REVISION OF THE FLORA OF THE GREEN RIVER FORMATION, WITH DESCRIPTIONS OF NEW SPECIES.

By F. H. KNOWLTON.

THE GREEN RIVER FORMATION.

The Green River shales, later known as the Green River formation, were named and described by F. V. Hayden in 1869.[1] After discussing the coal and lignite beds along the Union Pacific Railroad in western Wyoming, Hayden says:

> A little east of Rock Spring station a new group commences composed of thinly laminated chalky shales, which I have called the Green River shales, because they are best displayed along Green River. They are evidently of purely fresh-water origin and of middle Tertiary age. The layers are nearly horizontal and, as shown in the valley of Green River, present a peculiarly banded appearance. When carefully studied these shales will form one of the most interesting groups in the West. The flora is already very extensive, and the fauna consists of Melanias, Corbulas, and vast quantities of fresh-water fishes. There are also numerous insects and other small undetermined fossils in the asphaltic slates. One of the marked features of this group is the great amount of combustible or petroleum shales, some portions of which burn with great readiness and have been used for fuel in stoves.

The decade that followed the naming and defining of the Green River shales as a formational unit by Hayden was one of increased geologic study in the West, with the result that these beds were recognized and more or less fully described at a number of widely separated points. Thus Peale[2] recognized the Green River group, as he called it, between Grand (now Colorado) and Gunnison rivers in Colorado; Powell[3] noted it along the northern foothills of the Uinta Mountains, distinguishing a "Lower" and "Upper" Green River; Emmons,[4] who was connected with the Fortieth Parallel Survey, described it very fully for the Green River Basin; Peale[5] found it along the Book Cliffs in western Colorado; White[6] studied it in western Colorado and eastern Utah; Endlich[7] described its occurrence along White River in western Colorado and south of the Wind River Mountains in Wyoming;[8] and Peale[9] noted it in the northern and western parts of the Green River Basin.

One of the most complete of the earlier accounts of the Green River formation is that given by Emmons[10] in his description of the Green River Basin. Three Tertiary formations—or "series," as they were then called—were recognized, the oldest of which was the Wasatch formation (nearly the same as the "Vermillion Creek group" of King and the upper part of the "Bitter Creek series" of Powell). Above this, without apparent discordance, was the Green River formation, which in turn was overlain by the Bridger formation.

The Green River beds were described by Emmons as follows:

> The beds of the Green River series contrast with those of the other two groups by the relative prevalence of calcareous material and the fineness of their sediments. They were deposited in quiet, probably deeper waters and perhaps during the time that erosion was wearing away the limestones of the Upper Coal Measures. They consist of a lower series of calcareous sandstones and impure limestones, containing some lignite seams, overlain by a great thickness of remarkably fissile calcareous shales abounding in remains of fish and insects, which reach an aggregate thickness of about 2,000 feet and are characterized throughout by their prevailing white color. The extent of the sea in which these beds were deposited was somewhat less than that of the previous period, a strip of land having been elevated above its level along the flanks of the Wasatch, and probably also a narrower strip along the shores of the Park Range; its beds, however, were deposited continuously over the ridge of Vermillion Creek Wasatch beds, between the Bitter Creek

[1] U. S. Geol. Survey Terr. Third Ann. Rept. (reprint, 1873), p. 190.
[2] Peale, A. C., U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1874, pp. 147, 156–158, 1876.
[3] Powell, J. W., Geology of the Uinta Mountains, pp. 40, 45, 166, 167, 1876.
[4] Emmons, S. F., U. S. Expl. 40th Par. Rept., vol. 2, pp. 203, 240, 1877.
[5] Peale, A. C., U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1876, p. 184, 1878.
[6] White, C. A., idem, pp. 19–35.
[7] Endlich, F. M., idem, p. 111.
[8] Idem for 1877, p. 130, 1879.
[9] Peale, A. C., idem, p. 525.
[10] Emmons, S. F., U. S. Expl. 40th Par. Rept., vol. 2, pp. 203, 240, etc., 1877.

Cretaceous uplift and the Archean body of Red Creek, and also connected, through the low gap of the White River divide, at the eastern end of the Uinta Range, with the region to the south, in which beds corresponding to these and to the Bridger beds have been recognized, although their direct connection has not yet been traced.

It is not within the scope of the present paper to give a complete review of the literature relating to the Green River formation, but simply enough to show its areal distribution and physical characteristics that may serve as a setting for the discussion of its flora and fauna. From data obtained within the first dozen years after it was formally recognized by Hayden and abundantly confirmed by subsequent investigators, the Green River formation is known to extend from the headwater region of Green River in the Wind River Mountains, Wyo., southward to Grand Mesa, between Colorado and Gunnison rivers, Colo., a distance of approximately 300 miles. The western limit of the formation is rather sharply defined, for it abuts on the eastern foothills of the Wasatch Mountains. The eastern limits, however, are less sharp. Emmons expressed the opinion that the formation originally extended to the western slopes of the Park Range, but the evidence for this opinion is not conclusive. The Green River formation was not recognized by E. E. Smith[11] in his study of the eastern part of the Great Divide coal field, though the Wasatch formation, with thicknesses ranging between 900 and 1,800 feet, is present there, nor was it definitely identified by M. W. Ball[12] in his study of the western part of the Little Snake River coal field, though it may be represented in some undifferentiated beds above the Wasatch formation. The Green River formation is said by A. R. Schultz[13] to extend over the north end of the Rock Springs uplift and out into the Red Desert to a point about 20 miles southeast of the Antelope Hills. It is also present at the south end of the Rock Springs uplift, along the divide between Sage and Red creeks. It thus appears that in all probability these beds once covered a large part of the Great Divide Basin and the Red Desert but were later removed by erosion. In any event, it seems fairly well established that the maximum width of the area once covered in whole or in part by the Green River formation was little if any less than 150 miles.

As already mentioned, Powell divided the Green River formation into a "Lower Green River" and an "Upper Green River." The latest report in which these beds are discussed is that by A. R. Schultz[14] on the area around the Rock Springs uplift, in Sweetwater County, Wyo. Schultz recognizes four members of the Green River formation, which in ascending order are as follows: (1) Tipton shale member, consisting of fissile shale, conglomerate, oolitic limestone, shale, clay, and sandstone; (2) Cathedral Bluffs red-beds member, composed of red or varicolored conglomeratic sandstone, shale, and clay; (3) Laney shale member, made up of white and green fissile shale, limestone, and sandstone, "similar to those so characteristic of the lower member or Tipton shale of the Green River in this part of the field and to the entire Green River formation in other parts of the Green River Basin;" (4) "Tower sandstone" and plant beds of Powell, which consist of massive, regularly bedded sandstone, sandy limestone, and shale.

Just how far these proposed subdivisions of the Green River formation can be recognized in other parts of the vast area over which it extends is not now known, though some subdivision is undoubtedly possible. The earliest known and most thoroughly exploited of the plant-bearing beds are along the Union Pacific Railroad 2 or 3 miles west of the town of Green River, where, according to Hayden, Ward, and others, they occur about 100 feet above the fish beds. This places their position some hundreds of feet below the "Tower sandstone" that is so well exposed at the town of Green River. Powell and others who have followed him seem to be in error in speaking of the plant beds as overlying the "Tower sandstone."

It seems rather remarkable, in view of the thickness and areal extent of the Green River formation, that it has been found to be fossiliferous at so few localities. Endlich remarked on this peculiarity many years ago, pointing out that it was possible to follow these beds for miles without finding a trace of animal or plant life. There is such an area north of Rock Springs, Wyo., where beds hundreds of feet in thickness are seemingly well fitted to preserve any forms of life that may have been

[11] U. S. Geol. Survey Bull. 341, p. 220, 1909.
[12] Idem, p. 243.
[13] U. S. Geol. Survey Bull. 702. p. 24, 1920.
[14] Idem, pp. 24–31.

present in the region, and yet so far as known they are absolutely barren of fossils. The suggestion that these beds may have been deposited in deep water far from shore does not fully explain their barrenness, for even if they were it would seem that they should contain a few specimens.

So far as now known the first fossil form from the Green River formation to be brought to scientific attention was a small herring-like fish described by Joseph Leidy[15] in 1856, under the name *Clupea humilis*, later changed to *Diplomystus humilis*. It was collected by Dr. John Evans, who visited the Rocky Mountain region in 1849 and 1856, from the so-called fish beds near the town of Green River and was the forerunner of thousands of wonderfully preserved fish remains that have since been found.

As already stated, Hayden named the Green River formation in 1869, and at that time he mentioned the presence of "an extensive flora," but it is not a matter of record that he brought actual specimens to Washington. However, Hayden again visited the plant and fish beds near Green River during the summer of 1870, writing as follows:[16]

> About a mile west of the "petrified fish bed" is a cut along the railroad which passes through a moderate thickness of buff chalky limestones, filled with impressions of leaves of deciduous plants.

These plants were submitted to J. S. Newberry, and his preliminary report in the form of a letter was published by Hayden in the report cited. The collection comprised only about half a dozen forms sufficiently well preserved to be capable of identification, and of these he wrote as follows:

> Among them I find two palms, both quite unlike anything before found on this continent. One is a new *Phoenicites*, resembling Heer's *Manicaria formosa;* the other but an imperfect fragment, yet altogether new and strange to me. The most abundant species contained in the collection is a *Magnolia*, allied to *M. tenuinervis* Lesquereux but more elongate and acute; also an oak resembling *Quercus saffordi* of Lesquereux. There is another oak in the collection, a laurel (probably), and fragments of two ferns, too imperfect for determination.

This account of the Green River flora, although relatively unimportant, is so far as known the first one published.

On his way back from the field in 1870 Hayden passed over the old overland stage route, which follows Bitter Creek nearly to its head, crosses the Red Desert, and thence goes through Bridger Pass to the Laramie Plains.

THE OIL SHALE AND ITS MICROSCOPIC FLORA AND THE BEARING OF THE FLORA ON THE ORIGIN OF THE SHALE OIL.

The intensive search for sources of petroleum that is now being prosecuted in many parts of the world has naturally directed renewed attention to the oil shales of the Green River formation, which are known to occur over vast areas in Wyoming, Colorado, and Utah. According to Winchester,[17]

> Approximately 5,500 square miles in northwestern Colorado and northeastern Utah are underlain by beds of oil shale thick enough to mine and apparently rich enough to warrant the development of an industry for the manufacture of shale oil and other products.

Concerning the origin of the shale oil Winchester[18] wrote as follows:

> The Green River formation or that part of it including the oil shales consists of remarkably persistent and thinly bedded shales with some sandstone and at places oolite and limestone. The beds were laid down in fresh water which had an enormous expanse and was deep enough so that wave action had little effect on the sediments. The shale is in most places free from grit and contains an immense amount of vegetable matter; the richer beds show by far the greater amount of such material. Singularly enough, such low plant forms as the blue-green algae are represented in great abundance and in a state of almost perfect preservation. Pollen grains are present which came from coniferous trees which grew on land perhaps at considerable distances from the great inland lake in which the shale was deposited. There is also a vast amount of organic material which is too macerated for identification. Complete insects and excellently preserved dipterous larvae as well as fish scales and even perfect fish skeletons have been found, but in most hand specimens of the shale there is little evidence of other plant life.

The microscopic life, especially plant life, of the Green River oil shale, and its probable bearing on the origin of the oil, were under critical study by the late C. A. Davis, of the U. S. Bureau of Mines, and many valuable data have been accumulated, but his death in 1915 brought the study to a close before much had been recorded. A great number of thin sections and other especially prepared material had been brought together, and a few months more of study would have placed the subject

[15] Philadelphia Acad. Nat. Sci. Proc., vol. 8, p. 256, 1856.
[16] Hayden, F. V., U. S. Geol. Survey Wyoming Prelim. Rept., p. 143, 1871.
[17] Winchester, D. E., Oil shale in the United States: Econ. Geology, vol. 13, p. 508, 1917.
[18] Idem, p. 510.

on a firm basis. As it is, the only recorded facts resulting from this study are in the form of the following notes prepared by Davis for Winchester's paper:

Flora of the oil shale of the Green River formation.

(*a*) Bacteria, *Crenothrix*, and similar low filamentous types.
(*b*) Myophyceae: Blue-green algae.
(*c*) Algae: (1) Protococcaceae: *Protococcus*, *Pediastrum*.
(2) Conjugatae: *Spirogyra*.
(*d*) Fungi: Saprophytic molds, etc.
(*e*) Mosses: Spores probably from these plants.
(*f*) Pteridophyta: Ferns; annuli from fern sporangia.
(*g*) Spermatophyta:
(1) Gymnospermae: Pinaceae; pollen of *Picea* and *Pinus*.
(2) Angiospermae: Pollen and fragments of cells, tissues, etc. Bark cells and residues, small pieces poorly preserved. In addition there are abundant and well-preserved remains which are of good size and of frequent occurrence, which seem to be structureless so far as cellular structures are concerned. However, they have definite and pretty regular forms and, in *Dictyonophora*, definite areas which carry well-marked and characteristic patterns which seem like cells but which show no cell walls. These anomalous forms seem to have been the most abundant organisms in the waters in which the shales were laid down and are evidently vegetables of a low order of development. They are manifestly in place as they grew, since they do not show in pressed down masses but were buried in natural positions, very slowly.

The bearing of this microscopic flora on the origin of the shale oil is further discussed by Davis in notes quoted by Winchester but need not be mentioned here further than to state that the evidence seems to indicate that the oil was produced in place and not by migration from some other source.

GREEN RIVER LAKE.

The Green River lake was a very considerable body of water, as its length from north to south was approximately 300 miles and its width more than 150 miles. It is not known that this maximum extent was reached at any one time, but at some time during its existence its waters spread in one direction or another to these wide-flung limits. It was bordered on the north and west by what are now lofty mountain ranges, though they were then of far less elevation. Its containing barriers on the east and south are less easily recognizable but were apparently certain low-lying Cretaceous and perhaps earlier rocks that were then emergent. It may have extended as far as the western foothills of the Park Range, but this is somewhat uncertain. The lake was almost bisected by what are now the Uinta Mountains, but it is clear that there was a waterway around the east end of the Uinta Range through Brown's Park. Clarence King's conception of the physical conditions that existed in and adjacent to the Green River Basin during early Eocene time was set forth in the volume devoted to the general geology of the region traversed by the Fortieth Parallel Survey under his direction. Among the subjects discussed are the supposed Tertiary lakes in that region.[19] King pointed out that at the end of Cretaceous time "the relative upheaval of the whole Rocky Mountain chain and the west shore of the Cretaceous sea, including the system of the Wahsatch and its northerly extension, resulted in walling in the system of the Colorado River, which then for the first time became an area from which the sea was quite excluded."

The Wasatch and Rocky mountains converge toward the north and join near the present headwaters of Green River, but toward the south they diverge more and more until in southern Colorado and New Mexico they are 500 miles or more apart. It was within the area inclosed by these mountain systems, but more especially in the northern part, largely in what is now the Green River Basin, that King located his succession of Tertiary lakes. The earliest of these lakes, according to his conception, was a great body of fresh water that extended 150 miles north of the 40th parallel and, from some evidence, for 200 miles to the south and was perhaps 150 miles wide. For this lake he proposed the name Ute Lake. According to King it was in the waters of this lake that the great body of sediments were deposited that later constituted the Wasatch formation.

Subsequent study has more or less discredited King's conclusion as to the lacustrine origin of the Wasatch rocks, many observers regarding them as more probably flood-plain deposits. Be this as it may, at the end of Wasatch time there was a subsidence that

[19] King, Clarence, U. S. Geol. Expl. 40th Par. Rept., vol. 1, pp. 444–448, 1878.

permitted a wider overflow of impounded waters. It was in this body of water, named Gosiute Lake by King, that the sediments of the Green River formation were laid down. Whatever may be the origin of the Wasatch sediments, all are apparently agreed that the Green River shales are of lacustrine origin. King says:

> As developed at characteristic localities in the neighborhood of Green River, this group embraces about 2,000 feet of conformable fine-grained rocks, giving general evidence of accumulation in still, rather deep water. The lower 1,200 feet are made up of finely fissile shales and calcareous clays, with some quite fine limestones. Many of the upper shales are strongly bituminous.

The position of the outlet of Green River lake is not known, though it was doubtless somewhere to the south or southwest. It seems not unlikely that it followed approximately the present Colorado River drainage system, as its surplus waters undoubtedly found their way into the Pacific Ocean.

If the deductions to be drawn from the fish fauna have been correctly interpreted the lake was at a comparatively slight elevation above sea level. Data regarding this fauna furnished by Dr. O. P. Hay, of the United States National Museum, show that about 35 fairly well authenticated species of fish are known from the Green River shales. Three families, represented in this fauna by four genera and eight species, have pronounced marine affiliations. Thus the Clupeidae, which include the very large group of herrings, are represented by three genera and six species. The herrings to-day are mainly confined to the ocean, though some ascend rivers to spawn, and a few live in rivers. The sting rays, represented by a fine, clearly defined species (*Heliobatis radians*) in the Green River, are mainly marine, though a few forms live in rivers. A third family is also represented by a single species, the living representatives of which are found in estuaries and rivers of Australia.

From these facts it seems certain that the sea was not far away from the Green River lake or at least was readily accessible. Cope,[20] who described most of the Green River fishes, says:

> True herring, or those with teeth, are chiefly marine, but they run into fresh-water rivers and deposit their spawn in the spring of the year and then return to salt water. The young run down to the sea in autumn and remain there until old enough to spawn. The size of the fry of the Rocky Mountain herring indicates that they had not long left the spawning ground, while the abundance of adults suggests that they were not far from salt water, their native element. To believe, then, that the locality from which these specimens were taken was neither far from fresh nor far from salt waters is reasonable.

Osborn in discussing the Green River fishes in his "Age of mammals," says in part:

> A large part of the teliosts are related to fishes at present confined to the Eastern Hemisphere. Thus the diplomystids ("rough-backed herrings") survive only in certain rivers and along portions of the coasts of Chile and eastern Australia.

The distance from the Green River lake to the ocean can only be approximated, though it must have been some hundreds of miles. This distance, however, would not have been a serious obstacle to the passsage of fish from one to the other, provided, of course, there were no insurmountable falls or other obstructions in the stream. Salmon are known to ascend to the upper waters of the Yukon to spawn, a distance of 2,250 miles.

About a dozen species of land and fresh-water invertebrates (*Helix, Physa, Viviparus, Pupa, Unio*, and others) have been found in the Green River shales, but they throw little light on the ecologic conditions that prevailed at that time.

FOSSIL LOCALITIES AND LISTS OF SPECIES.

Locality unknown.—Under the heading "hard, shaly, fine-grained whitish sandstone," Lesquereux[21] enumerated the species listed below and continued:

> About the same consistence and color as the specimens from Carbon station. The precise locality is unknown, the labels having been lost or forgotten.

However, in Lesquereux's "Tertiary flora"[22] all these species are referred without question to the Green River formation.

Cyperus chavannesi Heer.
Populus arctica Heer.
Ficus multinervis Heer.
Ficus lanceolata Heer.
Ficus arenacea n. sp.
Ficus gaudini n. sp.
Platanus sp.
Cinnamomum sp.

These species of *Ficus* have been subsequently identified only in older rocks, such as

[20] Cope, E. D., U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1870, p. 431, 1871.

[21] Lesquereux, Leo, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, pp. 300, 301, 1872.

[22] U. S. Geol. Survey Terr. Rept., vol. 7, pp. 194, 195, 1878.

the Mesaverde and "Laramie." There is absolutely no warrant for calling them Green River, and they are consequently dropped from this flora.

Alkali stage station, Wyo.—In 1874 Lesquereux[23] described the following species from Alkali stage station, on the Sweetwater road, about 30 miles north of Green River station on the Union Pacific Railroad:

Alnites unequilateralis n. sp.
Juglans alkalina n. sp.
Carpites viburni n. sp.

Lesquereux was uncertain as to the age of these species but finally concluded that they were probably of the same age as the plant beds at Black Buttes, Wyo. Although the locality has not been revisited it has usually been classed as of Green River age.

Mouth of White River and west of Green River station, Wyo.—In 1874, under the caption "New species of Tertiary fossil plants briefly described," Lesquereux[24] enumerated the following Green River species:

1. Lygodium dentoni n. sp.
2. Myrica ludwigii Schimper.
3. Quercus haidingeri Ettingshausen.
4. Ficus wyomingiana n. sp.
5. Cissus parrottiaefolia n. sp.
6. Phaseolites juglandinus? Heer.
7. Leguminosites alternans n. sp.
8. Sapindus dentoni n. sp.
9. Lomatia microphylla n. sp.

Nos. 1, 2, 6, 7, 8, and 9 were collected by William Denton at the mouth of White River, which empties into Green River. Nos. 3, 4, and 5 were found west of Green River station.

Green River station, Wyo.—In 1872 Lesquereux[25] published a paper entitled "An enumeration with descriptions of some Tertiary fossil plants from specimens procured in the explorations of Dr. F. V. Hayden, in 1870." Under the caption "Green River, above the fish beds," he enumerated the following forms:

Hemitelites torelli Heer?
Arundo göpperti Münster.
Phragmites oeningensis Al. Braun.
Juncus sp.
Salix angusta Al. Braun.
Salix media Al. Braun.
Salix sp.
Myrica nigricans n. sp.
Myrica salicina Unger.
Quercus lonchitis Unger.
Ficus populina Heer.
Ficus ungeri n. sp.
Cinnamomum scheuchzeri Heer.
Eucalyptus americanus n. sp.
Ampelopsis tertiaria n. sp.
Ilex affinis n. sp.
Ilex stenophylla Unger. [Excluded.]
Ceanothus cinnamomoides Lesquereux.
Rhus acuminata n. sp.
Juglans schimperi n. sp.
Juglans acuminata Heer?
Juglans denticulata Heer?

In the same year, under the caption "Green River group, high on hills from river," Lesquereux enumerated the following species:

Ceanothus cinnamomoides Lesquereux.
Carya heerii Ettingshausen.

In the "Tertiary flora" (p. 277) Lesquereux states that *Ceanothus* (or *Zizyphus*) *cinnamomoides* came from "Green River station, Wyo., above the fish beds with *Ampelopsis tertiaria*." It was collected by F. V. Hayden and is preserved in the United States National Museum (No. 431).

Bridger Pass (?) and Washakie station, Wyo.—In the "Tertiary flora" Lesquereux enumerates three species as having come from Bridger Pass, Wyo., as follows:

Laurus utahensis Lesquereux (p. 216).
Aralia? gracilis (Lesquereux) Lesquereux (p. 236).
Rhamnus intermedius Lesquereux (p. 282).

On referring to the place of original description it appears that *Aralia? gracilis* (or *Liquidambar gracile*, as it was first called) and *Rhamnus intermedius* are recorded by Lesquereux[26] as having come from "Washakie station, near Bridger Pass." *Laurus utahensis* was described as new in the "Tertiary flora" and was said to have come from Bridger Pass, "in connection with *Araliopsis* [error for *Aralia*] *gracilis* and *Populus arctica*." Both these species are found at Washakie station, and with little doubt the species of *Laurus* was also found there.

From this evidence it seems reasonably certain that the three species above mentioned did not come from Bridger Pass, but from Washakie station, which is about 12 miles west of Bridger Pass. The improbability of their hav-

[23] Lesquereux, Leo, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1874, pp. 307, 308, 1876.

[24] Idem, pp. 308-315; also U. S. Geol. and Geog. Survey Terr. Bull., 2d ser., No. 5, pp. 382-389, Jan. 8, 1876.

[25] U. S. Geol. Survey Terr. Fifth Ann. Rept., for 1871, Suppl., pp. 5-9, 22, 1872.

[26] Lesquereux, Leo, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, p. 286, 1872.

ing come from Bridger Pass is further emphasized by the fact that, according to Ball,[27] the rocks in the pass are referred to the Mesaverde. On the other hand, Washakie station is in an area in Ball's "upper coal group," which includes "Upper Laramie," Fort Union, and basal Wasatch. As there is no indication by Lesquereux, or by Hayden, who collected these plants, as to where they came in the local section, it is absolutely impossible to place them until they are again collected from beds of known position. To refer them to the Green River formation is not warranted, and, at least for the present, they are excluded from this flora.

Green River, Wyo. (plants described by J. S. Newberry).—In 1883 Newberry[28] named and gave preliminary descriptions of the following species:

Acrostichum hesperium.
Pecopteris (Phegopteris) sepulta.
Sabal powellii.
Manicaria haydenii.
Quercus castanoides.
Juglans dentata.
Juglans occidentalis.
Planera variabilis.
Planera nervosa.
Zizyphus longifolia.
Aralia macrophylla.

In 1898 Newberry[29] described and figured the plants enumerated in the preceding paper under the following names:

Lygodium kaulfussii.
Acrostichum hesperium.
Pecopteris (Cheilanthes) sepulta.
Equisetum wyomingense.
Sabal powellii.
Manicaria haydenii.
Juglans occidentalis.
Salix angusta?
Quercus castanoides.
Planera nervosa.
Planera variabilis.
Zizyphus longifolia.
Aralia macrophylla.
Nordenskioldia borealis.

Colorado localities (collections of D. E. Winchester).—The collections of D. E. Winchester include the species listed below.

Yellow sandstone of "Upper Green River," on Greasewood Creek, 40 miles west of Meeker, Rio Blanco County, Colo. (Winchester 7379):

Aralia wyomingensis Knowlton and Cockerell.

Green River oil shale, Cathedral Bluff, Little Tommies Draw, 20 miles west of Rio Blanco post office, Rio Blanco County, Colo. (Winchester 7399):

Caenomyces eucalpytae n. sp.
Myrica sp.
Pimelea spatulata n. sp.
Sedum? hesperium n. sp.
Eucalyptus? americanus Lesquereux.
Carpites inquirenda n. sp.

Green River oil shale, Greasewood Creek, 40 miles southwest of Meeker, Rio Blanco County, Colo. (Winchester 7381):

Caenomyces sp.
Danaea coloradensis n. sp.
Pontederites hesperia n. sp.
Salix sp.
Myrica minuta n. sp.
Myrica praedrymeja n. sp.
Comptonia? anomala n. sp.
Oreodaphne viridiflumensis n. sp.
Sapindus winchesteri n. sp.
Rhus n. sp.
Zizyphus longifolia Newberry.
Sambucus? winchesteri n. sp.
Carpolithes caryophylloides n. sp.

Green River oil shale, Little Duck Creek, 50 miles southwest of Meeker, Rio Blanco County, Colo. (Winchester 7381a):

Dalbergia retusa n. sp.
Sophora coloradensis n. sp.
Mimosites coloradensis n. sp.

Green River oil shale, Cathedral Bluff, 20 miles west of Rio Blanco post office, Rio Blanco County, Colo., in sec. 33, T. 4 S., R. 100 W. (Winchester 7382):

Lygodium kaulfussii Heer.
Salix linearis n. sp.
Salix longiacuminata n. sp.
Juglans winchesteri n. sp.
Dalbergia viridiflumensis n. sp.
Eucalyptus? americana Lesquereux.
Phyllites winchesteri n. sp.

Green River oil shale, Camp Gulch, 25 miles northwest of De Beque, Colo. (Winchester 7384):

Achaenites cichorioides n. sp.

Green River oil shale, head of trail up ridge between Carr and Bushy creeks, 25 miles northwest of De Beque, Colo. (Winchester 7386):

Eucalyptus? americana Lesquereux.

Green River oil shale, head of Carr Creek, 30 miles northwest of De Beque, Colo. (Winchester 7387):

Myrica sp.

SPECIES EXCLUDED FROM GREEN RIVER FLORA.

The following species have been dropped from the Green River flora for the reasons stated:

Acer sp. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, p. 286, 1872.
From Barrel Springs, Wyo.; not afterward recognized by Lesquereux.

Aralia gracilis (Lesquereux) Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 236, pl. 39, fig. 1, 18, 78.

[27] Ball, M. W., U. S. Geol. Survey Bull. 341, pl. 13, 1909.
[28] U. S. Nat. Mus. Proc., vol. 5, pp. 502–514, 1883.
[29] Later extinct floras of North America: U. S. Geol. Survey Mon. 35, 1898.

Liquidambar gracile Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, p. 287, 1872.

From Bridger Pass, Wyo., hence excluded. (See p. 138.)

Arundo göpperti Münster. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, Suppl., p. 5, 1872; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 86, pl. 8, figs. 3–5.

This species is rejected from the Green River flora and probably should not be recognized in North America. In the "Tertiary flora" Lesquereux figured three specimens that he referred to this species. Of these only one, the original of his Plate VIII, figure 3, is now preserved in the United States National Museum (No. 95), and is before me. It is fully 8 centimeters wide, nearly three times the size of the largest specimen figured by Heer,[30] and is very unlike Heer's figure in appearance. It is marked with numerous fine longitudinal veins or lines, and at fairly regular intervals, about 1 centimeter apart, are stronger lines or folds. It may be a large leaf of *Cyperacites* or possibly a palm leaf. It is too indefinite to be identified.

Blechnum göpperti Ettingshausen. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, p. 283, 1872.

From Henry's Fork, Utah; not again referred to by Lesquereux.

Carya heerii (Ettingshausen) Heer. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, p. 289, 1872.

Not afterward recognized by Lesquereux.

Cinnamomum scheuchzeri Heer. Lesquereux, U. S. Geol and Geog. Survey Terr. Ann. Rept. for 1871, Suppl., p. 7, 1872.

Concerning this species Lesquereux said: "I refer to this species two leaves of *Cinnamomum*, one of which is contracted above the base, as in some forms of *C. buchi* Heer; the other narrower, like a variety of *C. lanceolata* Heer. Both specimens are incomplete and have the nervation of *C. scheuchzeri*, as represented in many specimens from other localities of our Tertiary." This species was not again alluded to as a member of the Green River flora, and the two leaves were probably transferred to some other species, but of this there is no record; they are not now known to be in existence.

Cyperites deucalionis Heer. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, p. 285, 1872.

From Barrel Springs, Wyo.; not afterward referred to by Lesquereux.

Cyperus braunianus? Heer. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, p. 285, 1872.

From Barrel Springs, Wyo.; not afterward mentioned by Lesquereux.

Cyperus chavanensis Heer. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, p. 300, 1872.

Not from the Green River formation. (See p. 137.)

Equisetum haydenii Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, p. 284, 1872; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), pl. 6, figs. 2–4, 1878.

[30] Heer, Oswald, Flora tertiaria Helvetiae, vol. 1, pl. 23, fig. 1, 1854.

Ficus arenacea Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, p. 300, 1872.

Not from the Green River formation. (See p. 137.)

Ficus gaudini Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, p. 200, 1872.

Not from the Green River formation. (See p. 137.)

Ficus lanceolata Heer. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, p. 300, 1872.

Not from the Green River formation. (See p. 137.)

Ficus multinervis Heer. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, p. 300, 1872.

Not from the Green River formation. (See p. 137.)

Ficus populina Heer, Flora tertiaria Helvetiae, vol. 2, p. 66, pl. 85, figs. 1–7; pl. 86, figs. 1–11, 1856; Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, Suppl., p. 6, 1872.

Ficus populina was characterized by Heer from specimens obtained in the Swiss Miocene. A number of leaves from the Green River formation were identified by Lesquereux with Heer's species, although he states that they show "some marked differences," such as being obtuse rather than long and acutely pointed, having the veins nearer the borders, and having the marginal teeth pointed rather than round. There is a great deal of variation in the size and appearance of the forms referred to *Ficus populina* by Heer, and as Lesquereux did not specify the particular forms he regarded as most like those he had from Green River there is no way of telling where he later referred them. This species will have to be excluded from the Green River flora.

Geonomites goldianus (Lesquereux) Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 115, pl. 9, fig. 9, 1878.

Wrong identification.

Palmacites goldianus Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1874, p. 311, 1875.

From Barrel Springs, Wyo.

Hemitelites torrelli Heer? Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, Suppl., p. 5, 1872.

Not afterward referred to by Lesquereux.

