Paleocene Flora of the Rocky Mountains and Great Plains

By ROLAND W. BROWN

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A study of 170 kinds of plants and the strata
that yield them, showing how they apply in
the delimitation of the Paleocene series

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CONTENTS

ILLUSTRATIONS

[Plates 1-69 follow index]

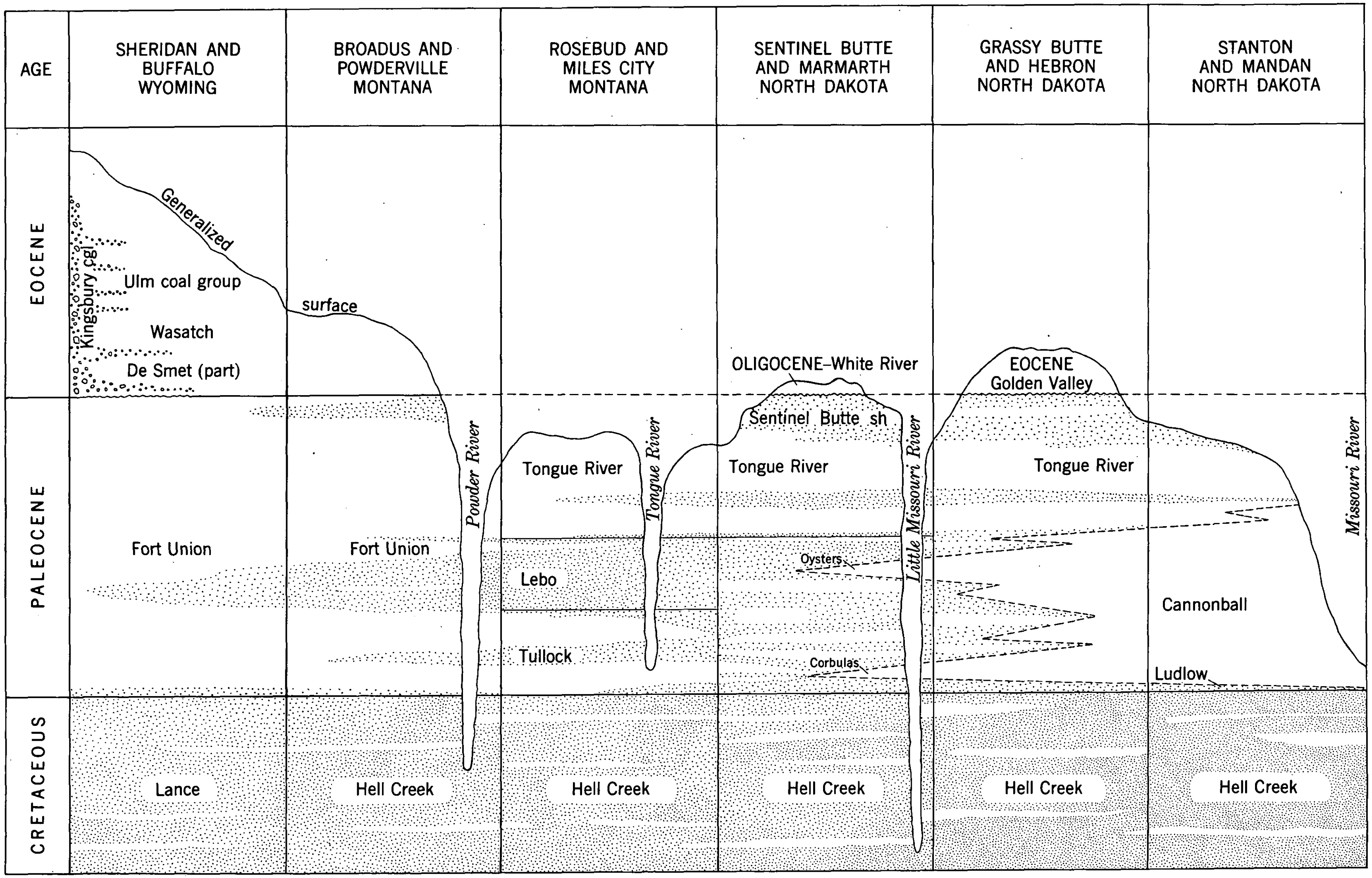

FIGURE 1.—Diagrammatic cross section from Sheridan, Wyo., to Mandan, N. Dak., showing correlation of Cretaceous and Tertiary formations as interpreted by the writer. The Broadus and Rosebud columns are interchanged to show closest relations to adjacent columns. Stippling indicates dark zones of strata of all kinds. Unstippled parts are light-colored zones. (After Brown, 1948a.)

PALEOCENE FLORA OF THE ROCKY MOUNTAINS AND GREAT PLAINS

By Roland W. Brown

ABSTRACT

The description of the Paleocene series as a whole and particularly the determination of its lower and upper limits in the Rocky Mountains and the adjacent Great Plains have been matters of practical interest since the late 1850's. As this series contains much of the coal in that area, its mapping for the purpose of classifying the public lands has necessarily involved consideration of its boundaries; but, until recently, no general agreement prevailed about the position of these limits. Since 1929 a reexamination of the Paleocene strata has resulted in the collection of much additional and more precisely located fossil material and in the conclusion that the Cretaceous-Paleocene boundary is at the base of the first coal zone not very far above the latest remains of dinosaurs. Representative collections of fossil plants from above and below this level can usually be readily distinguished, but fragmentary collections may not always be distinctive. More species crossed the boundary than was formerly supposed and indicate that no radical break in the floral sequence occurred, just as, at many localities, the stratigraphic succession continued unbroken from the Cretaceous into the Paleocene and beyond.

The upper limit of the Paleocene, the Paleocene-Eocene boundary, can be detected locally by the presence of an obvious unconformity and of distinctive mammalian fossils. The flora of the early Eocene, however, except for a species of the fern *Salvinia* and perhaps a few others, does not seem to be greatly different in general composition from that of the late Paleocene.

The restudy of the Paleocene flora has revealed many synonyms and has thus reduced the variously published estimates of its size to a tentative list of 170 recognizable species or forms. The presence of palms and breadfruit on the one hand and of birches, hazels, maples, and ashes on the other suggests either that remains from different ecologic habitats in a warm temperate to temperate environment mingled or that some Paleocene species were adapted to environmental niches different from their comparable living descendants or relatives.

INTRODUCTION

GEOLOGICAL BACKGROUND

This paper is the outgrowth of an investigation I was asked to make when I joined the staff of the U.S. Geological Survey in 1929. W. C. Mendenhall, then chief geologist, specifically instructed me as follows: "Your job, in part, will be to solve the long-debated problem of the Cretaceous-Tertiary contact in the western interior. In doing this you will be concerned with the "somber beds" and their fossils, principally in the Dakotas, Montana, Wyoming, and Colorado." That summer, and many succeeding field seasons, often and for long intervals interrupted by other work, found me mapping and exploring the strata involved in this problem.

Eastward for distances of as much as 500 miles from the foothills of the Rocky Mountains, the Great Plains area, extending from central-western Canada to New Mexico, is underlain beneath its Quaternary or other cover by Cretaceous and Tertiary coal-bearing strata. Erosion has carved this area into low, rolling hills, wide and narrow valleys, and in some localities, fantastic and colorful badlands (pls. 1–3). The marine and nonmarine strata thus exposed, and once collectively called the "Great Lignite," aggregate thousands of feet in thickness and comprise soft or indurated, sometimes conspicuously crossbedded sandstones; carbonaceous, calcareous, and sandy shales; clays; and coal beds, in more or less repetitive sequence. A diagrammatic cross section showing the stratigraphic units involved is given in figure 1.

Comparable correlative strata occur, in somewhat isolated patches, high in the Rockies close to the continental divide in North, Middle, and South Parks, Colo.; in the Bighorn Basin of Wyoming and its northwestward extension in Montana; in the Wind River Basin of Wyoming; and on the west side of the Rockies from Mexico northward through the San Juan Basin of New Mexico and Colorado, and from southwestern to eastern Utah, northwestern Colorado, and western Wyoming.

Seen close at hand on a drab or rainy day, most exposures of the nearly horizontal lignitic strata above the Fox Hills sandstone (Upper Cretaceous) in eastern Montana, eastern Wyoming, and adjacent areas are monotonously similar to one another. Their general color tone is dull, gray or even dark, from which they have been characterized as "somber beds." The subdued or dark colors of the carbonaceous shales and coals contrast with the lighter colored, yellowish sandstones and, here and there, with the pinks or brilliant reds of the baked and sometimes fused rock (Collier and Smith, 1909, p. 45; Rogers, 1918) above burned coal beds. The coal outcrops were ignited for the most part spontaneously, but sometimes perhaps by lightning or by fires resulting from human negligence. The uninitiated often mistake this clinker or scoria for volcanic rock.[1]

From a distance, however, and on a clear, bright day, thick, well-exposed sequences above the Fox Hills sandstone in any part of the area, but particularly in the eastern part of the Yellowstone Valley, can be divided roughly by eye into a number of contrasting light and dark zones beginning with a dark zone at the bottom. This lowest zone is coal barren except at the very base and is chiefly brownish sandstone or sandy clay characterized by a tinge of greenish rustiness and by the fact that it contains the last, and locally abundant, remains of the horned dinosaurs. Above this dark zone is a light-colored, yellowish sequence consisting principally of sandstones, shales, and coal beds. This is overlain by a dark zone, whose duskiness can best be described as livid, or grayish black. Near its base is a thick coal bed or carbonaceous shale—the Big Dirty—which is continuous over many square miles and serves well locally as a stratigraphic marker. This dark sequence is capped by a notable light-colored, yellowish group of sandstones, clays, and coals, making a zone that is conspicuous on all the higher hills and peaks along the Yellowstone and its tributaries from Forsyth to Sidney, Mont. Overlying this light-colored zone is a somewhat darker lignitic sequence exposed typically at Sentinel Butte, N. Dak., and at the original type section of the Fort Union formation on the north side of the Missouri opposite the mouth of the Yellowstone. Perhaps no better description of all these conditions and circumstances has been given than that by Leonard (1908; 1911). For further details on specific areas, the reader is referred to the U.S. Geol. Survey bulletins on the coal fields of the western interior, the latest list of references being by W. W. Olive (1957, p. 5), and W. C. Warren (1960, p. 563).

To the west in the direction of the source of the sediments that became these strata, the older light and dark zones for the most part lose their distinguishing colors and merge into a greenish or gray sandy sequence with little or no coal. In the easternmost areas farthest from the source of the sediments, color distinction between these zones is also either impossible or very unsatisfactory.

Except that they are lignitic and may be somber-colored, the correlative strata in some adjacent regions cannot be so readily characterized. Each area has variant lithologic and structural features peculiar to itself.

The mapping and classification of these lignitic strata were accompanied by much speculation and discussion about the respective limits of the several postulated large geologic units and particularly about the position of the Mesozoic-Cenozoic boundary, which was suspected early of being present somewhere in the sequence. Four reasons for the warm debate about these matters can be cited: 1, Among the earlier investigators there was a tendency to generalize without completely understanding the significance of the limited data in hand. 2, There was confusion, pointed out by Marvin in 1874, in considering lithologically similar strata, although geographically distant from one another, as contemporaneous and correlative. 3, The third reason was the dogma that unconformities of considerable magnitude are necessary to mark systemic and series boundaries. 4, No good formula, applicable in the field, as to the probable position of the Mesozoic-Cenozoic boundary, was proposed until 1912. This was not tried out deductively and unanimously by all mappers in the pertinent areas but was more or less neglected until recently.

On the map by Brown (1949) both the lower and the upper limits of the Paleocene strata of the Rocky Mountains and Great Plains are shown in the light of reconnaissance studies to that date. Since then, more detailed mapping by others indicates that in some localities the boundary lines need minor readjustment.

The principal assumption in this study is that the last dinosaurs in the Rocky Mountains and Great Plains region vanished some time before the extreme end of the Cretaceous and that some species of plants, now regarded as strictly Paleocene in age, left no apparent antecedent records in that region in the Cretaceous. Nevertheless, I admit the possibilities that fragmentary dinosaur bones may have been reworked into Paleocene deposits and that antecedents of the Paleocene plants may be found in the Cretaceous. Unless the principal assumption be granted as a factual, working hypothesis I can at present see no other satisfactory, concrete basis for agreement on a

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[1] In his lively and entertaining book, "A Ghost Town on the Yellowstone," Elliot H. Paul described the extinct town of Trembles, in existence for about 15 years (1907–22) on the left bank of the Yellowstone River, 6 miles southwest of Sidney, Mont. He painted a stirring word-picture of the landscape from Glendive to the mouth of the Yellowstone but repeated two commonly held errors, namely, that the red rocks of the badlands are volcanic (p. 32) and that the lower end of the valley, in relatively recent prehistoric days, was a favorite haunt of dinosaurs (p. 6). The red rock, as explained, is clinkered sedimentary shale and sandstone. The uppermost Cretaceous strata that contain remains of the last dinosaurs—trachodon, triceratops, and tyrannosaurus—crop out in the badlands on the flanks of the Cedar Creek anticline near Glendive but dip eastward to hundreds of feet below the surface at Sidney and the mouth of the Yellowstone where they are covered by Paleocene rocks. Therefore, the dinosaurs once existing in that area wandered around on a terrain antedating the present surface of the Yellowstone Valley by at least 60 or 70 million years.

solution of the Cretaceous-Paleocene (or Mesozoic-Cenozoic) dating problem.

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Local residents were uniformly cordial and helpful, but in particular the following: George Fountain, Circle, Mont.; Dell and Edwin Lewis, Glendive, Mont.; George Newlin, Ashland and Billings, Mont.; W. H. Peck, Ekalaka, Mont., and A. C. Silberling, Harlowton, Mont. In the office and elsewhere many colleagues have contributed valuable criticism during this investigation. The photographs of specimens were made chiefly by N. W. Shupe.

Unless otherwise stated all the photographed specimens here reproduced are deposited in the U.S. National Museum.

HISTORICAL REVIEW OF THE SUBDIVISION OF THE "GREAT LIGNITE"

EARLY OBSERVATIONS

The evolution of ideas about the appropriate division of this great group of lignitic strata into identifiable, mappable, and datable parts, according to the general geologic column, is a long story involving many actors and the interplay of much fact, fancy, and opinion. Accounts of this development may be found in the writings of G. M. Dawson (1875, p. 182–202), L. F. Ward (1886, p. 406–436), G. P. Merrill (1906, p. 647–658), F. H. Knowlton (1922 a, p. 3–81), L. S. Russell (1932 a, p. 121–156; 1953, p. 106–113); R. L. Nace (1936, p. 66–87), and E. M. Spieker (1946, p. 135, 142–160). As my immediate concern here is to produce and discuss the evidence that purports to establish the position of the boundary limits of the Paleocene series only, I shall not attempt to recount all the details of the progress in classifying the entire lignitic sequence. I shall not cite all the literature, but shall confine myself to a statement of only those opinions and decisions that resulted in positive action or that had a distinct influence toward clarification in delimiting the Paleocene series.

In 1854 and the immediately following years, F. V. Hayden and his colleagues explored large parts of the coal-bearing terrain of the Rocky Mountains and Great Plains, particularly the region accessible from the Missouri and Yellowstone Rivers in Montana (Hayden, 1861; Raynolds, 1868). They accumulated fundamental data about the general stratigraphy and made collections of fossil vertebrates, invertebrates, and plants. Because of the coal seams, Hayden at first called these strata the "Great Lignite" group, but later he and his chief collaborator, F. B. Meek, substituted for it the more specific name, Fort Union group (Meek and Hayden, 1862, p. 433). More particularly, this term applied to outcrops, now known to be only a part of the "Great Lignite," on the north side of the Missouri River between the present Snowden, Mont., and Buford, N. Dak. (pl. 1, fig. 1).[2]

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[2] Fort Union, located on what is now the Montana side of the line, was erected by the Northwest Fur Co. in the 1820's. In 1867 when the fort was razed, some of the material was purchased by the Federal Government and used in building Fort Buford across the line in North Dakota. See "Tales from Buffalo land. The story of Fort Buford," by Usher L. Burdick, 1940, Wirth Brothers, Baltimore, Md.

Among Hayden's collections in 1854 were dinosaurian remains from the Judith River region of Montana; and in 1872 Meek found part of a saurian skeleton (*Agathaumas sylvestris* Cope) in lignitic strata near Black Buttes Station, Wyo. In consequence there was general agreement that the older parts of the "Great Lignite" are Cretaceous in age.

The fossil plants taken from the upper part of the "Great Lignite" by Meek and Hayden were identified by J. S. Newberry in 1868 as Tertiary in age. Thus, at an early stage of exploration and discovery in the western interior States and adjacent parts of Canada, geologists recognized that the Mesozoic-Cenozoic boundary lay somewhere between the older dinosaur-bearing strata and younger plant-bearing strata of the great lignitic sequence.

In 1876, Clarence King, without designating a specific type locality, introduced the term "Laramie" for lignitic beds on the Laramie Plains of Wyoming and thus, although denying identity of the Laramie and Fort Union strata, unwittingly complicated the Cretaceous-Tertiary boundary discussion because shortly the "Great Lignite" of Hayden (including the Fort Union group) was being referred to loosely as the Laramie group. Not until 1910 were the terms Laramie and Fort Union divorced, and Laramie was restricted to strata conformably overlying the Fox Hills sandstone in the Denver Basin of Colorado. This Laramie was conceded by all to be Late Cretaceous in age.

The paleobotanist Leo Lesquereux had no clear idea about the age of the "Great Lignite," for his publication, "*The Tertiary flora*" (1878), included notice of many plants now known to have come from Cretaceous strata. Indeed, there was a vigorous exchange between Lesquereux and Newberry concerning the age of some lignitic strata in New Mexico and adjoining portions of Colorado, Newberry insisting upon Cretaceous and Lesquereux upon Tertiary age. Newberry (1888, p. 329) strongly maintained however, that "The Fort Union group * * * in my judgment, should be considered the basal member of the Tertiary."

As late as 1883, C. A. White, on the evidence of nonmarine invertebrates, regarded the "Great Lignite" as transitional between the Cretaceous and Tertiary and, therefore, partaking of both. This idea was accepted by the paleobotanist Lester Ward (1886, p. 435) who, after examining the opinions of Newberry, Lesquereux, Cope, White, and others, commented:

> The discussions with regard to the age of the Laramie group which have been rapidly passed in review have, perhaps, sufficiently shown that it is impossible to refer that group either to the Cretaceous or to the Tertiary and in so doing harmonize all the facts that the group presents with those in conformity with which other deposits in other countries of the world have been so referred; but they have also sufficiently shown that this is not the fault of the investigators, but so to speak, of the facts, and the real disagreement is in the organic forms and the nature of the deposits, so that omniscience itself could never harmonize them with all kinds of forms and deposits in all parts of the world. It is, therefore, futile and indeed puerile, longer to discuss this question, and we can well afford to dismiss it altogether and settle down to the more serious study of the real problems which still lie before us.

After sounding this discouraging note, Ward, not realizing the age significance of the compositional differences he recognized between the floras of the "Wyoming and Colorado Laramie" and the "Fort Union Laramie" (1886, p. 438, 439, 1887, p. 1; Newberry, 1890, p. 529), but still persuaded that "Laramie" was synonymous with "Great Lignite" and indivisible into formations of different ages, proceeded to confuse the situation still further by lumping plant collections from many localities and widely spaced stratigraphic levels in his "*Types of the Laramie flora*" (1887). This "Laramie" flora, as we now know, is a composite of items representing floras from Mesaverde (Upper Cretaceous) to Wasatch (Lower Eocene). Newberry (1888, p. 329), who was probably the first to perceive a marked difference between the floras of the lower and upper parts of the "Great Lignite," referring to Ward's paper, remarked that:

> It [the "Laramie" flora] contains few of the Lower or true Laramie plants, and is chiefly descriptive of the Upper Laramie or Fort Union flora, of which it affords the most important review yet published. The flora of the Lower or true Laramie has been made known to me by collections from * * * Black Buttes, Walsenburg, Canon City * * *, etc. These show that there is almost nothing in common between the Fort Union and Laramie floras, and that the two divisions of the so-called Laramie group, judging from the fossil plants, which are very numerous, must be regarded as distinct formations.

This opinion was reiterated in 1890 (p. 525). In 1940 and 1942 Erling Dorf published a preliminary comparison of the Lance and Fort Union floras showing that, with increased knowledge of these floras, Newberry's original opinion is in large part still pertinent.

The reasons for the general mixed state of opinion about the "Great Lignite" in 1890 lay, contrary to Ward's statement, not with the facts, but with the interpreters and appliers of the facts. The paleobotanists, for example, had not worked out or agreed upon a satisfactory American standard of comparison to cover the floras in question, but, with the exception of Newberry, as just stated, persisted in assuming that the flora of the "Great Lignite" is an indivisible unit. Furthermore, no geologist or paleontologist proposed and applied a good working formula for identifying the probable position of the Mesozoic-Cenozoic boundary in the western interior States and Canada. Some of the critical stratigraphic sections also were not carefully measured and compared. Here, to cite an example, Ward erred in regard to the geologic situation on the west flank of the Cedar Creek anticline, 12 miles southwest of Glendive, Mont. In a discussion of a paper by Newberry (1890, p. 531) he said:

> I have one fact of my own observations which may be worth stating and which may not be known to all. About 15 miles above the town of Glendive, on the right bank of the lower Yellowstone river, there is a cliff, known as Iron bluff, which is colored very bright red from having the carbonaceous matter burned out, and which is full of fossil plants . . . This bluff is right on the bank of the Yellowstone river, and the railroad cuts through it, which makes the cliff conspicuous. Immediately below (east) there is a short anticline (Cedar Creek anticline), and apparently a little island about a mile in extent, filled with characteristic Fox Hills Cretaceous fossils. I have been on the ground and collected large numbers of them, and everywhere we meet with them: the wheels of the wagon as one drives over them crush the shells, so abundant are they; and there is no doubt that this is a typical Fox Hills bed, in Dr. White's understanding of the term "Fox Hills." Now, so far as I can tell, and so far as he could tell from a careful study of the ground, this Iron bluff deposit—this Laramie or Fort Union leaf-bed—rests directly and immediately upon the Fox Hills bed. If there is any difference of age there is no indication at that point * * *.

The sequence of strata at Iron Bluff, as measured by me in 1936, is as follows:

Section on the west flank of Cedar Creek anticline, 12 miles southwest of Glendive, Mont.

	Thickness (feet)
4. Fort Union formation:	
Light-colored shale and sandstone, coal, plants	50+
Somber carbonaceous shale, sandstone, coal, plants	224
Gray shale, light-colored sandstone, coal, lowest bed locally clinkered, plants, fresh-water shells	170
3. Hell Creek formation:	
Rusty green to gray carbonaceous shales and sandstones, three thin coal seams in basal part, dinosaur bones, fragmentary plants	385
2. Fox Hills sandstone:	
Gray to light-colored shales and sandstones, capped by the white Colgate member, apparently barren of fossils at this locality	140
1. Pierre shale:	
Dark-colored marine shales, with concretions full of fossils	75+
Base of section.	

Ward's "Fox Hills" with Cretaceous fossils is thus seen to be what is now called the Pierre shale, and the lowest burned coal bed with plants is near the base of the Fort Union formation. Therefore, instead of resting directly upon the fossiliferous marine Pierre shale, as averred by Ward, this clinkered bed is separated from it by at least 525 feet of Fox Hills and Hell Creek strata, the latter containing diagnostic dinosaurian remains.

THE LIGNITIC STRATA FROM 1890 TO 1912

F. H. Knowlton succeeded Ward on the U.S. Geological Survey staff as paleobotanist in the study of Mesozoic and Cenozoic plants, and from the early 1890's until his death in 1926 greatly influenced the opinions pertaining to the age of the "Great Lignite." He, like his Survey predecessors, made a number of field trips into the disputed areas and obtained numerous collections. Stanton and he (1897), after a study of the terrain and fossils on Lance Creek, in eastern Wyoming, differentiated the Upper Cretaceous Lance formation, with its primitive mammals, dinosaurs, nonmarine invertebrates, and plants, from the overlying Fort Union formation with its invertebrates and flora, but no dinosaurs. Had this initial example been followed in subsequent years during the mapping and correlation of strata in adjacent areas, there might have been little difficulty about the Cretaceous-Tertiary contact; but in areas to the north, particularly in northeastern Wyoming, Montana, and the Dakotas, strata that looked lithologically similar to those in the upper part of the Lance, except that they contained coal seams, a Fort Union flora, and lacked dinosaurs, were assumed to be Lance. In many papers they were called Lance or Upper Lance (Eocene?), with much resultant confusion. This condition was aggravated by Stanton's misidentification of the Cannonball marine strata in the Dakotas as Lance (Upper Cretaceous) in age (Lloyd, 1914, p. 250; Stanton, 1921, p. 18). A correlation sketch that illustrates these opinions and practices was published by Winchester and others (1916, p. 15, fig. 2). A similar sketch by me (1948a, p. 1266, fig. 2) reproduced here as figure 1, shows the present conception of the same situation.

The mappers in Montana and the Dakotas had by this time begun to recognize and name the local zones of light-colored and dark-colored strata in the upper part of the "Great Lignite." The designation of these zones, beginning with the lowest and oldest, resulted eventually as follows: Hell Creek formation (dark); Tullock member (light); Lebo member (dark); Tongue River member (light), which for a long time was itself erroneously considered synonymous with Fort Union or upper Fort Union; and Sentinel Butte member (dark). This nomenclature was found convenient in local mapping, but most observers discovered that color contacts between some of the contrasting zones are evanescent and migratory, both vertically and horizontally (Rogers, 1913b, p. 719–721; Pierce, 1936, p. 60; Brown 1948a, p. 1270–1271). This is particularly noticeable from the vicinity of Miles City toward Glendive and from Miles City toward Ekalaka and Baker, Mont., and Marmarth, N. Dak. In those directions, zones recognized as more or less distinct west of Miles City become increasingly difficult or impossible to separate. For this reason the Lebo and Tullock in the eastern part of the area were lumped as the Ludlow lignitic member. In the vicinity of Glendive the base of the otherwise light-colored Tullock equivalent appears darker than the underlying Hell Creek formation because its strata consist of closely spaced dark carbonaceous shales and coal seams.

In 1909 Knowlton and Stanton separately published preliminary opinions on these strata. Knowlton (1909, p. 180–193, 237) divided the sequence above the Fox Hills sandstone into an "upper" and "lower" Fort Union. His "upper" part, a light-colored unit, corresponded to that now called the Tongue River member. His "lower" part comprised the "somber beds" underlying the Tongue River member; that is, the Lebo member, Tullock member, and the "Ceratops beds" or Hell Creek formation, as now known. In thus lumping the dinosaur-bearing Hell Creek with the remainder of the non-dinosaur-bearing "somber beds" he originated an error that led to and was comparable with another made by the mappers, namely, in applying the term "Upper Lance" to the "somber beds" (chiefly the Tullock member) overlying the Hell Creek. In consequence of all this, Knowlton did not distinguish the flora of the Hell Creek and of the correlative Lance in Wyoming from that in the remainder of the "somber beds" and "upper" Fort Union, but regarded all as a unit, Tertiary in age. This position, so far as I know, he never changed (Knowlton 1911, p. 358; 1914, p. 325; 1922a, p. 31). Thus, the confusion of floras remained much as Ward left it in 1887.

It is now evident that Knowlton's conception of the stratigraphic situation along the lower reaches of the Yellowstone Valley was not sound in that he did not differentiate the two dark zones of his "lower" Fort Union, the Lebo and Hell Creek, and did not realize that strata now called Tullock lie between the Lebo and Hell Creek. Thus, concerning the outcrops at Miles City and Glendive, respectively, he said (1909, p. 186):

> With the exception of some unimportant alluvial deposits in the valleys, all the rocks of this region [around Miles City] were found to belong to the Fort Union formation, which is comprised of two members. The lower member, which corresponds to the "Hell Creek beds," is about 500 feet in thickness, but the base is not exposed; however, from the comparison of the Miles City section with that at Glendive, it is inferred that the base is not very deeply buried.

What are the facts about the correlation of the sections at Miles City and Glendive? The strata exposed in the bluffs on the left bank of the Yellowstone River at Miles City belong to the so-called Tullock and Lebo members of the Fort Union sequence. The base of this sequence, and hence the top of the Hell Creek formation, is about 100 feet below river level. The Hell Creek, according to a well log taken 12 miles west of Miles City approximates 500 feet in thickness beneath the Fort Union formation under Miles City. At Glendive the lowest strata exposed in the bluffs south of the city contain distinctive Upper Cretaceous plants and abundant ceratopsian bones and thus belong to the Hell Creek formation. Only about 100 feet of the top of the bluffs belong to the Tullock member, which lacks dinosaur bones but contains Fort Union plants (pl. 3, fig. 2). These definitive stratigraphic facts, however, were never, so far as I have been able to learn, recognized by Knowlton, but T. W. Stanton (1909, p. 286) remarked:

> Doctor Knowlton's statistics show a close relation between the flora of the lower Fort Union and the upper Fort Union; if, however, comparison were made between the Ceratops beds that have actually yielded dinosaurs and the typical or upper Fort Union [Tongue River member] the figures would possibly be different, because in many sections such as those of the Bighorn Basin, Red Lodge, Sheridan, Fish Creek, and probably along the Yellowstone, he has included more than the Ceratops beds in his lower Fort Union.

Had Knowlton acted on this cautious suggestion and reevaluated the fossil and stratigraphic situation, particularly along the Yellowstone River between Miles City and Glendive, the Laramie—Fort Union or Cretaceous—Tertiary problem might have been solved at that time.

The Hell Creek beds were named and described by Barnum Brown (1907) from the type section on Hell Creek, north of Jordan, Mont., and were unequivocally correlated with the Lance formation of Wyoming (B. Brown, 1914, p. 356). Brown was particularly careful to point out, by italicizing the statement, that the latest remains of dinosaurs in that area were confined to these strata, because after 5 years of fieldwork he and his party failed to find any evidence of dinosaurs in the overlying lignitic beds that contain the Fort Union flora. The Cretaceous-Paleocene boundary at the contact between the Hell Creek and Tullock in the region immediately east of Hell Creek was shown on the map accompanying the description of the coal resources of McCone County, Mont., by Collier and Knechtel (1939), although the ceratopsian

Hell Creek and lignitic Tullock, or basal Fort Union, were, according to prevailing custom, referred to the Eocene(?).

EFFECT OF THE DISCOVERY OF MAMMALS IN THE LIGNITIC STRATA

Perhaps the first illuminating clue to the position of the Cretaceous-Paleocene contact in the western interior came from the San Juan Basin of Colorado and New Mexico. There in 1880 and subsequent years, distinctive Tertiary mammals (Matthew, 1937) were found in the Puerco and Torrejon formations, which overlie strata containing dinosaurian remains. By contrast the lignitic strata of the Fort Union sequence in Montana yielded no mammals until Earl Douglass in 1901 found the first specimens on Fish Creek just east of the Crazy Mountains. In the following years this area was thoroughly explored, chiefly by A. C. Silberling of Harlowton, Mont., under the inspiration of J. W. Gidley, who began a study of the fossils that was completed later by G. G. Simpson (1937b). That part of the geologic section pertinent to this discussion, as generalized by Simpson and amended by me, is as follows:

Generalized section east of the Crazy Mountains, Mont.

[Adapted from Simpson, 1937b, p. 15]

Fort Union	No. 3	Melville	Dark shales, greenish or gray with numerous gray to yellow sandstones. Mammals, plants.	5,000 +ft.
	No. 2	Lebo	Soft somber greenish, sandy shales and gray sandstones. Mammals, plants.	850 ft.
	No. 1		Somber shales with some hard brown sandstones. Mammals, plants.	500 ft.
	Bear		Alternating pale crossbedded sandstones and shale. Rare turtle bones, etc. No dinosaurs (except possibly reworked fragments) or mammals. Plants.	500-600 ft.
Hell Creek			Pale, variegated clays with some gray sandstone. Dinosaurs.	2,000 ft.

Simpson concluded that the paleontologic evidence from that part of the Fort Union he called No. 1 Lebo was inadequate for exact correlation, but tentatively assigned these strata to the middle Paleocene or Torrejonian of the vertebrate paleontologists. Concerning the next immediately underlying beds, which he called Bear, he pointed out that this sequence overlies the dinosaur-bearing Hell Creek formation at a relatively sharp and observable contact, that it contains no dinosaurs except possibly reworked fragments in its basal part, that the invertebrates are Paleocene forms, and that, therefore, it is likely the Bear is Tertiary rather than Cretaceous, and probably in part equivalent to the Tullock or basal Fort Union farther east. Accordingly, on his chart Simpson assigned the Bear to Fort Union or Lance. In 1936, I obtained a satisfactory collection of plants from the Bear in SW¼ sec. 29, T. 6 N., R. 16 E. Of the 10 species present, few seem referable to the Cretaceous, but nearly all are present in the basal Fort Union in the vicinity of Miles City and Glendive. On this and the stratigraphic evidence I am convinced that the Bear belongs with the Tertiary sequence and that the contact between it and the Hell Creek marks the Cretaceous-Paleocene boundary.

The scarcity or lack of mammals in the Bear of the Crazy Mountain region is matched by a similar condition in the Paleocene sequence of extreme eastern Montana and the adjacent Dakotas. So far as known, the eastern outcrops have yielded only a few specimens, representing six genera: *Titanoides primaevus* Gidley from Buford,, N. Dak. (Gidley, 1917. Near Vernon Bailey's original find, Glenn Jepsen and Theodore White recovered additional parts of skulls of *T. primaevus*); *Tetraclaenodon* sp. and *Pantolambda* sp. from southwestern North Dakota (Lloyd and Hares, 1915, p. 538); *Aphronorus* sp., an unpublished insectivore tooth from Donnybrook, North Dakota; and *Claenodon* sp., *Tricentes* sp. from Medicine Lake, Mont. (pl. 69, figs. 9, 10).

In 1926, Dr. J. C. F. Siegfriedt, of Red Lodge, Mont., discovered another locality that has yielded significant mammalian remains. It is the roof of the Eagle coal mine, 1 mile south of Bear Creek, Mont., at a level about 1,500 feet above the base of the Fort Union formation. These fossils, according to Simpson (1928; 1929), indicate a fauna that inhabited a heavily forested and swampy region and that was different in facies from the fauna on Fish Creek, no genus being common to the two. He conjectured its age to be late Paleocene and approximately that of the Tiffany fauna of southwestern Colorado.

The first mammals from the lignitic strata of the Big Horn Basin were discovered in 1881. Since that time, active exploration has resulted in the accumulation of much paleontologic and stratigraphic information, giving a fairly clear picture of the geologic situation in that basin. All this has been summarized and discussed by G. L. Jepsen (1930; 1940) and is indicated on the correlation chart compiled by H. E. Wood and others (1941). Jepsen gave a new name to the Paleocene section in the Polecat Bench area—Polecat Bench formation. At that locality he found no angular unconformity between the dinosaur-bearing Lance and the Polecat Bench formation, but the contact may be locally undulatory. Elsewhere in the Big Horn Basin, however, an unconformity marks the Cretaceous-Paleocene boundary, as for example, on the south side of

Dry Creek, 5 miles west of Greybull, Wyo. Similarly, Hewett (1926, p. 30–40) found an angular unconformity separating the Cretaceous and Tertiary beds on the southwestern side of the basin.

In 1933 Bryan Patterson reported the finding of large titanoid mammals in strata southwest of De Beque, Colo., which in 1936 he proposed to call the Plateau Valley beds. These beds, according to the fauna, are of late Paleocene age.

My finding of mammalian remains in 1939 and 1940 at several strategic localities in the Denver Basin, Colorado, helped materially to restrict the position of the Cretaceous-Paleocene boundary in that area (Gazin, 1941a; Brown, 1943a,). Gazin (1942; 1956c) reported late Paleocene mammals from the Almy formation in southwestern Wyoming, (1956a) a large fauna from late Paleocene strata in Bison Basin, on the north border of the Red Desert, Wyo., and (1956b) a Tiffanian fauna from Fossil Basin, west of Kemmerer, Wyo. In the vicinity of Hoback Canyon, south of Jackson, Wyo., Dorr (1952; 1958) found significant mammalian remains in what he and Eardley call the Hoback formation, a possible northward correlative of the Evanston and Almy formations near Evanston. During the summer of 1958 A. E. Roberts, of the U.S. Geological Survey, found a portion of the jaw, with three teeth, of a Paleocene condylarth, *Tetraclaenodon symbolicus* Gidley, in strata on Willow Creek, 9 miles north of Livingston, Mont. This find is stratigraphically close to the tentative Cretaceous-Paleocene boundary I drew (1949) in the Livingston area and narrows materially the search for the exact line. The recent discovery of fragmentary vertebrate remains in the Medicine Rocks area north of Ekalaka, Mont., by members of the Carter County Geological Society, has led G. L. Jepsen, of Princeton University, to further prospecting in those Paleocene strata. In a personal communication he states that the unpublished material now includes fish scales and teeth, amphibian and reptilian vertebrae, and mammalian teeth and jaws, indicating a probable middle Paleocene age.

In Canada the Paskapoo formation, which at some localities in Alberta is clearly unconformable on the Edmonton formation (Upper Cretaceous), contains fragmentary remains of Paleocene mammals (Russell, 1929, 1932a, 1932b, p. 137), associated with fishes, amphibians, and reptiles.

A general survey of Paleocene vertebrate faunas was published by Simpson (1936; 1937a), and Van Houten (1945b) has reviewed the latest Paleocene and early Eocene mammalian faunas, with suggestions about the associated climatic conditions and depositional facies.

Thus, the revelation of the mammalian evidence has helped greatly in dating parts of the "Great Lignite" and in narrowing the quest for the lower and upper limits of the Paleocene series.

THE CANNONBALL MARINE STRATA

Not long after the finding of mammals in the Paleocene rocks of the Crazy Mountain region came the unexpected discovery of fossiliferous marine strata intercalated in the lignitic sequence near Mandan and southwestward in North and South Dakota. Speculations about the age of these strata soon produced a name that caused much discussion—the Cannonball marine member of the Lance. In 1907, before the main discovery in 1912 by Lloyd and Hares (1915, p. 523), A. G. Leonard, exploring the steep bluffs along the Little Missouri River south of Yule, N. Dak., found an oyster bed (*Ostrea glabra* Meek and Hayden) lying between two coal seams about 150 feet above the river (pl. 2, fig. 2). This was later interpreted as a brackish-water tongue of the Cannonball member. In 1931 I discovered a second and lower brackish-water tongue at river level one-half a mile south of Leonard's oyster bed locality (pl. 2, fig. 3). It contains species of *Corbula* and *Corbicula* but apparently no oysters. These tongues of the Cannonball, which were probably deposits in estuarine channels or embayments of the Cannonball sea, interfinger with the nonmarine strata of the Ludlow member, which has never yielded any authentic indigenous dinosaurian remains but contains abundant specimens of the typical Fort Union flora.

T. W. Stanton concluded that the Cannonball fauna has a general Tertiary aspect because of the absence of the exclusively Mesozoic forms and the presence of many long-lived modern forms; but that it has a closer relation with the Cretaceous because 24 of its species (40 percent of its known molluscan fossils) were identified with species found in the Late Cretaceous formations of the same general region (Stanton, 1914, p. 351; 1921, p. 13). He, therefore, regarded the Cannonball strata as Cretaceous in age. The element of doubt that this fauna might after all not be Cretaceous in age lay not only in the absence of ammonites but in the presence of the mollusks *Calyptraphorus* and *Cylichnella*, the former occurring in North America only in strata ranging from Midway (Paleocene) to Jackson (Eocene) in age and the latter with no definite record older than Tertiary.

Soon after Stanton's paper on the Cannonball appeared, Charles Schuchert (1921, p. 45, 47) reviewed it and forthwith advocated that the line between the Cretaceous and Tertiary be drawn at the contact of the Fort Union and overlying Wasatch. Knowlton, after reading Schuchert's proposal, remarked that "If the Cannonball marine member is Cretaceous then both Lance and Fort Union are Cretaceous, for there is no stopping point short of the top of the Fort Union."

The reason for this statement was Knowlton's belief in the existence of an unconformity of great proportions at the contact of the Fox Hills sandstone and Hell Creek formation, and this being the only such purported, available unconformity known to him in the "Great Lignite" he picked that contact as the Cretaceous-Tertiary boundary. Investigation of this alleged unconformity, mainly in eastern Montana and the Dakotas, resulted in the publication by Dobbin and Reeside (1929, p. 25) of observations tending to explain the phenomena at the localities they examined as local channeling, minor faulting, crossbedding, or slumping. This conclusion harmonized with the previous opinion expressed by Barnum Brown (1914, p. 357) about stratigraphic relations along Dry Creek, north of Van Norman, Mont. However, Dobbin and Reeside cited Bauer (1925) as reporting that he had traced around Freedom Dome, south of Jordan, Mont., a stratum of coarse material consisting of quartzitic and other pebbles, at the base of the Hell Creek formation. Only Dobbin checked this report, finding some evidence of channeling, but both Dobbin and Reeside (p. 17) concluded: "As the conglomerate occurs only in this small area, its presence affords little proof of the existence of a major unconformity at the contact of the Fox Hills and Lance." Fieldwork by Fred Jensen, Roger Colton, and me in 1950 and subsequently (Colton, 1955) indicates that this channeled contact cannot be dismissed as a local condition. It is much more widespread than was known to Barnum Brown, Dobbin, Reeside, and Bauer. We found it at numerous localities over hundreds of square miles of the terrain north and south of the Missouri River, east, west, and south of Fort Peck Dam, and southward as far as Forsyth on the Yellowstone River. The conglomerate consists mainly of quartzitic and porphyritic pebbles, cobbles, and boulders, occasional worn dinosaur bones, shark's teeth, and rounded pellets of wood and lignite. Moreover, the interstitial sand of this conglomerate and that of the immediately overlying beds is somewhat yellowish brown with a liberal sprinkling of black grains, so that once seen at a typical outcrop it can be readily recognized elsewhere. This characteristic, friable, salt-and-pepper Hell Creek sand appears abruptly above the contrasting grayish-white upper Fox Hills strata. Thus, although the transition from Fox Hills to Hell Creek is physically and lithologically sharp over a large area, the debate about the nature, magnitude, distribution, and correlation of the unconformity may go on. On one point, however, there is certainty—this unconformity, however interpreted, did not mark the end of the Cretaceous and the beginning of the Tertiary.

