Cretaceous Plants from Southwestern Colorado

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By ROLAND W. BROWN

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A study of fossil plants useful in determining the probable boundary between the Lower and Upper Cretaceous deposits

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CONTENTS

ILLUSTRATIONS

CRETACEOUS PLANTS FROM SOUTHWESTERN COLORADO

By ROLAND W. BROWN

ABSTRACT

In southwestern Colorado a sequence of strata between the Jurassic carnotite-bearing Morrison formation (†McElmo) and the Upper Cretaceous marine Mancos shale contains fossil plants that are described here and used for determining the most likely position of the Lower Cretaceous-Upper Cretaceous boundary. The plants fall into two groups, the older, with the conifer *Frenelopsis varians* Fontaine, indicating Lower Cretaceous age, and the younger, with numerous ferns and well-developed dicotyledons, characterizing the early Upper Cretaceous. The boundary is probably at the top of the unit that Coffin called †Post-McElmo and at the base of his overlying Dakota.

GEOLOGICAL BACKGROUND

Investigation during the past 30 years of the carnotite-bearing sedimentary rocks of the †McElmo (now Morrison) formation of southwestern Colorado and adjacent areas in Utah has resulted in the collection of plants from different horizons in the strata above the †McElmo formation and beneath the Mancos shale. As the †McElmo is considered, for the most part at least, to be of Jurassic age and equivalent to the Morrison of other regions, and as its uppermost beds are separated from the overlying plant-bearing strata by an unconformity of unknown extent, and as marine beds of the Mancos shale of Upper Cretaceous age conformably overlie the plant-bearing beds, it follows that all of Lower Cretaceous (unless some of the uppermost part of the †McElmo is Lower Cretaceous in age) and part of Upper Cretaceous time must be represented by the interval between the †McElmo and Mancos deposits. How much, if any, of this sequence is Lower Cretaceous and how much is Upper Cretaceous is the problem posed for solution by a study of the fossil plants.

The best collections of plants have come from southwestern Colorado, and this area, therefore, will receive most attention here. A complete description of the area, with maps and geologic sections, was published by R. C. Coffin (1921) and further data and opinions concerning ages and correlations were published by W. L. Stokes (1944, 1948). Generalized from Coffin and in his nomenclature, a composite geologic section southwest of Nucla, Colo., includes the following sequence of strata in descending order.

Geologic section near Nucla, Colo.

Mancos shale. Dark Upper Cretaceous marine shales with *Gryphaea newberryi*. These lie comformably on the Dakota sandstone.

Dakota sandstone. Sandstone, shale, coal (some minable), 100–200 feet of basal conglomeratic sandstone. Plants.

†Post-McElmo. Green to purple or somewhat varicolored shale, sandstone, limestone, dark shale, 100–200 feet of basal conglomeratic sandstone. Plants. The basal conglomerate, like that at the base of the Dakota, is a cliff-maker, and the two may readily be confused under given circumstances. This conglomerate lies on an undulating †McElmo surface. At one locality, according to Coffin (1921, p. 112), *Halymenites* was found in the sandstone not far above the †McElmo–†Post-McElmo contact, thus indicating a temporary interruption of fresh- by brackish-water or marine conditions. This †Post-McElmo unit was named Burro Canyon formation by Stokes in 1948.

†McElmo formation. The upper part is chiefly variegated shale, whereas the lower part is white to greenish-gray sandstone that contains the carnotite-bearing beds. Fossil wood, poorly preserved twigs, and other plant fragments occur throughout the formation. Large reptilian bones occur in the basal portion. Coffin designated the †McElmo as Jurassic or Cretaceous. The U. S. Geological Survey regards it as Morrison (Jurassic).

The †Post-McElmo and Dakota of the foregoing section are the debatable strata whose age is in question. Because only plant fossils have been obtained from them, the history of attempts to determine their age is that of the treatment of the several collections, as, in part, already related by Junius Henderson (Coffin, 1921, pp. 113–118.) Of these collections, the first to be reported was made in 1915 by J. T. Duce for the Geological Survey of Colorado. This came from the upper sandy beds of the Dakota and was studied by Cockerell (1916), who tentatively identified in it the following species

†Indicates the name has been abandoned or rejected for use in classification in Geological Survey publications.

(with later emendations suggested by E. W. Berry, in parentheses):

Equisetum (=stipe of *Matonidium americanum*)
Matonidium althausi (=*Matonidium americanum*)
Fragments of other ferns (?=*Onychiopsis*)
Cycadospadix? (=frond base of *Matonidium americanum*)
Sapindopsis (=undetermined dicotyledon)

Cockerell considered that this assemblage indicated Lower Cretaceous age, probably the same as the Fuson shale in the vicinity of the Black Hills, S. Dak., and somewhat younger than the Kootenai formation of Montana.

In 1914 Henderson and others collected plants from a black shale horizon south of Nucla, but these were not seen or considered by Cockerell at the time he reported the 1915 collection by Duce. They were, however, sent to E. W. Berry early in 1919 along with the Duce material. Berry (1919) shortly thereafter published a paper dealing with the principal and most striking species in the Duce collection, namely, the fern *Matonidium americanum*. His opening statement, unfortunately, is misleading, for it says that "In 1916 Professor Cockerell, of the University of Colorado, published a brief note based upon plant material collected from the supposed McElmo formation of southwestern Colorado." Reference to Cockerell's opening paragraph (1916, p. 109), however, shows that Berry misread the locality citation, which says in part, "Above the McElmo, black shales alternate with massive sandstone, the two combined including the uppermost 131 feet of the whole exposure. The plants are preserved in hard white quartzose sandstone, with occasional iron concretions about 10 feet below the top of the section." In this paper Berry did not express a definite opinion as to the age of the collections. Concerning the stratigraphic level of the black shale, Henderson said (Coffin, 1921, p. 116) that it was "in a shale lens in the basal conglomerate of the so-called Dakota, near the top of Norwood Hill, where the wagon road from Placerville to Norwood leaves the San Miguel Canyon." Henderson's use of the term "so-called Dakota" would superficially suggest the Dakota of Coffin, but, in reality, the black shale is in the basal part of the †Post-McElmo as a letter, dated Feb. 1, 1919, from Henderson to Berry indicates:

> The material from the black shale, . . . occurred in a lens of shale in the basal conglomerate, just above the variegated shales of the McElmo, far below the upper sandstone. . . . Since the question of the position of this shale was raised by the discovery of the material in the upper sandstone, Mr. Worcester, who is a very careful observer, revisited the place, and fully confirms my notes.