Ilex dissimilis Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 271, pl. 50, figs. 7–9, 1878.

This species comes from Sage Creek, Mont., in beds of doubtful age. There seems no longer any valid reason for including this in the Green River formation, even with a question, and it is excluded.

Ilex stenophylla Unger. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, Suppl., p. 8, 1872.

Not afterward mentioned by Lesquereux in connection with the Green River flora.

Juglans acuminata Heer? Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, Suppl., p. 8, 1872.

Lesquereux compares his Green River leaf with a peculiar form of *Juglans acuminata* from the Swiss Miocene, but as he did not afterward allude to it in this connection it was probably placed under some other form without record of such transfer.

Juglans dentata Newberry, U. S. Nat. Mus. Proc., vol. 5, p. 507, 1882 [1883].

Although this species was described by Newberry it was evidently merged with some other species in the

formal publication of the "Later extinct floras," but just which one can not be determined. Hollick, who edited this work of Newberry's, states that he could find neither specimen, figure, nor manuscript relating to it, so it would best be dropped.

Laurus utahensis Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 216, 1878.

Said to have come from Bridger Pass, Wyo., but the locality is uncertain, hence it is best excluded from the Green River flora. (See p. 138.)

Leguminosites lesquereuxiana Knowlton, U. S. Geol. Survey Bull. 152, p. 131, 1898; Mon. 32, pt. 2, p. 730, pl. 79, fig. 4, 1899. [See below.]

Leguminosites cassioides Lesquereux, U. S. Geol. Survey Terr., Rept., vol. 7 (Tertiary flora) p. 300, pl. 59, figs. 1–4, 1878. [Homonym; replaced by *L. lesquereuxiana*.]

It seems probable that this species would best be excluded from the Green River flora, for although Lesquereux states that three of the figured types were obtained above the fish beds at Green River, they are not to be found with the other material from this locality that is preserved in the United States National Museum, and their present location is unknown. The other type is from the supposed Livingston formation of the Bozeman coal field, Mont. As this species has not subsequently been found in the Green River formation, it is excluded, at least for the present.

Magnolia sp. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, p. 287, 1872.

This is stated to have come from Washakie station, Wyo., but as it was not afterward referred to by Lesquereux it should be dropped.

Myrica studeri? Heer. Lesquereux, U. S. Nat. Mus. Proc., vol. 10, p. 38, 1887.

The locality for this specimen is supposed to be White River, Wyo., but it is so uncertain and the specimen is so obscure that it is here excluded from the Green River flora.

Phaseolites juglandinus? Heer. Lesquereux, U. S. Geol. and Geog. Survey Terr. Bull., vol. 1, p. 388, 1875 [1876].

Undoubtedly an error for *Phyllites juglandinus* Heer, as no record can be found in Heer of the combination given by Lesquereux. This species was described by Lesquereux from material collected near the mouth of White River, Wyo., but it was not afterward referred to and was probably merged with some other form, without record of its transfer. It is consequently dropped from the Green River flora.

Poacites laevis Al. Braun. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, p. 285, 1872.

From Barrel Springs, Wyo.

Populus arctica Heer. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, p. 300, 1872.

Not from the Green River formation. (See p. 137.)

Quercus lonchitis Unger. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, Suppl., p. 6, 1872.

This species was identified by Lesquereux in a collection of plants from Green River but was never figured and is now lost or merged with some other form; it has not since been identified with American material. It was not mentioned by Lesquereux in the "Tertiary flora."

Rhamnus washakiensis Cockerell, Am. Mus. Nat. Hist. Bull., vol. 24, p. 74, 1908. [See below.]

Rhamnus intermedius Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, p. 286, 1872; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 282, pl. 54, fig. 3, 1878. [Homonym, Steudel and Hockstetter, 1827; replaced by *R. washakiensis*.]

This species rests on the single type specimen as figured by Lesquereux (U. S. N. M. No. 447). It is a rather nondescript oblong-elliptical leaf, about 6 centimeters long and a little less than 2 centimeters wide, with a strong midrib and about 16 pairs of close, parallel camptodrome secondaries. This species seems to approach most closely *Rhamnus obovatus* Lesquereux,[31] a species of somewhat doubtful age but distinguished by its obovate instead of elliptical outline. More material might bring them closer together, but for the present they are best kept apart.

From Bridger Pass, Wyo., and hence excluded from the Green River flora. (See p. 138.)

Sequoia heerii Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, p. 290, 1872; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 77, pl. 7, figs. 11–13, 1878.

This species was described as coming from "Sage Creek, Mont.," a locality that has not since been found; hence, of course, its age is in doubt. *Sequoia heerii* has been subsequently identified in the upper part of the Clarno formation of Oregon, the Kenai formation of Alaska, and the Lance formation of Montana and Wyoming. It has not been reported from any Green River locality, and the manner in which it came to be even tentatively accredited to this formation is unknown.

Zanthoxylon juglandinum? Al. Braun. Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 294, pl. 58, fig. 10, 1878.

This species comes from Washakie, Wyo., from beds whose position is not definitely settled as in the Green River formation; hence it is excluded.

SYNONYMS AND CHANGES OF NAMES.

Acer indivisum Lesquereux=*Acer lesquereuxii* Knowlton.

Alnites inaequilateralis Lesquereux=*Planera inaequilateralis.*

Alnus inaequilateralis Lesquereux=*Planera inaequilateralis.*

Ampelopsis tertiaria Lesquereux=*Parthenocissus tertiaria.*

Apocynophyllum scudderi Lesquereux=*Eucalyptus? americana.*

Aralia macrophylla Newberry=*Aralia wyomingensis.*

Ceanothus cinnamomoides Lesquereux=*Zizyphus cinnamomoides.*

Juglans denticulata Heer. Lesquereux=*Juglans crossii.*

Juglans occidentalis Newberry (part)=*Carpites newberryana.*

Juglans schimperi Lesquereux (part)=*Juglans occidentalis.*

Lygodium neuropteroides Lesquereux=*Lygodium kaulfussii*

Myrica nigricans Lesquereux=*Rhus nigricans.*

Pecopteris sepulta Newberry=*Osmunda? sepulta.*

Planera variabilis Newberry (part)=*Planera inaequilateralis.*

[31] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p 281, pl. 54, figs. 1, 2, 1878.

Quercus castaneoides Newberry=*Quercus castaneopsis.*
Rhus acuminata Lesquereux=*Rhus lesquereuxii* Knowlton and Cockerell.
Salix angusta Al. Braun? Newberry=*Eucalyptus? americana.*
Salix media Heer. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, Suppl., p. 6, 1872=*Salix* sp.
Spheria myricae Lesquereux=*Sphaerites myricae.*
Zizyphus longifolia Newberry (part)=*Zizyphus cinnamomoides.*

THE ACCEPTED GREEN RIVER FLORA.

The Green River flora as here described comprises the following species:

Caenomyces eucalyptae Knowlton, n. sp.
Caenomyces sapindicola Knowlton, n. sp.
Sphaerites myricae (Lesquereux) Meschinelli.
Acrostichum hesperium Newberry.
Lygodium kaulfussii Heer.
Lygodium dentoni Lesquereux.
Osmunda? sepulta (Newberry) Knowlton.
Danaea coloradensis Knowlton, n. sp.
Equisetum wyomingense Lesquereux.
Arundo reperta Lesquereux.
Cyperus chavannesi Heer.
Cyperacites haydenii (Lesquereux) Knowlton.
Geonomites haydenii (Newberry) Knowlton, n. comb.
Sabal powellii Newberry.
Flabellaria florissanti Lesquereux.
Pontederites hesperia Knowlton, n. sp.
Juncus sp. Lesquereux.
Musophyllum complicatum Lesquereux.
Salix linearis Knowlton, n. sp.
Salix longiacuminata Knowlton, n. sp.
Salix sp. Knowlton.
Salix sp. Knowlton.
Myrica salicina Unger.
Myrica minuta Knowlton, n. sp.
Myrica praedrymeja Knowlton, n. sp.
Myrica ludwigii Schimper.
Myrica sp. Knowlton.
Myrica sp. Knowlton.
Comptonia? anomata Knowlton, n. sp.
Juglans occidentalis Newberry.
Juglans schimperi Lesquereux.
Juglans crossii Knowlton.
Juglans alkalina Lesquereux.
Juglans winchesteri Knowlton, n. sp.
Quercus castaneopsis Lesquereux.
Planera inaequilateralis (Lesquereux) Knowlton, n. comb.
Ficus ungeri Lesquereux.
Ficus wyomingiana Lesquereux.
Ficus tenuinervis Lesquereux.
Lomatia? microphylla Lesquereux.
Oreodaphne viridiflumensis Knowlton, n. sp.
Pimelea spatulata Knowlton, n. sp.
Brasenia? antiqua Newberry.
Sedum? hesperium Knowlton, n. sp.
Amygdalus gracilis Lesquereux.
Dalbergia viridiflumensis Knowlton, n. sp.
Dalbergia retusa Knowlton, n. sp.
Leguminosites alternans Lesquereux.
Sophora coloradensis Knowlton, n. sp.
Mimosites coloradensis Knowlton, n. sp.
Ailanthus longe-petiolata Lesquereux.
Sapindus dentoni Lesquereux.
Sapindus obtusifolius Lesquereux.
Sapindus winchesteri Knowlton, n. sp.
Rhus lesquereuxii Knowlton and Cockerell.
Rhus variabilis (Newberry) Knowlton, n. comb.
Rhus nigricans (Lesquereux) Knowlton, n. comb.
Rhus myricoides Knowlton, n. sp.
Euonymus flexifolius Lesquereux.
Acer lesquereuxii Knowlton.
Ilex? affinis Lesquereux.
Ilex maculata Lesquereux.
Ilex vyomingiana Lesquereux.
Zizyphus longifolia Newberry.
Zizyphus cinnamomoides (Lesquereux) Lesquereux.
Cissus parrottiaefolia Lesquereux.
Parthenocissus tertiaria (Lesquereux) Knowlton, n. comb.
Eucalyptus? americanus Lesquereux.
Aralia wyomingensis Knowlton and Cockerell.
Andromeda delicatula Lesquereux.
Sambucus? winchesteri Knowlton, n. sp.
Achaenites cichorioides Knowlton, n. sp.
Antholithes improbus Lesquereux.
Carpolithus caryophylloides Knowlton, n. sp.
Carpites viburni Lesquereux.
Carpites newberryana Knowlton, n. sp.
Carpites inquirenda Knowlton, n. sp.
Phyllites winchesteri Knowlton, n. sp.
Phyllites fremonti Unger.
Phyllites coloradensis Knowlton, n. sp.
Nordenskiöldia borealis Heer.

RELATION OF GREEN RIVER FLORA TO OTHER FLORAS.

The position of the Green River formation above the Wasatch and below the Bridger fixed its stratigraphic horizon as approximately middle Eocene. Hayden when he named the formation made no attempt to fix its position definitely within the Tertiary, though by inference it fell within the Eocene. Cope, who first studied the Green River fish, did not venture more than to place it in the Eocene, because he regarded the available data as insufficient.

Lesquereux,[32] who was the first to study the flora systematically, placed these beds in his so-called fourth group, which comprised a "Lower Green River" and an "Upper Green River." To the first of these he referred the

[32] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), pp. 314-326, 1878.

localities of Barrel Springs and Green River station (above fish beds), Wyo., and Sage Creek, Mont., and to the second the localities Florissant, Colo., Elko, Nev., and White River, Wyo.

In his final consideration of the Green River flora Lesquereux [33] referred all these localities to the Green River formation. For many years thereafter the Florissant lake beds were generally regarded as of Green River age, but subsequent study had placed them in the upper Miocene. The plants from Elko, Nev., have not been critically studied and revised in recent years, but they are probably slightly younger than the Green River.

As pointed out in another place, the localities of Barrel Springs, Fort Bridger, and Sage Creek have been removed from the Green River formation on the ground of uncertainty as to their position.

The only described middle Eocene flora with which the Green River flora may be compared is one from the so-called Congaree clay member of the McBean formation of the Claiborne group [34] of Georgia, described by Berry.[35] This is a small flora of only 17 species, belonging to the following genera:

Acrostichum.
Arundo.
Castanea.
Conocarpus.
Dodonaea.
Ficus.
Malapoenna.
Mimosites.
Momisia.
Pisonia.
Pistia.
Potamogeton.
Rhizophora.
Sapindus.
Sphaerites.
Terminalia.
Thrinax.

The genera common to these two floras are

Acrostichum.
Arundo.
Ficus.
Mimosites.
Sapindus.
Sphaerites.

Although none of the species are held to be common to the two, there are several that are evidently rather closely related. Thus *Acrostichum georgianum* is regarded by Berry as closely related to *Acrostichum hesperium*, "differing from it in being somewhat more slender in habit and in having straighter midveins and less elongate, finer areolation." *Arundo pseudogoepperti*, although a mere fragment, is regarded as very similar to and possibly identical with *Arundo reperta*, from the Green River. The only species of *Ficus* from the Georgia locality is *Ficus claibornensis*. It is an oblong-lanceolate leaf in which very little of the nervation is preserved and is quite different from either of the Green River species. *Mimosites georgianus* is certainly very similar to *Mimosites coloradensis*. *Sapindus georgiana*, according to Berry, suggests *Sapindus angustifolius* and *S. stellariaefolius*, both from the Florissant lake beds, but is not particularly close to any Green River species. The Georgia species of *Sphaerites* is similar to *Sphaerites myricae* from the Green River, but all fossil leaf-spot fungi are so similar that without the essential organs it is almost impossible to be certain of identifications.

The ecologic conditions under which this Georgia flora grew are discussed at length by Berry, who concludes that it was distinctly a coastal flora. The only forms to which this interpretation would not apply are *Castanea*, which is an upland type, and *Pistia* and *Potamogeton*, both of which are aquatic but not of coastal waters. All these could have been brought down from higher land by a stream. Concerning the others Berry says:

> It is interesting to note that the remaining 12 species are all plants of a coastal habitat, their modern representatives flourishing in the tidal nipa swamps of the Orient, in mangrove swamps of the Orient and Occident, on the strand in beach jungle, or on the landward side of coastal sand dunes. Nearly all are represented by forms found in the existing flora on the Florida keys or along the shores of peninsular Florida, some, like *Conocarpus*, flourishing equally well on either muddy or sandy shores. Every species has representatives in the American Tropics.

The actual physical conditions Berry interprets as follows:

> The present winter isotherm in the latitude of Grovetown [Ga.] is approximately 48° F. None of the closely allied modern plants flourish north of the winter isotherm of 52° F., and most of them do not occur north of the winter isotherm of 60° F. None of the fossil forms except possibly the *Potamogeton*, the modern species of which range over a great many degrees of latitude, or the *Castanea*, which likewise has a wide range, would be expected to occur outside the latitudes where what Schimper calls the subtropical or warm temperate rain forests are found. We would expect the Claiborne climate, at least at low elevations along the coast and in proximity to the warm Eocene ocean current or currents, to have been uniformly humid, with an annual rainfall somewhere between 150

[33] U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), pp. 206–218, 1883.

[34] Later more detailed work revealed the fact that the deposits from which this flora was collected are of Jackson (upper Eocene) age and belong to the Twiggs clay member of the Barnwell formation. See U. S. Geol. Survey Prof. Paper 120, pp. 41–77, 1919.

[35] Berry, E. W., The Upper Cretaceous and Eocene floras of South Carolina and Georgia: U. S. Geol. Survey Prof. Paper 84, pp. 129–163, pls. 24–29, 1914.

and 200 centimeters. The actual rainfall could become a more or less negligible factor provided the water table approached close to the surface and the humidity was high and constant. The temperature would have to be uniform rather than hot, judging by modern standards, for any degree of winter cold would have been fatal. The climate need not have been tropical, nor would it be surprising if the Claiborne marine fauna failed to show tropical forms or reef corals, for the main factors which would limit the spread of a flora like the one described would be uniform humidity, ample rainfall, and the absence of severe cold.

As might perhaps be expected, there is comparatively little identity of species between the Green River flora and early Eocene floras. At one time it was thought that there were several "Laramie" species that persisted into the Green River, but as shown in another place this belief was due to a small collection of obviously older forms for which the locality label had been either "lost or forgotten" and which were wrongly placed in the Green River.

According to the books the following species have been found common to the Green River and Fort Union formations:

Lygodium kaulfussii.
Juglans occidentalis.
Quercus castanopsis.
Ficus ungeri.
Zizyphus cinnamomoides.
Andromeda delicatula.

The Fort Union flora, however, is much in need of critical revision, and it is probable that when this revision is made it will be found that some of these species were misidentified.

A single Green River species (*Juglans crossii*) has been reported in the Hanna formation of south-central Wyoming.

So far as known no species has been found common to the Green River flora and those of the Arapahoe, Denver, Raton, or Lance formations. One Green River species (*Rhus affinis*) has been reported from the Wilcox flora, but as Berry seriously questions the identification it can not be considered of much importance. Another Green River species (*Ficus tenuinervis*) has been identified in the lower part of the Clarno formation of Oregon, and another (*Sapindus obtusifolius*) in the Mascall (Miocene) formation of Oregon.

Although Lesquereux referred the Florissant lake beds to the Green River formation, the present revision has shown only one species (*Amygdalus gracilis*) as common to the two, and even this is open to some question.

BIOLOGIC AND ECOLOGIC INTERPRETATION OF THE FLORA.

Although the known flora of the Green River formation is still rather small, it includes a number of species that are of considerable biologic interest, and it is perhaps large enough to permit the drawing of at least tentative conclusions regarding the climatic conditions under which it flourished. As already pointed out, the great bulk of the formation is almost if not entirely unfossiliferous, but where any fossils occur in it they are generally very abundant. Thus, the so-called fish beds near the town of Green River have yielded many thousands of fish remains, as many as a hundred occurring on a small slab. In some layers—for example, in the layers just above the fish beds that contain the remains of palms—the plant remains are so matted together as to be individually indistinguishable. In southwestern Colorado the fossiliferous beds associated with the oil shale contain a profusion of plant and insect remains. As already stated, the study of the microscopic flora of the oil shale has been only partly completed, though sufficient to show the presence of bacteria, blue-green algae, *Protococcus*, *Spirogyra*, saprophytic fungi, mosses, ferns, and various types of seed-bearing plants. Some of these—perhaps all of them—but particularly the algae appear to have contributed to the accumulation of the oil in the shale. The algae are said to occur in great abundance and in a very perfect state of preservation, which would imply warm, rather shallow water. The great mass of amorphous undifferentiated vegetable matter in the oil shale indicates the action of bacteria in its reduction, which could hardly have taken place at depths much exceeding 20 feet. There is little evidence of the presence of moss plants, and the presence of spores must have been more or less fortuitous, for the mosses are plants so small and inconsequential that their spores could hardly have been much of a factor. The moss spores, the spores and sporangia of ferns, and the pollen of conifers must have been blown from adjacent land, and hence they give no indication of the depth of water in which they fell, nor of the temperature at which they grew, for it is not possible from available data to identify the types of plants that produced them.

Turning now to the plants described in this paper, we have at least three distinct forms of leaf-spot fungi, occurring on three types of leaves—*Myrica*, *Sapindus*, and *Eucalyptus*. They have the same general appearance as many present-day leaf-spot fungi, but as their spore characters can not be made out their systematic position is subject to more or less question. Their requirements as to temperature are, of course, the same as that of the leaves on which they grew.

The ferns of the Green River formation are represented by five well-marked forms, some of which are of exceptional interest. Thus *Danaea*, although described from a fragment, is perfectly authenticated and so far as known is the first example of the living type to be found fossil. This genus comprises more than 25 living species, all strictly American, ranging from Cuba and southern Mexico to Brazil. They are terrestrial ferns of rather coarse habit, mostly 2 or 3 feet in height, growing in the shade in moist but well-drained tropical valleys and slopes, where the humidity is high and constant. The fossil form seems to be most clearly related to a species living on the island of Trinidad. Another rather striking Green River fern is *Acrostichum*, which has only three living species living in tropical tidal marshes in both old and new worlds. Climbing ferns of the genus *Lygodium* are represented by two nominal species in the Green River flora. The better known of these is identified as *Lygodium kaulfussii*, a form first described from specimens obtained in the Miocene of Thuringia but since widely known from collections in Europe and this country. The genus is a large one distributed mainly in the Tropics of both hemispheres, especially in coastal thickets. The remaining fern of the Green River flora is referred with question to the genus *Osmunda*.

The Equisetacae are represented by a single species of *Equisetum* that is poorly preserved and can not be of much value in the present connection.

With the exception of some pollen grains found in connection with the oil shale, no remains of conifers have been reported from the Green River formation.

The monocotyledons are better represented, though there is nothing very remarkable. There are the usual nondescript forms referred to *Arundo*, *Cyperus*, and *Cyperacites*, with a doubtful species of *Juncus*. The most impressive things are the palms, of which there are three nominal forms referred to different genera, though more complete material may change certain of these references. The species of *Geonomites* and *Sabal* are very rare—in fact, are known only from the type material—but the form referred to *Flabellaria* was very abundant at one locality and of large size. The leaves are so matted together that it is impossible to get them out whole, but from many fragments studied the conviction grows that they must have been at least 4 or 5 feet in diameter. They had a long, rather slender, unarmed petiole.

The family Palmaceae, which comprises about 150 genera and 1,000 species, is essentially tropical and about equally distributed in the Eastern and Western hemispheres. At the present time the highest northern latitude it reaches in Europe is about 43° and the highest southern latitude about 45° in New Zealand. A few species extend their range into temperate regions, and some can even endure a temperature below 32°, but they are the exception.

Palms were introduced at least as early as middle Cretaceous time and during the early part of the Tertiary period had attained a wide range, occurring, for instance, in Grinnell Land, Spitzbergen (80° north), in Greenland (70°), and in this country in Fort Union beds near the mouth of the Yellowstone, in the Puget group of Oregon and Washington, in the Kenai formation and other Eocene beds of Alaska, in the Denver and Raton formations of eastern Colorado and northeastern New Mexico, and in the Wilcox group of the Gulf region.

The two remaining monocotyledons are *Musophyllum*, based on large but fragmentary *Musa*-like leaves that may or may not be correctly referred to the Musaceae, and *Pontederites*, a newly described form that seems correctly interpreted as ancestral to the genus *Pontederia*. The Pontederiaceae are a small American family of 5 genera and about 25 species living in warm and temperate regions. *Pontederia* is a variable aggregation, by some regarded as a single species; others recognize two species, one confined to North America and one to South America; but the latest view inclines to the recognition of seven or eight species. The North American species (*Pon-*

tederia cordata Linné), the well-known pickerel weed, ranges from Nova Scotia to Minnesota and south to Florida and Texas. It grows in shallow fresh water. The leaf of the Green River form is certainly very similar to the living form.

The Salicales are represented in this flora by four forms of *Salix*, two of which are so fragmentary that they have not been given specific names. The others are small, narrow, rather nondescript leaves that it is difficult to place satisfactorily. They appear to be willow leaves, but their affinities are more or less doubtful. Hence any conclusions as to their ecologic conditions must be more or less tentative.

The Myricales are represented by six forms of *Myrica* and a single anomalous and more or less doubtful leaf referred to *Comptonia*. The five species of *Juglans* representing the Juglandaceae are not particularly noteworthy, nor is the single species of *Quercus* which represents the Fagaceae. The single species of *Planera*, of the family Ulmaceae, was a very abundant plant in the Green River and seems to be very well authenticated. The three species of *Ficus* representing the Moraceae were not apparently very numerous, but one (*Ficus ungeri*) had large, fine leaves. The Proteaceae are questionably represented by a single species of *Lomatia*. The type specimens are lost, and the generic reference is more than doubtful. They might be leaflets of some mimosaceous or *Sapindus*-like form. To the Lauraceae are referred two genera (*Oreodaphne* and *Pimelea*), each with a single species and each based on a single specimen. The species of *Pimelea* is rather closely related to a species from the Florissant lake beds. The species of *Brasenia*, the sole representative of the Nymphaeaceae, seems well authenticated. *Brasenia* is a monotypic genus of aquatic perennial plants found in North America, Cuba, eastern and tropical Asia, western tropical Africa, and Australia. The Crassulaceae are doubtfully represented by a species referred with question to *Sedum*, but the resemblance may be only superficial. The single species of *Amygdalus* is involved in so much doubt that it is hardly worth while discussing its affinities. The Papilionaceae are represented by two species of *Dalbergia* and one each of *Sophora* and *Leguminosites*, and the Mimosaceae by one species of *Mimosites*. These are all small, narrow leaves or leaflets and if correctly identified would seem to indicate a moist lowland habitat. The living species of these genera are very numerous and are widely scattered over the warmer parts of both hemispheres, being especially abundant on all tropical seashores. In the order Geraniales the Simarubaceae are represented by a very well authenticated species of *Ailanthus*, though the connection between the leaf and the winged fruit may be uncertain. *Ailanthus* is not now a native of the Western Hemisphere, the seven living species being confined to eastern Asia and the East Indies. They are at home in warm or subtropical temperatures.

The order Sapindales is represented by several families in the Green River flora. Of these the Anacardiaceae claim four species of *Rhus*. This family numbers about 60 genera and 450 living species of trees and shrubs and is present in the Tropics and subtropics of both hemispheres, being specially abundant in Malaysia. *Rhus* is the only genus of the family found outside the Tropics. The Celastraceae are represented by a single species of *Euonymus*. This genus has about 60 living species, widely distributed throughout the Northern Hemisphere, but is most abundant in the Asiatic Tropics and in Japan and China. The Sapindaceae, represented in the Green River by four species of *Sapindus*, constitute a very large family of over 100 genera and 1,000 species. They are mostly confined to tropical or subtropical regions. The Ilicaceae comprise only five genera and less than 200 species. The principal genus is *Ilex*, which is found in nearly all tropical and temperate regions and is represented in the Green River flora by three species. In the order Rhamnales the family Rhamnaceae includes about 50 genera and 500 living forms, mainly of the Tropics but a few, among them *Rhamnus*, extending into temperate regions. The only genus of this family represented in the Green River flora is *Zizyphus*, with two well-marked species. There are about 40 living species of *Zizyphus*, mainly shrubs or small trees, of warm temperate regions, with a few in the Tropics of both hemispheres. The Vitaceae comprise about a dozen genera and nearly 500 species, mainly tropical or subtropical, though a few, such as *Vitis*, extend into temperate regions. *Cissus* is the largest genus, including 250 species, all

or nearly all tropical. Inasmuch as the *Eucalyptus* in the Green River flora is questioned there is perhaps no necessity for going further into the history of this family. The final family that needs to be considered is the Araliaceae, represented in the Green River flora by a very well-defined species of *Aralia*. This family embraces about 50 genera and over 500 species, mainly tropical, but a considerable number extend into temperate regions, especially in North America and eastern Asia.

The remaining forms are referred to the genera *Antholithes*, *Carpolithus*, *Carpites*, *Phyllites*, and *Achaenites* and need not be further discussed. The species of *Achaenites* is noteworthy in that it appears to indicate with much certainty the presence of the great group of Compositae.

From the foregoing account it appears that an overwhelming preponderance of the living forms in the families represented in the Green River flora are inhabitants of tropical or subtropical regions, many of them in both hemispheres, yet a considerable number include either genera or species that extend into temperate regions. There is some evidence to show that there were at least two ecologic provinces in Green River time. Thus, there are a number of the genera that are of the lowland type, such as

Lygodium	Lomatia
Acrostichum	Pimelea
Danaea	Oreodaphne
Osmunda	Dalbergia
Arundo	Leguminosites
Cyperus	Sophora
Geonomites	Mimosites
Sabal	Ailanthus
Flabellaria	Sapindus
Pontederites	Eucalyptus?
Musophyllum	Aralia
Planera	Brasenia
Ficus	

There are other genera that seem to find a more congenial home on higher ground. These are

Salix	Acer?
Myrica	Zizyphus
Comptonia?	Ilex
Juglans	Andromeda
Quercus	Sambucus?
Rhus	

This division is not a very satisfactory one, and the assignments may not all be valid, but there were evidently some differences in the conditions under which the several elements were found. The physical setting can be pictured somewhat as follows: About the shores of the lake were certain flat, low-lying areas, some of them probably swampy, others sandy, whereon grew the palms, figs, *Lomatia*, *Oreodaphne*, hackberries, the several papilionaceous trees and shrubs, the ferns, grass, sedge, etc., and in the water the pickerel weed, *Brasenia*, algae, etc. On the adjacent somewhat higher land might have been the willows, waxberries, sweet fern, walnuts, oaks, sumacs, maples(?), hollies, etc.

The conditions of temperature and moisture under which the Green River flora flourished are somewhat difficult of interpretation, as there is seemingly more or less conflict between the elements of the flora. The nearest living relatives of certain of the genera that are believed to have inhabited the lowlands, such as *Lygodium*, *Acrostichum*, *Danaea*, *Geonomites*, *Sabal*, *Flabellaria*, *Musophyllum*, *Planera*, *Ficus*, *Lomatia*, *Pimelea*, *Oreodaphne*, the leguminous genera, and possibly *Sapindus*, *Eucalyptus*, and *Aralia*, are found mainly in subtropical or tropical areas. The palms, at least one species of which existed in abundance, could hardly have lived where the temperature fell below 42° F. and probably not even where it was considerably higher than this. Certain of the other genera, such as *Osmunda*, *Arundo*, *Cyperus*, *Aralia*, and *Brasenia*, might have withstood frost, for although the species of these genera are largely tropical or subtropical they include species that extend into temperate regions. All things considered it seems probable that this lowland flora must have required a temperature that was at least warm temperate and possibly bordered on subtropical.

The upland flora, including such genera as *Salix*, *Myrica*, *Juglans*, *Quercus*, *Rhus*, *Acer*, and *Ilex*, could well have withstood some degree of frost, but on the other hand all these genera contain species that could find a congenial habitat in a warm temperate region. It is doubtful if any of them had to withstand cutting frosts.

The inferences to be drawn regarding the climatic requirements of the insect fauna are in substantial accord with those suggested by the flora. I am informed by Prof. T. D. A. Cockerell that the known insect fauna of the Green River

shales now numbers 296 species. Concerning this fauna he says:

> The really dominant and characteristic insects of the Green River shales, if any such can be specially designated, are the Fulgoridae, which have a most distinctly tropical aspect and in many cases closely resemble living tropical genera. The other groups of insects do not appear tropical, though one of the dragon-fly genera is closely related to a neotropical one. The dragon flies, caddis flies, etc., indicate that there was plenty of fresh water, but it does not follow that these breed in the lake.

Alexander,[36] the well-known authority on the crane flies, has the following to say regarding the geologic history of this group:

> The North American Eocene and Miocene, as represented by the White River and Green River beds and the Florissant shales, respectively, give evidence of having had a northern [tipulid] fauna, especially the Eocene. This is well shown by the great development of the Cylindrotominae, which in the White River basin almost dominated the crane-fly fauna during the Eocene. It seems probable, moreover, that the group was forced into colder regions of the globe during the Oligocene, when the tropical element reached far north. No group of crane flies that can be considered tropical has yet been found in the Florissant beds. On the other hand, the European Oligocene, as shown by the Garnet Bay beds and the lower Oligocene Baltic amber, has a considerable tropical element apparent.

From these statements it appears that the evidence of the insects is practically the same as that of the plants, namely, they comprise a certain element that indicates tropical surroundings, and another, or others, that indicate cooler, perhaps temperate conditions.

THE FLORA.

Phylum THALLOPHYTA.

Class FUNGI.

Series ASCOMYCETES.

Order LABOULBILIALES.

Family LABOULBILIACEAE.

Genus CAENOMYCES Berry.

Caenomyces eucalyptae Knowlton, n. sp.

Plate XXXVI, figures 8, 9.