Fieldwork by Laird and Mitchell (1942, pl. 1) and by me since the publication of Stanton's paper shows that the Cannonball member at most localities rests upon a tongue of the lowest coal-bearing zone of the Ludlow member, exposures of which can be seen beneath the lower brackish-water tongue of Cannonball deposits on the Little Missouri River, south of Yule; along the upper reaches of Cedar Creek, a tributary of Cannonball River; and north of Cannonball River across the southern part of Morton County, N. Dak. This 50-foot zone has yielded collections of typical Fort Union plants but no dinosaurs.

Finally, S. K. Fox, Jr., and R. J. Ross, Jr., reported that "an analysis of 64 species of Foraminifera indicates Midway (Paleocene) age for the Cannonball beds of North Dakota" (1940, p. 1970; 1942). This study apparently climaxes the search for evidence necessary to settle the question of the age of the Cannonball member, and also that of the Ludlow member and equivalent beds with which the Cannonball brackish-water tongues interfinger. As early as 1931, I had become convinced of the Paleocene age of the Cannonball member and its correlative nonmarine equivalent but first expounded this opinion in detail before the Geological Society of Washington on March 9, 1938 (1938, p. 421).

FORMULA FOR LOCATING THE CRETACEOUS-PALEOCENE CONTACT

Just as the phrase "somber beds" occurs repeatedly in this boundary discussion, so another is also much used, namely, "the lowest persistent bed of lignite," invented by W. R. Calvert (1912a, p. 196, 197). Calvert observed that in the vicinity of Glendive, Mont., the latest dinosaurian remains are found just below (he says "above," but this is erroneous, as explained in what follows) a "persistent bed of lignite," or perhaps better, a persistent lignite zone. Coinciding with this level locally, a marked change in color takes place, from the dark Lance (Hell Creek) to the yellowish basal Fort Union. This is the first clear hint of a practical formula for locating the Cretaceous-Paleocene boundary in the lignitic sequence east of the Rocky Mountains.

This lowest lignite zone, indicating the renewal of coal formation after a long coal-barren interval, represents a widespread, simultaneous phenomenon throughout eastern Montana, Wyoming, and the Dakotas (Winchester and others, 1916, p. 19; Laird and Mitchell, 1942, p. 12; Denson and others, 1959, p. 16). Can the base of this lowest coal zone be mapped and, therefore, be accepted as a close approximation of the Mesozoic-Cenozoic or Cretaceous-Paleocene contact? To answer this question several conflicting published statements must first be considered. Calvert (1912a, p. 197, 198) reported dinosaurian remains from above this lignite zone, as follows:

> One collection from a horizon just above the lowest persistent lignite bed [sec. 36, T. 13 N., R. 59 E., 11 miles south of Wilbaux, Mont.] represented the following forms as recognized by C. W. Gilmore. [Here follows a list of turtles, crocodiles, Champosaurus, and a caudal vertebra of an undescribed dinosaur.]

He also ventured the opinion that such remains may occur through perhaps 500 feet more of overlying strata. Were these statements correct, the detection of another usable contact would be extremely difficult, if not impossible, because the color and lithologic composition of the strata above the basal coal do not permit satisfactory distinction for mapping purposes.

The field notes of neither Calvert nor his assistant, Hance, yielded any further clues about the dinosaur vertebra. My examination of the area in 1941 showed that with the exception of a small patch of Lebo in the southwest corner, all the strata in sec. 36 belong to the Tongue River member. Therefore, the dinosaur vertebra could not have come from "just above the lowest persistent lignite," for that lignite is not present in sec. 36 but occurs 500 feet lower stratigraphically than the lowest stratum cropping out in that section. Some mixup in locality citation or in the fossil collections probably accounts for this erroneous record.

Another report that dinosaurian remains occur above the basal coal zone is that cited by Rogers and Lee (1923, p. 34), who mapped the Tullock Creek coal field, Montana:

> The single bone fragment found was identified by C. W. Gilmore as a section of a supraorbital horn core of a ceratopsian, probably *Triceratops*. This fossil which was collected [by W. C. Mansfield] in sec. 22, T. 5 N., R. 35 E., was found associated with other bone fragments on the surface of a steep slope about 50 feet above the base of the Tullock member.

The base of the Tullock here was considered to be at a coal seam called coal A. In 1941, I visited this locality and found that Rogers and Lee had stated the field relations correctly and that the steep slope mentioned in the locality citation does indeed yield dinosaurian bones. Coal A, however, crops out near the top of the hill, and in the strata above it I found only turtle remains. Subsequent examination of Rogers' field notes covering this locality revealed on page 1028 of notebook 2745 the clarifying and saving statement that the horn core fragment was picked up 50 feet *below* coal A and that other bone fragments, presumably of turtles similar to those I also saw, were found *above* coal A.

These dubious or erroneous records have had misleading consequences. Thus, in describing a new species of *Triceratops* from what he called the Torrington member of the Lance in Goshen Hole in eastern Wyoming, Schlaikjer (1935) said that the skull was found in the upper strata of a 240 to 425-foot sequence of shales, sandstones, and a brackish-water bed; which overlies a lignite seam at or near the contact with the Pierre shale or perhaps Fox Hills sandstone. Influenced by the geologic similarity of the upper part of this section to that in the bluffs of the Little Missouri River near Yule, N. Dak., and unaware that a second brackish-water tongue of the Cannonball member occurs 150 feet below the oyster bed originally reported at Yule, he concluded that his *Triceratops* postdated the Cannonball deposits. In support of this conclusion he cited the dinosaur bone reported by Calvert but misinterpreted Calvert's statement to mean that "* * * in eastern Montana ceratopsian bones were found in beds which are supposed to be stratigraphically higher than the Cannonball." Calvert, however, stated specifically that the bone came from "a horizon just above [below] the lowest persistent lignite bed." This, as has been shown, is a position just above the top of the Hell Creek formation and represents a level below, not above, the base of the Cannonball member. Schlaikjer (p. 54), it is true, recognized the possibility that the Goshen Hole tongue of brackish-water deposits may represent an earlier extension of the sea than the Cannonball tongue on the Little Missouri River. As the Lance of Goshen Hole lies (unconformably according to Schlaikjer) upon Pierre or Fox Hills strata, it invites comparison with the basal rather than the upper part of the true Lance in neighboring areas. In the Lance Creek area, 100 miles to the northwest, a lignitic zone and brackish-water bed occur near the base of the Lance or top of the Fox Hills (Stanton, 1909, p. 242; 1910, p. 187), and this lignitic zone appears at approximately the same level in other parts of eastern Wyoming and western North and South Dakota (Shaw, 1909, p. 158; Wegemann, 1912, p. 446; Laird and Mitchell, 1942, p. 8). In the Cannonball River region of North Dakota, a thin marine tongue, called the Breien member, in the basal part of the Hell Creek formation may be the equivalent of the Goshen Hole brackish-water stratum. This correspondence in lithologic composition and stratigraphic position suggests that the Lance in Goshen

Hole is basal Lance and that Schlaikjer's dinosaur is an early rather than a late form of *Triceratops.*

No other published reports of the occurrence of indigenous dinosaurian remains above Calvert's "lowest persistent bed of lignite" have appeared, so far as I am aware. That reworked fragments may, however, occur in the basal Tertiary strata is quite possible, but diligent search by myself and field parties I have visited during the past 20 years has brought none such to light.

My conclusion is that the last dinosaurs disappeared, for causes unknown, from the western interior area at or somewhat before the time when the latest sediments of the Hell Creek and Lance formations were deposited, and new environmental conditions were inaugurated. The depositional area began to subside, and the low flood plains of the Late Cretaceous changed to widespread Tertiary sloughs and swamps in which vegetation accumulated to form lignite. Species of a characteristically new flora and fauna appeared, so that when good representations of their fossilized remains are now found they can be easily distinguished from Late Cretaceous assemblages.

Calvert's basal coal zone, as proved at all localities east of the present Continental Divide and north of the Colorado-Wyoming line to the Canadian border, can, with a little experience, be detected readily and mapped satisfactorily. When the paleontologic evidence from above and below this zone is compared with that from strata in adjacent or distant areas where the coal zone does not occur, those strata can in accordance with their fossil content be identified as Tertiary or Late Cretaceous, respectively, and the contact between Mesozoic and Cenozoic beds can usually be fairly closely determined. In general, the horizon of the contact is nearly everywhere marked by changes, either subtle or obvious, in lithologic composition and color features that become more distinct as familiarity with the strata grows.

PALEOCENE-EOCENE CONTACT

Before use of the term Paleocene became common, the earliest Tertiary of the western interior was called Eocene, but the strata were regarded by many geologists as transitional between Cretaceous and Tertiary, and the upper limit of this transitional series was considered to be the true Cretaceous-Tertiary boundary. The oldest strata overlying the Paleocene, conformably or unconformably, in many parts of the Rocky Mountains and the Great Plains, are conglomerates, sandstones, clays, shales, and coal seams, sometimes resembling the underlying beds in general aspect but more often being coal-barren, sandy, and varicolored. These strata are commonly called the "Wasatch" formation, and pending a restudy and possibly a renaming of much that is now called Wasatch, I shall here use the term only in a general identifying sense. For a review of the mixed situation involving the term Wasatch, the reader is referred to publications by Nace (1936, p. 120–146), Jepsen (1940, p. 223, 224), and Van Houten (1944, p. 172–174).

The upper limits of the Paleocene have been determined in part by lithologic changes and in part by mammalian and floral remains. Thus, when examining a given terrain for this contact, the geologist, finding relics of the early horse, *Hyracotherium* (eohippus), and of the floating fern, *Salvinia preauriculata* Berry, will know that the upper limit of the Paleocene has been passed and that the containing strata are Eocene. Specific references to this contact will be found in the discussions of the Hanna Basin, Powder River Basin, western North Dakota, etc.

SUMMARY OF PALEOCENE STRATIGRAPHY

Because my chief purpose in this paper is to discuss the plants of the Paleocene and the evidence pertaining to detection of its boundaries, I shall not here review Paleocene stratigraphy in more than necessary detail. Readers interested in the minutiae of thicknesses and lithologic variations of strata should consult the numerous pertinent coal and other reports.

As now recognized, the Paleocene units or formations and their members in the Rocky Mountains and Great Plains are:

Canada: Paskapoo, Ravenscrag, Willow Creek (part).
Montana, the Dakotas: Fort Union (Tullock, Lebo, Ludlow, Cannonball, Tongue River, Sentinel Butte members), Willow Creek (? part), Livingston (part), Melville of Simpson (1937), Bear of Simpson (1937).
Wyoming: Fort Union, Polecat Bench of Jepsen (1940), Ferris, Evanston, Almy, Hoback of Horberg, Nelson and Church (1949).
Colorado: Denver (part), Dawson (part), Coalmont, Middle Park, Plateau Valley of Patterson (1936), Raton, Poison Canyon, Animas (part).
New Mexico: Raton, Animas (part), Puerco, Torrejon, Tiffany of Granger (1917).
Utah: North Horn, Dragon of Kugler (1953), Henefer.

In particular, the Fort Union of the northern areas, having been the subject of so much dispute and because the type section is not typical, has been redefined as follows and is thus virtually synonymous with Paleocene series in that region: The Fort Union formation in eastern Montana, western North and South Dakota, and eastern Wyoming is typified by the sequence of lignitic strata exposed in the right bank of the Yellowstone River from the top of the Cretaceous dinosaur-bearing Hell Creek formation at Glendive to and including the original type section (pl. 1, fig. 1) in the badlands on the left bank of the Missouri River, opposite the mouth of the Yellowstone River. The top of the formation is the base of the Golden Valley ("Wasatch") formation (Eocene) in isolated outcrops in western North Dakota.

The Paleocene series of the western interior includes coal seams, sandstones, conglomerates, shales, clays, thin impure limestones, and in some areas, igneous rocks or the products of igneous activity. The series attains a thickness of 5,000 feet or more in the Hanna Basin, Wyo., the Crazy Mountains, Mont., and North Park, Colo., but in most areas less than 2,000 feet remain. Eastward, or seaward, from the mountains the strata thin and decrease in coarseness. Where the strata now lap against the mountains the sandstones may be coarse to conglomeratic. Some channel deposits within the sequence contain fairly coarse material at a considerable distance from the assumed source (Lloyd and Hares, 1915, p. 538, 539). Hewett (1926, p. 30–40) reported conglomerates in the Fort Union of the west side of the Big Horn Basin in Wyoming.

The terrain that received the Paleocene sediments was physiographically a vast low-lying and intermittently subsiding flood plain over which flowed meandering and braided streams through poorly drained inland swamps and marshes, with shallow bogs, sloughs, low moors, ponds, lakes, and lagoons, where, during sediment-free intervals, peat-forming processes were active. The piedmont portions of the flood plains nearest the sources of the silts and sands that buried the subsiding accumulations of vegetable remains, lapped against the flanks of the mountains and received the coarser detritus. Crossbedding of the sandstones, channeling, overlap, and interfingering suggest intermittent diversion and change of the inflowing sediment-bearing currents that buried the subsiding, incipient coal beds. With the exception of the coal, all these sedimentary deposits may be said to be of fluviatile origin (Davis, W. M., 1900). Generally, but not always, the coal seams thin out and disappear by lateral gradation into carbonaceous shales. The coals may be underlain by light-colored or bluish underclays that were in part the soils or substrates for the coal-forming plants. Besides this peaty material, the abundant plant remains in the sandstones, clays, and shales show that vegetation was more or less luxuriant on the higher parts of the flood plains and in the highlands. Van Houten (1945a, p. 444; 1948, p. 2121), discussing depositional conditions in this general area during the early Cenozoic, suggests that the gray strata, because they contain small arboreal animals, probably accumulated in heavily wooded lowlands or swamps, whereas the variegated strata, containing remains of ungulates and carnivores, probably accumulated on flood plains, piedmont areas, and valley flats, and reflect a grassland or savannah environment.

Today, in few localities do these Paleocene strata retain their original more or less horizontal attitudes. All have been raised vertically, and in many localities they are now tilted, the steepest inclinations being on the flanks of anticlines or where they lap against the mountains that had intermittent uplifts during or after the deposition of the sediments. Viewed in large perspective, most of the Paleocene strata in and around the Rocky Mountains lie in synclinal basins such as the Williston Basin in North Dakota, Powder River Basin, Bighorn Basin, Wind River Basin, and Hannah Basin in Wyoming, Denver Basin and North Park Basin in Colorado, and the San Juan Basin in Colorado and New Mexico. Such folds as occur in these large basins are, for the most part, fairly gentle, such as Porcupine dome (Bowen, 1916) and Cedar Creek anticline (Erdmann and Larsen, 1934; Dobbin and Larsen, 1934) in Montana; Nesson anticline (Collier, 1918) and Keene dome (Nevin, 1946) in North Dakota. Many minor unnamed swells are found in nearly all the basins. Other deformations of not clearly explained origin also occur (Townsend, 1950). Over large areas on the Great Plains east of the Rocky Mountains the general attitude of the Paleocene strata superficially seems to be that of horizontality, but in reality there is, particularly in Montana and North Dakota, a low dip to the northeast.

Faulting is comparatively rare, but slumping and landslipping are common, particularly where thick coal beds have burned. Some sediments were covered, intruded, or otherwise affected by igneous activity, as for example, at Golden, Castle Rock, and Walsenburg, Colo.; in the Crazy Mountains northeast of Livingston, Bearpaw Mountains south of Havre, and Smoky Butte west of Jordan, Mont. Some of this igneous action, particularly in Colorado, occurred during the Paleocene. The age of that in the Bearpaws is Eocene, but of that in the Crazy Mountains and near Jordan is indeterminate.

On the Little Missouri River, near Yule in southwestern North Dakota, the early nonmarine Paleocene sediments interfinger with brackish-water strata that probably represent former estuarine channels of the Cannonball sea in which, near Mandan, about 300 feet of marine sediment comprising the Cannonball member was deposited. The fact that brackish-water tongues of the Cannonball member (pl. 2, figs. 2, 3) lie in the midst of thick coal seams indicates that those and most likely all the Paleocene coals were paralic, that is, they were deposited at or near sea level in extensive coastal swamps and marshes that may at times have been considerably inland from the open coast. These marshy basins subsided intermittently and locally for a total of thousands of feet in the course of millions of years, but the subsidences were interrupted by periods of relative stability permitting vegetation to grow and its remains to accumulate as peat that was eventually transformed into lignite beds (Thom, 1929, p. 19; Stutzer, 1940, p. 162) after burial under a cover of sand and mud. The repetitive occurrence of coal beds through the Paleocene sequence into the Eocene suggests the inference that not only before and during Cannonball time but for a long time afterward an open sea, perhaps extending from the Gulf of Mexico to the Arctic Ocean, occupied, more or less continuously, an unknown area not far to the east or northeast, where, however, there are now no marine strata left to testify to its former presence. There is perhaps no exactly comparable existing situation on the same scale. The Dismal Swamp area of Virginia and North Carolina (Osbon, 1920) may be cited, but it is small compared with the Tertiary lignitic area of the Rocky Mountains and Great Plains. I gather that conditions of sedimentation in the basins of the Amazon and Parana Rivers of South America may approximate those of the early Tertiary in the Rocky Mountains and Great Plains, for large areas on both sides of these rivers may be inundated during flood stages. Peat, I am also told, is accumulating in many of the swampy localities there.

If the inference that all the Paleocene coals were formed at sea level is correct, the difference in level between the average base of the Paleocene (about 5,000 feet above the sea) in the plains just east and west of the Rockies and its average base in North, Middle, and South Parks, now high (about 8,000 above the sea) in the Rockies near the Continental Divide, indicates a differential uplift by folding and faulting of the park areas above the plains of at least 3,000 feet and a total uplift for some outcrops of at least 8,000 feet since Paleocene time. The general similarity in the composition of the floras from several basins now separated by mountain ranges also suggests that the basins were once more or less continuous or were at least not separated by barriers that prevented interchange of plants. W. T. Lee (1915, p. 27, 56) claimed there is lithologic and physiographic evidence that all the Upper Cretaceous formations from the Dakota sandstone through the Laramie once covered the Rocky Mountain region, the source of the sediments being an ancient landmass occupying the present site of the Great Basin and portions of the Sierra Nevada. On the other hand, Lovering (1929, p. 88 ff.) states that "there are a few places in the Front Range where the evidence strongly suggests that Dakota sandstone was never deposited," and that "some areas of the Front Range highland were above water at the close of Dakota time." The inference is that they remained above water and were never again completely covered by sedimentary formations. I am inclined to the opinion, after seeing the coarse andesitic and arkosic conglomeratic material in the Paleocene of the Denver Basin and Middle Park, Colo., that during most of Paleocene time the present site of the Rocky Mountains was occupied by an emerging chain of large hilly islands separated by shallow channels and fringed by very broad unstable coastal areas and that these landmasses contributed a fair percentage of clastic sediments to the making of the Paleocene formations. Some sediments, however, very likely originated in the ancient landmass still farther west and southwest.

Intermittent orogenic uplifts of the ancestral Rocky Mountains core during the continuing so-called Laramide Revolution were reflected in the clastic sediments deposited near the source of supply by resulting unconformable relations between the strata. Localities or regions where the Paleocene strata overlie older strata unconformably may be seen on Dry Creek, 5 miles west of Greybull, Wyo.; 2 miles southeast of Black Buttes Station, Wyo. (pl. 1, fig. 3); in Rifle Gap, 6 miles north of Rifle, Colo.; in North and Middle Parks, Colo. (Beekly, 1915, p. 20; Grout and others, 1913, p. 36, 37); and on Cimarron River, northeast of Ute Park, N. Mex. (Lee, 1917, p. 69–74).

At the close of Paleocene time, uplift in the Bighorn Mountains in Wyoming resulted in the deposition of conglomerate on both flanks of the mountains. This basal Eocene conglomerate, called the Kingsbury conglomerate member of the Wasatch formation on the east flank, is unconformable on Paleocene lignitic strata.

Although locally, as in eastern Montana and adjacent areas, the Paleocene series has been divided into members of the Fort Union formation, largely for mapping purposes, these divisions (Tullock, Lebo, Ludlow, Cannonball, Tongue River, Sentinel Butte) cannot be extended as such into all areas by either lithologic or paleontologic means. The fossil floras, for example, are notably different in the basal and upper strata—a condition that should not be considered unusual because the long time interval separating them made changes in the composition of the flora at any given locality inevitable. Intergrading floras, however, connect the two extremes. Moreover, collections from widely separated localities, latitudinally, although from the same general stratigraphic level, also differ notably, as might be expected if climatic zones prevailed in the Paleocene as they do today.

No sharp distinctions can be made stratigraphically within the Paleocene at any given locality on the basis of the floras. Such distinctions as have been made on the basis of mammalian remains in the Crazy Mountains, Polecat Bench, San Juan Basin, and Bison Basin are to the point and may be useful some day in many other areas that have not as yet yielded such fossils.

The differentiation of the several members of the Paleocene by comparison of their mineral constituents has made little progress, except perhaps, locally, as, for example, in its application to the Lebo shale member. Stone and Calvert (1910, p. 753) described the Lebo in the Crazy Mountain area of Montana as andesitic in character and as passing westward into the Livingston formation. Eastward, Woolsey and others (1917, p. 25) found the Lebo still andesitic in the Bull Mountain coal field, and Rogers and Lee (1923, p. 36–40) detected a similar condition in the Tullock Creek coal field. North of the Yellowstone River in the Sheep Mountain coal field, between Miles City and Terry, Rogers (1913a, p. 171; 1913b, p. 723) reported what he considered to be andesitic material in the Lebo. On the other hand, chiefly south of the Yellowstone River, between Forsyth and Hathaway, Renick (1929, p. 17, 19, 21) found no essential difference in mineral constituents between the Hell Creek formation and Tullock member of the Fort Union formation. These formations, besides being very arkosic, contain quartz and volcanic debris. He found that the Lebo also contains considerable amounts of arkosic material and some volcanic debris, but did not consider the term "andesitic" as applicable. In short, he found that the Lebo is not markedly different, mineralogically, from either the Tullock or the Tongue River member. Andrews (1936, p. 387) and others concur in Renick's opinion that analysis of their mineral constituents seems at present ineffectual for differentiating these several formations in extreme eastern Montana and adjacent terrain.

Although Stow (1938) made numerous heavy-mineral analyses in an attempt to distinguish the Cretaceous from the Tertiary and the several divisions of the Tertiary from one another in the vicinity of Red Lodge, Mont. the results were not definitely conclusive. Marie Lindberg's more recent study (1944) of the Cannonball area southwest of Mandan, N. Dak., divides the section from the Fox Hills sandstone through the Cannonball member into nine mineral zones and finds that the Fox Hills and Cannonball contain a high percentage of green amphibole, whereas the Hell Creek formation differs by its characteristic epidote, garnet, and sphene content. Whether these conclusions are of more than local application remains to be tested by a similar investigation of the correlative strata farther west in the valley of the Little Missouri River in western North Dakota and elsewhere.

LIMITS OF THE PALEOCENE IN SPECIFIC AREAS

Inasmuch as this paper is concerned principally with the strata at the boundaries of the Paleocene series, I shall here center attention on that phase of the stratigraphy. It seems appropriate to begin with the areas at first largely involved in the debate about these limits and then develop the subject from these focal points.

MONTANA

Glendive.—Mention has already been made of the fact that Calvert considered the Cretaceous-Tertiary boundary as at or just above the level of the highest dinosaurian remains, which are found below the "lowest persistent bed of lignite" in the vicinity of Glendive. This horizon is just above the level of the city water tank, about 100 feet below the top of the bluffs south of the city. If, on a clear day and preferably in the afternoon when the color of the bluffs is not modified by shadows, one views this line of bluffs from the north side of the Yellowstone River at a distance of approximately 1 mile, one can pick out this horizon by eye and follow it around the crests of the highest badland hills. On the outcrop itself, one can follow the "lowest persistent lignite zone" southeastward around the tops of the hills at Graveyard Coulee, thence around the hilltops on the west side of Glendive Creek to a point 5 miles out of Glendive on U.S. Highway 10 toward Wibaux, where, by reason of the gentle northeastward dip of the strata away from the Cedar Creek anticline, the lignite zone crosses the highway. In the badlands on the east side of the highway, this zone is burned at a number of exposures. Looking southwest from this point toward the badlands and mesas in the escarpment on the left bank of Glendive Creek, one can readily pick out the same lignite zone. Plate 3, figure 2 shows part of this view. It will be noted that the strata (Tullock) in the upper fourth of the exposure are darker, that is, more coaly, above a fairly sharp line, the "lowest persistent lignite zone" in this area, below which the strata (Hell Creek) are distinctly lighter in color, a local reversal of the usual color distinctions. I collected dinosaur bones from beds about 50 feet below this level and Fort Union plants from the carbonaceous shale just above, not only at this locality but everywhere in the vicinity of Glendive; and I conclude, therefore, that this level is the closest mappable approximation of the Cretaceous-Paleocene boundary that can be found in that area.

The boundary follows the base of the hills on the right bank to a point 4 miles down the Yellowstone River from Glendive, where it crosses the river and reappears in the low bluffs just northwest of a point on State Highway 14 to Sidney, 3 miles from the Yellowstone bridge. The horizon is marked by the red clinker of the "lowest persistent lignite bed." Here I found triceratopsian bones 75 feet below the coal, and Fort Union plants in the clinkered shale. This zone can be traced around the hills to the northwest. At a point 8.5 miles along State Highway 18 from the Yellowstone bridge toward Circle, a clinkered coal can be seen in the ridges one-half mile to the west. As these strata are on the east flank of the Cedar Creek anticline, the coal bed can be seen dipping across the highway just one-half mile ahead and from thence can be followed at the base of the low hills to the east. Here, however, another thin coal seam occurs about 25 feet below the clinkered bed; and in the carbonaceous shale just above the coal, I found typical Fort Union plants, but no dinosaurian remains, from which I infer that the Cretaceous-Paleocene boundary is at the level of the lower coal seam.

Graveyard Coulee, extending southeastward from Glendive, is the location of the city dump. The surrounding eerie, somber badlands are, however, notable for the even more ancient relics that may be found in and on the almost bare outcrops. Dinosaur, turtle, and crocodile fragments are plentiful in the lower exposures of Hell Creek strata. These beds also yield such typical Cretaceous plants as *Sequoia dakotensis*, Brown, *Ginkgo laramiensis* Ward, *Ficus ceratops* Knowlton, *Vitis stantoni* (Knowlton) Brown, *Dryophyllum subfalcatum* Lesquereux, and *Cissus marginata* (Lesquereux) Brown. From the same strata on Glendive Creek, southeast of Graveyard Coulee, Dell and Edwin Lewis of Glendive, collected several multituberculate mammalian jaws and the problematical plant, *Paleoaster inquirenda* Knowlton; but in the overlying basal Tullock in Graveyard Coulee I collected the following Fort Union plants: *Thuja interrupta* Newberry, *Paranymphaea crassifolia* (Newberry) Berry, and *Viburnum asperum* Newberry.

I have already (p. 5) discussed the section and situation on the west flank of the Cedar Creek anticline, 12 miles southwest of Glendive. Northeastward from Glendive the average dip of the strata of about 15 feet to the mile, about six times the gradient of the Yellowstone River, brings higher and higher strata to the level of the river, so that at the original type locality of the Fort Union formation in the hills on the north side of the Missouri River opposite the mouth of the Yellowstone only the highest beds of the formation can be seen and all or nearly all of these belong to the Sentinel Butte member.

Tullock Creek coal field.—G. S. Rogers and Wallace Lee in 1923 divided the enlarged but ambiguous Lance into a lower part (now the dinosaur-bearing Hell Creek formation) and the Tullock member. The latter, a light-colored, yellowish zone, with coal beds, was separated from the Hell Creek at the level of the lowest persistent coal seam—bed A. This, from what has just been said about the Glendive area, is the level of the Cretaceous-Paleocene boundary.

Baker and Ekalaka.—From Glendive, on the east flank of the Cedar Creek anticline, the Cretaceous-Paleocene boundary strikes southeastward toward Marmarth, N. Dak., and Buffalo, S. Dak. On the west flank of that anticline it runs southeastward toward Baker and Ekalaka. Ten miles north of Baker it crosses State Highway 7 (pl. 3, fig. 3). Here, as at the locality 5 miles southeast of Glendive, the lowest Tullock strata are highly carbonaceous and coaly and, therefore, appear darker than the underlying Hell Creek formation, in which, a quarter of a mile west of the highway and 25 feet below the base of the Tullock, I found a leg bone and part of the skull of a *Triceratops.*

Along the border of Montana and South Dakota, east of Ekalaka, there was, until the dinosaur-lignite contact formula was applied, considerable uncertainty as to the position of the Cretaceous-Paleocene boundary. Thus, much of the area along Coal Bank Creek formerly mapped as Hell Creek (Bauer, 1924, pl. 33) has extensive outcrops of coal or clinker, said, however, by Bauer (1924, p. 239) to be in the upper 100 feet of that formation. Search of the area by me through the sequence of strata from the base of this lignitic zone upward, and interviews with the ranchers in the vicinity, proved negative in the finding of dinosaurian remains, which, however, can be had at nearly every good outcrop beneath that zone, showing that the true Hell Creek does not include anything above that contact. South and southeast of Ekalaka are high forested buttes of Paleocene capped by later-than-Paleocene strata. Southwest of Ekalaka the Cretaceous-Paleocene contact swings around the rim of the escarpment facing Spring Creek and the Powder River valley.

Powder River region.—Northeast of Powderville on the east side of Powder River the Cretaceous-Paleocene boundary follows the rim of the badlands east of Spring Creek and eventually descends to and crosses Powder River about 6 miles southeast of Mizpah. Thence it passes in and out along the hills and coulees on the left bank (pl. 3, fig. 1) to a point about 14 miles southwest of Powderville, where it crosses to the east, following a zigzag course almost directly south and keeping to the east side of the Little Powder River. About 4 miles east of Biddle it crosses Ranch Creek, where, in the Hell Creek formation on the south bank, I found a large dinosaur vertebra, and in the overlying Tullock cropping out in the hills to the north I found specimens of the Paleocene flora.

The map accompanying the description of the Mizpah coal field by Parker and Andrews (1939, pl. 16) correctly depicts the Cretaceous-Paleocene boundary, although the legend to the map does not name it so. The contact as mapped is between Tls (sandstone member of Lance formation) and Tlsh (somber-colored beds). The latter strata, according to the map legend and text description, are said to include at their base about 300 feet of beds equivalent to the upper strata of the Hell Creek formation as mapped in the adjacent Rosebud coal field (Pierce, 1936) to the west. In 1929, I assisted in mapping the Rosebud field and have reexamined both areas a number of times since. No part of the basal coal-bearing strata of the Rosebud field is equivalent to any dinosaur-bearing part of the Hell Creek formation. No dinosaur remains have ever been found in the 300 feet of beds in question, but on the contrary, these strata have yielded satisfactory collections of Fort Union plants. The upper strata of the Hell Creek formation, however, do crop out along Rosebud Creek in the northwestern part of the field.

West and southwest of Powderville toward Coalwood, Broadus, and on to the Montana-Wyoming line, the altitude of the terrain increases and younger strata of the Fort Union formation appear (Bryson, 1952; Warren, 1960).

Red Lodge and Livingston.—The folded and faulted coal-bearing strata in the vicinity of Red Lodge and Bear Creek are in the upper part of the Fort Union formation. Just west of Red Lodge the upper beds of these strata, perhaps in part equivalent to the Sentinel Butte shale (Thom and Dobbin, 1924, p. 496; Simpson, 1929, p. 8), are cut by the Beartooth fault that strikes northwestward. Northeast and east of Red Lodge and Bear Creek, the lower limit of the Paleocene, because of the folding, faulting, and lack of fossil evidence, is not as closely located as is desired in that area. From such reconnaissance studies as I have been able to make and with the few collections of fossil plants that have been gathered, I infer that this eastern boundary enters Montana from Wyoming in sec. 34, T. 9 S., R. 23 E., Mont., passes northwestward through a much-faulted area (Wilson, 1936, fig. 2) about 4 miles west of Bridger and about 3 miles northeast of Absarokee (Stow, 1938, pl. 1) but loops around about 4 miles east of Reed Point without crossing the Yellowstone. North of the river the contact encircles a large patch of Paleocene and in the Crazy Mountain region becomes the Hell Creek—Bear contact.

Gradually along the western boundary of the Paleocene in the direction of Livingston and westward against the Bridger Range (McMannis, 1955) lower and lower strata appear. In 1908, about 3,700 feet of older beds underlying the productive coal strata in the vicinity of Livingston, and originally assigned to the Colorado and Montana groups, were definitely determined to be of Colorado age on the basis of marine invertebrates. This sequence, for convenience of discussion, was divided by Richards (1957) into 10 units, which were tentatively correlated with similar Colorado units elsewhere in Montana, South Dakota, and Wyoming. The 800 to 1,000 feet of conformably overlying coal measures, originally called Laramie, were found to include marine strata containing invertebrates identified by T. W. Stanton as a lower Montana fauna, indicating probable equivalence to the Eagle sandstone or to the Mesaverde formation as developed in Colorado and Wyoming (Stone and Calvert, 1910, p. 660, 738; Calvert, 1912b, p. 388).

The dark-colored remainder of the section above the coal measures, west and south of the Crazy Mountains, is an apparently conformable sequence and comprises from 5,000 to 7,000 feet of greenish- or somber-colored andesitic and tuffaceous sandstone and flinty shale (Weed, 1893, p. 21; Stone and Calvert, 1910, p. 662; Calvert, 1916, p. 202; Wilson, 1936, p. 1165–1166), including a lens of conglomerate 2,000 feet thick where it is cut by the Stillwater River. These andesitic beds were called Livingston beds and later the Livingston formation (Richards and Prichard, 1950). The rocks of more strictly volcanic derivation included in this sequence have been studied by Parsons (1942). Conformably overlying the Livingston formation are 4,000 feet, more or less, of light-colored sandstones and gray shales acknowledged to be of Fort Union age and, from the contained flora, are equivalent in part to the light-colored beds east of the Crazy Mountains called "Melville" by Simpson (1937b) and of the Tongue River member of the Fort Union farther east. If, therefore, the several thousand feet of somber-colored andesitic beds between the lignitic Eagle and the light-colored Fort Union are in conformable sequence, they must represent the time equivalents of the Claggett, Judith River, Bearpaw, Fox Hills, Hell Creek, and early Paleocene units. A diagram purporting to represent the probable relations of these strata was published by Woolsey, Richards, and Lupton (1917, p. 26, fig. 2). The resolution of this apparently homogeneous lithologic sequence into its component parts constitutes the "Livingston problem."

From a number of scattered localities about 1,200 to 1,500 feet above the Eagle sandstone, Stone and Calvert gathered invertebrates and plants identified by Stanton and Knowlton, respectively, as of Judith River age. The fossils, it should be stated, came principally from strata in the northern part of the area that are laterally equivalent to a level at or beneath the horizon of the lenticular agglomerate that is said to rest unconformably upon underlying beds in the southern part of the area. A good section of this agglomerate, about 50 feet thick can be seen along U.S. Highway 10 on the south side of the Yellowstone River just west of Springdale. I have found only a few fragmentary plants (*Araucarites* sp.) in it, and they appear to be Cretaceous forms. The beds overlying the agglomerate, although still somewhat greenish, gradually become brownish to somber up to the transition into the lighter-colored, grayish beds of the Fort Union formation.

From the highest locality yielding marine invertebrates, about 2,500 to 3,000 feet (according to Stone and Calvert) above the Eagle, came a collection identified by Stanton as being near the top of the Bearpaw. At this locality, sec. 25, T. 4 N., R. 8 E., about 5 miles north of Wilsall, there is an anticlinal structure exposing Bearpaw (Pierre) shale and higher, sandy beds in the top of which in 1949 I found dinosaurian bones. Such remains were also found by McMannis and party (1955, p. 1408) in outcrops 3,200 feet above the base of the Livingston formation, 13 to 16 miles east of Bozeman, and were tentatively considered to be Lancian in age. My saurian locality is 3 miles west of the outcrop of the base of the light-colored Fort Union. The 4,000 feet, more or less, of strata in this 3-mile interval are shaly and sandy, but they evidently include time equivalents of Fox Hills, Hell Creek, and early Paleocene beds.

Knowlton, Berry, and Stanton in 1913 collected fossil plants on Brackett Creek in sec. 9, T. 1 N., R. 7 E., southwest of Wilsall. I made similar collections in that vicinity in 1940. These collections, however, are not strictly diagnostic but contain species found in the Bear and Lebo on the east side of the Crazy Mountains. My tentative conclusion, pending receipt of more informative collections, therefore, is that about 1,500 feet of the upper part of the andesitic Livingston unit are basal strata of early Paleocene age, but are not now clearly separable from the underlying Cretaceous beds by recognizable lithologic differences and well-distributed unequivocal fossils. If this be true, the Cretaceous-Paleocene boundary roughly parallels the Livingston-Fort Union contact as mapped by Stone and Calvert (1910, pl. 7) but at some indefinite distance west of their line. The boundary probably crosses the Yellowstone River at or just a little west of Big Timber, undulates almost directly westward to the northeast corner of T. 1 N., R. 7 E., and then curves northward and northeastward around the north end of the Crazy Mountains. Confirmation of this assumption and the fact that the upper part of the Livingston formation is Paleocene in age was made during the summer of 1958 when A. E. Roberts, of the U.S. Geological Survey, found the jaw of a Paleocene condylarth, *Tetraclaenodon symbolicus* Gidley, in strata on Willow Creek in the NW¼ sec. 4, T. 1 S., R. 9 E., 9 miles north of Livingston.

The thick Fort Union sequence in the Crazy Mountains is preserved by intrusive igneous rocks. Simpson (1937b, p. 15) reports a thickness of more than 5,000 feet for the Melville or his Fort Union No. 3. If to this be added the Lebo and the Bear, a total of more than 6,800 feet is indicated for the entire series. As mammalian remains have been found in only the lower 3,000 feet of the Melville, the age of the upper strata of this unit is conjectural. Whether or not any of these upper strata are Wasatch equivalents remains to be seen.

Bull Mountain coal field.—The authors (Woolsey, Richard, Lupton, 1917) of the bulletin dealing with this coal field say little about the stratigraphy of what they call the "Lance" formation but report that coal seams occur in its upper portion. This fact, judging by analogy with the situation in the coal fields farther east, suggests that the Cretaceous-Paleocene boundary at a number of localities is slightly below the contact of the "Lance" and Fort Union as mapped by those authors. In 1936, I studied the section from Big Timber to Roundup, and found that the outcrops of the strata between the Bearpaw and Fort Union—that is, of the "Lance" formation—are poor in every respect. Consequently, no satisfactory evidence seems to be available now for locating the boundary precisely in parts of this field.

Bearpaw Mountains.—In small, faulted patches on the northeast, west, and south sides of the Bearpaw Mountains are outcrops of lignitic strata of Fort Union age (Pepperberg, 1912; Bowen, 1914; Reeves, 1925; Brown and Pecora, 1949). Collections of fossil plants from a number of mines and prospects, particularly from the vicinity of the Mackton mine, 6 miles east of Big Sandy, contain *Glyptostrobus dakotensis* Brown, *Metasequoia occidentalis* (Newberry) Chaney, *Cercidiphyllum arcticum* (Heer) Brown, *Platanus nobilis* Newberry, *Viburnum antiquum* Newberry, and *Viburnum asperum* Newberry. Beneath Fort Union outcrops east of Big Sandy are several hundred feet of Hell Creek equivalents (Brown and Lindvall, 1953), and faulted against Fort Union in some localities are remnants of the variegated Wasatch formation with diagnostic plants and animals. The preservation of these relics of Late Cretaceous and early Tertiary formations now exposed at or near the level of the Great Plains suggests that a stratigraphic sequence probably exceeding 5,000 feet in thickness has been eroded from north central Montana since Eocene time.

Browning.—A narrow synclinal strip of variegated beds, called the Willow Creek formation (Stebinger, 1916, pl. 15) extends from a point about 10 miles north of Browning deep into Alberta, Canada. As the underlying beds, the St. Mary River formation, contains dinosaurian remains, they are reliably regarded as of Late Cretaceous age. The Willow Creek formation, at least in its upper part, has yielded no dinosaurs but an essentially Fort Union invertebrate fauna; and the strata, according to Williams and Dyer (1930, p. 61), L. S. Russell (1932, p. 140), and E. T. Tozer (1956, p. 27) are in part, at least, equivalent to the Paskapoo formation. The flora from the latter at Calgary, Cochrane, and Red Deer River, Alberta, as listed and reviewed by Penhallow (1908, p. 13–15) and Berry (1926) is clearly a Fort Union flora, and the mammalian remains (Russell, 1932, p. 137–138) are considered to be undoubtedly Paleocene. The Cretaceous-Paleocene boundary, therefore, would seem to be at the contact of the St. Mary River or its Edmonton equivalent and the Paskapoo or its Willow Creek equivalent in Alberta. However, according to Rutherford (1947) who has studied the Cretaceous-Tertiary boundary question in Alberta, there remain unreconciled lithologic and paleontologic anomalies. Tozer (1953) and Thompson and Axford (1953) think that the lower part is Cretaceous and the upper part is Paleocene.

Scobey.—Collier described the geology of northeastern Montana in 1919 (p. 17–39), and in 1925 (p. 165) he reported the geologic section in the glaciated Scobey lignite field to consist in part of Hell Creek, 150–180 feet; Tullock, 30–40 feet; Lebo, 200–275 feet; and Tongue River, 600± feet. His Hell Creek includes lignite bed A in its upper part, and bed C marks the base of his overlying Tullock. He did not state why bed C was chosen as the level for separating Hell Creek from Tullock, and in particular, he reported no dinosaur remains from the strata between bed A and bed C.

Bauer (1914, p. 298) drew the boundary at the contact of somber-colored beds ("Lance") and yellow beds (Fort Union), but this, from what has already been said about the unreliability of colors in these strata, is not a satisfactory solution. From Penhallow's (1908, p. 9–13) review of the fossil plants contained in the lignitic strata of southern Saskatchewan adjacent to the Scobey lignite field, I conclude that most of those plants are Fort Union species. Further, the absence of any authentic dinosaurian remains strongly indicates that all these lignite-bearing strata both in Saskatchewan and in the vicinity of Scobey are Paleocene in age. Southwestward toward Wolf Point and Fort Peck, Hell Creek strata appear in the valleys of Wolf Creek and Poplar River (Colton, 1955; Colton and Bateman, 1956).

