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.		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.
		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.]				
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-

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.

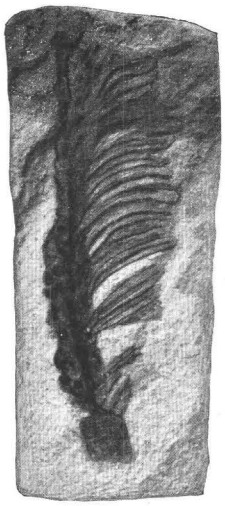
[14] Heer, Oswald, Flora tertiaria Helvetiae, vol. 3, pl. 121, fig. 6, 1859.

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.



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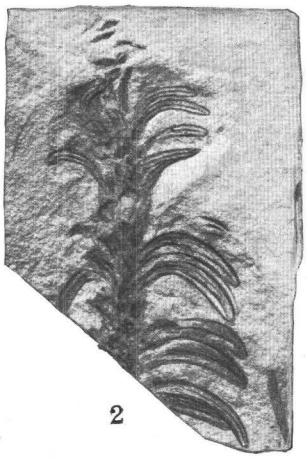

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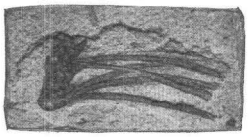

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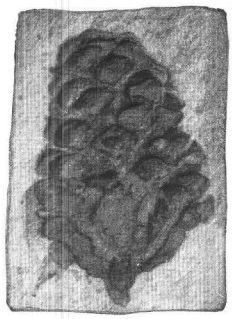

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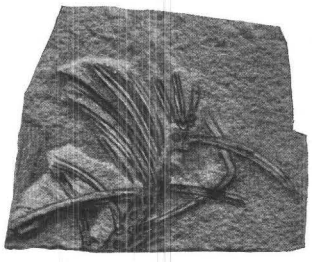

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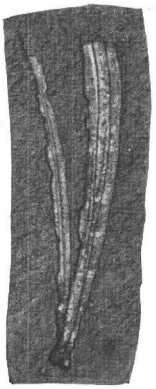

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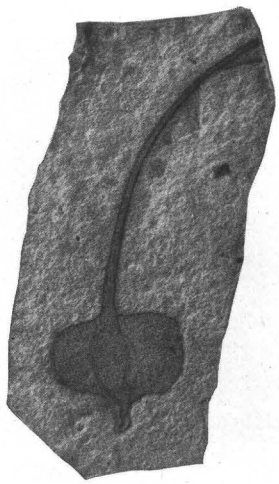
FOSSIL PLANTS FROM THE TERTIARY LAKE BEDS OF SOUTH-CENTRAL COLORADO.



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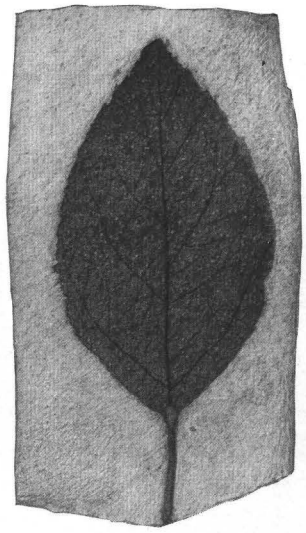

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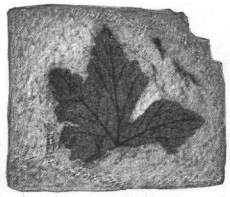

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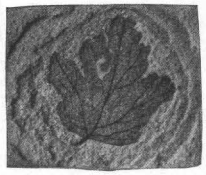

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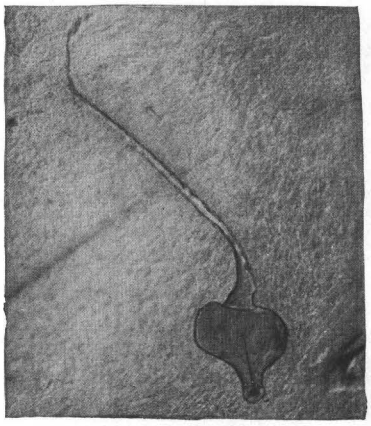

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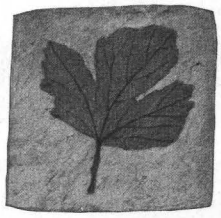

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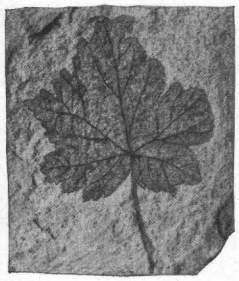

