THE PHYSICAL CONDITIONS AND AGE INDICATED BY THE FLORA OF THE ALUM BLUFF FORMATION.

By EDWARD WILBER BERRY.

INTRODUCTION.

The present paper has for its purpose the description of a small flora collected from the Alum Bluff formation, representing a horizon hitherto unrepresented paleobotanically in southeastern North America, and the discussion of the bearing of this flora on the physical conditions of deposition and the probable age of the deposits.

GEOLOGY OF THE DEPOSITS.

The Alum Bluff formation was named from the bluff of that name on the east bank of the Apalachicola River, about 25 miles below Chattahoochee or River Junction, in Liberty County, Fla.[1] (See Pl. VII, *B*, p. 56.) It is, according to present knowledge, the uppermost formation of the Apalachicola group. It comprises three members, which, named in ascending order, are the Chipola marl member, the Oak Grove sand member, and the Shoal River marl member.

The Chipola marl, which is a thin yellowish clay marl at the base of the formation as defined by Matson and Clapp, carries a very extensive and well-preserved marine fauna. It was named from Chipola River, in Calhoun County, Fla. The Oak Grove sand, stratigraphically intermediate between the Chipola and Shoal River, is a thin, highly fossiliferous gray or greenish fine sand named from Oak Grove, on Yellow River, and not represented by a lithologic unit at Alum Bluff. The Shoal River marl, the highest known fossiliferous member of the formation, is a thin series of interbedded greenish sands and marls overlying the Oak Grove sand. It was named from Shoal River, in western Florida, and is not represented by a lithologic unit at Alum Bluff.

The following section was taken at the point where the fossil plants were collected, near the lower end of the bluff and in the immediate vicinity of the section measured by Dall.[2] It is deemed worthy of reproduction because it differs in certain particulars from Dall's section. Still other sections from different parts of the bluff are given by Sellards and Gunter.[3]

Section at Alum Bluff, Fla.

	Feet.
Pleistocene (?):	
Light-colored ferruginous, rather loose sands.	9
Hard reddish clay	2
Variegated reddish and yellowish ferruginous sands	65
Miocene:	
Choctawhatchee marl:	
Dark-gray pyritiferous clay, more or less carbonaceous but scarcely meriting the term lignitic given to it by Langdon, as no lignite or plant fossils were observed in it. Traces of invertebrate fossils, for the most part undeterminable, were observed in places. The pyritiferous character of the clay gives it an alum-like taste, which accounts for the name of the bluff. Approximate thickness.	25
Bluish (when unweathered) fossiliferous clay marl of irregular thickness, carrying *Mulinia congesta*, *Ecphora quadricostata*, *Turritella variabilis*, and other species; much oxidized in its upper portion, in which the fossils are represented by poor casts, owing to the solution of the shell substance	15–30
Erosion unconformity.	

[1] The geology of this region is fully discussed in the following publications:

Matson, G. C., and Clapp, F. G., A preliminary report on the geology of Florida: Florida Geol. Survey Second Ann. Rept., pp. 21–173, 1909.

Vaughan, T. W., A contribution to the geologic history of the Floridian Plateau: Carnegie Inst. Washington Pub. 133, pp. 99–185, 1910; see also U. S. Geol. Survey Prof. Paper 71, pp. 741–745, 1912.

[2] Dall, W. H., and Stanley-Brown, J., Cenozoic geology along the Apalachicola River: Geol. Soc. America Bull., vol. 5, p. 157, 1894

[3] Sellards, E. H., and Gunter, Herman, Florida Geol. Survey Second Ann. Rept., pp. 275, 276, 1909.

Oligocene:

Alum Bluff formation: Feet.

Cross-bedded laminated sands with clay laminæ and thin distorted clay lenses of small extent. The sands are locally thicker bedded and argillaceous, especially in the upper part, where they are in places packed with the distorted detached rays of a Sabal-like palm. In the lower part they are more evenly bedded and less argillaceous, being composed largely of a somewhat coarser gray iron-stained sand with vegetable matter aggregated in definite but not everywhere horizontal layers. Here and there are thin iron crusts, and some of the more argillaceous laminæ are bluish in color. Leaf impressions are much more abundant and varied in these lower layers. The thickness is variable, the maximum observed being about..... 10

Gray calcareous compact massive, in places slightly phosphatic sand, somewhat fossiliferous; thickness about..... 12

Chipola marl member: Compact ferruginous, abundantly fossiliferous argillaceous sand carrying Orthaulax and other characteristic Oligocene invertebrates; thickness exposed..... 3–4

most Oligocene or basal Miocene flora, practically the only one known in North America.

In Forrest County, Miss., in beds included by L. C. Johnson in the Hattiesburg clay (see Pl. VII, *A*, p. 56), I discovered in the summer of 1910 a small flora that appears to be synchronous with that at Alum Bluff. The exact locality is on the south side of the New Orleans, Mobile & Chicago Railroad, 1 mile east of Raglan, and the outcrop shows the following section (see also fig. 8):

Section near Raglan, Miss.

	Feet.
1. Compact reddish argillaceous sand.....	0–12
2. Light sandy clay.....	1–2
3. Compact argillaceous lignite or brown lignitic clay.....	2
Unconformity (local?).	
4. Yellowish or gray argillaceous fine sand or sandy clay, grading into underlying beds.....	10
5. Similar materials of greenish color, weathering yellowish, irregularly bedded and carrying large numbers of poorly preserved plant remains, mostly palm rays; grades into underlying beds; thickness about.....	4
6. Yellowish or greenish much-jointed sandy clay..	6

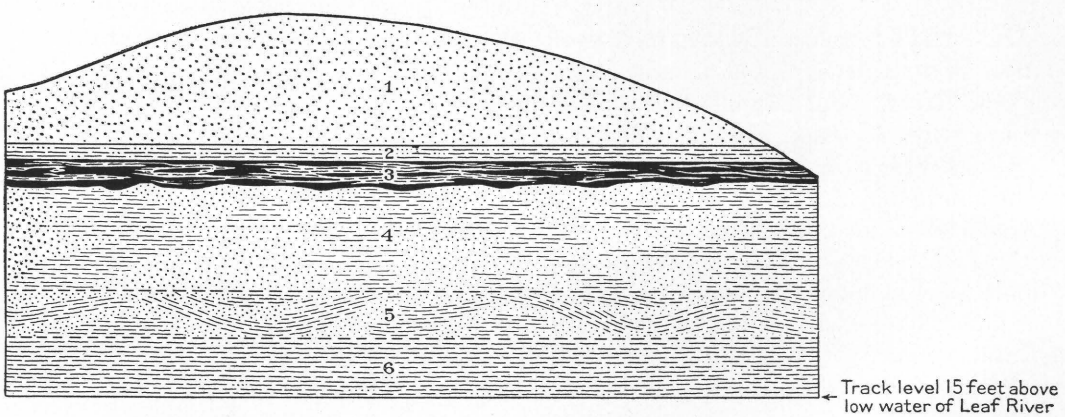


FIGURE 8.—Section of Hattiesburg clay near Raglan, Miss. Numbers correspond to those given in the section in the text.

Alum Bluff is a most interesting spot to the physiographer, because of the striking contrast in topography between the east and west banks of the river; to the geologist, because it is a classic locality for the so-called Old Miocene and represents also the oldest known southern outcrop of the Chesapeake Miocene; and to the botanist, because in the wooded and damp ravines along the bluff are to be found two isolated gymnosperms, both relics of bygone floras, *Taxus floridana* Nuttall and *Tumion taxifolium* (Arnott) Greene. Alum Bluff is of particular interest to the paleobotanist, because it furnishes a representation of an upper-

The plants in the sands at both the localities mentioned above are few and very friable. Collections could not be made in the usual way, and as my improvised method proved very satisfactory it is worth describing. A small excavation in the loose, slumped sand was lined with a large piece of burlap. This was partly filled with plaster. While the plaster was still soft the sandy specimen was placed in it, the face of the specimen being left about on the level of the plaster. After the plaster had set the face was thickly covered with cotton, over which the free ends of the burlap were wrapped and tied firmly. Every speci-

men treated in this way, some of which were 10 inches in diameter, survived the rough handling on the river boat and the freight transportation to Baltimore.

Fossil plants from Alum Bluff have been mentioned by Langdon,[1] Foerste,[2] and Dall.[3] A few fragments of Sabalites were collected by Dall, but no systematic collections were made until I visited this outcrop in 1910 in company with E. H. Sellards, State geologist of Florida.

CHARACTER OF THE FLORA.

The flora is limited to 13 described species, although fragments of other species are present, and I observed but did not succeed in collecting a palmately veined Ficus, leaves of Gyminda or Xanthoxylum, and pods resembling those of the existing *Gleditsia aquatica* Marsh.

