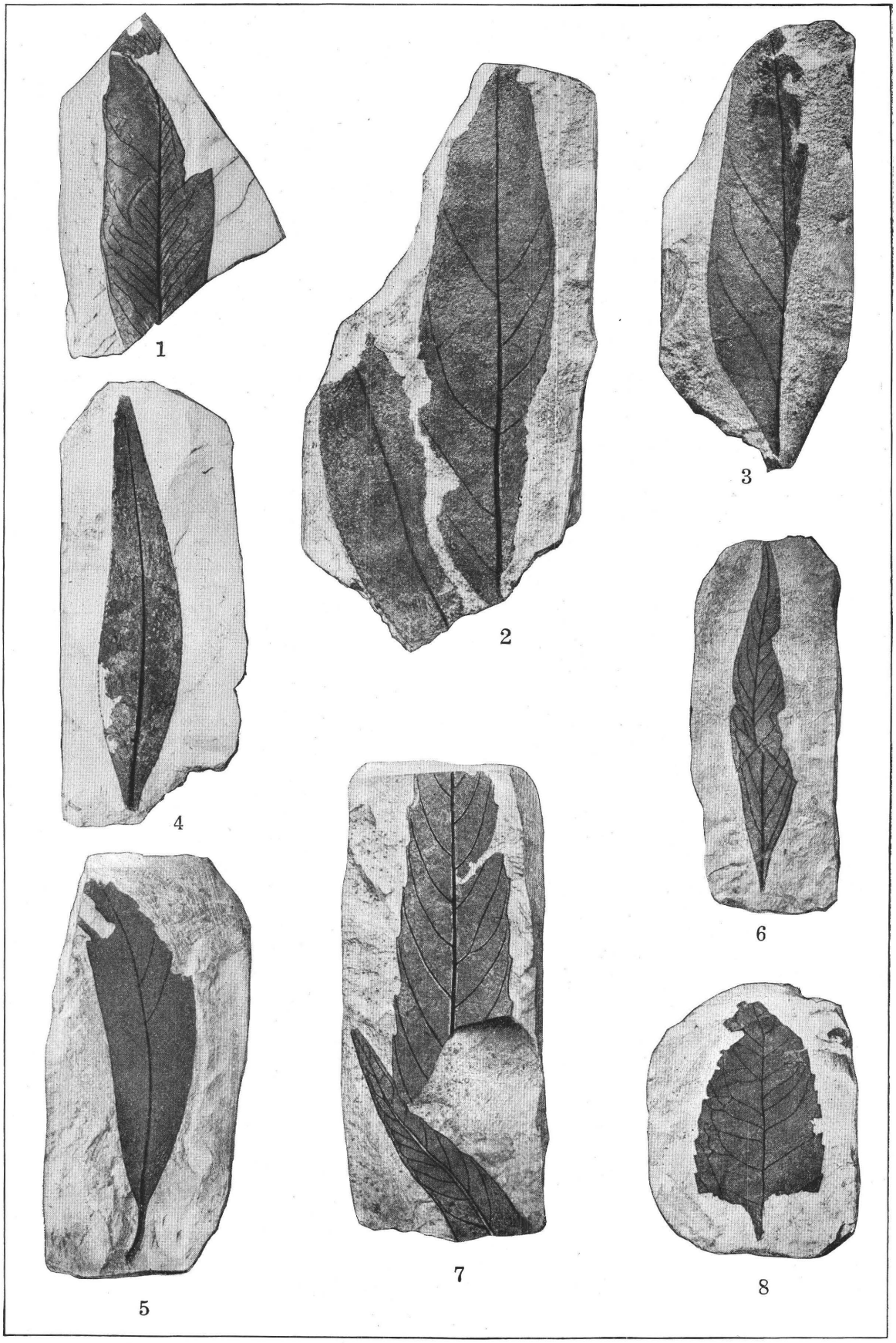
FOSSIL FLORA FROM THE FRONTIER FORMATION.

PLATE XXXIII.

PLATE XXXIV.