Berry (Coffin, 1921, p. 116) identified the following species in the black shale:

Brachyphyllum sp.
Pinus susquaensis Dawson
Sphenolepis kurriana (Dunker) Schenk
Cissites sp.
Sassafras mudgei Lesquereux

Berry's opinion (Coffin, 1921, p. 117) concerning the age of both collections, that in the upper sandstone and that in the black shale, is as follows:

> Regarding the age of the material, it is not extensive or good enough for one to be dogmatic about, but I see nothing to indicate that either the older shale or the younger sandstone represents the true Dakota. There are no typical Dakota species in either and the general facies appears to me to be slightly older. Neither would I place either in the Lower Cretaceous, but would be inclined to consider that both floras represent the same general horizon, and I am strongly of the opinion that this horizon is to be correlated with what has been called the Purgatoire formation in southeastern Colorado. . . . It is also to be correlated with the Belvidere section of southern Kansas at the top of the Washita division of the Texas Comanchean. The Washita is commonly considered to represent the top of the Lower Cretaceous, but I am confident that it is Cenomanian in age and represents the lower part of the Upper Cretaceous as I stated in my "Upper Cretaceous Floras of the World", and in this I am corroborated by European paleontologists from the faunal evidence.

Thus the matter stood until 1925, when W. W. Boyer found fragmentary plants in the Dakota at the Liberty Bell mine near Naturita, south of Nucla. These were identified in a routine report, by F. H. Knowlton, as including the species:

Cladophlebis falcata montanensis Fontaine
Gleichenia nordenskioldi Heer

Of the age Knowlton said: "It may be Dakota, but somehow I cannot escape the conviction that it is older than Dakota."

In 1944 W. L. Stokes, associated with R. P. Fischer of the U. S. Geological Survey, obtained an excellent collection from gray shales in the Dakota at an abandoned coal mine in SW¼SE¼ sec. 11, T. 46 N., R. 16 W. In 1945 he found a good specimen of *Frenelopsis varians* Fontaine in black shale in the upper part of the †Post-McElmo, one-half mile east-southeast of the junction of Disappointment Creek and Dolores River. He also found a fragment of a cycadeoid in the basal †Post-McElmo on the southwest side of Little Gypsum Valley. From sandstone in the Dakota near the black shale locality, but about 20 feet higher stratigraphically, he obtained a collection containing numerous dicotyledonous leaves. Finally, in 1948, he made another excellent collection in pinkish-gray shale of the Dakota near the coke ovens at Naturita. This collection con-

tains the same ferns as occur in his original 1944 collection but also includes several well-preserved dicotyledons.

The best material of each recognizable species in all these collections, now available to me, is here illustrated and described, and an attempt is made to integrate all the information into a satisfactory picture of the entire situation.

AGE AND SIGNIFICANCE OF THE FOSSIL PLANTS

The fossil plants here described fall into two groups. The first includes *Cycadeoidea* sp. (pl. 9, fig. 13), *Brachyphyllum crassicaule* Fontaine (pl. 9, figs. 5, 6), *Frenelopsis varians* Fontaine (pl. 9, fig. 12), *Sphenolepis kurriana* (Dunker) Schenk (pl. 9, fig. 14), and a few undetermined specimens (pl. 9, figs. 8–11). The second group contains all the remaining specimens, including numerous ferns and well-developed dicotyledons.

Three of the specifically identified species of the first group, but particularly *Frenelopsis varians*, are characteristic Lower Cretaceous forms. *Cycadeoidea* falls readily into this picture. *Frenelopsis varians*, however, is the clue to the age of this group, as it has never been found in younger strata. All the specimens in this group occur in the †Post-McElmo of Coffin (p. 3) and beneath the conglomeratic sandstone of the Dakota, above which all the plants of the second group were collected.

The plants of the second group include chiefly species that occur in the large flora described by Lesquereux, Newberry, and others from the brownish Dakota sandstone of Kansas and Nebraska, in the Woodbine formation of Texas, the Dakota of the Black Hills, S. Dak., and the Upper Cretaceous rocks of Greenland. A few species were probably closely related to some in the Patapsco formation of the Potomac group in the Atlantic Coastal Plain.

In view of these facts I conclude that in southwestern Colorado the †Post-McElmo is Lower Cretaceous and the Dakota of Coffin is Upper Cretaceous. I would draw the boundary line at the bottom of the conglomeratic sandstone at the base of Coffin's Dakota.

The scarcity of well-preserved plants in the Lower Cretaceous section in southwestern Colorado is matched by a similar condition east of the Rocky Mountains in the vicinity of Morrison and Walsenburg, Colo. Stose (1912, p. 3) described the typical Purgatoire formation in the Apishapa quadrangle east of Walsenburg, Colo., as including 220 feet of beds, chiefly sandstone in the basal portion and coal, shale, and sandstone in the upper portion, the whole lying conformably between variegated Morrison (Jurassic) and massive Dakota sandstone (Upper Cretaceous). The age of the Purgatoire was determined as Comanche (Lower Cretaceous) by Stanton on the evidence of characteristic marine invertebrates and fishes. *Gryphaea corrugata*, in particular, was said to indicate equivalence of at least part of these beds with the Kiowa shale of Kansas. No plants have been taken from the type area of the Purgatoire formation, but some poorly preserved leaves were collected by W. T. Lee in beds so designated by him at the type section of the Morrison formation near Morrison, Colo. These plants were identified by F. H. Knowlton and restudied by E. W. Berry (Brown, 1946, p. 240), with rather inconclusive results, except that the flora resembles that from the Cheyenne sandstone of Kansas.