The determined species comprise a spot fungus (Pestalozzites), a very abundant fan palm (Sabalites), and 11 species of dicotyledons, including an elm, breadfruit, buckthorn, camphor, satinwood, ironwood, and persimmon. There are 11 genera in 9 families and 8 orders. These families are the elm (Ulmaceæ), mulberry (Moraceæ), pisonia (Nyctaginaceæ), senna (Cæsalpiniaceæ), rue (Rutaceæ), buckthorn (Rhamnaceæ), laurel (Lauraceæ), sapodilla (Sapotaceæ), and ebony (Ebenaceæ). The families Lauraceæ and Sapotaceæ are each represented by two species; the remaining seven families have each a single species. By far the most abundant form is the palm, broken stipes and detached rays of which are thickly crowded in the sands in places. Four of the plants are ordinarily considered strictly tropical—the breadfruit (Artocarpus), brasiletto (Cæsalpinia), Nectandra, and satinwood (Fagara). The genera Pisonia and Cinnamomum are commonly considered tropical, but Pisonia reaches the keys of southern Florida in the existing flora and the camphor tree (Cinnamomum) ranges northward to southern Japan and to the rain forests of southwestern China, while *Cinnamomum camphora* Linné is hardy in cultivation around Tallahassee, Fla., and is not uncommon as an escape from cultivation in woods and thickets throughout peninsular Florida, being freely seeded by birds. In fact, soil, humidity, and the length of the growing season seem to govern the extension of the tropical flora into the temperate zones to a much greater extent than actual extreme temperatures, the existing floras of both southeastern Asia and southeastern North America showing many parallel examples of such extensions.

The Sabalites is represented in the existing flora by the genus Sabal Adanson, which is now confined to America. It consists of eight coastal or stream-border shrubs and trees, five of which are confined to the West Indies, Mexico, and Venezuela; one is confined to peninsular Florida, and two range northward along the Atlantic coast to the Carolinas.

The large mass of frayed and tangled rays and stipes of Sabalites in a matrix of sandy alluvium both at Raglan, Miss., and Alum Bluff, Fla., suggest that at the time these deposits were laid down the shores were low and were densely clothed with palmetto "swamps" or brakes.

The genus Ulmus, although it has tropical allies, is in the existing flora a strictly north-temperate form having about 16 widely distributed species.

The family Rhamnaceæ is mostly tropical, but several of the genera extend into the Temperate Zone, and Rhamnus, in particular, is mostly extratropical in the North Temperate Zone. There are about 75 existing species, and of the dozen North American forms several range northward to Canada and British America and only 1 ranges as far south as Florida.

The genus Bumelia has about a score or more of existing species, ranging from Brazil northward through Central America and the West Indies to the United States, where two species are found as far north as Virginia and Illinois.

The genus Diospyros belongs to a large family that is mostly tropical in its distribution. Of the more than 200 existing species our common *Diospyros virginiana* Linné is found as far north as southern New York and New England. The genus is represented in southern Europe, and there are several species in eastern Asia. Moreover, of the 100 or more

[1] Langdon, D. W., Some Florida Miocene: Am. Jour. Sci., 3d ser., vol. 38, p. 322, 1889; Geology of the Coastal Plain of Alabama, p. 373, 1894.

[2] Foerste, A. F., Studies on the Chipola Miocene of Bainbridge, Ga., and of Alum Bluff, Fla.: Am. Jour. Sci., 3d ser., vol. 46, pp. 244–254, 1893; Fossil palmettos in Florida: Bot. Gaz., vol. 19, p. 37, 1894.

[3] Dall, W. H., and Stanley-Brown, Joseph, Cenozoic geology along the Apalachicola River: Geol. Soc. America Bull., vol. 5, pp. 147–170, 1894.

fossil species that have been described many occur in associations that are obviously temperate in character.

To summarize the climatic conditions indicated by the flora, they are those of a tropical flora becoming replaced by a temperate flora, namely, subtropical or very warm temperate. These conditions are obviously different from those indicated by the Chipola marine fauna, which comprises over 400 known species, mostly Mollusca, and indicates a shallow sea (maximum depth not over 20 fathoms) and, according to Vaughan,[1] strictly tropical temperatures—that is, the bottom temperature of the water did not go below 70° F. during the year.

As has already been indicated, the flora embraces a number of tropical types which, as is shown by the existing flora, are legitimately to be expected to extend more or less beyond the equatorial belt in areas where rainfall is abundant and where extremes of low temperature are absent. Associated with these are forms like Ulmus, whose modern representatives are prevailingly north temperate but some of which extend into boreal regions. Still other of the Alum Bluff forms, the Rhamnus, Bumelia, and Diospyros, represent families which are mainly tropical in the existing flora but which as represented by these genera have extended over large areas of the warmer parts of the Temperate Zone.

It seems to me that among existing plant assemblages the Alum Bluff flora represents three types of plant associations. One corresponds in a general way to the "low hammock" of present-day peninsular Florida, a type intermediate between the true hammock and the swamp type. A second plant assemblage indicated is that of the low-lying semiswamp palmetto-brake type, along with some forms of the sandy strand, such as Pisonia, Cæsalpinia, and Fagara. In other words, this flora would find a congenial habitat at the present time in the delta of Apalachicola River or almost anywhere along the coast of peninsular Florida. Although so much less extensive, the Alum Bluff flora is somewhat less tropical in its facies than the flora of the Wilcox group and decidedly less tropical than the floras of the Claiborne, Jackson, Vicksburg, or Catahoula. On the other hand, it has not nearly the temperate facies of the flora of the overlying Chesapeake Miocene and also indicates much more humid conditions than the latter. This statement is based on the flora of the Calvert and a consideration of the abundant marine faunas of the Calvert, St. Marys, Yorktown, Duplin, Choctawhatchee, and Jacksonville formations.

The Alum Bluff flora may be considered to be the result of a reversal of the history of the present flora of peninsular Florida. That is to say, the present flora represents primarily a temperate flora receiving additions from the Tropics, whereas the Alum Bluff flora represents an endemic tropical flora gradually becoming invaded by members of a temperate flora as a result of changing climatic conditions.

AGE OF THE FLORA.

The stratigraphic relations clearly indicate that the Alum Bluff flora is younger than the Vicksburg Oligocene and older than the Chesapeake Miocene. The faunal and floral evidence is equally conclusive. Not a single Alum Bluff plant is common to the Oligocene (Vicksburg and Catahoula) floras of Mississippi, Louisiana, and Texas nor to the Chesapeake Miocene floras, which are, however, smaller than those from the Oligocene. Moreover, the facies of the Alum Bluff flora is decidedly different from that of the floras of any of these horizons. There are no western United States or West Indian fossil floras for comparison, so that it remains to consider the probable European equivalents of the Alum Bluff.

As the Alum Bluff flora is obviously younger than the abundant European floras of the Sannoisian (Lattorfian, Tongrian) and Stampian (Rupelian) and older than the exceedingly rich floras of the Helvetian and Tortonian (Vindobonian), the only stages remaining are the Chattian (Kasselian), Aquitanian, and Burdigalian (Langhian, Mayencian).

The Chattian (Fuchs, 1894) is the lower Aquitanian of Munier Chalmas and De Lapparent (1893). It is considered the equivalent of the Kasselian and in the Paris Basin is represented, according to Lemoine, by the meulières de Montmorency. According to Haug its invertebrate fauna is distinguished by the absence of Miocene types.

The Aquitanian (Mayer, 1857) now has the narrow limits assigned by Dollfus (1906–7). It marks the maximum regression of the Oligocene

[1] Vaughan, T. W., Carnegie Inst. Washington Pub. 133, p. 156, 1910.

sea due to the elevation of the Pyrenees and the beginning of Alpine orogenesis. Marine waters invaded the marginal coasts in Aquitaine, the Gironde, and Provence, in southern Spain, in Italy, and at various points on the south side of the eastern Alps; but the great bulk of the Aquitanian sediments are those of lakes, swamps, and lagoons, with lignites and abundant and widespread mammals and plants. In Aquitaine the Tongrian is said to grade imperceptibly into the Aquitanian both lithologically and faunally, and the latter passes into the Burdigalian in the same gradual manner. The floras of the Aquitanian are likewise transitional in character between Oligocene and Miocene. The marine faunas, however, are said by Haug to contain only 4 per cent of Oligocene species and many Miocene species, but the foraminiferal genus Lepidocyclina passes without modification from the Chattian into the Aquitanian. The Aquitanian has long been considered the uppermost stage of the Oligocene, although many paleontologists have pointed out the resemblances between the upper Aquitanian floras and faunas and those of the Burdigalian. In recent years, under the leadership of Dollfus and other French students, the Aquitanian has been made the basal stage of the Miocene, although the question of its reference to the Oligocene or Miocene is vigorously disputed.

The Burdigalian (Depéret, 1892) is closely related to the Aquitanian both faunally and florally. The marine faunas as well as the terrestrial floras are said to indicate a slight lowering of temperatures since Aquitanian time. Tectonic changes had caused the disappearance of the broad lakes of the Aquitanian, and the Burdigalian materials comprise marine sediments on the southern and western borders of the continent and a series of river, flood-plain, and swamp deposits (brown coal) in the region extending from France to Bohemia.