CANADA, NORTH DAKOTA, AND SOUTH DAKOTA

The strata of the Cannonball and Tongue River members that may be seen along the bluffs of the Missouri River west of Bismarck, N. Dak., pass under a cover of glacial debris east and northeast of that city. In 1947 Richard W. Lemke and I (Brown and Lemke, 1948) discovered isolated outcrops of the Cannonball member near Sawyer and Velva, 55 miles northeast of the nearest previously reported outcrops at Washburn, N. Dak. From the well log records accumulated by Virginia Kline (1942) it appears that any Paleocene rocks, if ever present, were removed before the Pleistocene from the terrain east of the 100th meridian in the central part of the State; but the Turtle Mountains of Bottineau and Rolette Counties in the northern part are an elevated, more or less flat, isolated area in whose south-facing escarpment the bedrock contains lignite of Fort Union age (Hendricks and Laird, 1943, p. 593) underlain by brownish Cannonball strata containing foraminifers (Lemke, 1960, p. 28, 31). Thus, it is probable that subsurface records may reveal the presence of Cannonball deposits even farther north in adjacent parts of Canada.

The Cretaceous-Paleocene boundary, so far as can be determined in the glaciated area, is an undulating line running northwestward to the Canadian border and thence into Saskatchewan and Alberta. The Canadian strata chiefly involved are the St. Mary River, Edmonton, Whitemud, Paskapoo, and Ravenscrag formations, succinctly reviewed by E. W. Berry (1930b), W. A. Bell (1949), and L. S. Russell (1953). The Ravenscrag has been divided into a Lower and Upper Ravenscrag. The Whitemud yields a characteristic flora of Fox Hills age, whereas the Lower Ravenscrag is coal-barren (Fraser, and others, 1935, p. 39) but contains plant and dinosaurian remains. The Upper Ravenscrag is lignitic, lacks dinosaurian remains, but yields the typical Fort Union flora. Its base is marked by a coal seam called the Ferris or No. 1 (Fraser and others, 1935, fig. 1).

The earliest account of these differences in stratigraphy and paleontology appears to be by G. M. Dawson (1875), who described the geology along the 49th Parallel for the British-North American Boundary Commission. On page 104 he gives a section which he illustrates in plate 7, figure 2. The B portion of the section is the critical part and consists of an upper lignitic sequence with Fort Union plants, and a lower nonlignitic arenaceous sequence with dinosaurs, turtles, garpike scales, and a fruit which he called *Aesculus antiquus* (his pl. 16, figs. 8, 9). The latter, although not identifiable as a species of *Aesculus*, is an index fruit that occurs abundantly with dinosaurian remains in the Hell Creek formation 3 miles southwest of Glendive, Mont., and elsewhere, but not in any Paleocene strata so far as I am aware. This contrast between the lower and upper parts of Dawson's B division clearly indicates the Cretaceous-Paleocene boundary, which here, in modern terminology separates the Lower and Upper Ravenscrag. This, however, was not Dawson's conclusion (p. 183–202). He located the boundary between what would now be called Eastend and Whitemud plus Lower Ravenscrag (Hell Creek). Fraser and others (1935, p. 37–55, and map, fig. 1, opp. p. 24) accept the top of the Lower Ravenscrag and base of the Upper Ravenscrag as the Cretaceous-Paleocene boundary.

In northwestern South Dakota, in a gentle synclinal basin 12 to 15 miles north of Camp Crook, the Lance as mapped by Winchester and others (1916, pl. 1) contains coal seams in its upper strata. My examination of this area in 1950 showed that no dinosaur bones occur above the base of the lowest lignite zone but that such remains are abundant beneath that zone. Further, the Fort Union flora occurs in the shales above the base of the coal zone. The Cretaceous-Paleocene contact, therefore, is at the base of this zone, and none of the sequence above this contact is Lance.

The upper limits of the Paleocene are present in the high buttes in the contiguous areas of Montana and North Dakota and at a few localities farther east, near Dickinson, Hebron, and Beulah (Benson, 1951; Johnson and Kunkel, 1954; 1959). In western North Dakota is the conspicuous mesa called Sentinel Butte, whose lignitic strata are the type Sentinel Butte member of the Fort Union formation. This unit overlies the Tongue River member and underlies a massive sandstone that may be Eocene in age, and a thin bed of fish-bearing shale of White River (Oligocene) age, that caps the butte. The further distribution of the Sentinel Butte member in western North Dakota is described by O. A. Seager and others (1942, p. 1417), and Collier and Knechtel (1939, p. 13) thought that 50 feet of shale on Antelope Mountain in T. 18 N., R. 50 E., 10 miles southeast of Circle, Mont., might be Sentinel Butte.

If the coal bed at the base of the Sentinel Butte member be traced northwestward to the Yellowstone and Missouri River valleys, its gentle northeastward dip of about 15 feet to the mile brings it or its equivalent horizon into the low hills north of Buford, N. Dak. Consequently, some of the strata exposed there in the bluffs on the north side of the Missouri River (pl. 1, fig. 1), that is, at part of Meek and Hayden's original type section of the Fort Union group, are laterally equivalent to the Sentinel Butte member. One Paleocene mammal, *Titanoides primaevus* Gidley, was found in this type section.

O. A. Seager and others (1942, p. 1416) and Laird (1944, p. 7) were inclined to accept a Wasatch age for the Sentinel Butte shale on the basis of their areal studies in western North Dakota and adjacent terrain, where they found Leonard's (1911, p. 535) additional but undifferentiated light-colored unit, having an approximate maximum thickness of 100 feet, lying above the Sentinel Butte shale. This unit they regarded as the younger member of the Wasatch. An attempt to reinforce the Seager classification and clarify the position of these stratigraphic units was made by R. V. Hennen (1943) who compiled a series of columnar sections across western North Dakota which he correlated by means of a so-called marker bed of grayish-white quartzitic sandstone containing a zone of silicified wood. At the west end of Hennen's group of sections, near Sentinel Butte, this bed is about 90 feet below the large coal seam that was considered to be the top of the Fort Union formation. Unfortunately, this "marker bed" was mistaken for another about 100 feet higher in the sequence near Sully Springs station southeast of Medora. This mistake invalidates the correlation and the structural deductions based on it. As similar quartzitic beds have been reported from both lower and higher horizons in the Fort Union formation in southwestern North Dakota and northwestern South Dakota (Winchester and others, 1916, p. 30; Bauer and Herald, 1922, p. 115, and sec. 5, pl. 16); Johnson and Kunkel, 1959, p. 12), and as they indicate repetition of similar silicifying conditions at intervals over a long period of time, correlations based on them across long distances of covered strata must be received with caution. For a full discussion of these siliceous beds, see Hares (1928, p. 34–36). The present stratigraphic and paleontologic evidence indicates that the Sentinel Butte shale belongs with the Paleocene sequence (Brown, 1948a). The beginning of the Eocene is marked by the strata of the Golden Valley formation containing the floating fern *Salvinia preauriculata* Berry, not hitherto found in the Paleocene of the Rocky Mountains and Great Plains.

WYOMING

Eastern Wyoming.—The broad basin of northeastern Wyoming, drained by the Tongue, Powder, Belle Fourche, and Cheyenne Rivers, is a continuation of the Plains region of southeastern Montana and displays thick outcrops of the same sedimentary formations (Brown, 1958a). The Lance Creek area northwest of Lusk, on the discovery of dinosaurs and oil, was the first part of the basin to receive close geologic attention. Hatcher (1896), and Stanton and Knowlton (1897) made close determinations of the limits and distribution of the formations, naming the 1,650 feet, more or less, of dinosaur-bearing strata first Ceratops beds, then Lance Creek beds, and finally Lance formation. The immediately overlying strata, with diagnostic plants were referred to the Fort Union formation. In following years when coal-mapping parties investigated the contiguous areas to the north toward the Wyoming-Montana line, the Lance unfortunately was made to include much of the somber-colored sequence of strata (called Fort Union on Lance Creek and Tullock in the Gillette coal field) overlying the typical dinosaur-bearing Lance. However, plates 9 and 10 accompanying the report on the Gillette coal field by C. E. Dobbin and V. H. Barnett (1928) show the position of the "lowest persistent coal beds," a zone, the base of which marks the position of the Cretaceous-Paleocene boundary, continuous with that originally determined by Stanton and Knowlton in the Lance Creek area. In 1938 and 1948, I studied profile sections at spaced intervals from Lance Creek to Moorcroft and found that dinosaurian remains and typical Cretaceous plants are present in the Lance up to the lowest coal zone of the overlying strata. Dorf (1942) has studied the Lance flora at length. No dinosaur bones were found above the Lance, but the Fort Union flora could be had at every favorable locality. Thus, the boundary runs irregularly northward from Lance Creek through points about 4 miles west of Clareton and Moorcroft, thence northwestward, keeping to the east side of Little Powder River to the Wyoming-Montana line (Love, Weitz, and Hose, 1955; Dobbin, Kramer, and Horn, 1957).

The Cretaceous-Paleocene contact strikes southwest on the west side of Lightning Creek, western tributary of Lance Creek in eastern Wyoming, and passes through the town of Douglas, thence westward, crossing the North Platte River about 2 miles east of Careyhurst. For several miles east of this point, the basal 500 feet of the Paleocene are reddish as though discolored by particles derived from erosion of a red Chugwater (Triassic) source. Seven miles north of Glenrock the basal Paleocene is marked by openings on a large coal seam. At the M–C mine on Sand Creek I obtained Fort Union plants. Northwestward the strata adjacent to the boundary were mapped and described by Wegemann (1912; 1917). In his opinion the Lance comprised about 3,000 feet of gray shale and buff sandstone with coal beds in the basal and uppermost parts; and the Fort Union included 2,000 feet of white sandstone and interbedded gray shale topographically expressed as a prominent pine-covered ridge ("Great Pine Ridge") which is transected by the Powder River east of Kaycee. Of Wegemann's 3,200 feet of Lance, only the lower 2,000 feet (about 2,400, according to Horn, 1955) contains dinosaurian remains. The upper 1,200 feet has yielded no vertebrate and only a few plant fossils. One collection of plants, from the north side of the highway 7 miles from Kaycee toward Sussex and 200 feet below the white sandstone, contains *Paranymphaea crassifolia* (Newberry) Berry, which is a characteristic species in early Paleocene rocks. Thus it is clear that Paleocene time began earlier than the deposition of the white sandstone and that the Cretaceous-Paleocene contact is several hundred feet lower in the section; that is, at the level where coal formation was resumed just above the top of the dinosaur-bearing coal-barren sequence. Thus the upper 1,200 feet of Wegemann's Lance, with coal beds, must be added to the Tertiary sequence, making the Fort Union approximately 2,900 feet thick in that area.

For about 25 miles from a point southwest of Buffalo northward to a point west of Banner, the Fort Union, except in the Mowry Basin (Mapel, 1959, p. 61), does not crop out, being either absent or widely overlapped by Wasatch strata, thus breaking the otherwise continuous outcrop around the Powder River Basin.

The upper limit of the Paleocene on the west side of the Powder River Basin between Sussex and Buffalo is marked by a slight angular unconformity with the overlying coarse conglomeratic Kingsbury conglomerate (Gale and Wegemann, 1910, p. 143–146). This basal conglomerate of the "Wasatch" formation does not occur on the east side of the basin, but at numerous localities on the west side, tongues of it can be seen interfingering eastward into lignitic strata. Notable among such localities are the right bank of Powder River at Sussex, hilltops 5 miles east of the point where U.S. Highway 87 crosses the south fork of Crazy Woman Creek, and hilltops and roadcuts south and east of Banner.

That the Kingsbury conglomerate is definitely of Eocene age was first suggested by Wegemann (1917), who reviewed the fossil-mammal evidence as of that date. Jepsen (1940, p. 240, 241) concurred in this assignment. In 1941, I found additional *Coryphodon* material as well as a fragmentary jaw of *Hyracotherium* (eohippus) in the Kingsbury conglomerate member on a hilltop 4.5 miles southwest of Buffalo (Brown, 1948b) and a jaw of *Hyracotherium* about 200 feet above the conglomeratic base of the recognized varicolored Wasatch on the east side of the Carl Volkner ranch, 5 miles north of Sussex.

At localities on the west side of the basin where the Kingsbury conglomerate is absent and lignitic strata of the Fort Union and Wasatch are apparently conformable, the Paleocene-Eocene contact was tentatively considered to be (Baker, 1929, p. 28; Thom, 1935, p. 66) at the top of the Roland coal bed. This bed, named by Taff (1909, p. 100) from a mine 2 miles northeast of Dietz, has been traced more or less confidently around most of the Powder River Basin and some of the higher parts of adjoining Montana on the divides between Little Big Horn and Tongue River and between Tongue River and Powder River. In areas of the Spotted Horse coal field, Olive (1957, p. 10–20) found that the Roland coal is discontinuous by reason of an erosion interval and, therefore, chose as the Paleocene-Eocene contact the top of a limy shale and sandstone containing many fresh-water invertebrates, from 5 to 65 feet above that coal. Yen (1946) identified the mollusks as Paleocene in age. The most notable change in the fresh-water invertebrate fauna appears about 200 feet above this level, and there, just below the Felix coal, I found the first evidence of *Salvinia preauriculata* Berry in the sequence. It may be that the strata once or now present between the Roland coal and the Felix coal represent the time equivalent of the Sentinel Butte member in western North Dakota. The boundary, it would thus seem, is a little higher in the section than the Roland coal, the level previously assumed.

Hanna and Carbon Basins.—In 1918, C. F. Bowen reviewed the stratigraphy of this area, the map and description of which accompany the fuller report by Dobbin, Bowen, and Hoots (1929). Bowen's particular purpose was to show that A. C. Veatch's great unconformity between the Medicine Bow formation ("Lower" Laramie) and Ferris formation ("Upper" Laramie) is actually 6,000 feet higher in the section and separates the Ferris and Hanna formations. The Medicine Bow formation plus the lower coal-barren 1,000 feet of the Ferris formation comprise a dinosaur-bearing unit, with Cretaceous plants (Dorf, 1938; Brown, 1943a), between the Fox Hills sandstone and the base of the Paleocene, which here, as in eastern Montana, is marked by the appearance of lignite beds after a sequence of coal-barren sandy and conglomeratic strata. In 1938 and 1940, I found typical Fort Union plants immediately above these basal lignitic beds. The Cretaceous-Paleocene boundary, therefore, cuts through the basal part of the Ferris formation in the Hanna and Carbon Basins. Only a small triangular patch of what in my opinion is Paleocene Ferris remains in the Carbon Basin just south of Como. The remainder of the Ferris in that basin appears to be the equivalent of the coal-barren Cretaceous Ferris in the western part of the Hanna Basin. One collection of apparently brackish-water invertebrates I found in the old railroad cut in NW¼ sec. 30, T. 22 N., R. 80 W., 4 miles west of Carbon, is, however, not diagnostic.

As stated, an unconformity representing erosion that truncated the edges of 20,000 feet of gently inclined strata separates the Ferris formation from the overlying Hanna formation (Bowen, 1918, p. 232) in the Hanna and Carbon Basins. Most of the present productive coal mines in these basins are in the Hanna formation, now believed to be of Wasatch age.

In the Rock Creek oil field, southeast of the Carbon Basin, Dobbin, Hoots, Dane, and Hancock (1929) mapped areas of the Hanna formation but found no definite evidence of the presence of the Ferris formation.

Great Divide Basin.—Ten miles west of Rawlins westward-dipping Cretaceous strata are succeeded by the coal-bearing Tertiary of the Great Divide Basin. The Cretaceous-Paleocene contact is just east of Knobs Station on the Union Pacific Railroad, at the base of conglomeratic beds just below the first lignites of the Tertiary sequence. E. E. Smith (1909, p. 233), discussing the lignitic zone above this horizon, called it "undifferentiated Tertiary," and found that it was mappable for a considerable distance because there occurs at its top a distinctive conglomerate with granite pebbles which he regarded as the base of the coal-bearing Wasatch.

On the west side of this basin, that is, on the east flank of the Rock Springs uplift, the Cretaceous-Paleocene boundary crosses U.S. Highway 30 at a point 7 miles east of Point of Rocks. There the transition from the somber-colored Cretaceous to the lighter colored Paleocene is plainly visible in the ridge north of the highway and is at the contact of the Black Buttes coal group with the Black Rock coal group as mapped by Schultz (1909). This contact, as noted by Schultz (1909, p. 264) and Stanton (1909, p. 273), is similarly clear about 2 miles southeast of Black Buttes Station (pl. 1, fig. 3), where the somewhat conglomeratic basal white sandstone of the Black Rock coal group overlaps unconformably the shales of the Black Buttes coal group (Cretaceous). No diagnostic mammalian remains have been found in the Cretaceous and Paleocene strata of this area.

North of Wamsutter, part of the Great Divide Basin is called the Red Desert. Its uranium-bearing strata (Masursky and Pipiringos, 1959) are Eocene in age, but on its northern border is Bison Basin, an eroded anticlinal structure exposing late Paleocene strata overlain by younger rocks. In 1952 I was present at and in part responsible for the discovery of a rich mammalian fauna in the Paleocene strata (Gazin, 1956a). A few plants were found in surrounding correlative beds.

Rock Springs.—The city of Rock Springs is underlain by the Mesaverde formation on the west flank of the Rock Springs dome. In 1952, on Killpecker Creek, about 3 miles northwest of Rock Springs, I found fossil plants indicating that 1,000 feet, more or less, of the nonmarine lignitic strata above a brackish-water sequence of the Lance formation are Paleocene in age—the first time strata of this age were recognized on the west flank of the uplift. Outcrops of these Paleocene strata appear northward from Killpecker Creek to about 3 miles south of the Boars Tusk, from whence they strike northeastward and pass under a cover of younger sediments. To the south the unconformable contact of Mesaverde and Tertiary can be seen (pl. 3, fig. 4) just east of Little Bitter Creek, at a point 2.5 miles above its mouth. These Tertiary strata may be divided into a lower, somber-colored lignitic series and an upper, coal-barren, variegated sequence. The lower strata here, as well as on the southeast side of the Rock Springs dome just north of Vermillion Creek, yield fossil plants of Fort Union aspect, but the only mammalian remains I have found in them are fragmentary teeth of *Coryphodon*? sp., which are not diagnostic. From the overlying varicolored sandy nonlignitic strata, I collected in 1941 a skull of *Meniscotherium* as well as other mammalian remains diagnostic of Wasatch age (Gazin, 1952, p. 13, 62). Until further evidence is found, the probability that the Paleocene-Eocene boundary separates these two lithologically different zones of strata must remain conjectural.

West of Casper.—With C. E. Dobbin and F. S. MacNeil, I examined the Cretaceous-Paleocene section on Poison Spider Creek in 1936 and found Paleocene plants in the strata previously identified as Fort Union. In the Wind River Basin, isolated patches of Paleocene rocks make an irregular elliptic pattern along the border of the Wind River formation (Eocene). At Twin Buttes, 30 miles northwest of Riverton, the outcrops yield shark teeth, indicating an origin comparable to that of the Cannonball member in North Dakota (Keefer, 1961, p. 1315, 1322).

Southwestern Wyoming.—The Paleocene of southwestern Wyoming includes the Evanston and Almy formations described by A. C. Veatch (1907) and Tracey and Oriel (1959). The Evanston yields diagnostic plants in the vicinity of the coal mines near Almy and in a Union Pacific Railroad cut about 1 mile east of the Evanston station. Strata in Fossil Basin probably equivalent to the upper part of the type Evanston contain Tiffanian mammals (Gazin, 1956a), and the Almy formation on La Barge Creek near La Barge yields mammalian remains said by Gazin (1942; 1956b) to be Clarkforkian in age. Northward in Hoback Canyon a thick sequence of sandstones, conglomerates, and shales, called by Eardley and others the Hoback formation, contains only fragmentary plant remains; but Dorr (1952; 1958) has found a considerable mammalian fauna indicative of Paleocene age. It seems likely that these strata are in part, at least, correlative with the Evanston and Almy formations to the south and with part of the Pinyon conglomerate just south of Yellowstone National Park. In the latter at Whetstone Falls on a tributary of Pacific Creek, J. D. Love and I found well-preserved Paleocene plants.

Overlying the Almy formation is a unit composed of light-colored rhyolitic ash and thin fresh-water limestones, which Veatch called the Fowkes formation. The limestones contain invertebrates, fish remains, reptiles, and a few plants. One of the latter is a fern, *Acrostichum hesperium* Newberry, a species unreported from pre-Eocene strata. This occurrence suggests strongly that the Fowkes is of Eocene age and that the Paleocene-Eocene boundary separates the Almy and Fowkes formations.

Bighorn Basin.—Jepsen has called the Paleocene strata in the northwest part of the Big Horn Basin the Polecat Bench formation. Of its boundaries he says (1940, p. 232):

> No angular unconformity between the Cretaceous and the Paleocene sediments has been detected at Polecat Bench, although the fossils suggest a disconformity or hiatus. At the top of the Polecat Bench formation there may be, locally, angular unconformities between it and the overlying Gray Bull beds, but in most places where the contact has been determined the units are conformable. Conglomerates and thick beds of coarse bluff sandstones mark the base of the Gray Bull in several localities.

On the other hand, Hewett (1926, p. 38) reports the following conditions in the southwest part of the Basin:

> The upper limit of the Fort Union is the basal sandstone, generally conglomeratic, of the Wasatch formation. This sandstone is unconformable with the Fort Union, for it may be traced from the northeast corner of T. 48 N., R. 100 W., where it overlaps the base of the Fort Union formation, both northward and eastward to points where the Fort Union is about 2,000 feet thick. Here and there the surface of unconformity is readily recognizable * * *. [See Hewett, pl. 16.]

More recently, Van Houten (1944, pl. 7) has mapped the Eocene formations above the Polecat Bench formation in the Bighorn Basin as the Willwood and Tatman formations, the base of the Willwood being regarded, at least locally, as the Paleocene-Eocene boundary. The upper part of Van Houten's Willwood is equivalent to those strata generally understood to be Eocene "Wasatch," but the basal strata contain Clark Fork or upper Paleocene mammals. Van Houten's comparisons with other areas, however, do not include any reference to the Wasatch east of the Bighorn Mountains in the Tongue River and Powder River Basins, but this Wasatch appears to be stratigraphically, lithologically, and paleontologically of the same age as that part of the Willwood above the zone of Clark Fork mammals.

COLORADO AND NEW MEXICO

Denver Basin.—The strata (table 1) involved in the location of the Cretaceous-Paleocene boundary in this area crop out in a roughly oval, synclinal basin extending from Brighton to Colorado Springs and from the Rocky Mountain front to points 50 miles eastward on the Plains.

TABLE 1.—*Latest Upper Cretaceous and earliest Tertiary formations in the Denver Basin, Colorado*

[Dotted line indicates the position of the Cretaceous-Paleocene contact, according to Brown (1943a, table 2, p. 78)]

North	South
Denver formation (400–1,200 ft): Arenaceous clays, shales, basalt flows,	Dawson arkose (2,000±ft): Arenaceous clays, shales, coals, rhyolite flows,
andesitic sandstones.	andesitic and arkosic sandstones,
Arapahoe formation (500±ft): Conglomerate, arenaceous shales.	conglomerate, arenaceous shales.
Laramie formation (600–1,200 ft): Sandstones, shales, clays, coals.	Laramie formation (300±ft): Sandstones, shales, clays, coals.
Fox Hills sandstone (800 ft): Arenaceous marine shales, sandstones.	Fox Hills sandstone (200–300 ft): Arenaceous marine shales, sandstones.

Along the western side of the basin, there lies upon the Laramie formation a conglomerate, called the Arapahoe conglomerate, whose vertical to gently dipping outcrops can be seen at intervals from Golden to Jimmy Camp Creek, east of Colorado Springs. It is inferred that this conglomerate reflects diastrophic movements to the west and represents a change from the lignitic conditions of the Laramie, but it is not clear how much erosion of the Laramie occurred before the conglomerate was deposited. Emmons, Cross, and Eldridge (1896, p. 29, 31) estimated that probably 600 feet may have been removed locally. Because this erosional contact offered the first visible evidence of discordance after the deposition of the Laramie, it was made the upper boundary of that formation in accord with King's definition that the Laramie comprises the conformable lignitic strata above the Fox Hills sandstone; and it also became to many geologists the Mesozoic-Cenozoic boundary, despite the fact that remains of ceratopsian dinosaurs were known to occur indigenously in the base of the Denver formation several hundred feet higher in the section. The fossil plants found in the strata between the conglomerate and those containing the latest dinosaurs were originally referred to the Tertiary flora, whose remains, however, in this area are now known only from the Denver formation and Dawson arkose above the dinosaur-bearing strata.

The paleozoologists were reluctant to include any dinosaur-bearing beds in the Tertiary, and consequently the question of the location of the Cretaceous-Paleocene boundary remained under active discussion and investigation. In my fieldwork in the Denver Basin, I applied the same methods I had used successfully in Montana and Wyoming, namely, a concentrated study of the zone in the vicinity of the latest dinosaurian remains. On June 13, 1939, on the bare slope on the southeastern flank of South Table Mountain, in the SW¼NW¼ sec. 31, T. 3 S., R. 69 W., about 3 miles east of Golden, I found some mammal jaws and teeth, together with fragments of turtles and crocodiles, and impressions of Tertiary leaves in light-colored sandy clay just 50 feet above an outcrop of drab-green sandy beds containing the highest dinosaurian remains in the Denver formation. In 1940, I found additional mammal specimens at the same spot. These, together with others, found at approximately the same stratigraphic level, but in the upper part of the Dawson arkose, in SW¼NE¼ sec. 6, T. 13 S., R. 64 W., on Corral Bluffs, 11 miles east of Colorado Springs, were identified and described by Gazin (1941b) as Paleocene forms, indicating an age equivalent to the Puercan or oldest division of the Tertiary in the paleozoological standard.

From this evidence, checked by that of the fossil plants, it is possible to locate the Cretaceous-Paleocene boundary in the Denver Basin fairly closely (Brown, 1943a, fig. 1), but this contact is not marked by an evident unconformity nor always by distinguishable differences in lithologic composition.

The youngest indurated strata of the Denver Basin occur in the vicinity of Castle Rock and were originally called the Monument Creek group. Subsequently, the upper part of this group was differentiated as the Castle Rock conglomerate of Oligocene age, whereas the lower part was included in the upper part of the Dawson arkose. This phase of the Dawson arkose has been described as unconformably overlying Laramie, Arapahoe, and Denver strata (Emmons, Cross, Eldridge 1896, p. 195–199). No mammals have been taken from these beds, and such plants as have been found are equivocal, although they indicate that the strata are not much younger than the underlying mammal and plant-bearing Dawson and Denver. The base of these strata may mark the Paleocene-Eocene boundary, but tentatively I regard the Paleocene as extending upward to the base of the Castle Rock conglomerate.

Walsenburg, *Trinidad*, *and Raton*.—Along the Rocky Mountain front west of Walsenburg and Trinidad, Colo., and northwest of Raton and Cimarron, N. Mex., is a dissected elevated area that includes the Raton Mesa and adjacent coal fields. The sequence of sedimentary strata in this region, pertinent to the present discussion, has been classified as follows, beginning at the bottom: Pierre shale, Trinidad sandstone (100 ft±), Vermejo formation (425 ft±), Raton formation (1,800 ft±), Poison Canyon formation (2,000 ft±), Cuchara formation (500 ft±), and Huerfano formation (3,500 ft±). The chief concern here is with the coal-bearing Vermejo and Raton formations. Between these formations W. T. Lee (1917, p. 55, 56) recognized an erosional boundary that was magnified into a considerable unconformity and stated to be the line separating the Mesozoic and Cenozoic. From several weeks' field study of Lee's sections, I confirm the presence of the unconformity and the distinctness of the basal conglomerate of the Raton formation as compared with any other coarse sandstone or conglomerate in either the Vermejo or Raton. There is an indefinable "sugary" texture and aspect about the matrix of this conglomerate that, once seen, may be readily identified wherever the conglomerate occurs throughout the area. Depending upon Knowlton's study of the floras, Lee held that the Vermejo formation is of Montana and the Raton of Tertiary age. So far as I am aware, no mammalian remains have been found in these strata. Additional collections and a restudy of the floras indicate that Knowlton's conclusions need amendment and that, although some of the earliest strata now assigned to the Vermejo may be of Montana age, the bulk of the formation is of Laramie age (Brown, 1943a, p. 82). Immediately above the Vermejo-Raton boundary is a sequence of relatively barren deposits, but overlying this zone are the productive coal measures of the Raton formation from which the greater part of the Raton flora was described. No one questions that this is a Tertiary flora, but doubts arise concerning the age of the relatively barren basal strata. In these, at the Bowen mine, locality 109 (Lee, 1917, p. 128, 279), and at locality 30 (Lee, 1917, p. 90), about 50 feet above the basal conglomerate of the Raton, was found the problematic Upper Cretaceous plant, *Paleoaster inquirenda* Knowlton. As this plant has never been collected elsewhere from strata proved to be Tertiary, it may indicate here that an indefinite thickness of the basal Raton is Late Cretaceous in age. If so, the erosion interval between the Vermejo and Raton formations, while appreciable, does not mark the end of the Cretaceous but represents only an episode in Late Cretaceous history and is apparently correlative with the similar interval that preceded the deposition of the Arapahoe conglomerate (Cretaceous) in the Denver Basin.

In the Raton Mesa and adjacent coal fields, the Raton formation is overlain unconformably, according to Johnson (1958; 1959, p. 101), by the coal-barren massive coarse-textured sandstones and conglomerates of the Poison Canyon formation. However, except for the lack of coal in the Poison Canyon, the two formations resemble one another in general color and lithologic composition. No mammalian fossils have been taken from the Poison Canyon formation, and the few collections of fossil plants are similar to those from the Raton, or can be duplicated from the Paleocene in adjacent regions. The probabilities favor the top of the Poison Canyon formation as the Paleocene-Eocene boundary. The Cuchara formation (Johnson and Stephens, 1954, 1955), unconformably overlying the Poison Canyon formation, is generally regarded as of early Eocene age, because the next overlying beds, the Huerfano formation, contain Bridger or middle Eocene mammals.

Canon City coal field.—This field occupies an isolated Cretaceous-Tertiary(?) area midway between the Denver Basin and the Raton Mesa coal field. The critical physical feature here, as in the Raton field, is an unconformity between the Vermejo (Laramie) formation and overlying conglomerate (Washburn, 1910, p. 348–350), which can be seen clearly in the vicinity of Alkali Gap south of Canon City. The conglomerate occupies the same stratigraphic position as that at the base of the Raton formation in the Raton field, but its lithologic composition is notably different. On the other hand, it also occupies the same stratigraphic position as the Arapahoe conglomerate in the Denver Basin and is remarkably like it in lithologic composition. It would seem, therefore, that orogenic movements on the west side of these basins of deposition in the later part of Vermejo and Laramie time were reflected in erosional activity on the upturned edges of the sediments and in the subsequent deposition of conglomerate on the eroded surface.

The small patches of strata overlying the conglomerate in the Canon City field were called Denver(?), but as I found no identifiable fossils in them, I am uncertain of their age.

North, Middle, and South Park.—In North Park, according to Beekly (1915), from 4,000 to 5,000 feet of fresh-water beds, called the Coalmont formation, lie unconformably on the marine Pierre shale (Cretaceous). In some parts of the area, they underlie variegated sandy beds believed to be Wasatch (Eocene); at others they underlie whitish beds that may be White River (Oligocene); and at still other localities they underlie the sandy tuffaceous North Park formation (Pliocene?). The lower 3,000 to 4,000 feet of the Coalmont are dark colored and coal bearing, whereas the overlying 2,000 feet are light-colored barren sandstones and conglomerates. Beekly suggested that these lithologic differences might serve to distinguish two formations, but confirmatory paleontologic evidence for such a division is lacking. The fossil plants on both sides of this tentative boundary are identical Paleocene forms. No diagnostic animal remains have been taken from the upper beds. This suggests another interpretation of the twofold character of the formation, namely, that the total 5,000 feet, more or less, of the Coalmont may be equivalent to the Paleocene part of the Ferris formation in the Hanna and Carbon Basins across the Colorado-Wyoming boundary to the north. The Paleocene Ferris approximates 5,500 feet in thickness and also has a lower coaly part overlain by an upper part that, with the exception of one or two relatively small seams, is nearly coal barren. Tentatively I am regarding the entire Coalmont formation as of Paleocene age, but the discovery of some species of pollen in the upper part of the formation may, on further confirmation, indicate that that part of the Coalmont is Eocene in age (Hail and Leopold, 1960).

Middle Park is separated from North Park by the Continental Divide, the former being west and the latter east of the Divide. About 5,000 feet of strata composed of a basal breccia and conglomerate, andesitic shales and sandstones, and thin coal seams are called the Middle Park formation. These beds, at least in part, are lithologically similar to the Denver and Coalmont formations and contain a similar flora (Cross, 1892). They are of Paleocene age and lie unconformably on marine strata of Montana age.

Narrow strips of Paleocene outcrops may be seen between Jefferson and Hartsel on the east side of South Park, which lies east of the Continental Divide. These are dark, sandy, and conglomeratic strata that overlie lignitic Laramie and underlie light-colored tuffaceous beds that may be somewhat younger than Paleocene. Chiefly through the efforts of J. H. Johnson and C. H. Behre, Jr., collections of fossil plants have been made that indicate close similarity to the flora of the Denver formation (Stark and others, 1949).

Rifle and DeBeque.—The Grand Hogback extending from New Castle on the Colorado River, northwestward to Meeker, is largely composed of the Mesaverde and related coal-bearing formations (Gale, 1910). Unconformably upon these strata, lie approximately 1,200 feet of drab and varicolored beds, which in turn are overlain by the more distinctly yellow, red, and green beds of the typical Wasatch. A small collection of fossil plants was obtained by T. W. Stanton in 1907 in Rifle Gap, 6 miles north of Rifle, in gray sandy shales at a level 170 feet above the top of the Mesaverde formation; and a larger collection was obtained at the same locality in 1937 by Bryan Patterson, of the Chicago Natural History Museum. In

1939 and 1940, I obtained additional material at the same locality. Many species in these collections also occur in the flora of the Denver formation, indicating Paleocene age. These and especially the immediately overlying varicolored beds are apparently the stratigraphic equivalents of similar beds (Plateau Valley beds of Patterson) in the Plateau Valley southwest of DeBeque, that have yielded upper Paleocene mammals. Patterson's Plateau Valley beds are the Paleocene portion of Whitman Cross's Ruby formation the base of which may be, in part at least, equivalent to the Ohio Creek conglomerate. Along U.S. Highway 24 at the first hill east of DeBeque is an outcrop of carbonaceous shale about 100 feet beneath yellow sandstones of the Wasatch formation. The small collection of fossil plants obtained there in 1939 proved not to be diagnostic.

From DeBeque westward to the Colorado-Utah line, the Paleocene is apparently represented by an unfossiliferous sandstone-shale unit, 155–370 feet thick, lying unconformably between the Hunter Canyon formation of the Mesaverde group and the varicolored Wasatch. This unit was described as Tertiary(?) sandstone by Erdmann (1934, p. 53).

I conjecture, but have no fossils to substantiate it, that the Paleocene beds of the Rifle Gap section, or their equivalents, may be present, although perhaps intermittently, along the west side of the Grand Hogback to Meeker, thence to the west of the Danforth Hills and around to Rangely west of Cathedral Bluffs.

The Ohio Creek conglomerate in the Anthracite, Crested Butte, and Grand Mesa regions (Lee, 1912, p. 48) is a conglomeratic sandstone 100 to 200 feet thick, occurring in isolated patches and said to rest unconformably upon Upper Cretaceous strata and to underlie the Wasatch formation. It has been assigned to the Tertiary, but the only fossils found in it have been fragments of carbonized wood. Consequently, its equivalence to the Paleocene of Rifle Gap, to Erdmann's Tertiary(?) sandstone, and to Fisher's Tuscher formation of the Book Cliffs in Utah, though stratigraphically indicated, is not proved.

Northwestern Colorado.—In the region extending east and west of Cedar Mountain, 5 miles northwest of Craig, is a 2- to 3-mile-wide belt of coal-bearing strata, about 800 feet thick, assigned originally to the "post-Laramie," now Fort Union (Gale, 1910, pl. 16; Sears, 1924, pl. 35). The basal strata of this sequence are coarse sandstones or conglomerates that lie unconformably on Upper Cretaceous rocks of Laramie (now called Lance) age. No mammalian remains have been found in these strata, but such vetebrates, invertebrates, and plants as have been collected, particularly in the sandstones, dark sandy shales, and clays cropping out on the hillsides in secs. 28 and 29, T. 8 N., R. 93 W., indicate Paleocene age. Overlying the Fort Union of this region are the variegated sandstones and shales of the Wasatch (Sears, 1924, p. 292).

Southwestern Colorado and New Mexico.—In 1874, E. D. Cope discovered and named the mammal-bearing Puerco formation in the San Juan Basin of Colorado and New Mexico. The strata were described by Gardner (1910b) and Reeside (1924), and the mammals by Matthew (1937). Reeside (1924, p. 34) suggested that the Puerco formation is possibly equivalent to the upper beds of the Animas formation, a conclusion that appears to be confirmed by the fieldwork of C. H. Dane (1946) and also by the evidence of the fossil plants from both formations, the bulk of those described as Tertiary by Knowlton (1924) from the Animas formation having come from the upper beds. Dinosaurian remains have been taken from the lower beds of the Animas and their lateral equivalent, the Ojo Alamo sandstone; but only a few fragmentary, indeterminable plants have been found in these basal beds. It seems most probable, therefore, that the Cretaceous-Paleocene boundary passes through the basal part of the Animas formation and is the lower limit of the Puerco formation.

The variegated clays and sands of the Puerco and Torrejon formations are not readily separable lithologically, and together the two formations are sometimes called the Nacimiento group. This group is overlain by the "Tiffany beds" now assigned to the upper Paleocene, and these are covered by Eocene beds that Simpson (1948) proposed to call the San Jose formation.

In the Cerillos and Hagan coal fields, New Mexico, the Mesaverde formation is unconformably overlain by varicolored, sandy, and conglomeratic strata called the Galisteo sandstone. According to Lee (1913, p. 288, 1917, p. 184) some petrified wood and fossil leaves were found in these beds. Similarly, a small area on the southeast side of Elephant Butte Dam displays an exposure of reddish beds overlying coal-bearing strata and containing large quantities of fossil wood and some dinosaur bones (Lee, 1907, p. 57). Because of this resemblance Lee was disposed to regard the two occurrences as of the same age, namely Late Cretaceous. Recently (Stearns, 1943, p. 310; 1953, p. 467), however, mammalian remains, particularly of the titanothere *Teleodus* and the carnivore *Uintacyon*, have been found in the uppermost beds of the Galisteo sandstone. They indicate a probable late Eocene age for those strata. As the Galisteo at some localities is 4,000 feet thick, its lowermost beds may be considerably older.

Southwest of Gallup, Winchester mapped a number of outcrops which Sears (1925) has designated Tertiary undifferentiated. Whether any of these strata may be Paleocene has not been determined.

ARIZONA

From the Navajo country of Arizona and New Mexico, Gregory (1917) reported outcrops of unfossiliferous sandstone and shale, which he called Chuska sandstone and Tohachi shale, the former being regarded as of Wasatch and the latter of Puerco and Torrejon age on stratigraphic and lithologic grounds. Until fossils are found in the remarkably barren Chuska sandstone, its age will continue to remain doubtful. The Tohachi shale, however, is now known to be Late Cretaceous in age (Repenning, 1954).

UTAH

The Cretaceous and Tertiary formations of the Wasatch Plateau in central Utah were described by Spieker and Reeside in 1925 and by Spieker in 1931. At that time, a hiatus was recognized between the Cretaceous Price River formation and overlying beds mapped as Wasatch. Since then, the basal part of this "Wasatch," beneath the Flagstaff limestone, averaging 1,500 feet in thickness, has been called the North Horn formation. The lower 800 feet of the North Horn has been found to contain dinosaurian remains indicative of Cretaceous age (Spieker, 1946, p. 134). The upper 600 feet has yielded mammalian remains described by Gazin (1941a) as the Dragon fauna intermediate in development between the Puerco and Torrejon faunas. According to Gazin, "the variegated clays of the Paleocene series [called by Gazin the Joes Valley member] resemble those in the lower portion of the North Horn formation but are usually not so thick and appear to be more gaudily colored and with conspicuous white channel sands." The only plants found in the North Horn are macerated, unidentifiable fragments of dicotyledonous leaves.

Eastward in the Book Cliffs toward the Utah-Colorado boundary, Fisher (1936) mapped intermittent exposures of a light-colored unfossiliferous sandstone and shale unit, 130 to 600 feet thick, apparently disconformable between the Cretaceous Price River formation and the varicolored Tertiary Wasatch. He called this unit the Tuscher formation and suggested that it might be the equivalent of the Ohio Creek conglomerate in the Anthracite-Crested Butte region of Colorado. Tentatively, I am regarding the Tuscher formation as probably of Paleocene age and perhaps equivalent to the similarly situated unfossiliferous unit in Colorado immediately east of Fisher's area which Erdmann (1934, p. 53) called Tertiary(?) sandstone. It should be stated, however, that Erdmann (p. 51) considered the Tuscher formation, in whole or in part, to be equivalent to a portion of the Hunter Canyon formation of the Mesaverde group.

Westward from the outcrops of the Wasatch formation described by Spieker and on the west side of the Sevier River valley in the escarpment of the Gunnison Plateau are outcrops assigned to the Tertiary. Richardson (1906, p. 281) described these beds as light-colored, gray, and red shales with interbedded limestones and sandstones, approximating 2,000 feet in thickness. How much, if any, of this sequence is Paleocene remains to be determined.

In the vicinity of Henefer and Coalville, Summit County, are outcrops of variegated shale, sandstone, and conglomerate that Eardley (1944, p. 840) called the Henefer formation and correlated tentatively, on stratigraphic grounds, with the Evanston formation (early Paleocene) of southwestern Wyoming. Above the Henefer is a conglomeratic sequence with shales and coal seams that he assigned to the Almy formation (late Paleocene).