The only forms in common between the †Post-McElmo and the Kootenai formation of Montana are *Sphenolepis kurriana* (Dunker) Schenk and the problematic *Pinus susquaensis* Dawson.

An interesting situation has arisen in regard to the Potomac group of the Atlantic Coastal Plain, which has long been regarded as Lower Cretaceous. In the volume, edited by Anderson (1948, pp 126–151), on the subsurface geology in three deep wells, H. E. Vokes discusses the Mollusca found at depths 4,875 to 4,885 in the Maryland Esso No. 1 well, 4½ miles north of Ocean City, Md. Vokes inclines to the belief that the Patuxent formation is Lower Cretaceous and the Arundel and Patapsco formations are earliest Upper Cretaceous, for he finds that the Mollusca of the two latter formations have their closest affinities with those of the Woodbine formation (Upper Cretaceous) of Texas. This conclusion appears to be fortified by C. W. Gilmore's opinion that the dinosaurs of the Arundel formation have closest affinities with those of the Belly River formation (Upper Cretaceous) in Canada. The great development of dicotyledons in Patapsco time, and especially of species similar to, if not identical with, some in the Dakota sandstone and other Upper Cretaceous formations of the western interior, lends considerable weight to the view that the Patapsco, at least, should be removed from the Lower Cretaceous classification.

Not much can be inferred from the fossil plants concerning the climate and environment of southwestern Colorado during Lower Cretaceous and early Upper Cretaceous time. The probability is that the region was low lying and not far above sea level. *Frenelopsis varians*, as judged by its occurrence in the Trinity group of Texas where it is found with marine inverte-

brates, preferred a coastal environment. *Cycadeoidea* may indicate a somewhat drier location on a hillside.

The early Lower Cretaceous sediments in this area were deposited near sea level, because at one locality *Halymenites* has been found. The ferns *Matonidium* and *Bolbitis*, if judged by their modern relatives in the Malay region, would indicate a relatively warm and moist environment at the beginning of the Upper Cretaceous. These ferns, however, were found in the shales associated with coal beds and reflect a swampy condition. The dicotyledons, on the other hand, indicate drier situations probably not far from the coal-forming swamps.

SYSTEMATIC DESCRIPTIONS

ASPLENIACEAE

Asplenium sp.

Plate 10, figure 4

Asplenium dicksonianum Heer. Ward, U. S. Geol. Survey 19th Ann. Rept., pt. 2, p. 704, pl. 170, fig. 1, 1899.

The specimen figured here appears to agree in every respect with that reported by Ward from the basal beds of the Dakota sandstone in Evans quarry, 5 miles southeast of Hot Springs, S. Dak. This fern was evidently bipinnate, with the pinnules in some instances deeply cut. These lobes have entire margins. The venation is open and once or twice forked. No fertile fronds have been seen.

It does not seem to me that either the present specimen or Ward's specimen from the Black Hills should be referred to Heer's *Asplenium dicksonianum*, which, according to the figured type and other supplementary specimens, is a smaller, more delicate fern, although perhaps of the same genus. There is doubtless confusion in regard to the generic assignment, as somewhat similar or perhaps identical material has been referred to *Onychiopsis*, *Aneimia*, and other genera. I know of no method to resolve this difficulty until adequate fertile material is found.

Occurrence: Abandoned coal mine near Naturita, 4 miles south of Nucla, Colo. Collected by W. L. Stokes, 1944.

GLEICHENIACEAE

Gleichenia kurriana Heer

Plate 10, figures 5, 6

Gleichenia kurriana Heer. Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 6, p. 47, pl. 1, figs. 5, 5b, 5c, 1874.

Many species of Cretaceous gleichenias have been described, especially by Oswald Heer from Greenland. The Greenland species were reviewed by A. C. Seward, who resurrected the Paleozoic name *Gleichenites* for the few species to which he reduced the many described by Heer.

As the specimens under consideration here bear no sori, they can be compared but probably not identified satisfactorily with any described species. They resemble closely some specimens of *Gleichenites giesekiana* (Heer) Seward, as synonymized by Seward (1926, p. 69). They are somewhat like *Gleichenia argentinica* Berry (1924, p. 17). However, no matter how these comparisons may be evaluated, the species is very likely that identified as *Gleichenia kurriana* Heer by Lesquereux from the Dakota sandstone, 3 miles east of Fort Harker (now Kanopolis), Kans. Lesquereux was uncertain that the Dakota species is identical with *G. kurriana* from Europe.

That the *Gleichenia* represented by the Colorado specimens has a long chronological range is likely, for Heer's Lower Cretaceous species seem to range locally also into the Upper Cretaceous.

A small fragment of what appears to be this species was collected by Karl Waage in 1943 from a white sandstone in the Dakota near Stone City, 15 miles northwest of Pueblo, Colo.

Occurrence: One and one-half miles southwest of coke ovens, Montrose County, Colo. Collected by W. L. Stokes, 1948.

MATONIACEAE

Matonidium americanum Berry

Plate 10, figures 7, 8

Matonidium americanum Berry, Torrey Bot. Club Bull., vol. 46, p. 287, fig. 2; pl. 12, figs. 1–12; pl. 13, figs. 3–6, 1919.
Matonidium althausi (Dunker) Ward. Cockerell, Washington Acad. Sci. Jour., vol. 6, p. 111, fig. 2, 1916.
Cycadospadix? sp. Cockerell, idem, p. 110, fig. 1.