It can not be said that the Alum Bluff flora offers conclusive evidence for detailed correlation, as it is too small. All but two of the species are new and offer only indirect evidence. Of these new species the Ulmus is very similar to *Ulmus longifolia* Unger, of the Aquitanian of Bohemia, Germany, Styria, and France, and the Sapotacites is most like *Sapotacites* (*Chrysophyllum*) *sagorianum*, from the Aquitanian of Sagor, in Carniola, described by Ettingshausen. The two species with an outside distribution, *Cinnamomum scheuchzeri* and *Diospyros brachysepala*, have both been identified in beds from a great variety of horizons in Europe. Although many of these identifications are of doubtful value, both species had a wide range, geographic as well as geologic. The original descriptions of both, by Alexander Braun, were based on material from the Tortonian of Oeningen in Baden. The two species are typically Oligocene-Miocene forms and both are common and characteristic in the Aquitanian and Burdigalian of Europe.

It is thus apparent that the Alum Bluff flora can be considered either Aquitanian or Burdigalian, with a slight preponderance of the evidence in favor of the Aquitanian. Maury [1] on the evidence of the molluscan fauna correlated the Chipola marl with the Aquitanian and considered the Oak Grove fauna, as well as that of the sands at Alum Bluff above the Chipola, as "transitional" between Aquitanian and Miocene. If subsequent paleozoologic studies corroborate Maury's work, there will be substantial agreement between the floral and faunal evidence.

If the Alum Bluff formation is of Aquitanian or Burdigalian age—and one or the other alternative seems certain—the more or less academic question is raised whether it shall be classed as Oligocene or Miocene.

Since the proposal of the term Oligocene by Beyrich in 1854 many have questioned its utility or ultimate survival. Certainly there is but slight structural (diastrophic) evidence for placing the Oligocene-Miocene boundary in Europe between the Aquitanian and Burdigalian, and the marine faunas as well as the terrestrial floras and faunas show a gradual transition from the one stage to the other, so that the French paleontologists will probably be followed in their contention that the Aquitanian should be placed in the Miocene.

In considering the American application of the term Oligocene, it may be noted that there appears to have been continuous and uninterrupted sedimentation in the Florida area from the deposition of the underlying Chattahoochee formation into Alum Bluff time. There also seems to have been a succession of minor earth movements during this period, and there was a greater influx of terrigenous materials into

[1] Maury, C. G., Bull. Am. Paleontology No. 15, 1902.

the Alum Bluff sea than into the Chattahoochee sea, a change in sedimentary character more probably due to an inland rise of the land which accelerated erosion than to the shallowing of the sea.

It seems obvious that the Alum Bluff formation as a whole is a predominantly shallow-water deposit of clays and sands and that the Chipola, Oak Grove, and Shoal River members are faunal zones contained in successive lenticular beds in the clays or sands. The faunules of these zones are closely related but show, according to Dall,[1] certain elements of transition in the Oak Grove sand from the tropical Chipola fauna to one indicating a slight lowering of the temperature.

There is thus no structural (diastrophic) evidence for drawing the Oligocene-Miocene boundary between the Chattahoochee and Alum Bluff formations, nor is there any floral or faunal evidence for such a boundary. There is such a break between the Vicksburg and Apalachicola groups, and the Alum Bluff is separated by an erosion unconformity from the overlying Choctawhatchee Miocene. It rests with invertebrate paleontology to determine whether or not the whole of the Apalachicola group shall be considered Miocene. Whatever may be the final verdict, it remains true that the flora preserved at Alum Bluff records the last phase of sedimentation before the area emerged from the sea and that the most profound break in Tertiary sedimentation in the southeastern United States, emphasized equally by epeirogenic, faunal, and floral changes, was at the end of Apalachicola time—that is, it is represented by the unconformity at the top of the Alum Bluff formation.

SYSTEMATIC ACCOUNT OF THE FLORA.

Class FUNGI.

Order MELANCONIALES.

Family MELANCONIACEÆ.

Genus PESTALOZZITES Berry.

Pestalozzites sabalana Berry, n. sp.

Plate VIII, figure 3; Plate IX, figure 9.

Essential characters unknown. Found infesting the leaves of *Sabalites apalachicolensis* Berry in considerable abundance and causing the formation of leaf spots. These spots are of definite form and regular outline, small and circular at first, becoming larger with age and elongated parallel to the long axis of the ray, thus becoming elliptical or lenticular in outline. Maximum size observed, 1.5 centimeters in length and 0.5 centimeter in width. Average size, about 6 by 2 millimeters. The appearance of the infested leaves is well illustrated in the figures, and they are scarcely to be distinguished from numerous leaves of the existing scrub palmettos, as for example, *Serenoa serrulata* (Michaux) Hooker, infested with the existing leaf-spot fungus Pestalozzia sp.

Occurrence: Hattiesburg clay, Raglan, Forrest County, Miss.; collected by E. W. Berry. Alum Bluff formation, Alum Bluff, Liberty County, Fla.; collected by E. W. Berry.

Collections: United States National Museum.

Class ANGIOSPERMÆ.

Subclass MONOCOTYLEDONÆ.

Order ARECALES.

Family PALMACEÆ.

Genus SABALITES Saporta.

Sabalites apalachicolensis Berry, n. sp.

Plate VIII, figures 1–5; Plate IX, figure 9.

Leaves of variable size, the maximum diameter estimated (from collected material) at about 120 centimeters. Rachis large, linear, not enlarged at the base of the leaf, lenticular in cross section, with straight unarmed edges, continued for a short distance on the lower side of the leaf as a rapidly narrowed acumen which is only 3.5 centimeters in length in the small specimen figured; abruptly rounded-truncate at the base of the leaf on the upper side, where an inconspicuous ligule is present. Rays numerous, 40 to 60 in number, carinate, linear-lanceolate in form, expanding to their middle, and free for about the upper third of their length, more or less curved at the base. Maximum width observed about 4 centimeters; average about 2 centimeters. Midribs of rays not especially strong or prominent. Secondaries numerous, fine, longitudinal, parallel, largely immersed in the leaf substance, which must have been coriaceous. No transverse veinlets observed.

This species has a recorded range along the coast of the Gulf of Mexico from Florida to

[1] Dall, W. H., Contributions to the Tertiary fauna of Florida: Wagner Free Inst. Sci. Trans., vol. 3, pt. 2, pp. 1574–1575, 1903.

central Mississippi and is in places abundant but everywhere fragmentary. In the absence of fairly well preserved specimens showing the rachis and acumen it is impossible to distinguish this form from the Wilcox species *Sabalites grayanus* Berry or the Oligocene species *Sabalites vicksburgensis* Berry, so that possibly the latter species, represented by incomplete material, may be present in the Alum Bluff sands, although I consider this extremely doubtful.

Sabalites grayanus differs from the present species in the expanded upper end of the rachis, the longer and more gradually narrowed acumen, and the more numerous rays, which are usually more conspicuously veined.

The fragments of rays which are so common in some of the deposits of the Vicksburg group and which are made the basis of *Sabalites vicksburgensis* are to be distinguished from *S. apalachicolensis* chiefly by their much more prominent venation and longer and more slender acumen. The present species at its region of maximum occurrence at Alum Bluff is badly infested with a leaf-spot fungus which I have described as *Pestalozzites sabalana* Berry, n. sp.

The foliage of palms is abundant and well distributed throughout the deposits of the Wilcox, Claiborne, Vicksburg, and Apalachicola groups, indicating the abundance of plants of this type in southeastern North America during the Tertiary period. Few of these remains represent entire leaves, and in many places only fragments of rays are preserved. Palm leaves are notoriously difficult of determination, and the bulk of remains representing flabellate fan palms with an acumen are referred by American students to the genus Sabalites and by European students to Sabal. Two methods of specific differentiation are possible. Minor differences and stratigraphic position may be ignored, as in the case of the geographically and geologically wide-ranging *Sabal major* Unger of Eurasia, or minor differences that also represent differences in geologic age may have considerable weight in specific differentiation. The latter is the method that I have found most useful from both the biologic and the geologic viewpoint.

The extreme tropical climate of Vicksburg and Catahoula time, which is reflected in the abundant traces of palms found in deposits of Vicksburg or Catahoula age from Texas eastward, continued through the time of deposition of the Chipola marl member of the Alum Bluff formation. Fortunately conditions were favorable for petrification, and fragments of petrified palm trunks, many of them of large size, are abundant throughout the area underlain by the Vicksburg or Catahoula deposits. Seven species of Palmoxylon have been described from these deposits. So far as I am aware no petrified palms have thus far been obtained from the Alum Bluff sands, but palm foliage is very abundant in the leaf-bearing lens at Alum Bluff. I have never seen so great an abundance of stipes and rays of palms as occur at this outcrop. In places whole layers consist of a mass of frayed and tangled rays in a matrix of sandy alluvium. They are usually much macerated, and only here and there can larger fragments of leaves be found. They are almost equally abundant in the similar materials cropping out near Raglan, Miss. This suggests the presence near the coast in late Alum Bluff time of extensive palmetto swamps or brakes along the lower reaches of a sluggish river or estuary only a few feet above mean water level—not flooded or true swamps, but subject to periodic overflow.