I follow Berry in adopting *Caenomyces* as the generic name of this leaf-spot fungus. Berry's description[37] is as follows:

> The presence of spots of different shapes on the leaves of fossil plants is exceedingly common, and a very large number of so-called species of fossil leaf-spot fungi have been described by Ettingshausen, Heer, Saporta, and others. * * * The identification of these fossil forms obviously rests on a very insecure foundation, especially when it is recalled that scale insects and a great variety of insect galls would resemble epiphyllous fungi when preserved on impressions of fossil leaves. Nevertheless, large numbers of undoubted fungi are preserved in this manner, and it is the legitimate duty of the paleobotanist to describe and illustrate them. In order to accomplish this work without unwarranted definiteness in generic classification, I propose the term *Caenomyces* as a form genus for leaf-spot fungi of Cenozoic age whose precise botanic affinities can not be determined.

One of the leaves of *Eucalyptus? americanus* from western Colorado shows about twenty very well preserved leaf spots, apparently caused by a fungus. They are circular, are about 1.5 or 2 millimeters in diameter, and have an outer black ring perhaps 0.05 millimeter in width under which the substance of the leaf has shrunken. The center of the ring is elevated, and on the top of this in the center are several black pustules evidently where the mature spores are being or about to be discharged.

The disposition and general appearance of these leaf spots is shown in figure 8 natural size, and one of the most perfect spots in figure 9, which is enlarged six times.

Occurrence: Green River formation, on leaf of *Eucalyptus? americanus* Lesquereux, Cathedral Bluff, south of Little Tommies Draw, about 20 miles west of Rio Blanco post office, Rio Blanco County, Colo., collected by D. E. Winchester, 1917.

Caenomyces sapindicola Knowlton, n. sp.

Plate XXXVI, figure 10.

The type leaflet of *Sapindus winchesteri* (Pl. XXXVIII, fig. 1) shows the presence of several leaf-spot fungi. The spots are circular, 1.5 to 2 millimeters in diameter, and some show an inner ring with a slightly raised central portion. It is evidently not mature and is so obscure that it is hardly worthy of mention except to call attention to the presence of fungi of this general type on *Sapindus*.

Occurrence: Green River formation, on type leaflet of *Sapindus winchesteri* Knowlton, oil shale, Smith ranch, on Greasewood Creek, about 40 miles southwest of Meeker, Colo., collected by D. E. Winchester, 1917.

[36] Alexander, C. P., The crane flies of New York, pt. 2: Cornell Univ. Agr. Exper. Sta. Mem. 38, p. 764, 1920.

[37] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, p. 162, 1916.

Order SPHAERIALES.

Family SPHAERIACEAE.

Sphaerites myricae (Lesquereux) Meschinelli.

Sphaerites myricae (Lesquereux) Meschinelli, Sylloge fungorum fossilium, p. 23, 1892.

Spheria myricae Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 390, 1873; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 34, pl. 1, fig. 4, 1878.

This species was first described from specimens collected at Black Buttes, Wyo., where it was found on leaves of *Myrica torreyi* Lesquereux. It was later found at Green River, Wyo., on leaves of *Myrica nigricans* (now *Rhus nigricans*).

It was described by Lesquereux as follows: "Perithecia punctiform, minute, either sparse or in a circle, forming round spots" about a millimeter in diameter, "the center of which is clear and of a light color." It may be the same as *Caenomyces eucalyptae*, described on page 148, but as it can not be certainly identified with that species it is permitted to stand as left by Lesquereux.

Occurrence: Green River formation, Green River, Wyo., on leaves of *Myrica nigricans* Lesquereux. "Post-Laramie" (type), Black Buttes, Wyo.

Phylum PTERIDOPHYTA.

Class FILICES.

Order FILICALES.

Family POLYPODIACEAE.

Acrostichum hesperium Newberry.

Acrostichum hesperium Newberry, U. S. Nat. Mus. Proc., vol. 5, p. 503, 1882 [1883]; U. S. Geol. Survey Mon. 35, p. 6, pl. 61, figs. 2–5, 1898.

The illustrated types of this splendid fern are all preserved in the United States National Museum (Nos. 7013–7016).

Occurrence: Green River formation, Green River, Wyo., collected by C. A. White.

Family SCHIZAEACEAE.

Lygodium kaulfussii Heer.

Plate XXXVI, figure 7.

Lygodium kaulfussii Heer, Beiträge zur nähern Kenntniss der sächsisch-thuringischen Braunkohlenflora, p. 400, pl. 8, fig. 21; pl. 9, fig. 1, 1861.

Newberry, U. S. Geol. Survey Mon. 35, p. 1, pl. 62, figs. 1–4, 1898.

Knowlton, U. S. Geol. Survey Mon. 32, pl. 2, p. 672, pl. 80, figs. 1, 2, 1898.

Lygodium neuropteroides Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1870, p. 384, 1871; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 61, pl. 5, figs. 4–7; pl. 6, fig. 1, 1878.

The genus *Lygodium* is so characteristic in shape and nervation that with reasonably adequate material it is easily and certainly identified. Its presence in the Green River formation was first made known by Lesquereux, who described and figured *Lygodium neuropteroides*. Subsequently a very large number of very well preserved examples were procured from the Green River formation by J. S. Newberry. These were identified as Lesquereux's species, and, as Newberry said, "They illustrate the growth of the plant far better than those he figured. Coming all from the same locality, indeed thickly impacted together and having the same nervation, they unquestionably represent a single species."

Before Newberry's account was published, however, Gardner[38] published an account of British Eocene ferns in which he pointed out the identity of Lesquereux's *Lygodium neuropteroides* with Heer's *Lygodium kaulfussii*, and this view was accepted by both Lesquereux and Newberry. Lesquereux was shown specimens of the true *Lygodium kaulfussii* and pronounced them "positively identical" with his species from the Green River formation. If there is any difference it is that the American specimens are somewhat more robust and have slightly broader and less undulate lobes, but the differences are not great.

Newberry[39] also reported *Lygodium* leaves from Fletts Creek and Carbonado, Wash. [Puget group], which, he said,

> offer no characters by which they can be distinguished from those found in the Green River group, and it seems to me probable that we have in all these specimens relics of one of those widespread and long-lived species which occur at different geological horizons among both animal and plant remains.

Newberry's conclusion has since been verified by the finding of specimens identified[40] as *Lygodium kaulfussii* on Elk Creek, in the Yellowstone National Park, in beds believed to be of Fort Union age, and also on the bank

[38] Gardner, J. S., British Eocene flora, pt. 1, Filices, p. 47, pls. 7, 1884.

[39] Newberry, J. S., U. S. Geol. Survey Mon. 35, p. 3, 1898.

[40] Knowlton, F. H., U. S. Geol. Survey Mon. 32, pt. 2, p. 672, pl. 80, figs. 1–3, 1898.

of Lamar River between Cache and Calfee creeks, in beds of Miocene age. The specimens from Elk Creek are as large as the largest specimens from Green River figured by Newberry, and the specimens from Lamar River are about the size of the smaller ones figured by Newberry.

The collections from the Green River shales made by D. E. Winchester in northwestern Colorado include a number of specimens of *Lygodium kaulfussii* that are undoubtedly identical with certain of the smaller ones figured by Newberry. Only one of these has been figured here.

Occurrence: Green River formation, Green River, Wyo., collected by C. A. White about 1879?; Barrel Springs, Wyo., type locality for *Lygodium neuropteroides*, collected by F. V. Hayden, 1870; spring on Little Duck Creek, Rio Blanco County, Colo., and sec. 33, T. 4 S., R. 100 W., Colo., collected by D. E. Winchester, 1917.

Lygodium dentoni Lesquereux.

Lygodium dentoni Lesquereux, U. S. Geol. and Geog. Survey Terr. Bull., vol. 1, p. 383, 1875 [1876]; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 63, pl. 65, figs. 12, 13, 1878.

The status of this species is unsatisfactory. The type specimens are now lost, and our knowledge of it depends on the two fragments figured by Lesquereux. It appears to be a *Lygodium*, but it is so fragmentary that there is little use in attempting comparison with other species.

Occurrence: Green River formation (?), mouth of White River, Wyo.

Family OSMUNDACEAE?

Osmunda? sepulta (Newberry) Knowlton, n. comb.

Pecopteris (Phegopteris) sepulta Newberry, U. S. Nat. Mus. Proc., vol. 5, p. 503, 1883.

Pecopteris (Cheilanthes) sepulta Newberry, U. S. Geol. Survey Mon. 35, p. 12, pl. 62, figs. 5, 5a, 6, 1898.

Described as follows by Newberry:

Frond small, delicate, pinnate; lower pinnae straight, broadly linear in outline, rounded above, attached to the rachis by the whole breadth of base; margins strongly lobed by the confluent pinnules, 1 centimeter wide by 5 centimeters long; upper pinnules crowded, conical in outline, gently curved upward, with waved or lobate margins; pinnules united by one-third of their length, oblong, obtuse; basal ones on lower side round, on the upper side flabellate, both attached by all their lower margin to the rachis of the frond; nervation strong and wavy, consisting of one many-branched nerve stem in each pinnule, each branch once or twice forked; fructification unknown.

The two figured types of this species are in the United States National Museum (Nos. 7042, 7043). Of course Newberry recognized the fact that this fern should properly be referred to a modern genus, and pending the determination of what that genus should be he referred it temporarily to *Pecopteris*. At different times in considering this species Newberry employed *Phegopteris* and *Cheilanthes* as subgenera, and in his final discussion of its possible affinities he mentioned *Gleichenia*, but in the absence of fructification all were dismissed as improbable.

I have ventured to transfer this form tentatively to the genus *Osmunda*, as it seems to agree in a number of respects with certain fossil species that have been so referred. We still lack the fruit, and in its absence any reference is more or less open to uncertainty, but it is impossible to permit this form to remain under *Pecopteris*.

Occurrence: Green River formation, Green River, Wyo., collected by C. A. White.

Order MARATTIALES.

Family MARATTIACEAE.

Danaea coloradensis Knowlton, n. sp.

Plate XXXVI, figure 4.

This species is based on the impression of the under side of the terminal portion of a pinnule in fruit. Its length is about 13 millimeters and its width 4 millimeters, and as it is broken squarely across the base there is strong presumptive evidence that it was considerably longer when living. It was evidently thick and fleshy and had a very strong midrib, and the synangia are closely packed on either side, though not quite reaching the margin, where there is a distinct fleshy rim. As the apical pores of the sporangia do not show it is presumed that the fruit was not quite mature.

Among living species it appears to approach most closely in size and general appearance *Danaea fendleri* Underwood, of the Island of Trinidad, but it differs specifically in having the synangia relatively very broad and short.

The genus *Danaea* is represented by about 25 species confined to tropical America from Cuba and southern Mexico to Brazil. They are terrestrial ferns of rather coarse habit and

are dimorphous, with simply pinnate fronds (simple in one species) with linear segments bearing parallel linear synangia, each composed of two rows of closely packed sporangia opening by a terminal pore. These fruiting characters are so strongly marked that there is little difficulty in recognizing a fossil form that is adequately preserved.

The species here described is not only the first North American fossil form to be made known, but it is apparently the only fossil species thus far described from any part of the world that is reasonably authenticated. Thus, Racyborski [41] described a species from the Jurassic of Krakow, Poland, under the name *Danaea microphylla*, but it has the outline, size, and nervation of a *Taeniopteris* (cf. *T. parvula* Heer). The fruit as figured may entitle it to be included in the Marattiaceae, but it is so unlike the fruit of *Danaea* that it can hardly be placed in this genus. Several Carboniferous species were described originally under the name *Danaea*, but they have later and more correctly been referred to *Danaeites*, *Danaeopsis*, etc.

The Marattiaceae are supposed to be of very ancient lineage—in fact, up to a decade or so ago it was commonly believed that they formed a dominant element in the forests of the coal age, but with the discovery of the "ever-widening territory of the pteridosperms" they have been brought more or less in question. Arber says:

> The evidence, formerly regarded as beyond suspicion, that the eusporangiate ferns formed a dominant feature of the vegetation of the Paleozoic period has been undermined, more especially by the remarkable discovery of the male organs of *Lyginodendron* by Mr. Kidston. At best we can only now regard them as a subsidiary group in the epoch of the past history of the vegetable kingdom.

Even the reproductive organs are no longer decisive unless the seeds are found, for, as Seward says:

> We can not in most cases be certain whether the small sporangium-like bodies on fertile pinnules are true fern sporangia or the micro-sporangia of a heterosporous pteridosperm. What is usually called exannulate fern sporangium * * * has no distinguishing features which can be used as a decisive test. The microsporophylls of the Mesozoic Bennettitales produced their spores in sporangical compartments grouped in synangia like those of recent Marattiaceae.

The Pteridospermae so far as known disappeared with the end of the Paleozoic era, and the marattiaceous type was carried on to the present by sparsely represented forms, such as *Marratiopsis*, *Danaeopsis*, *Bernouillia*, and perhaps *Nathorstia* of the Lower Cretaceous of Greenland, and a supposed Tertiary species of *Marattia* (*M. hookeri* Gardner and Ettinghausen) from the Eocene of the Isle of Wight. It is therefore of interest to be able to add another step in the recorded progress from the Paleozoic to the present in the shape of an undoubted *Danaea* from the middle Eocene of America.

This specimen has been submitted to Mr. Wm. R. Maxon, of the United States National Herbarium, and he pronounces it unqualifiedly as referable to *Danaea*.

Occurrence: Green River formation, oil shale, Rio Blanco County, about 40 miles southwest of Meeker, Colo., collected by D. E. Winchester, 1917.

Order EQUISETALES.

Family EQUISETACEAE.

Equisetum wyomingense Lesquereux.

Equisetum wyomingense Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1873, p. 409, 1874; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 69, pl. 6, figs. 8–11, 1878.

Newberry, U. S. Geol. Survey Mon. 35, p. 15, pl. 65, fig. 8, 1898.

Lesquereux's description and figures of this species are rather vague and unsatisfactory. He states that the specimens are preserved on a large slab of very hard white shale, which is "covered with a profusion of fragments of the same plants, rootlets, rhizomes, stems crushed, pressed together, and rarely separated distinctly enough to clearly show their characters." He further states that the stems and rhizomes are equally and regularly striate, and the "sheaths are dentate on the borders, and short." The stems and rhizomes are of equal size, about half a centimeter in width.

Newberry figures a single stem from Green River under Lesquereux's name but makes no comment or comparison in the text. The figured specimen is a fragment of stem about 6 centimeters long and 0.5 centimeter wide and shows three sheaths with some 10 or 12 slender, sharp-pointed teeth. It is difficult to determine whether this is really the same as Lesquereux's *Equisetum wyomingense*, but it perhaps is best left as at present pending additional information.

[41] Racyborski, Maryjan, Pamietnik Akad. Umiejetn., vol. 18, p. 155, pl. 6, figs. 1–6, 1894.

Occurrence: Green River formation, type found 3 miles east of Green River, Wyo.; Newberry's specimen from Green River.

Phylum SPERMATOPHYTA.

Class ANGIOSPERMAE.

Subclass MONOCOTYLEDONES.

Order GRAMINALES.

Arundo reperta Lesquereux.

Arundo reperta Lesquereux, U. S. Geol. and Geog. Survey Terr. Bull., vol. 1, p. 384, 1875 [1876]; idem, Ann. Rept. for 1874, p. 311, 1876; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 87, pl. 8, figs. 6–8, 1878.

This species, it seems to me, is very unsatisfactory, and the propriety of recognizing it is doubtful. It was described by Lesquereux as follows:

> Stem thick, distinctly articulate; surface striate, marked with round obtuse knots, either placed at the articulation or here and there scattered upon the stem; fruiting panicle crushed, oval-oblong, bearing ovate-lanceolate seeds, and pallets mixed with a coating of hairs.

All the figured types of this form are in the United States National Museum (Nos. 96, 119) and are before me. The stem is striate, as described, and was apparently circular in cross section before it was entombed but is now much flattened. It may have been a hollow reedlike stem, but it also suggests a decorticated branch of a tree. The so-called articulation is only a check or crack filled with mud and thus simulating a joint. The "knots" are difficult to interpret. There are two in line with the axis of the stem, and they are about 7 millimeters in diameter and some 3 millimeters high. They seem to rest on and hardly to be a part of the organic structure of the stem—in fact, they have much the appearance of being little mud balls that happened to lodge on the specimen.

The specimen described as an underground stem is apparently correctly placed—that is to say, the scars, which occur at fairly regular intervals, are clearly the scars of roots or rootlets. The type specimen is fully 18 centimeters long and shows little diminution in size.

The cluster of seeds, although seemingly quite complete as depicted in the drawing, are really so obscure and fragmentary as to be almost impossible of accurate determination. A few of the specimens have somewhat the appearance of the palets of a large grass, but I should hesitate to say positively that this is their nature.

There is also little basis for supposing that these several organs are really parts of one species of plant. They are, indeed, associated on the same piece of matrix, but there is no positive evidence of former organic union.

With the above strictures this form is left as last revised by Lesquereux, but with the frank admission that it is seemingly of very little biologic or stratigraphic value.

Occurrence: Green River formation, Green River, Wyo., above the fish beds.

Family CYPERACEAE.

Cyperus chavannesi Heer.

Cyperus chavannesi Herr, Flora tertiaria Helvetiae, vol. 1, p. 72, pl. 22, fig. 7; pl. 28, fig. 1, 1855.

Cyperus "chavanensis"? Heer. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, p. 291, 1872; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 92, pl. 9, figs. 1, 2, 1878.

Lesquereux first mentioned this species as coming from Evanston, Wyo., "below the coal." Later, in the "Tertiary flora," it was given as coming from Green River, Wyo., and one of the figured specimens (pl. 9, fig. 1, U. S. Nat. Mus. No. 122) is in the United States National Museum. It is a mere fragment from the middle area of a large leaf and must be considered as doubtfully the same as the European type.

Occurrence: Green River formation, Green River, Wyo.

Cyperacites haydenii (Lesquereux) Knowlton.

Cyperacites haydenii (Lesquereux) Knowlton, U. S. Geol. Survey Bull. 152, p. 83, 1898.

Cyperites haydenii Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 140, pl. 23, figs. 1–3a, 1883.

The types of this species are preserved in the United States National Museum (Nos. 1565, 1569). It has been well described and figured by Lesquereux.

Occurrence: Green River formation, Uinta (formerly incorrectly given as Randolph) County, Wyo.

Order ARECALES.

Family ARECACEAE.

Geonomites haydenii (Newberry) Knowlton, n. comb.

Manicaria haydenii Newberry, U. S. Nat. Mus. Proc., vol. 5, p. 504, 1883; U. S. Geol. Survey Mon. 35, p. 31, pl. 64, fig. 3, 1898.

The following description was given by Newberry:

Frond large, leaves pinnately plicated, folds 1.5 centimeters in width above, slightly narrowed below; flat or gently arched, smooth, springing from the midrib at an angle of 25°, 30° below; folds attached to the midrib [rachis] obliquely by the entire width, and to each other by their entire length (?); nervation fine, uniform (?), parallel.

This Green River palm is very imperfectly known—in fact, the only specimen I have seen is the type as figured by Newberry (U. S. Nat. Mus. No. 7016). It is impossible to determine the position of this fragment in relation to the whole leaf, though from its size as compared with leaves from other localities believed to be congeneric with it, it was probably from the middle or lower portion.

Newberry was frank to state in the discussion of his *Manicaria haydenii* that it certainly belongs to the same genus as Lesquereux's *Geonomites tenuirachis*,[42] and with this statement I am inclined to agree. I have figured[43] a much larger and far more nearly complete specimen of *Geonomites tenuirachis*, from the Raton formation, than Lesquereux's type, and from this it is fairly clear that the type specimen is a small segment from the upper portion of the leaf. I can see no characters by which this Green River palm can be excluded from *Geonomites*, and consequently I have transferred it to this genus. It seems closer to *Geonomites tenuirachis* than to *Manicaria formosa* Heer,[44] from the Swiss Miocene, with which Newberry compared it—in fact, it would be difficult with the scant material available to separate them specifically. However, as they are so imperfectly known, and as there is so much difference in their stratigraphic position, it is perhaps best to regard *Geonomites haydenii* as distinct until its status can be settled with better material.

Occurrence: Green River formation, Green River, Wyo.

Sabal powellii Newberry.

Sabal powellii Newberry, U. S. Nat. Mus. Proc., vol. 5, p. 504, 1882 [1883]; U. S. Geol. Survey Mon. 35, p. 30, pl. 63, fig. 6; pl. 64, figs. 1, 1a, 1898.

The following is Newberry's description:

Leaves of medium size, 4 or 5 feet in diameter, petiole smooth, unarmed, terminating above in an angular or rounded area from which the folds diverge beneath, concavely narrowing to form a spike 3 or 4 inches in length; rays about 50, radiating from the end of the petiole, perhaps 60 in the entire leaf, compressed to acute wedges where they issue from the petiole; strongly angled and attaining a maximum width of about 1 inch; nerves fine, about 12 stronger ones on each side of the keel, with finer intermediate ones too obscure for enumeration.

Although the remains of palms are abundant in a number of Tertiary formations they are unusually difficult of satisfactory diagnosis. Their large size, the fragmentary state in which they are usually collected, and the lack of good diagnostic characters in the leaves make their identification more or less uncertain. The allocation of *Sabal powellii* is a case in point. In his discussion Newberry points out that it bears considerable resemblance to *Sabal? eocenica* (Lesquereux) Knowlton (formerly *Flabellaria eocenica*) as figured by Lesquereux,[45] differing in having a larger number of folds and a longer point of support on the under side of the leaf. Newberry also compares his species to *Sabalites grayanus* (Lesquereux) Lesquereux, but this has been since divided. The type locality was the Wilcox group of the Gulf region, and the name *Sabalites grayanus* is retained for this form, which has also been reported from the Laramie, Lance, and Raton formations. The large leaves, which are evidently the ones Newberry had in mind, mainly from the Montana group, have been separated under the name *Sabal? montana* Knowlton.[46] Although this species is still imperfectly known it seems to be distinguishable by its very large size, being perhaps the largest palm in the Rocky Mountain region, and by the greater number of folds (about 90).

Sabal grandifolia Newberry[47] is another large-leaved palm that may be compared with *Sabal powellii*. It has nearly twice the number of folds.

Occurrence: Green River formation, Green River, Wyo.

[42] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 117, pl. 11, fig. 1, 1878.

[43] Knowlton, F. H., U. S. Geol. Survey Prof. Paper 101, p. 291, pl. 62, 1917.

[44] Heer, Oswald, Flora tertiaria Helvetiae, vol. 1, pl. 38, 1856.

[45] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), pl. 13, figs. 1–3, 1878.

[46] Knowlton, F. H., U. S. Geol. Survey Prof. Paper 101, p. 253, pl. 32, fig. 3, 1918.

[47] Newberry, J. S., U. S. Geol. Survey Mon. 35, p. 28, pl. 25; pl. 63, fig. 5 (not pl. 64, figs. 2, 2a), 1898.

Flabellaria florissanti Lesquereux.

Flabellaria florissanti Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 144, pl. 24, figs. 1–2a, 1883.

The following is Lesquereux's characterization of this species:

Fronds large; rays diverging all around from the top of the long, nearly flat, unkeeled rachis; rays large, very numerous, acutely keeled; primary nerves distinct; close intermediate veinlets three or four.

Lesquereux did not give any actual dimensions, and the two figured types are all of the original material now known to be extant. Subsequently, however, L. F. Ward collected extensively at Green River station, at a point known locally as Bell's fish cliff, and procured some very large palm leaves that in all reasonable probability are the same as Lesquereux's species. It must have been at least 5 feet in diameter and has the same rather slender petiole as the figured type. Our specimen includes the outer edge of the leaf and shows that the rays are split apart for a distance of at least 20 centimeters.

Occurence: Green River formation [types], Uinta (formerly incorrectly called Randolph) County, Wyo.; Bell's fish cliff, Green River, Wyo., collected by L. F. Ward.

Order XYRIDALES.

Family PONTEDERIACEAE.

Genus PONTEDERITES Knowlton, n. gen.

Pontederites hesperia Knowlton, n. sp.

Plate XXXVI, figure 6.

Although it is perhaps more or less hazardous to base a new genus on a single fragment, the present one seems so distinct that it merits at least temporary characterization until more complete material can be procured. It is the well-preserved upper part of a leaf that was presumably broadly ovate below and rather abruptly narrowed above into a deltoid-lanceolate apical portion, 1 centimeter wide at the base, 2 centimeters long, and acute at the tip. The length of the part preserved is 8 centimeters and the width about 5 centimeters. The total length was presumably not less than 12 or 15 centimeters. It is unfortunate that the shape of the base is unknown. The nervation consists of numerous close, mainly parallel veins that arise from a slightly enlarged midvein which is reduced in the apical portion to the same size as the other veins. Those that can be seen arise from the midvein at a very acute angle—about 80°—but in the lower portion they are closer together and apparently arise at a less acute angle. The veins spread in the broad portion of the blade, then approach again in the upper part, where some of them terminate, only about a dozen passing into the reduced apical portion. A few intermediate veins come up from the lower portion of the blade and die out above, but so far as can be ascertained there are no fine intermediate veinlets, or at least but faint traces of them. There are, however, numerous cross veinlets, mainly at right angles to the veins.

This leaf appears to resemble most closely the leaves of *Pontederia cordata* Linné, the well-known pickerel weed, which grows on the borders of ponds and streams from Nova Scotia to Minnesota and south to Florida and Texas. In the living plant the thick, petioled leaves are ovate, cordate-sagittate, and 5 to 20 centimeters long, with the basal and apical lobes rounded. It has a fairly distinct midrib in the lower portion, but this disappears above. It is, of course, much to be regretted that the basal portions of these leaves can not be compared, but such a comparison must await more nearly perfect specimens. So far as the available material goes I can see no essential difference between the fossil and the living forms, and the name given to the genus brings out this point.

The fossil has some resemblance to certain forms that have been referred to *Canna*, such as *Canna eocenica* Berry,[48] from the Wilcox group of the Gulf region, but this is more nearly lanceolate, with no contraction into the reduced apical portion. The midrib is also stronger in *Canna eocenica*.

The only other Green River monocotyledon with which it could possibly be compared is *Musophyllum complicatum* Lesquereux,[49] but this is of a totally different character.

Under the name *Zingiberites dubius* Lesquereux[50] described a fragment from the Denver formation of Colorado, but this is too much broken to give any reliable conception of its

[48] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, p. 181, pl. 15, figs. 7, 8, 1916.

[49] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 96, pl. 15, figs. 1–6, 1878.

[50] Idem, pl. 16, fig. 1.

form and size, and hence it can not be compared with the present form.

Occurrence: Green River formation, Greasewood Creek, Rio Blanco County, 40 miles west of Meeker, Colo., collected by D. E. Winchester, 1917.

Order **LILIALES.**

Family **JUNCACEAE.**

Juncus sp. Lesquereux.

Juncus sp. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, Suppl., p. 6, 1872.

Lesquereux says:

Fragments of stems of various sizes, like *Juncus retractus* Heer, or *Juncus scheuzeri* Heer, in Flora tertiaria Helvetiae, pl. 30, figs. 2e, 3c.

These specimens are not known to be in existence, and the species should probably be discarded.

Occurrence: Green River formation, Green River, Wyo.

MONOCOTYLEDONAE OF UNCERTAIN POSITION.

Musophyllum complicatum Lesquereux.

Musophyllum complicatum Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1873, p. 418, 1874; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 96, pl. 15, figs. 1–6, 1878.

Most of the type material on which this species is based is preserved in the United States National Museum (Nos. 132–135). It is very obscure and difficult to interpret, and on this point Lesquereux said:

The exact character of these leaves, especially their form, their size, and their relation to the main stem, or stipe, is very obscure. I have found a bed of shale nearly 1 foot thick filled entirely with fragments of this species and have worked a whole day with a miner, trying, without avail, to get specimens more definite than those which are figured here. Large pieces of shale are covered with fragments of leaves, folded in various ways, where no trace of any middle nerve may be discovered. This proves the large size of the leaves.

As nearly as can be made out it may be described as follows: Stem or stipe very stout, at least 3 centimeters in width, longitudinally wrinkled and striate. Leaves large, with a thick irregularly veined midrib 1 centimeter or more in width. Veins of the leaf numerous, thin but distinct, mainly simple but occasionally dichotomous, especially toward the margins.

Occurrence: Green River formation, 8 miles southeast of Green River station, Wyo.

Subclass **DICOTYLEDONES.**

Order **SALICALES.**

Family **SALICACEAE.**

Salix linearis Knowlton, n. sp.

Plate XXXVII, figure 8.

Leaf very small, linear-lanceolate, 3.5 centimeters long, 5 millimeters broad, with a petiole 5 millimeters long; margin with a few rather remote teeth; midrib very strong; secondaries as many as the teeth, which they enter, arising at an angle about 40°, little curved upward; finer nervation not discernible.

This little leaf is also the only one of its kind observed in the collections. It is perhaps hazardous to characterize a new *Salix* on a single leaf, but it differs so clearly from any other in the collection that it is presented with the reservation that it may be shown to belong elsewhere when more material is available.

Among living species this strongly resembles a small leaf of *Salix fluviatilis* Nuttall, the well-known sand-bar or river-bank willow, which ranges from Quebec to Oregon and south to Virginia, Kentucky, and New Mexico. There is no fossil species, at least from the Green River, that could be confused with this.

Occurrence: Green River formation, Rio Blanco County, 20 miles west of Rio Blanco post office, Colo. (sec. 33, T. 4 S., R. 100 W.), collected by D. E. Winchester, 1917.

Salix longiacuminata Knowlton, n. sp.

Leaves thin but firm in texture, lanceolate, broadest a short distance above the base, whence it is gradually narrowed to a long, slenderly acuminate apex and to a wedge-shaped base; margin slightly irregular though scarcely to be called toothed; length 9 or 10 centimeters, width 1.2 centimeters; petiole slender, about 1.75 centimeters long; midrib relatively very strong, especially in the lower third; secondaries numerous, arising at various angles, in the lower part falling below a right angle, then many nearly at a right angle, and finally some at an angle of perhaps 20°; all secondaries curved and each joining the one next above, forming a series of loops just within the margin; intermediate secondaries numerous; finer nervation irregularly quadrangular.

The only specimen found in the collections, a nearly perfect leaf, seems well characterized by its long, slenderly acuminate apex, thick

midrib, and very numerous secondaries, which arise at various angles and by joining form a series of bows well inside the margin.

This leaf is not greatly different in size and shape from leaves referred by Lesquereux [51] to *Salix angusta*, though it is more slenderly acuminate, but it differs wholly in the secondary nervation. Thus, in *Salix angusta* the secondaries are numerous, close, parallel, and little curved upward, whereas in the present species the secondaries are more remote and by joining form a series of loops.

Among other fossil species the present one resembles in nervation *Salix arcinerva* Heer,[52] from the Swiss Miocene, but that species differs in shape and has the margin finely toothed. It also resembles in shape and somewhat in nervation *Salix longa* Heer,[53] from the same area, but that species is much larger and its secondaries do not form loops.

Occurrence: Green River formation, Rio Blanco County, 20 miles west of Rio Blanco post office, Colo. (sec. 33, T. 4 S.; R. 100 W.), collected by D. E. Winchester, 1917.

Salix sp.

Plate XXXVII, figures 3–5.

The collection made by Winchester includes a number of small leaves that appear to belong to *Salix*, though the nervation is so obscure that this assignment is not certain. They are linear-lanceolate leaves, 3.5 to about 6 centimeters long and 6 to 10 millimeters wide, and have a petiole 5 or 6 millimeters long. They are narrowed to a wedge-shaped base and are rather obtuse at the apex. The margin is perfectly entire. The nervation, with the exception of a relatively very strong midrib, is obscure but appears to consist of numerous thin secondaries at an angle of 35° or 40° that are camptodrome and arch just inside the margins; none of the finer nervation is observable.

Considering the uncertainty regarding these leaves it seems hardly worth while to attempt comparisons with either living or fossil species. Small, narrow, entire willow leaves are so nondescript that it is difficult to be sure of their subsequent recognition, and for this reason the present form has not been given a specific designation.