This species was as well described by Berry as was possible with the fossil material at his disposal. To that description need be added perhaps only a few minor details. The venation of the fertile pinnules is obscure, but that of the sterile pinnules is as shown in figure 7. The secondary veins may be simple, branched, with a few scattered anastomoses, the principal forming lateral areolations along the midribs.

The features that distinguish this species from the Lower Cretaceous *Matonidium althausi* (Dunker) Ward are: more numerous pinnae, shorter and broader pinnules, fewer sori, and more conspicuously scorpioid disposition of the pinnae at the top of the stipe. As no exactly identical material has been described before, the presumption is that *M. americanum* represents an advance on *M. althausi*. This inference is strengthened by the fact that in the present material are fragments,

such as relatively long, slender pinnules completely covered with sori, that suggest throwbacks to *M. althausi.*

An Upper Cretaceous species comparable to *Matonidium americanum* is *Matonia wiesneri* Krasser (1896, p. 119, pl. 11, fig. a1; pl. 12, figs. 1, 2; pl. 17, fig. 10) from Cenomanian beds near Kunstadt, Austria. Krasser's illustrations, showing the habit of the species, suggest a peltate arrangement of pinnae around the apex of the stipe, but I suspect that the drawings perhaps do not represent the specimens adequately on this point and that the pinnae are actually disposed in a rather close scorpioid fashion—fanwise, as stated in Krasser's description. According to Krasser's figures, the venation of the pinnules is without anastomoses or areolations. Such fruiting specimens as Krasser found had few sori per pinnule. Despite these close similarities, I am disinclined to recognize the two species as identical.

Matonidium americanum resembled the graceful, existing *Matonia pectinata* Robert Brown, of southeastern Asia and the East Indies. This species has a creeping rhizome that produces at distant intervals simple, unbranched fronds composed of a tall, upright stipe, the apex of which widens into a semicircular base or crown, giving rise dichotomously to the scorpioidly disposed pinnae, which spread out horizontally, that is, at right angles to the stipe.

Occurrence: At abandoned coal mine near Naturita, 4 miles south of Nucla, and at coke ovens, Montrose County, Colo. Collected by W. L. Stokes.

POLYPODIACEAE

Bolbitis coloradica Brown, n. sp.

Plate 12, figures 6, 7

Sterile frond pinnate below, but with segments tending to coalesce into a lobed blade toward the apex. Margin entire. Basal pinnae linear lanceolate, sessile or nearly so, with slightly asymmetric rounded bases. Secondary veins numerous, closely spaced, slightly curved, almost at right angles to the midrib, simple until near the margin, where they may fork or branch. Areoles between the secondary veins somewhat rhomboidal and elongated parallel to the secondaries.

Fertile fronds not present in the collection.

Comparison of these fossils with living ferns reveals closest resemblance to the entire-margined species of *Bolbitis*, formerly variously called *Campium*, *Poecilopteris*, *Heteroneuron*, and others. The genus comprises about 85 species, distributed in the tropics, particularly of Africa and the Indo-Malayan region.

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Occurrence: At the abandoned coal mine near Naturita, Colo.

PTERIDACEAE

Llavea hesperia Brown, n. sp.

Plate 11, figure 6

This somewhat eroded sterile leaf is nevertheless well enough preserved to indicate its original cordate outline. The veins are open, closely spaced, and repeatedly forked. The margin is minutely dentate.

At least three living species of ferns may be considered for comparisons with the fossil. *Humata ophioglossoides* Cavanilles, a davallioid fern from the Malay-Polynesian region, is an epiphyte with simple, lanceolate-cordate, sterile fronds that are about the same size as the fossil. The veins, however, are thicker and less forked. *Pellaea cardiomorpha* Weatherby, from Mexico, is a pinnate pteridoid fern with cordate pinnules closely simulating the fossil. It, however, prefers relatively dry, rocky situations, whereas the fossil, judging from its associates, lived in a moister habitat. *Llavea cordifolia* Lagasca, a monotypic pteridoid fern from central Mexico to Guatemala and distantly related to *Pellaea cardiomorpha*, has cordate pinnules and seems to compare best of all with the fossil. The assignment of the fossil to *Llavea* must be considered tentative until a fertile pinnule or other confirmatory material is found.

For making available material of living ferns and for helpful consultation toward identification, I am grateful to C. V. Morton, curator of ferns in the U. S. National Herbarium, Smithsonian Institution.

Occurrence: One and one-half miles southwest of coke ovens, Montrose County, Colo.

TEMPSKYACEAE

Tempskya knowltoni Seward

Plate 9, figure 15

Tempskya knowltoni Seward, Annals of Botany, vol. 38, pp. 485–507, pls. 16, 17, 1924; Brown, Washington Acad. Sci. Jour., vol. 26, pp. 46, 47, fig. 5, 1936; Read and Brown, U. S. Geol. Survey Prof. Paper 186, pp. 112–114, pl. 29, figs. 1–3, 1937.

This piece of a trunk of *Tempskya* measures 4 by 6 cm. It contains a few sections of stems surrounded by roots. The stems are relatively small like those of *Tempskya knowltoni* Seward from the Upper Cretaceous of Montana.

Occurrence: SW¼ sec. 28, T. 22 S., R. 22 E., Utah. In lower part of Dakota?, 100 feet above the Morrison formation. Collected by W. L. Stokes, 1944.

CYCADACEAE

Cycadeoidea sp.

Plate 9, figure 13

This fragment of a cycadeoid trunk, showing part of a fruit and numerous leaf bases or traces, is too poorly preserved for specific identification.

Occurrence: In the basal part of the †Post-McElmo beds, not far above the unconformity with the †McElmo. Southwest side of Little Gypsum Valley, San Miguel County, Colo. Collected by W. L. Stokes, 1946.