GULF COAST

The lower limits of the Tertiary on the gulf coast have been described chiefly by Vaughan (1900), Stephenson (1915), Trowbridge (1932), and Gardner (1935). The Paleocene there is comprised in the Midway formation which is reported as unconformably overlying the Cretaceous, and also at most localities as unconformably underlying the succeeding Eocene deposits of the Wilcox group. The Midway is almost entirely marine, and has yielded few fossil plants. Simpson (1932) has reported the almost miraculous recovery of a Paleocene mammal, *Anisonchus fortunatus* Simpson, from probable Midway strata in a core from a depth of 2,460 feet in the Junior Oil Co. Beard No. 1 well, sec. 9, T. 18 N., R. 16 W., Caddo Parish, La. The only correlation, therefore, between the Paleocene of the Gulf Coast and that of the western interior is in the faunas of the Midway and Cannonball which are said to have a number of genera of mollusks and species of foraminifers in common.

In the trans-Pecos region of Texas, particularly in the vicinity of Fort Davis and the Barilla Mountains, Upper Cretaceous sandy and shaly limestones identified as Taylor marl are unconformably overlain by variegated deposits of calcareous clay and volcanic ash interbedded with other volcanic rocks (Jones, 1938, p. 1432; Ives, 1941, p. 343). The basal tuffs of the latter strata contain fossil plants in the area of the Barilla Mountains. Six species of these were described by Berry (1919), who concluded from them "that the basal tuffs in the Barilla Mountains are post-Cretaceous and pre-Wilcox in age and that they and the volcanic activity which they represent were probably contemporaneous with the floras and similar volcanic activity reflected in the Raton and Denver formations and elsewhere in the Rocky Mountain Region." As the plant specimens are fragmentary and the species indicated few, comparisons with the floras of the Raton and Denver formations are dubious and inconclusive.

ATLANTIC COAST

The age of the Vincentown sand of New Jersey was long in dispute. Greacen (1941) reviewed the whole problem and, although inclined to regard both the Vincentown and the underlying Hornerstown marl as Tertiary, did not decide whether they should be called Paleocene or Eocene. Cooke and Stephenson (1928), however, assigned them to the Eocene without qualification. Spangler and Peterson (1950) inclined toward allocating the Hornerstown to the Paleocene.

Near Brightseat in Maryland, strata overlying Upper Cretaceous beds contain foraminifers and megafossils said to indicate Paleocene age (Bennett and Collins, 1952). Previous studies by Shifflett (1948) and Cushman of drill cuttings from a water well near Upper Marlboro also revealed foraminifers probably of Paleocene age. However, none of these writers suggested correlations of the Maryland deposits with the Hornerstown marl to the north or the Midway formation to the south. Johnson and Richards (1952) suggested that the lower part of the Hornerstown is Midway (Paleocene) and the upper part is Wilcox (Eocene) in age. Loeblich and Tappan (1957) referred the Hornerstown and Vincentown to the Paleocene, but Miller (1960, text fig. 2) concluded that the bulk of the Hornerstown is Paleocene and the uppermost part is Eocene in age.

PACIFIC COAST

Resting upon a basement of igneous and metamorphic rocks, the Swauk is apparently the earliest Tertiary formation of Washington. At some localities it contains leaves that inclined Knowlton to regard the formation as probably of the same age as the Denver and Fort Union formations (Weaver, 1937, p. 47–49). An Eocene age appears to be a more likely assignment.

In 1939 the U.S. Geological Survey recognized the Martinez formation of California as Paleocene in age. It is probable that nonmarine deposits containing leaves near Elsinore, Riverside County, may also be Paleocene.

ARCTIC REGIONS

Greenland, Alaska.—On the west coast of Greenland, particularly the south coastal region of the Nugsuak peninsula, which is just north of Disko Island and well within the Arctic Circle, there are outcrops of a Cretaceous-Tertiary section that have been examined by a number of explorers and geologists (Berry, 1916b, p. 186). Accounts of the geology and paleontology of this area are to be found in the publications of Oswald Heer (1868–83), White and Schuchert (1898), Seward (1926), Seward and Conway (1935), Imlay and Reeside (1954), and others. The generalized section for the Nugsuak peninsula includes the following strata, beginning with the oldest Cretaceous: Kome (said to be Lower Cretaceous), Atane (approximately middle Upper Cretaceous), Patoot (Upper Cretaceous), lower Atanekerdluk (Upper Cretaceous), and upper Atanekerdluk (Paleocene). This sequence, comprising shales, lignites, sandstones, ironstones, and thick beds of basalt, lies unconformably upon an old crystalline metamorphic basement and is intruded by many dikes. Fossil plants have been collected from all the named divisions of the sequence. The Atane beds, or their equivalents, have also yielded marine invertebrates that Stanton identified as belonging to the Senonian of Europe, approximately equivalent to the Montana group of the Western United States (White and Schuchert, 1898, p. 356). The Patoot beds likewise have yielded marine invertebrates, but Stanton considered their evidence somewhat equivocal (White and Schuchert, 1898, p. 362). Heer, however, assigned these beds to the uppermost Cretaceous. Their flora is relatively rich in species and bears considerable resemblance to that from the Laramie, Lance, and Hell Creek formations of the Western United States and to the Late Cretaceous of Alaska. The bulk of the "Miocene" plants described by Heer from Atanekerdluk came from the strata not far above a 125-foot conglomeratic sandstone that crops out 1,000 feet above sea level and overlies the Patoot beds. White and Schuchert assumed that this sandstone probably marks the base of the Tertiary. As pointed out by Saporta, the flora of these Tertiary beds resembles that from Sezanne and Gelinden in the Paris Basin and is of Paleocene rather than "Miocene" age, a term used by Heer apparently in the sense of early Tertiary rather than in its modern specialized meaning. Except for a few insects, no animal remains have been reported from these beds. That some of the highest Tertiary strata of this series may be of Eocene age is a probability that should be considered by future collectors.

Cretaceous and Tertiary deposits occur on the east coast of Greenland. Mathiesen (1932) contributes references to descriptions of this terrain and a report on some of the fossil plants found in those strata. He concludes that the plants with which he was concerned indicate an early Tertiary age.

The Cretaceous and Tertiary floras of Alaska have been described chiefly by Hollick (1930, 1936), although a number of other paleobotanists and paleozoologists have contributed identifications of Alaskan fossils. P. S. Smith (Hollick, 1936, p. 24; Smith, 1939) has reviewed the areal geology. Concerning the Cretaceous-Tertiary boundary G. C. Martin (Hollick, 1930, p. 36) concluded:

> Upper Cretaceous time ended with the complete withdrawal of the sea from the Alaskan area and probably was closely followed by the folding and erosion of the Cretaceous rocks. The Cretaceous rocks of Alaska are highly folded everywhere, and many of them are cut by intrusive rocks and by metalliferous veins. In many places it is not possible to determine the exact date of the folding, intrusion, and mineralization, especially as some of the Tertiary rocks have been similarly affected. It is believed, however, that at least part of the folding, intrusion, and mineralization dates from about the end of Cretaceous time. The earliest post-Cretaceous rocks in most of Alaska are the widespread Tertiary coal-bearing beds. Although these rocks are highly folded in some places and have been cut by dikes and veins, they are in general notably less indurated, folded, and altered than the Cretaceous rocks. In some places there is clear proof of an unconformity at the base of the Tertiary rocks, and the writer believes that the Cretaceous rocks of Alaska were uplifted and eroded, if not folded, immediately at the end of Cretaceous time in all parts of the Territory.

The Cretaceous plants described by Hollick are said to be from two distinct horizons (1930, p. 34) the upper of which, according to the correlation chart facing page 34, is considered equivalent to the Lance and Laramie formations of the Western United States. The flora of this division comprises many species identical with or at least closely related to species in the Lance and Laramie floras.

The Tertiary flora described by Hollick and generally considered Eocene in age is a composite of a number of floras whose separation has not yet been attempted, and may not be possible until additional fieldwork supplies further stratigraphic and paleontologic information, particularly mammalian remains.

EUROPE

The Paris and London Basins, as well as a few other areas in Europe, display contiguous outcrops of Cretaceous and Tertiary strata. Unfortunately, but quite naturally, different parts of the sequence are present at different localities, and these are diversely fossiliferous, so that matching of the several sections paleontologically is not altogether satisfactory. Consequently, Europeans have had a Mesozoic-Cenozoic boundary problem known as the Danian-Montian question. The strata and fossils involved in this problem have been discussed by Saporta and Marion (1873, 1878), Kayser (1908, p. 531–539), Berry (1917, p. 175–185), Simpson (1937a, p. 6), Wells (1938, p. 193–202), Tromp (1949, p. 673–676), Hofker (1960, p. 584–588), Jeletsky (1960, p. 1896), Brown (1961, p. 632–A), Chandler (1961, p. 16–23), and others. The consensus now seems to be that the Danian, in whole or large part, is early Paleocene in age.

Although Kayser considers the Sparnacian to be the upper stage of the Paleocene, Simpson, supported by Wells, assigns it unqualifiedly to the early Eocene. In the London Basin the Sparnacian includes the Woolwich and Reading beds. Beneath these are less than 100 feet of the marine Thanet sands, which Kayser assigns to the middle Paleocene, but more recent correlators to the upper Paleocene because the Cernay conglomerate in France contains a very late Paleocene mammalian fauna. At Ardtun Head, Island of Mull, Scotland, plant remains have been found in the sediments intercalated between lava flows and have been interpreted as Thanetian in age but are probably Eocene or Miocene. Whatever the final conclusion about the limits of the European Paleocene may be, there are fossil-bearing beds near the middle of the sequence that contain plants and animals sufficiently different from those of the Cretaceous and Eocene to warrant the term Paleocene series.

ASIA

No extended study of the Cretaceous-Tertiary boundary in Siberia has been made. Kryshtofovich (1918, p. 7–9) reports that on Sakhalin Upper Cretaceous strata are conformably overlain by Tertiary conglomerates, sandstones, shales and lignites. Simpson (1937a, p. 9) reports that a Mongolian formation called Gashato has yielded 11 genera and 12 species of fossil mammals that seem to be definitely of Paleocene age. Young (1934) discussed the uncertainties about the early Tertiary of China.

The Cretaceous-Tertiary boundary is involved in the history of the Deccan traps of India. Sahni (1940; 1943) has reviewed the situation and concludes that the evidence points toward an early Tertiary age for the first outpourings of the Deccan lavas.

SOUTH AMERICA

The most likely Paleocene strata in South America are those called the Rio Chico formation in Argentina

(Simpson, 1937a, p. 10). This formation has yielded a variety of mammals described by Simpson and 11 species of plants described by Berry (1937).

AFRICA

Nakkady (1957) has attempted a correlation of the late Cretaceous and early Paleocene deposits of Egypt with those in other parts of the world. He concluded that the Danian and Montian of Egypt are early Paleocene and are comparable to the lower and upper parts, respectively, of the Midway formation of the Gulf Coast of the United States. This paper contains an extensive and helpful bibliography.

PALEOCENE LOCALITIES, EXCEPT AS NOTED

[Many locality numbers in the text are not listed; some are under a prior number, as 8663 under 317, 8196 under 2416]

229. 2 miles west of Wales, San Pete County, Utah.
317 (320, 321, 322, 324, 8663). South Table Mountain, Golden, Colo.
318. Northwest side of Green Mountain, Golden, Colo.
323. Bluff one-fourth of a mile south of Reform School and two-thirds of a mile southwest of South Table Mountain, Golden, Colo. (Probably Cretaceous.)
325. 3,000 ft east of Douglas (Lehigh) coal mine, 3 miles west of Sedalia, Colo.
326. Sandstone at coal seam in Laramie at Morrison, Colo. (Cretaceous.)
331. 1,900 ft east of Douglas (Lehigh) coal mine, Sedalia, Colo.
333 (334, 335, 8788). North side of Potato Hill Gap, 2 miles east of Hot Sulphur Springs, Colo.
336. Near Sheriff's coal shaft on Sheriff Creek east of Hot Sulphur Springs, Colo.
337 (338, 8787). Mount Bross, Hot Sulphur Springs, Colo.
436. Red Lodge, Mont.
541. At head of Buck Creek, Niobrara County, Wyo.
607. On Sweetgrass Creek, west of Porcupine Butte, Mont.
750. Fossil Forest Ridge, Yellowstone National Park, Wyo. (Eocene.)
1468. On Lightning Creek, 2 miles above mouth of Walker Creek, Lance Creek, Wyo.
1471. Coal mines at Almy, Wyo.
1474. At mine No. 5, Almy, Wyo.
1502. 2½ miles southeast of Black Buttes, Wyo.
2414. 24 miles northwest of Glendive, Mont.
2416 (2426, 8196). 6 miles above the mouth of Sevenmile Creek, northeast of Glendive, Mont.
2417. On Crackerbox Creek, 18 miles northwest of Glendive, Mont.
2420. Left bank of Yellowstone River at Burns, about 30 miles below Glendive, Mont.
2421. Iron Bluff, 12 miles southwest of Glendive, Mont.
2422. 2 miles east of Gladstone, N. Dak., on north side of Heart River.
2423 (4984). Bull Mountains, 40 miles north of Billings, Mont.
2424. Near Medora, N. Dak.
3653 (5538, 5542). Union Pacific Railroad cut, 1 mile east of station, Evanston, Wyo.
3658 (5539). At mine No. 7, Almy, Wyo.
3661. SE¼SW¼ sec. 19, T. 16 N., R. 120 W., Almy, Wyo.
3667. SW¼ sec. 33, T. 16 N., R. 120 W., near Evanston, Wyo.
3728. Williston, N. Dak.
3852. On Meeyero Creek, 8 miles southwest of Winchester Post Office, Wyo.
3963. Southeast corner sec. 24, T. 22 N., R. 83 W., Wyo.
3979. Signal Butte, 5 miles southeast of Miles City, Mont.
3980. Left bank of Yellowstone River at Miles City, Mont.
4005. West flank of Cedar Creek anticline, 12 miles southwest of Glendive, Mont.
4010. 4 miles southwest of Winchester Post Office, Wyo.
4028. On Turner ranch, 20 miles northwest of Jordan, Mont.
4029. 13 miles north of Jordan, Mont.
4031. At Kern ranch, 24 miles northwest of Jordan, Mont.
4035. About T. 14 N., R 42 E., Mont.
4050. Three-fourths of a mile east of Florida River crossing, east of Durango, Colo.
4256. 1½ miles northwest of Coleharbor, N. Dak.
4264 (4262). Bluffs on west side of Little Missouri River, 2 miles south of Medora, N. Dak.
4265. Bluffs on Little Missouri River, three-fourths of a mile south of Custer Trail ranch, on Davis Creek, 4 miles south of Medora, N. Dak.
4268. Face of Picket Butte, facing Little Missouri River, 4 miles south of Medora, N. Dak.
4272. One-fourth of a mile southeast of mouth of Davis Creek, south of Medora, N. Dak.
4273. On Davis Creek, south of Medora, N. Dak.
4280. Bank of Yellowstone River, 10 miles northeast of Glendive, Mont.
4293. Hedges coal mine, left bank of Yellowstone River at Miles City, Mont.
4310. 3 miles north of Clyde Park, on east side of Shields River, Mont.
4311. 2 miles north of Clyde Park, Mont.
4315. Sec. 24, T. 8 N., R. 49 E., 18 miles east of Miles City, Mont.
4323. NE¼ sec. 20, T. 8 N., R. 48 E., Mont.
4325. Signal Butte, south of Miles City, Mont.
4334. Sentinel Butte, N. Dak.
4368. NE¼ sec. 32, T. 8 N., R. 93 W., 1 mile north of Emerson ranch, 6 miles north of Lay, Colo.
4369. Sec. 5, T. 19 N., R. 90 W., north side of Separation Creek, Wyo.
4395. 20 miles southwest of Rawlins, Wyo.
4404. NW¼SE¼ sec. 27, T. 33 N., R. 72 W., Wyo.
4421 (4882, 8666). Sec. 16, T. 33 N., R. 73 W., at mine southwest of Inez, Wyo.
4468. SE¼ sec. 31, T. 33 N., R. 2 W., Colo. (Cretaceous.)
4474. SW¼ sec. 24, T. 51 N., R. 99 W., Wyo
4571. Sec. 36, T. 6 N., R. 26 E., southeast of Roundup, Mont.
4514. Sec. 21, T. 7 N., R. 10 E., 3 miles south of Lennep, Mont.
4515. Ridge crossing near the mouth of Shields River below Livingston, Mont.
4570. Sec. 22, T. 7 N., R. 26 E., 3 miles from head of Razor Creek, Mont.
4582. Sec. 34, T. 6 N., R. 27 E., 6 miles east of Buckey, Mont.
4617. 3 miles southeast of Lennep, Mont.
4618. Lebo Creek, Mont.
4620. On Lebo Creek, east of Crazy Mountains, Mont.
4625. 9 miles west of Miles City, Mont.
4626. SW¼ sec. 22, T. 8 N., R. 47 E., Miles City, Mont.
4661 (6666). SW¼ sec. 5, T. 45 N., R. 97 W., near Ilo Post Office, Wyo.
4665. 2 miles north of Ilo Post Office, Wyo.

4674. On Shoshone River, Cody, Wyo.
4676. East side of divide between Red Lodge and Bear Creek, Mont.
4694. Roof of Black Diamond mine, 3 miles north of Meeteetse, Wyo.
4696. 9 miles southwest of Bridger, Mont.
4699. Fort Keogh Military Reservation, Miles City, Mont.
4725. South center sec. 25, T. 19 N., R. 100 W., Wyo.
4843. SW¼ sec. 23, T. 22 N., R. 104 W., Wyo.
4860. Sec. 6, T. 55 N., R. 85 W, three-fourths of a mile northwest of Beckton, Wyo.
4870. SW¼ sec. 12, T. 57 N., R. 85 W., Wyo.
4871. Sec. 2, T. 57 N., R. 85 W, Wyo.
4874. Sec. 13, T. 57 N., R. 85 W., about 5½ miles east of Ranchester, Wyo.
4875. Sec. 13, T. 57 N., R. 85 W., one-half of a mile west of 4874.
4876. Sec. 10, T. 57 N., R. 85 W., 3 miles northwest of Monarch, Wyo.
4877. Sec. 14, T. 57 N., R. 85 W., 2¼ miles northwest of Monarch, Wyo.
4878. Sec. 19, T. 57 N., R. 84 W., near Monarch, Wyo.
4881. South side of sec. 20, T. 57 N., R. 84 W., 1½ miles southeast of Monarch, Wyo.
4892. 2 miles southeast of Carneyville, Wyo.
4896. 1 mile southeast of Dietz, Wyo.
4897. SW¼ sec. 2, T. 57 N., R. 84 W., on west side of Tongue River, Wyo.
4898. Sec. 13, T. 57 N., R. 84 W., 3 miles east of Carneyville, Wyo.
4908. Southeast corner sec. 15, T. 57 N., R. 83 W., one-half of a mile east of Prairie Dog Creek, Wyo.
4909. Three-fourths of a mile east of Prairie Dog Creek in southeast corner sec. 15, T. 57 N., R. 83 W., Wyo.
4910. Near Decker, Mont.
4974 (4976, 8563). Sec. 33, T. 6 N., R. 16 E., in sandstone capping Bear Butte, near Melville, Mont.
4975 (8567). Sec. 29, T. 6 N., R. 16 E., northeast of Widdecombe ranchhouse, Wyo.
4977. Sec. 25, T. 5 N., R. 15 E., Mont.
4981. Sec. 23, T. 8 N., R. 25 E, one-half of a mile northeast of Roundup, Mont
4984 (4985, 8568). NE¼SW¼ sec. 23, T. 5 N., R. 26 E., 2 miles south of Buckey, Mont.
5025. 2 miles east of Black Buttes, Wyo.
5029. 35 miles southwest of Black Buttes, Wyo.
5030. Sec. 35, T. 15 N., R. 102 W., Wyo.
5043. One-fourth of a mile north of center sec. 32, T. 19 N., R. 100 W., Wyo.
5046 (5122). 5 miles above Aguilar on Gonzales Creek, Colo.
5063. At Bud Kimball mine in SW¼ sec. 33, T. 46 N., R. 89 W., Wyo.
5094. At Bowen mine, 200 ft above lowest coal, Bowen, Colo.
5099. Floor of Fishers Peak mine, 3 miles southeast of Trinidad, Colo.
5121. NE¼ T. 32 S., R. 66 W., Colo.
5132. Norman ranch, 12 miles east of Raton, N. Mex.
5133. Sec. 30, T. 32 N., R. 25 E., N. Mex.
5134. Yankee mine No. 5, near top of section, Raton, N. Mex.
5137. Near Yankee, N. Mex.
5139. On ridge east of Yankee mine, Raton, N. Mex.
5140. Honeyfield mine, Yankee, N. Mex.
5142. Sec. 29, T. 32 N., R. 25 E., N. Mex.
5144. In Tin Pan canyon, northwest of Raton, N. Mex.
5147. West side of Dillon canyon, 1 mile north of mouth of Coal canyon, N. Mex.
5151. South end of Raton tunnel, Raton, N. Mex.
5194. Sec. 30, T. 6 N., R. 2 E., Wyo.
5236. Spring canyon, Vermejo Park, N. Mex.
5255. Sec. 12, T. 16 N., R. 102 W., Wyo.
5259. NE¼NE¼ sec. 27, T. 16 N., R. 102 W., Wyo.
5291. About sec. 14, T. 31 N., R. 22 E., Red River canyon, 1 mile east of Jones Canyon, N. Mex.
5300. Sec. 9, T. 6 N., R. 28 E., near head of Cow Gulch, about 7 miles southeast of Fattig Post Office, Wyo.
5321. Sec. 16, T. 16 N., R. 105 W., Wyo.
5322. North of road across creek at big bend in road, sec. 35, T. 16 N., R. 105 W., Wyo.
5332. 4 miles east of Parkman, Wyo.
5374. NW¼ sec. 10, T. 14 S., R. 65 W., east bank of Jimmy Camp Creek, Colo.
5385. River bluffs, right bank of the Missouri River, southeast of Brockton, Mont.
5387. Near mouth of Smoke Creek, sec. 3, T. 29 N., R. 54 E., Mont.
5388. 2 miles east of Ralston ranch, south of Brockton, Mont.
5389. Right bank of Missouri River, south of Brockton, Mont.
5437 (5438). NW¼ sec. 5, T. 129 N., R. 88 W., N. Dak.
5455. Sec. 31, T. 35 N., R. 6 W., Colo.
5456. Sec. 15, T. 35 N., R. 6 W., Colo.
5458. NW¼ sec. 30, T. 35 N., R. 6 W., Colo.
5460. Southeast from center of sec. 19, T. 35 N., R. 8 W., Colo.
5461. 110 ft below 5460.
5469. At Bowen mine, 5 miles north of Trinidad, Colo.
5480. Minturn, Wyo.
5495. Sec. 18, T. 22 N., R. 80 W., 5 miles east of Hanna, Wyo.
5509. 8 miles northeast of Parkman, Wyo.
5512. 7 miles northeast of Parkman, Wyo.
5526 (9112). NE¼SE¼ sec. 22, T. 1 N., R. 2 E., east of Ethete, Wyo.
5551. 150 ft above coal at mine No. 9, Almy, Wyo.
5555. Mine No. 8, Almy, Wyo.
5557. Ridge above coal mines No. 1 and No. 4, Almy, Wyo.
5578. 4 miles southeast of Black Buttes, Wyo.
5579. 1½ miles east of Black Buttes, Wyo.
5582. 2 miles east of Black Buttes, Wyo.
5594 (5595, 5596). SW¼NW¼ sec. 28, T. 31 N., R. 19E., south of Chinook, Mont.
5609. 2 miles north of Musselshell, Mont.
5612. NW¼NW¼ sec. 13, T. 9 N., R. 29 E., Mont.
5613. SE¼SW¼ sec. 15, T. 8 N., R. 31 E., Mont.
5618. Sec. 15, T. 52 N., R. 72 W., Wyo.
5619. At mouth of Elk Creek on Little Powder River, Mont.
5667. Top of Animas beds, Ignacio quadrangle, Colorado.
5678. South side of Cucharas River, 3 miles southwest of Walsenburg, Colo.
5679. One-eighth of a mile northeast of Rockland mine, 3 miles southwest of Walsenburg, Colo.
5683. Canyon west of Old Rouse, Colo.
5684. Dump of Green Canyon mine near Aguilar, Colo.
5686. One-half of a mile east of Abeton, Colo.
5687. 1 mile north of Trujillo, Colo.
5688. Apishapa Canyon, 3 miles northeast of Abeton, Colo.
5689. 1 mile northeast of 5688.
5690. At Delagua mine west of Hastings, Colo.
5695. 3 miles west of Bowen, Colo.
5697. Sec. 9, T. 33 S., R. 64 W., Colo.

5699. Riley canyon, one-half of a mile north of Cokedale, Colo.
5701. Riley canyon, near Cokedale, Colo.
5711. One-half of a mile north of Wooton, Colo.
5712. Wooton, Colo.
5714. At Turner mine, 1½ miles north of Wooton, Colo.
5716. 14 miles east of Douglas, 2 miles north of junction of western and middle forks of Shawnee Creek, Wyo.
5720. Sec. 27, T. 34 N., R. 68 W., Wyo.
5721. Sec. 35, T. 34 N., R. 68 W., at Sunset mine, Wyoming.
5738 (8656). In clinker above burned coal at top of a conical hill, three-fourths of a mile south of a dry hole in NW¼ sec. 33, T. 9 S., R. 61 W., 6 miles northwest of Ramah, Colo.
5760. 1½ miles east of Old Washakie Station on north side of Muddy Creek, Wyo.
5796. 1½ miles south of Starkville, Colo.
5798. Dump of mine at Primero, Colo.
5799. 5 miles northwest of Weston, Colo.
5803. Tercio, Colo.
5826. Sec. 36, T. 30 N., R. 19 E., on Vermejo Creek, N. Mex.
5831. Six-tenths of a mile north of Richfield Springs ranch, 9 miles east of Colorado Springs, Colo.
5835. 1 mile east of Richfield Springs ranch on Jimmy Camp Creek, Colo.
5836 (8655). Railroad cut three-fourths of a mile west of Falcon, Colo.
5837. 1 mile southwest of Calhan, Colo.
5838. Dump of Mosby coal mine, Mosby, Colo.
5839. Sec. 27, T. 11 S., R. 61 W., one-fourth of a mile east of Purdon mine, Colorado.
5840. 4 miles south of Ramah, Colo.
5842. Sec. 2, T. 5 N., R. 58 E., 16 miles southwest of Baker, Mont.
5863. Center sec. 9, T. 47 N., R. 70 W., Wyo.
5882. Sec. 36, T. 12 N., R. 52 E., on O'Fallon Creek, east of Terry, Mont.
5885. Sec. 14, T. 10 N., R. 58 E., near Terry, Mont.
5886. NE¼ sec. 17, T. 10 N., R. 59 E., Mont.
5889. Sec. 32, T. 11 N., R. 59 E., near Terry, Mont.
5905. Sec. 2, T. 53 N., R. 71 W., Wyo.
5911. Sec. 29, T. 47 N., R. 81 W., Wyo.
5917. T. 42 N., R. 78 W., Wyo.
5987. On west side of Illinois River, southwest of Walden, Colo.
5994. SW¼NW¼ sec. 2, T. 10 N., R. 80 W., Colo.
5997. SE¼ sec. 31, T. 10 N., R. 81 W., in North Park, Colo.
6000. SE¼NW¼ sec. 28, T. 9 N., R. 80 W., 7 miles west of Walden, Colo.
6005. NW¼NW¼ sec. 19, T. 9 N., R. 80 W., in bluff on north fork of Platte River, Colo.
6006. NE¼ sec. 14, T. 7 N., R. 81 W., Colo.
6050. SW¼ sec. 7, T. 49 N., R. 68 W., Wyo.
6051. NE¼SE¼ sec. 6, T. 49 N., R. 68 W., 6 miles west of Moorcroft, Wyo.
6057. NE¼ sec. 13, T. 46 N., R. 70 W., 20 miles southwest of Moorcroft, Wyo.
6083. SE¼ sec. 20, T. 45 N., R. 69 W., Wyo.
6084. Sec. 3, T. 42 N., R. 67 W., 20 miles above Hampshire on Black Thunder Creek, Wyo.
6099. NE¼SE¼ sec. 9, T. 7 N., R. 81 W., in bluff 3 miles northwest of Coalmont, Colo.
6102. SE¼NE¼ sec. 30, T. 6 N., R. 80 W., Colo.
6103. NE¼NE¼ sec. 19, T. 6 N., R. 79 W., Colo.
6105. NE¼ sec. 25, T. 7 N., R. 80 W., about 3 miles north of Riding ranch, in North Park, Colo.
6107. SW¼NE¼ sec. 36, T. 8 N., R. 78 W., Colo.
6110. SE¼SE¼ sec. 29, T. 9 N., R. 78 W., near Capron mine, Colorado.
6113. Head of Wolf Draw in about sec. 24, T. 17 N., R. 9 E., S. Dak.
6114. Sec. 7, T. 17 N., R. 11 E., S. Dak.
6116. Sec. 17, T. 17 N., R. 13 E., S. Dak.
6117. Sec. 17, T. 21 N., R. 16 E., S. Dak.
6131. NE¼ sec. 20, T. 12 N., R. 50 E., near Terry, Mont.
6142. 2¼ miles southeast of Monument, Colo.
6154. Sec. 1, T. 17 N., R. 7 E., S. Dak.
6155. Center sec. 1, T. 17 N., R. 9 E., S. Dak.
6156. Sec. 12, T. 17 N., R. 7 E., S. Dak.
6161. Sec. 25, T. 19 N., R. 7 E., S. Dak.
6171. North half of sec. 24, T. 50 N., R. 100 W., Wyo.
6173. Sec. 31, T. 50 N., R. 99 W., Wyo .
6176. SE¼ sec. 6, T. 49 N., R. 99 W., Wyo.
6215. Sec. 36, T. 136 N., R. 105 W., south of Yule, N. Dak.
6219. Sec. 6, T. 137 N., R. 102 W., N. Dak.
6225. SW¼ sec. 7, T. 134 N., R. 102 W., N. Dak.
6297. 3 miles north of Craig, Colo.
6299. 7 miles northwest of Craig, Colo.
6309. One-half of a mile downstream from station at Pagosa Junction, Colo.
6344. SW¼NW¼ sec. 22, T. 33 N., R. 73 W., 2 miles southeast of Inez, Wyo.
6359. Near center sec. 14, T. 51 N., R. 100 W., Wyo.
6360. Sec. 24, T. 50 N., R. 100 W., Wyo.
6376. SW¼SE¼ sec. 33, T. 132 N., R. 91 W., 10 miles south of Bentley, N. Dak.
6377. Sec. 6, T. 133 N., R. 88 W., 1 mile south of Kayser, N. Dak.
6382. 3 miles east of Scranton, N. Dak.
6384 (9125). NW¼ sec. 34, T. 22 N., R. 9 E., at Anarchist Butte, S. Dak.
6416. NW¼SW¼ sec. 24, T. 23 N., R. 84 W., Wyo.
6417. SE¼SE¼ sec. 23, T. 23 N., R. 84 W., in north bank of Big Ditch, Wyo.
6419. NW¼SW¼ sec. 26, T. 23 N., R. 84 W., Wyo.
6420. NW¼NW¼ sec. 16, T. 22 N., R. 83 W., Wyo.
6428. SE¼SW¼ sec. 11, T. 23 N., R. 84 W., Wyo.
6431. SW¼NE¼ sec. 27, T. 23 N., R. 84 W., Wyo.
6437 (5994). SW¼NW¼ sec. 2, T. 10 N., R. 80 W., Colo.
6440. NE¼SW¼ sec. 24, T. 7 N., R. 81 W., Colo.
6443. 1 mile northeast of Pagosa Junction, Colo.
6444. 1 mile northwest of Pagosa Junction, Colo.
6525. South bank of Heart River, one-half of a mile south of Mandan, N. Dak.
6592. Sec. 4, T. 7 N., R. 94 W., Colo.
6594. Sec. 2, T. 7 N., R. 94 W., Colo.
6598. SW¼ sec. 3, T. 131 N., R. 85 W., N. Dak.
6625. SE¼ sec. 29, T. 23 N., R. 83 W., Wyo.
6630. NE¼NW¼ sec. 12, T. 22 N., R. 84 W., Wyo.
6652. NE¼ sec. 30, T. 136 N., R. 82 W., N. Dak.
6667. North of Ilo Post Office, Wyo.
6668. 200 ft above base of Fort Union, Ilo quadrangle, Wyoming.
6669. Near Ilo Post Office, Wyo.
6738. SW¼ sec. 9, T. 35 N., R. 75 W., Wyo.
6765. Railroad cut three-fourths of a mile south of Wilsall, Mont.
6765–A. Three-fourths of a mile north of Wilsall, Mont.

6767. On Brackett Creek, 12 miles west of Clyde Park, Mont.
6845. Sec. 1, T. 27 N., R. 90 W., on Coal Creek, northwest of Rawlins, Wyo.
6892. SW¼ sec. 14, T. 139 N., R. 84 W., N. Dak.
6905. SW¼ sec. 22, T. 138 N., R. 85 W., N. Dak.
6943. One-half of a mile west of Ramah, Colo.
6944. Coal gulch 2 miles northwest of Ramah, Colo.
6971. NW¼ sec. 34, T. 22 N., R. 82 W., east of Dana, Wyo.
7004. Sec. 33, T. 37 N., R. 47 E., Mont.
7005. One-half of a mile north of northwest corner of sec. 4, T. 37 N., R. 49 E., Mont.
7371. 3 miles southwest of Farmington, N. Mex.
7480. Top of hill west of Talian mine, 5 miles north of Pagosa Junction, Colo.
7481. Above Talian mine, 5 miles north of Pagosa Junction, Colo.
7483. 4½ miles north of Pagosa Junction, Colo.
7484. Near 7483.
7485. Near 7483.
7495. 1 mile northwest of Ojo Alamo, N. Mex.
7496. One-half of a mile west of Pagosa Junction, Colo.
7498. On Cat Creek, 1 mile north of Pagosa Junction, Colo.
7538. SE¼ sec. 22, T. 16 N., R. 33 E., Mont.
7547. NW¼SE¼ sec. 22, T. 3 N., R. 16 E., 14 miles northeast of Big Timber, Mont.
7548. NW¼NE¼ sec. 4, T. 2 N., R. 16 E., 14 miles northeast of Big Timber, Mont.
7552 (8540). At clay pit, 1 mile south of Dickinson, N. Dak. (Eocene.)
7623. Sec. 35, T. 9 N., R. 89 W., at Pugh's place, northeast of Craig, Colo.
7659. South half sec. 7, T. 1 N., R. 40 E., 10 miles west of Colstrip, Mont.
7662. SE¼ sec. 36, T. 1 N., R. 39 E., Mont.
7663. 4 miles west of Camp Crook, S. Dak.
7685. NE¼ sec. 35, T. 6 S., R. 43 E., Mont.
7688. Sec. 20, T. 6 S., R. 43 E., Mont.
7695. Sec. 20, T. 6 S., R. 43 E., Mont. Near 7688.
7776. 2 miles southeast of coal mine at Black Buttes, Wyo.
7839 (8249). 2 miles southwest of Edwards, Mont.
7989. Weldon, McCone County, Mont.
8163. SW¼ sec. 12, T. 5 N., R. 43 E., Mont.
8164. Sec. 23, T. 3 N., R. 45 E., Mont.
8165. SW¼ sec. 15, T. 5 N., R. 47 E., Mont.
8166. Southeast of Colstrip, Mont.
8167. Southwest corner of sec. 35, T. 3 N., R. 44 E., Mont.
8187. NW¼ sec. 30, T. 11 S., R. 60 W., Colo.
8188. NE¼ sec. 25, T. 11 S., R. 61 W., south of Ramah, Colo.
8190 (8542). 1 mile north of Intake, Mont.
8191. On left bank of Yellowstone River, north of Burns, Mont.
8193. Right bank of Yellowstone River, east of Sidney, Mont.
8199. 4 miles north of Stipek, along Sevenmile Creek, Mont.
8200. 3 miles up Clear Creek, west of Glendive, Mont.
8202. In left bank of Missouri River, 10 miles north of Sanish, N. Dak.
8203. Between Sanish and Hoflund, N. Dak.
8204. Near 8203.
8205. 18 miles along river road from Sanish to Hoflund, N. Dak.
8206. 6 miles north of Armstrong, N. Dak.
8212. Near Elbowoods, N. Dak.
8213. 5 miles southeast of Elbowoods, N. Dak.
8215. 9 miles north of Sixmile Creek, Armstrong, N. Dak.
8220. At Hoffman, west of Sanish, N. Dak.
8222. Blue Buttes, near Keene, N. Dak.
8224. At Brittian mine, 6 miles southeast of Mott, N. Dak.
8225. At Hoffman mine, right bank of Missouri River, across from Sanish, N. Dak.
8227. In North Dakota, 3 miles north of Watauga, S. Dak.
8230. Near Grassy Butte, N. Dak.
8231 (8232, 8233). Near Bicycle Post Office, N. Dak.
8234. West of Grassy Butte, N. Dak.
8238. In clinkered sandstone and shale near top of Sentinel Butte, N. Dak.
8239. Left bank of Little Missouri River, three-fourths of a mile south of Yule, N. Dak.
8240. On Little Missouri River, 3 miles southwest of Yule, N. Dak.
8245. One-half of a mile north of Ekalaka, Mont.
8246. Left bank of Yellowstone River at Terry, Mont.
8247. Left bank of Yellowstone River near 8246.
8248. At Roberts coal mine, 3 miles west of Amidon, N. Dak.
8250. Signal Butte, southeast of Miles City, Mont.
8252. 8 miles south of the mouth of Armell Creek, west of Forsyth, Mont.
8253. 2 miles east of Powder River bridge, Mizpah, on road to Ekalaka and Ismay, Mont.
8255 (8520). Colstrip, Mont.
8256. 8 miles south of the mouth of Armell Creek, west of Forsyth, Mont.
8257. 5 miles northeast of Kinsey, Mont.
8258 (8259, 8549). 1 mile east of Hathaway, Mont.
8261. 2 miles west of Cap Rock, 18 miles northeast of Miles City, Mont.
8262. At Cap Rock, on north side of the Yellowstone River, 20 miles east of Miles City, Mont.
8307. NW¼ sec. 7, T. 12 S., R. 61 W., southeast of Calhan, Colo.
8426. 6 miles south of Como, in South Park, Colo.
8447. 6 miles south of Como, near 8426.
8493. 6 miles south of Como, near 8426.
8516. 1 mile east of filling station near Dana, Wyo.
8517. North side of U.S. Highway 10, in bank of Moon Creek, 10 miles west of Miles City, Mont.
8519. Hillside south of U.S. Highway 10, 25 miles east of Miles City, Mont.
8521. Near top of conical hill, sec. 23, T. 2 S., R. 44 E., Mont.
8522. On Dry Creek, 5 miles west of Greybull, Wyo.
8523. Sec. 19, T. 5 N., R. 13 E., on Sweetgrass Creek, Mont.
8526. 600 ft south of Jepsen mammal quarry on Polecat bench, west of Frannie, Wyo.
8529. 10 miles east of Roundup, Mont.
8535. On Poison Spider Creek, southwest of Casper, Wyo.
8545. Sec. 23, T. 4 N., R. 40 E., east of highway Forsyth to Colstrip, Mont.
8547. Near top of "Bear" formation on south side of Lebo Creek, Mont.
8548. Near center of sec. 10, T. 22 N., R. 82 W., near Hanna, Wyo. (Eocene.)
8550. 18 miles northeast of Miles City, Mont.
8551. On Sand Creek, 7 miles north of Glenrock, Wyo.
8552. 3 miles west of Marsh station on Northern Pacific Railroad, west of Glendive, Mont.
8553. West of Cap Rock, about 18 miles northeast of Miles City, Mont.
8554. 25 ft above Big Dirty coal, on north side of Yellowstone River at Terry, Mont.