Occurrence: Hattiesburg clay, Raglan, Forrest County, Miss. (common; collected by E. W. Berry); and near Chicoria, on Chickasawhay River, Wayne County, Miss. (collected by E. W. Berry). Alum Bluff formation, Alum Bluff, Liberty County, Fla. (collected by E. W. Berry), and Boynton Bluff, Choctawhatchee River, Fla. (collected by E. H. Sellards).

Collections: United States National Museum.

Subclass DICOTYLEDONÆ.

Order FAGALES.

Family ULMACEÆ.

Genus ULMUS Linné.

Ulmus floridana Berry, n. sp.

Plate IX, figures 5–7.

Leaves of medium or small size, ovate-lanceolate in general outline, with slightly inequilateral cuneate rounded or subcordate base, and a gradually narrowed, somewhat extended acuminate tip. Length from 4 to 7 centimeters. Maximum width, in the basal half of the leaf, from 1.5 to 3 centimeters. Margins entire at the extreme base, above which they are finely and sharply doubly ser-

rate, the teeth increasing slightly in size distad. Petiole short and stout, about 2.5 millimeters in length. Midrib of medium size, relatively thin and flexuous. Secondaries thin, 10 to 12, subopposite to alternate, in rather irregularly spaced pairs; they diverge from the midrib at angles varying from about 75° near the base to 30° near the tip, averaging about 50°; they pursue a rather straight craspedodrome course and near their tips give off one or two outwardly directed tertiaries, which run to the teeth or to the sinuses.

This well-marked species of Ulmus appears to have been common during Alum Bluff time and constitutes the one strictly temperate element in the Alum Bluff flora. Among existing species it is most similar to *Ulmus alata* Michaux, which ranges from western Florida northward to Virginia and from Texas to Illinois. Like *U. alata*, the fossil species was probably an inhabitant of rich alluvial swamp and stream borders, for it seems probable that the fossiliferous lens in the Alum Bluff sands is the result of stream action. Among fossil species, of which many have been described, it bears more or less resemblance to a number of widely scattered forms, especially because the limits of variation of the foliage among different species of Ulmus are not wide. The most similar fossil form is *Ulmus longifolia*, described by Unger [1] and subsequently recorded from the Aquitanian of Bohemia, Germany, Styria, and France, which is extremely close to the American species.

The genus Ulmus may be distinguished from the allied genus Carpinus by the usually more inequilateral leaves and by the tertiaries to the marginal sinuses.

Occurrence: Hattiesburg clay, Raglan, Forrest County, Miss. (collected by E. W. Berry). Alum Bluff formation, Alum Bluff, Liberty County, Fla. (collected by E. W. Berry).

Collection: United States National Museum.

Order URTICALES.

Family MORACEÆ.

Genus ARTOCARPUS Förster.

Artocarpus lessigiana floridana Berry, n. var.

Plate X, figures 5–7.

Leaves of large size, rather smaller than the type, but very poorly preserved in the current-bedded sands. At least 25 centimeters in length and about 13 centimeters in maximum width, thus more narrowly oblong in general outline than the type. Pinnately 8 to 10 lobed; the lobes short, relatively broad and conical, acutely pointed and directed obliquely outward, separated by very narrow sinuses. Midrib stout. Lateral primaries stout, diverging from the midrib at angles of about 45°, one to each lobe, terminating in its tip. Secondaries alternating with the primaries, one to each sinus, the latter with the characteristic marginal hem. Tertiaries mostly obsolete. Areolation quadrangular where seen. Texture coriaceous. There was evidently considerable variation in outline, for the basal portion of the leaf shown in figure 6 has a cuneate base and must have had strongly ascending lobes.

This form is based on very fragmentary specimens from the Alum Bluff sands. It may be distinguished from *Artocarpus lessigiana* by its relatively narrower form and its finer venation. The latter comes from the Wilcox group, a much earlier horizon, and has not been found in the intervening interval, represented by the Claiborne, Jackson, Vicksburg, and Catahoula deposits. I have a feeling that the Alum Bluff material represents a new species, but I hesitate to set up a species on such fragmentary material, which is, however, the best obtainable by the most careful collecting.

Remains of Artocarpus have been found in Europe, Greenland, and the United States. In this country we have the Laramie-Denver type, which is considered the parent stock of the present variety. This type and two other species are represented in the late Wilcox of Louisiana and Arkansas by excellent material. There is a Fort Union species and another Eocene form on the Pacific coast. In Europe several species range from the Upper Cretaceous to the Pliocene.

There are about 40 existing species of Artocarpus, all endemic in the southeastern Asiatic region, ranging from Ceylon throughout Malaysia to China and represented by cultivated forms in all tropical countries. They apparently did not become extinct in North America until the interval between the deposition of the Alum Bluff formation and the migration of the Chesapeake Miocene fauna into the Florida region, a migration indicating a lowering of

[1] Unger, Franz, Chloris protogæa, p. 101, pl. 26, fig. 5, 1847.

temperatures entirely sufficient to explain the extinction of Artocarpus on the mainland, but not offering a satisfactory explanation of its failure to survive in more southern latitudes.

Occurrence: Alum Bluff formation, Alum Bluff, Liberty County, Fla. (collected by E. W. Berry).

Collection: United States National Museum.

Order CHENOPODIALES.

Family NYCTAGINACEÆ.

Genus PISONIA Linné.

Pisonia apalachicolensis Berry, n. sp.

Plate X, figure 1.

Leaves of relatively large size for this genus, obovate in general outline, with a broad apex, which is evenly rounded or bluntly pointed, and a gradually narrowed, sharply cuneate base. Length about 5.75 centimeters; maximum width, above the middle, about 2.4 centimeters. Margins entire. Texture coriaceous. Petiole short and stout, about 6 millimeters in length. Midrib stout but immersed in the thick leaf substance, curved. Secondaries entirely immersed and obsolete.

The modern species of Pisonia are numerous; they occur chiefly in the Tropics in both hemispheres and are largely coastal types. They are abundantly developed in Central America and tropical South America, and several species occur in the West Indies and Antilles. About 15 fossil species have been described, the earliest recorded being from the Upper Cretaceous of both America and Europe. The lower Eocene of southeastern North America has furnished two well-marked species, there is a species said to be represented by both leaves and fruit in the basal Eocene of the Rocky Mountain area, a fourth species occurs in the Claiborne group, and a fifth has been found in the Jackson. Perhaps the most similar fossil form, based on both leaves and fruits, is *Pisonia eocenica* Ettingshausen,[1] from the lignites of Haering, in Tyrol, which is upper Eocene or lower Oligocene in age, occurring also as early as the Lutetian of England.

Among existing species several are close to the present form. *Pisonia longifolia* Sargent, of the beaches and shores of lagoons from the Florida keys through the West Indies to Brazil, is very similar to *Pisonia apalachicolensis*, though only about two-thirds as large.

Occurrence: Alum Bluff formation, Alum Bluff, Liberty County, Fla. (collected by E. W. Berry).

Collection: United States National Museum.

Order ROSALES.

Family CÆSALPINIACEÆ.

Genus CÆSALPINIA Linné.

Cæsalpinia sellardsi Berry, n. sp.

Plate IX, figures 1, 2.

Leaflets small, sessile, inequilateral, elliptical in outline, 7.5 millimeters in length and 4.2 millimeters in greatest width. Apex broadly rounded. Base strongly inequilaterally truncated, one margin ascending and the opposite margin subauriculate. Midrib slender. Secondaries two or more, slender, ascending, camptodrome. Margins entire.

This species, which is obviously new, is clearly the leaf of some shrub or tree of the family Cæsalpiniaceæ. Though only a few specimens were observed, this can not be considered as indicating scarcity, for the plant material at Alum Bluff is all rather meager and poorly preserved. It seems probable that the present species was a member of the strand flora, the strand being the habitat preferred by a number of species of this genus in the modern tropical American flora.

The fossil species may be compared with a number of existing species, with which it shows a very close agreement. Among previously described fossil species it is very close to what has been identified by Schenk [2] as *Cæsalpinia townshendi* Heer, from the Stampian of Sieblos, originally described by Heer [3] from the Aquitanian and Tortonian of Switzerland and Baden and identified by Geyler from the Messinian of Sicily.

There is a very notable display of Mimosaceæ and Cæsalpiniaceæ in the flora of the Wilcox group, and these elements probably continued to be prominent throughout the remainder of the Eocene and the Oligocene,

[1] Ettingshausen, Constantin, Die tertiäre Flora von Häring in Tirol, p. 43, pl. 11, figs. 1–22, 1853.

[2] Schenk, August, in Zittel, K. A., Handbuch der Palaeontologie, Abth. 2, Palaeophytologie, p. 700, fig. 369 (4), 1890.