CONIFERALES

Brachyphyllum crassicaule Fontaine

Plate 9, figures 5, 6

Brachyphyllum crassicaule Fontaine, U. S. Geol. Survey Mon. 15, p. 221, pl. 100, fig. 4; pl. 109, figs. 1–7; pl. 110, figs. 1–3; pl. 111, figs. 6, 7; pl. 112, figs. 6–8; pl. 158, fig. 9, 1889.

A number of Lower and Upper Cretaceous species of the conifer *Brachyphyllum* have been described, but methods for clearly distinguishing them, especially when possible variations in individual trees and parts of trees are taken into account, have not been stated. The situation has been reviewed by Berry (1911, p. 389).

The specimens in this collection are poorly preserved in respect to details, although in places enough of the spirally arranged, closely appressed leaves can be seen to permit reconstruction as shown in the illustrations. Assignment to *Brachyphyllum crassicaule* Fontaine seems reasonable, although *B. macrocarpum* Newberry and *B. parceramosum* Fontaine are also very similar. The latter is a common Lower Cretaceous species, including, according to Berry, *B. texense* Fontaine, from the Glen Rose limestone of the Trinity group in Texas.

Figure 5 apparently represents the termination of a twig or a fruiting organ with elongated leaves or bracts.

Occurrence: In black shale in lower part of †Post-McElmo, south of Nucla, Colo. Collected by Junius Henderson and party, 1914.

Frenelopsis varians Fontaine

Plate 9, figure 12

Frenelopsis varians Fontaine, U. S. Nat. Mus. Proc., vol. 16, p. 273, pl. 40, figs. 1, 2; pl. 41, figs. 1–3a, 1893.

This coniferous fragment is characteristic of the species, showing little or no development of leaves at the nodes, the twigs having served the function of leaves. The parallel rows of dots represent stomata.

The species was described from the Trinity group (Lower Cretaceous) on the Paluxy River, near Glen Rose, Texas. It resembles most closely *Frenelopsis parceramosa* Fontaine (1889, p. 218) found in the Patuxent formation of the Potomac group at Trents Reach, Va. The latter, however, displays a little leaf development at the nodes.

As *Frenelopsis varians* and its closest relatives have never been found in other than Lower Cretaceous strata, I am inclined to regard it as a Lower Cretaceous time index.

Occurrence: Black shale in upper part of †Post-McElmo but beneath basal sandstone of the Dakota. Collected by W. L. Stokes, 1945.

Sphenolepis kurriana (Dunker) Schenk

Plate 9, figure 14

Sphenolepis kurriana (Dunker) Schenk. Berry, Maryland Geol. Survey, Lower Cretaceous, p. 432, pl. 74, figs. 2, 3, 1911. See extensive synonymy.

This many-named conifer, or a very closely related species, is common in Lower Cretaceous strata in Virginia, South Dakota, Montana, and California. Without attached fruits the species of *Sphenolepis* are not readily distinguishable from one another.

Occurrence: In black shale in lower part of †Post-McElmo, south of Nucla, Colo. Collected by Junius Henderson and party, 1914.

JUGLANDACEAE

Juglans crassipes Heer

Plate 12, figures 8, 9

Juglans crassipes Heer. Lesquereux, U. S. Geol. Survey Mon. 17, p. 69, pl. 49, figs. 1–3, 1892.

These specimens from southwestern Colorado seem to fall readily into this classification, but doubt must be entertained concerning the reference of the species to *Juglans*.

Occurrence: One and one-half miles southwest of coke ovens, Montrose County, Colo.

MORACEAE

Ficus daphnogenoides (Heer) Berry

Plate 11, figures 1, 2, 5

Proteoides daphnogenoides Heer. Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 6, p. 85, pl. 15, figs. 1, 2, 1874.
Ficus daphnogenoides (Heer) Berry, Torrey Bot. Club Bull., vol. 32, p. 329, pl. 21, 1905; Berry, U. S. Geol. Survey Prof. Paper 129, p. 163, pl. 39, fig. 1, 1922. See synonymy.

These entire-margined leaves have been referred to many different genera with little satisfaction, as might be expected for entire leaves, the internal venational structure of which tends in many toward similarity. I regard the reference to *Ficus* as a makeshift. Many similar leaves from the Dakota sandstone have been referred with little evidence to *Andromeda*. All are

perhaps examples of lauraceous species that are difficult to separate. At any rate, they are fairly abundant in early Upper Cretaceous strata.

Occurrence: Near junction of Disappointment Creek and Dolores River, San Miguel County, Colo. Collected by W. L. Stokes, 1945.

NYMPHAEACEAE

Nelumbium sp.

Plate 10, figure 2

This fragment, with a portion of the entire margin and a number of the radial veins preserved, has the characteristic features of a waterlily leaf. It, however, is so imperfect that a specific designation does not seem warranted.

No waterlily has thus far been identified from Lower Cretaceous strata in the western states, but species appear in early Upper Cretaceous deposits.

Occurrence: One and one-half miles southwest of coke ovens, Montrose County, Colo.

BERBERIDACEAE

Mahonia furnaria Brown, n. sp.

Plate 12, figure 4

Compound leaf with five lanceolate leaflets, the laterals being sessile, the terminal long-petioled. Margins serrate, with sharp teeth. Sinuses between the teeth scalloped. The secondary venation makes conspicuous internal, closed areas, with anastomoses and with thin branches to the teeth.

All the features of this leaf seem to ally it clearly with the genus *Mahonia* in the barberry family. If so, it may be in the ancestral line of the numerous species described from Eocene, Oligocene, and Miocene strata in the northwestern states.

Occurrence: One and one-half miles southwest of coke ovens, Montrose County, Colo.

LAURACEAE

Sassafras cretaceum Newberry

Plate 11, figure 8

Sassafras cretaceum Newberry, U. S. Geol. Survey Mon. 35, p. 98, pl. 6, figs. 1–4; pl. 7, figs. 1–3; pl. 8, figs. 1, 2, 1898.