[51] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), pl. 22, fig. 4, 1878.

[52] Heer, Oswald, Flora tertiaria Helvetiae, vol. 2, pl. 65, figs. 4, 5, 1856.

[53] Idem, pl. 69, figs. 12, 13.

Occurrence: Green River formation, Rio Blanco County, about 40 miles southwest of Meeker, Colo., collected by D. E. Winchester, 1917.

Salix sp.

Salix media Heer. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, Suppl., p. 6, 1872; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 168, pl. 22, fig. 3, 1878.

The specimen on which Lesquereux based the presence of *Salix media* Heer in American beds is in the United States National Museum (No. 198). It is a small leaf about 7 centimeters long and lacks most of one side and the tip. It is without a trace of nervation except a strong midrib, though secondaries have been added in the figure given in the "Tertiary flora." The leaves from the Swiss Miocene referred by Heer [54] to *Salix media* are all mostly without nervation except the midrib, and of course it is easy to match the American leaf with one of these, but such a comparison is obviously without value.

In the Museum collection there is another leaf not figured that was identified by Lesquereux as *Salix media*—in fact, it is recorded under the same number (198) as the other—but it is a long, narrow leaf with obscurely preserved nervation in which a small portion is so preserved as to show an intramarginal vein, as in *Eucalyptus? americana*, and it should be referred to that species.

As the leaf figured by Lesquereux is so obscure it is here removed from *Salix media* and regarded as *Salix* sp.

Occurrence: Green River formation, Green River, Wyo.; also reported from Elko, Nev.

Order MYRICALES.

Family MYRICACEAE.

Myrica salicina Unger.

Myrica salicina Unger, Genera et species plantarum fossilium, p. 396, 1850.

Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, Suppl., p. 6, 1872.

The status of this species is doubtful. It was identified by Lesquereux under the above name, but the specimen on which the identification was based is lost or merged with something else without a record of such transfer. It was neither figured nor again referred to by Lesquereux.

Occurrence: Green River formation, Green River, Wyo.

[54] Heer, Oswald, Flora tertiaria Helvetiae, vol. 2, pl. 68, figs. 14–19, 1856.

Myrica minuta Knowlton, n. sp.

Plate XXXVII, figure 12.

Leaves coriaceous or at least firm in texture, linear-lanceolate, prolonged above to a slender acuminate apex and scarcely less so below to the narrowly wedge-shaped base; margin entire for the lower third, thence rather strongly toothed, the teeth moderately sharp; midrib relatively strong; secondaries numerous, thin, at an angle of about 40°, slightly curved upward, ending in the margin in the lower untoothed portion and in the teeth in the middle and upper portion.

This little leaf, the only one observed, is about 18 millimeters long and 3 millimeters wide and has a delicate petiole 1 millimeter long. It is evidently rather thick, as the secondary nervation is faintly visible.

This species is of the same type as *Myrica scottii* Lesquereux, from the Florissant lake beds, but it is only one-fourth the length of that species and has rather blunt instead of very sharp teeth.

Occurrence: Green River formation, oil shale, Smith ranch, on Greasewood Creek, about 40 miles southwest of Meeker, Colo., collected by D. E. Winchester, 1917.

Myrica praedrymeja Knowlton, n. sp.

Plate XXXVI, figures 1–3.

Leaves small, firm in texture, lanceolate, acuminate at apex, rounded below, with the sides of the leaf at angles of about 45°, slightly unequal sided; margin entire for a short distance, thence with numerous rounded teeth; petiole short, stout; midrib relatively very strong, straight; secondaries numerous, 18 or 20 pairs, alternate, close, parallel, little curved upward, ending in the teeth; finer nervation obsolete.

This species is represented by a number of specimens, and three of the most nearly perfect ones are figured. They are 4 or 5.5 centimeters long and about 1.2 centimeters wide, with the petiole at least 4 millimeters long. This species is very closely similar to *Myrica callicomaefolia* Lesquereux[55] (now *Myrica drymeja* (Lesquereux) Knowlton), from the Florissant lake beds—in fact, they may be identical. *M. praedrymeja* differs slightly, however, in having the marginal teeth obtuse or rounded instead of sharp-pointed and a stronger nervation. These differences are not marked, and a fuller series might readily show them breaking down.

Occurrence: Green River formation, oil shale, Smith ranch, on Greasewood Creek about 40 miles southwest of Meeker, Rio Blanco County, Colo., collected by D. E. Winchester, 1917.

Myrica ludwigii Schimper.

Myrica ludwigii Schimper, Paléontologie végétale, vol. 2, p. 545, 1872.

Lesquereux, U. S. Geol. and Geog. Survey Terr. Bull., vol. 1, p. 385, 1875 (1876); idem, Ann. Rept. for 1874, p. 311, 1876; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 133, pl. 65, fig. 9, 1878.

The single broken leaf figured is all there is to represent this species, and this is now lost. Its status is therefore rather unsatisfactory, but it will have to stand as above until further material can be procured.

Occurrence: Green River formation, mouth of White River (emptying into Green River), Wyo.

Myrica sp.

Plate XXXVII, figure 2.

Winchester's collection contains a fragment that evidently belongs to *Myrica*, but it is so deficient that I have not given it a specific name. It is a fragment 2.5 centimeters long and 0.5 centimeter wide, of the upper part of a linear-lanceolate, sharply acuminate leaf. The margin in the lower part is nearly entire, with only an occasional tooth, but in the upper part it is provided with low, obtuse, irregularly spaced teeth. The nervation consists of a relatively strong, straight midrib and very numerous secondaries that arise at a low angle and curve slightly in passing to the borders, which most of them seem to enter. These secondaries are somewhat irregularly placed; the finer nervation is not observable.

This form has the same type of nervation as *Myrica nigricans* Lesquereux, but it differs in the narrowly lanceolate, acuminate, irregularly toothed blade.

Occurrence: Green River formation, Cathedral Bluff, south of Little Tommies Draw, 20 miles west of Rio Blanco post office, Rio Blanco County, Colo., collected by D. E. Winchester, 1917.

[55] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 146, pl. 26, figs. 5–14, 1883.

Myrica sp.

Plate XL, figure 13.

In the Winchester collection I find the single specimen here figured, which seems to be different from any other noted. It is coriaceous in texture, narrowly lanceolate, prolonged above into an acute apex (base destroyed). It was probably 9 or possibly 10 centimeters long and about 13 millimeters wide. The margin is remotely toothed, the teeth low and rather obtuse. The nervation consists of a very strong, straight midrib and numerous pairs of mainly alternate secondaries which arise nearly at right angles to the midrib, considerably curved upward and ending in the teeth or in the margin; finer nervation not well preserved.

This somewhat resembles what Lesquereux called *Myrica nigricans* [56] (now *Rhus nigricans*), but it is longer and more narrowly acuminate, and has fewer secondaries. It is even closer to *Myrica ludwigii* Schimper, as identified by Lesquereux [57] from the mouth of White River, Wyo., but that species is shorter and broader and has very large marginal teeth and different secondary nervation.

Occurrence: Green River formation, head of Carr Creek, Garfield County, Colo., 30 miles northwest of De Beque, collected by D. E. Winchester, 1917.

Comptonia? anomala Knowlton, n. sp.

Plate XXXVII, figure 1.

Leaf small, sessile, 2 centimeters long, 6 millimeters wide; coriaceous; lanceolate, obtuse and rounded at apex, strongly unequal-sided at base; margin strongly undulate-toothed, the teeth low and rounded; midrib very strong for the size of the leaf; secondaries thin, opposite or nearly so, at a low angle, very little curved upward, ending in the marginal undulations; intermediate secondaries occasional; finer nervation obsolete.

It is with grave doubt that this little leaf is referred to the genus *Comptonia*. In the undulate-toothed margin and in nervation it seems identical with this genus, but the strongly unequal-sided base suggests that it is a leaflet and not a distinct leaf. However, I have not thus far been able to place it satisfactorily in any genus with compound leaves, and temporarily it is referred to *Comptonia*. It is so strongly marked that it can easily be recognized in future and perhaps more correctly placed when opportunity offers.

Occurrence: Green River formation, Smith ranch, on Greasewood Creek, about 40 miles southwest of Meeker, Rio Blanco County, Colo., collected by D. E. Winchester, 1917.

Order JUGLANDALES.

Family JUGLANDACEAE.

Juglans occidentalis Newberry.

Juglans occidentalis Newberry, U. S. Nat. Mus. Proc., vol. 5, p. 507, 1882 [1883]; U. S. Geol. Survey Mon. 35, p. 34, pl. 65, fig. 1; pl. 66, figs. 2–4 [not pl. 66, fig. 1], 1898.

Juglans schimperi Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), pl. 56, figs. 7, 8, 10 [not figs. 5, 6, 9, which remain under *Juglans schimperi*], 1878.

Hollick, Louisiana Geol. Survey Special Rept. 5, p. 280, pl. 33, fig. 1; pl. 25, fig. 3 [not pl. 32, fig. 5?; pl. 33, fig. 2, which remain under *Juglans schimperi*], 1899.

Berry, U. S. Geol. Survey Prof. Paper 91, p. 182, pl. 18, figs. 3, 5 [not pl. 18, fig. 4, which remains under *Juglans schimperi*], 1916.

Knowlton, U. S. Geol. Survey Prof. Paper 101, pl. 64, fig. 1, 1918.

Leaves supposedly pinnate; leaflets somewhat variable in form and size, from about 8 to 18 centimeters in length, 3 to 6 centimeters wide, generally about 15 centimeters long and 4 centimeters wide, broad lanceolate, broadest near the middle, summit acute, base rounded, unsymmetrical; margin entire; midrib very strong, straight; secondaries numerous, about 20 pairs, rather slender, at a low angle of emergence, slightly curved upward, camptodrome, forming a series of bows or loops along the margin; finer nervation not well retained, but nervilles mainly oblique to the secondaries and unbroken.

Juglans occidentalis was named and described by Newberry in 1883 but was not figured until the publication of his "Later extinct floras" in 1898. He stated that there were a large number of specimens in the collection submitted to him, some of which "are found attached to the stems that bore them, but generally separated and more or less torn and broken. The tree was evidently a strong-

[56] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 132, pl. 17, figs. 9–12, 1878.

[57] Idem, pl. 65, fig. 9.

growing and luxuriant one, for some of the leaves are not less than 8 inches in length."

Newberry called attention to the fact that his specimens were from the same locality as that which furnished the leaves described by Lesquereux as *Juglans schimperi* but concluded that the two were not identical, because Lesquereux had described *Juglans schimperi* as long, narrow leaves, broadest near the base and with a camptodrome nervation, whereas Newberry stated that in *Juglans occidentalis* "a large part of the lateral nerves terminate in the margins, and the tertiary nervation is more open and irregular."

The figured types of both species are before me and disclose that Newberry was wrong in saying that a large part of the nerves terminate in the margins in his species; they are all camptodrome and form loops along the margin, exactly as described by Lesquereux for his *Juglans schimperi*. This character therefore fails, and the only way of distinguishing them is by the long, narrow, sharp-pointed leaflets with a rounded equal-sided base and slightly more acute-angled secondaries in *Juglans schimperi*, and the broader, less acuminate leaflets with unequal-sided base and very low-angled secondaries in *Juglans occidentalis*. But, as pointed out in the discussion of *Juglans schimperi* below, the possibility should be considered that the leaflets now allocated to *Juglans schimperi* may be terminal leaflets, and if so all would naturally have to be included under Lesquereux's species. It is also pointed out in the discussion of *Juglans schimperi* that the disposition mentioned makes necessary certain transfers of figures from one to the other. Thus, those of Lesquereux's types of *Juglans schimperi* will go to *Juglans occidentalis*. All but two of the leaflets identified by Hollick as *Juglans schimperi* from the Wilcox group will go to *Juglans occidentalis*, as indicated in the above synonymy. These figures as reproduced by Berry in his paper on the Wilcox flora will have the same disposition, and the leaflets from the Raton flora that I identified as *Juglans schimperi* will also find place under *Juglans occidentalis*.

Occurrence: Green River formation, Green River, Wyo. Wilcox group, Louisiana and Mississippi. Raton formation, northeastern New Mexico and southeastern Colorado.

Juglans schimperi Lesquereux.

Juglans schimperi Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, Suppl., p. 8, 1872; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 287, pl. 56, figs, 5, 6, 9 [not figs. 7, 8, 10, which=*Juglans occidentalis* Newberry], 1878.

Hollick, Louisiana Geol. Survey Special Rept. 5, p. 280, pl. 32, fig. 5?; pl. 33, fig. 2 [not pl. 33, fig. 1; pl. 35, fig. 3, which=*Juglans occidentalis* Newberry], 1899.

Berry, U. S. Geol. Survey Prof. Paper 91, p. 182, pl. 18, fig. 4; pl. 19, fig. 4? [not pl. 18, figs. 3, 5, which=*Juglans occidentalis* Newberry], 1916.

Leaves firm in texture, pinnately compound, leaflets lanceolate, 8 to 14 centimeters long, 2 to 3.5 centimeters wide, broadest near the abruptly rounded and equal-sided base, tapering to a long, slender point above; margin entire, slightly undulate; petiolule very short; midrib very strong, straight; secondaries numerous, about 18 pairs, rather thin, emerging at angles of 40° to 50°, close, parallel, slightly curved in ascending to the middle of the area, but more and gradually curved on nearing the margin, which they closely follow in simple bows; secondaries connected by close, distinct nervilles, generally at right angles to them.

Juglans schimperi was named and described by Lesquereux in 1872 but was not figured until the publication of the "Tertiary flora" in 1878. Six specimens were figured as the types, and all are in the United States National Museum and are before me. Although several of the specimens are fragmentary, it has long seemed to me that they show differences that might amount to specific distinctness, but they have never before been very critically examined. Three specimens (Tertiary flora, pl. 56, figs. 5, 8, 9) are long, narrowly acuminate leaflets with an equal-sided base, whereas the others (figs. 7, 8, 10) are markedly unequal-sided at the base and have the secondaries at a much lower angle.

A few years later Newberry studied a large number of very well preserved leaves from the same locality (Green River, Wyo.) that had supplied Lesquereux's types of *Juglans schimperi*. These Newberry [58] described and figured under the name *Juglans occidentalis*. It needs but a glance to show that so far as the base of the leaflets is concerned *Juglans occidentalis* is absolutely identical with the three figures

[58] Newberry, J. S., U. S. Geol. Survey Mon. 35, p. 34, pl. 65, fig. 1; pl. 66, figs. 1-4c, 1898.

above mentioned (figs. 7, 8, 10) of Lesquereux's *Juglans schimperi*, and the question immediately arises as to the disposition that is to be made of the various forms. If all the specimens figured by Lesquereux as types of his *Juglans schimperi* are considered as conspecific, then Newberry's *Juglans occidentalis* must be referred to it. However, it seems best to regard *Juglans schimperi* as a composite species and to retain the narrow, sharp-pointed leaflets with an equal-sided base and allocate them to Lesquereux's name, referring the unequal-sided specimens to *Juglans occidentalis*. The possibility is not to be lost sight of, however, that the narrow leaflets may be really terminal leaflets and hence would be likely to have an equal-sided base, but thus far no specimens have been found that show the leaflets attached.

The proposed splitting up of *Juglans schimperi* makes some complications with certain subsequent identifications. Thus, Hollick [59] referred a number of leaflets from the Wilcox group of Louisiana to *Juglans schimperi* Lesquereux. Of the four examples figured only one (pl. 33, fig. 2) appears to belong to Lesquereux's species as now restricted.

Hollick's figures above mentioned were republished by Berry [60] in his paper on the Wilcox flora, but only figure 4 of Plate XVIII is to be retained under *Juglans schimperi*, the others going to Newberry's species.

In my report on the flora of the Raton formation [61] I identified a single leaflet as *Juglans schimperi* on the basis of its resemblance to leaflets so identified by Hollick. This now becomes *Juglans occidentalis*.

Occurrence: Green River formation, Green River, Wyo. Wilcox group, Louisiana and Mississippi. Beds of Wilcox age, western Kentucky. Denver formation, Golden, Colo. Clarno formation (upper part), Bridge Creek, Oreg.

Juglans crossii Knowlton.

Juglans crossii Knowlton, U. S. Geol. Survey Bull. 152, p. 122, 1898.

Juglans denticulata Heer. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, p. 298, 1872; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 289, pl. 58, fig. 1, 1878. [Homonym, Weber, 1852.]

[59] Hollick, Arthur, Louisiana Geol. Survey Special Rept. 5, p. 280, pl. 32, fig. 5; pl. 33, figs. 1, 2; pl. 35, fig. 3, 1899.

[60] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, p. 182, pl. 18, figs. 3–5; pl. 19, fig. 4, 1916.

[61] Knowlton, F. H., U. S. Geol. Survey Prof. Paper 101, p. 296, pl. 64, fig. 1, 1918.

The first locality from which this species was identified by Lesquereux appears to have been the Bozeman coal field of Montana, in beds presumed to belong to the Livingston formation, but the only specimen figured in the "Tertiary flora" was obtained at Green River, Wyo., above the so-called fish beds. This specimen is in the United States National Museum (No. 482) and has been fairly well described and figured. This species has also been reported from the Hanna formation of Carbon, Wyo.

Juglans alkalina Lesquereux.

Juglans alkalina Lesquereux, U. S. Geol. and Geog. Survey Terr. Bull., vol. 1, p. 382, 1875 [1876]; idem, Ann. Rept. for 1874, p. 308, 1876; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 288, pl. 62, figs. 6–9, 1878.

Leaves pinnately compound; leaflets lanceolate, tapering upward to a long acumen, either narrowed or rounded to a short petiole; borders crenulate; lateral veins distant, mostly alternate, parallel, separated by short intermediate tertiary veins, curving in passing toward the borders at an open angle of divergence and ascending high along them in festoons; nervilles in right angle to the veins, branching in the middle, and forming by subdivisions irregularly quadrate or polygonal meshes.—Lesquereux.

Three of the four types of this species—figures 6, 7, and 8 of Plate LXII in the "Tertiary flora"—are preserved in the United States National Museum collections (Nos. 527–529).

Occurrence: Green River formation, Alkali stage station, 30 miles north of Green River, Wyo.

Juglans winchesteri Knowlton, n. sp.

Plate XXXVIII, figure 5.

Leaflet firm in texture, elliptical or ovate-elliptical, strongly unequal-sided, broadest near the middle, thence gradually narrowed to an apparently rather obtuse apex and downward to the rounded base; margin entire below, then obscurely toothed, the teeth low; petiole short, very thick and stout, curved; midrib very thick just above the petiole, very much thinner above; secondaries ten or twelve pairs, alternate, at irregular distances, arising at very low angles, much curved upward, camptodrome, sending slender branches to the marginal teeth; nervilles strong.

The specimen figured is the only one of this species noted. It is about 9 centimeters long and 4.5 centimeters wide. The petiole is 3 millimeters thick and about 8 millimeters long.

Occurrence: Green River formation, Rio Blanco County, 20 miles west of Rio Blanco post office, Colo. (sec. 33, T. 4 S., R. 100 W.), collected by D. E. Winchester, 1917.

Order FAGALES.

Family FAGACEAE.

Quercus castaneopsis Lesquereux.

Quercus castaneopsis Lesquereux, U. S. Geol. Survey Terr. Rept. vol. 8 (Cretaceous and Tertiary floras), p. 155, pl. 28, fig. 10, 1883.

Quercus castanoides Newberry, U. S. Nat. Mus. Proc., vol. 5, p. 506, 1883; U. S. Geol. Survey Mon. 35, p. 70, pl. 65, fig. 6, 1898.

Leaf firm in texture, lanceolate or narrowly ovate-lanceolate, 12 to 16 centimeters long, 2.5 to 6 centimeters wide, narrowly acuminate at the apex, rather abruptly rounded to a wedge-shaped base; margin remotely and somewhat irregularly set with coarse teeth, some of them spinous; nervation strong, the midrib especially so, straight; secondaries numerous, 18 or 20 pairs, unequally spaced, emerging nearly at right angles, slightly curved upward, all camptodrome, curving near the borders, following them and entering the short teeth by oblique nervilles; areolation of minute polygonal meshes.

This description is drawn from the type specimens of *Quercus castaneopsis* Lesquereux and *Quercus castanoides* Newberry, both of which are preserved in the United States National Museum (Nos. 1575 and 7044, respectively). Leaves obviously of the same species were described independently by Lesquereux and Newberry, but as Lesquereux's publication antedates that of Newberry by a few months his name is selected as the one the species is to bear. Both noted the resemblance to leaves of *Castanea* or *Castanopsis*, and curiously enough both selected almost identical specific names.

Occurrence: Green River formation, Uinta (formerly incorrectly called Randolph) County Wyo. (type of *Quercus castaneopsis* Lesquereux); Green River, Wyo. (type of *Quercus castanoides* Newberry).

Order URTICALES.

Family ULMACEAE.

Planera inaequilateralis (Lesquereux) Knowlton, n. comb.

Alnites inaequilateralis Lesquereux, U. S. Geol. and Geog. Survey Terr. Bull., vol. 1, p. 381, 1875 [1876]; idem, Ann. Rept. for 1874, p. 307, 1876; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 141, pl. 62, figs. 1–4, 1878.

Alnus inaequilateralis Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 151, 1883.

Planera variabilis Newberry, U. S. Nat. Mus. Proc., vol. 5, p. 508, 1882 [1883]; U. S. Geol. Survey Mon. 35, p. 83, pl. 66, figs. 5, 6 [not fig. 7], 1898.

Leaves evidently firm in texture, somewhat variable in size (4 to 8 centimeters long, 2.5 to 6 centimeters wide), broadly ovate or nearly oval, acute or rather obtusely acute at apex, strongly unequal-sided at the rounded or obtusely wedge-shaped base; margins crenulate-dentate; petiole short or absent; midrib strong, straight; secondaries mainly alternate, the lowest one on the broad side of the leaf usually with several outside branches, others considerably curved upward, ending in the low teeth or sending out minor branches that enter the teeth; nervilles at right angles to the secondaries, mainly unbroken.

This species as now accepted has had a rather complicated history. The original material was named and described, but not figured, by Lesquereux in 1875, under the name *Alnites inaequilateralis*. It was figured in the "Tertiary flora" (pl. 62, figs. 1–4) in 1878, but only two of the figured types (figs. 1 and 3) are now to be found in the collections of the United States National Museum. On the publication of the "Cretaceous and Tertiary floras," in 1883, Lesquereux changed the generic name to *Alnus*.

Subsequently C. A. White made a large collection of plants from the same region that had supplied Lesquereux's *Alnites* or *Alnus inaequilateralis*. This material was described by Newberry[62] in 1883 and contained several leaves that he named *Planera variabilis*. These were not figured, however, until 1898,[63] when it was at once apparent that at least two of his figured types (figs. 5, 6) were identical with Lesquereux's *Alnus inaequilateralis*.

Of course Lesquereux's specific name has priority, but a question arises as to the proper generic designation. It does not seem to me that these leaves can belong to *Alnus*, in which, so far as I know, the leaves are symmetrical at the base. I have transferred them to *Planera*, the genus adopted by Newberry, although it is to be admitted that they differ

[62] Newberry, J. S., U. S. Nat. Mus. Proc., vol. 5, p. 508, 1883.

[63] U. S. Geol. Survey Mon. 35, p. 83, pl. 66, 1898.

in some particulars from leaves of the monotypic living genus. The leaves of the living species, *Planera aquatica* Gmelin, are 5 or 6 centimeters long, 2 to 3 centimeters wide, unequally wedge-shaped or rounded at the base, and with the margins coarsely crenulate-serrate. They do not appear to have the lower secondary on the broad side of the leaf branched, but otherwise the difference is not great between these leaves and those of the fossil form under consideration.

Occurrence: Green River formation, Alkali stage station, Wyo. (type locality for *Alnus inaequilateralis* Lesquereux); Green River, Wyo. (type locality for *Planera variabilis* Newberry).

Family **MORACEAE.**

Ficus ungeri Lesquereux.

Ficus ungeri Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, Suppl., p. 7, 1872; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 195, pl. 30, fig. 3, 1878; idem, vol. 8 (Cretaceous and Tertiary floras), p. 163, pl. 44, figs. 1–3, 1883.

The type of this species is the specimen figured in the "Tertiary flora" (pl. 30, fig. 3) and is No. 265 in the United States National Museum; it is very well described and figured. It came from Green River, Wyo., where it was found above the so-called fish beds.

The specimens figured in the "Cretaceous and Tertiary floras" (pl. 44, figs. 1–3) are all in the Museum collection (Nos. 1598, 1599, 1600). They came from Alkali stage station, which is about 30 miles north of Green River, Wyo.

Occurrence: Green River formation, Green River, Wyo., above fish beds (type); Alkali stage station, 30 miles north of Green River, Wyo.

Ficus wyomingiana Lesquereux.

Ficus wyomingiana Lesquereux, U. S. Geol. and Geog. Survey Terr. Bull., vol. 1, p. 387, 1875 [1876]; idem, Ann. Rept. for 1874, p. 314, 1876; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 205, pl. 33, fig. 3, 1878.

The type and so far as known the only specimen of this species thus far found is in the United States National Museum collection (No. 289). It is fragmentary, lacking all of the upper portion and much of one side. As Lesquereux has said, this leaf is strikingly similar in general appearance to *Ficus pseudo-populus* Lesquereux, which was described from material collected at Evanston, Wyo., and which has since been found abundantly in the Raton formation of eastern Colorado and northeastern New Mexico and the Wilcox group of the Gulf region. It differs, however, in having the lateral ribs running nearly or quite to the apex of the blade and in the absence of any secondary branches, the space between the midrib and the lateral ribs as well as between the ribs and the margin being filled with numerous fine nervilles, which are nearly at right angles to the midrib.

Occurrence: Green River formation. Green River, Wyo.

Ficus tenuinervis Lesquereux.

Ficus tenuinervis Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 164, pl. 44, fig. 4, 1883.

This is a mere fragment of the basal part of a leaf that Lesquereux says is "oblong, or lanceolate, tripalmately nerved, rounded at base, entire." As it stands it is of comparatively little value, for it probably could not be identified again.

Occurrence: Green River formation, Alkali stage station, about 30 miles north of Green River, Wyo.

Order **PROTEALES.**

Family **PROTEACEAE.**

Lomatia? microphylla Lesquereux.

Lomatia microphylla Lesquereux, U. S. Geol. and Geog. Survey Terr. Bull., vol. 1, p. 389, 1875 [1876]; idem, Ann. Rept. for 1874, p. 346, 1876; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 211, pl. 65, figs. 14, 15, 1878.

Described by Lesquereux as follows:

Leaves very small, coriaceous, entire, linear-lanceolate, gradually narrowed from the middle to a point and in the same degree to the base; secondary veins simple, abruptly curving near the borders and following them or entering a marginal band.

The two figured specimens on which this species is based are not now known to be in existence. The smaller is about 2 centimeters long and the larger one only 3 centimeters long; the width is 2 to 4 millimeters.

The generic reference of these little leaves is extremely uncertain. It is to be doubted if they are correctly placed in *Lomatia*, though they somewhat resemble certain forms from the Swiss Miocene so referred by Heer. They suggest leaflets of *Mimosites*, of *Sophora*, or of *Sapindus*, such as *Sapindus angustifolius* Lesquereux.

Occurrence: Green River formation, near mouth of White River (emptying into Green River), Wyo.

Order THYMELEALES.

Family LAURACEAE.

Oreodaphne viridiflumensis Knowlton, n. sp.

Plate XXXVIII, figure 6.

Leaf coriaceous in texture, lanceolate, long wedge-shaped at the base, probably about equally narrowed above, about 12 centimeters long, 3 centimeters wide; margin perfectly entire; petiole very strong, 1 centimeter long, over 2 millimeters thick; midrib straight, very thick below and in the middle of the leaf but becoming thin above; secondaries somewhat irregular, lowest pair subopposite, thin, at an angle of about 40°, each running up for some distance and joining the secondary next above by a broad loop; next secondaries alternate, much stronger, each joining the one above by a loop far inside the margin, then with a series of large bows on the outer side; other secondaries similar, alternate, with a few intermediate secondaries joining the primary ones; nervilles very numerous, mostly broken, forming large rectangular areas, and filled with irregularly quadrangular areas and these again with still finer nerves.

This is a very fine species, but unfortunately it is represented by only the lower half of a leaf, though this is absolutely perfect. It may be known by its narrowly lanceolate shape, short, very thick petiole, unusually thick midrib, and the peculiar arching and branching secondaries.

In shape and size this species seems nearest to *Oreodaphne salinensis* Berry,[64] from the Wilcox group of Arkansas, but it differs in nervation, especially in the secondaries.

Occurrence: Green River formation, Rio Blanco County, about 40 miles southwest of Meeker, Colo., collected by D. E. Winchester, 1917.

Pimelea spatulata Knowlton, n. sp.

Plate XXXVII, figure 6

Leaf apparently firm in texture, narrowly spatulate, broadest in the upper third, whence it tapers to an acuminate apex and downward into a long, narrowly wedge-shaped base that merges with the petiole; nervation consisting of a relatively strong midrib and numerous thin, close, nearly parallel secondaries.

This little leaf, which is the only one noted in the collection, is very narrowly spatulate, about 17 millimeters long including the petiole, and about 4 millimeters wide. The base is so merged into the petiole that no more than a length of 4 millimeters can be considered as petiole.

This species seems to approach most closely *Pimelea delicatula* Lesquereux,[65] from the lake beds at Florissant, Colo., but differs in being much smaller and narrower and in the apparently somewhat thicker substance of the leaf.

Occurrence: Green River formation, oil shale, Cathedral Bluff, south of Little Tommies Draw, Rio Blanco County, about 20 miles west of Rio Blanco post office, Colo., collected by D. E. Winchester, 1917.

Order RANALES.

Family NYMPHAEACEAE.

Brasenia? antiqua Newberry.

Brasenia antiqua Newberry, U. S. Nat. Mus. Proc., vol. 5, p. 514, 1882 [1883]; U. S. Geol. Survey Mon. 35, p. 93, pl. 68, fig. 7, 1898.

The type of this species is No. 7018 of the United States National Museum collections and has been well described and figured by Newberry. No additional material has been procured, and hence there is nothing to make the identification either more or less certain.

Occurrence: Green River formation, Green River, Wyo.

Order ROSALES.

Family CRASSULACEAE?

Sedum? hesperium Knowlton, n. sp.

Plate XXXVII, figure 7.

Leaf apparently thick and fleshy, broadly lanceolate, widest near the middle, thence narrowed to the obtusely wedge-shaped base, obtuse and obscurely three-lobed at the apex; margin with two or three large teeth or lobes on each side; petiole very thick and stout; nervation peculiar, consisting of a rather strong midrib and numerous thin veins that arise in the lower part of the blade and spread out, a few of them forking to occupy the area between midrib and margin.

This form is represented by the single specimen figured. It is about 2.4 centimeters long and 1 centimeter wide, with the thick petiole

[64] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, p. 303, pl. 82, figs. 1, 2, 1917.

[65] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 168, pl. 33, figs. 15, 16, 1883.

2 millimeters long. It is a very peculiar leaf, well characterized by the thick, evidently fleshy substance, obtuse, three-lobed apex, several large irregular lobes or teeth, and above all by the thick petiole, strong midrib, and thin, longitudinal veins.

I am uncertain as to its affinity. I have referred it with a question to *Sedum* on account of its fleshy character and resemblance to the living *Sedum telephioides* Michaux, but this resemblance may be only superficial. In any event it may be easily recognized in future, and more and better material may serve to place it more certainly.

Occurrence: Green River formation, Cathedral Bluff, south of Little Tommies Draw, 20 miles west of Rio Blanco post office, Rio Blanco County, Colo., collected by D. E. Winchester, 1917.

Family DRUPACEAE.

Amygdalus gracilis Lesquereux.

Amygdalus gracilis Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 199, pl. 40, figs. 12–15; pl. 44, fig. 6, 1883.