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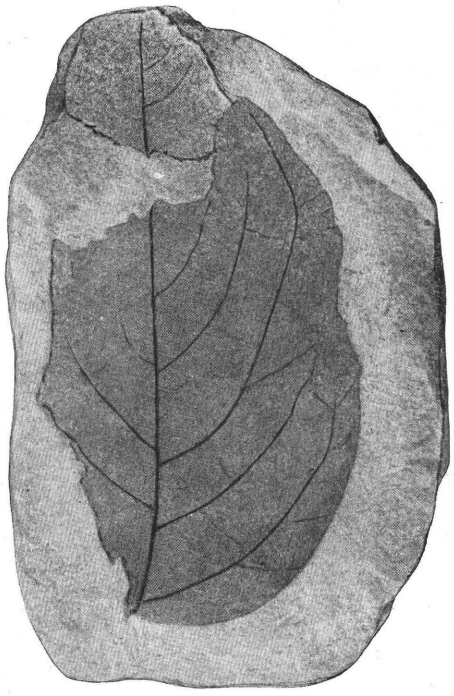

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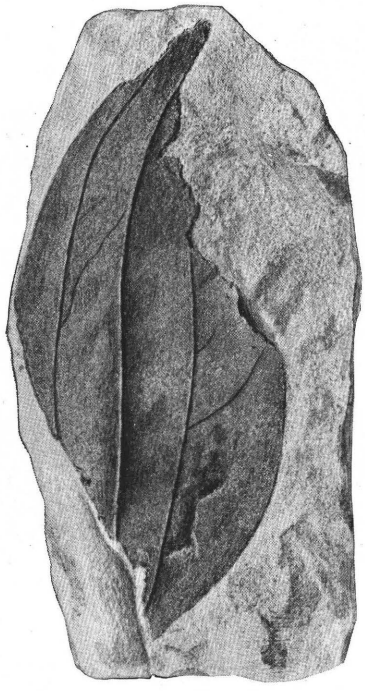

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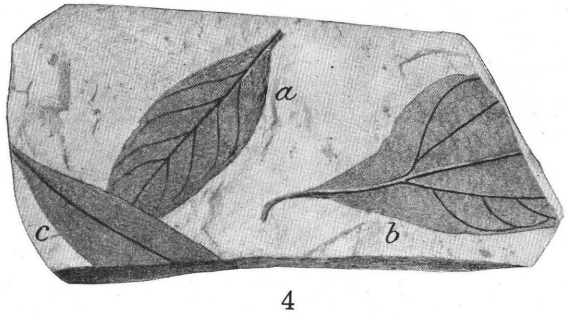

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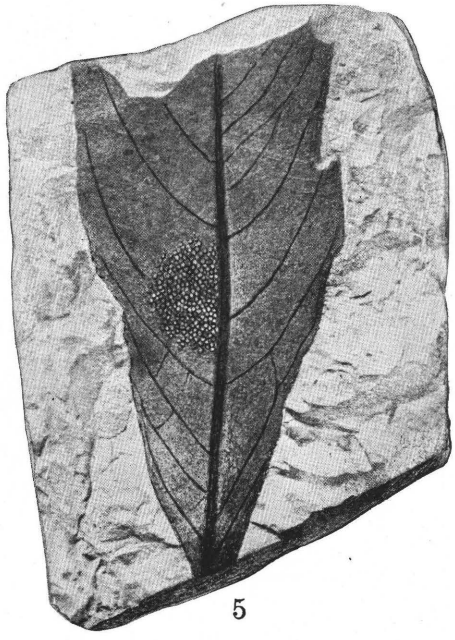

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FOSSIL FLORA FROM THE FRONTIER FORMATION.

PLATE XXXV.

PLATE XXXVI.

Page.