[3] Heer, Oswald, Flora tertiaria Helvetiæ, vol. 3, pl. 137, figs. 26–37, 1859.

although the record is much less completely preserved in the post-Wilcox sediments. The present species is probably but one of many related forms that inhabited southeastern North America during the deposition of the Alum Bluff formation. It is more inequilateral than any of the known Tertiary species from this general region, although it might perhaps be considered a descendant of *Cæsalpinites pinsonensis* Berry, a somewhat smaller, less oblique, and more coriaceous form, from the sands of middle Wilcox age in Madison County, Tenn. It is named for Dr. E. H. Sellards, State geologist of Florida, who visited this celebrated locality with me and helped collect the fossil plants.

Occurrence: Alum Bluff formation, Alum Bluff, Fla. (collected by E. W. Berry).

Collection: United States National Museum.

Order GERANIALES.

Family RUTACEÆ.

Genus FAGARA Linné.

Fagara apalachicolensis Berry, n. sp.

Plate IX, figure 2.

Leaves compound. Leaflets sessile, of medium size for this genus, elliptical in general outline, with a broadly rounded apex and a broadly pointed base. Length about 3 centimeters; maximum width, above the middle, about 1.75 centimeters. Margins entire. Texture coriaceous. Midrib stout, somewhat flexuous. Secondaries four or five, subopposite to alternate pairs, irregularly spaced, diverging from the midrib at angles varying from 35° to 50°, rather straight in their courses, abruptly camptodrome close to the margins. Tertiaries thin, more or less immersed, forming small quadrangular or polygonal meshes.

The genus Fagara, which contains more than 150 living species of shrubs and trees, is cosmopolitan in tropical and subtropical countries. A few forms more properly referable to Xanthoxylum range for considerable distances in the Temperate Zone, particularly in southeastern North America. Fossil forms based on foliage are usually confused with the closely allied genus Xanthoxylum Linné. Leaflets referable to Fagara are not uncommon throughout our southern Tertiary deposits, several different forms from the Eocene and Oligocene having been described. The genus appears to have been especially prominent in the torrid flora of the Vicksburg group, and the leaflets are very abundant in the clays of that age. The present species is clearly unlike any of these, being especially different in its broad apex and narrowed base, and might readily be confused with the small entire leaves of some live oak. The scarcity of leaf remains in the Alum Bluff formation renders any remarks on the relative abundance of their described flora without much significance.

Occurrence: Alum Bluff formation, Alum Bluff, Liberty County, Fla. (collected by E. W. Berry), and Boynton Bluff, Choctawhatchee River, Fla. (collected by E. H. Sellards).

Collection: United States National Museum.

Order RHAMNALES.

Family RHAMNACEÆ.

Genus RHAMNUS Linné.

Rhamnus apalachicolensis Berry, n. sp.

Plate IX, figure 8.

Leaves rather large for this genus, broadly elliptical in general outline, with a broad and evenly rounded apex and base. Length about 8 centimeters; maximum width, in the middle part of the leaf, about 4.6 centimeters. Margins entire, evenly rounded. Texture subcoriaceous. Midrib stout. Secondaries stout, four or five alternate pairs, diverging from the midrib at angles of about 55° to 60°, curving upward almost immediately in a broad, sweeping curve, becoming subparallel with the lateral margins, along which they arch camptodromely. Tertiaries thin, closely set, subparallel, mostly percurrent at right angles to the midrib.

This large leaf is distinct from the numerous fossil species of Rhamnus previously described, although it resembles a number of them more or less closely. The genus has about 60 existing species, widely distributed in nearly all temperate and many tropical parts of the world and found on all the continents except Australia.

The genus Rhamnus is fairly prominent in Tertiary floras of southeastern North America, the Rhamnaceæ being also represented by forms of Zizyphus and Paliurus of tropical type. Six species from the Wilcox group have been described, but none are yet known from

the Claiborne, Jackson, Vicksburg, or Catahoula.

Occurrence: Alum Bluff formation, Alum Bluff, Liberty County, Fla. (collected by E. W. Berry).

Collection: United States National Museum.

Order **THYMELEALES**.

Family **LAURACEÆ**.

Genus **NECTANDRA** Roland.

Nectandra apalachicolensis Berry, n. sp.

Plate IX, figure 3.

Leaves oblong-ovate in general outline, broadest near the middle and tapering to the bluntly pointed apex and base. Length about 8 centimeters; maximum width, halfway between the apex and the base, about 2.5 centimeters. Margins entire, evenly curved. Texture coriaceous. Midrib stout. Secondaries about 10 subopposite pairs, diverging from the midrib at wide angles, about 60°, rather straight in their courses two-thirds of the distance to the margins, where they curve abruptly upward and form a succession of small camptodrome arches along the margins. Tertiaries obsolete.

The genus Nectandra has about 70 existing species confined to tropical and subtropical America, several of which are practically identical with this Alum Bluff species. There are numerous fossil species, the genus being well represented throughout the Eocene of southeastern North America, especially in the sediments of the Wilcox group, from which at least five species are known. It is represented in the Claiborne and Jackson but has not yet been found in the Vicksburg or Catahoula. The present species is not particularly close to any of the described fossil forms.

Occurrence: Alum Bluff formation, Alum Bluff, Liberty County, Fla. (collected by E. W. Berry).

Collection: United States National Museum.

Genus **CINNAMOMUM** Blume.

Cinnamomum scheuchzeri Heer.

Plate X, figure 4.

Cinnamomum scheuchzeri. Heer, Flora tertiaria Helvetiæ, vol. 2, p. 85, pl. 91, figs. 4–22; pl. 92; pl. 93, figs. 1, 5, 1856.

This species was described by Alexander Braun from both calyx and leaves, obtained in the Tortonian of Oeningen, Baden. Typical material is common in the type area in both the Aquitanian and the Burdigalian. Only the original description of Heer, which is accompanied by ample figures, is cited above, for sanguine students have fancied that they had found this species at all horizons from the Upper Cretaceous to the Pliocene, and at a very large number of localities throughout the Northern Hemisphere. Some of these identifications are undoubtedly correct, and the species certainly had a wide geographic and geologic range. Other identifications are unquestionably erroneous, but it is impossible to sift the good from the bad without access to the original material, and I have therefore not attempted to give the synonymy or range.

The Alum Bluff material appears to be identical with a part of Heer's material from the type area, and it is also of the same age, so that I have no hesitation in identifying it with Heer's species. It denotes an ovate-lanceolate leaf, rather abruptly pointed at the extremities, the base being broader than the apex. Length about 8 centimeters; maximum width, in the middle part of the leaf, 2.7 centimeters. Margins entire. Texture coriaceous. Midrib stout. Lateral primaries one on each side, subopposite, suprabasilar, camptodrome. Secondaries thin, three or four camptodrome pairs in upper half of the leaf.

Occurrence: Alum Bluff formation, Alum Bluff, Liberty County, Fla. (collected by E. W. Berry).

Collection: United States National Museum.

Order **EBENALES**.

Family **SAPOTACEÆ**.

Genus **BUMELIA** Swartz.

Bumelia apalachicolensis Berry, n. sp.

Plate IX, figure 4.

Leaves oblong-obovate in general outline, with an evenly rounded apex and a narrowed cuneate base. Length about 4 centimeters; maximum width, above the middle of the leaf, about 1.9 centimeters. Margins entire, rather full. Texture coriaceous. Petiole short and stout, about 2.5 millimeters in length. Midrib stout, especially proximad, curved. Secondaries thin, numerous, 10 to 12 subopposite to alternate pairs, subparallel, at approximately regular intervals; they diverge from the midrib at angles of about 40° and are camptodrome

in the marginal region. Tertiaries immersed in the leaf substance.

In the modern flora the genus Bumelia embraces about 20 species of shrubs and mostly small trees, confined to the Western Hemisphere, where they are distributed from the southern United States through the West Indies, Mexico, and Central America to Brazil. Some of the species range northward to Virginia and southern Illinois. They inhabit for the most part the strand, sandy soil near the coast, river bottoms, and the borders of swamps. Fossil species of Bumelia are numerous and the genus was probably cosmopolitan during the Tertiary—it was certainly common in the European area. It has been continuously represented in southeastern North America since the Upper Cretaceous. Four lower Eocene species from this area have been described, one of which, *Bumelia pseudotenax* Berry, from the Wilcox group of northern Mississippi, is not unlike the Alum Bluff species but somewhat smaller and relatively narrower. Other species are present in the deposits of the Claiborne and Vicksburg groups.

Compared with existing American species the present form is closer to the temperate than to the tropical species. It is intermediate between *Bumelia tenax* Willdenow and *B. lanuginosa* Persoon and may stand in an ancestral relationship to these modern forms. The former ranges along the coast from Cape Canaveral to North Carolina and the latter from northern Florida along the Gulf coast and up the Mississippi Valley to southern Illinois and is abundant and of its largest size in the river bottoms of eastern Texas.

Occurrence: Alum Bluff formation, Alum Bluff, Liberty County, Fla. (collected by E. W. Berry).

Collection: United States National Museum.

Genus SAPOTACITES Ettingshausen.

Sapotacites spatulatus Berry, n. sp.

Plate X, figure 2.