Penhallow, Report on Tertiary plants of British Columbia, p. 37, 1908.

Lesquereux characterized this species as follows:

> Leaves ovate-lanceolate, gradually narrowed to the acuminate point and in the same degree to the petiole; serrulate; lateral nerves at a more or less acute angle of divergence, much curved, camptodrome and reticulate along the borders.
>
> These fine leaves of solid membranaceous tissue average 7 centimeters long and 2 centimeters broad, with a slender petiole about 2 centimeters long. They are more or less distinctly minutely serrate; the nerves, open at base and much curved toward the borders, are joined by undulate nervilles nearly at right angles.

There appears to be much confusion regarding this species. It is based on five figured specimens, one of which (the original of pl. 40, fig. 12, of the "Cretaceous and Tertiary floras") is said to be in the Museum of Princeton University; the others should be in the United States National Museum, but only one can now be found. The original of figure 6 of Lesquereux's Plate XLIV is said to have come from Uinta County (formerly incorrectly called Randolph County), Wyo., but this specimen is missing. All the specimens shown on his Plate XL (figs. 12 to 15) are supposed to have come from Florissant, Colo., but the only specimen available (the original of fig. 13) is No. 1588 of the United States National Museum and is recorded as coming from Uinta County, Wyo., and this record is borne out by the matrix, which is clearly identical with the others from Uinta County and wholly unlike the Florissant material. This species has not been identified in any of the recently studied material from Florissant, and unless the missing specimens can ultimately be shown to have come from that locality it should be dropped from the Florissant list.

Two of the figured types of *Amygdalus gracilis* (pl. 40, figs. 14, 15) are poorly preserved fruits of which Lesquereux wrote as follows: "The fruits appear to belong to this genus and possibly to this species. The reference is of course hypothetical." Without access to the original specimens it is impossible to say much about them, and to judge from the figures alone there seems very little warrant for referring them to *Amygdalus* and absolutely none for connecting them with these leaves.

Occurrence: Green River formation. Uinta County (formerly erroneously called Randolph County), Wyo. All reference to the occurrence in the Florissant lake beds is extremely doubtful.

Family PAPILIONACEAE.

Dalbergia viridiflumensis Knowlton, n. sp.

Plate XL, figure 10.

Leaflet small, very thick in texture, obovate, strongly emarginate at the apex, wedge-shaped at the base, length 15 millimeters, width 11 millimeters; petiolule slender, 4 millimeters long; margin perfectly entire; midrib very strong, especially on the under side of the leaf, straight; secondaries thin but distinct, seven or eight pairs, at an acute angle, camptodrome, probably uniting with each other, but this point is obscure.

Unfortunately this specimen is the only one found in the collection, but it is so well marked that it can easily be recognized.

The genus *Dalbergia* is a large one, comprising over 80 species, mainly of the Tropics of both Old and New worlds. Many of the species have similar leaves and hence are hard to separate on this character alone. Among the 25 or more fossil species that have been described the one perhaps approached most

closely by the present form is *Dalbergia eocenica* Berry,[66] from the Lagrange formation of Puryear, Tenn. *D. viridiflumensis* differs from that species, however, in being more regularly obovate and in being petiolulate instead of sessile.

Occurrence: Green River formation, Rio Blanco County, 20 miles west of Rio Blanco post office, Colo. (sec. 33, T. 4 S., R. 100 W.), collected by D. E. Winchester, 1917.

Dalbergia retusa Knowlton, n. sp.

Plate XL, figures 5, 6.

Leaflet thick in texture, elliptical, strongly retuse at the apex, abruptly rounded and equilateral at the base; petiolule short, very strong; midrib very strong; secondaries thin, immersed in the leaf substance, at a low angle of emergence, camptodrome, forming loops just inside the margin; fine nervation not discernible.

Unfortunately this species is represented only by a single leaflet with its counterpart, both of which have been figured, as there are certain features that can not be seen from either impression. It is regularly elliptical or slightly broader above the middle, being about 2.5 centimeters long and 2 centimeters wide. The very thick petiolule is 2 millimeters long. With the exception of the strong midrib the nervation is rather obscure but is thought to be as described above.

This little leaflet seems referable to the genus *Dalbergia* on the ground of being strongly retuse at the apex and slightly broader above the middle and having the type of nervation usual in the genus. It is, for instance, very similar to *Dalbergia eocenica* Berry,[67] from the Lagrange formation (in beds of Wilcox age) of western Tennessee, except as regards size. It also resembles certain leaflets from the Swiss Miocene described by Heer.[68]

Dalbergia retusa is also similar to *Simaruba eocenica* Berry [69] and *Canavalia eocenica* Berry,[70] both from the Wilcox group.

Occurrence: Green River formation, Little Duck Creek, Rio Blanco County, about 50 miles southwest of Meeker, Colo.; collected by D. E. Winchester, 1917.

[66] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, p. 245, pl. 53, figs. 1, 2, 1916.

[67] Idem.

[68] Heer, Oswald, Flora tertiaria Helvetiae, vol. 3, pl. 133, 1859.

[69] Op. cit., pl. 54, fig. 7.

[70] Op. cit., pl. 53, fig. 3.

Leguminosites alternans Lesquereux.

Leguminosites alternans Lesquereux, U. S. Geol. and Geog. Survey Terr. Bull., vol. 1, p. 388, 1875 [1876]; idem, Ann. Rept. for 1874, p. 315, 1876; U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 202, 1883.

Leaflet lanceolate, narrowed to the sessile base (point broken), apparently tapering and acute; secondary veins close, numerous, 15 pairs in a space of 2.5 centimeters, with indeterminate shorter tertiary veins anastomosing by crossing veinlets; areolation obsolete.

This leaf is comparable to a *Dalbergia* or a *Podogonium* by its nervation; its form, especially the narrowed base, is comparable to *Cassia*.

The above description by Lesquereux is all that has been written concerning this species. The type or types are not known to be in existence, and as it was never figured its status must be considered more or less unsatisfactory.

Occurrence: Green River formation, near mouth of White River (emptying into Green River), Wyo.

Sophora coloradensis Knowlton, n. sp.

Plate XXXVII, figures 14–16; Plate XL, figure 11.

Leaflets rather thin in texture, ovate or ovate-elliptical, obtuse and rounded at the apex, abruptly rounded or obtusely wedge-shaped at the base; petiolule short, stout; midrib moderately strong, straight; secondaries few, mainly opposite, thin, at a low angle, camptodrome, forming broad loops, especially in the upper part.

The smallest of the several leaflets referred to this species (fig. 14) is about 2.25 centimeters long and 1.8 centimeters wide, and the largest (fig. 16) about 4 centimeters long and 2 centimeters wide. In both these leaflets the base is obtusely wedge-shaped, but in another example (fig. 16) the base is much more abruptly rounded—in fact, almost truncate. It is nearly 2.5 centimeters wide and was probably not far from 5 centimeters long.

This species suggests some of the forms of *Sophora wilcoxiana* Berry,[71] from the Wilcox group, but is more ovate or ovate-elliptical and has more arched secondaries.

Occurrence: Green River formation, Little Duck Creek, Rio Blanco County, about 50 miles southwest of Meeker, and Camp Gulch, 25 miles northwest of De Beque, Colo., collected by D. E. Winchester, 1917.

[71] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, p. 241, pl. 47, figs. 1–13, 1916.

Family MIMOSACEAE.

Mimosites coloradensis Knowlton, n. sp.

Plate XL, figures 1–3.

Leaves pinnate; leaflets opposite, sessile or nearly so, linear or linear-lanceolate, slightly unequal-sided, rather abruptly rounded at the base, acuminate or obtuse at the apex; margin perfectly entire; nervation, except for a strong midrib, mainly obsolete.

This species is represented by one leaf that has the petiole preserved complete—2.5 centimeters long—with parts of two sessile leaflets, as well as by a considerable number of detached leaflets. The smallest is about 8 millimeters long and the longest 28 millimeters long. The width is 2 or 3 millimeters. The leaflets are evidently thick, as hardly anything but the midrib is discernible.

This species is very closely related to and perhaps identical with *Mimosites linearifolius* Lesquereux,[72] from the lake beds at Florissant, Colo., but appears to differ in being less fulcate and less sharply pointed. In one of the leaflets there is a slight indication that the midrib is excurrent.

This species is similar to certain of the smallest leaflets of *Mimosites variabilis* Berry,[73] from beds of Wilcox age in the Lagrange formation of western Tennessee and Kentucky, and from the Wilcox group of Mississippi, but these are more nearly elliptical with obtuse base and apex.

Occurrence: Green River formation, spring on Little Duck Creek, about 50 miles southwest of Meeker, Rio Blanco County, Colo., collected by D. E. Winchester, 1917.

Order GERANIALES.

Family SIMARUBACEAE.

Ailanthus longe-petiolata Lesquereux.

Ailanthus longe-petiolata Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 197, pl. 40, figs. 6, 7, 1883.

Both figured types of this species are preserved in the United States National Museum, the leaflet being No. 1586 and the fruit No. 1587. No additional examples of either leaves or fruit have been collected, and it may stand as left by Lesquereux.

[72] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 300, pl. 59, fig. 7, 1878; idem, vol. 8 (Cretaceous and Tertiary floras), p. 203, pl. 37, figs. 10–13, 1883.

[73] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, p. 227, pl. 45, figs. 6–11, 1916.

Occurrence: Green River formation, Uinta County (formerly wrongly called Randolph County), Wyo.

Order SAPINDALES.

Family SAPINDACEAE.

Sapindus dentoni Lesquereux.

Sapindus dentoni Lesquereux, U. S. Geol. and Geog. Survey Terr. Bull., vol. 1, p. 388, 1875 [1876]; idem, Ann. Rept. for 1874, p. 315, 1876; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 265, pl. 44, figs. 2–4, 1878.

Described by Lesquereux as follows:

Leaflets with entire or slightly undulate borders, lanceolate [6 or 7 centimeters long, 1.1 to 1.7 centimeters wide], gradually tapering to a long acumen, rounded to the [slightly unequal-sided] base and narrowed to a short petiole [1 centimeter long]; lateral nerves close, parallel, nearly straight to the borders, where they abruptly curve.

Unfortunately the type specimens of this species are now lost; at least, they do not appear to be in the United States National Museum, and their location is not known. Lesquereux compares these "leaflets" with those of *Sapindus angustifolius* Lesquereux, from the Florissant lake beds, but there are sufficient differences to separate them. They can also be compared with leaves of *Eucalyptus? americanus* Lesquereux, as figured in the "Tertiary flora," Plate LIX, figures 11 and 12, but as we have only the drawings to go by it is perhaps best to leave them under *Sapindus*.

Occurrence: Green River formation, near the mouth of White River, Utah, collected by William Denton, for whom the species is named.

Sapindus obtusifolius Lesquereux.

Sapindus obtusifolius Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1873, p. 419, 1874; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 266, pl. 49, figs. 8–11, 1878; idem, vol. 8 (Cretaceous and Tertiary floras), pp. 181, 235, pl. 48, figs. 5–7, 1885.

The type locality of *Sapinus obtusifolius* is about 8 miles southeast of Green River, Wyo., where it was found in association with *Musophyllum complicatum* Lesquereux and a fragment of a leaf of *Carpinus grandis*. The four figured types are all preserved in the United States National Museum (Nos. 392–395).

Subsequently Lesquereux[74] stated that he found a single specimen with the leaflets attached in material from the lake beds at Floris-

[74] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 181, 1883.

sant, Colo. I have not seen this specimen, but Lesquereux says it is even smaller than that of figure 8 of the "Tertiary flora."

In the "Cretaceous and Tertiary floras" Lesquereux[75] also reported this species from the Fort Union formation of North Dakota. The present location of the specimens so designated is not known, but they were very well figured, and from the figures it appears that, although they resemble the originals of *S. obtusifolia*, they are probably a different species. The largest leaflet is 11.5 centimeters long and 4 centimeters wide, and it seems questionable to place them with leaflets only 1 to 1.5 centimeters long. It will require a considerable series of connecting forms to show the relationship.

The recent collections from western Colorado contain a number of leaflets that are to be referred to *Sapindus obtusifolius*, but as they add nothing to our knowledge of the species they have not been figured.

Occurrence: Green River formation, 8 miles southeast of Green River, Wyo., collected by Leo Lesquereux, 1873; spring on Little Duck Creek, about 50 miles southwest of Meeker, Rio Blanco County, Colo., collected by D. E. Winchester, 1917.

Sapindus winchesteri Knowlton, n. sp.

Plate XXXVIII, figure 1.

Leaflet very large, 14.5 centimeters long and 3.5 centimeters wide, lanceolate, strongly unequal-sided, broadest at about one-third of the length above the base, whence it narrows gradually to the rather obtuse apex and downward to the wedge-shaped base; nervation strong, especially the midrib, with about 16 pairs of alternate, irregularly spaced camptodrome secondaries, which arise at low angles, curve upward slightly, and arch just inside the margin, each joining the one next above; there are a few intermediate secondaries and a strong secondary nervation.

This splendid species is represented by the nearly perfect leaflet figured and a number of smaller fragments. It is one of the largest, if not indeed the largest species thus far described in this country. It somewhat resembles *Sapindus affinis* Newberry,[76] an extremely abundant form in the Fort Union, but it is more than twice the size of the ordinary leaflets of that species and is much more obtuse at the apex and has a much stronger nervation. It is more like certain leaflets from the Fort Union of the Yellowstone Park identified as *Sapindus affinis*,[77] though it is much larger and has a stronger nervation.

The only species of *Sapindus* heretofore noted in the Green River formation is *S. dentoni* Lesquereux,[78] but this is a small-leaved form wholly unlike the present one.

Occurrence: Green River formation, oil shale, Smith ranch, on Greasewood Creek, about 40 miles southwest of Meeker, Rio Blanco County, Colo., collected by D. E. Winchester, 1917.

Family ANACARDIACEAE.

Rhus lesquereuxii Knowlton and Cockerell.

Rhus lesquereuxii Knowlton and Cockerell, U. S. Geol. Survey Bull. 696, p. 552, 1919.

Rhus acuminata Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, Suppl., p. 8, 1872; U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 194, pl. 42, figs. 14–17, 1883. [Homonym, De Candolle, 1865.]

The type locality for *Rhus acuminata* Lesquereux is Green River, Wyo., above the so-called fish beds, but the type specimen is not known to be in the collection of the United States National Museum and is presumably lost. It has not subsequently been found in the Green River formation, the figured specimens being from the lake beds at Florissant, Colo. (U. S. Nat. Mus. Nos. 1871–1874). Its status as a Green River species is therefore open to question.

Occurrence: Green River formation, Green River, Wyo., above the fish beds.

Rhus variabilis (Newberry) Knowlton, n. comb.

Planera variabilis Newberry, U. S. Nat. Mus. Proc., vol. 5, p. 508, 1883; U. S. Geol. Survey Mon. 35, p. 83, pl. 66, fig. 7 [not figs. 5 and 6, which=*Planera inaequilateralis* (Lesquereux) Knowlton], 1898.

Leaf firm in texture, lanceolate, about 6 centimeters long and 2 centimeters wide, acute at the apex, evenly wedge-shaped (at about 45° angle) at the base; margin coarsely and somewhat irregularly toothed; petiole stout, at least 1 centimeter long; midrib strong; secondaries numerous, irregularly spaced, parallel, at a low angle, ending in the margin.

[75] U. S. Geol. Survey Terr. Rept. vol. 8, p. 235, pl. 48, figs. 5–7, 1883.
[76] Newberry, J. S., U. S. Geol. Survey Mon. 35, p. 116, pl. 30, fig. 1, 1898.
[77] Knowlton, F. H., U. S. Geol. Survey Mon. 32, pt. 2, pl. 102, figs. 1–3, 1899.
[78] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 265, pl. 64, figs. 2–4, 1883.

This species is based on one of the figured types of Newberry's *Planera variabilis*. At the time it was made a type Newberry apparently had some misgiving, for he said:

> Possibly future collections will prove that the narrower, more rigid form with the deeply cut and acute serrations and parallel, nearly straight lateral veins, shown in figure 7, belongs to a different species; but in the very large number of *Planera* leaves before me it is impossible to make any division without making several. They are therefore all grouped together for the present.

He further adds that he had at his disposal a large number of specimens that seem to connect the two forms, but as these are not available it appears best to consider them as distinct.

It may also be pointed out that the leaf under discussion seems to be congeneric with *Myrica* (now *Rhus*) *nigricans* Lesquereux [79] and for this reason has been transferred to the genus *Rhus*. It is more nearly lanceolate and has rather coarser marginal teeth, but otherwise does not greatly differ. It is not contained in any of the more recent collections.

Occurrence: Green River formation, Green River, Wyo. (one of the types of *Planera variabilis*), collected by C. A. White.

Rhus nigricans (Lesquereux) Knowlton, n. comb.

Myrica nigricans Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, Suppl., p. 6, 1872; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 132, pl. 17, figs, 9–12, 1878.

Myrica nigricans was described as follows by Lesquereux:

> Leaves nearly sessile, alternate, oblong or linear-lanceolate, acuminate, round-cuneate to the base, obtusely dentate; nervation camptodrome.

He supplemented this description with the following remarks:

> The leaves of this species are like those of the former [*Myrica undulata?* Heer], only narrower, all narrowly lanceolate or linear-lanceolate, narrowed to a long acumen, and about sessile or with a very short petiole about 1 millimeter long. They are more or less unequal at the base, distantly obtusely dentate in the middle.

Three of the figured types of this species are preserved in the United States National Museum (figs. 9–11, Nos. 401a, 150, 151) and are seen to be fragmentary. The specimen shown in figure 9 is evidently the one on which is based the statement that the leaves are simple and alternate, but a close view of the original disclosed that there was a piece of the matrix covering the point of attachment of one leaf, and when this was removed they were found to be practically opposite. They are slightly unequal-sided and in my opinion are leaflets of a pinnately compound leaf. This conclusion of necessity removes the form from *Myrica*, which has simple leaves, and it seems to justify their reference to *Rhus*. The other types are also slightly unequal-sided and are probably conspecific. The margin is undulate-toothed in these three-figured specimens, but another figure (fig. 10a) shows the margin with sharp teeth.

Occurrence: Green River formation, Green River, Wyo., northwest of station and above the fish beds, collected by F. V. Hayden, 1868.

Rhus myricoides Knowlton, n. sp.

Plate XXXVII, figures 9–11.

Leaflets of firm texture, narrowly lanceolate, prolonged above into a slender acuminate tip, abruptly narrowed and unequal-sided at the base; margin entire for a short distance at the base, thence strongly toothed, the teeth deltoid, pointing upward; petiolule short, stout; midrib relatively strong, especially below; secondaries and intermediate secondaries numerous, mainly alternate, thin, emerging at a low angle, slightly curved upward, craspedodrome, the stronger ones entering the teeth, the others at intermediate points; finer nervation obscure.

This species is represented by a number of very well preserved leaflets, three of the most nearly perfect of which have been figured. The length was apparently from about 5.5 to 6.5 centimeters and the width approximately 1 centimeter. The petiolule is very short, hardly exceeding 2 milimeters.

This species is undoubtedly most closely related to *Rhus nigricans* (*Myrica nigricans* Lesquereux[80])—in fact, they may be identical. *Rhus myricoides* appears to differ in being more strongly toothed and to a minor degree in the nervation.

Occurrence: Green River formation, Smith ranch, on Greasewood Creek, about 40 miles southwest of Meeker, Rio Blanco County, Colo., collected by D. E. Winchester, 1917.

[79] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 132, pl. 17, figs. 9–12, 1878.

[80] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 132, pl. 17, figs. 9–12, 1878.

Family CELASTRACEAE.

Euonymus flexifolius Lesquereux.

Euonymus flexifolius Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 183, pl. 38, fig. 13, 1883.

This splendid species is described as follows by Lesquereux:

Leaves large [16.5 centimeters long, 5 centimeters wide], ovate-acuminate from an oval base, flexures at the apex, narrowed from the middle to the petiole, sharply deeply serrate; secondary nerves alternate, equidistant and parallel, camptodrome.

The single type specimen is the only one thus far obtained. It is No. 1585 of the United States National Museum collection.

Occurrence: Green River formation, Uinta County (formerly incorrectly called Randolph county), Wyo.

Family ACERACEAE.

Acer lesquereuxii Knowlton.

Acer lesquereuxii Knowlton, U. S. Geol. Survey Bull. 152, p. 26, 1898.

Acer indivisum Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 180, pl. 36, figs. 6, 9, 1883. [Homonym, Weber, 1852.]

Lesquereux's original description reads as follows:

Leaves small, of thin texture, round-truncate in outline, five-nerved and five-lobed; lobes entire, sharply acuminate; sinuses broad, entire or dentate in the middle; petiole comparatively long, inflated under the point of attachment.

The leaves are 5.5 centimeters broad between the points of the upper lobes and only 4 centimeters long from the top of the petiole, which is 5.5 centimeters long.

The type of the leaf on which this species is based is preserved in the United States National Museum (No. 1582), but the fruits also made cotypes are not to be found here. This species has not been found in subsequent collections.

Occurence: Green River formation, Uinta County (formerly wrongly called Randolph County), Wyo., collected by F. V. Hayden.

Family ILICACEAE.

Ilex? affinis Lesquereux.

Ilex? affinis Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, Suppl., p. 8, 1872; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 270, pl. 50, figs. 2, 3, 1878.

This species is based on two examples, both of which were figured by Lesquereux, and both are in the United States National Museum collection (Nos. 400, 401). They are fragmentary, as he states, both having lost the upper portion. Lesquereux says:

These leaves, inequilateral at base, seem like pinnules of a compound leaf. The midrib is thick, the secondary veins numerous, parallel, inequidistant, and, at an open angle of divergence, either enter the point of the teeth and, by their branches, follow the borders in festoons or are truly camptodrome, with nervilles passing up from the back of the curves into the teeth.

Lesquereux questioned the generic reference of these leaves, and it is more than probable that they should be placed elsewhere, but they are so fragmentary that affinities are interpreted with difficulty, and it may be best to leave them for the present in *Ilex*.

Occurrence: Green River formation, Green River, Wyo., above the fish beds.

Ilex maculata Lesquereux.

Ilex maculata Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 186, pl. 44, fig. 5, 1883.

The single type specimen (No. 1603, U. S. Nat. Mus.) is the only one recorded of this species. It is poorly preserved and the generic reference is open to more or less question.

Occurrence: Green River formation, Alkali stage station, about 30 miles north of Green River, Wyo.

Ilex vyomingiana Lesquereux.

Ilex vyomingiana Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 270, pl. 50, fig. 1, 1878.

The type of this species (No. 399, U. S. Nat. Mus.) is so fragmentary and obscure that it is difficult to interpret. Its reference to *Ilex* may well be questioned, but as no other relationship can reasonably be suggested it is left as placed by Lesquereux.

Occurrence: Green River formation, Green River, Wyo., above the fish beds.

Order RHAMNALES.

Family RHAMNACEAE.

Zizyphus longifolia Newberry.

Plate XL, figure 7.

Zizyphus longifolia Newberry, U. S. Nat. Mus. Proc., vol. 5, p. 513, 1882 [1883]; U. S. Geol. Survey Mon. 35, p. 119, [pl. 65, figs. 3, 4 [not fig. 5, which= *Zizyphus cinnamomoides* Lesquereux], 1898.

Leaves evidently very firm in texture, 7.5 to 9.5 centimeters long, about 1.5 centimeters

wide, lanceolate, rather abruptly rounded to the obtusely wedge-shaped base, long pointed at apex; margins waved or more or less distinctly toothed; petiole slender, at least 2 centimeters long; midrib well defined from base to summit; lateral nerves or ribs arising with the petiole and nearly as strong, passing up close to the margin for nearly one-half the length of the blade, then joining the lowest pair of secondaries on the midrib; secondaries three or four pairs, alternate, curving upward, forming a festoon near the margin; nervilles finely reticulated.

Newberry figured three specimens as the types of this species, and all are preserved in the United States National Museum (Nos. 7020, 7021, 7022). Of these, two (figs. 3 and 4 of his plate) agree with the above description and are here taken as typical of *Zizyphus longifolia*. The other specimen is obviously different—in fact, it agrees with *Zizyphus cinnamomoides* Lesquereux,[81] as Newberry himself pointed out, and it is transferred to that species. Newberry states that *Zizyphus longifolia* is very abundant in the collections submitted to him and is usually associated in the beds with *Lygodium* and *Acrostichum*.

In the collections from western Colorado I find several leaves of this species, one of which I have figured. It is a narrow leaf about 8 centimeters long and 1.6 centimeters wide. Its margin is provided with remote, low, rounded teeth. The nervation is that described and figured for the species.

Occurrence: Green River formation, Green River, Wyo.; oil shale at Smith ranch, on Greasewood Creek, about 40 miles southwest of Meeker, Colo., collected by D. E. Winchester, 1917.

Zizyphus cinnamomoides (Lesquereux) Lesquereux.

Zizyphus cinnamomoides (Lesquereux) Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 277, pl. 52, figs. 7, 8, 1878.

Zizyphus longifolia Newberry, U. S. Geol. Survey Mon. 35, pl. 65, fig. 5 [not figs. 3, 4], 1898.

Ceanothus cinnamomoides Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, p. 289, 1872.

Leaves of firm texture, 5 to 9 centimeters long, 1.5 to 2.5 centimeters wide, oblong or ovate-lanceolate, broadest at or a little below the middle, wedge-shaped below, prolonged above into a slender point; margin more or less crenate from a point well above the base of the blade; triple-nerved from the top of the petiole, the midrib straight, with four or five pairs of thin secondaries in the upper part; lateral nerves or ribs closer to the margin than the midrib, joining the lowest pair of secondaries; finer nervation irregularly recticulate.

Lesquereux based this species on two leaves from Green River shale, both of which lack the upper portion. Later Newberry received material from the same locality and from it he characterized his *Zizyphus longifolia*. Of the three types figured by Newberry two are alike and are long, narrow, three-nerved leaves, but the other is clearly identical with Lesquereux's *Zizyphus cinnamomoides* and has been transferred to it.

Ward[82] identified a single small leaf from the Fort Union formation near Glendive, Mont., with Lesquereux's *Zizyphus cinnamomoides*, but it has a very different nervation and must be excluded.

Occurrence: Green River formation, Green River, Wyo.

Family VITACEAE.

Cissus parrottiaefolia Lesquereux.

Cissus parrottiaefolia Lesquereux, U. S. Geol. and Geog. Survey Terr. Bull., vol. 1, p. 388, 1875 [1876]; idem, Ann. Rept. for 1874, p. 314, 1876; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 239, pl. 40, figs. 15–17; pl. 42, fig. 1, 1878.

The three types of this species supposed to be from Green River, Wyo., are in the United States National Museum (Nos. 343, 344, 345). The matrix is rather soft yellowish sandstone, quite unlike anything from the Green River beds with which I am familiar, and there is doubt as to the propriety of continuing this as a Green River species.

Occurrence: Green River formation, Green River, Wyo., west of station.

Parthenocissus tertiaria (Lesquereux) Knowlton, n. comb.

Ampelopsis tertiaria Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, Suppl., p. 7, 1872; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 242, pl. 43, fig. 1, 1878.

The type and only specimen of this species found is preserved in the United States National Museum (No. 361) and has been

[81] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 277, pl. 52, figs. 7, 8, 1878.

[82] Ward, L. F., U. S. Geol. Survey Sixth Ann. Rept., for 1884–85, p. 554, pl. 52, fig. 3, 1886; idem, Bull. 37, p. 74, pl. 33, fig. 7, 1887.

fairly well characterized by Lesquereux. The two leaflets on the left-hand side are represented as broken, but really they pass under one of the type specimens of *Juglans schimperi* and can not be excavated without destroying the *Juglans*.

Occurrence: Green River formation, Green River, Wyo., above the fish beds.

Order MYRTALES.

Family MYRTACEAE?

Eucalyptus? americanus Lesquereux.

Plate XXXIX, figures 1–3.

Eucalyptus? americana Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 296, pl. 59, figs. 11, 12, 1878.

Eucalyptus americanus Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, Suppl., p. 7, 1872.

Apocynophyllum scudderi Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8, (Cretaceous and Tertiary floras), p. 172, pl. 45, *A*, figs. 1–5, 1883.

Salix angusta Al. Braun? Newberry, U. S. Geol. Survey Mon. 35, p. 54, pl. 65, fig. 2, 1898.

Leaves coriaceous in texture, narrowly lanceolate, gradually tapering upward from below the middle into a long, narrow acumen and narrowed in nearly the same degree to the base, slightly unequal-sided and very slightly undulate; petiole very thick, about 1 centimeter long; midrib extremely thick, especially below, where it merges into the petiole; lateral nerves thin, immersed in the substance of the leaf, emerging at angles of 30° to 45°, about 5 millimeters apart, irregular, many of them with intermediate nerves that join others at various distances below the margin; the main nerves all terminate in a strong, continuous intramarginal vein which is about 1 millimeter from the margin; finer nervation consisting of very thin, irregular veins oblique to the principal veins.

These are splendid leaves, clearly coriaceous or leathery in texture. There is considerable range in size, the larger ones being nearly 13 centimeters long and about 2 centimeters wide and the smaller ones 6 or 8 centimeters long and 1.5 centimeters wide. The petiole, which is enlarged at the point of attachment, does not exceed 1 centimeter in length.

The types of *Eucalyptus? americana* as figured by Lesquereux in the "Tertiary flora" (pl. 59, figs. 11, 12) are preserved in the United States National Museum (Nos. 489, 489a). The best preserved leaf is a nearly perfect one 12 centimeters long and 1.5 centimeters wide. The other was a larger leaf, fully 2 centimeters wide, but lacks the upper portion. The nervation is that above described.

In 1883 Lesquereux[83] described some rather fragmentary leaves from Alkali station under the name *Apocynophyllum scudderi*. These specimens are in the United States National Museum (Nos. 1605–1609) and are before me. Although they are somewhat smaller than the types of *Eucalyptus? americanus*, they clearly belong with them. They have the same coriaceous texture, very thick midrib, thin, immersed lateral veins, and continuous intramarginal vein. They seem properly to be referable to *Eucalyptus? americanus*.

The leaf figured by Newberry[84] as *Salix angusta* Al. Braun? is also preserved in the United States National Museum (No. 7023) and clearly belongs to *Eucalyptus? americanus*. It comes from Green River and is said by Newberry to be exceedingly common, "some slabs of the rock being quite covered with the leaves." Newberry does not mention the strongly marked intramarginal vein, though it is shown in his figure and, of course, in the specimen.

The propriety of referring these leaves to the genus *Eucalyptus* may perhaps be open to question, as it is doubted by some that this genus ever reached America. Be that as it may, their facies—long, narrow, coriaceous leaves with exceedingly thick midrib and deeply immersed veins running into a strong intramarginal vein—is distinctly that of *Eucalyptus*, and I have retained them as left by Lesquereux. There are some other things that are to be considered in this connection. Thus Lesquereux in the original discussion of his *Eucalyptus? americanus* compares them to species of *Tricera* from Cuba. This is a euphorbiaceous genus with narrow leaves having a nervation similar to that of *Eucalyptus*. I have not seen these leaves and so can not say anything as to their probable affinity with the Green River leaves under consideration.

Berry[85] has described as *Ficus myrtifolius* some narrow leaves from the Wilcox group

[83] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 172, pl. 45, *A*, figs. 1–5, 1883.

[84] Newberry, J. S., U. S. Geol. Survey Mon. 35, p. 54, pl. 65, fig. 2, 1898.

[85] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, p. 205, pl. 30, figs. 1–3, 1916.

that he says are nearest to Lesquereux's *Apocynophyllum scudderi*. The Wilcox leaves are of about the same size and shape as Lesquereux's species and have the thick midrib and well-marked intramarginal vein, but the lateral veins are almost at right angles and are more numerous than in the Green River leaves.