FIGURES 1–3. *Dewalquea pulchella* Knowlton, n. sp..... 90
4. *Aralia veatchii* Knowlton, n. sp..... 92

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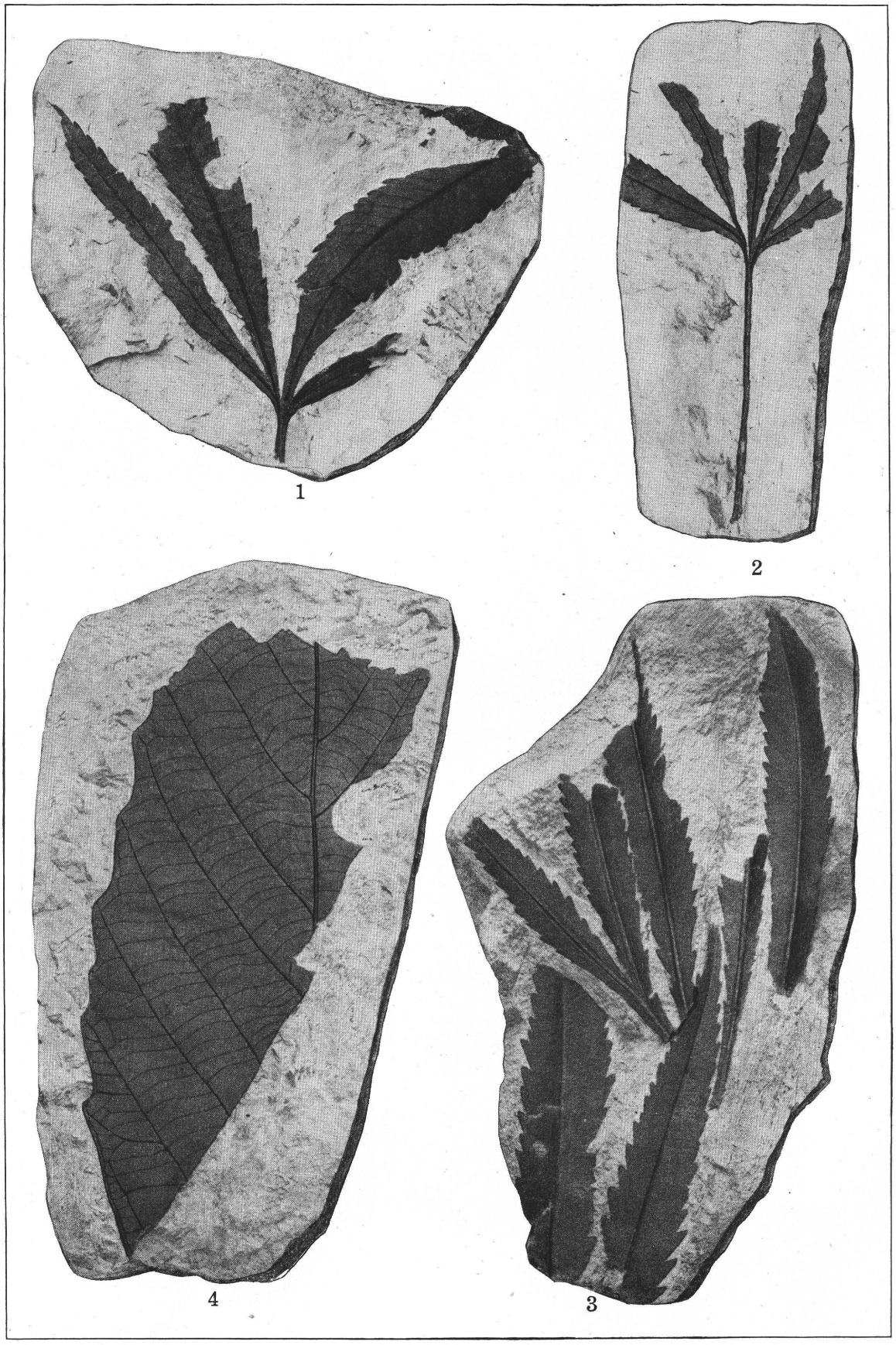
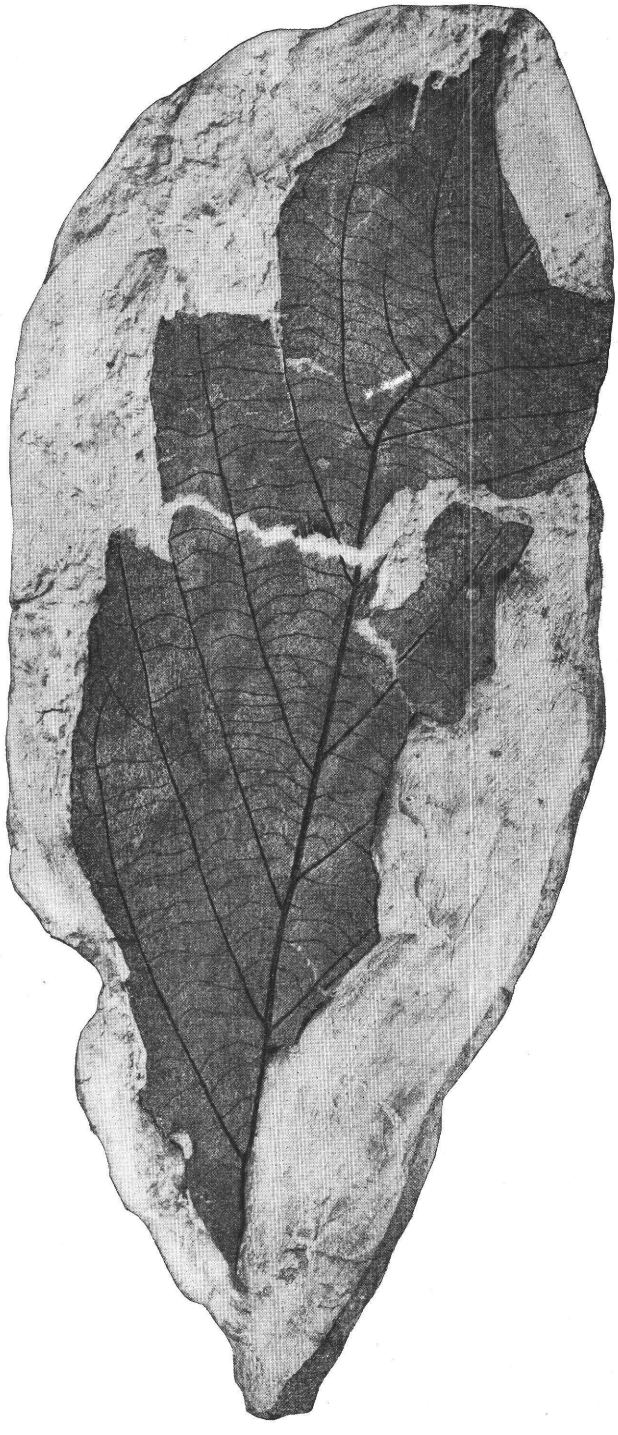
FOSSIL FLORA FROM THE FRONTIER FORMATION.