Leaves of medium size, obovate or spatulate in general outline, with a broadly rounded apex, from which it narrows gradually with nearly straight lateral margins to the sharply cuneate base. Length about 7 centimeters; maximum width in the upper part of the leaf, about 2.75 centimeters. Margins entire. Texture coriaceous. Petiolar portion missing. Midrib stout but more or less immersed. Secondaries obsolete by immersion. Tertiaries shown in microscopic preparations to form a very close meshed areolation.

Sapotacites is a form genus for generically undifferentiated or undeterminable members of the family Sapotaceæ, and numerous species that range from the Upper Cretaceous through the Tertiary have been described. It is possible to refer many of these ancient species, such as the numerous forms in the flora of the Wilcox group, to Bumelia, Mimusops, Sideroxylon, Chrysophyllum, and other allied genera. The present form is much like a number of existing species of Mimusops as well as some forms of Bumelia. The family is chiefly tropical and subtropical.

No fossil species are especially close to the present one, although it shows considerable resemblance to *Chrysophyllum sagorianum* Ettingshausen,[1] from the Aquitanian of Sagor, in Carniola.

Occurrence: Alum Bluff formation, Alum Bluff, Liberty County, Fla. (collected by E. W. Berry).

Collection: United States National Museum.

Family EBENACEÆ.

Genus DIOSPYROS Linné.

Diospyros brachysepala Alex. Braun.

Plate X, figure 3.

Diospyros brachysepala. Alex. Braun, Die Tertiär-Flora von Öningen: Neues Jahrb., 1845, p. 170.

Diospyros brachysepala. Heer, Flora tertiaria Helvetiæ, vol. 3, p. 11, pl. 102, figs. 1–14; pl. 153, fig. 39b, 1859.

Diospyros brachysepala. Friedrich, Beiträge zur Kenntniss der Tertiärflora der Sachsen, pp. 63, 119, 126, 253, 255, pl. 6, fig. 1, 1883.

Diospyros brachysepala. Ward, Types of the Laramie flora: U. S. Geol. Survey Bull. 37, p. 104, pl. 49, figs. 1, 2, 1887.

This early described species has been recorded from a large number of American and Eurasian localities ranging in age from basal Eocene to Pliocene. It is improbable that a single species existed for so long a period, and I have therefore reduced the synonymy of

[1] Ettingshausen, Constantin, Die fossile Flora von Sagor in Krain, pt. 2, p. 14, pl. 12, figs. 19–21, 1877.

this species to a few representative citations.[1] The species has been recorded by Lesquereux, Ward, and others from the lower Eocene of the Rocky Mountain area, as well as by Heer from West Greenland. I am not certain that all these records are correct, for *Diospyros brachysepala* is typically an Oligocene-Miocene form. It is found in the type area in both the Aquitanian and Burdigalian.

The Alum Bluff leaves, like most of the material referred to this species, are relatively small, about 5.5 centimeters in length and 2.8 centimeters in maximum width, midway between the apex and the base, which are about equally pointed, the general outline being almost elliptical. The midrib is stout and the secondaries thin, numbering six or seven subopposite to alternate camptodrome pairs. The leaves here described are close to a number of examples figured by Heer from the type locality, but are relatively slightly broader than some of the forms referred to this species by different authors. In some respects they are very similar to *Diospyros lamarensis* Knowlton,[2] from Lamar (probably upper Miocene), in Yellowstone Park.

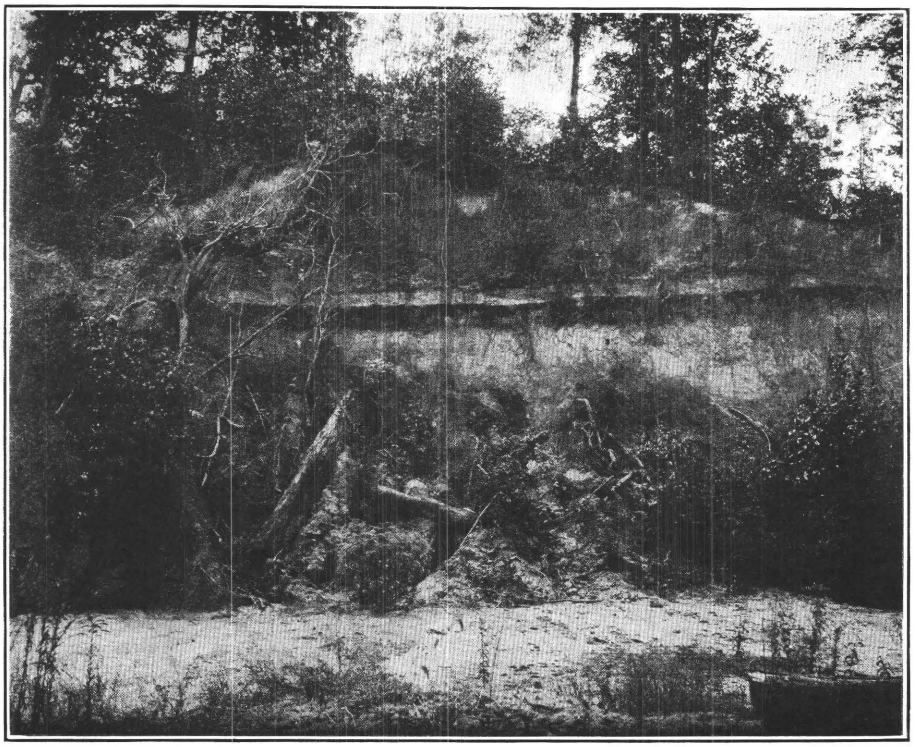
Occurrence: Alum Bluff formation, Alum Bluff, Liberty County, Fla. (collected by E. W. Berry).

Collection: United States National Museum.

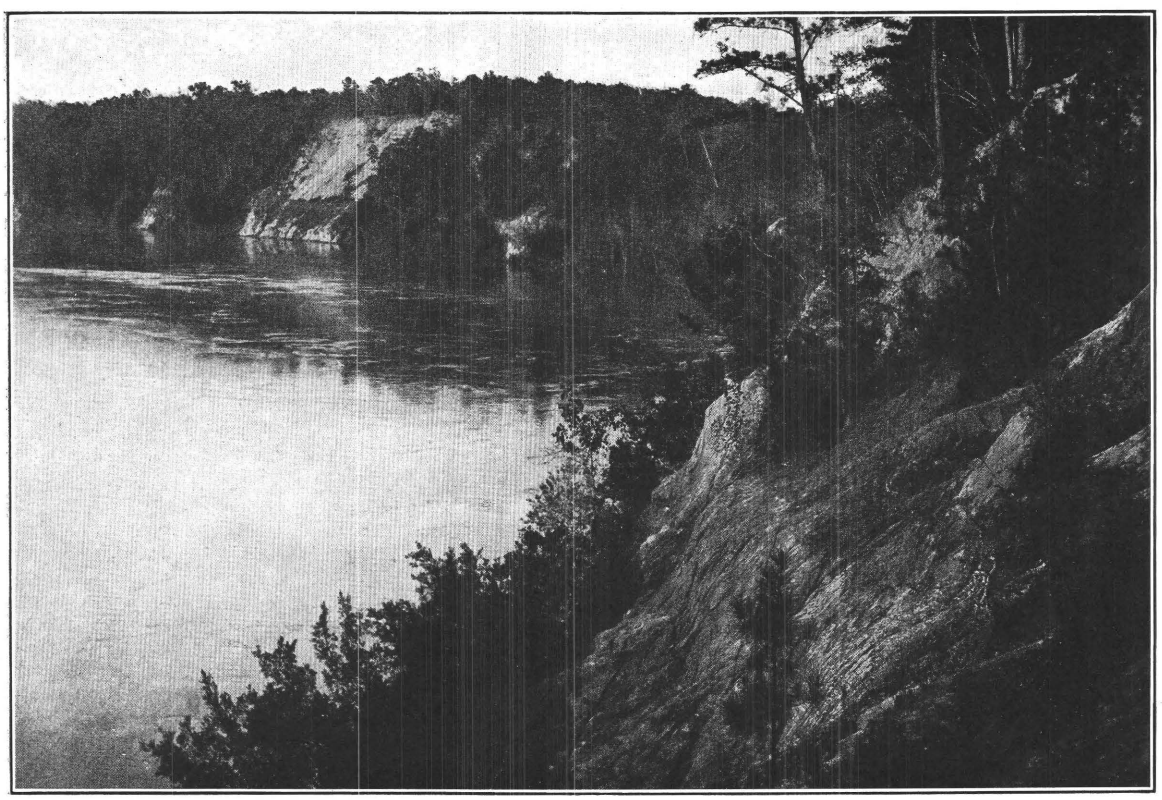
[1] A much more complete synonymy is given in my paper The lower Eocene floras of southeastern North America: U. S. Geol. Survey Prof. Paper 91 (in press).

[2] Knowlton, F. H., U. S. Geol. Survey Mon. 32, pt. 2, p. 751, pl. 95, figs. 5, 6; pl. 96, fig. 4, 1899.