Occurrence: Green River formation, Green River, Wyo., above the fish beds, types collected about 1870 by F. V. Hayden, others collected by C. A. White and still later by L. F. Ward; Alkali stage station, about 30 miles north of Green River, type locality for *Apocynophyllum scudderi*, collected by F. V. Hayden; Cathedral Bluff, south of Little Tommies Draw, about 20 miles west of Rio Blanco post office, Rio Blanco County, Colo., in sec. 35, T. 4 S., R. 100 W., Colo., and above oil shale, head of trail up ridge between Carr and Bushy creeks, Garfield County, Colo., collected by D. E. Winchester, 1917.

Order UMBELLALES.

Family ARICACEAE.

Aralia wyomingensis Knowlton and Cockerell.

Plate XXXIX, figure 4; Plate XL, figure 12.

Aralia wyomingensis Knowlton and Cockerell, U. S. Geol. Survey Bull. 696, p. 88, 1919.

Aralia macrophylla Newberry, U. S. Nat. Mus. Proc., vol. 5, p. 513, 1882 [1883]; U. S. Geol. Survey Mon. 35, p. 121, pl. 67, fig. 1; pl. 68, fig. 1, 1898. [Homonym, Lindley, 1844.]

This species was described by Newberry as follows:

> Leaves large, long-petioled, palmately five-parted from the middle upward, divisions conical in outline, sometimes entire, often remotely, occasionally coarsely toothed; nervation strong and regular; the midrib of the divisions strong and straight, those from the second lateral lobes springing from near the bases of the first lateral lobes; secondary nerves numerous, distinct, curved gently upward; where the margins are entire, partially camptodrome; where dentate, terminating in the teeth; tertiary nerves anastomosing to form quadrangular and very numerous areoles.

In speaking of the occurrence of these leaves, Newberry says:

> In the localities where they are found the leaves of *A. macrophylla* [*A. wyomingensis*] are exceedingly abundant, sometimes matted together so as to obscure their outlines. These show that they vary in size, in the number of lobes, and in the character of the margins, occasionally one occurring which is only three-lobed, while almost all are five, and the margins are sometimes nearly entire, while in other leaves they are all strongly, even spinously, dentate. The leaves vary from 3 to 12 inches in length, and the lobes are sometimes long and narrow, in others much broader.

The two figured types of this species, both preserved in the United States National Museum, are large leaves, hence the name *macrophylla* was very appropriate, but in Newberry's discussion of the species he states that they range in length from 3 to 12 inches.

In the collections recently made in western Colorado there are a number of leaves that must be referred to *Aralia wyomingensis*. Two of these have been figured. One (Pl. XL, fig. 12) is a very small leaf only 6 centimeters long and a little over 7 centimeters wide, with slender petiole 2 centimeters long. The other (Pl. XXXIX, fig. 4) is somewhat larger, probably 12 or 14 centimeters long and some 12 centimeters broad.

The leaf from Bridger Pass, Wyo., described by Lesquereux[86] under the name *Aralia? gracilis*, may belong here, but it is so fragmentary that it can not be compared fully with *Aralia wyomingensis*.

Occurrence: Green River formation, Green River, Wyo. (types), collected by C. A. White; Cathedral Bluff, south of Little Tommies Draw, about 20 miles west of Rio Blanco post office, Rio Blanco County, Colo.; collected by D. E. Winchester, 1917.

Order ERICALES.

Family ERICACEAE.

Andromeda delicatula Lesquereux.

Andromeda delicatula Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 175, pl. 34, figs. 10, 11, 1883.

The two type specimens on which this fine species is based are preserved in the United States National Museum (Nos. 1580, 1581) and have been very well described and figured by Lesquereux. The species has not been since collected in the Green River formation, but has been reported from the supposed upper Eocene of British Columbia and the Fort Union formation of the Bull Mountains, Mont.; the latter is perhaps doubtful.

Occurrence: Green River formation, Uinta County (formerly wrongly called Randolph County), Wyo.; Eocene, Tranquille River, British Columbia; Fort Union formation, Bull Mountains, Mont.

[86] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 236, pl. 39, fig. 1, 1878.

Order RUBIALES.

Family CAPRIFOLIACEAE.

Sambucus? winchesteri Knowlton, n. sp.

Plate XL, figures 8, 9.

This flower is very small, having a spread of only about 4 millimeters. In the exact center is a circular mass of black carbonaceous substance that is without any observable structure. The flower is perfectly regular, with five oblong obtuse petals, alternating with which are the five stamens. At first sight it appears that the petals are free, but as the actual insertion of both petals and stamens is obscured by the central carbonaceous mass, it is possible that the corolla is slightly gamopetalous—in fact, if the identification given is correct the petals must be slightly united. The petals are about 1.7 millimeters long and 0.8 millimeter broad, and each has three relatively strong veins which run from the base nearly to the apex. The stamens are slightly more than half the length of the petals and have large anthers.

A great many flowers have been studied in comparison with this fossil flower, and all things considered it seems to approach *Sambucus* most closely. This genus has the calyx tube ovoid or turbinate, adnate to the ovary, with its limb three to five toothed, and the corolla rotate or slightly campanulate, regular, and usually five-lobed; the five stamens are inserted on the base of the corolla.

The fossil flower under consideration seems to agree fairly well with the above diagnosis, at least so far as can be made out, but as there are some points that can not be settled with certainty, the generic reference has been questioned. This flower is named in honor of the collector.

Occurrence: Green River formation, oil shale, Rio Blanco County, about 40 miles southwest of Meeker, Colo.; collected by D. E. Winchester.

Order CAMPANULALES.

Family COMPOSITAE.

Achaenites cichorioides Knowlton, n. sp.

Plate XL, figure 4.

Achene narrowly obconical, about 7 millimeters long, 2 millimeters in diameter at the top, strongly ribbed (apparently four-ribbed) with several (at least three) thinner intermediate striae; pappus simple, apparently sparse, not barbed, about 7 millimeters long.

This little achene, the only one found in the collection, is surprisingly well preserved considering the delicate nature of some of its parts. The achene itself was evidently hard and resistant and apparently has suffered little distortion. It is strongly ribbed or ridged, especially in the lower part, and from the disposition of these ridges it seems probable that they were four in number, but this is of course somewhat uncertain. The pappus is certainly simple and without obvious barbs; it was at least as long as the achene. It appears to occupy a single ring around the outer edge of the flat-topped achene.

It is perhaps hazardous to attempt a close comparison of this fossil achene with those of any living species, though it may be pointed out that it seems to fall within the family Cichoriaceae, whence the specific name adopted for it. It is, for instance, suggestive of the achenes in certain species of *Nabalus*, *Hieracium*, etc., but more evidence will be needed before it can be placed in any living genus. It is believed to be the first composite achene from this country to be described.

A word may be said as to the selection of the generic name for this achene. The genus *Achaenites* was established by Braun[87] in 1851, with *A. ungeri* as the type species. It was not figured at that time, but in the Neues Jahrbuch for 1854 Braun described and figured it. It is an oblong, long-beaked achene with a plumose pappus, and came from the Swiss Miocene.

In 1859, when Heer [88] came to the consideration of the numerous fruits of the Compositae found in the Miocene of Switzerland, he established the genus *Cypselites*, with which he merged Braun's *Achaenites*, notwithstanding the fact that the latter had some eight years priority. Heer described and figured no less than 19 species under his *Cypselites*, which he stated probably really belong to a number of different genera. None of them seem to be very close to the Green River species under discussion.

The law of priority does not sanction the substitution of one genus for another without reason, and therefore *Achaenites* will have to be restored for Heer's species of *Cypselites*. Moreover, *Achaenites* is more appropriate than *Cypselites* for these obvious achenes.

Occurrence: Green River formation, above rich oil shale, Camp Gulch, about 25 miles northwest of De Beque, Colo., collected by D. E. Winchester, 1917.

[87] Braun, Al., in Stizenberger, Ernst, Uebersicht der Versteinerungen des Grossherzogthums Baden, p. 83, 1851.

[88] Heer, Oswald, Flora tertiaria Helvetiae, vol. 3, p. 2, 1859.

PLANTS OF UNCERTAIN POSITION.

Antholithes improbus Lesquereux.

Antholithes improbus Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 204, pl. 40, figs. 20, 21, 1883.

Both the figured types of this peculiar organism are preserved in the United States National Museum (No. 1666). I am not able to interpret them any more satisfactorily than Lesquereux did.

Occurrence: Green River formation, Uinta County (formerly wrongly called Randolph County), Wyo.

Carpolithus caryophylloides Knowlton, n. sp.

Plate XXXVII, figure 13.

The collections from western Colorado made by Winchester include the little specimen here figured. It is apparently a dry capsule, ovoid in shape, about 5 millimeters long and 4 millimeters in diameter at the base, and with a slender pedicel 2 millimeters long. It appears to be made on the plan of five, and is split down about half its length, each segment being apparently bifid at the apex and with a strong central rib or ridge.

This specimen is so small and indifferently preserved that it is difficult of interpretation. From the fact that it is not much crushed or distorted the inference is drawn that it was a dry capsule that had discharged its seeds when entombed. It may be split down for more than half its length, but it does not seem to be.

It is of course more or less hazardous to attempt to refer this capsule to a living genus or even family, and consequently it has been placed in the form genus and convenient catch-all *Carpolithus*, until it can be more definitely assigned. However, it may be pointed out that this specimen undoubtedly has a strong albeit superficial likeness to the capsule of certain Caryophyllaceae, as, for example, the genus *Lychnis*. The several species of *Lychnis* have a globular or ovoid one-celled capsule that opens by the splitting apart of the ten or five segments, which are often two-cleft at the apex. The capsule of *Lychnis dioica* Linné is especially suggested by this Green River capsule.

Occurrence: Green River formation, Smith ranch, on Greasewood Creek, about 40 miles southwest of Meeker, Rio Blanco County, Colo,. collected by D. E. Winchester, 1917.

Carpites viburni Lesquereux.

Carpites viburni Lesquereux, U. S. Geol. and Geog. Survey Terr. Bull., vol. 1, p. 382, 1875 [1876]; U. S. Geol. Survey Terr. Rept., vol. 7 (Tertiary flora), p. 305, pl. 60, figs. 26, 26a, 1878.

The original description by Lesquereux reads as follows:

> Seeds or nutlets cordate, obtuse, 5 to 7 millimeters long, 3 or 4 millimeters broad, convex, grooved in the middle from the point to the base, surrounded by a membranaceous pellicle, the remains of an apparently fleshy outer envelope.
>
> They resemble seeds of a similar kind which I have found in great quantity at Golden [Colo.] and referred to the genus *Viburnum*.

A complication has arisen concerning the locality from which this species came. At the time it was named and described it was distinctly stated by Lesquereux to have come from Alkali stage station, 30 miles north of Green River, Wyo., but three years later, when it was described and figured in the "Tertiary flora," the locality was given as Black Buttes, Wyo. The type specimen is fortunately preserved in the United States National Museum (No. 494), and it is there recorded in Lesquereux's handwriting as coming from Black Buttes. There is reason to believe, however, that the original assignment is correct, and that it really came from Alkali station and hence from the Green River formation, and not from Black Buttes. The matrix is a fine-grained yellowish sandstone, similar in character to that of other specimens from Alkali station, and, moreover, the temporary label affixed to the specimen by Lesquereux is an oval, blue-bordered "sticker" identical with those used on other specimens from Alkali station, whereas those on the specimens from Black Buttes are of a different shape and bordered with red. No specimens from Black Buttes were described by Lesquereux in the report in which the specimens from Alkali station were described, and, further, it seems inherently improbable that a mixture would occur when a collection from a given locality was first considered. It is believed that this species actually came from Alkali station, and it will be so regarded hereafter.

Occurrence: Green River formation, Alkali stage station, 30 miles north of Green River, Wyo. [incorrectly accredited to Black Buttes, Wyo.].

Carpites newberryana Knowlton, n. sp.

Juglans occidentalis Newberry, U. S. Geol. Survey Mon. 35, p. 34, pl. 66, figs. 4a–4c, 1898 [not figs. 1–4].

This species was characterized by Newberry as follows:

> Fruit small, elongated, somewhat prismatic; divisions of the envelope lenticular in outline, narrow, thin.
>
> The fruit, of which fortunately one specimen was found in immediate contact with the leaves, is small, marked with raised lines, elongate in form, and resembles more the fruit of

Carya olivaeformis [*Hicoria pecan* Britten?] than any other of our living species. It might be inferred from the size of the nut and its elongated form that it was immature, but near it lies a segment of the envelope which has apparently exfoliated at maturity. As only one specimen of the fruit has been discovered, it is possible that it does not represent the average size and form.

Newberry placed this form under *Juglans*, although he expressly states that it clearly belongs to *Hicoria*, but justified this disposition on the ground of the wider limit of the old genus *Juglans*. He also stated that the fruit is in "immediate contact" with the leaves, but a study of the types, which are preserved in the United States National Museum, shows that they are merely associated with leaves of *Juglans occidentalis* on the same piece of matrix but are not in organic connection with them or in a position that suggests such union. It therefore seems necessary to transfer it to the genus to which it apparently belongs. if it has been correctly interpreted, and to give it a new name.

The three type specimens have been very carefully studied. The original of figure 4a is about 16 millimeters long and 7 millimeters broad near the middle. It stands on a short, stout pedicel, which is somewhat expanded and probably cup-shaped and in which rests the fruit. It has a deep longitudinal median furrow and on either side a slender ridge that nearly or quite disappears before reaching the apex. There is very little other structure or marking between the ribs or ridges.

On the same piece of matrix as the specimen just described, about 1 centimeter from it, is the specimen shown in Newberry's figure 4b. It is about 15 millimeters long and about 4 millimeters wide. When viewed in the position in which it was drawn for Newberry's figure it appears to be concave, much as one of the segments of the exocarp of *Hicoria* would appear, but when the orientation is reversed it is found to be convex.

The third specimen (Newberry's fig. 4c) is 19 millimeters long and about 7 millimeters wide. It appears to sit in the excavated apex of the pedicel as described for the first specimen mentioned. It has a single furrow a little to one side of the middle, and there is some evidence of the presence of a thin exocarp or something of the kind on one side.

It seems to me very unlikely that these specimens can belong to *Hicoria*, and they certainly can not belong to *Juglans*. Under the circumstances it appears best to refer them to the noncommittal *Carpites* until additional material may help to place them more definitely.

Occurrence: Green River formation, Green River, Wyo. (described and figured as fruit of *Juglans occidentalis* Newberry; types, U. S. Nat. Mus., Nos. 7031, 7032).

Carpites inquirenda Knowlton, n. sp.

Plate XXXVIII, figure 4.

The collection from western Colorado includes a small fruit that I am not able to place biologically. It is elliptical in outline, about 6 millimeters long and 5 millimeters broad, and has an inner dark nucleus, also elliptical, about 3 millimeters long and 2 millimeters broad. This inner part has a slight projection at one end, but whether this is the apex or the point of attachment has not been determined. Similarly it is impossible with present knowledge to determine whether the outer portion is to be interpreted as a wing, or whether the whole thing is a monospermous capsule.

This organism is so little understood that it might perhaps better be omitted altogether, yet it is a very definite entity that someone may be able to interpret correctly.

Occurrence: Green River formation, oil shale, Cathedral Bluff, south of Little Tommies Draw, Rio Blanco County, Colo., collected by D. E. Winchester, 1917.

Phyllites winchesteri Knowlton, n. sp.

Plate XXXVIII, figure 2.

The collections from the oil shales of western Colorado include the present nearly perfect little leaf. It seems unfortunate to be compelled to describe so fine a specimen under the name *Phyllites*, but I am wholly unable to suggest a generic name with any degree of assurance. It is a linear-lanceolate leaf about 3 centimeters long and 6 millimeters wide. The upper part is narrowed for fully a third the length of the blade into a sharp-pointed apex; below it is more abruptly narrowed to the rather thick petiole, which is nearly 1 centimeter in length. The margin is perfectly entire. The nervation is peculiar. In the middle and upper portions there is some indication of a thin midrib, but in the basal portion the midrib can not be differentiated. Five or six nerves of equal strength arise below the base of the blade and spread out to divide equally the area of the lower third of the leaf, with little indication that the middle one is

the stronger. In the middle and upper portions even these nerves appear to be immersed in the leaf substance.

Occurrence: Green River formation, Rio Blanco County, 20 miles west of Rio Blanco post office, Colo., in sec. 33, T. 4 S., R. 100 W., collected by D. E. Winchester, 1917.

Phyllites fremonti Unger.

Phyllites fremonti Unger, Genera et species plantarum fossilium, p. 503, 1850.
Knowlton, U. S. Geol. Survey Prof. Paper 108, p. 94, 1917.
Leaf of a dicotyledonous plant (?) Hall, in Frémont, Report of the exploring expedition to the Rocky Mountains in 1842, etc., Appendix B, p. 306, pl. 11, fig. 4, 1845.

This species has had an interesting history. It was collected by Frémont in 1843 on his celebrated exploring expedition to the Rocky Mountains and beyond and was included in a collection of plants from the vicinity of what is now Cumberland, Wyo. The plants from this locality were long supposed to be of Jurassic age but are now known to belong to the Colorado group (Frontier formation).[89] The plant under consideration was placed by Hall, who described the collection, at the end of his paper 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 August 19. Frémont's itinerary for the earlier date 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. The type specimen is now lost, and hence a study of the matrix in which it was preserved is impossible.

[89] Knowlton, F. H., U. S. Geol. Survey Prof. Paper 108, pp. 73–107, 1917.

This species was named and described as *Phyllites fremonti* from Hall's figure. 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 somewhat unsatisfactory status of this species and thus preventing future misunderstanding.

Occurrence: Green River formation(?), Blacks Fork of Green River, Wyo.

Nordenskiöldia borealis Heer.

Nordenskiöldia borealis Heer, Flora fossilis arctica, vol. 2, Abt. 3, p. 65, pl. 7, figs. 1–13, 1870.
Newberry, U. S. Geol. Survey Mon. 35, p. 137, pl. 68, figs. 4–6, 1898.

Whatever the nature of this organism may be there seems no doubt that it is identical with that described and figured by Heer.

Occurrence: Green River formation, Green River, Wyo.

Phyllites coloradensis Knowlton, n. sp.

Plate XXXVIII, figure 3.

Leaf compound; rachis strong, straight; leaflets opposite, lanceolate, unequal-sided, sharply acuminate at the apex, narrowed to the base and decurrent in a narrow wing that reaches the leaflets next below; margin perfectly entire; nervation obscure, consisting of a fairly strong midrib and apparently with thin secondaries at an angle of about 40°, but this is uncertain.

This species is represented by the single specimen figured, which shows three pairs of opposite leaflets. The lower pairs are about 3 centimeters long and 8 or 9 millimeters wide; the next pairs are about 2 centimeters long and 5 or 6 millimeters wide, and the terminal (or uppermost pair preserved) leaflets are only 5 millimeters wide.

I am uncertain as to the generic reference of this specimen. The shape and nervation of the leaflets strongly suggest *Sapindus*, and it may be recalled that in certain of the living species, such as *Sapindus saponaria* Linné, the rachis is winged between the leaflets, as indeed it is in some living species of *Rhus*, but in the present specimen it is the basal portion of the leaflet that is prolonged as a narrow wing down the rachis.

Occurrence: Green River formation, spring on Little Duck Creek, about 50 miles southwest of Meeker, Rio Blanco County, Colo., collected by D. E. Winchester, 1917.

PLATES XXXVI–XL.

PLATE XXXVI.

FIGURES 1–3. *Myrica praedrymeja* Knowlton. From Greasewood Creek, about 40 miles southwest of Meeker, Colo. U. S. Nat. Mus. Nos. 36557, 36558, 36559. (See p. 157.)

4. *Danaea coloradensis* Knowlton. From Rio Blanco County, Colo., about 40 miles southwest of Meeker. Pinnule, × 2. U. S. Nat. Mus. No. 36560. (See p. 150.)

5. *Danaea fendleri* Underwood. Living species from Trinidad, introduced for comparison. Segment of fruiting pinnule, × 6.

6. *Pontederites hesperia* Knowlton. From Greasewood Creek, about 40 miles southwest of Meeker, Colo. U. S. Nat. Mus. No. 36561. (See p. 154.)

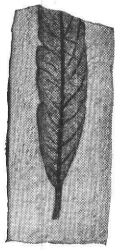
7. *Lygodium kaulfussii* Heer. From Little Duck Creek, Rio Blanco County, Colo. U. S. Nat. Mus. No. 36582. (See p. 149.)

8. *Caenomyces eucalyptae* Knowlton, on leaves of *Eucalyptus? americanus* Lesquereux. From Little Duck Creek, about 50 miles southwest of Meeker, Colo. × 2. For natural size, see Plate XXXIX, figure 2. U. S. Nat. Mus. No. 36589. (See p. 148.)

9. Same as figure 8, × 6. Figure retouched.

10. *Caenomyces sapindicola* Knowlton, on leaflet of *Sapindus winchesteri* Knowlton. From Greasewood Creek, about 40 miles southwest of Meeker, Colo. × 4. For natural size, see Plate XXXVIII, figure 1. Figure retouched. U. S. Nat. Mus. No. 36590. (See p. 148.)

1



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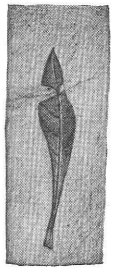

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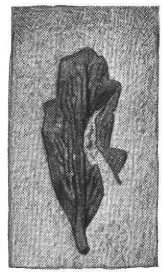

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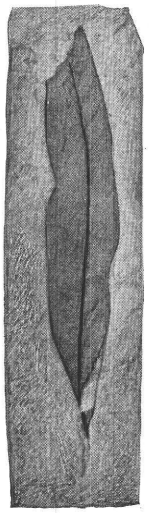

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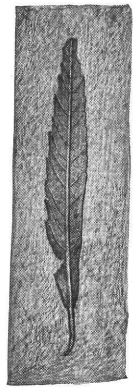

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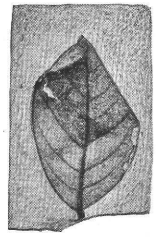

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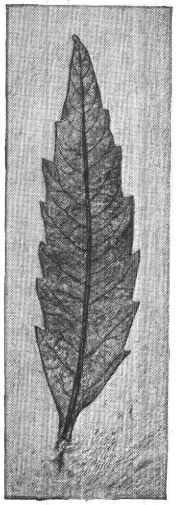

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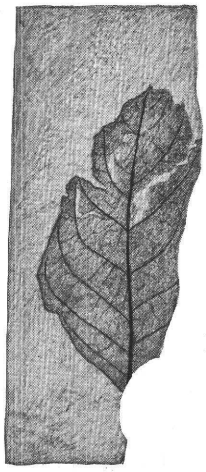

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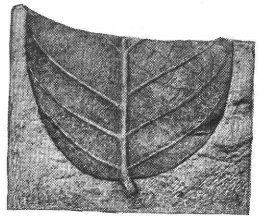
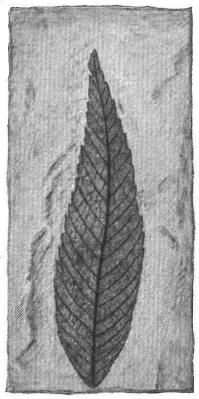


16

FLORA OF THE GREEN RIVER FORMATION.



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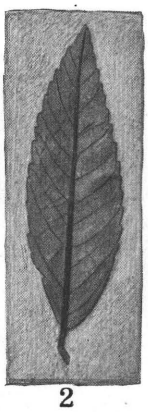

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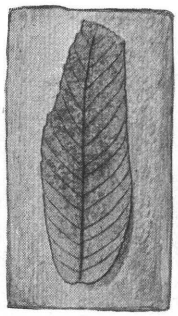

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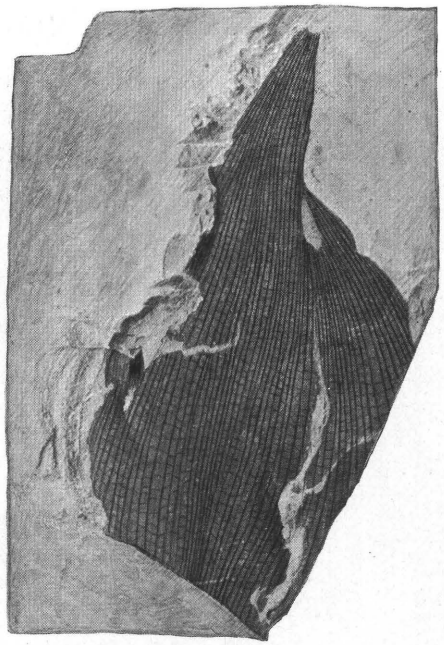

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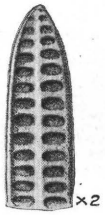

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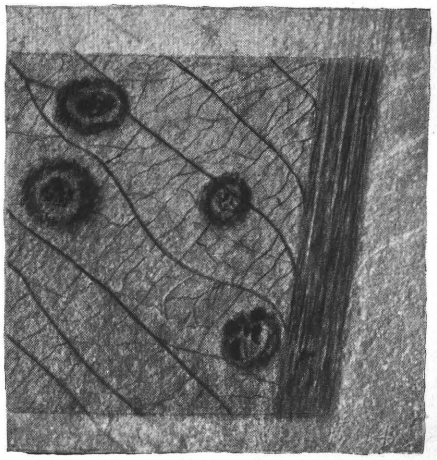

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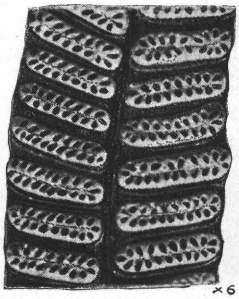

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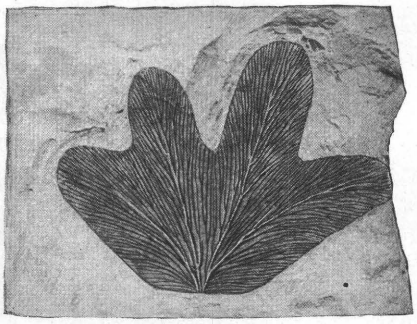

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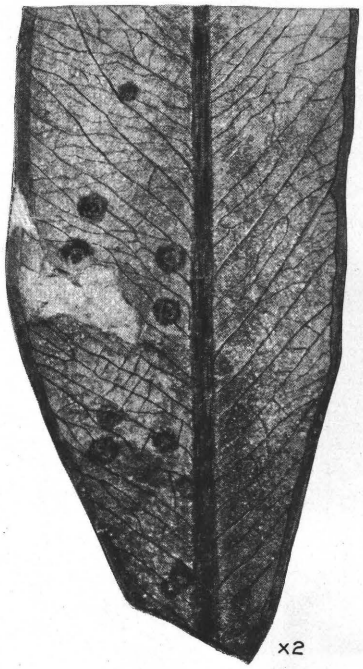

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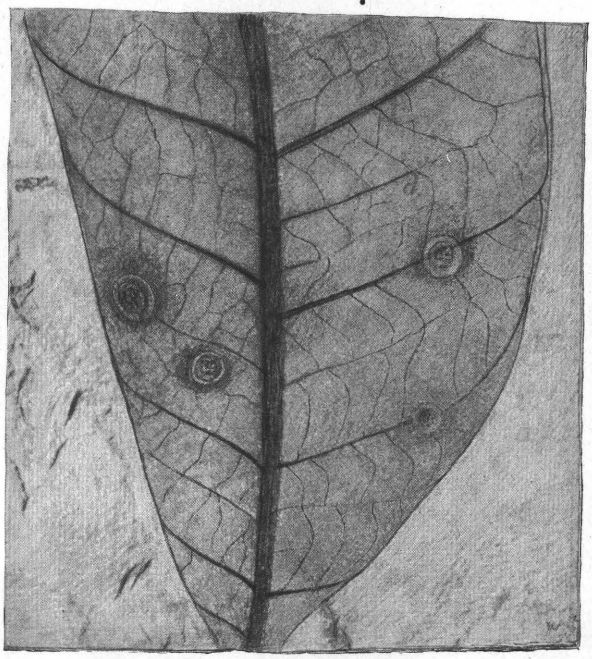


10

FLORA OF THE GREEN RIVER FORMATION.

PLATE XXXVII.

FIGURE 1. *Comptonia? anomala* Knowlton. From Greasewood Creek, about 40 miles southwest of Meeker, Colo. U. S. Nat. Mus. No. 36563. (See p. 158.)

2. *Myrica* sp. From Cathedral Bluff, 20 miles west of Rio Blanco post office, Colo. U. S. Nat. Mus. No. 36564. (See p. 157.)

3–5. *Salix* sp. From Rio Blanco County, about 40 miles southwest of Meeker, Colo. U. S. Nat. Mus. Nos. 36565, 36566, 36567. (See. p. 156.)

6. *Pimelea spatulata* Knowlton. From Cathedral Bluff, about 20 miles west of Rio Blanco post office, Colo. U. S. Nat. Mus. No. 36568. (See p. 163.)

7. *Sedum? hesperium* Knowlton. From Cathedral Bluff, about 20 miles west of Rio Blanco post office, Colo. U. S. Nat. Mus. No. 36569. (See p. 163.)

8. *Salix linearis* Knowlton. From Rio Blanco County, Colo., about 20 miles west of Rio Blanco post office. U. S. Nat. Mus. No. 36570. (See p. 155.)

9–11. *Rhus myricoides* Knowlton. From Greasewood Creek, about 40 miles southwest of Meeker, Colo. U. S. Nat. Mus. Nos. 36571, 36572, 36573. (See p. 168.)

12. *Myrica minuta* Knowlton. From Greasewood Creek, about 40 miles southwest of Meeker, Colo. U. S. Nat. Mus. No. 36574. (See p. 157.)

13. *Carpolithus caryophylloides* Knowlton. From Greasewood Creek, 40 miles southwest of Meeker, Colo. U. S. Nat. Mus. No. 36575. (See p. 174.)

14–16. *Sophora coloradensis* Knowlton. Figures 14 and 16 from Little Duck Creek, Rio Blanco County, Colo., about 50 miles southwest of Meeker; figure 15 from Camp Gulch, 25 miles northwest of De Beque, Colo. U. S. Nat. Mus. Nos. 36576, 36577, 36578. (See p. 165.)

PLATE XXXVIII.

FIGURE 1. *Sapindus winchesteri* Knowlton. From Greasewood Creek, about 40 miles southwest of Meeker, Colo. U. S. Nat. Mus. No. 36579. (See p. 167.)

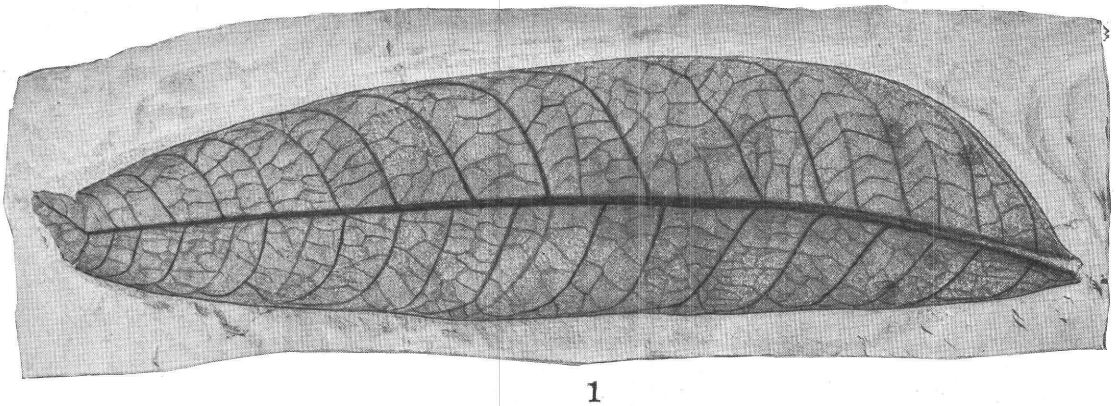
2. *Phyllites winchesteri* Knowlton. From Cathedral Bluff, about 20 miles west of Rio Blanco post office, Cool. U. S. Nat. Mus. No. 36580. (See p. 175.)