FOSSIL FLORA FROM THE FRONTIER FORMATION.

PLATE XXXVII.

PLATE XXXVIII.



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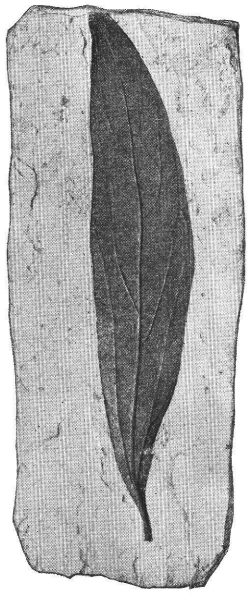

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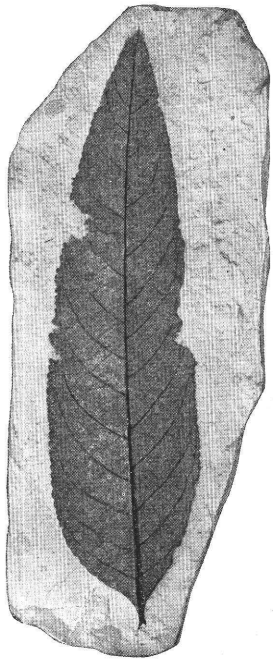

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FOSSIL FLORA FROM THE FRONTIER FORMATION.

FOSSIL FLORA FROM THE FRONTIER FORMATION.

PLATE XXXIX.