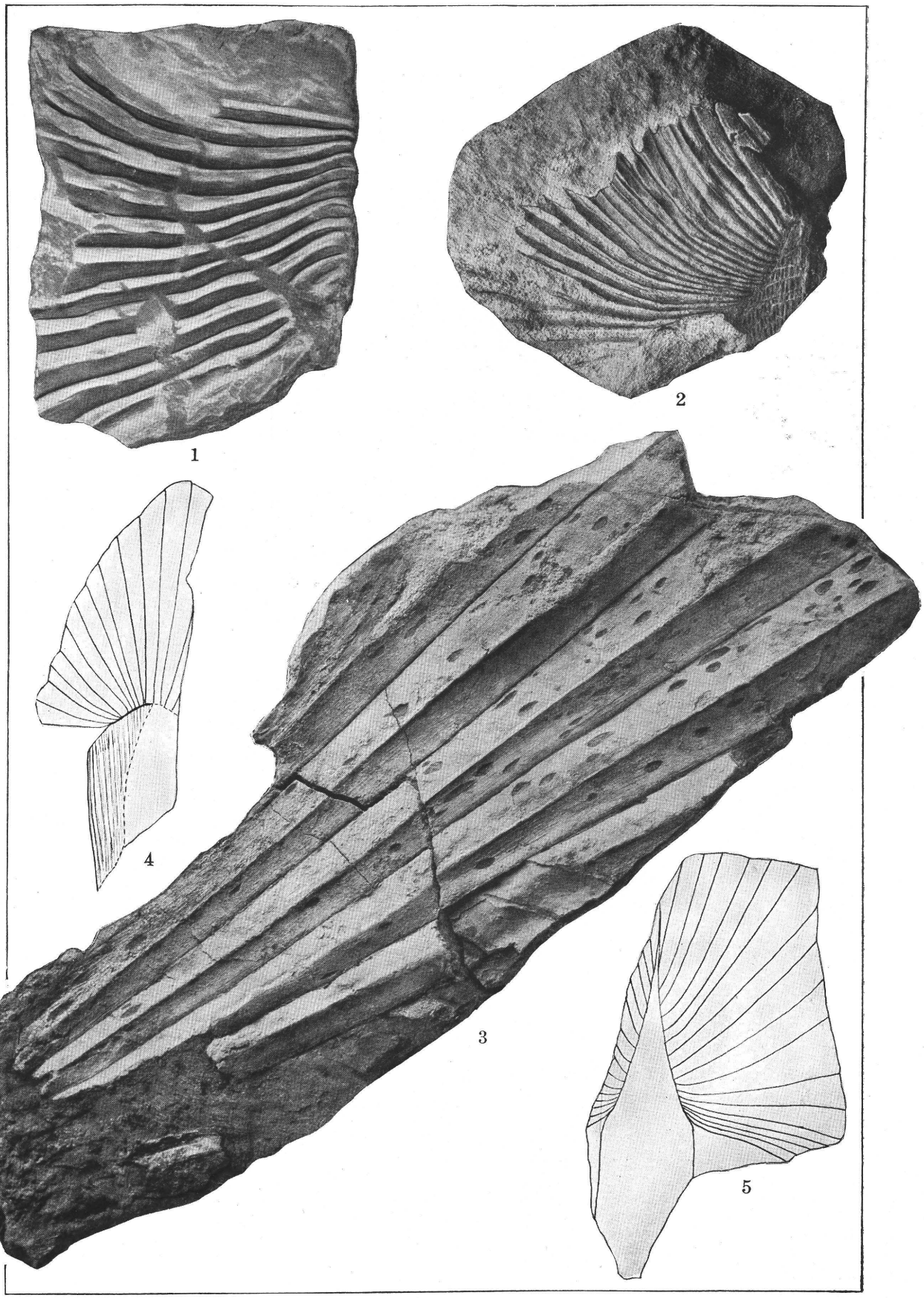
PLATES VII-X.



A. PLANT-BEARING BEDS IN THE HATTIESBURG CLAY NEAR RAGLAN, FORREST COUNTY, MISS.



B. PLANT-BEARING BEDS AT THE TYPE LOCALITY OF THE ALUM BLUFF FORMATION, ALUM BLUFF, APALACHICOLA RIVER, LIBERTY COUNTY, FLA.



FOSSIL PLANTS FROM THE ALUM BLUFF FORMATION AT ALUM BLUFF, FLA.

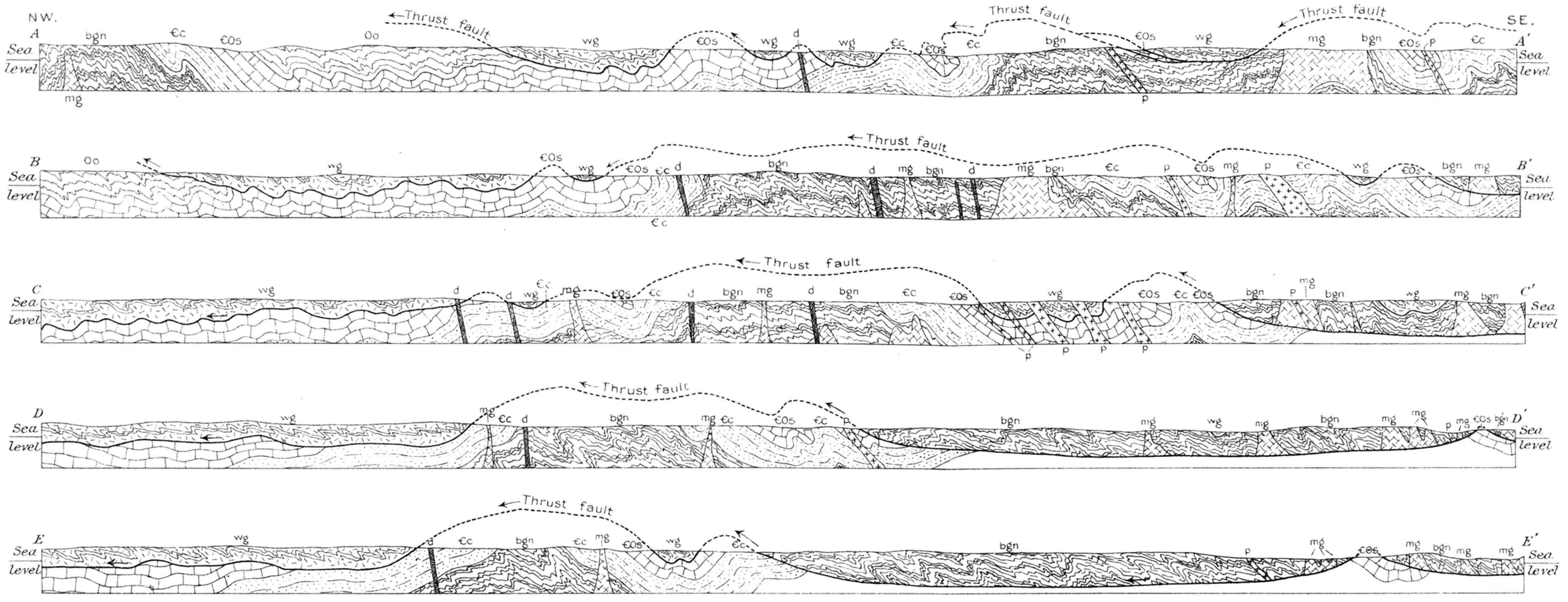
PLATE VIII.

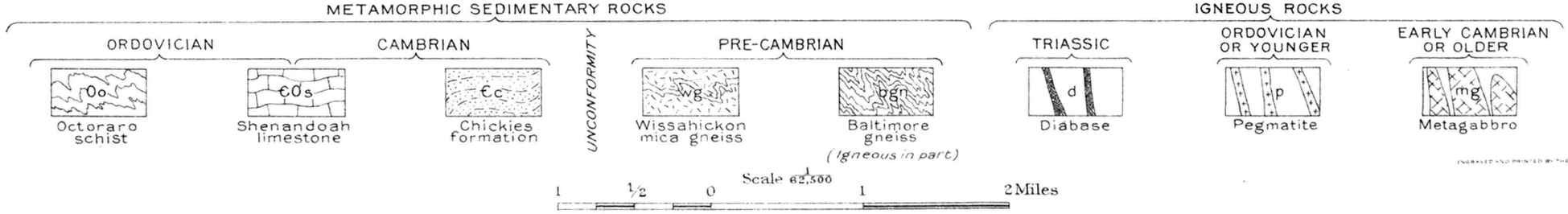
FIGURES 1–5. *Sabalites apalachicolensis* Berry, n. sp., from the Alum Bluff formation, Alum Bluff, Liberty County, Fla.

Figures 2 and 5 show prolongation of the rachis as a midrib on the under side of the leaf.

Figure 3 shows fragment of a leaf infested with *Pestalozzites sabalana* Berry, n. sp.

Figure 4 shows the upper side of a leaf base and the termination of the rachis as a truncate ligule.