3. *Phyllites coloradensis* Knowlton. From Little Duck Creek, about 50 miles southwest of Meeker, Colo. U. S. Nat. Mus. No. 36581. (See p. 176.)

4. *Carpites inquirenda* Knowlton. From Cathedral Bluff, about 20 miles west of Rio Blanco post office, Colo. U. S. Nat. Mus. No. 36582. (See p. 175.)

5. *Juglans winchesteri* Knowlton. From Cathedral Bluff, about 20 miles west of Rio Blanco post office, Colo. U. S. Nat. Mus. No. 36583. (See p. 160.)

6. *Oreodaphne viridiflumensis* Knowlton. From Rio Blanco County, Colo., about 40 miles southwest of Meeker. U. S. Nat. Mus. No. 36584. (See p. 163.)



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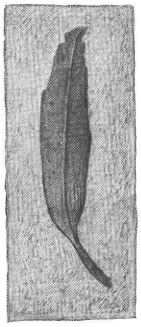

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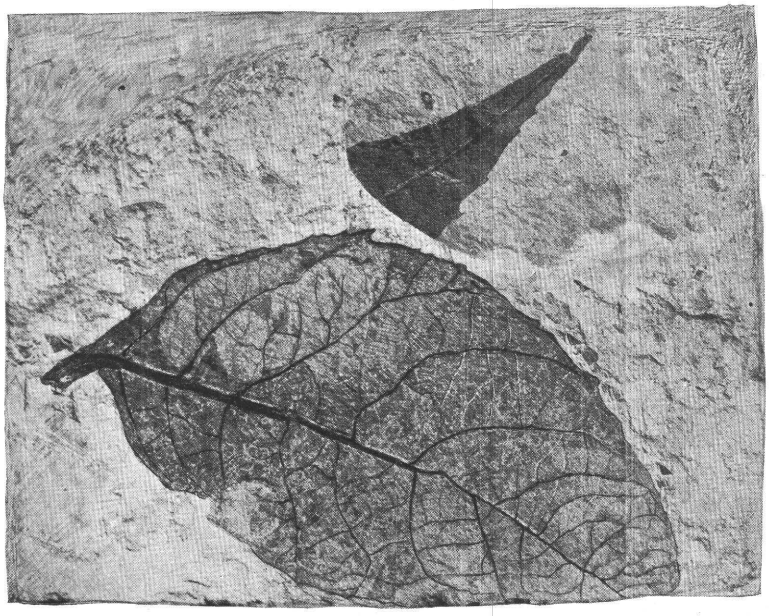

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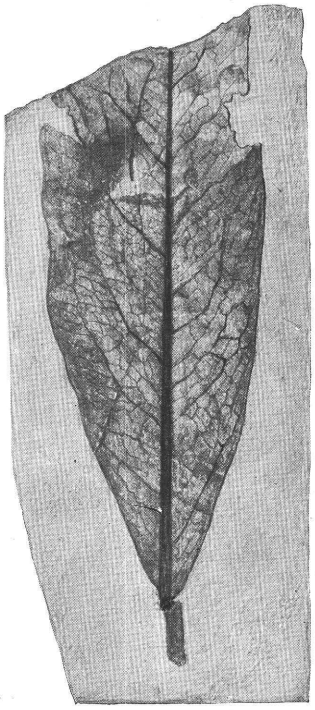

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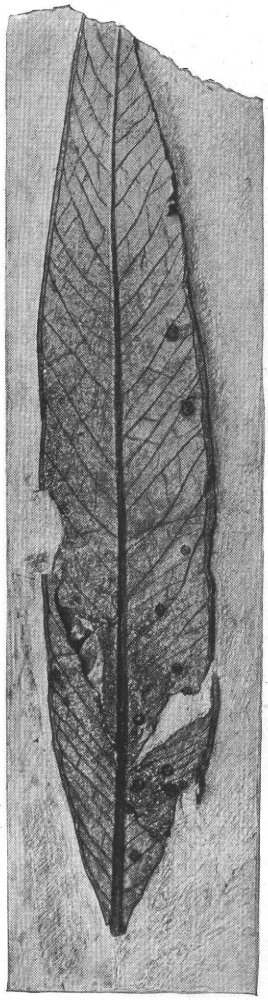
FLORA OF THE GREEN RIVER FORMATION.



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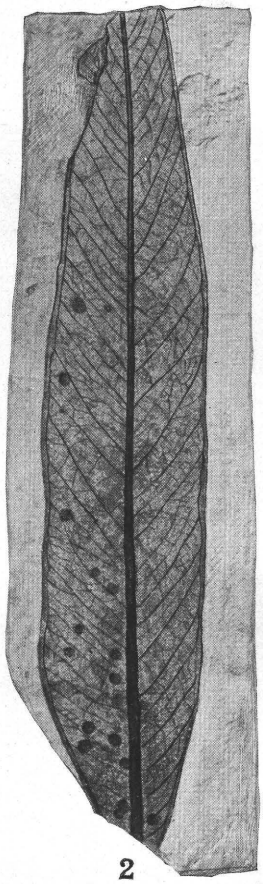

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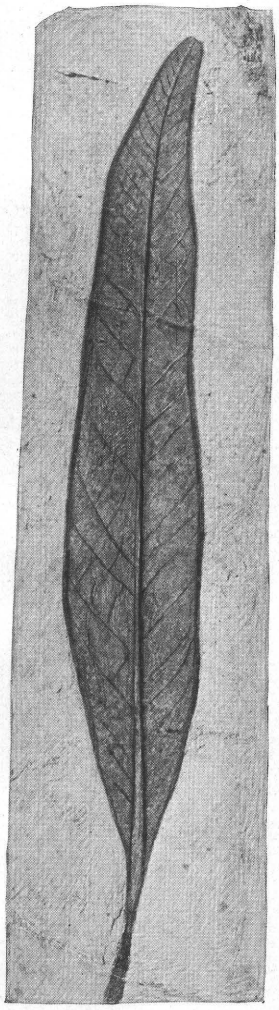

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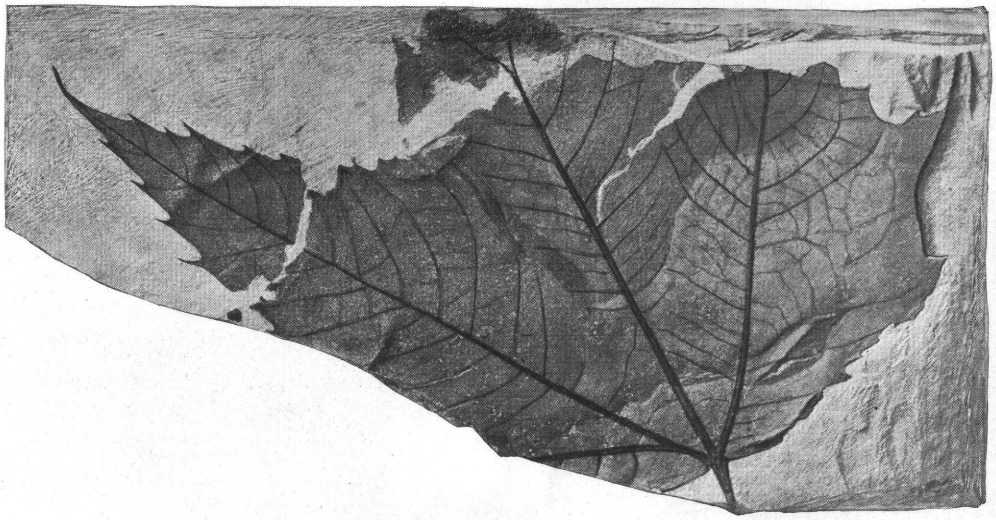

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FLORA OF THE GREEN RIVER FORMATION.

PLATE XXXIX.

FIGURES 1–3. *Eucalyptus? americanus* Lesquereux. Figures 1 and 2 from Little Duck Creek, 50 miles southwest of Meeker, Colo.; figure 3 from ridge between Carr and Bushy creeks, Garfield County, Colo. U. S. Nat. Mus. Nos. 36585, 36586, 36587. (See p. 171.)

4. *Aralia wyomingensis* Knowlton and Cockerell. From Cathedral Bluff, about 20 miles west of Rio Blanco post office, Colo. U. S. Nat. Mus. No. 36588. (See p. 172.)

PLATE XL.

FIGURES 1–3. *Mimosites coloradensis* Knowlton. From Little Duck Creek, about 50 miles southwest of Meeker, Colo. U..S. Nat. Mus. Nos. 36591, 36592, 36593. (See p. 166.)

4. *Achaenites cichorioides* Knowlton. From Camp Gulch, about 25 miles northwest of De Beque, Colo. U. S. Nat. Mus. No. 36594. (See p. 173.)

5, 6. *Dalbergia retusa* Knowlton. From Little Duck Creek, about 50 miles southwest of Meeker, Colo. U. S. Nat. Mus. Nos. 36595, 36596. (See p. 165.)

7. *Zizyphus longifolia* Newberry. From Greasewood Creek, about 40 miles southwest of Meeker, Colo. U. S. Nat. Mus. No. 36597. (See p. 169.)

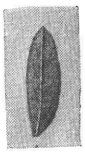
8, 9. *Sambucus? winchesteri* Knowlton. Figure 8, natural appearance, × 6; figure 9, restoration of figure 8, × 9 From Rio Blanco County, Colo., about 40 miles southwest of Meeker. U. S. Nat. Mus. No. 36598. (See p. 173.)

10. *Dalbergia viridiflumensis* Knowlton. From Rio Blanco County, Colo., about 20 miles west of Rio Blanco post office. U. S. Nat. Mus. No. 36599. (See p. 164.)

11. *Sophora coloradensis* Knowlton. From Little Duck Creek, about 50 miles southwest of Meeker, Colo. U. S. Nat. Mus. No. 36600. (See p. 165.)

12. *Aralia wyomingensis* Knowlton and Cockerell. From Cathedral Bluff, about 20 miles west of Rio Blanco post office, Colo. U. S. Nat. Mus. No. 36601. (See p. 172.)

13. *Myrica* sp. From head of Carr Creek, about 30 miles northwest of De Beque, Colo. U. S. Nat. Mus. No. 36602. (See p. 158.)



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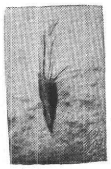

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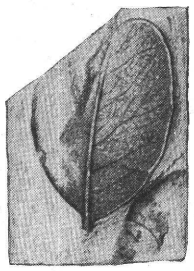

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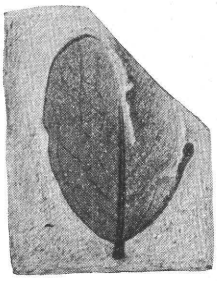

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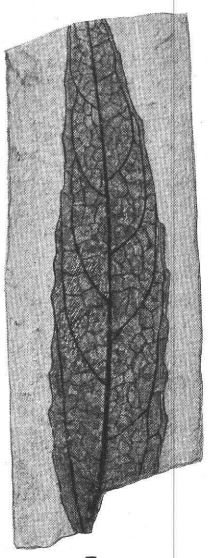

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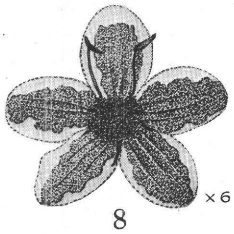

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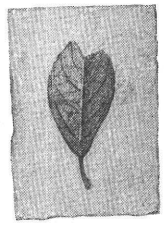

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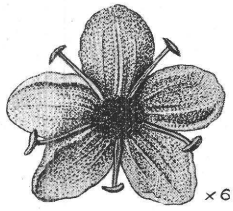

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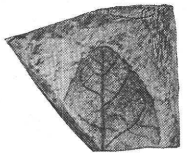

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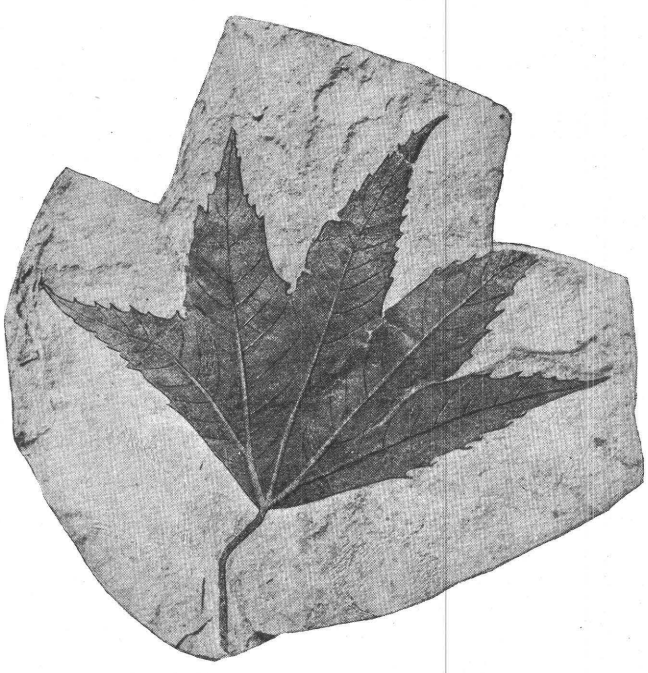

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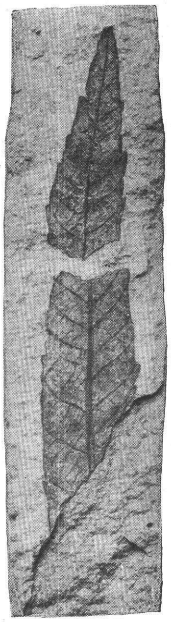

13

FLORA OF THE GREEN RIVER FORMATION.

FOSSIL PLANTS FROM THE TERTIARY LAKE BEDS OF SOUTH-CENTRAL COLORADO.

By F. H. KNOWLTON.

The first of the Tertiary lake beds of Colorado to be brought to scientific attention were those at Florissant, discovered in 1873 by Dr. A. C. Peale, of the Hayden Geological Survey. Lake Florissant was a small lake, approximately 5 miles in length and not much if any exceeding a mile in width, occupying a mountain valley with its laterals eroded in granite by stream action. The present altitude of the lake beds is a little more than 5,000 feet above sea level. The composition of these beds is described by Henderson [1] as follows:

> The beds are composed chiefly of volcanic ashes, mud, and sand, the component particles of which are generally somewhat though not very much worn by the action of water. The conclusion reached in both field and laboratory is that the deposits were formed largely by volcanic ashes from repeated eruptions falling upon the surface of the water and settling to the bottom, assorted by the sluggish lake currents; also by mud and ashes falling or flowing into position where they were rapidly washed into the lake by rains, streams, and waves without much grinding.

The Florissant lake beds have proved to be highly fossiliferous, perhaps more abundantly so than any other deposits in the world. They are especially rich in remains of plants and insects. During the period of nearly 50 years since their discovery these fossil riches have been abundantly exploited, and they are now known to include more than 1,000 species of insects and nearly 250 species of plants.

The Florissant lake beds were long supposed to be unique, but the more and more intensive geologic work prosecuted in the Rocky Mountain region, especially within the last 20 years, has disclosed a number of other lake-bed deposits in the San Juan Mountain region of south-central Colorado. The object of the present paper is to bring to scientific attention the location, present known extent, and flora of these scattered lake beds. The description of the flora is purely preliminary and will undoubtedly be greatly increased with more thorough exploration.

The plants described in the following pages were all collected from rocks deposited during the volcanic period of the San Juan Mountain region, though from several different formations. The lake beds aggregate some thousands of feet in thickness, and there is evidence to show that several of the formational units were separated by periods of extensive erosion, during which canyons were cut to the depth of several thousand feet. The position in the geologic column can be understood from the accompanying generalized section, which has been supplied by E. S. Larsen, of the United States Geological Survey.

Mr. Larsen makes the following statement:

> The periods of erosion separating these formations were all of sufficient length to develop canyons several thousand feet deep and a youthful topography comparable to that of the present San Juan Mountains. This no doubt represents a very great number of years but only a small fraction of the time required to develop a mature topography.
>
> The most abundant and best-preserved plant remains were collected from the Creede formation. This formation is made up chiefly of thin-bedded rhyolite tuff in its lower part, but it carries much gravel, and some lava flows in its upper part. Some travertine is present. The formation was deposited in a deep, steep-walled basin that was cut in rocks of the Potosi volcanic series and that coincides approximately with the present valley of the Rio Grande from Wagon Wheel Gap westward to the mouth of Trout Creek, a distance of about 25 miles, but was considerably narrower. The maximum thickness is over 2,000 feet. The best plant remains were collected from the thinly laminated tuffs in the lower part of the formation. The cliffs exposed above Sevenmile Bridge are about 100 feet high and are almost continuous on the northwest bank of the river for over a mile.

[1] Henderson, Junius, Colorado Univ. Studies, vol. 3, pp. 145–151, 1906.

The localities and the species found at each are listed below.

Cross. No. La G. 2 [5951]. Crude formation, La Garita quadrangle, Colo. Ridge north of stream which passes Hot Spring Hotel at altitude of 9,000 feet:

Minute fragments of bark, coniferous leaves, etc., but nothing determinable.

Cross. No. La G. 24 [5952]. Creede formation, south bank of Rio Grande 150 yards above wagon bridge, 3½ miles below Creede, Colo.:

Feather of bird.
Planera myricaefolia (Lesquereux) Cockerell.
Fragments.

Cross. No. La G. 93 [5953]. Creede formation, west side of Rio Grande one-fourth mile north of Sevenmile Bridge, below Creede, Colo., near boundary of San Cristobal quadrangle:

Pinus crossii Knowlton, n. sp.
Abies rigida Knowlton, n. sp.
Myrica myricaefolia (Lesquereux) Cockerell.
Feather of bird.

Cross. No. S. C. 1566 [5954]. Huerto formation, in a lens 100 yards long, N. 37½° E. of houses at north end of Lake Santa Maria, San Cristobal quadrangle, Colo., altitude 10,350 feet:

Pinus similis Knowlton, n. sp.
Ribes protomelaenum Cockerell.
Planera myricaefolia (Lesquereux) Cockerell?
Phyllites potentilloides Knowlton, n. sp.

Cross. 1911. No. La G. 536 [6198]. Creede formation, west side of Rio Grande near Sevenmile Bridge, near Creede, Colo., altitude 8,800–9,000 feet:

Pinus crossii Knowlton, n. sp.
Abies rigida Knowlton, n. sp.
Planera myricaefolia (Lesquereux) Cockerell.
Odostemon marginata (Lesquereux) Knowlton, n. comb.
Vitis florissantella Cockerell.
Populus lesquereuxi Cockerell.
Insect (beetle?).
Feathers.

Cross. 1914. No. 516 [6889]. Conejos (?) formation, Saguache quadrangle, Colo., gulch west of Henderson Mountain, about 1¼ miles north of Saguache River:

Coniferous wood, not further studied.

Cross. 1914. No. 437 [6858]. Saguache quadrangle, Colo., rhyolite tuff in railroad cut below (west of) Marshall Pass, where railroad crosses gulch at Shavano siding; geologic position uncertain but probably considerably below Conejos formation:

Pinus crossii Knowlton, n. sp.?
Fragments not determinable.

Larsen. 1916. [7242]. Creede formation, north bank of Rio Grande near Sevenmile Bridge, above Creede, Colo.:

Pinus crossii Knowlton, n. sp.
Pinus similis Knowlton, n. sp.
Pinus coloradensis Knowlton, n. sp.
Pinus florissanti? Lesquereux.
Abies rigida Knowlton, n. sp.
Sabina linguaefolia (Lesquereux) Cockerell.
Alnus? larseni Knowlton, n. sp.
Populus lesquereuxi Cockerell.
Planera myricaefolia (Lesquereux) Cockerell.
Ribes protomelaenum Cockerell.
Rubus? inquirendus Knowlton, n. sp.
Vitis florissantella Cockerell.
Odostemon marginata (Lesquereux) Knowlton, n. comb.
Odostemon hakeaefolia (Lesquereux) Knowlton, n. comb.
Sterculia aceroides Knowlton, n. sp.
Phyllites, two sp.

From the foregoing lists it appears that 5 of the 8 collections and no less than 18 of the 19 forms enumerated come from the Creede formation. From beds believed to belong to the Huerto formation the single collection yielded three named species, all of which occur also in the Creede formation.

A complete list of forms described in this paper is as follows:

Pinus crossii Knowlton, n. sp.
Pinus similis Knowlton, n. sp.
Pinus florissanti? Lesquereux.
Pinus coloradensis Knowlton, n. sp.
Abies rigida Knowlton, n. sp.
Abies longirostris Knowlton, n. sp.
Sabina linguaefolia (Lesquereux) Cockerell.
Populus lesquereuxi Cockerell.
Alnus? larseni Knowlton, n. sp.
Planera myricaefolia (Lesquereux) Cockerell.
Ribes protomelaenum Cockerell.
Rubus? inquirendus Knowlton n. sp.
Vitis florissantella Cockerell.
Odostemon marginata (Lesquereux) Knowlton, n. comb.
Odostemon hakeaefolia (Lesquereux) Knowlton, n. comb.
Sterculia aceroides Knowlton, n. sp.
Phyllites potentilloides Knowlton, n. sp.
Phyllites, two sp.

On eliminating the forms not named there remain 8 species described as new and 8 previously known species. As all these previously known species are found in the lake beds at Florissant, Colo., it seems reasonable to conclude that the age of the lake beds of the Creede formation is the same as that of the Florissant beds, namely, upper Miocene. From the Huerto formation were obtained three named species (*Pinus similis*, *Planera myricaefolia*, and *Ribes protomelaenum*) and an unamed *Phyllites*. All three of the named species are found in the Creede formation, and two of them are well-known Florissant species. The only other collection—that from Marshall Pass—contains a single doubtfully identified form (*Pinus crossii?*) and detached

Geologic formations in a part of southwestern Colorado.

[Supplied by E. S. Larsen. The waved lines indicate erosion intervals.]

Platoro-Summitville district, southwestern Colorado. (Patton, H. B. (quoting unpublished names of Whitman Cross and E. S. Larsen), Colorado Geol. Survey Bull. 13, with map, 1917.)	Creede district, southwestern Colorado. (Emmons, W. H., and Larsen, E. S., U. S. Geol. Survey Bull. 718, 1923.)	San Juan Mountain region, southwestern Colorado. (Cross, Whitman, folios of U. S. Geol. Survey Geol. Atlas and other published reports.)
Hinsdale volcanic series.		Hinsdale volcanic series. 0–1,200± feet. Probably Miocene or Pliocene. Lava flows of rhyolite, andesite, and basalt. Named in 1911 (U. S. Geol. Survey Bull. 478, p. 22), for important development in Hinsdale County, Colo.
	Quartz latite porphyry dikes. Miocene.	
Fisher quartz latite. [0–3,000+ feet. Named for exposures in vicinity of Fisher Mountain, Creede quadrangle.]	Fisher quartz latite. Miocene. 0–100± feet.	Intrusive rhyolite, andesite, latite, and quartz monzonite porphyry.
	Creede formation. 0–2,000± feet. Lake beds of tuff with some flows of quartz latite in upper part. Miocene.	
Potosi volcanic series. Piedra formation. [A series of volcanic flows, with subordinate tuff, predominantly of rhyolite and quartz latite. 0–2,000+ feet. Separated from underlying Huerto formation by an erosion interval. Named for exposures in Piedra Peak, San Cristobal quadrangle, Colo.]	Potosi volcanic series (Miocene). Piedra group. Nelson Mountain quartz latite. 0–350 feet.	
	Rat Creek quartz latite. 0–500 feet.	
	Quartz latite tuff. 0–500 feet.	
	Andesite. 0–500 feet.	
	Intrusive andesite.	
	Tridymite latite. 0–400 feet.	
	Windy Gulch rhyolite breccia. 100–200+ feet.	Rhyolite tuff (to east). 0–200 feet. Mammoth Mountain rhyolite. 0–1,000 feet.
	Hornblende-quartz latite 200 feet.	
Huerto formation. [A series of andesitic flows and tuff breccias, 0–2,000+ feet thick, which commonly overlie the Alboroto formation rather regularly. Named for occurrence on Huerto Peak, in the southern part of the San Cristobal quadrangle, Colo., west of Huerto Creek.]		Potosi volcanic series. 0–2,000± feet, Miocene. Lava flows of rhyolite, quartz latite, andesite, and tuff. Locally divisible into several formations. Named in 1899 (U. S. Geol. Survey Geol. Atlas, Telluride folio, No. 57), for development on Potosi Peak, Silverton quadrangle, Colo.
Alboroto formation. [A series of quartz latite and rhyolite flows with some tuff. 0–3,000+ feet. Separated from Summitville andesite by an erosion interval. Named for occurrence in Alboroto Mountain, in the southeast corner of the San Cristobal quadrangle, Colo.]	Alboroto group. Equity quartz latite. 0–1,000 feet.	
	Phoenix Park quartz latite. 0–500 feet.	
	Intrusive rhyolite.	
	Campbell Mountain rhyolite. 0–1,000 feet.	
	Willow Creek rhyolite. 0–1,000+ feet.	
	Outlet Tunnel quartz latite. 250–350+ feet.	
Summitville andesite. [Named for exposures near Summitville, Colo. 0–3,000+ feet.]		
Treasure Mountain latite. [Named for exposures on Treasure Mountain, in the northwestern part of the Summitville quadrangle. 0–1,000+ feet.]		
Palisade andesite (Conejos formation). [Palisade has long been preoccupied by the Palisade diabase of New Jersey. The name adopted by the U. S. Geol. Survey for these rocks is Conejos formation, derived from their exposures along Conejos River. 0–3,000+ feet.]		
		Silverton volcanic series. 0–4,000± feet. Probably Oligocene or early Miocene. Succession of flows of andesite, latite, rhyolite, tuff, and breccia. Locally divisible into several formations. Named in 1901 (U. S. Geol. Survey Bull. 182, p. 32) for extensive development in Silverton quadrangle, Colo.
		San Juan tuff. 0–3,000± feet. Probably Eocene. Series of stratified and water-laid andesitic tuffs, breccias, and agglomerates. Named in 1896 (Colorado Sci. Soc. Proc., vol. 5, pp. 225–241) for important development in San Juan Mountains, Colo.
		Lake Fork breccia. 0–1,000± feet. Probably Eocene. Chiefly chaotic andesitic flows and breccias locally developed in the Uncompahgre and adjoining quadrangles, Colo. Here named by Whitman Cross and E. S. Larsen for exposures on the Lake Fork of Gunnison River, in the Uncompahgre quadrangle, Colo.
		Telluride conglomerate. 0–1,000 feet. Probably Eocene. Coarse conglomerate, containing pebbles and boulders of schist, granite, quartzite, limestone, and other Paleozoic rocks, with locally fine sandy limestones. Originally named "San Miguel formation" in 1896 (Colorado Sci. Soc. Proc., vol. 5, pp. 225–241) for exposures on north side of San Miguel River in the vicinity of Telluride, Colo. San Miguel being preoccupied by a Cretaceous formation of Texas, this conglomerate was in 1905 (U. S. Geol. Survey Geol. Atlas, Silverton folio, No. 120) renamed Telluride conglomerate.

leaves of *Pinus* and probably *Abies*. This collection is supposed to be much older than the others, but its position is somewhat uncertain.

So far as present known facts go it appears that the same flora ranges through the entire thickness of these lake deposits. Although the formational units involved are hundreds of feet thick, and although many of these units are separated by unconformities representing periods of erosion during which thousands of feet of beds were cut out, the deposition of the whole series occupied relatively so short a time that the changes in conditions do not appear to be reflected in the flora. Of course subsequent studies and collections may modify this conclusion, but it is all that can be said at present.

The flora of these lake beds as described in this paper is so small that it is perhaps hardly worth while to attempt any extensive discussion of the affinity, probable origin, and climatic requirements of the species included, yet they show a number of biologic features of considerable interest. The most abundant element in the flora consists of the Coniferae, which comprise over a third of the species and nearly half of the individual specimens. Although nine forms of conifers have been reported from the Florissant lake beds, all but one or two are very rare as individuals. It is probable that the increased elevation of the Creede deposits may account for the abundance of conifers, though more extended exploration will doubtless reduce this apparent preponderance. The most interesting of these conifers are the species of *Abies*, of which the specimens collected represent leafy branches and cone scales. It is possible that the branches and scales may belong to a single species, but as they are wholly unconnected it has been necessary to give them separate names. The cone scales indicate the group of *Abies* in which the bracts adhere firmly to the scale and are prolonged above into a long, slender tip, which may be as much as 4 centimeters in length. This group seems to be most closely related to *Abies venusta* Koch, the so-called silver fir of California. This is the first time, at least in this country, that cone scales of this type have been observed. The pines represent both the soft or white pines and the hard pines, the former known by their cluster of leaves in fives or fours.

The next in abundance and interest are the two species of *Odostemon*, the genus to which the well-known Oregon grape belongs. Both species—if they are really distinct—occur also in the Florissant beds, and it is believed that they are correctly placed generically, as they agree in all essential particulars with the living species. Four living species of *Odostemon* are now found in the Rocky Mountain area, and it would seem that they are the direct descendants of the Miocene forms.

None of the other genera (*Populus, Alnus, Ribes, Vitis*) offer features of particular biologic interest. The species referred with some question to *Rubus* is a small spray of flowers and immature fruit that if not actually a member of this genus is certainly very strongly suggestive of it.

The climatic requirements of this little flora would seem to be temperate, perhaps cool temperate, but it is still too small to warrant a very positive conclusion.

Pinus crossii Knowlton, n. sp.

Plate XLI, figures 3, 8–10.

Leaves in clusters of five, stout, rigid, slightly incurved, sharp pointed, 2.5 to about 4 centimeters long; sheaths of the leaf clusters deciduous.

This species is represented by a number of specimens, several of the best of which are figured. It is assumed that the normal number of leaves is five in each cluster, but there are a few examples in which only three can be made out. Thus, in the fragment of a branch shown in figure 3, there are two clusters, each with three leaves that otherwise agree with the five-leaved clusters. Although it is not impossible for the leaves to vary in number from three to five in the same species, it seems improbable in the present case, and, as stated above, the normal number is presumed to be five.

This species seems clearly to belong to the group of soft or white pines, not only as shown by the leaves being in clusters of five but more particularly by the complete absence of the sheath to the leaf bases. It seems to be most closely related to *Pinus albicaulis* Engelmann, a species of alpine slopes and exposed ridges

throughout the Rocky Mountain region, at altitudes ranging from 5,000 to 12,000 feet.

Two species based on leaves have been described from the lake beds at Florissant—*Pinus hambachi* Kirchner,[2] supposed to have the leaves in clusters of three, and *Pinus wheeleri* Cockerell,[3] with the leaves in fives. In the original description of *P. wheeleri* the leaves are said to be 12 centimeters or more in length, but in descriptions of later specimens the length has been given as somewhat less. Nothing is said as to the sheath in this species, so this feature can not be compared with *P. crossii*.

Occurrence: Creede formation, north bank of Rio Grande near Sevenmile Bridge, Creede, Colo.; rhyolite tuff of unknown age but probably considerably older than Conejos formation, below (west of) Marshall Pass, Saguache quadrangle, Colo.

Pinus similis Knowlton, n. sp.

Plate XLI, figures 11, 12.

Leaves in clusters of four, stout, straight, 4.5 to 5.5 centimeters long; sheath of the leaf clusters absent.

It is with considerable hesitation that this form is described as a new species, as it may be only a slightly larger form of *Pinus crossii*. The base of the leaves is indistinguishable in appearance in the two forms, and the presence of only four leaves in the cluster of *P. similis* may be due to accident, though there is no evidence of it in the best preserved example. A single detached leaf on the same piece of matrix is the largest one observed (5.5 centimeters).

Individual leaves of this form are indistinguishable from leaves of *Pinus hambachi* Kirchner,[4] from the Florissant lake beds, but that species is said to have the leaves in clusters of three, and the resemblance may be only superficial.