The blunt, rounded lobes, as well as the venation of this specimen, conform closely to those of Newberry's plate 8, figure 1, and to several figured by Lesquereux as *Sassafras cretaceum* var. *obtusum*, and *S. obtusum* from the Dakota sandstone of Kansas and Nebraska. The reference of these leaves to *Sassafras* is questionable, but transfer to *Aralia*, *Araliopsis*, *Araliopsoides*, *Platanus*, *Sterculia*, or to some other genus is untimely and of no advantage so far as stratigraphy is concerned.

Occurrence: Near junction of Disappointment Creek and Dolores River, San Miguel County, Colo.

PLATANACEAE

Platanus newberryana Heer

Plate 12, figure 3

Platanus newberryana Heer. Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 6, p. 72, pl. 8, figs. 2, 3; pl. 9, fig. 3, 1874.

The fragment figured here is the tip of the middle lobe of a leaf of this species. The scalloped sinuses between the teeth and the disposition of the secondary veins and their branches into the teeth are characteristic features.

Occurrence: One and one-half miles southwest of coke ovens, Montrose County, Colo.

CELASTRACEAE

Celastrophyllum stokesi Brown, n. sp.

Plate 12, figures 1, 2

Lanceolate leaves, with rounded, crenate-dentate marginal teeth. Midrib strong. Secondary veins and intersecondaries form an anastomosing, more of less looped, network with short branches into the teeth.

This species approaches closely to *Celastrophyllum ensifolium* Lesquereux (1874, p. 108, pl. 21, figs. 2, 3) from near Fort Harker, Kans., but the leaves of the latter, especially Lesquereux's figure 2, are elliptic rather than lanceolate and the teeth are shorter and sharper. Berry (1911, pp. 474–481) recognized seven species of *Celastrophyllum* in the Patapsco formation, the species most closely resembling *C. stokesi* being perhaps *C. acutidens* Fontaine (Berry, 1911, p. 478, pl. 89), a specimen of which Ward had tentatively labeled *C. pulchrum*. He, however, did not publish the name until later (1899, p. 706, pl. 171, figs. 3, 4) in connection with what he considered identical material from the Dakota of the Black Hills. *C. stokesi* may be the same as *C. acutidens*, but the leaves of the latter appear to be shorter and more elliptic. It is significant that, as Berry (1911, p. 475) pointed out, *Celastrophyllum* is not present in the Patuxent and Arundel formations of the Potomac group. Neither is it present in any other formations attributed to the Lower Cretaceous. Consequently, this may be additional evidence for considering the Patapsco formation as Upper Cretaceous in age.

Occurrence: One and one-half miles southwest of coke ovens, Montrose County, Colo. Collected by W. L. Stokes, 1948, for whom the species is named.

STERCULIACEAE

Sterculia towneri (Lesquereux) Berry

Plate 9, fig. 7; plate 11, figs. 3, 4

Sterculia towneri (Lesquereux) Berry, U. S. Geol. Survey Prof. Paper 129, p. 217, 1922. See synonymy and cited figures.

These lobed Cretaceous leaves arouse considerable speculation as to separation of species and assignment to a definite botanical category. Berry's synonymy includes leaves from both Lower and Upper Cretaceous zones, and, therefore, if correct, the species cannot serve for distinguishing one zone from the other. Doubts, however, may well be expressed about the Berry synonymy, after examining numerous leaves from both zones.

Berry included under *Sterculia towneri* only lobed leaves with entire margins. A critical feature of the venation of these leaves must also be noted, namely, that the branching of primary veins from the midrib occurs at some distance above the top of the petiole and actual base of the blade. If the leaf is five-lobed, the lateral primaries fork at 1 or 2 cm. from the midrib. Thus the venational architecture is strikingly like that of *Platanus*. This pattern is also seen in the lobed Cretaceous leaves assigned by Lesquereux to various species of *Aralia*, *Cissites*, *Liquidambar*, and *Sassafras*. The lobes of the *Aralia* species, however, have more or less toothed margins, with scalloped sinuses between the sharp teeth, thus especially simulating leaves of *Platanus*. The association of similar, entire-margined with toothed-margined, lobed leaves that have been assigned to the same species in Paleocene, Eocene, and Oligocene strata in the northwestern states suggests a need for further study of the Cretaceous species here discussed and of Berry's *Sterculia towneri* synonymy.

Be all this as it may, the prime question so far as dating is concerned is whether any differences can be detected in these leaves that will permit separation of Lower and Upper Cretaceous strata. Unfortunately, too few of these leaves (except in the Cheyenne sandstone where they are not very well preserved), have been found in known Lower Cretaceous strata, thus giving perhaps an imperfect idea of their features. However, I find that the known Upper Cretaceous leaves are more deeply lobed, with a greater tendency to being toothed and with lobes that tend to be wider medianly. The Lower Cretaceous leaves are less deeply lobed, with scarcely any toothing, and the lobes tend to be cuneate, with scarcely any median widening.

It will be noted that the leaves here figured display the features noted for the Upper Cretaceous leaves. If, as seems most likely, the Lower Cretaceous leaves are immediately ancestral to those in the Upper Cretaceous it would not be surprising to find reversions or throwbacks to such leaves in Upper Cretaceous collections.

On this basis, the lobed leaves of the Lower Cretaceous Cheyenne sandstone, assigned by Berry to *Sterculia towneri*, ought perhaps to be given a new name, whereas those of the Upper Cretaceous Dakota sandstone remain *S. towneri*. The reassignment of some or all of these leaves to another genus than *Sterculia* must some day be considered.

Occurrence: Near junction of Disappointment Creek and Dolores River, San Miguel County, Colo.

Capsulocarpus dakotensis Berry

Plate 9, figure 3

Capsulocarpus dakotensis Berry, Washington Acad. Sci. Jour., vol. 29, pp. 331–336, figs. 1–4, 1939.