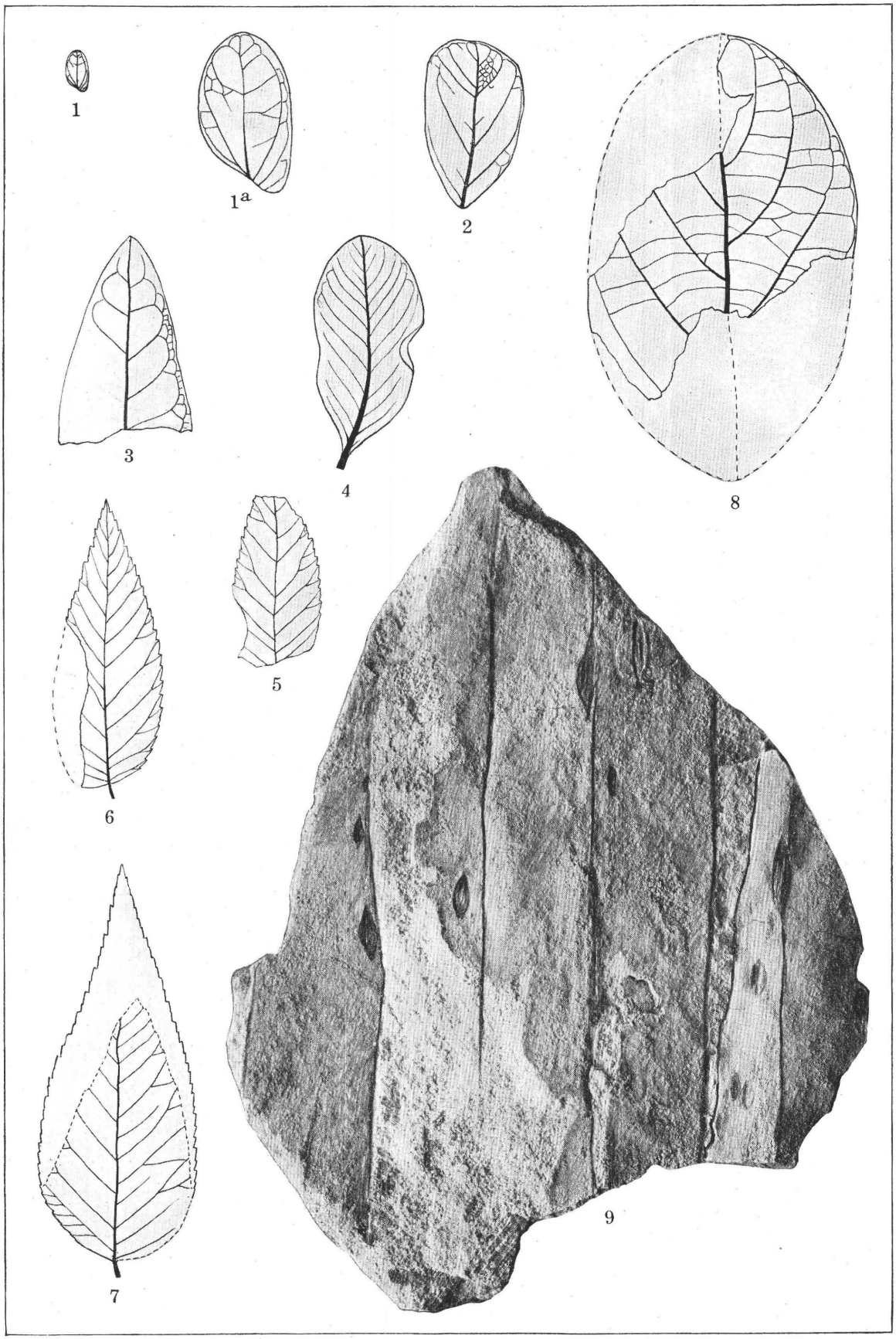


STRUCTURE SECTIONS OF DOE RUN AND AVONDALE REGION, CHESTER COUNTY, PA.

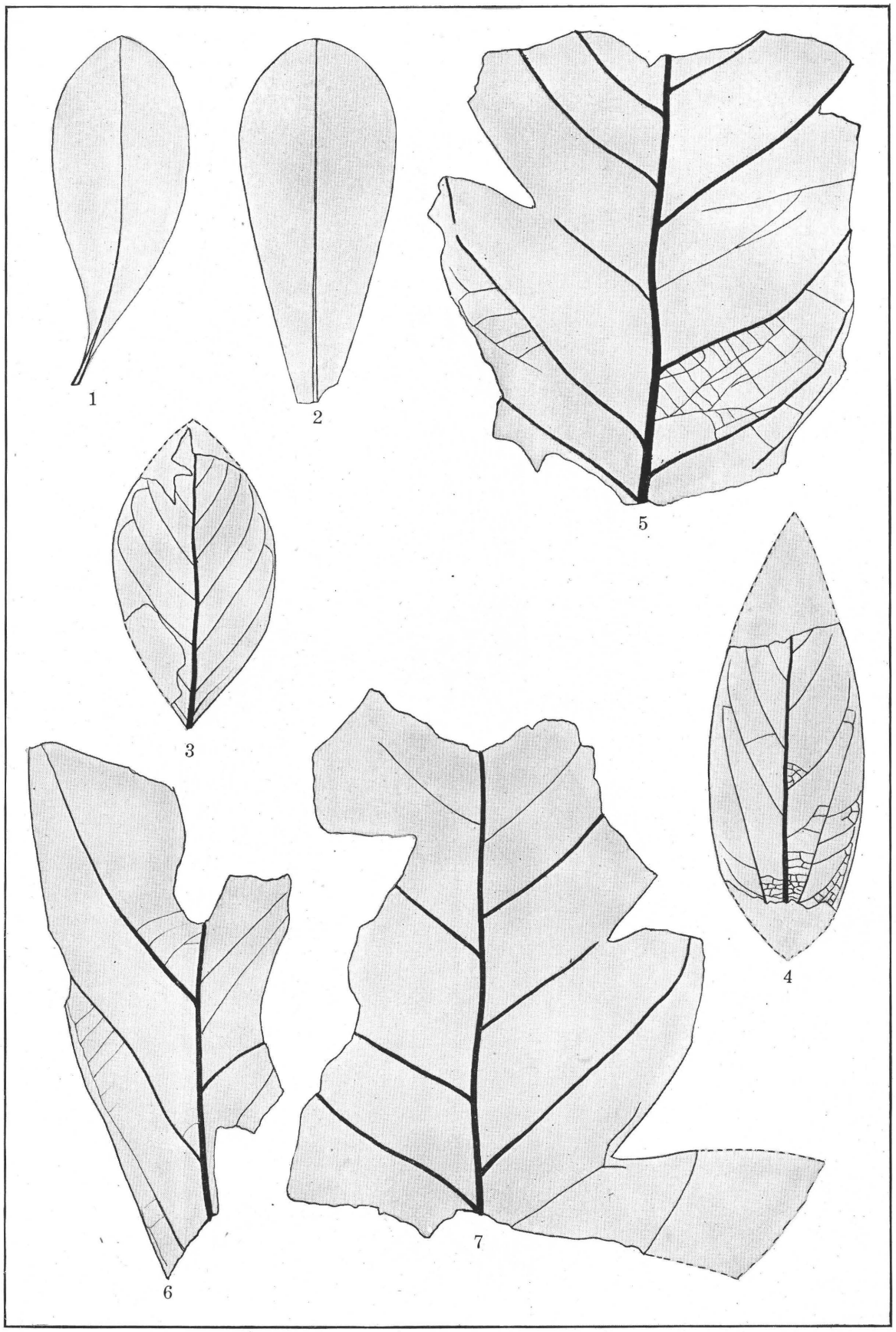
For lines of sections see geologic map (Plate I).

PLATE IX

FIGURE 1. *Cæsalpinia sellardsi* Berry, n. sp.
FIGURE 1a. The same, × 5.
FIGURE 2. *Fagara apalachicolensis* Berry, n. sp.
FIGURE 3. *Nectandra apalachicolensis* Berry, n. sp.
FIGURE 4. *Bumelia apalachicolensis* Berry, n. sp.
FIGURES 5–7. *Ulmus floridana* Berry, n. sp.
FIGURE 8. *Rhamnus apalachicolensis* Berry, n. sp.
FIGURE 9. *Sabalites apalachicolensis* Berry, n. sp. Portion of a very large leaf infested with *Pestalozzites sabalana* Berry, n. sp.



FOSSIL PLANTS FROM THE ALUM BLUFF FORMATION AT ALUM BLUFF, FLA.



FOSSIL PLANTS FROM THE ALUM BLUFF FORMATION AT ALUM BLUFF, FLA.

PLATE X.

FIGURE 1. *Pisonia apalachicolensis* Berry, n. sp.
FIGURE 2. *Sapotacites spatulatus* Berry, n. sp.
FIGURE 3. *Diospyros brachysepala* Alexander Braun.
FIGURE 4. *Cinnamomum scheuchzeri* Heer.
FIGURES 5–7. *Artocarpus lessigiana floridana* Berry, n. var.

30830°—17——5