8556. 10 miles north of Terry, Mont., in sec. 19, T. 13 N., R. 50 E.
8558. Near center of sec. 21, T. 6 N., R. 13 E., Mont.
8566. In clinker near Wyodak coal mine, 4½ miles east of Gillette, Wyo.
8652. 2 miles southeast of Black Buttes, Wyo.
8654. South side of U.S. Highway 30, 7½ miles east of Point of Rocks, Wyo.
8660. Above coal at mine 1 mile northeast of U.S. Highway 30 at Hadsell, 10 miles west of Rawlins, Wyo.
8662. In bluff on north side of Big Ditch, in sec. 32, T. 23 N., R. 83 W., Wyo.
8668. 10 miles south of Rozet, Wyo.
8669. 4 miles west of Bayfield, Colo., in dump from large roadcut.
8670. At mine No. 1, Almy, Wyo.
8672. Sec. 36, T. 2 S., R. 66 W., in bank of Second Creek, 10 miles east of Derby, Colo.
8673. Sec. 3, T. 35 N., R. 66 W., west of Lance Creek, Wyo.
8677. 8 miles west of Clareton, Wyo.
8678. Near 8677.
8774 (4370, 4457). In almost vertical beds 170 ft above top of Mesaverde formation, on south side of creek in Rifle Gap, 6 miles north of Rifle, Colo.
8775. Nigger Hill, 1 mile east of DeBeque, Colo., along U.S. Highway 6.
8776. 20 ft above level of Cucharas River, 1½ miles west of Walsenburg, Colo. (Cretaceous.)
8777. West side of Platte River, near Colfax Pressed Brick Co., Denver, Colo.
8779. Three-fourths of a mile east of ranch on Jimmy Camp Creek, 9 miles east of Colorado Springs, Colo.
8780. South side of Beebe-Powderville road, 4 miles west of Powderville, Mont.
8781. 2 miles up Little Powder River from junction with Powder River, northeast of Broadus, Mont.
8786. SW¼ sec. 27, T. 5 S., R. 50 E., about 6 miles southwest of Broadus, Mont.
8881. One-half of a mile west to northwest of Ramah, Colo.
8882. One-half of a mile east of Purdon mine, 5 miles southwest of Ramah, Colo.
8884. 2 miles east of Ohlman, Wyo.
8885 (6342). Makton coal mine, 7 miles northeast of Big Sandy, Mont.
8886. NW¼ sec. 23, T. 7 S., R. 45 E., west of mouth of Cub Creek, on Otter Creek, Mont.
8887. Sec. 33, T. 8 S., R. 46 E., Mont.
8888. 5 miles northeast of Kinsey, Mont.
8893. North of center of T. 46 N., R. 81 W., Wyo.
8896. North side of Yellowstone River, at Big Timber, Mont.
8897. 8½ miles north of Glendive, Mont.
8898. 2 miles west of Douglas, Wyo.
8899. South of highway at Gwynn ranch on Grass Creek, Wyo.
8901. East side of Graveyard Coulee, south of Glendive, Mont.
8910. NW¼ sec. 11, T. 8 S., R. 49 E., 1½ miles north of Traub ranch on Bayhorse Creek, Mont.
8913. Above coal in small hill to north of road leading up to Sentinel Butte, Sentinel Butte, N. Dak.
8917. 3 miles east of Black Buttes, Wyo.
8920. Sec. 13, T. 15 N., R. 105 W., one-fourth of a mile north of gate on road, 20 miles south of Rock Springs, Wyo.
8921. Sec. 14, T. 16 N., R. 105 W., southwest of Antelope Butte, Wyo.
8922. Sec. 26, T. 16 N., R. 105 W., east of Bacon ranch, east side of Bitter Creek, Wyo.
8928. Sec. 2, T. 7 N., R. 92 W., northwest of Craig, Colo.
8930. 7 miles east of Point of Rocks and 1 mile north of U.S. Highway 30, Wyoming.
9056. About 17 miles southwest of Musselshell, Mont.
9071. Sec. 16, T. 41 N., R. 110 W., about one-fourth of a mile east of mouth of Buck Creek, Wyo.
9072. NE¼ sec. 32, T. 1 S., R. 50 E., 1½ miles southeast of Coalwood, Mont.
9084. NW¼SW¼ sec. 16, T. 142 N., R. 91 W., N. Dak.
9085. Near Young Man's Butte, 2½ miles east of Richardson, N. Dak.
9092. SE¼ sec. 15, T. 55 N., R. 75 W., Wyo. About 50 ft above Roland coal.
9104. At coal mine in NW½ sec. 4, T. 36 N., R. 52 E., Mont.
9109. NW¼SW¼ sec. 29, T. 1 S., R. 6 E., 13 miles east of Riverton, Wyo.
9111. East of Little Dome, Carter Oil site 2, north of Lander, Wyo.
9129. SE¼SE¼ sec. 36, T. 35 N., R. 91 W., Wyo.
9130. SW¼ sec. 31, T. 34 N., R. 92 W., Wyo.
9131. NE¼ sec. 20, T. 6 N., R. 1 E., Wyo.
9132. Center of south half SE¼NW¼ sec. 35, T. 6 N., R. 1 E., on southwest side of Shotgun Butte, Wyo.
9134. At Blue Pony coal mine in SW¼SW¼ sec. 25, T. 29 N., R. 14 E., Mont.
9141. SW¼ sec. 30, T. 11 N., R. 1 E., on Cedar Creek a tributary of Salmon Creek, Wash. (Miocene.)
9180. In carbonaceous shale west of Killpecker Creek, 3 miles northwest of Rock Springs, Wyo.
9193. Whetstone Falls, on a tributary of Pacific Creek, northeast of Moran, Wyo.
9194. NW¼NW¼ sec. 1, T. 17 N., R. 7 E., at Mendenhall mine, South Dakota.
9196. NE¼SE¼ sec. 17, T. 6 N., R. 1 E., Wyo.
9198. SE¼ sec. 8, T. 20 N., R. 90 W., Wyo.
9199. Sec. 33, T. 1 N., R. 47 E., Custer County, Mont.
9200. 8 miles south of Taylor, N. Dak.
9201. Sec. 24, T. 28 N., R. 14 E., about 4 miles east of Mackton coal mine, east of Big Sandy, Mont.
9202. 3 miles east of Fort Stevenson on north side of Missouri River, 71 miles north of Bismarck, N. Dak.
9203. 1 mile south of Como, Colo.
9204. Sec. 14, T. 4 S., R. 41 E., Mont.
9205. NE¼ sec. 18, T. 142 N., R. 90 W., N. Dak.
9206. NE¼ sec. 31, T. 33 N., R. 55 E., Mont.
9207. Near 9109, but stratigraphically below.
9208. South half of sec. 15, T. 34 N., R. 91 W., Wyo.
9210. SE¼ sec. 26, T. 18 N., R. 100 W., Black Buttes, Wyo.
9235. About 2 miles east of Viola, Wyo., on north side of road along LaBarge Creek.
9236. NW¼NW¼ sec. 22, T. 12 N., R. 100 W., Colo. Hiawatha Unit well 2.
9237. Above white sandstone of "Castle Gardens" on Muskrat Creek, south of Moneta, Wyo.
9239. NE¼ sec. 10, T. 9 S., R. 47 E., Mont.
9248 (9334). East side of Smoky Butte Creek, 14 miles northwest of Jordan, Mont.
9249. Southeast corner of sec. 10, T. 16 N., R. 38 E., Mont.
9252. 1 mile above mouth of Powder River, 6 miles southwest of Terry, Mont.
9253. West side of Little Powder River, near Biddle, Mont.
9322. At Eagle coal mine, 1 mile southwest of Bear Creek, Mont.

9342. Sec. 28, T. 8 S., R. 93 W., one-half of a mile south of Blevin mine, Colo.
9398. SW¼ sec. 20, T. 142 N., R. 90 W., N. Dak.
9399. NE¼SW¼ sec. 15, T. 6 N., R. 1 E., Wyo.
9400. About 2 miles southwest of Black Rock, which is northeast of Point of Rocks, Wyo.
9401. Sec. 2, T. 9 S., R. 62 W., about 5 miles northeast of Fondis, Colo.
9402. About 5 miles southwest of Bridger, Mont.
9403. North side of highway, 5 miles northwest of Rock Springs, Wyo.
9404. About 3 miles west of Elk Basin, Wyo.
9405. Center of sec. 32, T. 6 N., R. 3 E., Wyo.
9421 (9180). NE¼ sec. 22, T. 19 N., R. 105 W., about 1½ miles north of Rock Springs, Wyo.
9445. Sec. 9, T. 4 N., R. 81 W., about 1½ miles northeast of Whitely Peak, Colo.
9446. NW¼NE¼ sec. 35, T. 9 N., R. 78 W., at Marr coal mine, Colorado.
9476. At Nygard coal mine, about 5 miles northeast of Big Sandy, Mont.
9477. NE¼NW¼ sec. 33, T. 27 N., R. 95 W., Bison Basin, Wyo.
9478. SE¼ sec. 11, T. 27 N., R. 95 W., Bison Basin, Wyo.
9479. Center of sec. 14, T. 27 N., R. 95 W., Bison Basin, Wyo.
9482. NW¼SW¼ sec. 10, T. 34 N., R. 90 W., Wyo.
9488. NE¼NW¼ sec. 19, T. 27 N., R. 15 E., Mont.
9489. SW¼ sec. 18, T. 27 N., R. 15 E., northeast of Ryan Butte, Bearpaw Mountains, Mont.
9490. NW¼SW¼ sec. 12, T. 27 N., R. 14 E., Mont.
9491. NW¼ sec. 26, T. 28 N., R. 14 E., Mont.
9492. On west side of highway, 3½ miles north of Pagosa Junction, Colo.
9501. NW¼ sec. 16, T. 9 S., R. 97 W., along highway on left bank of Colorado River, 4 miles southwest of DeBeque, Colo.
9502. Sec. 15, T. 50 N., R. 68 W., 4 miles northwest of Moorcroft, Wyo.
9532. Center of SW¼ sec. 27, T. 33 N., R. 95 W., Wyo. (Eocene.)
9533. Sec. 10, T. 42 N., R. 108 W., Wyo.
9540. Northeast of Muskrat Creek camp at cabin, on road to Riverton, Wyo.
9554. 2 miles north of Highway 94, 3 miles east of bridge over Jimmy Camp Creek, 9 miles east of Colorado Springs, Colo.
9558. Center of NE¼ sec. 36, T. 21 N., R. 117 W., Wyo.
9564. Sec. 2, T. 130 N., R. 104 W., 8 miles south of Rhame, N. Dak.
9565. Sec. 7, T. 30 N., R. 7 W., 1 mile above confluence of Los Pinos and San Juan Rivers, N. Mex.
9566. 3 miles west of Douglas, just north of U.S. Highway 20, Wyoming.

METHODS APPLIED IN THE STUDY OF THE PLANTS

The numerous collections of Paleocene plants used in this study differed greatly in quantity and quality of specimens. Some comprised a large assortment of well-preserved leaves, flowers, fruits, seeds, pollen, spores, and wood; but many consisted of only a few specimens, often very poorly preserved. Nevertheless, whatever the condition of the collection, the first step in its study was the trimming and preliminary sorting of the specimens and the assignment of a locality number, which was put on each specimen. After a general survey of the collection to get a tentative idea of its contents and of its approximate place in the geologic column, I began concentrated examination of the specimens to fulfill the threefold purpose, as I see it, of studying fossil plants: first, to segregate and identify the kinds as accurately as possible in order to establish their place in the evolution of the plant kingdom; second, to find items of restricted geologic range for the determination of the relative age and correlation of the containing strata; and third, to infer from the composition of the flora the probable ecologic conditions that prevailed when the plants were alive.

The process of identifying fossil plants is fraught with many difficulties. Chief among these is the comparative scarcity of satisfactory specimens in many collections; and second to this is the often poor quality of types and their illustrations, if these are still available. Not all fragmentary specimens, however, are useless, for some may retain the very features necessary for their identification. Sometimes the fragments have proved to be worse than useless, for species founded on them have caused endless quibbling and frustration about their identities and the priority of the names given to them. In my opinion many paleobotanical names are invalid because they apply to fragments that were not and cannot be adequately characterized for practical use. Instead of scarcity there may, on the other hand, be a surplus of good but variant specimens, and this may compel the identifier and describer to be a "lumper" or a "splitter."

Fortunately, for this study of the Paleocene plants of the Rocky Mountains and Great Plains, I had at hand for comparison in the U.S. National Museum collections most of the type specimens described by previous writers. To these, as a result of many field trips during which I became intimately acquainted with the pertinent fossiliferous strata, I was able to add a large quantity of supplementary material.

Unfortunately, I have not had an opportunity to see some types now located at other museums but have had to depend on the published descriptions and illustrations. Particularly is this true of all foreign Paleocene collections, more especially those described by Heer from Greenland, Watelet from the Paris Basin, France, and Saporta and Marion from Gelinden, Belgium. This foreign material is illustrated chiefly by drawings, for the most part beautifully done, but how faithful to the specimens I do not know. For this reason I have refrained from adopting the names of some of those types for American specimens even though the latter may seem, superficially at least, indistinguishable from them. A considerable number of the foreign types, as identified and illustrated, seem not to be represented by similar specimens in the American Paleocene flora.

In any case, identifications will depend largely upon the identifier's knowledge of the morphology, classification, nomenclature, geographic distribution, and ecology of living plants, and his familiarity with paleobotanical literature. At the heart of all this will be his native botanical capacity and his philosophy about species, living and fossil.

On theoretic grounds I have difficulty in accepting the proposition that species, considered to be groups of closely related individuals having in common a multiplicity of features, are discrete, natural entities. However discrete such species may seem to be now, their discreteness vanishes when they are viewed in the perspective of their ancestral history. If the parade of organic life—every individual plant and animal that has ever lived—were passed in review from the beginning to the present before a competent biologist, could he, except arbitrarily, classify the colossal array into species, genera, and families? I doubt it and I deny that any of his arbitrary species would in actuality be a natural entity. If only one individual of *Ginkgo biloba* Linnaeus or one individual of the passenger pigeon, *Ectopistes migratorius* (Linnaeus) Swainson, remained, those specimens would simply be the last of many millions that preceded them in an uninterrupted line yesterday and ad infinitum into the limbo of the past. In the fossil record of *Ginkgo* many "species" appear, but it is now manifestly impossible to circumscribe those "species" exactly and to decide upon the precise genetic moment when one evolved into a new "species." As I conceive it, the organic world from the beginning to now has been like a continuous tapestry, a fabric woven without observable natural breaks and obvious seams. The only separations are the purely arbitrary ones that have been invented and applied for practical, talking purposes.

Repeatedly, therefore, in the following systematics I point out that the species I recognize are not necessarily natural but are in many instances dubious and are chiefly form or practical species. For example, some such aggregates are: *Ginkgo adiantoides* (Unger) Heer, *Cercidiphyllum arcticum* (Heer) Brown, *Ampelopsis acerifolia* (Newberry) Brown, *Platanus raynoldsi* Newberry, and *Viburnum antiquum* (Newberry) Hollick. These species, as I treat them, include a large variety of leaf forms. Within this variety, however, in each species there is a mode or norm that I visualize as the average mature leaf of that species. My synonymies, consequently, indicate a tendency to "lump" rather than to "split," and my species names are merely labels for identifying recognizable, usable combinations of form and organization. I practice this method because, after long experience with the publications and collections of "splitters," I conclude that upon the latter rests the greater burden of proof that they have erected valid, usable species. I find it much easier to justify a norm, with its variants, as typical of a species or a geographic race than to define many similar though slightly different leaves (or other parts of plants) as separate species because they have somewhat different shapes and some divergence, more or less, in the number of marginal teeth. Over-refined species in an abundance of material seem difficult to define, comprehend, and use, even by their describer. On the other hand, a common but sometimes deceptive practice in paleontological work seems to be: the fewer specimens a student has the more species he is likely to make!

In many instances named species are considered dubiously identified, but question marks are not used. This practice may be condemned on the ground that all such species should be assigned to *Phyllites*, *Carpites*, or similar catchall form genera. Nevertheless, it seems to me that a usable distinction in the degree of doubt can be made. For example, a leaf may have nearly all the features of *Quercus*, and *Quercus* could be an item of the flora, but the student may still have reservations because no acorns or other remains of *Quercus* have been found in the same strata as the leaf. Why should he relegate this leaf to *Phyllites*? If, however, the leaf has no features definitely suggestive of *Quercus* or any other genus known to him, he should not assign it to *Quercus* even with a question mark. I hold that binomials, especially when used as center headings in publications and in systematic lists, should be kept as free as possible of question marks and parenthetical or other material that properly belongs in the discussion of the species.

The descriptions of species sometimes leave much to be desired. Some students think they have done justice to a specimen when they have described it minutely to the last millimeter, marginal tooth, and surface hair. Although for some specimens this may be appropriate, I consider that it is more important to be told concisely by what particular feature the species differs from those with which it might be confused. The detection and clear description of specific distinguishing features is the nub and hardest part of paleobotanical work, but it emphasizes the fact that publication is intended for the benefit of others rather than as an outlet for the author.

Casting about for help in identifying his material, the paleobotanist consults type collections, botanical manuals, herbarium sheets, seed collections, and experts. In my studies I have been privileged with the opportunity of using the U.S. National Herbarium and the U.S. Department of Agriculture seed collection, to whose courteous and helpful staffs I am greatly indebted. Despite all this help I have been disappointed many times, and my failures to find satisfactory comparative living material together with the possibility that many fossil specimens may represent extinct taxa, have caused me regretfully to relegate numerous items to the catchall genera *Carpites*, *Phyllites*, etc., and to leave many unnamed.

Another source of frustration is the not infrequent wrong citation of the locality of the type specimens in the older paleobotanical publications. Nevertheless, specimens of different ages and localities were thus mixed, some so much so that they have not been and perhaps never can be correctly placed geographically and stratigraphically.

Still another annoyance derives from the fact that the drawings in many paleobotanical publications are of doubtful merit and are often misleading in that they do not show the outlines, margins, and venational details of the specimens accurately. Sometimes the specimens were not adequately cleaned and prepared before being handed to the artist, who, although professionally skillful, was most likely not a trained botanist and, consequently, could not be expected to recognize some significant details. Thus, for example, the figure of *Cornus newberryi* Hollick (Newberry, 1898, p. 124, pl. 37, fig. 4) illustrates a specimen as having an entire margin. However, when I cleaned the specimen, well-defined marginal teeth emerged (pl. 28, fig. 1), necessitating its reallocation. In the figures of *Lastrea* (*Goniopteris*) *polypodioides* Ettingshausen (Lesquereux, 1878, p. 57, p. 4, figs. 11, 12), the venational details are altogether misleading. Although the specimens are poorly preserved, careful inspection with a good lens in just the right light shows that they are examples of the same species of *Woodwardia* as illustrated by Lesquereux in his plate 3, figure 1a. Numerous other examples could be cited, if it were necessary to emphasize this point. Practitioners of paleobotany, it would seem, may learn several lessons from such mistakes: specimens and especially types should be studied first before relying on illustrations. If an artist does the drawing or retouching, the figures should be checked minutely against the specimens before publication. In lieu of the best photographs, the most faithful drawings possible should be made. Even with the best photographic technique, satisfactory illustrations cannot be made from fossils, and recourse must be had to drawings. Because the purpose of illustrations is primarily for the reader's benefit and not to display the author's photographic skill, I have little patience with those paleontologists who stubbornly insist upon no retouching of photography. True, if retouching is necessary, it should be done accurately. To say that reasonably accurate and satisfactory retouching is impossible is sophistry based on the platitude that no one is perfect. Should retouching be done with a steady hand and keen eye for morphological details, such slight deviation from the truth as may occur is likely to be immaterial as compared with the benefit to the reader from having legible and informative illustrations.

The treatment of the names of some species calls for a statement of my policy in this respect. When species based on obscure, atypical, and perhaps now lost fragments, have been given names that are inappropriate and misleading, and if better specimens have been described subsequently under more appropriate names, I have sometimes waived priority in favor of the better specimens and names. If the facts are stated clearly in each instance, I deny that this practice leads to confusion.

For consistency in typography I have decapitalized all specific terms, no matter what their source, and have reduced all personal, specific terms ending in *ii* to *i*, except where *ii* is absolutely required grammatically.

A fossil flora from a given area was preceded there yesterday by a flora only slightly, if any, different; but could one examine the continuous record backward for many millions of years great differences in floral composition would be apparent. These differences may be inferred to have been caused by the evolution, emigration, immigration, and extinction of species, climatic conditions, and physical avenues or barriers. Consequently, in the study of a collection I have begun by comparing its composition first with that of the flora living in the area. Such comparisons, however, often prove futile, and one must look for clues in exotic floras, perhaps in distant parts of the world. The composition of the distant flora or floras may include species that give clues to other unknowns in the fossil flora under examination. By inference, all the satisfactory identifications together permit the formulation of a reasonably probable concept about the ecologic and climatic conditions that prevailed at the time the fossil flora lived.

Some species may seem to be restricted to the fossil flora and its correlatives, thus serving as indices to relative age. These "index species," however, must be accepted with reservations for they or their tentatively indistinguishable ancestors or descendants may subsequently be found in earlier or later strata. Further, the absence of a species or species from a given flora in which they apparently should be present must likewise be accepted with caution. In brief, to determine the relative geologic age of a flora, not only the "index species" but the whole flora must be evaluated, particularly in the light of its immediately surrounding relatives, predecessors, and successors.

The terms lower, middle, and upper following the formation name under each species description refer to general approximations within the Paleocene series and do not indicate definite stratigraphic limits within the Paleocene.

THE PALEOCENE FLORA

Distribution of the species is indicated by initials following their names, as Almy, AY; Animas, A; Canada, CA; Coalmont, CT; Denver and Dawson, D; Evanston, E; Ferris, F; Fort Union, FU; Livingston, L; Middle Park, MP; Puerco, P; Raton, R. See page 11 for names and distribution of formations and members. The Paleocene flora, for practical reasons, is here treated as a composite unit instead of by florules taken from the separately identified but fairly closely equivalent formations.

SEEDLESS PLANTS

Chara spp	FU
Fungi	FU
Marchantia lignitica (Ward) Brown, n. comb	FU
pealei Knowlton	FU
Preissites wardi Knowlton	FU
Hypnum coloradense Brown, n. sp	D
Mnium montanense Brown, n. sp	FU
Hymenophyllum confusum Lesquereux	D
Allantodiopsis erosa (Lessuereux) Knowlton and Maxon	A, CT, D, FU, MP, R
Blechnum anceps (Lessuereux) Brown, n. comb	D, FU, R
Dennstaedtia americana Knowlton	CA, D, FU
Dryopteris lakesi (Lesquereux) Knowlton	D, FU, R
meeteetseana Brown, n. sp	FU
serrata Brown, n. sp	D, FU
Lastrea goldiana (Lesquereux) Lesquereux	A, CT, D, FU, MP, R
Onoclea hesperia Brown, n. name	F, FU
Saccoloma gardneri (Lesquereux) Knowlton	AY, D, FU
Woodwardia arctica (Heer) Brown, n. comb	D, F, FU, MP
Gleichenia hesperia Brown, n. sp	FU
Anemia elongata (Newberry) Knowlton	A, D, FU, L, MP, R
Lygodium coloradense Knowlton	CT, D, FU
Osmunda greenlandica (Heer) Brown, n. comb	D, FU
macrophylla Penhallow	CA, FU
Equisetum spp	D, FU, MP
Isoetites horridus (Dawson) Brown	D, F, FU, R
Selaginella berthoudi Lesquereux	D
collieri Knowlton	FU
monstrosa (Hollick) Brown, n. comb	FU

SEED PLANTS

Gymnosperms

Zamia coloradensis (Knowlton) Brown, n. comb	FU, MP
wyomingensis Brown, n. sp	FU
Ginkgo adiantoides (Unger) Heer	FU, L
Amentotaxus campbelli (Gardner) Florin	FU
Araucaria longifolia (Lesquereux) Brown, n. comb	FU
Glyptostrobus nordenskioldi (Heer) Brown, n. comb	CT, D, E, F, FU, L, MP
Metasequoia occidentalis (Newberry) Chaney	CT, E, F, FU
Taxodium olriki (Heer) Brown, n. comb	FU, L
Fokienia catenulata (Bell) Brown, n. comb	CA, FU
Thuja interrupta Newberry	D, F, FU

Monocotyledons

Sparganium antiquum (Newberry) Berry	CT, FU
Alismaphyllites grandifolius (Penhallow) Brown, n. comb	FU, R
Sagittaria megasperma Brown, n. sp	FU
Hydromystria expansa (Heer) Hantke	CT, D, F, FU
Grasslike monocotyledons	
Chamaedorea danae (Lesquereux) Berry	R
Paloreodoxites plicatus (Lesquereux) Knowlton	D, R
Sabal grayana Lesquereux	D, F, FU, R
imperialis Dawson	D, FU
powelli Newberry	FU, R
Thrinax dorfi Brown, n. sp	FU
Canna? magnifolia Knowlton	FU
Zingiberites dubius Lesquereux	D

Dicotyledons

Salix aquilina Brown, n. sp	FU
Carya antiquorum Newberry	A, CT, D, E, F, FU, MP, R
Juglandicarya spp	FU
Juglans berryana (Knowlton) Brown, n. comb	A, R
taurina Brown, n. sp	FU
Pterocarya glabra Brown, n. sp	FU
hispida Brown, n. sp	CT, FU
Betula stevensoni Lesquereux	CT, E, FU, L
Corylus insignis Heer	FU, L
Castanea intermedia Lesquereux	A, D, F, FU, MP, R
Quercus asymmetrica Trelease	FU
greenlandica Heer	A
macneili Brown, n. sp	FU
sullyi Newberry	CT, FU
yulensis Brown, n. sp	FU
Celtis newberryi Knowlton and Cockerell	FU
peracuminata Brown, n. sp	FU
Planera microphylla Newberry	D, FU
Ulmus rhamnifolia Ward	FU
Zelkova planeroides (Ward) Brown, n. comb	FU
Artocarpus lessigiana (Lesquereux) Knowlton	A, D, FU, P, R
Ficus affinis (Lesquereux) Brown	A, D, E, FU, R
artocarpoides Lesquereux	E, F, FU, L, MP, R
minutidens Knowlton	A, R
planicostata Lesquereux	A, D, E, F, FU, P, R

Ficus affinis (Lesquereux) Brown—Continued	
subtruncata Lesquereux	D, F, FU
uncata Lesquereux	R
Morus montanensis Brown, n. sp	FU
Platanus nobilis Newberry	CT, E, F, FU, MP, R
raynoldsi Newberry	CT, D, F, FU, L, MP, P, R
Credneria? daturaefolia Ward	FU
Cinnamomum sezannense Watelet	D, FU
Laurophyllum caudatum (Knowlton) Brown, n. comb	E, F, FU, R
perseanum Brown, n. sp	CT, E, FU, R
Laurus socialis Lesquereux	A, CT, D, E, FU, R
Lindera obtusata (Ward) Brown, n. comb	A, F, FU
Persea brossiana Lesquereux	A, CT, FU, L, MP, R
Sassafras thermale (Lesquereux) Brown, n. comb	CT, E, F, FU, MP
Cabomba inermis (Newberry) Hollick	FU
Nelumbium montanum Brown, n. sp	FU
tenuifolium Lesquereux	A, D
Nymphaea leei (Knowlton) Brown, n. comb	R
pulchella (Knowlton) Brown, n. comb	D
Paleonelumbo macroloba Knowlton	FU
Paleonuphar hesperium Brown, n. sp	FU
Paranymphaea crassifolia (Newberry) Berry	FU
Cercidiphyllum arcticum (Heer) Brown	CT, D, E, F, FU, L, MP, R
Magnolia berryi (Knowlton) Brown, n. comb	A, R
borealis Brown, n. name	FU, L
magnifolia Knowlton	A, D, FU, R
regalis Heer	D, R
rotundifolia Newberry	R
Hamamelites inaequalis (Newberry) Brown, n. comb	FU
Liquidambar dakotense Brown, n. sp	FU
Eucommia serrata (Newberry) Brown, n. comb	CA, CT, D, F, FU, R
Hydrangea antica Brown, n. sp	FU, MP
Asimina vesperalis Brown, n. sp	FU
Cercocarpus ravenscragensis Berry	CA
Prunus careyhurstia Brown, n. sp	FU
coloradensis Knowlton	D, R
corrugis Brown, n. sp	AY, A, CT, F, FU
mclearni Berry	CA
perita Brown, n. sp	FU
Bauhinia wyomingana Brown	FU
Leguminosites coloradensis Knowlton	FU, MP
williamsi Berry	CA
Mimosites coloradensis Knowlton	CT
Robinia wardi (Knowlton) Brown, n. comb	CT, FU
Staphylea minutidens (Knowlton) Brown, n. comb	R
Acer fragile Knowlton	R
newberryi Brown, n. name	FU
silberlingi Brown, n. sp	FU
spp.	FU
Sapindus Affinis (Newberry) Brown	D, FU
Koelreuteria annosa Brown	FU
Ilex artocarpidioides (Lesquereux) Brown, n. comb	D
Paliurus? sp. Berry	CA
Rhamnus cleburni Lesquereux	D, FU, R
goldiana Lesquereux	A, D, R
hirsuta Brown, n. sp	FU
Zizyphus fibrillosus (Lesquereux) Lesquereux	A, D, FU, R
Zizyphoides mackayi Bell	CA
Ampelopsis acerifolia (Newberry) Brown, n. comb	CT, D, E, FU, L, MP
Cissus marginata (Lesquereux) Brown, n. comb	A, CT, D, F, FU, P, R
Cissites rocklandensis Brown, n. sp	R
Parthenocissus ursina Brown, n. sp	FU
Vitis lobata (Knowlton) Brown, n. comb	A, FU
olriki Heer	D, E, FU, MP, R
sp	FU
Dombeyopsis magnifica Knowlton	D
Pterospermites cordatus Ward	D, FU, R
Dillenites garfieldensis Brown, n. sp	FU
Myrtophyllum torreyi (Lesquereux) Dorf	A, D, FU
Trapa angulata (Newberry) Brown, n. comb	CA, FU
Trapa paulula (Bell) Brown, n. comb	CA, FU
Melastomites montanensis Brown, n. sp	F, FU
Cornus hyperborea Heer	FU, MP
nebrascensis Schimper	FU, MP
Nyssa alata (Ward) Brown, n. comb	D, F, FU, R
borealis Brown, n. sp	F, FU
Nyssa? obovata Knowlton	D
Kalmia elliptica Brown, n. sp	D, FU
Fraxinus eocenica Lesquereux	CT, D, E, FU, MP
Apocynophyllum lesquereuxi Ettingshausen	R
Viburnum antiquum (Newberry) Hollick	F, FU
asperum Newberry	FU
cupanioides (Newberry) Brown, n. comb	CA, FU
tilioides Ward	A, FU
Macclintockia kanei (Heer) Seward and Conway	Greenland
Phyllites demoresi Brown, n. sp	FU
disturbans Brown, n. sp	FU
pagosensis Knowlton	A, D, R
Calycites hexaphylla Lesquereux	E, FU
polysepala Newberry	FU
Carpolithes spinosus Newberry	R
Nordenskioldia borealis Heer	CT, FU
Palmocarpon commune Lesquereux	D, R
compositum Lesquereux	R
lineatum Lesquereux	D
subcylindricum Lesquereux	D, FU
truncatum Lesquereux	D
Viburnum goldianum Lesquereux	D
solitarium Lesquereux	D
Ophiomorpha nodosa Lundgren	FU
Fossil wood and miscellaneous objects of uncertain affinity.	

SYSTEMATIC DESCRIPTION OF THE MEGASCOPIC FLORA

SEEDLESS PLANTS

ALGAE

Chara spp.

Plate 5, figures 1–6

Characeous oogonia, probably representing several distinct species, have been found in the Paleocene strata of the Rocky Mountains and Great Plains. One collection, made by Donald Duncan, of the U.S. Geological Survey, contains spherical oogonia (pl. 5, figs. 2, 3) averaging 1 mm in diameter. These resemble in size and number of sheathing cells or spiral ridges those (pl. 5, fig. 1) of *Chara compressa* Knowlton (1888, p. 156, 157), now called *Aclistochara compressa* (Knowlton) Peck and Reker (1948, p. 87, pl. 21, figs. 31–33), from the Flagstaff limestone near Wales, Utah, and the Willow Creek formation in Canada (Bell, 1949, p. 36, pl. 22, figs 1, 2, 3, 5, 7, 8). They also resemble those described by Watelet (1866, p. 50–56) from the Tertiary of the Paris Basin.

Somewhat similar specimens (pl. 5, figs. 4–6) were collected from about the same stratigraphic level in the Fort Union formation in North Dakota by W. E. Benson, of the U.S. Geological Survey; and by R. B. Colton, also of the Survey, from a slightly lower stratigraphic level in NE¼ sec. 31, T. 33 N., R. 55 E., Sheridan County, Mont. These smaller specimens appear to me to represent a different species than those in the Duncan collection and are perhaps close to *Aclistochara mitella* Peck and Reker (1948, p. 89, pl. 21, figs. 16–20) from the Evanston (Hoback) formation in Hoback Canyon, Wyo. Another species, *A. coronata* Peck and Reker also from the Evanston formation, is intermediate in size between *A. compressa* and *A. mitella.* I have seen none such in the Fort Union formation.

Occurrence: Fort Union formation (lower), 9206; (upper), 229 (fig. 1), 9204 (figs. 2, 3), 9205 (figs. 4–6).

FUNGI

Round or irregular spots occur on many species of Paleocene leaves. Oswald Heer described the following from the Paleocene strata of Greenland: *Depazea grönlandica*, *Rhytisma boreale*, *Sclerotium cinnamomi*, *S. populicola*, *Sphaeria annulifera*, *S. arctica*, and *S. interpungens.* Those called *Sclerotium rubellum* Lesquereux (1874, p. 35, pl. 1, fig. 2) occur on the leaves of a palm; and those called *Sclerotites? cypericola* Knowlton (1930, p. 16, pl. 1, fig. 7) and *S.? hesperius* Knowlton (idem, pl. 1, fig. 6) on sedgelike leaves. Doubtless some of these spots were caused by fungi or bacteria, but others may have been caused by insects, worms, or mechanical wear and tear. I have made no effort to study the spots microscopically by peel or other methods and have found no satisfactory criteria for distinguishing them megascopically. Consequently I offer no identifications of them. On the contrary I consider it best that such objects be not named unless characterizable spores are found. Notice of them may well be confined to the description of the foliage on which they occur.

What purports to be the context of a bracket-fungus was described by Heer as *Polyporites sequoiae* (1874, p. 48, pl. 83, fig. 10). This dubious object also might better have remained unnamed.

Spores of fungi occur in the Paleocene coals, as found by Wilson and Webster (1946, p. 271, fig. 1) who described *Brachysporium* sp. from near Red Lodge, Mont.

HEPATICAE

Marchantia lignitica (Ward) Brown, n. comb.

Plate 4, figures 4, 6

Fucus lignitum Lesquereux. Ward, 1886, p. 549, pl. 31, fig. 2; 1887, p. 13, pl. 1, fig. 2 [not fig. 1, which is *Trapa angulata* (Newberry) Brown].

Ward's illustration (his fig. 2) of this species (fig. 4) does not show a feature present on the specimen when cleaned up, namely, the distinct areolation, similar to that on the upper surface of the thallus of a living liverwort of the family Marchantiaceae. Reexamination of the specimens illustrated in Ward's figures 1 and 2 shows that they do not represent the same species of plant. Specimen 1 was collected from Upper Cretaceous strata at Point of Rocks, Wyo., and is the dissected, submerged foliage of *Trapa? angulata* (Newberry) Brown, whose typical floating rosettes are also found at the same locality. Specimen 2 is from Fort Union strata at Burns Ranch, on the left bank of the Yellowstone River, 30 miles northeast of Glendive, Mont. As these are fresh-water deposits, the specimen cannot be a species of *Fucus*, which is a genus of marine algae. The size of the thallus, surface markings, and general habit resemble those of the living *Marchantia polymorpha* Linnaeus. The areolations of the related *Conocephalus* are considerably larger.

Occurrence: Fort Union formation (middle), 2420 (fig. 4, 6).

Marchantia pealei Knowlton

Plate 4, figures 1, 10

Marchantia pealei Knowlton, 1908, p. 157–159, pl. 25.
Marchantites pealei (Knowlton) Steere, 1946, p. 305.

This species resembles *Marchantia lignitica* (Ward) Brown but apparently lacks the areolations of the latter. Hollick (1930, p. 37, pl. 1, fig. 2) described *M. yukonensis* from Cretaceous strata in Alaska. It also lacks distinguishing surface features and may be related to *M. pealei.* The transfer to *Marchantites* was a futile gesture.

Occurrence: Fort Union formation (lower), 4293 (fig. 10, a reproduction of Knowlton's type), 8517 (fig. 1), 8258; (upper), 8202.

Preissites wardi Knowlton

Plate 4, figure 7

Preissites wardii Knowlton, 1894, p. 458–460, pl. 219, figs. 1–3.
Marchantites wardii (Knowlton) Steere, 1946, p. 305.

The thalli of this species were represented as having "lines" simulating secondary veins branching from the "midrib." These "lines" are folds or wrinkles in the troughs of which some carbonaceous matter is preserved giving the appearance of veinlets. As no fruiting bodies have been found on these specimens, there remains some doubt as to the affinities implied in the generic name. The transfer to *Marchantites* by Steere, in my opinion, was needless.

Occurrence: Fort Union formation (lower), 8252; (middle), 2420 (fig. 7); (lower), 8252; (upper), 9125.

MUSCI

Hypnum coloradense Brown, n. sp.

Plate 5, figure 7

This is a leafy sterile shoot, of probable procumbent habit. The leaves are narrow ovate-lanceolate in outline, sharp-pointed, with costae. Sporophyte lacking.

Occurrence: Dawson arkose, 5738 (fig. 7).

Mnium montanense Brown, n. sp.

Plate 5, figure 12

Leaves ovate, acute, entire, in two rows. Costa fairly strong ending in the apex. In the absence of spore capsules and other distinguishing features, it seems futile to compare this species with any living species of *Mnium*. Resemblances to species of *Fissidens* are suggested.

Occurrence: Fort Union formation (lower), 8519 (fig. 12).

FERNS

HYMENOPHYLLACEAE

Hymenophyllum confusum Lesquereux

Plate 6, figure 9

Hymenophyllum confusum Lesquereux, 1878, p. 51, pl. 2, figs. 6–6a.
Knowlton, 1930, p. 17, pl. 1, fig. 4.

Knowlton's figure of this species is perhaps a little clearer than Lesquereux's, but all the specimens are poorly preserved, so that the species is difficult to characterize.

Occurrence: Denver formation, 317 (fig. 9).

POLYPODIACEAE

Allantodiopsis erosa (Lesquereux) Knowlton and Maxon

Plate 5, figures 13–16

Allantodiopsis erosa (Lesquereux) Knowlton and Maxon. Knowlton, 1919, p. 61.
Knowlton, 1924, p. 78, pl. 6, fig. 1; 1930, p. 24, pls. 4, 5. See synonymy.
Bell, 1957, p. 21, pl. 3, figs. 3, 6, 9.
Asplenium remotidens Knowlton, 1899, p. 669, pl. 80, fig. 7.
Osmunda affinis (Lesquereux) Lesquereux, 1878, p. 60, pl. 4, fig. 1.
Pteris pseudopennaeformis Lesquereux. Hollick, 1936, p. 39, pl. 75, fig. 1b.
Saccoloma gardneri (Lesquereux) Knowlton. Knowlton, 1930, p. 26, pl. 3, fig. 4. [not other figs.]

Not much can be added to the description of this species except the record of new localities. Apparently only one fruiting specimen—that illustrated by Knowlton (1930, pl. 4, fig. 1)—has ever been found in Paleocene strata.

The features that distinguish this species are: pinnules large, coarse, serrate with cuneate bases more or less petioled; secondary veins almost at right angles to the midrib, widely spaced, not anastomosing, branching once near the relatively slender midrib and sometimes again near the margin, with occasional unbranched intermediaries; vein terminations in the margin not conspicuously swollen; sori large, elliptic, astride the distal branch of a secondary vein near the midpoint between midrib and margin.

This or a very closely related species occurs in Upper Cretaceous strata in the Rocky Mountain region; and possibly the same or another species occurs in Eocene strata near Mitchell, Clarno, and Comstock, Oreg.; on Skookumchuck River, Swauk Creek, Fletts Creek (near Wilkeson), and other localities in Washington.

Occurrence: Fort Union formation (lower), 7663, 8551, 8884; (upper), 8774; Animas formation, 7496, 8447; Coalmont formation, 6105 (fig. 14); Denver formation, 317 (fig. 15), 318 (fig. 13), 325 (fig. 16, Knowlton's fruiting type reproduced), 8777; Middle Park formation, 326; Raton formation, 5826.

Blechnum anceps (Lesquereux) Brown, n. comb.

Plate 6, figures 3, 4

Salpichlaena anceps (Lesquereux) Knowlton, 1930, p. 27, pl. 7, figs. 1–3. [Omit all but last item of synonymy, for they are *Allantodiopsis erosa* (Lesquereux) Knowlton and Maxon.]
Pteris linearis Knowlton, 1917, p. 284, pl. 54, fig. 3.

From such fragments of this fern as are preserved, it would appear that the frond was branched and relatively open, like the living *Osmunda regalis*, with the pinnules widely spaced and approximately at right angles to the rachis. The pinnules have entire or subdenticulate margins, and rounded, cordate, or auriculate bases. The midvein is slender, and the secondary veins, although simulating those of *Allantodiopsis erosa*, are more closely spaced, the distal portions being directed almost at right angles to the midvein, and the vein terminations in the margin are conspicuously enlarged or club shaped. No fertile remains of this species have been recognized. *Blechnum* is now the accepted name for these ferns.

Occurrence: Fort Union formation (lower), 8666, 8678 (figs. 3, 4), 8928; Denver formation, 322, 6142; Raton formation, 5099.

Dennstaedtia americana Knowlton

Plate 6, figures 1, 2, 5–7

Dennstaedtia americana Knowlton, 1910, p. 492, pl. 63, fig. 4; pl. 64, figs. 3–5.
Berry, 1935, p. 16.
Dennstaedtia crossiana Knowlton, 1930, p. 21, pl. 2, figs. 7–9.
Dennstaedtia blomstrandi (Heer) Hollick. Bell, 1949, p. 39, pl. 24, figs. 1, 4; pl. 26, fig. 5.

Knowlton's types from North Dakota include both fertile and sterile fronds, and similar material, as illustrated, from other localities confirms the characterization of the species. The venation of the fertile pinnules consists of veins to the sori only, whereas that of the sterile pinnules is considerably more diffuse and forked.

The relationship of this species to the sterile foliage from the Tertiary of Greenland and Alaska called *Dennstaedtia blomstrandi* (Heer) Hollick, and to that from the Upper Cretaceous of western Alberta, called *Sphenopteris* (*Dennstaedtia*?) *burlingi* Bell, is problematical. Many of those specimens are fragmentary, and their characterization is difficult. This, or a close ancestral species occurs in the Cretaceous of northern Alaska.

Occurrence: Fort Union formation (upper), 4273 (fig. 1, Knowlton's type reproduced), 4334, 5029 (fig. 7), 6084, 8222 (figs. 2, 5), 8231 (fig. 6), 8913; Dawson arkose, 325; Paskapoo and Ravenscrag formations, Canada.

Dryopteris lakesi (Lesquereux) Knowlton

Plate 8, figure 15

Dryopteris lakesii (Lesquereux) Knowlton, 1930, p. 18, pl. 1, figs. 1, 2.
Asplenium? *primero* Knowlton, 1917, p. 285, pl. 54, fig. 4.

Knowlton's figure 2, from the Denver formation, shows a fruiting specimen, the numerous sori being small, round, and evenly spaced on both sides of the ultimate veins. Knowlton's figure 1, the specimen of which I cannot now locate, appears to be misleading in showing excessively forked venation. In most specimens the ultimate veinlets are simple, and enter the apexes of the lobes.

Occurrence: Fort Union formation (lower), 7538, 8899; Denver formation, 317 (fig. 15); Raton formation, 5798.

Dryopteris meeteetseana Brown, n. sp.

Plate 5, figure 17

Frond at least twice divided, anadromic, that is, with the first pinnule closest to the main rachis on the upper side of the pinna axis. Proximal pinnules free or almost free, but distal pinnules more or less united. Pinnules with rounded lobes each of which receives a vein. Astride the veins are round sori, but no spores are preserved.

Occurrence: Fort Union formation, 4694 (fig. 17).

Dryopteris serrata Brown, n. sp.