The fruit here figured is considerably smaller than those reported by Berry from the Dakota sandstone near New Ulm, Minn., but resembles them in all other respects—general outline, transverse plications, and marginal flange. As shown by Berry's figure 2 of the counterpart of his figure 1, the specimens with the flanges and transverse folds are casts of the interiors of fruits.

The relationship of this fruit is unknown. Except for the prominent flange, there is some resemblance to the fossil fruits of *Cercidiphyllum*, some of which are relatively large as compared with the fruits of the living species.

Occurrence: Near junction of Disappointment Creek and Dolores River, San Miguel County, Colo.

SPECIMENS OF UNCERTAIN IDENTITY

Plate 9, figure 1. This is part of a spherical fruit head with many closely packed, squarish carpels radiating from a round center. It may represent an early burreed, *Sparganium*. Disappointment Creek.

Plate 9, figure 2. This is a reticulately pitted seed that probably belongs with the fruit, plate 9, figure 1. Disappointment Creek.

Plate 9, figure 4. This may be the young stage of the fruit in plate 9, figure 1. Disappointment Creek.

Plate 9, figure 8. A lobed leaf, perhaps of a species of *Sassafras*. Black shale near base of †Post-McElmo.

Plate 9, figure 9. Perhaps a fragment of a cycad leaf. Black shale near base of †Post-McElmo.

Plate 9, figures 10, 11. These are the narrow needle-like specimens identified by Berry as *Pinus susquaensis* Dawson. Such material also occurs in the Kootenai formation of Montana and in other Lower Cretaceous strata in the United States and Canada. However, the

"needles" have never been seen in fascicles, nor have authentic pine seeds been found with them, and consequently the identification as *Pinus* remains unconfirmed. Black shale near base of †Post-McElmo.

Plate 10, figure 1. A dicotyledonous leaf with unusually coarse, serrate teeth. One and one-half miles southwest of coke ovens.

Plate 10, figure 3. An undetermined fern. Four miles south of Nucla.

Plate 11, figure 7. Apparently a fruit or husk of a fruit. Disappointment Creek.

Plate 12, figure 5. A flower with 3 broad-based, alternating with 3 narrow-based oblanceolate petals or sepals. In the center are 3 striated seeds. This structure may represent a monocotyledon. One and one-half miles southwest of coke ovens.