Occurrence: Creede formation, north bank of Rio Grande, near Sevenmile Bridge, Creede, Colo.; Huerto formation, north end of Lake Santa Maria, San Cristobal quadrangle, Colo.

[2] Kirchner, W. C. G., St. Louis Acad. Sci. Trans., vol. 9, p. 179, pl. 13, fig. 3, 1898.

[3] Cockerell, T. D. A., Am. Mus. Nat. Hist. Bull., vol. 24, p. 78, pl. 6, figs. 5, 11, 1908.

[4] Kirchner, W. C. G., St. Louis Acad. Sci. Trans., vol. 9, p. 174, pl. 13, fig. 3, 1898.

Pinus florissanti? Lesquereux.

Plate XLI, figure 7.

Pinus florissanti Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 138, pl. 21, fig. 13, 1883.

The collection contains a single large fragmentary cone that seems to be the same as *Pinus florissanti* Lesquereux.

Occurrence: Creede formation, north bank of Rio Grande, near Sevenmile Bridge, Creede, Colo.

Pinus coloradensis Knowlton, n. sp.

Plate XLI, figure 6.

Cone with a very short, thick stalk, ovoid, very obtuse at apex, 3 centimeters long, 2.3 centimeters in diameter; scales much thickened at the end; apparently with a short spine.

The example figured is the only one of this type observed in the collections. It is fairly perfect except for a few scales at the base. By making an impression in clay the original appearance is restored, as shown in figure 6. At first it was presumed that this specimen was probably the cone of *Pinus crossii*, with which it was associated, but whereas the absence of persistent sheaths to the leaf clusters proves that form to belong to the soft pines, the thickened tips of the scales in the present form show it clearly to belong to the hard pines. This form is, for instance, not greatly unlike the cone of *Pinus arizonica* Engelmann, but this resemblance is doubtfully to be interpreted as a real relationship.

The only fossil species of the region and age with which this may be compared is *Pinus florissanti* Lesquereux,[5] from the Florissant lake beds, but this is a cone 10 centimeters or more in length and 6 centimeters in diameter, and, moreover, the thickened tips of the cone scales appear to be different.

Occurrence: Creede formation, north bank of Rio Grande, near Sevenmile Bridge, Creede, Colo.

Abies rigida Knowlton, n. sp.

Plate XLI, figures 1, 2, 4, 5.

The collection from Creede contains a number of leafy branches that appear to belong to the genus *Abies*, but whether they represent

[5] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), pl. 21, fig. 13, 1883.

more than one species is difficult to decide. The one shown in figure 5 is a segment from a branch and is about 6 centimeters long, 6 millimeters in diameter at the base, and 5 millimeters at the apex. It shows the scars of leaves disposed in oblique rows. On one side the leaves are attached, these being apparently rather rigid, slightly arched upward, and obtusely pointed at the tips; they are about 12 millimeters long. The branch shown in figure 2 is the tip of a branch about 4 millimeters in diameter and has the leaves preserved on all sides. The leaves are much the same as in figure 5. Leaf scars are present at several points on the branch. Figure 4 is also the tip of a branch that retains most of the leaves. The leaves seem narrower and less rigid than in the other specimens mentioned; they are 2 centimeters or more in length. The specimen given in figure 1 is a shoot segment from which most of the leaves have fallen and is figured mainly because it shows the leaf scars so plainly. The leaves appear to agree most closely with those of figure 2.

It is possible that the specimens shown in figures 1 and 2 are specifically distinct from those of figures 4 and 5, but as only one type of *Abies* cone has been found it seems best to keep them together for the present. It is of course not at all certain that the cone scales belong to either of the branches, though it is perhaps a fair inference that they do.

Occurrence: Creede formation, north bank of Rio Grande, near Sevenmile Bridge, Creede, Colo.

Abies longirostris Knowlton, n. sp.

Plate XLII, figures 1, 2.

Cone scales thin, flat, much broader than long (16 to 18 millimeters wide, 8 to 10 millimeters long exclusive of the basal attached point); bracts of cone scales oblong, firmly attached to the scales and deciduous with them, prolonged above into a slender, rigid tip 2 to 4 centimeters long.

The collection contains a number of detached cone scales that appear certainly to belong to *Abies*. They are excellently preserved, the two selected for figuring being practically perfect. They show both sides of the scale. The one in figure 1 shows the back of the scale with the narrowly oblong bract firmly adhering to it and prolonged above into a rigid tip or spine fully 4 centimeters long. The other (fig. 2) exhibits the upper side of the cone scale with the bract prolonged above it for more than 4 centimeters.

This species appears to be most closely related to *Abies venusta* Koch, the so-called silver fir of the Santa Lucia Mountains in Monterey County, Calif.; at least it agrees with that species in some important particulars, such as the firm consolidation of the bract with the cone scale and its prolongation into the long, slender tip.

Occurrence: Creede formation, north bank of Rio Grande near Sevenmile Bridge, Creede, Colo.

Sabina linguaefolia (Lesquereux) Cockerell.

Sabina linguaefolia (Lesquereux) Cockerell, Colorado Univ. Studies, vol. 3, p. 175, 1906; Am. Mus. Nat. Hist. Bull., vol. 24, p. 79, 1908.
Knowlton, U. S. Nat. Mus. Proc., vol. 51, p. 249, 1916.
Widdringtonia linguaefolia Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 139, pl. 21, figs. 14, 14a, 1883.

This characteristic species is represented by a single branch with two or three short branchlets.

Occurrence: Creede formation, north bank of Rio Grande near Sevenmile Bridge, Creede, Colo.

Populus lesquereuxi Cockerell.

Plate XLIV.

Populus lesquereuxi Cockerell, Torrey Bot. Club Bull., vol. 33, p. 307, 1906.
Populus heerii Saporta. Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 157, pl. 30, figs. 1–8; pl. 31, fig. 11, 1883.

The basal portion with its petiole complete of a very large leaf is all that was found of this species. The petiole is nearly 3 millimeters thick and 7.5 centimeters long. The width of the blade is slightly more than 6 centimeters.

This leaf is similar in size to the largest one figured by Lesquereux (op. cit., pl. 30, fig. 5), which lacks the basal portion and the petiole, which the present leaf supplies. Lesquereux's leaf must have been nearly or quite 24 centimeters in length.

Occurrence: Creede formation, west bank of Rio Grande near Sevenmile Bridge, Creede, Colo.

Alnus? larseni Knowlton, n. sp.

Plate XLII, figure 3.

Leaf small, evidently firm in texture, elliptical, about equally narrowed to both base and apex; margin sharply serrate; petiole long, slender; nervation faintly preserved, consisting of a relatively strong midrib and seven or eight pairs of thin secondaries at an angle of about 40°; finer nervation not retained.

Only a single specimen of this form with its counterpart was found in the collection. It is regularly elliptical, 6 centimeters long and 2.8 centimeters wide, with the petiole preserved for a length of 1.5 centimeters.

I am a little in doubt as to the generic reference of this leaf. In living species of *Alnus* the margin is often doubly serrate, sometimes crenate-dentate, and only rarely—as, for instance, in *Alnus maritima* Nuttall—simply serrate. The present leaf is similar to *Alnus corrallina* Lesquereux,[6] from the Miocene of California, but it has fewer, more irregular secondaries. The finer nervation can not be compared.

The species is named in honor of Esper S. Larsen, of the United States Geological Survey, who collected it.

Occurrence: Creede formation, north bank of Rio Grande near Sevenmile Bridge, Creede, Colo.

Planera myricaefolia (Lesquereux) Cockerell.

Plate XLIII, figures 16, 17.

Planera myricaefolia (Lesquereux) Cockerell, Am. Mus. Nat. Hist. Bull., vol. 24, p. 88, 1908.
Knowlton, U. S. Nat. Mus. Proc., vol. 51, p. 266, pl. 21, fig. 2, 1916.
Planera longifolia myricaefolia Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 161, pl. 19, figs. 14–27, 1883.

The collection from Creede contains about a dozen leaves that are undoubtedly identical with this species. They are smaller than the average leaves figured by Lesquereux, though not smaller than the smallest one.

Occurrence: Creede formation, north bank of Rio Grande near Sevenmile Bridge, Creede, Colo. Huerto formation, north end of Lake Santa Maria, San Cristobal quadrangle, Colo.

[6] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), pl. 51, figs. 1–3, 1883.

Rubus? inquirendus Knowlton, n. sp.

Plate XLIII, figure 11.

Inflorescence racemose, main axis zigzag, about 14 millimeters long, flowers scattered, pediceled, the pedicels slender, 2 or 3 millimeters long; calyx inferior, five-parted; fruit (?) obscure.

It is with some hesitation that this little inflorescence is referred to *Rubus*. It is very small and delicate, and the preservation is not all that could be desired. Neither the main axis nor the pedicels are provided with prickles or glands, nor is each pedicel subtended by a bract, as in many living species; but, on the other hand, there are a number of recent species without all or some of these features. The calyx is very obscure. It appears certainly to be inferior and five-parted, though only three lobes are preserved in any one flower. The central part of the "flower" is so poorly preserved that its exact nature can not be made out with certainty. It may consist of a definite number or possibly a mass of carpels.

It is possibly unwise to attempt even a tentative placing of this fragment, but fossil flowers and fruits are so rare that even poorly preserved specimens may have some value. This form is perhaps definite enough to permit its recognition if again found.

Occurrence: Creede formation, north bank of Rio Grande near Sevenmile Bridge, Creede, Colo.

Ribes protomelaenum Cockerell.

Plate XLII, figures 5–9.

Ribes protomelaenum Cockerell, Am. Mus. Nat. Hist. Bull., vol. 24, p. 93, pl. 7, fig. 15, 1908.

This species was founded on a single example from the Florissant lake beds and is described as being about 4.6 centimeters long and fully 6 centimeters broad. It is described as having the base deeply cordate, "the sides of the basal portion rounded, without lobes." The figure shows that the basal portion is entirely absent on one side, and the other appears rather indefinite.

The collection from Creede contains about a dozen leaves referred to this species, of various sizes and very perfectly preserved. They are all distinctly five-lobed, and the

basal lobes are smaller than the upper lobes and in some specimens nearly entire. The largest leaf (fig. 8) is 5.3 centimeters long to the top of the petiole and 5.7 centimeters broad. It has the petiole preserved for a length of 1 centimeter. The next in size (fig. 9) is absolutely perfect and is 3 centimeters long and 4 centimeters broad between the upper lobes. The petiole complete is 1.8 centimeters long. Still smaller leaves are shown in figures 5–7. Figure 7 represents an almost perfect leaf 1.7 centimeters long and 2.3 centimeters wide, with the petiole 1.2 centimeters long.

Ribes protomelaenum resembles closely a number of living species. Cockerell compared it to *Ribes nigrum* Linné and *R. hudsonianum* Richards, but even more clearly it seems to me to resemble *R. rubrum* Linné and *R. prostratum* L'Héritier.

Occurrence: Creede formation, north bank of Rio Grande near Sevenmile Bridge, Creede, Colo.; Huerto formation, north end of Lake Santa Maria, San Cristobal quadrangle, Colo.

Vitis florissantella Cockerell.

Plate XLII, figure 4.

Vitis florissantella Cockerell, Am. Mus. Nat. Hist. Bull., vol. 24, p. 102, pl. 7, fig. 18, 1908.

A single leaf with its counterpart clearly belongs to this species. It is even smaller than the type, being only about 22 millimeters long and 23 millimeters broad. It lacks the basal portion but otherwise agrees with the type.

Occurrence: Creede formation, west bank of Rio Grande near Sevenmile Bridge, Creede, Colo.

Odostemon marginata(?) (Lesquereux) Knowlton, n. comb.

Plate XLIII, figures 7–10.

Hedera marginata Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 177, pl. 40, fig. 8, 1883.

Leaves pinnate (?), at least trifoliolate, petiole short, stout; leaflets coriaceous in texture, closely sessile at the top of the petiole, nearly circular or broadly ovate, very obtusely wedge-shaped, truncate or even slightly heart-shaped at base, the margin with usually three strong teeth or lobes on each side, the lobes sharp-pointed and apparently spine-tipped; nervation palmate from the base, the middle rib slightly stronger, other nervation much joined or sometimes running to the lateral lobes.

The specimens from Creede that are here figured have been the basis of a good deal of study and not a little speculation. It was early recognized that they were certainly identical with the *Hedera marginata* of Lesquereux, but the question of their relationship was much in doubt. It seemed improbable that they were correctly referred to *Hedera;* in fact, Lesquereux expressed the opinion when the species was first described that he knew "nothing to which this leaf may be related," and others have expressed the same uncertainty. It was not until the specimen with the leaflets attached was discovered that the affinity of this form was suspected. This specimen (fig. 7) has one leaflet complete and the bases of the other two, together with the perfect petiole. The best leaflet is 10 millimeters long and 7 or 8 millimeters broad. The spread of the whole leaf should be about 22 millimeters; the length of the petiole is 8 millimeters. The best preserved leaflet has three teeth on the lower side and two on the upper side. The terminal leaflet has only the obtusely wedge-shaped basal portion preserved.

Another well-preserved leaflet is the one shown in figure 9. It is slightly larger than the one just described, being about 18 millimeters long and 17 millimeters wide. It has large spine-tipped teeth and in size, teeth, and nervation closely resembles the type of *Hedera marginata*. Still larger, but so fragmentary that it can not be accurately measured, is the one seen in figure 10. This has the nervation well preserved and also the spine on one of the teeth. The largest specimen—figure 8—is nearly perfect. It is oblique and slightly heart-shaped at the base and has the usual strong teeth and the characteristic nervation. Its length is about 28 millimeters and its width about 30 millimeters.

The genus *Odostemon* Rafinesque (*Mahonia* of Nuttall; *Berberis* section *Mahonia* of authors) comprises about 20 species in central Asia, China, North America, and adjacent Mexico. They are unarmed shrubs with pin-

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nately compound spinose-toothed evergreen leaves.

Occurrence: Creede formation, north bank of Rio Grande, near Sevenmile Bridge, Creede, Colo.

Odostemon hakeaefolia (Lesquereux) Knowlton, n. comb.

Plate XLIII, figures 1–6.

Lomatia hakeaefolia Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 166, pl. 32, fig. 19, 1883.

Lomatites haekaefolia (Lesquereux) Cockerell, Am. Mus. Nat. Hist. Bull., vol. 24, p. 89, 1908.

Knowlton, U. S. Nat. Mus. Proc., vol. 51, p. 267, pl. 26, figs. 1, 2, 1916.

Carduus florissantensis Cockerell, Torrey Bot. Club Bull., vol. 33, p. 311, text fig. 6, 1906.

?*Odostemon florissantensis* Cockerell, Am. Mus. Nat. Hist. Bull., vol. 24, p. 91, 1908.

The leaves of *Odostemon* are pinnate, and it is assumed that the leaves of the present fossil species were similarly arranged, but as none have thus far been found attached it is impossible to be certain. The leaflets, if this has been correctly interpreted, were closely sessile, with an obtusely wedge-shaped or nearly truncate base and slender, sharp-pointed apex. They are lanceolate in general outline, with usually three teeth on each side; these teeth are separated by rounded sinuses and are spinous tipped, as is the apical lobe. The nervation consists of a relatively strong midrib and a rather loose network of veins that supply the several lobes. The leaflets are evidently thick and coriaceous in texture and have the margin all around thickened as if bound with a cord, precisely as in the living species. The length varies between 2 and 4 centimeters and the width between 1 and 2 centimeters. Some of the specimens, perhaps the majority, are broadest at the base, and others are broadest between the points of the upper lobes.

If my assumption is correct, as it is now believed to be, this species was first described under the name *Lomatia hakeaefolia* Lesquereux[7] from material collected in the Florissant lake beds. It was based on a single specimen about 5 centimeters long and 2.5 centimeters wide. It has four teeth or lobes on each side and no trace of nervation except a strong midrib.

Lesquereux states that his *Lomatia hakeaefolia* he regards as closely related to his *Lomatia spinosa*, which was described[8] at the same time. *L. spinosa* was also based on a single specimen about 8 centimeters long and 2.5 centimeters wide and differs from *L. hakeaefolia* in being deeply cut into very large, sharp-pointed lobes. The apical portion especially is drawn out into a long, slender point. There is no nervation preserved except a short basal portion of the midrib.

These two species are certainly congeneric and probably conspecific. Additional examples of Lesquereux's *Lomatia hakeaefolia* have been procured at Florissant by Cockerell, Knowlton, and others. The leaves figured in my recent paper[9] on the Florissant plants are undoubtedly identical with *L. hakeaefolia;* and *L. spinosa* of Lesquereux is only an elongated, narrow, stronger-toothed form. It is comparable, for instance, to the specimen shown in figure 1 except as regards size, the latter being only about half as long.

The leaf described by Cockerell[10] as *Carduus florissantensis* undoubtedly belongs here, being indistinguishable from figure 1. The thickened margin and peculiar arched veins more or less parallel to the midrib he describes are characters of *Odostemon.*

Cockerell[11] also described as *Odostemon florissantensis* a leaflet from Florissant that probably belongs with *Odostemon hakeaefolia.* It was not figured but is said to be similar to *Odostemon simplex* (Newberry) Cockerell (*Berberis simplex* Newberry), from the upper Eocene of Bridge Creek, Oreg., except that the "inferior basal angle is produced into a tooth, so that the truncate base of the leaf is greatly broadened." It is about 4.2 centimeters long and 4.8 centimeters wide and has three teeth on each side, "not counting the base." This seems to fit the description of *Odostemon hakeaefolia,* and therefore Cockerell's form has been referred to that species.

Occurrence: Creede formation, north bank of Rio Grande near Sevenmile Bridge, Creede, Colo.

[7] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 166, pl. 32, fig. 19, 1883.

[8] Lesquereux, Leo, op. cit., p. 166, pl. 43, fig. 1.

[9] Knowlton, F. H., U. S. Nat. Mus. Proc., vol. 51, p. 267, pl. 26, figs. 1, 2, 1916.

[10] Cockerell, T. D. A., Torrey Bot. Club Bull., vol. 33, p. 311, text fig. 6, 1906.

[11] Cockerell, T. D. A., Am. Mus. Nat. Hist. Bull., vol. 24, p. 91, 1908.

Sterculia aceroides Knowlton, n. sp.

Plate XLIII, figure 12.

Leaf small, semicoriaceous in texture, rounded and truncate at the base, three-lobed, the central lobe apparently much the longest and strongest (broken), lateral lobes short, acute, at an angle of about 45°; nervation obscure, except for the very strong midrib and the much lighter lateral ribs. which arise near the base of the blade.

This little leaf, the only one seen in the collection, has the basal portion well preserved, but the evidently large central lobe is broken. The distance between the tips of the lateral lobes is about 3.5 centimeters.

Two species of *Sterculia* have been described from material found in the Florissant lake beds—*Sterculia rigida* Lesquereux[12] and *S. engleri* Kirchner.[13] These species are of the same type, about the only difference being in size; they should probably be combined.

The present form differs from the Florissant forms in being rounded and full instead of wedge-shaped at the base and in having relatively shorter lateral lobes. The central lobe, to judge from the very strong midrib, was probably very long and slender. The nervation, except for the three ribs, is practically obsolete.

Occurrence: Creede formation, north bank of Rio Grande. near Sevenmile Bridge, Creede, Colo.

Phyllites sp.

Plate XLIII, figure 15.

Leaf minute, delicate in texture, obovate, rounded at the apex, long ridge-shaped at the base; apparently short petioled; margin entire; nervation very delicate, consisting of a straight midrib and about three pairs of thin secondaries that pass up for a considerable distance; finer nervation obsolete.

This little leaf or leaflet, the only one observed in the collection, is about 7 millimeters long and 5 millimeters broad. It was apparently sessile, or nearly so.

I have hesitated to assign this leaf to a definite genus, as it is so nondescript that it is hard to place with any degree of reasonableness. It resembles a number of described forms, such as *Celastrus murchisoni* Heer,[14] from the Swiss Miocene, though it is much smaller. It is also similar to certain leaflets that have been called *Leguminosites*, but conjectures as to its affinity would hardly serve any useful end.

Occurrence: Creede formation, north bank of Rio Grande near Sevenmile Bridge, Creede Colo.

Phyllites sp.

Plate XLIII, figure 13.

In the collections from Creede I find the little leaf here figured, which with its counterpart is the only one noted. It is small, about 18 millimeters long and 9 millimeters broad, ovate, somewhat decurrent at the base, and moderately pointed at the apex. The margin has about four relatively large, sharp-pointed teeth on each side. The nervation is very light, consisting of a straight midrib and four pairs of thin, opposite secondaries, which end in the teeth.

It is so difficult, not to say impossible, to place this little leaf in the correct genus that it has been referred without specific name to the nondescript genus *Phyllites*.

Occurrence: Creede formation, north bank of Rio Grande near Sevenmile Bridge, Creede, Colo.

Phyllites potentilloides Knowlton, n. sp.

Plate XLIII, figure 14.

The material from Lake Santa Maria includes the single example figured, which appears to be a small compound leaf with at least seven leaflets. The terminal leaflet is deeply cut into three lanceolate segments, the margins of which are provided with rather remote, sharp teeth. The lower leaflets are sessile or nearly so, lanceolate-acuminate, with sharply toothed margins. The nervation consists of a very strong midrib and a few secondaries that seem to enter the teeth. The whole leaf is about 5 centimeters long, and the lower leaflets are 1.5 to 2 centimeters long and 0.5 centimeter wide.

[12] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 8 (Cretaceous and Tertiary floras), p. 179, pl. 34, fig. 12, 1883.

[13] Kirchner, W. C. G., St. Louis Acad. Sci. Trans., vol. 8, p. 180, pl. 14, fig. 3, 1898.

[14] Heer, Oswald, Flora tertiaria Helvetiae, vol. 3, pl. 121, fig. 6, 1859.

This specimen is so well preserved that seemingly it should not be difficult to place generically, but nevertheless its generic reference is uncertain. It resembles a number of things, particularly certain pinnate-leaved species of *Potentilla*, such as *P. hippiana* Lehmann, but there are features that do not agree, and rather than make a wrong generic reference I think best to place it, at least temporarily, in *Phyllites*. It has been given a specific name that suggests its resemblance to *Potentilla*.

Occurrence: Huerto formation, north end of Lake Santa Maria, San Cristobal quadrangle, Colo.

PLATES XLI—XLIV.

PLATE XLI.

Page.

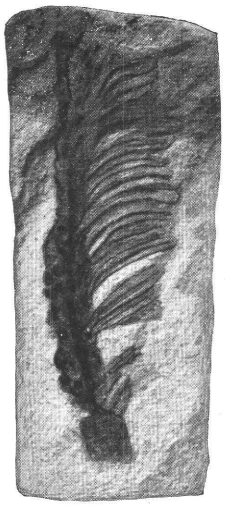
FIGURES 1, 2, 4, 5. *Abies rigida* Knowlton, from Creede formation, near Creede, Colo. U. S. Nat. Mus. catalog Nos. 36505, 36507, 36508, 36509 186

6. *Pinus coloradensis* Knowlton, from Creede formation, near Creede, Colo. U. S. Nat Mus. catalog No. 36506 186

7. *Pinus florissanti?* Lesquereux, from Creede formation, near Creede, Colo. U. S. Nat. Mus. catalog No. 36510 186

3, 8–10. *Pinus crossii* Knowlton, from Creede formation, near Creede, Colo. U. S. Nat. Mus. catalog Nos. 36511, 36512, 36513, 36514 185

11, 12. *Pinus similis* Knowlton, from Creede formation, near Creede, Colo. U. S. Nat. Mus. catalog Nos. 36515, 36516 186



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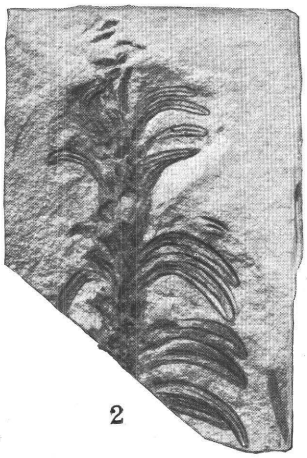

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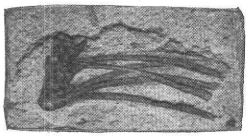

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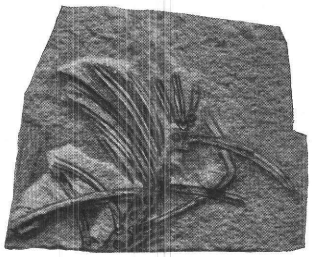

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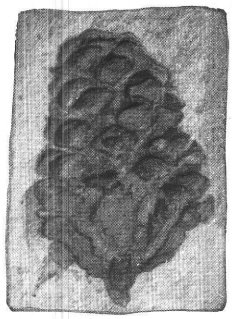

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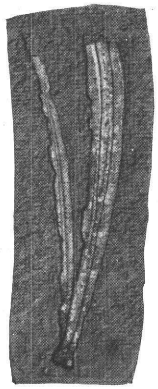

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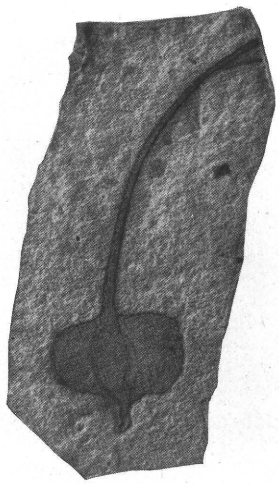
FOSSIL PLANTS FROM THE TERTIARY LAKE BEDS OF SOUTH-CENTRAL COLORADO.



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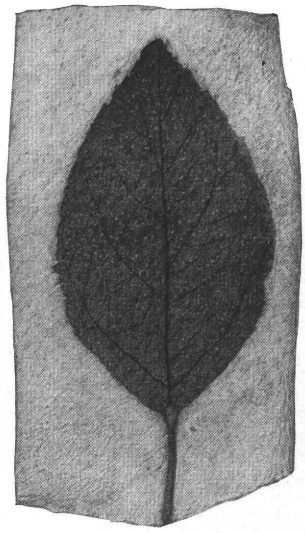

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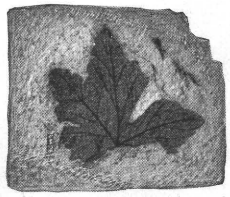

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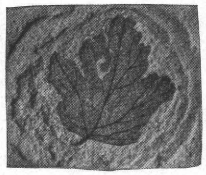

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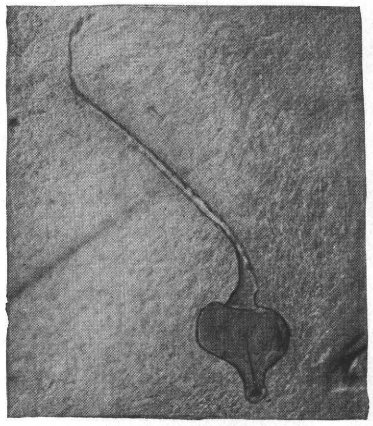

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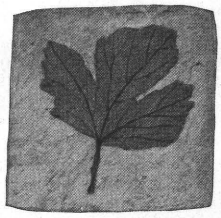

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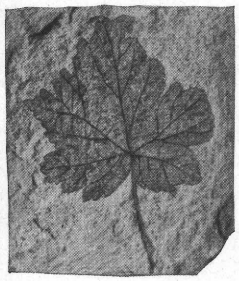

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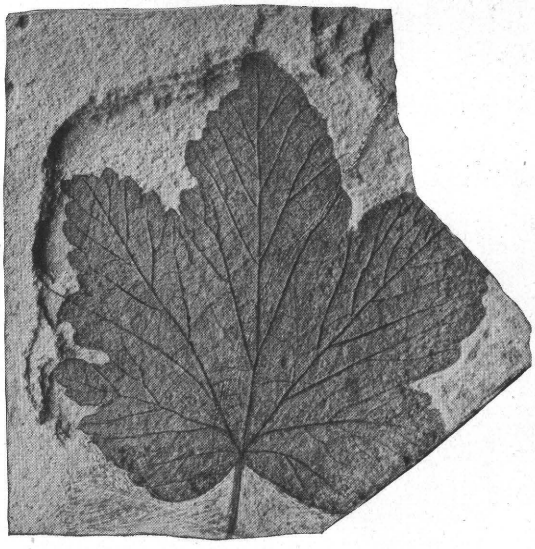

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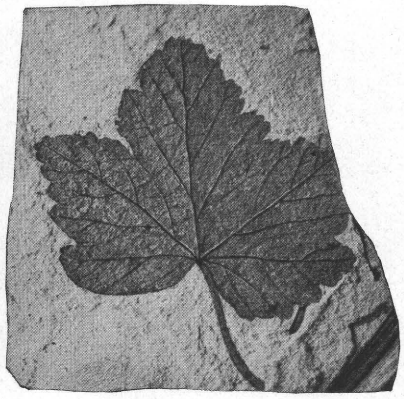

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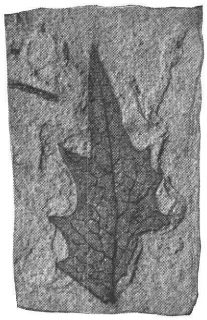
FOSSIL PLANTS FROM THE TERTIARY LAKE BEDS OF SOUTH-CENTRAL COLORADO.

PLATE XLII.

PLATE XLIII.



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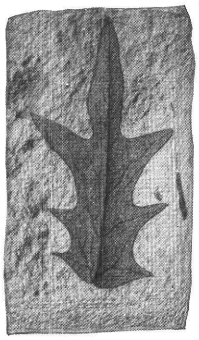

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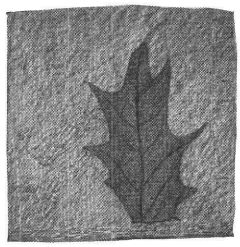

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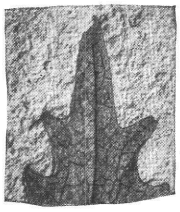

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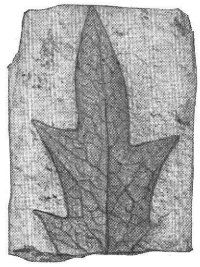

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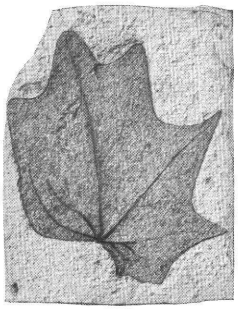

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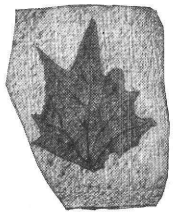

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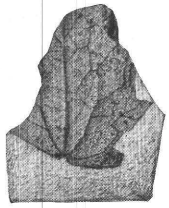

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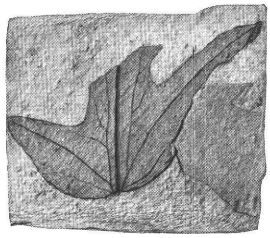

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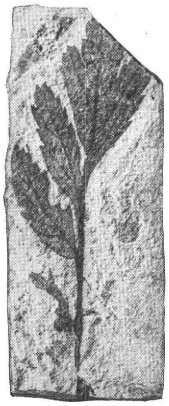

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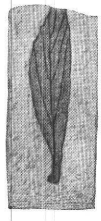

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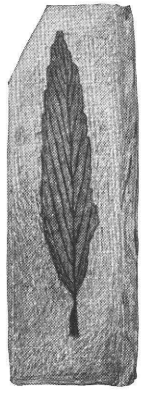

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FOSSIL PLANTS FROM THE TERTIARY LAKE BEDS OF SOUTH-CENTRAL COLORADO.

FOSSIL PLANT FROM THE TERTIARY LAKE BEDS OF SOUTH-CENTRAL COLORADO.

PLATE XLIV.

Page.

Populus lesquereuxi Cockerell, from Creede formation, near Creede, Colo. U. S. Nat. Mus. catalog No. 36543.... 187
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