Plate 8, figure 17

Frond at least once divided; lowermost pinnae petioled, parted to the midvein into rounded obtuse divisions; uppermost pinnae becoming more and more sessile and less divided. Margins serrate. Lowest secondaries of the almost free pinnules thrice forked, the next, twice forked, and the rest once forked. Similarly for the undivided pinnae.

No comparison with a living species is sugested, and the reference to *Dryopteris* is entirely nominal.

The species may be the same as *Hemitelites torelli* Heer (1871, p. 462, pl. 49, figs. 1–5a; pl. 55, fig. 2) from Atanekerdluk, Greenland.

Occurence: Fort Union formation (lower) 8519, 8678 (fig. 17); Dawson arkose, 5836.

Lastrea goldiana (Lesquereux) Lesquereux

Plate 5, figures 9–11, 18

Aspidium goldianum Lesquereux, 1874, p. 293.
Lastrea (*Goniopteris*) *goldiana* (Lesquereux) Lesquereux, 1878, p. 56, pl. 4, fig. 13.
Lastrea (*Goniopteris*) *fischeri* Heer. Lesquereux, 1883, p. 239, pl. 50, figs. 1, 1a.
Newberry, 1898, p. 10, pl. 48, fig. 6.
Lastrea (*Goniopteris*) *knightiana* Newberry, 1883, p. 503.
Asplenium? *penhallowi* Bell, 1949, p. 41, pl. 26, figs. 1, 3, 4.
Dryopteris? *cladophleboides* Knowlton, 1917, p. 284, pl. 54, fig. 1; 1924, p. 78, pl. 6, fig. 2.
Dryopteris integra Knowlton, 1930, p. 17, pl. 1, fig. 5.
Dryopteris lesquereuxii Knowlton, 1922a, p. 109.
Dryopteris richardsoniana Knowlton, 1930, p. 20, pl. 2, figs. 3–5.

The type specimen of this species, originally called *Aspidium goldianum*, is now poorly preserved but may have been in better condition when first studied and figured. In 1922 Knowlton (p. 109) recorded this specimen with the Laramie flora of the Denver Basin, but in 1930 (p. 20) spoke of it as being from the Denver formation although he did not list it as a species of the Denver (Tertiary) flora. Examination of the matrix, however, confirms the latter assignment.

The few to many equally spaced gracefully forward-curving, rarely forked, secondary veins of the entire-margined slightly falcate pinnules, characterize the specimens assigned to this species. Fertile pinnae are scarce (figs. 9, 11; and Knowlton's *Dryopteris integra*), but when present have small round sori on the secondary veins midway between the midrib and margin.

The relationship of this species to *Dryopteris laramiensis* Knowlton (1922a, p. 109, pl. 1, fig. 5) from the Laramie formation in the Denver Basin; to Heer's Paleocene specimens from Greenland called *Aspidium escheri*, *A. heeri*, and *A. meyeri;* to Saporta's *Alsophila thelypteroides* (1868, p. 324, pl. 3, fig. 1); to Knowlton's Eocene specimens from Yellowstone Park, called *Asplenium iddingsi*, *Dryopteris weedi*, *D. xantholithensis;* to Berry's Eocene species, *Goniopteris lesquereuxi*, from the Wind River Basin in Wyoming; to Hollick's Tertiary species, *Asplenium alaskanum* and *Dryopteris meyeri*, from Alaska; to Heer's *Lastrea fischeri* from Miocene lakebeds at Oeningen, Germany; and to specimens from many Eocene localities in Washington and Oregon, is difficult to evaluate, for in many instances the figured specimens involved are poorly preserved and provide only tantalizing resemblances. The Eocene specimens, however, appear to be somewhat larger, with more secondary veins in each pinnule.

Occurrence: Fort Union formation (lower), 4661, 8258 (fig. 18); Animas formation, 7484; Coalmont formation, 6105 (fig. 11); Dawson arkose, 325 (figs. 9, 10), 5738; Denver formation, 317; Middle Park formation, 333; Raton formation, 5803.

Onoclea hesperia Brown, n. name

Plate 7, figures 1, 4

Onoclea sensibilis fossilis Newberry, 1868, p. 39; 1898, p. 8, pl. 23, fig. 3.
Knowlton, 1902, p. 705, pl. 26, figs. 1–4.
Berry, 1935, p. 16, pl. 1, figs. 2, 3; pl. 2. [From Berry's synonymy delete the items *Woodwardia latiloba* and *W. latiloba minor*, which are *W. arctica* (Heer) Brown.]
Onoclea hebridica (Forbes) Ettingshausen and Gardner. Bell, 1949, p. 40, pl. 20, fig. 5; pl. 24, figs. 3, 5; pl. 25, fig. 2.

This species is represented by characteristic sterile foliage at many Paleocene localities, but fertile fronds have been reported from only one locality, along Sweetgrass Creek, west of Porcupine Butte, on the east side of the Crazy Mountains, Mont. (Knowton, 1902, p. 705). Similar fertile fronds, originally called *Caulinites fecunda*, were described by Lesquereux from the Laramie formation at Erie, Colo.

The sterile fronds most likely to be confused with *Onoclea* are those of *Woodwardia.* However, if the margins are well enough preserved, those of *Onoclea* will be entire, whereas those of *Woodwardia* will be minutely serrulate or serrate. If the venation is clearly preserved, the veins of *Onoclea* make a more uniform pattern of anastomosis, even close to the margins, than those of *Woodwardia*, which, after one or two anastomoses, tend to be forked to the margins.

This species is distinguished from the Cretaceous species, *Onoclea fecunda* Knowlton, in having more elongated, pointed, marginal lobes. It may be equivalent to *O. hebridica* (Forbes) Gardner and Ettingshausen (1879, p. 68) from the Eocene Ardtun beds, Isle of Mull.

A new name is hereby proposed for this American species, because the original trinomial is misleading, unnecessary, and inappropriate. First, there is no assurance that this species is identical with the living *O. sensibilis* Linnaeus, however closely they may resemble each other; nor that it is a variety or subspecies of *O. sensibilis*, as indicated by the third term *fossilis.* Moreover, every fossil species of *Onoclea* deserves the adjective *fossilis.* Finally, trinomials are unnecessary in paleobotany, for they suggest a degree of refinement in identification of fossil plant remains that is neither achieved nor even possible of achievement.

Occurrence: Fort Union formation (lower), 4029, 5842, 7004 (fig. 4), 8897, exact loc. not stated (fig. 1, Newberry's fig. 3 reproduced); (upper), 607, 5322, 8212, 8917, 8921, 8922, 9072; Ferris formation, 6419.

Saccoloma gardneri (Lesquereux) Knowlton

Plate 5, figure 19; plate 6, figures 12, 13

Saccoloma gardneri (Lesquereux) Knowlton, 1919, p. 560; 1930, p. 26, pl. 3, figs. 3, 5–8 [not fig. 4, which is *Allantodiopsis erosa* (Lesquereux) Knowlton and Maxon].
Bell, 1957, p. 20, pl. 1, figs. 6, 8.
Phanerophlebites pealei Knowlton, 1922a, p. 110, pl. 3, fig. 5.
Pteris goldmani Knowlton, 1922a, p. 111, pl. 2, fig. 3.
Saccoloma sp. Knowlton, 1930, p. 27, pl. 3, figs. 1, 2.

The distinguishing features of this species are: pinnules sometimes longer and larger than those of *Allantodiopsis erosa* and *Blechnum anceps;* margins entire or slightly undulating; bases rounded or cuneate; midrib stout; secondary venation somewhat resembling that of *Allantodiopsis erosa*, except for frequent anastomoses; in sterile pinnules the veins terminate in the margin without conspicuous thickening, but in fertile pinnules the veins terminate in round to squarish sori that unite to form a marginal border.

Occurrence: Fort Union formation (lower), 4029 (pl. 6, fig. 13), 6845, 7538, 8678 (pl. 6, fig. 12), 8897 (pl. 5, fig. 19); (upper) 5030; Almy formation, 3667; Dawson arkose, 325, 5738, 5831, 6142.

Woodwardia arctica (Heer) Brown, n. comb.

Plate 7, figures 2, 3, 5

Woodwardites arcticus Heer, 1868, p. 86, pl. 1, figs. 16, 16b; pl. 45, fig. 2c; pl. 48, fig. 9; 1871, p. 462, pl. 40, fig. 6.
Woodwardia latiloba Lesquereux, 1874, p. 391; 1878, p. 54, pl. 3, figs. 1, 1a.
Woodwardia latiloba minor Lesquereux, 1874, p. 391; 1878, p. 54, pl. 4, figs. 9, 9a.
Woodwardia latiloba serrata Knowlton, 1930, p. 22, pl. 2, figs. 1, 2.
Woodwardia maxoni Knowlton, 1910, p. 489, pl. 63, fig. 3; pl. 64, figs. 1, 2.
Berry, 1926, p. 95, pl. 10, figs. 2, 3.
Dryopteris polypodioides (Ettingshausen) Knowlton, 1930, p. 20.

Lastrea (*Goniopteris*) *polypodioides* (Ettingshausen) Lesquereux, 1878, p. 57, pl. 4, figs. 11, 12.
Onoclea sensibilis Linnaeus. Hollick, 1936, p. 35, pl. 2, figs. 2–4.
Onoclea sensibilis [*arctica*] Heer, 1883, p. 48, pl. 70, fig. 6.
Pteris pseudopennaeformis Lesquereux, 1878, p. 52, pl. 4, figs. 3, 4.

Sterile leaves of *Onoclea* and *Woodwardia* may resemble one another closely, a circumstance that renders fragmentary fossil material of these genera difficult to distinguish. In general, however, the leaf-margins of *Onoclea* are entire, whereas those of *Woodwardia*, except for some fertile fronds, are either minutely serrulate or conspicuously serrate. Thus, Hollick's figures of *Onoclea sensibilis* from the Tertiary of Alaska give the impression of having entire margins and therefore of being assignable to *Onoclea*. His specimens, however, particularly that of his figure 4, show clearly serrate margins, and therefore, they are transferred to *Woodwardia*. In Lesquereux's figures of *Pteris pseudopennaeformis* the venation is incorrectly illustrated. Practically, the misidentification of one for the other of these genera would probably make little or no difference for ecological or climatic interpretations.

The relationship of this species to *Woodwardia crenata* Knowlton (1900, p. 22, pl. 3, fig. 3) and other Cretaceous and post-Paleocene species is conjectural.

Occurrence: Fort Union formation (lower), 4661, 6116, 7005, 8519 (figs. 3, 5), 8852, 8666, 8897; (upper), 5030 (fig. 2), 6420, 8652, 8913; Denver formation, 318, 8447; Ferris formation, 6420; Middle Park formation, 333.

GLEICHENIACEAE

Gleichenia hesperia Brown, n. sp.

Plate 8, figures 11, 12, 16

Pinnules long, relatively narrow, squarely sessile on the rachis at right angles or nearly so, with crenate or rounded marginal lobes pointing slightly distad. The notches between the lobes do not reach the rachis, as in most fossil species of *Gleichenia*. The venation of each marginal lobe consists of one somewhat undulant vein and its two or three branches. No sori have been found.

These specimens are only nominally assigned to *Gleichenia*. Somewhat similar material from the Cretaceous of Greenland was called *Phegopteris jorgenseni* Heer (1883, p. 32, pl. 35, figs. 1–3), and later *Sphenopteris jorgenseni* (Heer) Seward. Saporta and Marion (1878, p. 16, pl. 1, figs. 2–3), described a comparable fragment as *Benitzia minima* from the Paleocene of Gelinden, Belgium.

Occurrence: Fort Union formation (lower), 8519 (figs. 12, 16), 8897 (fig. 11).

SCHIZAEACEAE

Anemia elongata (Newberry) Knowlton

Plate 6, figure 8

Sphenopteris (*Asplenium*) *elongatum* Newberry, 1863, p. 511.
Anemia elongata (Newberry) Knowlton, 1922a, p. 112, pl. 2, fig. 2. [In the synonymy, under *Anemia perplexa* Hollick, omit pl. 63, figs. 1–4.]
Aneimia eocenica Berry, 1916a, p. 164, pl. 9, fig. 7; pl. 10, fig. 2; pl. 11, figs. 1, 2; 1930, pl. 47, fig. 1.
Anemia grandifolia Knowlton, 1924, p. 78, pl. 5.
Anemia lanceolata Knowlton, 1930, p. 29, pl. 8, fig. 10.
Anemia mosbyensis Knowlton, 1930, p. 28, pl. 8, fig. 9.
Anemia occidentalis Knowlton, 1917, p. 285, pl. 54, fig. 2.
Anemia supercretacea Hollick. Knowlton, 1917, p. 248, pl. 30, fig. 5.
Anemia sp. Knowlton, 1916, p. 87, pl. 15, figs. 6, 7.
Anemia sp. Knowlton, 1916, p. 333, pl. 84, fig. 4.
Anemia sp. Knowlton, 1922a, p. 113, pl. 2, fig. 1.
Anemia sp. Knowlton, 1930, p. 30, pl. 8, fig. 7.
Aneimia sp. Dorf, p. 44, pl. 1, fig. 8.
Asplenium eoligniticum Berry, 1961a, p. 167, pl. 11, fig. 3; 1930c, p. 62, pl. 8, figs. 2–4. [Not *A. eoligniticum* described by Brown, 1934, p. 52, pl. 8, figs. 3, 4. This is probably *A. hurleyensis* Berry.]
Diplazium crossii (Knowlton) Knowlton, 1930, p. 23, fig. 6. [See synonymy.]
Lygodium? *compactum* Lesquereux. Knowlton, 1922a, p. 113, pl. 1, fig. 1.
Pteris pennaeformis Heer. Newberry, 1898, p. 7, pl. 48, fig. 5.
Pteris pseudopennaeformis Lesquereux. Knowlton, 1902, p. 22. [Lesquereux's original specimens are *Woodwardia arctica* (Heer) Brown.]
Berry, 1916, p. 168, pl. 9, fig. 6.
Pteris russellii Newberry, 1883, p. 503; 1898, p. 7, pl. 61, figs. 1, 1a.

Anemia is sometimes spelled *Aneimia*. Originally Swartz spelled it *Anemia*, but in a footnote gave the derivation as from the Greek *aneimon*, unclad, naked. The correct ultimate transliteration, therefore, would be *Animia*.

The reference of these Cretaceous and Tertiary ferns to *Anemia* seems to be justified, following the discovery by Andrews and Pearsall (1941, p. 168) of what purport to be the fertile parts of *Anemia fremonti* Knowlton from the Frontier formation (Cretaceous) in western Wyoming. No such fructifications have yet been found or reported from later formations containing sterile fronds. Collectors, however, should be on the alert for such remains.

The synonymy given here is the writer's opinion only and rests on no definite characters that ally all these specimens as one species. That a number of species may here be mixed is quite probable inasmuch as the range of specimens extends from uppermost Cretaceous into Eocene.

It will be noted that in general only fragments, usually the tips of fronds, are figured. Knowlton's *Anemia grandifolia*, from the Animas formation, is the largest figured specimen, and inspection of it reveals the great variation in degree of dissection of the pinnules. It is for this reason that the long synonymy includes species with pinnules that are practically entire, and others that are dissected almost, if not entirely, to the rachis.

The relationship of *Anemia elongata* to *A. fremonti* Knowlton of the Colorado group and to *A. delicatula* Brown of the Green River and related formations, is obscure. Gradations from one to the other seem plausible but hardly demonstrable.

Occurrence: Fort Union formation (lower), 2421; 4028; 7538, 8928; (upper) 1502, 2416, 4369, 6084 (fig. 8), 8678, 8775, 9532; Animas formation, 7481; Dawson arkose, 5738, 5836, 8188; Livingston formation, 8896; Middle Park formation, 333, 335, 337; Raton formation, 5697.

Lygodium coloradense Knowlton

Plate 8, figures 9, 10

Lygodium coloradense Knowlton, 1930, p. 30, pl. 8, fig. 8.

This species was based upon a single specimen whose base was deeply scalloped and venation widely spaced. Material collected subsequently from other Paleocene localities indicates that not all the specimens have bases like that of the type but that some may be cuneate. The relatively widely spaced and generally less forked venation, however, seems to be a persistent and distinguishing feature. The American Eocene species, *Lygodium neuropteroides* Lesquereux [*L. kaulfussi* Heer of authors], has more closely spaced venation, giving the pinnules a less coarse appearance.

Fertile pinnules (fig. 9) of *Lygodium coloradense* occur in the Coalmont formation of North Park, Colo., but these do not appear to be significantly different from those of Eocene species. No authentic remains of *Lygodium* have been reported from Laramie, Lance, and Hell Creek strata, the specimens from those formations alleged to belong to *Lygodium* being fragments assignable to other genera. The earliest known American climbing fern is *L. pumilum* Brown (1943b, p. 141, figs 1–5), with delicate, small pinnules, from the Montana group near Casper, Wyo.

Occurrence: Fort Union formation (lower), 8678 (fig. 10); Coalmont formation, 6105 (fig. 9); Dawson arkose, 5738 (type).

OSMUNDACEAE

Osmunda greenlandica (Heer) Brown, n. comb.

Plate 5, figure 8; plate 6, figures 14, 15

Pteris grönlandica Heer, 1883, p. 49, pl. 70, figs. 1–5; pl. 107, fig. 1.

Pteris oeningensis Unger. Heer, 1880, p. 9, pl. 3, figs. 2, 3, 4, 8b.
Cladophlebis groenlandica (Heer) Bell, 1949, p. 38, pl. 26, fig. 2.

Pinnules 2 cm long, somewhat broad falcate in outline, entire or only slightly crenulate, pointed, and separated from one another by narrow, rounded sinuses reaching to within 1 or 2 mm of the rachis. Secondary veins openly spaced, once forked near the midvein, and rarely forked again near the margin. No fertile fronds assignable to this species have been found. It can be compared with *Osmunda claytoniana* Linnaeus, of the Eastern United States.

The specimens described by Heer as *Pteris grönlandica* from Paleocene strata at Atanekerdluk, Greenland, have only slightly smaller pinnules than those of the Montana specimens here figured as the same species. The relationship of *Osmunda greenlandica* to species described by Hollick (1936) from the Tertiary of Alaska as *Pteris inaequilateralis* and *Osmunda dubiosa*, is problematical.

Occurrence: Fort Union formation (lower), 8519 (figs. 14, 15), 9253; (upper), 8774, 9238; Denver formation, 317 (fig. 8).

Osmunda macrophylla Penhallow

Plate 6, figures 10, 11; plate 8, figures 7, 8, 13, 14

Osmunda macrophylla Penhallow, 1908, p. 65, text fig. 15.
Bell, 1949, p. 38, pl. 24, fig. 2; pl. 25, figs. 1, 3, 4.
Osmunda heerii Gaudin. Heer, 1868, p. 88, pl. 1, figs. 6–11; pl. 8, fig. 15b.

Pinnules oblong, broad at the somewhat auriculate base, sessile, rounded at the apex. Margin crenulate. Secondary veins twice or thrice forked, undulant. No fertile fronds assignable to this species have been found. The species may be compared favorably with the royal fern, *Osmunda regalis* Linnaeus, of widespread occurrence.

This species apparently lived into Eocene time and perhaps later. It may be the same as *Osmunda eocenica* Saporta and Marion (1873, p. 30, pl. 1, fig. 2; 1878, p. 18, pl. 1, fig. 1) from Paleocene strata at Gelinden, Belgium.

Occurrence: Fort Union formation (lower), 8519 (figs. 10, 11); (middle and upper), 8220, 8248 (fig. 13); 9084 (fig. 8); 9085 (figs. 7, 14).

EQUISETACEAE

Equisetum spp.

Plate 8, figures 1–6

Remains of *Equisetum* in the Fort Union and related Paleocene formations include portions of sterile aerial shoots with sheaths, underground stems with tubers, and cross sections of both aerial and subterranean stems. One object that may be the fruiting cone of an *Equisetum* has been found (pl. 67, fig. 43).

The following species have been described: *Equisetum alexoensis* Bell (1949, p. 36, pl. 22, fig. 4; pl. 23, figs. 5, 7, 9: pl. 67, fig. 5); *E. arcticum* Heer (Bell, 1957, p. 37, pl. 23, figs. 2, 4, 8); *E. boreale* Heer (1868, p. 89, pl. 1, fig. 17; pl. 45, figs. 10, 13e, f); *E. coloradense* Knowlton (1930, p. 31, pl. 8, figs. 1–6); and *E. globulosum* Lesquereux (1883, p. 222, pl. 48, fig. 3). When, however, these species are examined in the light of the material now on hand, they do not seem to be readily distinguishable. Size of stem, number of teeth in the sheaths, shape of the tubers—all vary so greatly, with gradations from one to another, and with no apparent constancy in any set of features, that I shall not attempt to define the species.

Occurence: Fort Union formation (lower), 7538 (fig. 3), 8678; (middle), 2414 (figs. 2, 5), 2417 (fig. 1), 4474; (upper), 8164 (fig. 6), 8204 (fig. 4), 8774; Dawson arkose, 5838; Middle Park formation, 333.

ISOETACEAE

Isoetites horridus (Dawson) Brown

Plate 9, figures 1–8

Isoetites horridus (Dawson) Brown, 1939c, p. 268, figs. 3, 6. [See synonymy, and correct *Xantholithes* to *Xantholithus.*]

This species was characterized as having leaves (sporophylls) whose spatulate terminations had entire margins. A few specimens have since been found that have minute obscure teeth which are not nearly as conspicuous as those of *Isoetites serratus* Brown from Upper Cretaceous strata.

Additional collections also now permit illustration of the complete leaf, with its undulant margins and the ligule (figs. 1, 2) above the basal part containing the sporangium filled with spores. Some of this new material is from Eocene strata. Figure 4 shows the rosette of leaves around a center that is a mass of megaspores.

The genus *Isoetites* was already in existence in the Triassic as shown by a species called *I. circularis* (Emmons) Brown (1958b, p. 358, figs. 5, 8, 9, 11, 13), represented by specimens from the Pekin formation in the Deep River coal field, North Carolina, and the Chinle formation in the Petrified Forest National Monument, Ariz.

Occurrence: Fort Union formation (lower), 2432 (fig. 8), 5437, 8517; (middle), 2420 (figs. 4–6), 8535 (fig. 3); Dawson arkose, 8881 (fig. 2); Ferris formation, 5255 (fig. 7); Hanna formation (Eocene), 8548 (fig. 1); Raton formation, 5144.

SELAGINELLACEAE

Selaginella berthoudi Lesquereux

Plate 4, figure 9

Selaginella berthoudi Lesquereux, 1878, p. 46, pl. 5, figs. 12, 12a. Knowlton, 1930, p. 33.

This species has larger, more ovate leaves, and a more spreading branching habit than *Selaginella collieri* Knowlton.

Occurrence: Dawson arkose, 8779 (fig. 9); Denver formation, 317.

Selaginella collieri Knowlton

Plate 4, figures 2, 3, 8

Selaginella collieri Knowlton, 1916, p. 201, pl. 1, figs. 1–6.

There is nothing new to add to Knowlton's description of this species except to cite localities where it has since been found. This species may be related to *S. berthoudi* Lesquereux from the Denver formation, but differs in having smaller, more acute leaves, and apparently in the habit of branching.

Occurrence: Fort Union formation (lower), 6215, 7004 (figs. 3, 8); (middle) 2420 (fig. 2).

Selaginella monstrosa (Hollick) Brown, n. comb.

Plate 4, figures 12, 13

Anomalofilicites monstrosus Hollick, 1916, p. 474, pl. 31, figs. 1–3.

Hollick described this species from sterile fronds as a sport or monstrosity which he likened to some illustrated specimens of *Nephrolepis exaltata* (Linnaeus) Schott. Apparently the feature of these specimens that caused him to think of them as monsters is the fact that the side branches differ greatly in length.

In general appearance the sterile shoots are not unlike some mosses, but unfortunately the ultimate details are not clearly preserved and under magnifications of more than 5 or 6 the leaf details fade into the background of the matrix. However, the leaves appear to be sharp pointed.

With these sterile shoots are here associated fertile shoots that come from the same strata in Garfield County, Mont., but not from the same locality. The belief that the sterile and fertile shoots belong together is based upon the resemblance in general habit, both kinds of shoots having branches differing greatly in length.

The short ultimate branches carry sporangia bearing numerous megaspores (10–15), but no details of the megaspores can be seen clearly. Scattered along the main rachis are a few small ovate, hairy(?), pointed leaves.

Comparison of this species with any living species of *Selaginella* is not suggested.

Occurrence: Fort Union formation (lower), 4031 (fig. 13), 8249 (fig. 12).

SEED PLANTS

GYMNOSPERMS

CYCADACEAE

Zamia coloradensis (Knowlton) Brown, n. comb.

Plate 10, figures 6, 9, 12, 13

Chamaedorea? coloradensis Knowlton, 1930, p. 40, pl. 10, fig. 3.
Podozamites latipennis Heer. Brown, 1939b, p. 246, pl. 49, figs. 1–4.

Since my first report on material of this species, I have found additional specimens at other localities and have concluded that the fossils do not represent *Podozamites latipennis* Heer, described from Cretaceous strata in Greenland, but are more likely a species of *Zamia*.

The leaflets are linear, somewhat curved in outline, pointed, entire and are attached by either a broad or narrow base, depending upon their position on the main rachis, which is broad and stout. There is no midvein. The thin parallel veins arising from the base of the leaflet fork near the base and anastomose several times thereafter on their course through the leaflet. The palms of the genus *Chamaedorea* have neither forked nor anastomosing veins.

Heer described a fragment from strata at Puilasok on Disko Island, that he called *Poacites nielseni* (1874, p. 19, pl. 4, fig. 1) in honor of Jens Nielsen, a Dane who lived at Atanekerdluk and collected the first fossil plants in that area. Of him Heer said simply "Er verunglückte auf der Jagd und liegt in Atanekerdluk begraben." (He met misfortune while hunting and lies buried at Atanekerdluk). This fragment is from a blunt-pointed leaf with parallel veins that, according to the illustration, fork and anastomose —a feature not found in grasses. I suspect, therefore, that this specimen represents a cycad, but cannot identify it as definitely belonging to *Zamia coloradensis*.

I have no reason to abandon my hypothesis that the objects (figs. 12, 13) originally figured as the fruits of this species are properly allocated, for similar fruits have been found associated with the foliage of this species at three additional localities in the basal strata of the Paleocene series in Wyoming.

Occurrence: Fort Union formation (lower) 8551 (figs. 6, 9, 12, 13), 8884, 8893, 9130; (upper) 9195; Middle Park formation, 333 (type).

Zamia wyomingensis Brown, n. sp.

Plate 10, figure 1

Rachis stout, pinnules abruptly contracted near the base, but attached to the rachis by a broad insertion. Size of pinnules unknown. Veins widely spaced, forking near the insertion, and again, in some instances, farther along toward the apex. Anastomoses not present in the specimen.

This species differs from *Zamia coloradensis* (Knowlton) Brown in apparent lack of anastomosing veins and in having broad-based insertions of the pinnules. It resembles *Ceratozamia wrighti* Hollick (1936, p. 42, pl. 12, fig. 6) in general appearance, but in *C. wrighti* the veins do not fork at the base of the pinnule, and the pinnules may have scattered, marginal teeth distad.

Occurrence: Fort Union formation (upper) 5911 (fig. 1).

GINKGOACEAE

Ginkgo adiantoides (Unger) Heer

Plate 10, figures 2–5, 8

Ginkgo adiantoides (Unger) Heer. Ward, 1887, p. 15, pl. 1, figs. 5, 6.
Berry, 1926, p. 190.
Ginkgoites adiantoides (Unger) Seward. Bell, 1949, p. 43, pl. 32, figs. 1, 3.

In previous papers (Brown, 1939a, p. 246; 1943b, p. 862) discussing *Ginkgo laramiensis* Ward, I expressed my views on the distinction of fossil species of *Ginkgo* and concluded that the fossil record of *Ginkgo* indicates an evolution in leaf form from the deeply lobed, digitate cuneate in early Mesozoic strata, through entire or bilobed cuneate in late Mesozoic, to entire or bilobed reniform leaves in the Cenozoic. As is well known, the only living species, *Ginkgo biloba* Linnaeus, may produce all these leaf-forms on a single tree, or given trees may specialize in any one of the three kinds. In short, at any stage in the history of *Ginkgo* that stage may produce leaf forms occurring in its ancestors but will have few hints concerning the shapes of leaves to come, and thus, a good collection of *Ginkgo* leaves from a given geological level may provide a useful clue to stratigraphic dating.

As the first well-developed reniform leaves of *Ginkgo* appear in the Paleocene, I favor restriction of *G. adiantoides* to the Cenozoic. This species, however, like *G. biloba*, may include leaves having the form of the Cretaceous *G. laramiensis* and the Jurassic *G. digitata*. When, therefore, these kinds only are found in a Paleocene or later collection, they can, nevertheless, be identified as *G. adiantoides*, on the presumption that they are such variants. Certainly less harm, if any, is done by this practice than, for example, to identify simple, undivided cuneate *Ginkgo* leaves wherever found, whether in Mesozoic or Cenozoic strata, or even on the living tree, as *G. laramiensis!*

Except apparently during Eocene time, species of *Ginkgo* graced the landscape of the Northwestern States from the Jurassic to the late Miocene, but *G. adiantoides* was present in Alaska and probably British Columbia during the Eocene. Hence its apparent absence from the States during that epoch invites speculation about the possible reasons for this absence. Is the fossil record incomplete or was *Ginkgo* actually missing for climatic or other causes?

During the Paleocene *G. adiantoides* lived in the Dakotas, Montana, Wyoming, and perhaps Colorado. At a locality on the south side of Dry Creek, 5 miles west of Greybull, Wyo., the leaves are thickly matted and mixed with those of many other species of trees. Oval bodies (figs. 3, 4) chiefly internal molds of nuts or pits, are found among these leaves and presumably are the seeds of *Ginkgo*. Similar seeds associated with *Ginkgo* leaves have been found on Sevenmile Creek, east of Glendive, Mont., and at other localities, including Alberta, Canada, from which Bell reports one as *Carpolithus* (*Ginkgoites*?) *selwyni* (1949, p. 45, pl. 66, fig. 1). These objects may on the other hand, be the stone fruits of other plants, such as *Prunus*, etc. The specimen reported from the Denver formation at Golden, Colo., as *Ginkgo*? *tuncata* (Lesquereux) Knowlton (1930, p. 34, pl. 9, fig. 3) is very suggestive of *Ginkgo*, but no leaves of *Ginkgo* have been taken from that formation.

Occurrence: Fort Union formation (lower), 4661, 5526, 5721, 8256 (fig. 2), 9196, 9208, 9334; (middle and upper), 2416 (figs. 4, 5), 6219, 8522, 8786 (fig. 3), 9109 (fig. 8), 9125; Livingston formation, 6765, 6767.

PINACEAE

No foliage, seeds, or wood, attributable to the genus *Pinus*, have been found in the Paleocene strata of the Rocky Mountains and Great Plains. Oswald Heer, however, reported needles, purporting to be those of *Pinus*, from the Paleocene strata at Atanekerdluk and vicinity, Greenland: *Pinus hayesiana* Heer (1883, p, 66, pl. 71, figs. 13a, 14, 14b), *P. hyperborea* Heer (1868, p. 94, pl. 17, fig. 5f; 1871, p. 465, pl. 44, fig. 5; pl. 56, fig. 9c; 1874, p. 16, pl. 2, fig. 12). As undoubted remains of *Pinus* have been found in the Upper Cretaceous and Eocene of the Rocky Mountains and Plains region, the apparent absence of the genus from the Paleocene is, like the similar absence of *Salvinia*, cause for speculation.

CEPHALOTAXACEAE

Amentotaxus campbelli (Gardner) Florin

Plate 14, figures 7, 8

Podocarpus campbelli Gardner, 1886, p. 97, pl. 26.
Amentotaxus campbelli (Gardner) Florin, 1940, p. 163, text fig. 1.
Bell, 1957, p. 30, pl. 13, figs. 3, 4.
Amentotaxus florini Kräusel, 1935, p. 137, text figs. 1, 2, 5–8.
Cephalotaxus californica Potbury, 1935, p. 61, pl. 1, fig. 2.

Needles elliptic-lanceolate in outline, 3 to 6 cm long, 4 to 10 mm wide, with sharp-pointed apexes and with bases narrowed to a short, stubby petiole. Stomata in two broad bands.

These needles resemble closely those of the living *Amentotaxus argotaenia* (Hance) Pilger, from southeastern China. Comparisons, however, may also be made with those from some of the larger leaved species of *Cephalotaxus*. As only needles are represented, the foregoing synonymy may have to be changed when and if seeds, wood, and other material are found.

Occurrence: Fort Union formation (lower) 4696 (fig. 8); (upper) 9109 (fig. 7).

ARAUCARIACEAE

Araucaria longifolia (Lesquereux) Brown, n. comb.

Plate 13, figures 1–7

Sequoia longifolia Lesquereux, 1878, p. 79, pl. 7, figs. 14, 14a; pl. 61, figs. 28, 29.
Sequoia acuminata Lesquereux, 1878, p. 80, pl. 7, figs. 15, 16, 16a.
Dorf, 1938, p. 45, pl. 2, fig. 1.
Sequoiites artus Bell, 1949, p. 47, pl. 4, figs. 7, 8; pl. 16, fig. 2.
Abietites tyrellii Dawson, 1887, p. 17.
Araucaria hatcheri Wieland, 1910, p. 80, fig. 2.
Araucarites longifolia (Lesquereux) Dorf, 1942, p. 130, pl. 4, fig. 9.
Cunninghamites? sp. Knowlton, 1900, p. 29, pl. 5, fig. 3.
Cunninghamites elegans (Corda) Endlicher. Knowlton, 1905, p. 135, pl. 15, fig. 1.
Cunninghamites recurvatus Hosius and von der Marck. Knowlton, 1905, p. 136, pl. 16, fig. 6.
Torreya borealis Heer, 1883, p. 56, pl. 70, fig. 7a.
Torreyites tyrrellii (Dawson) Bell, 1949, p. 45, pl. 7, figs. 3, 4; pl. 8, figs. 1, 4.

Branches with spreading, recurved, lanceolate, pointed, apparently veinless, sometimes wrinkled needles, 2 cm or more long. Stomatal lines, about equally spaced and diffused over the surface of the needle. Base of the needle expanded, so that on its fall there remains a large obovate, smooth or striated scar. Cones 6 to 8 cm long, 3 cm wide, with many scales, apparently without spines but with rhombic, outer faces of apophyses. No detached scales or seeds were found.

In the Cretaceous of the Atlantic Coastal Plain and the western interior occur foliage, cones, and twigs that, at least superfiicially, appear to be related to those here described. These remains have been variously referred to *Abietites*, *Araucaria*, *Araucarites*, *Cephalotaxopsis*, *Cephalotaxus*, *Cunninghamites*, *Dam-*

mara, *Elatocladus*, *Geinitzia*, *Podocarpus*, *Sequoia*, *Sequoiites*, *Torreya*, and perhaps others of which I am not aware. Even casual inspection makes it apparent that several genera are represented by these fossils, but distinguishing features, such as stomatal lines on the needles and cones attached to twigs, are rarely found. At least three species and perhaps genera, however, can be predicated provisionally: (1) that here identified as *Araucaria longifolia*, having lanceolate fairly flexible needles with diffused stomatal lines, and cones without apparent spines on the persistent scales; (2) that having long, fairly straight, lanceolate, flexible needles with two stomatal lines in broad zones near the margins of the needles, exemplified by *Sequoia magnifolia* Knowlton, and probably *Cephalotaxus coloradensis* Knowlton; and (3) that having crowded, stiff, arcuate needles tapering to a broad base, and cones with readily deciduous spine-tipped scales, exemplified by *Geinitzia formosa* Heer, *Sequoia reichenbachi* (Geinitz) Heer, and *Dammara acicularis* Knowlton.

The foliage and cone features of *Araucaria longifolia* are closely comparable to those in living araucarias, and there seems to be little doubt that the species is an araucarian. It ranged across the Cretaceous-Paleocene boundary.

Occurrence: Fort Union formation (lower), 5886 (figs. 6, 7), 6738, 8519 (figs. 1–5), 8678.

TAXODIACEAE

Glyptostrobus nordenskioldi (Heer) Brown, n. comb.

Plate 11, figures 3, 7–22

Sequoia nordenskioldi Heer, 1871, p. 36, pl. 2, fig. 13b; pl. 4, figs. 1a, 1b, 4–38; 1874, p. 9, pl. 1, fig. 30.
Newberry, 1898, p. 20, pl. 26, fig. 4.
Sequoia affinis Lesquereux. Knowlton, 1930, p. 33.
Sequoia couttsiae Heer, 1883, p. 63, pl. 68, fig. 6b.
Sequoia langsdorfii (Brongniart) Heer, 1883, p. 61, pl. 68, figs. 6b, 6c; pl. 70, fig. 12; pl. 86, fig. 2b.
Sequoia sternbergi Goeppert. Heer, 1883, p. 63, pl. 70, fig. 13.
Cryptomerites lambii Bell, 1949, p. 49, pl. 29, figs. 2, 4; pl. 30, figs. 1, 3, 4, 5; pl. 31, fig. 4; pl. 32, figs. 2, 4.
Elatocladus (*Cryptomerites*?) *nordenskioldi* (Heer) Bell, 1949, p. 50, pl. 31, figs. 2, 3, 5.
Glyptostrobus dakotensis Brown, 1936, p. 355, figs. 2–4.
Glyptostrobus europaeus (Brongniart) Heer. Newberry, 1898, p. 24, pl. 26, figs. 6–8a; pl. 55, figs. 3, 4.
Hollick, 1936, p. 51, pl. 10, fig. 3b; pl. 17, fig. 1 (part), 2, 3, 4, 6; pl. 18, figs. 1–5a; pl. 19, figs. 1, 2; pl. 104, fig. 7b; pl. 109, fig. 11.
Glyptostrobus ungeri Heer, 1883, p. 61, pl. 70, figs. 9, 10; pl. 85, figs. 6–8.
Taxodium distichum miocenum Heer, 1871, p. 32, pl. 3, figs. 19, 20, 26; pl. 4, fig. 13b.

Occurring with the three kinds of foliage—cryptomeroid, cupressoid, and taxodioid—commonly seen on living *Glyptostrobus*, are fossil cones, cone scales, and seeds, the latter here identified for the first time as belonging to *Glyptrostrobus*. Heer assigned seeds of this kind and perhaps some cone scales, associated with *Glyptostrobus* foliage (called *Sequoia nordenskioldi*) to *Taxodium distichum miocenum* from Spitzbergen and to *Pterospermites vagans* from Oeningen. In 1936 I suggested several reasons for regarding the American species as distinct from *G. europaeus*, which is typically developed in the European Miocene.

The winged seeds are shaped somewhat like a boomerang and, except for size, resemble those of species of *Sagittaria*. The nutlet occupies a large, elliptic area from which a short, pointed wing extends at an oblique angle. In the only living species, *G. pensilis* Koch, of southeastern China, the wing of the seed is only slightly oblique to the nutlet. By contrast, the seeds of *Taxodium*, a close relative, are irregular, unwinged, somewhat triangular objects, in which the nutlet is not clearly defined.

Staminate catkins, not identifiable as those of *Metasequoia* or *Taxodium* but associated with *Glyptostrobus* foliage at Elbowoods, N. Dak., are here assigned to this species.

Remains similar to those here assigned to *G. nordenskioldi* occur at many Eocene localities in Oregon, Washington, and Alaska. The American Miocene species is *G. oregonensis* Brown.

Occurrence: Fort Union formation (lower) 4571, 5063, 5579, 6154, 7005, 8245 (fig. 17), 8249 (fig. 20), 8549 (fig. 12), 8552 (fig. 3), 8677 (fig. 14), 8781, 9104, 9180, 9192 (fig. 9), 9334; (upper), exact loc. unknown (fig. 22, reproduction of Newberry, 1898, pl. 26, fig. 4), 2416, 4625, 5194, 8193 (figs. 11, 16), 8203 (fig. 8), 8206 (fig. 21), 8212 (figs. 15, 19), 8224 (figs. 10, 18), 8521, 8529, 8786 (figs. 7, 13), 8885, 8917, 8928, 9125, 9135; Coalmont formation, 6105; Dawson arkose, 5836; Denver formation, 317, 8493; Evanston formation, 8670; Ferris formation, 4661, 4694, 6971; Livingston formation, 6765; Middle Park formation, 337.

Metasequoia occidentalis (Newberry) Chaney

Plate 12, figures 1–14

Taxodium occidentale Newberry, 1863, p. 516; 1868, p. 45; 1898, p. 23, pl. 76, figs. 1–3; pl. 55, fig. 5 (part).
Berry, 1935, p. 19.
Metasequoia occidentalis (Newberry) Chaney, 1951, p. 225, pl. 10, figs. 3–6. [See synonymy.]
Elatocladus (*Taxodites*?) *tinajorum* (Heer) Bell, 1949, p. 51, pl. 32, fig. 5.
Juniperus gracilis Heer, 1883, p. 57, pl. 70, figs. 18–20.
Sequoia brevifolia Heer, 1874, p. 5, pl. 2, figs. 7, 8.
Sequoia langsdorfii (Brongniart) Heer, 1868, p. 91, pl. 2, figs. 2–22; pl. 47, figs. 15, 15b; 1871, p. 464, pl. 40, fig. 5b; pl. 43, figs. 1–3; pl. 46, figs. 1a, 7b; pl. 55, fig. 3a; 1883, p. 61, pl. 68, fig. 8.

Sequoiites langsdorfii (Brongniart) Heer. Bell, 1949, p. 46, pl. 29, fig. 5;; pl. 30, fig. 2.

Taxites olriki Heer, 1868, p. 95, pl. 1, figs. 24a, b; 1874, p. 16, pl. 1, fig. 9.

Taxites validus Heer, 1874, p. 13, pl. 1, fig. 11.

Taxodium distichum miocenum Heer, 1869, p. 463, pl. 43, fig. 4c; 1874, p. 9, pl. 1, figs. 13c, d, 15b; p. 19, pl. 4, fig. 5; 1883, p. 60, pl. 70, fig. 11; pl. 87, fig. 7; pl. 88, fig. 2b; pl. 96, figs. 8, 9.

Taxodium dubium (Sternberg) Heer, 1868, p. 89, pl. 2, figs. 24–27; pl. 12, fig. 1c; p. 156, pl. 30, figs. 3, 4.