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PLATES 9–12

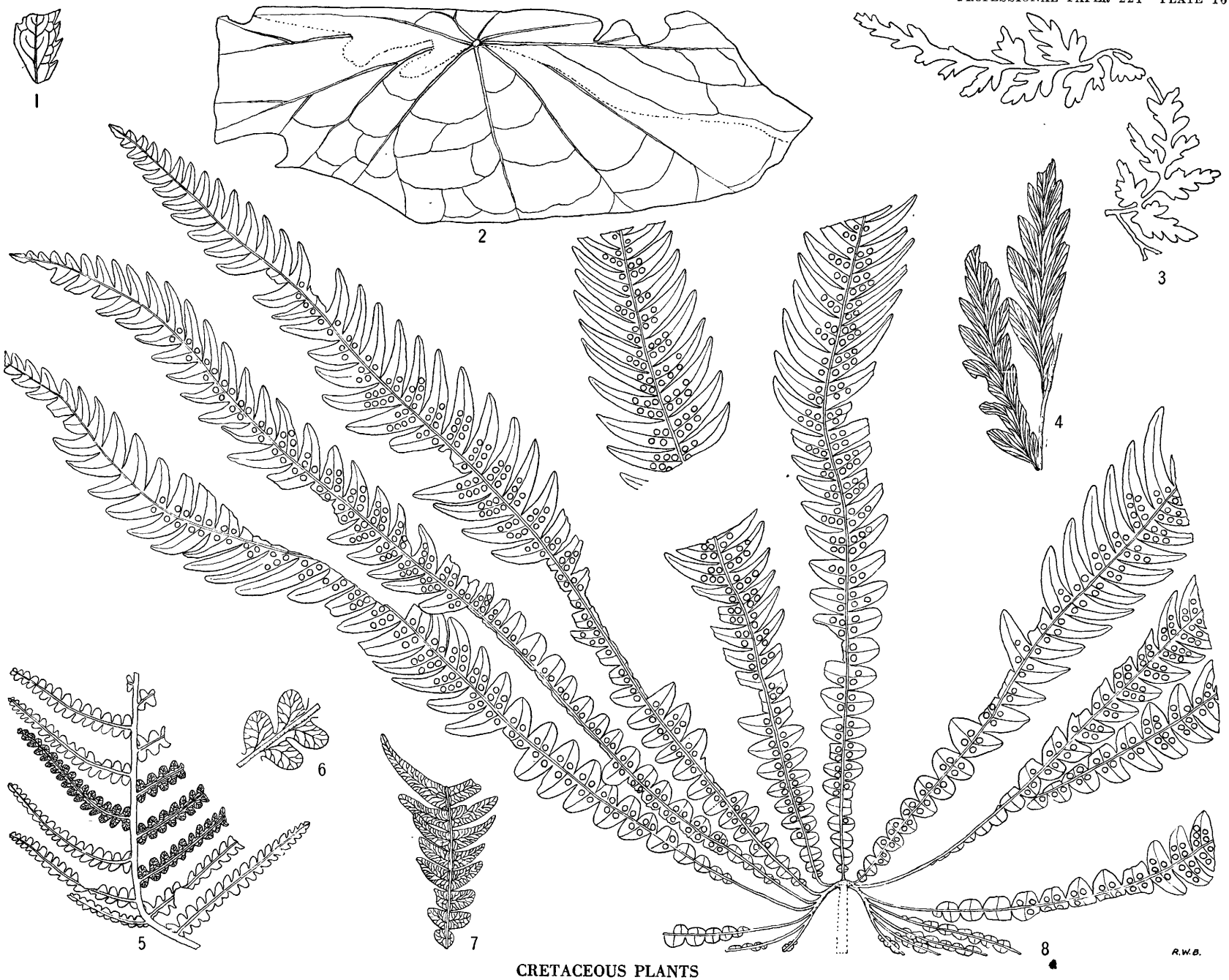
PLATE 9

Figure 1. Undetermined fruit with squarish carpels. × 2.
2. Undetermined pitted seed. × 8.
3. *Capsulocarpus dakotensis* Berry × 2.
4. Undetermined fruit.
5, 6. *Brachyphyllum crassicaule* Fontaine.
7. *Sterculia towneri* (Lesquereux) Berry.
8. Probably a species of *Sassafras.*
9. Probably a fragment of a cycad leaf.
10, 11. Probably *Pinus susquaensis* Dawson.
12. *Frenelopsis varians* Fontaine.
13. *Cycadeoidea* sp.
14. *Sphenolepis kurriana* (Dunker) Schenk.
15. *Tempskya knowltoni* Seward.

CRETACEOUS PLANTS

PLATE 10

Figure 1. Undetermined dicotyledonous leaf.
2. *Nelumbium* sp.
3. Undetermined fern.
4. *Asplenium* sp.
5, 6. *Gleichenia kurriana* Heer.
7, 8. *Matonidium americanum* Berry.



CRETACEOUS PLANTS

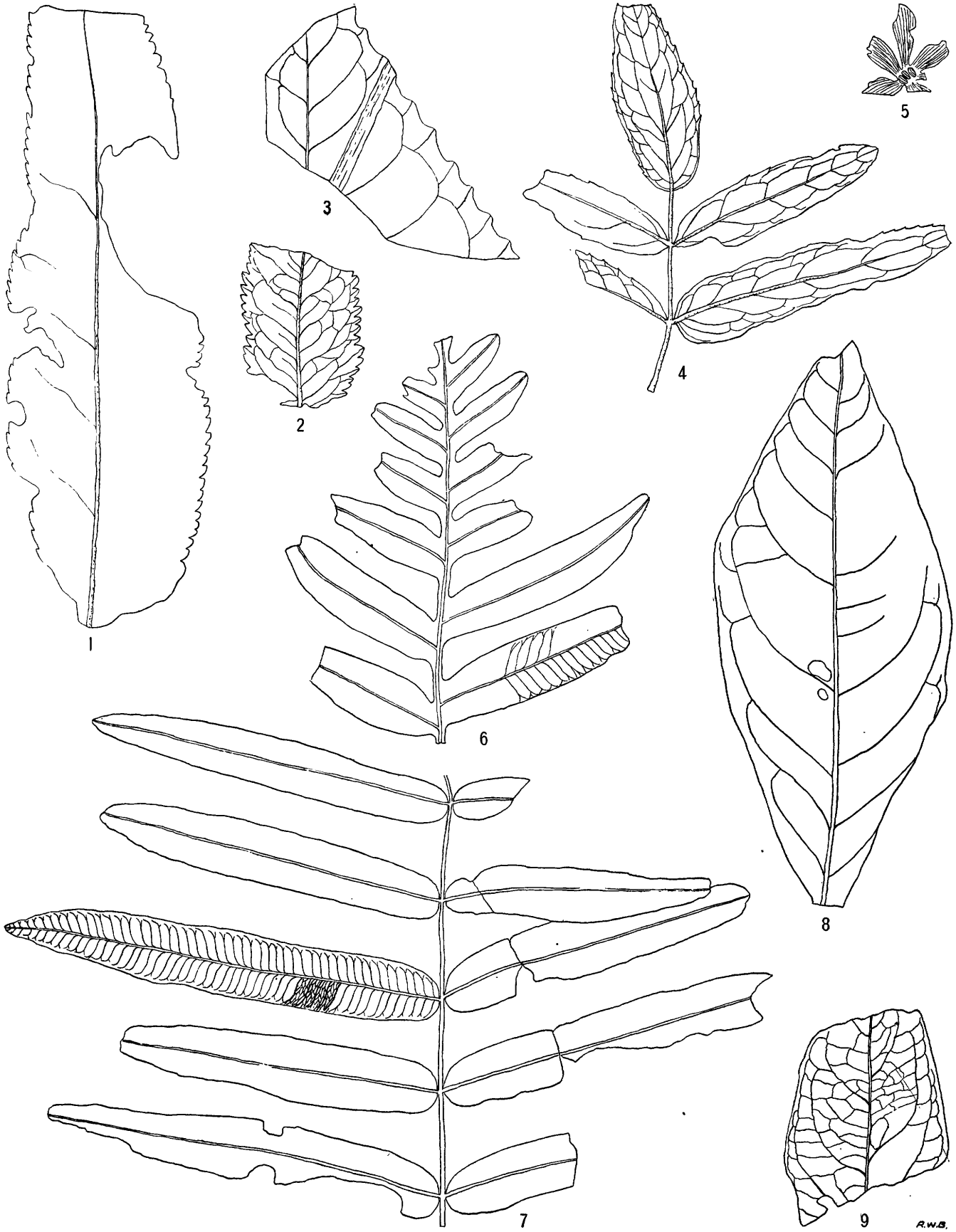
PLATE 11

Figures 1, 2, 5. *Ficus daphnogenoides* (Heer) Berry.
3, 4. *Sterculia towneri* (Lesquereux) Berry.
6. *Llavea hesperia* Brown, n. sp.
7. Undetermined fruit.
8. *Sassafras cretaceum* Newberry.

CRETACEOUS PLANTS

PLATE 12

Figures 1, 2. *Celastrophyllum stokesi* Brown, n. sp.
3. *Platanus newberryana* Heer.
4. *Mahonia furnaria* Brown, n. sp.
5. Undetermined flower.
6, 7. *Bolbitis coloradica* Brown, n. sp.
8, 9. *Juglans crassipes* Heer.



CRETACEOUS PLANTS

INDEX