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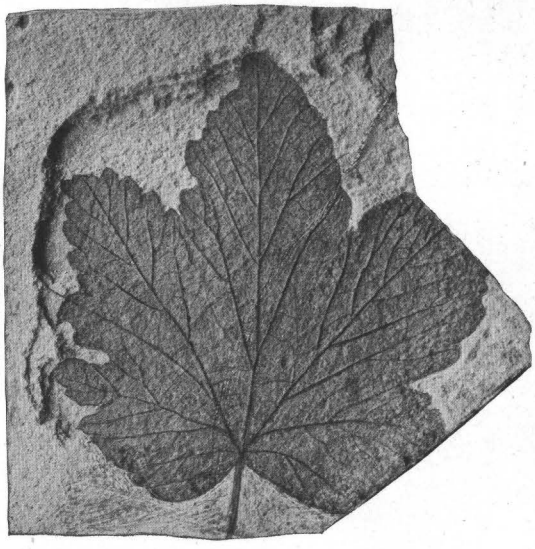

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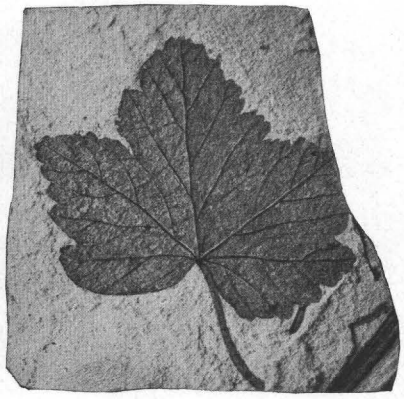

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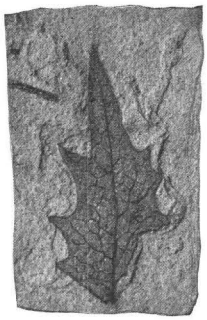
FOSSIL PLANTS FROM THE TERTIARY LAKE BEDS OF SOUTH-CENTRAL COLORADO.

PLATE XLII.

PLATE XLIII.



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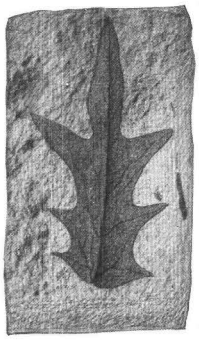

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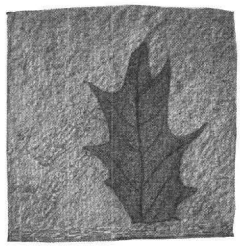

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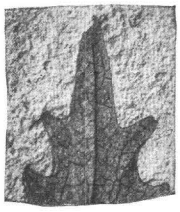

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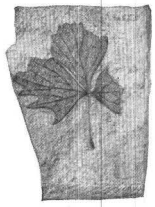

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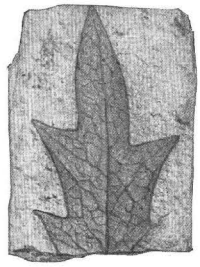

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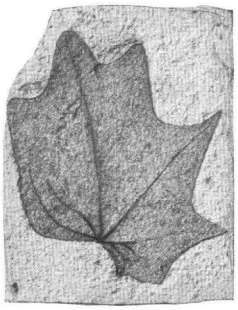

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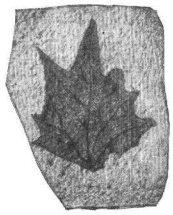

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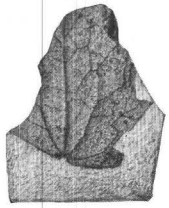

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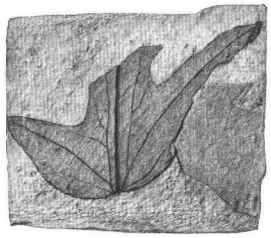

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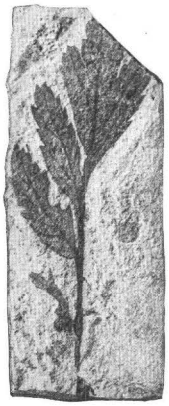

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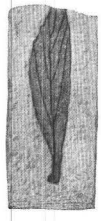

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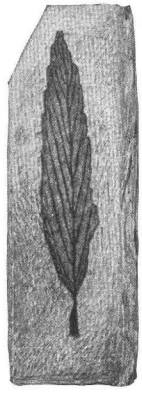

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FOSSIL PLANTS FROM THE TERTIARY LAKE BEDS OF SOUTH-CENTRAL COLORADO.

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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