The verification in 1946 of the occurrence of living trees called shuihsa, discovered in 1944 in a small area south of the Yangtse River in Szechuan and Hupeh provinces, China, and having foliage and cones similar to, if not identical with, fossil remains identified as *Metasequoia*, focussed attention on this genus and resulted during the next 5 years in many papers dealing with the living and fossil species. The data were summarized by Chu and Cooper (1950), who described the ecology of the living species, and by Chaney (1951), who restudied the fossil species.

The distinctive feature of the living tree, *Metasequoia glyptostroboides* Hu and Cheng, also seen in the fossils, is oppositeness, the twigs, needles, floral organs, and cone scales being opposite one another in two ranks. Here, to keep the record straight, it must be stated that *Metasequoia* is not the only conifer with oppositeness. *Amentotaxus* and *Cephalotaxus* also have opposite needles, although these are in general much stouter than those of *Metasequoia*. Nevertheless, confusion of the three genera is possible when dealing only with their fossil foliage.

The needles of *Metasequoia* are lanceolate to elliptic in outline, variable in size, and slightly rounded at the base, which is twisted and decurrent diagonally on the twig. The cones are pedunculate, relatively small, averaging less than 2 cm in length, with about 24 scales that, because of their decussate arrangement, give the cone a squarish appearance when viewed from above. The peduncles may be several centimeters long with little or no trace of foliage or foliage scars. The seeds are winged, flat, and irregularly oval in outline, with wings as wide as the nutlet or wider. They resemble those of the Sierra redwood or Big Tree (*Sequoia gigantea*) closely, and are somewhat larger than those of the coast redwood (*Sequoia sempervirens*). It is difficult to distinguish the wood from that of *Sequoia* and *Taxodium*.

The ecological studies by Chu and Cooper (1950) indicate many interesting associates of the living tree, including katsura (*Cercidiphyllum*) and others that, according to the fossil record, were companions of shuihsa in other parts of the world millions of years ago. Indeed, shuihsa and its associates today may represent a relict Pliocene flora. In its native habitat shuihsa lives at an altitude of about 3,000 feet and prefers a slightly acid soil along stream banks or wet places at the lower end of ravines and seepage areas at the foot of slopes. Climatic conditions there simulate those of the piedmont areas of the Southeastern United States. The planting of shuihsa in many places outside of China will, in the course of time, reveal the most suitable area for the tree and thus supply further data for speculation on the altitudinal, zonal, physiographic, and climatic requirements of its fossil antecedents.

Occurrence: Fort Union formation (lower), 4661, 5063, 7005, 8240, 8249, 8551 (fig. 9), 8899, 9193, 9334; (upper), 2420 (figs. 13, 14), 4264 (fig. 5), 4582 (fig. 6), 4984 (fig. 2), 5595, 8165 (fig. 11), 8196, 8212 (fig. 12), 8238 (fig. 3), 8521 (figs. 1, 8, 10), 8550 (figs. 4, 7) 8556, 8786, 8885, 9101, 9135; Coalmont formation, 6000; Evanston formation, 3563; Ferris formation, 6173, 6176.

Taxodium olriki (Heer) Brown, n. comb.

Plate 10, figures 7, 11, 15; plate 11, figures 4–6

Taxites olriki Heer, 1868, p. 95, pl. 1, figs. 21–24 c; pl. 45, figs. 1a, 1b, 1c; 1874, pl. 15, pl. 1, fig. 10.

Elatocladus (*Taxodites*?) *tinajorum* (Heer) Bell, 1949, p. 51, pl. 16, fig. 3.

These alternate, more or less pointed needles, inserted on the twig with their petioles decurrent parallel to the axis of the twig, make it appear that a species of *Taxodium* is represented. No seeds, however, have been found that confirm this suspicion. The twigs are somewhat rare, suggesting that the species had not yet become a dominant part of the swamp forests.

The description of *Parataxodium wigginsi* Arnold and Lowther (1955) from Upper Cretaceous strata in Alaska characterizes what may be a possible ancestral link between *Metasequoia* and *Taxodium*.

Occurrence: Fort Union formation (lower), 4661, 4984, 7548 (pl. 11, fig. 5), 8549 (pl. 10, fig. 15; pl. 11, fig. 6); (upper), 2420 (pl. 10, figs. 7, 11), 2416 (pl. 11, fig. 4), 8522, 8899, 9125; Livingston formation, 6767.

CUPRESSACEAE

Fokienia catenulata (Bell) Brown, n. comb.

Plate 11, figures 1, 2

Androvettia catenulata Bell, 1949, p. 46, pl. 15, figs. 1–5; pl. 16, fig. 4; pl. 27, figs. 5, 7, 8.

This species, well characterized by Bell, was identified by him as an *Androvettia*, similar to *A. carolinensis* Berry, *A. elegans* Berry, and *A. statenensis* Hollick and Jeffrey, from Upper Cretaceous strata of the Eastern and Southeastern United States. Superficially, the comparison is apt, but on closer examination significant differences become apparent. Hollick and Jeffrey (1909, p. 22), describing *A. statenensis*, remarked about its fernlike appearance and might have assigned it to the ferns but for the fact that sections of the stems indicate close affinity with the conifers.

The Paleocene specimens differ from the Cretaceous examples in being much less fernlike and in having a more pronounced jointed or segmented appearance. At some localities separate segments rather than twigs are the rule. For these reasons and their striking likeness to the foliage of *Fokienia* with at least two living species in China, I am inclined to refer them to the latter, although admitting the possibility that *Androvettia* may have been in their ancestry. Similar segments and twigs have been referred to *Libocedrus*, and Watelet (1866, p. 108, pl. 32) ascribed some to *Callitrites*.

Occurrence: Fort Union formation (lower), 7548 (figs. 1, 2), 8256, 9300; (upper); 9135, 9532; Evanston formation 9558; Paskapoo and Willow Creek formation, Alberta, Canada.

Thuja interrupta Newberry

Plate 10, figures 10, 14, 16

Thuja interrupta Newberry, 1868, p. 42; 1898, p. 25, pl. 26, figs. 5–5d.
Berry, 1935, p. 21, pl. 3, fig. 1. [See synonymy and discussion.]
Thuites interruptus (Newberry) Bell, 1949, p. 52, pl. 27, figs. 1–3.
Thujopsis europaea Saporta. Heer, 1868, p. 1, pl. 50, figs. 11 a–c.
Biota borealis Heer, 1874, p. 7, 13, pl. 1, figs. 13–29; 1880, p. 9, pl. 3, figs. 5, 5b.
Libocedrus sabiniana Heer, 1871, p. 34, pl. 2, figs. 6–15; pl. 4, fig. 4d; 1883, p. 58, pl. 70, fig. 17; pl. 86, figs. 1, 2; pl. 87, fig. 8.

There is considerable variation among the specimens of this species taken from different localities in the Paleocene strata of the Rocky Mountains and Great Plains. One specimen from the basal Fort Union north of Glendive, Mont., has branchlets whose leaves appear not as sharp pointed as those of most specimens and resemble those of Cretaceous species of *Moriconia* and *Brachyphyllum*. A species, *Thuja colgatensis* Brown (1939, p. 247, pl. 48, figs. 2–4) from the Upper Cretaceous Colgate member of the Fox Hills sandstone, southwest of Glendive, Mont., is most likely in the ancestral line of *T. interrupta* and differs chiefly in having longer internodes between leaf pairs, but intergrading specimens are likely to be found.

No cones or seeds attributable to this species have yet been recognized in the collections from the Rocky Mountains and Great Plains. Heer, however, illustrates a branch and cone from Greenland. There may here be a mixture of *Thuja*, *Chamaecyparis*, *Androvettia*, and other genera. Some examples may be the cupressoid foliage of *Glyptostrobus*.

Occurrence: Fort Union formation (lower), 4028, 8239, 8258, 8897 (fig. 14), 9194; (upper), 4395, 5030 (fig. 10), 7989 (fig. 16), 8222, 9180; Dawson arkose, 8882; Ferris formation, 6420.

MONOCOTYLEDONS

SPARGANIACEAE

Sparganium antiquum (Newberry) Berry

Plate 14, figures 4, 5

Brasenia? antiqua Newberry, 1883, p. 514; 1898, p. 93, pl. 68, fig. 7.
Sparganium antiquum (Newberry) Berry, 1924, p. 342–348, 7 text figs.; 1930c, p. 64, pl. 8, fig. 5, text fig. 5.
Sparganium stygium Heer, 1868, p. 97, pl. 45, fig. 2a [probably not fig. 13d]; 1871, p. 467, pl. 42, figs. 4b, 5, 5b.
Ward, 1887, p. 18, pl. 3, figs. 6, 7.
Berry, 1935, p. 22.
Platanus basilobata Ward. Bell, 1957, p. 58, pl. 43, fig. 1 only.

The identity of the specimens of Tertiary age now assigned to *Sparganium* has become somewhat mixed. Heer described several species, among them *S. stygium* and *S. valdense* from the middle Tertiary of southern Germany, but all may represent a single species. He identified somewhat similar material, including separate foliage and fruit, from the Paleocene of Greenland as *S. stygium* to which Ward and Berry also referred specimens from the Fort Union formation of Montana and the Ravenscrag formation of Saskatchewan. All the Heer material from Greenland except the fruits (1871, pl. 42, fig. 5) is fragmentary and indecisive. There is little question, however, that the fruits are identical with those figured by Ward and Bell, but that all these should be identified with *S. stygium* of Europe may well be questioned.

The fruits are born in racemes of pedunculate heads composed of numerous ovate to lanceolate long-beaked nutlets. Often the only part left is the small receptacle showing the attachment scars of the nutlets.

The Eocene specimens described by Berry (1930c) as *Sparganium antiquum* (Newberry) Berry from western Wyoming have sessile fruit heads with obovate angular unbeaked nutlets, borne on stouter branches of a fruiting stalk. It is perhaps possible that Berry's specimens represent only the uppermost fruit heads of the fruiting stalk or that they may be immature, and that the lower fruits may have been peduncled as they sometimes are in living species.

The peduncled heads of *Sparganium antiquum* resemble superficially the heads of *Platanus*, *Liquidambar*, *Echinodorus*, and others, but both the receptacles and the nutlets have features that seem not to be matched even remotely in those living genera.

This species ranged into the Eocene at numerous localities in Wyoming and in Yellowstone National Park.

Occurrence: Fort Union formation (lower) 9197; (upper) 2416 (fig. 5) 5594, 8230 (fig. 4), 8556, 9109, 9125; Coalmont formation, 5987.

ALISMACEAE

Alismaphyllites grandifolius (Penhallow) Brown, n. comb.

Plate 15, figures 1, 4, 6

Maianthemophyllum grandifolium Penhallow, 1902, p. 54, text fig. 5.
Bell, 1949, p. 80, pl. 63, fig. 2; pl. 64, figs. 1, 3; pl. 66, figs. 2, 3.
Alismaphyllites crassifolium Knowlton, 1917, p. 286, pl. 55, fig. 1.
Clintonia oblongifolia Penhallow, 1902, p. 55, text fig. 6.

Ovate leaves with entire margins, probably reaching a length of 30 cm and width of 10 cm. Midvein at base of leaf a composite of closely spaced veins giving it a stout appearance, but these veins separate in the body of the leaf and become 10 or 12 widely spaced, parallel veins that converge toward the apex. Closely spaced forked veinlets connect the main parallel veins.

These leaves may be compared with those of some species of *Alisma*, *Aponogeton*, *Echinodorus*, and *Potamogeton*, but as no fruits assignable clearly to any of these genera have been found at the same localities as the leaves, there is some uncertainty in the assignment. The regular, parallel, tertiary venation eliminates them from the liliaceous genera *Maianthemophyllum* and *Clintonia*.

This species is apparently closely related to *Alisma macrophyllum Heer* (1877, p. 66, pl. 26; pl. 27, figs. 3b, 3c, 4–7) and *Potamogeton nordenskioldi* Heer (1868, p. 157, pl. 30, figs. 1b, 5c, 5d, 6–8; 1871, p. 52, pl. 4, figs. 18b, 19; pl. 8, figs. 9, 10; pl. 15, fig. 51b; 1877, p. 66, pl. 27, figs. 1–3a), but these are considerably younger and may well be different species.

Occurrence: Fort Union formation (lower) 8567, 8227 (fig. 6); (upper) 7004, 8206 (figs. 1, 4), 8922; Raton formation, 5099.

Sagittaria megasperma Brown, n. sp.

Plate 68, figures 14–16

Achenes 2 cm long, asymmetric, winged, with beaks 4 mm long turned to one side, in dense heads borne on long pedicles. Wings with a few conspicuous parallel veins reticulated near the margin. Ultimate surface pattern minutely papillate.

No leaves identifiable as those of *Sagittaria* were found with the seeds; but foliage assigned to *Alismaphyllites* occurs at a number of other Paleocene localities. The relation if any, between these leaves and the seeds here called *Sagittaria* remains undemonstrated.

Occurrence: Fort Union formation (upper) 4268 (fig. 14), 9129 (figs. 15, 16), 9400.

HYDROCHARITACEAE

Hydromystria expansa (Heer) Hantke

Plate 16, figures 1, 3, 8–11

Hiraea expansa Heer, 1859, p. 65, pl. 121, figs. 16, 16b.
Hydromystria expansa (Heer) Hantke, 1954, p. 81, pl. 14, figs. 9–12.
Lemna (*Spirodela*) *scutata* Dawson, 1875, p. 329, pl. 16, figs. 5, 6, 7a; 1887, p. 23, pl. 1, fig. 16.
Ward, 1887, p. 17, pl. 3, figs. 4, 5. [Exclude Lesquereux citation in Ward's synonymy.]
Spirodela scutata Dawson. Berry, 1935, p. 182.
Bell, 1949, p. 82, pl. 63, figs. 1, 3; pl. 67, fig. 1.
Nymphaeites browni Dorf, 1942, p. 142, pl. 10, fig. 9.
Carpites verrucosus Lesquereux, 1878, p. 305, pl. 60, fig. 3.
Dorf, 1942, p. 157, pl. 17, fig. 7.

This was a creeping or floating aquatic with more or less asymmetrical, orbicular to reniform, cordate, fleshy, hairy, entire leaves, sometimes in pairs, one often smaller than the other, sessile or nearly so at nodes on a succulent prostrate stem or runner. Feathery rootlets may sometimes be seen at the nodes. The venation consists of 10 or more parallel veins that arise from the top of the petiole and converge toward the apex. Between the veins is a network of relatively large uniform areoles that probably were air chambers. In fossilization these spaces filled with mud that hardened and, after the residue of carbon was removed, caused the surface to be papillated, tuberculated or verrucose, deceptively like the surface of some seeds or fruits, whence the erroneous identification as *Carpites verrucosus* by Lesquereux.

Oswald Heer also identified as fruits some similar specimens he found in the Miocene strata of southern Germany. Hantke, after restudy of this and additional material, assigned the species to *Hydromystria*, a genus of the Hydrocharitaceae, which is a family of aquatic monocotyledons. *Hydromystria* includes only a few species that are distributed from Mexico to Paraguay.

I do not regard the assignment to *Hydromystria* as completely appropriate. Neither does Tilo Nötzold (1957, p. 95, 96). One objection is the fact that the leaves of living species of *Hydromystria* are long petioled, whereas those of the fossils are sessile or nearly so. An assignment to *Limnobium*, also in the Hydrocharitaceae, would be open to the same objection. *Pistia*, an aquatic in the Araceae, almost meets the requirement of matching the fossils, but its leaves differ notably in shape. *Lemna*, in the Lemnaceae, is too small. Thus, no closely comparable living counterpart seems to exist. The assignment to *Hydromystria* may be retained as a working hypothesis until further enlightening evidence accumulates. The fossil species ranged from the Late Cretaceous into the early Eocene in the United States and Canada and to the Miocene in Europe.

Occurrence: Fort Union formation (lower) 2421, 4031, 5512 (fig. 10), 6652, 6667, 8519, 9402, 9403, 9404; (upper) 436, 2420 (fig. 8), 4897 (fig. 1), 4974, 5321, 6376, 6985, 8191 (figs. 9, 11), 8196, 8212 (fig. 3), 8224, 8556, 8786, 8920, 8922, 9109, 9405; Coalmont formation, 6005; Dawson arkose 8881; Denver formation, 9401; Ferris formation, 6417.

Grasslike monocotyledons

Plate 14, figure 3; plate 16, figure 7

Fragments of linear strap-shaped leaves with closely spaced parallel venation have been described from Paleocene localities as species of *Carex*, *Cyperacites*, *Cyperus*, *Iris* (cf. *Iris sp.* Newberry, 1898, p. 33, pl. 22, fig. 6), *Phragmites* (cf. *P. alaskana* Heer in Ward, 1887, p. 17, pl. 3, figs. 1–3), and *Poacites*. Associated with this foliage (pl. 14, fig. 3) at the same localities are rootstocks (pl. 16, fig. 7) or rhizomes identified as *Caulinites* and *Culmites*. At present there seems to be no reliable method for distinguishing such remains as grass, sedge, iris, or something else.

Occurrence: Fort Union formation (lower) 8519, 8678 (pl. fig. 7); (upper), 2417 (pl. 14, fig. 3).

PALMACEAE

Students of fossil palms recognize the difficulties in identifying such remains in terms of living species. Consequently, arbitrary working classifications are necessary and herewith is such a key to the foliage of Cretaceous and Tertiary palms of the Rocky Mountains and Great Plains region.

Leaves fan shaped, with radiate venation:	
Apex (acumen or hastula) of upper and under side of the petiole wedge-shaped, very stout, much prolonged, with fairly straight margins	*Sabal imperialis.*
Apex of upper side of the petiole short, wedge-shaped, angular, with inside angle of less than 100°; apex of under side moderately prolonged with concave margins	*Sabal powelli.*
Apex of upper side of the petiole irregularly rounded or only slightly angular, with inside angle of 100° or more; apex of under side moderately prolonged, with concave margins	*Sabal grayana.*
Apex of both sides of the petiole very short, rounded	*Thrinax dorfi.*
Leaves pinnate or feather-shaped, with very gradually tapering rachis:	
Pinnules linear, narrow, not decurrent	*Phoenicites integrifolius.*
Pinnules linear, broad, decurrent	*Chamaedorea danae.*
Pinnules elliptic	*Paloreodoxites plicatus.*

A number of Paleocene seeds (*Palmocarpon*) have been described as those of palms, but most of these are doubtfully so assigned. See the discussion (p. 89) under "Objects of uncertain classification." Palm wood (*Palmoxylon*) is present at a number of Paleocene localities but is relatively rare, except in the Denver Basin, Colo. On the southeast-facing slope of South Table Mountain near Golden, I have seen a small palm stump in place, with adventitious roots running down into what was once the soil in which the tree grew.

The fragmentary foliage described by Heer (1883, p. 69, pl. 68, figs. 5, 5b, 6, 7; p. 70, pls. 140–106, fig. 1) as *Flabellaria grönlandica* and *F. johnstrupi*, from the Paleocene of Greenland, is indefinite, though perhaps not improbably palmaceous. No seeds or wood have been reported that might confirm the identification.

Rejected palm names

The binomials attached to the following fossil palm remains from the Rocky Mountains and Great Plains region are here rejected for naming purposes because the specimens described were mere fragments or were not figured.

Flabellaria communis Lesquereux, 1876, p. 385.
Flabellaria zinckeni Heer. Lesquereux, 1878, p. 110, pl. 9, figs. 6–8.
Geonomites goldianus (Lesquereux) Lesquereux, 1878, p. 115, pl. 9, figs. 9, 9b, 9c.
  Knowlton, 1930, p. 39, pl. 10, fig. 12.
Geonomites graminifolius Lesquereux, 1888, p. 44.
Geonomites tenuirachis Lesquereux, 1878, p. 117, pl. 11, fig. 1.
  Knowlton, 1917, p. 291, pl. 62; 1930, p. 38, pl. 6; pl. 9, figs. 1, 2, 6.
Geonomites schimperi Lesquereux, 1878, p. 116, pl. 10, fig. 1.
Manicaria haydeni Newberry, 1898, p. 31, pl. 64, fig. 3.
Palmacites goldianus Lesquereux, 1876, p. 385.
Sabal rigida Hatcher, 1901, p. 263.
Sabal communis Lesquereux, 1876, p. 385.

Chamaedorea danae (Lesquereux) Berry

Calamopsis danai Lesquereux, 1863, *in* Dana, p. 513, fig. 795.
  Lesquereux, 1869, p. 411, pl. 14, figs. 1–3.
Chamaedorea danai (Lesquereux) Berry, 1916a, p. 179, pl. 12, fig. 4; pl. 13, figs. 1–3.
"*Geonoma*" *gigantea* Knowlton, 1917, p. 291, pl. 61.
Geonomites haydenii (Newberry) Knowlton, 1923, p. 152.

The remains assigned to this species are fragments of more or less pinnate leaves. Characteristic features of the leaflets are their somewhat decurrent attachment to the rachis, and the comparatively slight development of their midribs as compared with the flanking veinlets.

Compared with the leaves called *Phoenicites integrifolius* Ball (1931, p. 35, pls. 42; 47, fig. 1) from the Indio formation (Eocene) of Texas, the latter have narrower, linear leaflets, attached by conspicuously constricted bases, not noticeably decurrent on the rachis.

Occurrence: Raton formation, 5679.

Paloreodoxites plicatus (Lesquereux) Knowlton

Plate 15, figures 3, 7

Oreodoxites plicatus Lesquereux, 1883, p. 122, pl. 18, figs. 1–4.
  Knowlton, 1917, p. 287, pl. 63, fig. 1.
Paloreodoxites plicatus (Lesquereux) Knowlton, 1930, p. 41, pl. 11, figs. 1–4.
  Brown, 1956, p. 208, pl. 33, fig. 5.

The relation of this species to living palms is uncertain because it is not known definitely whether or not the imprints are leaves or leaflets. The presumption is that they are leaflets of a pinnate palm, but they may represent some other monocotyledon than a palm.

Occurrence: Dawson arkose, 8188 (fig. 3); Denver formation, 317 (fig. 7); Raton formation, 5803.

Sabal grayana Lesquereux

Plate 15, figure 5; plate 16, figure 4

Sabal grayana Lesquereux, 1869, p. 412, pl. 14, figs. 4–6.
Sabalites grayanus (Lesquereux) Lesquereux. Berry, 1916a, p. 177, pl. 13, figs. 1–3; pl. 14, fig. 1.
  Knowlton, 1900, p. 32, pl. 6, fig. 5; 1930, p. 36, pl. 9, fig. 5.
Sabal campbelli Newberry, 1989, p. 27, pl. 21, figs. 1, 2.
  Dawson, 1985, p. 142, pl. 5, fig. 7.
Sabalites campbelli (Newberry) Lesquereux, 1878, p. 113.
Sabal grandifolia Newberry, 1898, p. 28, pl. 25; pl. 64, figs. 2, 2a.
Sabal inquirenda Knowlton, 1917, p. 288, pl. 56.
Sabal powelli Newberry, 1898, p. 30, pl. 64, figs. 1, 1a, only.
Sabal? rugosa Knowlton, 1917, p. 288, pl. 58.
Sabal? ungeri (Lesquereux) Knowlton, 1917, p. 254, 289, pl. 59.
Sabalites eocenica (Lesquereux) Dorf, 1938, p. 48, pl. 2, fig. 6; pl. 3, fig. 3; 1942, p. 131, pl. 7, fig. 1.
Sabalites florissanti (Lesquereux) Berry, 1930c, p. 66, pl. 9.
Flabellaria alaskana Hollick, 1936, p. 57, pl. 22, figs. 2a, 3; pl. 111; pl. 112.
Flabellaria eocenica Lesquereux, 1878, p. 111, pl. 13, figs. 1–3.
Flabellaria florissanti Lesquereux, 1878, p. 144, pl. 24, figs. 1, 2, 2a.
  Hollick, 1936, p. 56, pl. 21.

This fan palm with large many-rayed leaves differs from others discussed here as follows: The apex (acumen or hastula) of the petiole on the upper side is short, more or less rounded to slightly angular, with an inside angle of more than 100°. On the under side the hastula is moderately prolonged or attenuated, with concave margins. The type is from the Eocene of Mississippi.

To this species probably belong the Greenland specimens named *Flabellaria grönlandica* Heer (1883, p. 69, pl. 68, figs. 5, 5b, 6, 7) and *F. johnstrupi* Heer (1883, p. 70, pl. 104; 105; 106, fig. 1). However, a few paleobotanists, including Potonie and Gothan (1921, p. 14), Kryshtofovich (1929, p. 306), and Berry (1930d, p. 13), have expressed doubts concerning the identity of these specimens, as also of those from the Jurassic called *Propalmophyllum liasinum* by Lignier (1908, p. 121–152, figs. 1–6), some holding that they are not plants but rill or ripple marks. If Heer's specimens do not represent palms, one frequently used argument for a relatively warm climate in Paleocene time within the Arctic Circle in western Greenland, loses its force. On the other hand, the undoubted palms reported by Hollick from the Tertiary of Alaska came from localities only a few hundred miles south of the Arctic Circle.

The only palms so far reported from Canada are *Sabal imperialis* from the Upper Cretaceous at Nanaimo on Vancouver Island and *S. grayana* (called *S. campbelli* by J. W. Dawson) from the Tertiary on Burrard Inlet near Vancouver, British Columbia. Thus it appears that inland from the Pacific coast the northernmost limit for palms was in the latitude of the Yellowstone River in Montana.

Occurrence: Fort Union formation (lower), 6051, 8526, 8545, 8567; (middle) 2416; Animas formation 6443, 6444, 7480, 9565; Denver formation, 317 (pl. 16, fig. 4), 8672 (pl. 15, fig 5); Ferris formation, 8662; Raton formation, 5094, 5139, 5142, 5467, 5469, 5712, 5827.

Sabal imperialis Dawson

Plate 14, figures 2, 6

Sabal imperialis Dawson, 1883, p. 26, pl. 6, figs. 23, 23b; 1894, p. 57, pl. 14, fig. 61.
  Newberry, 1898, p. 30, figs. 6, 6a.
Sabal montana Knowlton, 1916, p. 335, pl. 85, fig. 2; 1917, p. 253, pl. 32, fig. 3; 1922, p. 119, pl. 3, fig. 4.
Sabal grandifolia Newberry, 1898, p. 28, pl. 63, fig. 5 only.
Sabal? leei Knowlton, 1917, p. 289, pl. 60.
Sabal sp. Knowlton, 1916, p. 336, pl. 85, fig. 1.
Sabalites grayanus (Lesquereux) Lesquereux, 1878, p. 112, pl. 12, fig. 1 (fig. 2 of doubtful nature).
Geonomites imperialis (Dawson) Bell, 1957, p. 37, pl. 22, fig. 5; pl. 23, fig. 2; pl. 24, fig. 3.
Geonomites ungeri Lesquereux, 1878, p. 118, pl. 11, fig. 2.

This fan palm with large, many-rayed leaves differs from others discussed here as follows: The apex (acumen or hastula) of the petiole on both the upper and the under side is unusually stout, greatly prolonged, and with relatively straight margins.

The species was most abundant in the late Cretaceous, but at some localities it ranged into the early Paleocene.

Occurrence: Fort Union formation (lower), 5886 (fig. 2); Dawson arkose, 8188 (fig. 6); Raton formation, 5146, 5147, 5679, 5826.

Sabal powelli Newberry

Plate 16, figures 2, 5, 6

Sabal powelli Newberry, 1883, p. 504; 1898, p. 30, pl. 63, fig. 6 only.
Sabalites powelli (Newberry) Berry, 1930c, p. 67, pl. 10, figs. 6, 7.
Sabal? ungeri (Lesquereux) Knowlton, 1917, p. 289, pl. 57.

This fan palm with large many-rayed leaves differs from others discussed here as follows: The apex (acumen or hastula) of the petiole on the upper side is short and wedge shaped, with slightly concave margins and an inside angle of about 75° at the tip. On the under side the hastula is moderately prolonged with concave margins.

The species was first described from the Green River formation (Eocene) of Wyoming.

Occurrence: Fort Union formation (lower) 8519 (figs. 2, 5, 6), 8673; Raton formation 5112, 5142.

Thrinax dorfi Brown, n. sp.

Plate 14, figure 1

Small fan palm with orbicular leaves, approximately 30 cm in diameter. Rays 30, radiating from the short rounded apex of the slender unarmed petiole, which is 5 mm in diameter.

This is apparently a smaller leaved species than *Thrinax eocenica* Berry (1914, p. 136, pl. 25) from the Eocene of Georgia, but the leaf has more rays. The genus *Thrinax* includes a number of living species growing near the coast from southern Florida through the West Indies to Central America.

The species is named for Dr. Erling Dorf, of Princeton University.

Occurrence: Fort Union formation (lower) 8256 (fig. 1).

CANNACEAE

Canna? magnifolia Knowlton

Plate 15, figure 2

Canna? magnifolia Knowlton, 1917, p. 254, pl. 36, fig. 3.
Canna? sp., Knowlton, 1917, p. 255.
Cyperacites? tesselatus Knowlton, 1922a, p. 117, pl. 3, figs. 1, 2.
Canna cf. *C.? magnifolia* Knowlton. Dorf, 1938, p. 49, pl. 2, fig. 5.
Cannophyllites magnifolia (Knowlton) Bell, 1949, p. 81, pl. 64, fig. 2; pl. 65.

There is little, if anything, to add to Knowlton's description of these monocotyledonous leaves. I can detect no constant differences between the specimens from the Vermejo, Medicine Bow, Laramie, and Fort Union formations. The type specimen from the Vermejo formation (Upper Cretaceous) is not well illustrated, much of the blade having been erased from the photograph. Furthermore, the heavier widely spaced veins appear somewhat exaggerated in the photograph, but in reality are comparatively subdued, and in some parts of the blade, as also in the Paleocene specimens, are not readily distinguishable. The thin veins are closely spaced and may number six or more between the slightly heavier veins.

The genus *Cannophyllites* was instituted by Brongniart in 1828 for a Paleozoic plant, *C. virletti*, from the Stephanian of the Loire Basin in France, and considered by him to have been a monocotyledon. Later it was found to be a fern. The term, therefore, cannot with propriety be applied to the monocotyledons described here.

Occurrence: Fort Union formation (middle and upper), 9134, 9200 (fig. 2).

ZINGIBERACEAE

Zingiberites dubius Lesquereux

Zingiberites dubius Lesquereux, 1878, p. 95, pl. 16, fig. 1.
Dorf, 1938, p. 49, pl. 2, fig. 4.

The upper half of Lesquereux's specimen is not as illustrated but appears to represent a fragment of wrinkled bark. The lower half is undoubtedly a portion of a monocotyledonous leaf. This specimen is from the Paleocene Denver formation. Dorf's small specimen from the Medicine Bow formation apparently resembles the lower half of the Lesquereux specimen.

Occurrence: Denver formation, 317.

DICOTYLEDONS

SALICACEAE

Salix aquilina Brown, n. sp.

Plate 61, figures 1–3

Leaves linear lanceolate, acute at apex and base. Margin with numerous crenate, gland-tipped teeth. Secondary veins widely spaced with a tendency to form closed loops. Intersecondaries obscure.

These fragmentary leaves are referred to *Salix* with some hesitation. If this plausible assignment holds, they are the first representatives of the genus and family to be recorded from the Paleocene of the Rocky Mountains and Great Plains.

Occurrence: Fort Union (lower), 6592, 8678; (upper), 9322 (figs. 1–3).

JUGLANDACEAE

Carya antiquorum Newberry

Plate 17, figures 1–7; plate 18, figure 4

Carya antiquorum Newberry, 1868, p. 72; 1898, p. 35, pl. 31, figs. 1–4.
Lesquereux, 1878, p. 289, pl. 57, figs. 1–5; pl. 58, fig. 2.
Ward, 1887, p. 34, pl. 15, fig. 2.

Celastrinites insignis (Heer) Bell, 1949, p. 71, pl. 57, fig. 4; pl. 58, fig. 2.
Dryophyllum aquamarum Ward. Knowlton, 1917, p. 299, pl. 70, fig. 2.
Hicoria antiquora (Newberry) Knowlton, 1919, p. 319.
Juglans leconteana Lesquereux. Bell, 1949, p. 54, pl. 57, fig. 1.
Juglans nigella Heer. Lesquereux, 1883, p. 235, pl. 46A, fig. 11. Bell, 1949, p. 55, pl. 57, fig. 5.
Juglans schimperi Lesquereux, 1878, p. 287, pl. 56, fig. 10 [not other figures].
Prunus dakotensis Lesquereux, 1883, p. 237, pl. 46A, fig. 8.
Quercus valdensis Heer. Lesquereux, 1878, p. 153, pl. 19, fig. 8.

So far as I am aware there is no reliable method for distinguishing between the many fossil leaflets assigned to *Carya* and *Juglans*. Consequently, those here called *Carya* may represent several species of *Carya*, or a mixture of *Carya*, *Juglans*, and other juglandaceous genera such as *Engelhardtia*, *Platycarya*, and *Rhoiptelea*. In general, however the leaflets of *Carya antiquorum*, especially the terminals, have an elliptic rather than a spatulate outline, and the marginal teeth appear to be more evenly sized without a marked tendency toward doubling.

The leaf called *Juglans schimperi* by Lesquereux, from the Evanston formation, contrary to the illustration, has a serrate margin, but the teeth are not well preserved. The leaf, *Prunus dakotensis* Lesquereux, as illustrated, has too many teeth. The teeth are fewer, coarser, and more unequal in size, as here illustrated (pl. 17, fig. 7). This dentition and a suggestion of asymmetry indicate that the specimen is a small leaflet of *Carya antiquorum*. Knowlton's illustration (1917, pl. 70, fig. 2) of *Dryophyllum aquamarum* shows many coarse teeth. Actually the specimen is poorly preserved and no teeth are clearly discernible.

The difficulty in distinguishing the leaflets of *Carya* and *Juglans* is duplicated for the nuts also. The latter are here assigned to the form genus *Juglandicarya*.

Occurrence: Fort Union formation (lower), 541 (pl. 17, fig. 1), 2432, 4688, 5259, 5526, 6299, 6738, 8551, 8660, 8884, 9112; (upper) exact loc. unknown (pl. 17, fig. 4, reproduction of Newberry's pl. 31, fig. 4), exact loc. unknown (pl. 17, fig. 7, reproduction of Lesquereux's *Prunus dakotensis*), 4262, 4898, 5905, 8195, 8206 (pl. 17, fig. 2), 8222, 8224 (pl. 17, figs. 3, 6), 8234, 8523, (pl. 17, fig. 5), 8566 (pl. 17, fig. 5), 9125, 9501; Animas formation, 9565; Coalmont formation, 5987; Dawson arkose, 5836, 8307; Evanston formation, Lesquereux's figures; Ferris formation, 6625, 6971; Middle Park formation, 3361; Raton formation, 5711 (pl. 18, fig. 4), 5712.

Juglandicarya spp.

Plate 19, figures 5, 7–11

Molds of that part of the cavity of a nut, exposed when the nut dehisces naturally into its two halves and loses the meat, have been found at a number of Paleocene localities. These molds represent the yoked halves of the two cotyledons. The cotyledons themselves would be at right angles to them.

As no husks or exteriors of shells seem to have been preserved, definite identification of these nuts, other than they belong to the Juglandaceae, does not seem warranted at this time. The different sizes and shapes suggest that different species are involved, but whether or not the differences are really specific or represent degrees of maturity is conjectural. Reid and Chandler (1933, p. 140) proposed a form genus, *Juglandicarya*, to receive similar remains from the London Clay (Eocene), and Kirchheimer (1935, p. 82) proposed *Caryojuglans* for equally unassignable nuts from the German brown coals (Oligocene). The status of *Juglandicarya* was discussed by Scott (1935, p. 667; 1954, p. 73).

Occurrence: Fort Union formation (lower), 4876, 5526, 5917 (figs. 5, 10), 6738, 9112 (figs. 9, 11); (upper), 8910 (fig. 7), 9198 (fig. 8).

Juglans berryana (Knowlton) Brown, n. comb.

Dryophyllum berryana Knowlton, 1924, p. 81, pl. 8, fig. 2.
Juglans rugosa Lesquereux. Knowlton, 1917, p. 293, pl. 112, fig. 4.
Magnolia angustifolia Newberry. Knowlton, 1924, p. 88, pl. 10, fig. 3 [counterpart of *Dryophyllum berryana*, pl. 8, fig. 2].
Nectandra lancifolia (Lesquereux) Berry. Knowlton, 1924, p. 87, pl. 13, fig. 1.
Rhus coloradensis Knowlton, 1924, p. 90, pl. 10, fig. 4.

These are long elliptic to oblanceolate leaflets with inconspicuously toothed margins. The secondary veins are widely spaced, parallel, looping near the margin. The items *Dryophyllum berryana* and *Magnolia angustifolia* were based inadvertently by Knowlton on counterparts of the same specimen.

Occurrence: Animas formation, 7496; Raton formation, 5679, 5714, 5797.

Juglans taurina Brown, n. sp.

Plate 56, figures 4, 8, 9

Berchemia multinervis (Braun) Heer. Ward, 1887, p. 73, pl. 33, fig. 1.

Broad ovate entire asymmetric leaflets with blunt to acuminate apexes and cuneate-rounded bases. Petioles short. Secondary veins numerous, sometimes branched, looping near the margin, with a tendency to branch from the midrib at right angles near the base of the blade. Tertiary connecting veinlets numerous, diagonal, conspicuous.

Occurrence: Fort Union formation (upper), 2423 (figs. 4, 9), 4262 (fig. 8), 5595, 6342.

Pterocarya glabra Brown, n. sp.

Plate 18, figures 1–3, 5–9, 13

Leaflets elliptic spatulate, smooth, serrate with small, moderately sharp teeth. Petioles rather long, unless all the leaflets seen are terminals. Secondary veins numerous, closely spaced. Tertiary veins very numerous.

Some of these leaflets are scarcely distinguishable from those of *Pterocarya hispida* Brown, except that under the magnifying glass they appear to lack the glandular dots of that species. Associated with these leaflets are nutlets (figs. 6–9) whose wings are 8 to 10-lobed. These are tentatively assigned to this species.

Occurrence: Fort Union formation (lower), 8930, 6594, (upper) 8921 (figs. 1–3, 5–9, 13).

Pterocarya hispida Brown, n. sp.

Plate 18, figures 11, 12; plate 19, figure 1; plate 68, figures 12, 13

Leaflets ovate to ovate spatulate, covered with minute, glandular dots, serrate with rather small, blunt teeth. Terminal leaflet long petioled, side leaflets short petioled. Secondary veins numerous, closely spaced. Tertiary veins very numerous.

Some of these leaflets, on the basis of shape, serration, and venation alone, apparently are indistinguishable from those of *Carya antiquorum* Newberry and *Pterocarya glabra* Brown. Associated with them, however, are entire-winged fruits (pl. 68, figs. 12, 13) similar to those of the living *Pterocarya paliurus* Batalin, and these are tentatively assigned to the same species. They are gland dotted, like the leaves.

Occurrence: Fort Union formation (lower), 6839 (pl. 68, figs. 12, 13); (upper) 8910 (pl. 19, fig. 1) 8920 (pl. 18, figs. 11, 12); Coalmont formation, 6005.

BETULACEAE

Betula stevensoni Lesquereux

Plate 20, figures 1–5, 7–9

Betula stevensoni Lesquereux, 1878, p. 139, pl. 18, figs. 1–5; pl. 34, fig. 1b.
Betula göpperti Lesquereux, 1878, p. 138, pl. 17, figs. 21–23.
Betula vogdesi Lesquereux, 1878, p. 137, pl. 17, figs. 18, 19.
Alnus americana Ettingshausen, 1883, p. 115.
Alnus kefersteinii Göppert. Lesquereux, 1878, p. 140, pl. 18, figs. 6–8.
Cassia concinna Heer. Lesquereux, 1878, p. 299, pl. 59, figs. 8, 8a.
Cassia evanstonensis Knowlton and Cockerell. Knowlton, 1919, p. 146.
Corylus macquarrii (Forbes) Heer. Lesquereux, 1878, p. 144, pl. 18, fig. 10.
Fraxinus denticulata Heer. Lesquereux, 1878, p. 228, pl. 40, fig. 1 [probably not fig. 2].
Rhus evansii Lesquereux, 1878, p. 291, pl. 58, figs. 5–9 [not pl. 50, fig. 4, which is *Castanaea intermedia* Lesquereux].

The foregoing synonymy may exceed the bounds of probability that all belong to a single species. However, many of the types are based on battered specimens that scarcely permit typification of a species, but if more than one species is represented the distinction must await the finding of better material at those localities.

These betulaceous leaves differ from those assigned to *Corylus insignis* Heer in having basal secondaries with less pronounced tertiary branching and margins with more numerous and less coarse teeth. No fruits and seeds of *Alnus*, *Betula*, or *Carpinus* have been found in association with the leaves, but catkins were found at localities 4661, 8551, and 9109.

Occurrence: Fort Union formation (lower), 4661 (figs. 1, 3), 8551, 8893 (figs. 2, 4) 9104, 9180; (upper), 2423, 4984 (fig. 8), 5905, 8522, 8917, 9109 (fig. 7), 9199 (fig. 9); Coalmont formation, 6110; Evanston formation, 3658, 3661 (fig. 5), Livingston formation, 6767, 8896.

Corylus insignis Heer

Plate 21, figures 1–11

Corylus insignis Heer, 1871, p. 469, pl. 49, fig. 5.
Corylus macquarrii (Forbes) Heer, 1868, p. 104, pl. 8, figs. 9–12; pl. 9, figs. 1–8; pl. 17, fig. 5d; pl. 19, fig. 7c; 1871, p. 469, pl. 44, fig. 11a; pl. 45, fig. 6b.
  Lesquereux, 1878, p. 144, pl. 18, fig. 11 [not fig. 9, which is *Viburnum asperum* Newberry; not fig. 10, which is *Betula stevensoni* Lesquereux].
  Ward, 1887, p. 30, pl. 13, fig. 7.
  Newberry, 1898, p. 61, pl. 32, fig. 5 [not pl. 48, fig. 4, which is *Tilia oregona* LaMotte].
Corylus fosteri Ward, 1887, p. 29, pl. 13, figs. 5, 6.
Corylus americana Walter. Ward, 1887, p. 28, p. 11, figs. 3–5; pl. 12, figs. 1, 2.
Corylus americana fossilis Newberry, 1898, p. 60, pl. 29, figs. 8–10.
Corylus orbiculata Newberry, 1898, p. 62, pl. 32, fig. 4.
Corylus rostrata Aiton. Ward, 1887, p. 29, pl. 13, figs. 1–4.
Corylus rostrata fossilis Newberry, 1898, p. 63, figs. 1–3.
Corylites fosteri (Ward) Bell, 1949, p. 53, pl. 33, figs. 1–5, 7.
Betula basiserrata Ward, 1887, p. 32, pl. 14, fig. 4.
Betula coryloides Ward, 1887, p. 31, pl. 14, fig. 3.
Betula prisca Ettingshausen. Ward, 1887, p. 31, pl. 14, fig. 2.
Pterospermites whitei Ward. Bell, 1949, p. 69, pl. 47, figs. 1, 5.

The leaf originally identified by Forbes from the Ardtun beds (?Eocene) of the Isle of Mull as *Alnites macquarrii* is fragmentary, but upon it Heer established *Corylus macquarrii* represented by equally fragmentary specimens from Atanekerdluk in Greenland. On the basis of a leaf from the same strata, *Corylus* *insignis* Heer is a less controversial name for these American specimens.

Although this species is represented by an abundance and variety of leaves in the Paleocene of the Western States, only one nut (fig. 6) has been taken. This is small, being only 5 mm in diameter. Perhaps some shrinkage occurred before fossilization. One male catkin (fig. 9) has also been found.

The relationship of this species to those identified by Hollick as *Corylus* in the Tertiary floras of Alaska is not clear. Some Alaskan Tertiary species of *Alnus* and *Betula* may also be confused with *Corylus*.

Occurrence: Fort Union formation (lower), 8224, 8519 (figs. 9, 10), 8551, 8552, 8897, 8930, 9104; (upper), 2414 (fig. 5), 2416 (figs. 1, 6, 11), 3979, 4974, 8231, 8255 (fig. 4), 8921, 9072 (figs. 2, 3, 8), 9202 (fig. 7); Livingston formation, 4310, 6765.

FAGACEAE

Castanea intermedia Lesquereux

Plate 22, figures 3, 4, 6, 7–10

Castanea intermedia Lesquereux, 1878, p. 164, pl. 21, fig. 7. Knowlton, 1917, p. 297, pl. 68, fig. 2; 1924, p. 81, pl. 8, fig. 1. 1930, p. 50.

Dryophyllum moori (Lesquereux) Berry. Knowlton, 1917, p. 299, pl. 70, fig. 1.

Rhus evansi Lesquereux, 1878, p. 291, pl. 50, fig. 4 [not other figures].

The type of this species, it should be noted, is from the Paleocene of Middle Park, Colo., and not from the Oligocene at Florissant, Colo., as listed in LaMotte's catalog (1952, p. 106).

In general the leaves here assigned to *Castanea* are relatively long and narrow, with fairly sharp, slightly hooked marginal teeth. Notably, the sinuses between the teeth are deep and angular below. The specimen described but not figured by Knowlton (1930, p. 50) is somewhat atypical in having one secondary vein that is forked near the midrib, and a number of secondaries that are forked near the margin, sending short branches into teeth.

No fruits or nuts recognizable as those of *Castanea* have thus far been found in American Paleocene strata. One specimen of *C. ungeri* Heer (1883, p. 84, pl. 69, fig. 3), from Atanekerdluk, Greenland, may belong here.

Occurrence: Fort Union formation (lower), 541 (fig. 7), 6344, 8928 (figs. 3, 4, 6); (upper) 8521, 8774; Animas formation, 7485; Dawson arkose, 5836 (fig. 9), 5839; Ferris formation, 5495 (fig. 10), 6428, 9203 (fig. 8); Middle Park formation, 333; Raton formation, 5712.

Quercus asymmetrica Trelease

Plate 22, figure 1

Quercus dubia Newberry, 1898, p. 73, pl. 37, fig. 5. [Homonym.]

Quercus asymmetrica Trelease, 1924, p. 27.

These fragments have the appearance of belonging to the Fagaceae but may, when adequate material is found, be assigned elsewhere.

Occurrence: Fort Union formation, exact locality unknown (fig. 1, reproduction of Newberry's type).

Quercus greenlandica Heer

Plate 19, figures 3, 6, 12; plate 22, figure 5; plate 40, figures 1, 2

Quercus groenlandica Heer, 1868, p. 108, pl. 8, fig. 8; pl. 10, figs. 3, 4; pl. 11, fig. 4; pl. 47, fig. 1; 1871, p. 56, pl. 12, figs. 1–4; p. 471, pl. 45, figs. 4, 4b; 1883, p. 89, pl. 69, fig. 4; pl. 89, figs. 1, 2; pl. 91, figs. 1, 2a.

Quercus furcinervis Rossmässler, Heer, 1868, p. 107, pl. 7, figs. 6a, 7a; pl. 45, fig. 1d; pl. 46, fig. 6.

Quercus steenstrupiana Heer, 1868, p. 109, pl. 11, fig. 5; pl. 46, figs. 8, 9; 1883, p. 92, pl. 69, fig. 5.

Castanea ungeri Heer, 1883, p. 84, pl. 69, fig. 3; pl. 73, fig. 14; pl. 88, fig. 3; pl. 89, fig. 4.

Fagus castaneaefolia Unger. Heer, 1868, p. 106, pl. 10, figs. 7a, 8; pl. 46, figs. 1–3.

Fagus dentata Unger. Heer, 1868, p. 106, pl. 10, figs. 1, 2, 7b, 9.

Fagus deucalionis Unger. Heer, 1868, p. 105, pl. 8, figs. 1–4; pl. 10, fig. 6; pl. 46, fig. 4; 1871, p. 470, pl. 46, fig. 9; 1875, p. 5, pl. 3, figs. 11, 12.

The numerous specimens here referred to *Quercus* and hitherto identified variously as *Castanea*, *Fagus*, and *Quercus*, are characterized particularly by large, more or less rounded teeth between which the sinuses, although somewhat scalloped, are nevertheless slightly or noticeably angular. Several species and genera may here be confused, but, in the absence of confirmatory seeds or fruits, I do not see how they can be separated satisfactorily. Probably the fragmentary leaves identified by Heer from the Paleocene strata at Atankerdluk, Greenland, as *Fagus macrophylla* Unger, *Quercus*? *atava* Heer, and *Quercus drymeia* Unger, also belong here.

Occurrence: Fort Union formation (lower), 4010 (pl. 19, fig. 3), 5526 (pl. 40, figs. 1, 2), 6171 (pl. 19, fig. 12), 9111, 9208, 9482; (upper), 4878 (pl. 19, fig. 6), 9132, 9196; Animas formation, 9549; Coalmont formation, 6000 (pl. 22, fig. 5); Evanston formation, 5551.

Quercus macneili Brown, n. sp.

Plate 19, figure 2

Leaves elliptic in outline, with cuneate bases. Margin with coarse toothlike, sharp-pointed lobes, separated by angular sinuses. Secondary venation somewhat irregular, the veins entering the marginal lobes. Surface pattern a quadrangular meshwork.

This species is a representative of the blackoak group.

Named for F. Stearns MacNeil, of the U.S. Geological Survey.

Occurrence: Fort Union formation (lower), 8239 (fig. 2).

Quercus sullyi Newberry

Plate 23, figures 1–7; plate 27, figure 9; plate 57, figures 6, 7

Quercus sullyi Newberry, 1883, p. 506; 1898, p. 79, pl. 60, fig. 2.
Quercus artocarpites Ettingshausen. Hollick, 1936, p. 102, pl. 43, fig. 1; pl. 56, fig. 6.
Quercus charpenteri Heer, 1883, p. 93, pl. 73, figs. 11–13; pl. 74, fig. 9.
Quercus conjunctiva Hollick, 1936, p. 101, pl. 42, figs. 3, 4a.
Quercus furcinervis Rossmässler. Heer, 1883, p. 89, pl. 74, fig. 8.
Quercus juglandina Heer, 1883, p. 89, pl. 71, fig. 19; pl. 74, figs. 4–7; pl. 76, fig. 12; pl. 102, fig. 9a.
Hollick, 1936, p. 101, pl. 42, figs. 1a, 2; pl. 43, fig. 2.
Quercus laharpi Gaudin. Heer, 1883, p. 92, pl. 74, figs. 1–3.
Quercus laurifolia Newberry, 1898, p. 76, pl. 59, fig. 4; pl. 60, fig. 3.
Quercus lyelli Heer, 1883, p. 87, pl. 72, figs. 1–10; pl. 73, figs. 1–6.
Quercus meriani Heer. Hollick, 1936, p. 102, pl. 44, fig. 1.
Quercus penhallowi Trelease, 1918, p. 499.
Andromeda denticulata Heer, 1868, p. 116, pl. 50, figs. 11d, 11e. [Specific term preoccupied by another fossil oak.]
Aralia taurinensis (Ward) Sanborn, 1937, p. 27, pl. 10, figs. 1, 2, 4.
Dryophyllum aquilonium Hollick, 1936, p. 104, pl. 43, fig. 6.
Fraxinus juglandina Saporta. Hollick, 1936, p. 163, pl. 42, fig. 4b only.
Ilex longifolia Heer, 1868, p. 124, pl. 48, figs. 3–6; 1871, p. 481, pl. 50, fig. 17; pl. 56, fig. 1. [Name given to a dubious Miocene fragment from Italy.]
Ilex? reticulata Heer, 1868, p. 124, pl. 48, fig. 7. [Name preoccupied by a living oak.]
Ilex triboleti Heer, 1883, p. 129, pl. 72, fig. 10b; pl. 73, figs. 7–10.
Juglans bilinica Unger. Heer, 1883, p. 100, pl. 69, fig. 8.
Juglans crossi Knowlton. Hollick, 1936, p. 80, pl. 44, figs. 3, 4.
Juglans denticulata Heer, 1871, p. 483, pl. 56, figs. 6–9a.
Juglans heeri Ettingshausen. Heer, 1883, p. 102, pl. 76, figs. 2–11.
Juglans sp. Hollick, 1926, p. 42, fig. 1b.
Myrica acuminata Unger. Heer, 1883, p. 78, pl. 71, figs. 6, 7.
Myrica langeana Heer, 1883, p. 78, pl. 71, figs. 1–5; pl. 86, fig. 5.
Myrsine grönlandica Heer, 1883, p. 111, pl. 81, figs. 4–8; pl. 85, fig. 4.
Populus meedsii Knowlton, 1893, p. 34, pl. 1, figs. 1, 2.
Protoficus inaequalis Newberry, 1898, p. 89, pl. 60, fig. 1 only.
Prunus scotti Heer, 1871, p. 483, pl. 55, fig. 5; 1883, p. 137, pl. 84, fig. 13.
Pterocarya denticulata Heer, 1883, p. 102, pl. 76, fig. 1.
Pterocarya septentrionale Hollick, 1936, p. 84, pl. 40, figs. 5–7.
Sapindus undulatus Braun. Heer, 1883, p. 127, pl. 84, figs. 1–3.

Well-preserved impressions of these elliptic-lanceolate entire to toothed leaves display several characteristic features that render identification easy. The sharp, somewhat dentate teeth, when present, are separated by scalloped sinuses; the prominent forks of the undulant secondary veins connect to form loops near the margin; and the minute venational surface pattern makes a conspicuous, quadrangular network.

Although these leaves have been variously identified, as shown by the synonymy, there is no certainty now that they represent *Quercus*. The species resembles variants of the Late Cretaceous *Dryophyllum subfalcatum* Lesquereux and may be descended from it. The resemblance to fossil species of *Celastrus* and *Viburnum* is more remote. The latter have rounded or sometimes cordate bases and more numerous teeth which are serrate, not dentate. The species left abundant remains at many localities, but particularly in the late Paleocene and early Eocene.

Occurrence: Fort Union formation (lower), 4289, 6602, 8239 (pl. 23, fig. 4; pl. 57, figs. 6, 7) 8253 (pl. 27, fig. 9), 8552 (pl. 23, fig. 3); (upper), exact locality unknown (pl. 23, fig. 2, reproduction of Newberry's type, pl. 60, fig. 2), 436 (pl. 23, fig. 1), 2414 (pl. 23, fig. 5, reproduction of Knowlton's pl. 1, fig. 1 of *Populus meedsii*), 5582, 6985, 8257, 8885, 8886 (pl. 23, figs. 6, 7), 8913, 8920; Coalmont formation, 6005.

Quercus yulensis Brown, n. sp.

Plate 19, figure 4

Leaf elliptic to obovate in outline with blunt apex, large rounded teeth and narrow, deep sinuses between the teeth. Secondary veins few, widely spaced, subparallel, and entering the teeth.

The fewer secondaries and larger teeth readily distinguish this species from *Quercus greenlandica* Heer, another member of the white oak group.

Occurrence: Fort Union formation (lower) 8239 (fig. 4).

ULMACEAE

Celtis newberryi Knowlton and Cockerell

Plate 27, figures 3, 4

Celtis newberryi Knowlton and Cockerell. Knowlton, 1919, p. 160.
Celtis parvifolia Newberry, 1898, p. 84, pl. 53, fig. 6.
Cornus denverensis Knowlton. Bell, 1949, p. 76, pl. 56, fig. 5 (lower leaf).

Leaves more or less asymmetric, with slightly rounded bases and acute apexes. Margins entire or with coarse, serrate teeth. Venation incipiently palmate, with a minor pair of subdued veins between the primary pair and the top of the petiole. Primary and secondary veins enter marginal teeth and emit branches to subsidiary teeth.

Occurrence: Fort Union formation (middle), exact locality unknown (fig. 3, reproduction of Newberry's type); (upper), 9109 (fig. 4).

Celtis peracuminata Brown, n. sp.

Plate 20, figure 6

Leaf ovate lanceolate in outline, with rounded base and attenuate apex. Margin with short serrate teeth. Venation palmate. Basal primaries curve narrowly upward toward the apex, their numerous branches forming conspicuous loops from which minute branches run into the teeth. Veinlets connecting the major venation relatively coarsely spaced.

Occurrence: Fort Union formation (upper), 7688 (fig. 6).

Planera microphylla Newberry

Plate 24, figures 1–11, 13, 15, 16

Planera microphylla Newberry, 1868, p. 55; 1898, p. 81, pl. 33, figs. 3, 4.
Rhus? *nervosa* Newberry, 1898, p. 114, pl. 33, figs. 5, 6.
Rhus unitus Knowlton and Cockerell. Knowlton, 1919, p. 553.
Ulmus antecedens Lesquereux. Knowlton, 1930, p. 62, pl. 23, fig. 7.

Most of these leaves are symmetric or only slightly asymmetric, with cordate bases. The marginal teeth are single, double, or mixed. The striking feature of the best leaves is the notable forking of many secondary veins at some distance inward from the margin. Because no characteristic fruits of *Planera* have been found with these leaves the identification should be regarded as tentative. The leaves may represent *Chaetoptelea*, *Ulmus*, *Zelkova*, or some other ulmaceous genus. A suggestion of an ancestral form may be *Phyllites* sp. (Dorf, 1942, p. 156, pl. 17, figs. 5, 13), from the Lance formation (Upper Cretaceous) in eastern Wyoming.

Occurrence: Fort Union formation (lower), 5385, 5387, 5885 (fig. 10); (upper), 4264 (figs. 3–5, 8, 9, 13), exact locality unknown (figs. 6, 16, reproduction of Newberry's type of *Rhus*? *nervosa*), 4898, 5300, 6225, 8206 (figs. 7, 11), 8166 (fig. 15), 8255, 8523, 8885 (figs. 1, 2) 9398; Denver formation, 317.

Ulmus rhamnifolia Ward

Plate 24, figures 17, 18, 21–23

Ulmus rhamnifolia Ward, 1887, p. 45, pl. 23, fig. 5.
Ulmus orbicularis Ward, 1887, p. 46, pl. 23, fig. 6.

Leaves relatively large, more or less asymmetric, with rounded double marginal teeth. Secondary venation curving, equidistant, as in living species of *Ulmus*. Fruit obovoid, with the seed about the width of the wing, resembling that of the living *Ulmus japonica* Sargent of eastern Asia.

The present correlation of leaves and fruit seems reasonably certain because no other elmlike leaves or leaves of any other family having elmlike fruits occur at these Paleocene localities. Heer's *Sorbus grandifolia* (1883, p. 483, pl. 54, fig. 4) is fragmentary, but it and his *Ulmus* fruit (1883, p. 94, pl. 75, fig. 12), from Atanekerdluk, Greenland, probably belong with this species. Newberry (1883, p. 508) described but did not illustrate some large leaves from the Yellowstone River region of Montana, as *Ulmus grandifolia*. These were probably the same as *U. rhamnifolia* but were never again alluded to, and their whereabouts is now unknown. As their identity cannot be established, the name is rejected.

Occurrence: Fort Union formation (lower), 4620; (upper), 2414 (fig. 21, reproduction of Ward's type of *Ulmus rhamnifolia*), 8910 (figs. 18, 23), 9109 (fig. 22), 9207 (fig. 17).

Zelkova planeroides (Ward) Brown, n. comb.

Plate 22, figure 2; pl. 24, figures 12, 14, 19, 20

Ulmus planeroides Ward, 1887, p. 44, pl. 23, figs. 1, 2.
Ulmus minima Ward, 1887, p. 45, pl. 23, figs. 3, 4.
Ulmus wardii Knowlton and Cockerell. Knowlton, 1919, p. 636.
Planera crenata Newberry, 1898, p. 81, pl. 67, fig. 3.
Planera lingualis Knowlton and Cockerell. Knowlton, 1919, p. 464.
Quercus castanopsis Newberry, 1898, p. 71, pl. 56, fig. 4.
Quercus praegroenlandica Berry, 1935, p. 26, pl. 3, figs. 3–7.
Bell, 1949, p. 53.

The best preserved of these leaves are comparatively long and narrow, with cuneate or rounded, not cordate, bases. The teeth are rounded, generally single, but may occasionally be double.

Occurrence: Fort Union formation (lower), 4035 (pl. 24, fig. 12), 4620, 6154, 8163, 9104; (upper), 2414 (pl. 24, figs. 14, 20, counterpart of Ward's type), 3979, 5613, 7662, 8196, 8255, 8521, exact locality unknown (pl. 24, fig. 19, reproduction of Newberry's type of *Quercus castanopsis*), exact locality unknown (pl. 22, fig. 2, reproduction of Newberry's type of *Planera crenata*).

MORACEAE

Artocarpus lessigiana (Lesquereux) Knowlton

Plate 25, figure 7

Myrica? *lessigii* Lesquereux, 1878, p. 136, pl. 64, fig. 1.
Artocarpus lessigiana (Lesquereux) Knowlton, 1893a, p. 24; 1922a, p. 128, pl. 12, fig. 1; pl. 22, fig. 4.
Berry, 1916a, p. 194, pl. 26, fig. 1.
Ball, 1931, p. 52, pl. 37, figs. 1–3; pl. 38, figs. 1–8; pl. 39, figs. 1, 2.
MacGinitie, 1941, p. 109, pl. 15; pl. 16, fig. 1.
Artocarpus dicksoni Nathorst, 1890, p. 1–10, pl. 1, figs. 1–4.
Artocarpus dissecta Knowlton, 1917, p. 67, pl. 42, fig. 6.
Artocarpus? *gigantea* Knowlton, 1930, p. 75.
Artocarpus liriodendroides Knowlton, 1922a, p. 129, pl. 21, fig. 2.
Artocarpus pungens (Lesquereux) Hollick, 1899, p. 281, pl. 38, figs. 1, 2.
Berry, 1916a, p. 195, pl. 25, fig. 1; pl. 27, fig. 1; pl. 29, fig. 1.
Knowlton, 1924, p. 85, pl. 12; 1930, p. 73, pl. 30, fig. 2; pl. 32, figs. 1, 2.

Artocarpus similis Knowlton, 1917, p. 306, pl. 77; pl. 78, figs. 1, 2; 1930, p. 75, pl. 32, fig. 6.

Artocarpophyllum occidentale Dawson, 1894, p. 60, pl. 12, fig. 51; pl. 13, fig. 52.

Aralia pungens Lesquereux, 1883, p. 123, pl. 19, figs. 3, 4.

Quercus angustiloba Braun. Lesquereux, 1878, p. 161, pl. 21, figs. 4, 5.

Quercus praeangustiloba Knowlton, 1922a, p. 126, pl. 5, figs. 6, 7.

Sterculia coriacea Knowlton, 1917, p. 272, pl. 48, fig. 1.

Phyllites sp. Knowlton, 1924, p. 98, pl. 19, fig. 1.

I have found no satisfactory method for distinguishing species among the materials here synonymized as *Artocarpus lessigiana* (Lesquereux) Knowlton. It, however, seems somewhat improbable that only one species prevailed over the range of time and space indicated by these specimens. Nevertheless, I can duplicate almost exactly Nathorst's *A. dicksoni* from the Upper Cretaceous of Greenland with a specimen from the Denver formation (Paleocene) on South Table Mountain, Colo. No fruits comparable to those illustrated by Nathorst have yet been found in the United States. Thus far, also, no leaves recognizable as those of *Artocarpus* have been reported from the Paleocene of any locality in the Rocky Mountain region north of latitude 43°. This or a similar species was present in the Eocene of the Gulf Coastal Plain and of Yellowstone National Park.

Occurrence: Fort Union formation (lower), 9237; Animas formation, 7496; Dawson arkose, 8779; Denver formation, 317 (fig. 7), 8777; Puerco formation, 7371; Raton formation, 5799.

Ficus affinis (Lesquereux) Brown, n. comb.

Plate 27, figures 1, 2, 5; plate 43, figures 7, 8

Cinnamomum affine Lesquereux, 1878, p. 219, pl. 37, fig. 5 [not other figures except the unnumbered one below fig. 1].

Cinnamomum? ficifolium Knowlton, 1917, p. 318, pl. 90, fig. 3.

Cinnamomum lanceolatum (Unger) Heer. Lesquereux, 1878, p. 219, pl. 36, fig. 12.

Cinnamomum linifolium Knowlton, 1917, p. 319, pl. 88, figs. 3–7; 1930, p. 86, pl. 59, fig. 3.

Dorf, 1938, p. 59, pl. 9, fig. 1.

Cinnamomum polymorphum Braun. Lesquereux, 1878, p. 221, pl. 37, fig. 10. [Same as *C. ellipticum* Knowlton, 1893, p. 54.]

Cinnamomum salicoides Knowlton, 1924, p. 88, pl. 15, fig. 2.

Cinnamomum? sp. Knowlton, 1930, p. 87, pl. 36, fig. 4.

Ficus cannoni Knowlton, 1922a, p. 136, pl. 6, fig. 3; pl. 10, fig. 1.

Ficus dalmatica Ettingshausen. Knowlton, 1922a, pl. 21, fig. 9; pl. 22, fig. 5.

Ficus haddeni Knowlton, 1917, p. 260, pl. 38, figs. 6, 7.

Ficus neoplanicostata Knowlton, 1930, p. 69, pl. 29, figs. 3, 4.

Ficus planicostata problematica Knowlton, 1930, p. 71, pl. 28, fig. 2.

Ficus populoides Knowlton, 1900, p. 44, pl. 8, fig. 3.

Ficus posttrinervis Knowlton, 1922a, p. 136, pl. 6, figs. 1, 2.

Ficus praetrinervis Knowlton, 1917, p. 263, 304, pl. 41, figs. 1–3 [not fig. 4, which is *F. planicostata* Lesquereux]; 1930, p. 71, pl. 28, figs. 8–10.

Ficus pseudopopulus Lesquereux. Knowlton, 1917, p. 304, pl. 72, fig. 2 [not figs. 3, 4, which are *F. planicostata* Lesquereux]; pl. 73, figs. 1, 2; pl. 112, fig. 3; 1924, p. 83, pl. 9, fig. 3.

Ficus trinervis Knowlton, 1900, p. 42.

Lee, 1912, pl. 20, fig. 1.

Dorf, 1938, p. 56, pl. 6, figs. 1, 4.

Ficus sp. Knowlton, 1930, p. 72, pl. 30, fig. 1.

Malapoenna louisvillensis Knowlton, 1922a, p. 144, pl. 7, fig. 5.

Phyllites herbacea Knowlton, 1924, p. 97, pl. 15, fig. 4.

Platanus platanoides (Lesquereux) Knowlton, 1930, p. 82, pl. 36, fig. 5.

Populus arctica Heer. Lesquereux, 1878, p. 178, pl. 23, fig. 4. [Locality dubious, but not Spring Canyon, Mont.]

Populus? distorta Knowlton, 1922a, p. 126, pl. 4, fig. 6.

Zizyphus lanceolatus Knowlton, 1924, p. 93, pl. 15, fig. 3.

Zizyphus minutus Knowlton, 1922a, p. 158, pl. 18, fig. 1.

These triveined leaves, hesitantly assigned to *Ficus*, differ from those called *Ficus planicostata* Lesquereux chiefly in the conspicuous decurrency of the lateral primaries into the petiole. Both species however, as now set up, include specimens having almost similar venation, so that choice of allocation is sometimes difficult and the result arbitrary. Both species range from the Cretaceous into the Paleocene and are associated at the same or nearby localities in correlative strata.

Some extremely narrow specimens, formerly called *Cinnamomum linifoluim* Knowlton, are here reassigned to *Ficus affinis*, because they seem to be variants of this species and are found at the same localities.

As this species was based by Knowlton on one of Lesquereux's types of *Cinnamomum affine*, its proper name, instead of *Ficus trinervis* Knowlton, should have been *Ficus affinis* (Lesquereux) Knowlton, n. comb.

Occurrence: Fort Union formation (lower) 4625 (pl. 43, fig. 8), 5194, 8899; Animas formation, 7481, (pl. 27, fig. 5), 7483; Dawson arkose, 5374, 5831, 6943, 8779, 9554; Denver formation, 317 (pl. 27, figs. 1, 2), 325, 8672, 8777; Evanston formation, exact locality unknown; Raton formation, 5683, 5684, 5686, 5699, 5796 (pl. 43, fig. 7), 5826, 5827.

Ficus artocarpoides Lesquereux

Plate 28, figures 1–7

Ficus artocarpoides Lesquereux, 1878, p. 47, pl. 47, figs. 1–5. Knowlton, 1917, p. 300, pl. 71, fig. 3.

Cornus? fosteri Ward, 1887, p. 54, pl. 25, fig. 5.

Cornus newberryi Hollick. Newberry, 1898, p. 124, pl. 37, fig. 4 only.

Meliosma cuneata (Newberry) Berry, 1939b, p. 377 [not text fig. 1].

Parrotia cuneata (Newberry) Berry, 1916a, p. 219; 1930a, p. 71 [not pl. 12, fig. 10].

Phyllites retusoides Knowlton, 1917, p. 349, pl. 102, fig. 5.

Protophyllum canadensis Berry, 1935, p. 31, pl. 4B.

Protophyllum sp. Berry, 1926, p. 194, fig. 1.

Pterospermites dawsoni (Knowlton) Bell, 1949, p. 70, pl. 47, figs. 2, 4; pl. 49, figs. 1, 2.
Pterospermites penhallowi Berry, 1935, p. 49, pl. 13.
Quercus bicornis Ward, 1887, p. 24, pl. 9, fig. 3.
Quercus dawsoni Knowlton, 1898, p. 191.
Quercus platania Heer. Dawson, 1889, p. 72, pl. 11.
Rhamnus cannoni Knowlton, 1930, p. 107, pl. 46, fig. 5.
Rhamnus cleburni Lesquereux. Knowlton, 1930, p. 104, pl. 46, figs. 10, 11 only.
Rhamnus goldianus Lesquereux. Knowlton, 1917, p. 332, pl. 101, fig. 4.
Viburnum cuneatum Newberry, 1883, p. 511; 1898, p. 130, pl. 57, fig. 2.

The types of this species, unfortunately, are fragmentary, and their present location is unknown to me. They are depicted as oval, blunt at the apex, cuneate, rounded, or cordate at the base, with entire margins, and long, stout petioles. The venation is pinnate, the secondaries evenly spaced, camptodrome, and connected by numerous parallel diagonal veinlets. The lower secondaries may be branched near the margin.

Collections from other localities in the Fort Union of Montana, particularly locality 8910, contain leaves that would be identified with the original *Ficus artocarpoides*, but they also include toothed leaves that have been identified as *Viburnum cuneatum*, *Quercus dawsoni*, *Cornus newberryi*, and *Pterospermites penhallowi*. As all these differently shaped specimens, however, have identical venation and as they occur together at a number of localities, I am inclined to regard them as representing a single species; but, although their features are suggestive, I am not certain that they represent a species of *Ficus*.

Except that these leaves are less coarse in every respect—size, venation, and dentition—they seem to be clearly descendant from *Ficus preartocarpoides* Brown (1939b, p. 249, pl. 53, figs. 3–5) and its synonym, *Araliaephyllum artocarpoides* (Lesquereux) Dorf (1942, p. 147, pl. 13, fig. 4) from the Hell Creek and Lance formations, respectively. Indeed, some of the Paleocene leaves may, by atavism, match those of the Late Cretaceous. Most of the Late Cretaceous leaves display an indefinable irregularity not found in the Paleocene specimens.

The original illustration of *Cornus newberryi* Hollick should be compared with that here (fig. 1) made of the same specimen after the margin was cleaned, showing that the leaf is toothed, not entire.

Occurrence: Fort Union formation (lower), 4570, 4625 (fig. 6), 4860, 4876, 4984, 5839, 6117, 6668, 8246, 8551, 8552; (upper), 2416 (fig. 5, reproduction of Ward's type of *Quercus bicornis*), 4369 (fig. 3), 4676, 5760, 8261 (fig. 4), 8774, 8910 (fig. 2), 8922, exact locality unknown (fig. 1, reproduction of Hollick's type of *Cornus newberryi*), exact locality unknown (fig. 7, reproduction of Newberry's type of *Viburnum cuneatum*); Evanston formation, 1474, 3653; Ferris formation, 6630, 6971, 8516; Livingston formation 4311; Middle Park formation, 337; Raton formation, 5711.

Ficus minutidens Knowlton

Plate 48, figure 8

Ficus minutidens Knowlton, 1917, p. 305, pl. 71, fig. 2.

The distinctive feature of these figlike leaves is their dentate margin, with scalloped or angular sinuses between the teeth. The venation is essentially pinnate but with a suggestion of a tendency toward palmateness. Acceptance of these leaves as *Ficus* is made with reservations, because they also resemble somewhat the leaves of some species of *Hydrangea*, *Morus*, *Populus*, *Tilia*, *Viburnum*, and *Vitis*.

Occurrence: Animas formation, 7496 (fig. 8); Raton formation, 5711.

Ficus planicostata Lesquereux

Plate 26, figures 1–8

Ficus planicostata Lesquereux, 1878, p. 201, pl. 31, figs. 1–8, 10–12.
  Lee, 1912, pl. 20, fig. 2.
  Knowlton, 1924, p. 82, pl. 9, fig. 2.
  Dorf, 1938, p. 53, pl. 5, figs. 3–5, 7; 1942, p. 136.
Ficus planicostata clintoni (Lesquereux) Knowlton, 1917, p. 303, pl. 76, fig. 3.
Ficus planicostata goldiana Lesquereux, 1878, p. 202, pl. 33, figs. 1–3.
  Knowlton, 1930, p. 70, pl. 28, fig. 5.
Ficus planicostata magnifolia Knowlton, 1922a, p. 133, pl. 10, fig. 3.
Ficus berryana Knowlton, 1922a, p. 139, pl. 11, fig. 11.
Ficus cockerelli Knowlton, 1922a, p. 132, pl. 12, fig. 2; pl. 23, figs. 1, 2.
  Dorf, 1938, p. 55, pl. 7, fig. 2.
Ficus dawsonensis Knowlton, 1930, p. 67, pl. 26, fig. 1.
Ficus denveriana Cockerell. Knowlton, 1917, p. 302, pl. 75, fig. 2 only.
Ficus impressa Knowlton, 1922a, p. 134, pl. 7, figs. 1–3.
Ficus leei Knowlton, 1916, p. 338, pl. 90, fig. 2; 1917, p. 261, pl. 39, figs. 1–6; pl. 40, figs. 1, 2.
Ficus neodalmatica Knowlton, 1922a, p. 135, pl. 7, fig. 6.
Ficus neoplanicostata Knowlton, 1922a, p. 303, pl. 73, fig. 4; pl. 74, figs. 2, 3; pl. 76, fig. 4; 1924, p. 82, pl. 9, fig. 4; 1930, p. 69, pl. 28, figs. 3, 4, 6, 7.
Ficus occidentalis (Lesquereux) Lesquereux, 1878, p. 200, pl. 32, fig. 4.
  Knowlton, 1917, p. 302, pl. 72, fig. 1; 1924, p. 82, pl. 8, fig. 5; 1930, p. 68, pl. 26, fig. 5.
Ficus pagosensis Knowlton, 1924, p. 84, pl. 11.
Ficus praeplanicostata Knowlton, 1922a, p. 133, pl. 22, fig. 2.
Ficus praetrinervis Knowlton, 1917, p. 263, pl. 41, fig. 4.
Ficus problematica Knowlton, 1900, p. 46, pl. 9, fig. 3.
Ficus pseudopopulus Lesquereux, 1878, p. 204, pl. 34, fig. 1a only.
  Knowlton, 1917, p. 304, pl. 72, figs. 3, 4 only; 1930, p. 66, pl. 25, figs. 3–5; pl. 26, figs. 2, 4 only.

Ficus richardsoni Knowlton, 1917, p. 304, pl. 76, fig. 1.
Ficus schimperi Lesquereux. Knowlton, 1917, p. 304, pl. 75, figs. 3, 4.
Ficus speciosissima Ward, 1887, p. 39, pl. 21, fig. 3.
  Lee, 1912, pl. 19.
  Knowlton, 1916, p. 90, pl. 16, fig. 3.
Ficus squarrosa Knowlton, 1900, p. 45, pl. 48, fig. 2.
Ficus tiliaefolia Braun. Lesquereux, 1878, p. 203, pl. 32, figs. 1–3; pl. 63, fig. 8.
  Knowlton, 1930, p. 67.
Ficus wardi Knowlton, 1900, p. 48, pl. 9, fig. 1.
Ficus cf. *mississippiensis* (Lesquereux) Berry. Bell, 1957, p. 44, pl. 33, figs. 1, 5.
Ficus sp. Knowlton, 1924, p. 84, pl. 6, fig. 7.
Cinnamomum mississippiense Lesquereux. Knowlton, 1917, p. 320, pl. 89, fig. 2.
Cissus coloradensis Knowlton and Cockerell. Knowlton, 1930, p. 112, pl. 47, fig. 6; pl. 50, fig. 2.
Cissus laevigata Lesquereux, 1878, p. 238, pl. 40, fig. 13 [not fig. 12, which is *Platanus raynoldsi* Newberry].
  Knowlton, 1917, p. 340, pl. 103, fig. 1.
?*Cornus studeri* Heer. Knowlton, 1917, p. 342, pl. 109, fig. 2.
Dombeyopsis obtusa Lesquereux. Knowlton, 1922, p. 162; 1930, p. 124, for reference to USNM 281d.
Hedera rotundifolia Knowlton, 1917, p. 272, pl. 47, fig. 8.
Juglans thermalis Lesquereux, 1878, p. 287, pl. 56, fig. 4 [not fig. 3, which is *Sassafras thermale* (Lesquereux) Brown].
Laurus utahensis Lesquereux. Knowlton, 1917, p. 318, pl. 70, fig. 4.
Phaseolites coloradensis Knowlton, 1930, p. 97, pl. 45, fig. 1.
Phyllites eocenica Knowlton, 1924, p. 96, pl. 18, fig. 4.
Phyllites sp. Knowlton, 1930, p. 130, pl. 56, fig. 3.

With the exception of the first and a few others, the citations in the foregoing synonymy concern specimens from known Paleocene localities. The first cites Lesquereux's types of this species from the Upper Cretaceous at Black Buttes, Wyo. Other citations for Cretaceous localities have been published by Dorf (1938, p. 53; 1942, p. 136). These synonymies indicate that this species, if it is a single species, comprises leaf specimens illustrating great variety of outline, but with virtually the same venation. The latter consists of a pair of strong lateral veins arising from or near the top of the petiole and curving upward toward the apex. These primary veins have relatively numerous, closely spaced, parallel side branches. Between the midvein and secondaries and between the secondaries are numerous, more or less closely spaced, parallel connecting veinlets. The apexes of these entire ovate to ovate-lanceolate leaves may be blunt rounded to long acuminate, and the bases may be strongly cordate to cuneate. The leaves from the Paleocene seem to average somewhat larger and are perhaps more acuminate than those from the Cretaceous. However, it seems that this species crossed the Cretaceous-Paleocene contact with only slight change, if any.

The Cretaceous specimens called *Ficus leei* and *F. speciosissima* have strongly cordate bases but are otherwise like typical *F. planicostata*. Moreover, they occur in association with the latter and, I suspect, are merely extreme variants of it.

Many items such as *Hedera rotundifolia*, *Juglans thermalis*, and *Phyllites* sp. are fragments that might better have been left unnamed, or at least they should have received more careful scrutiny before being named.

The relationship of *Ficus planicostata* to the Eocene specimens called *F. wyomingiana* Lesquereux and *F. mississippiensis* (Lesquereux) Berry is not clear but may be close.

The assignment of all these figlike leaves to *Ficus*, although plausible, is not confirmed by authentic associated fruits. The Cretaceous specimens named *Ficus ceratops* Knowlton are still controversial. Hence, there is an open possibility that *F. planicostata*, as well as *F. affinis*, may belong to some other genus and family.

The following statement of occurrence indicates that, so far as known, this species was absent from Paleocene areas north of the latitude of Terry, Mont.

Occurrence: Fort Union formation (lower), 4876 (fig. 6), 6057, 8246, 8666; (upper), 8774 (figs. 2, 5, 7, 8; fig. 2 is in Chicago Natural History Museum); 9501; Animas formation, 5456, 7481 (fig. 3); Dawson arkose, 8188 (fig. 4); Denver formation, 317 (fig. 1), 325, 8777; Evanston formation, exact locality unknown; Ferris formation, 8516; Puerco formation, 7371, 7495; Raton formation, 5046, 5132, 5147, 5236, 5678, 5679, 5684, 5687, 5688, 5689, 5711 5799.

Ficus subtruncata Lesquereux

Plate 25, figures 1–6

Ficus subtruncata Lesquereux, 1878, p. 205, pl. 30, figs. 7–9.
  Knowlton, 1919, p. 289; 1924, p. 83, pl. 8, fig. 3; 1930, p. 63.
Ficus auriculata Lesquereux, 1878, p. 206, pl. 30, figs. 4–6.
Ficus martini Knowlton, 1930, p. 69, pl. 40, fig. 5.

The assignment of these specimens to *Ficus* is unsatisfactory, but I have no better suggestion.

Occurrence: Fort Union formation (lower), 6598, 8227 (figs. 1, 4), 8551 (fig. 2), 8901 (fig. 5); Animas formation, 7483; Denver formation, 317 (fig. 6); Ferris formation, 8516 (fig. 3).

Ficus uncata Lesquereux

Ficus uncata Lesquereux, 1878, p. 197, pl. 35, figs. 1, 1a only.
Ficus duplicata Knowlton, 1917, p. 302, pl. 74, fig. 1.
Populus monodon Lesquereux, 1878, p. 180, pl. 24, figs. 1, 2.
Quercus? neomexicana Knowlton, 1917, p. 298, pl. 70, fig. 5.
Magnolia cordifolia Lesquereux. Knowlton, 1917, p. 315, pl. 86; pl. 88, fig. 1.
Magnolia rotundifolia Newberry. Knowlton, 1917, p. 314, pl. 83.

These leaves resemble those of some species of *Combretum* and *Magnolia*, and their present allocation is dubious.

Occurrence: Raton formation, 5142, 5684, 5714.

Morus montanensis Brown, n. sp.

Plate 20, figure 10

Leaf ovate, with cordate base and abruptly attenuate apex. Margin with numerous small rounded slightly crenate teeth, except in the region of the apex, which is smooth. Venation palmate with one pair of curved strong basal primaries, which have numerous side branches that connect near the margin to form loops. The first strong secondary branches from the midvein well below the middle of the leaf. Also branching from the midvein are short intermediates between the secondaries.

I have found no lobed leaves like those from the living species of *Morus*.

Occurrence: Fort Union formation (upper), 4032 (fig. 10), 8920.

PLATANACEAE

Platanus nobilis Newberry

Plate 29, figures 1, 3–6

Platanus nobilis Newberry, 1868, p. 67; 1898, p. 106, pl. 34; pl. 50, fig. 1 only.
 Dawson, 1886, p. 24, pl. 1, fig. 7.
Platanus basilobata Ward, 1887, p. 35, pl. 17, fig. 1; pl. 18, figs. 1–3; pl. 19, fig. 1.
 Berry, 1935, p. 32, pl. 6, fig. 7.
 Bell, 1949, p. 58, pl. 42; pl. 43, figs. 1–3.
Acer trilobatum tricuspidatum Heer. Ward, 1887, p. 66, pl. 29, fig. 3.
Aralia acerifolia Lesquereux, 1883, p. 232, pl. 49, fig. 5 only.
Aralia dakotana Knowlton and Cockerell. Knowlton, 1919, p. 82.
Aralia digitata Ward, 1887, p. 62, pl. 27, figs. 3–5; pl. 28, fig. 1.
Aralia? gracilis Lesquereux, 1878, p. 236, pl. 39, fig. 1.
Aralia looziana Saporta and Marion. Ward, 1887, p. 61, pl. 27, fig. 2.
Aralia notata Lesquereux, 1878, p. 237, pl. 39, figs. 2–4.
 Ward, 1887, p. 60, pl. 27, fig. 1.
Aralia wardiana Knowlton and Cockerell. Knowlton, 1919, p. 87.
Sassafras selwyni Dawson, 1886, p. 28, pl. 2, fig. 13.
Viburnum oxycoccoides Dawson, 1886, p. 29, pl. 2, fig. 15.

The consensus seems to be that these leaves represent *Platanus* rather than *Aralia*, despite the fact that in minute surface features and general outline they differ somewhat from those of living species of *Platanus*. Their gross architecture, however, is strikingly like that of the living leaves. In particular the forking of the lateral primary veins at a short distance above their emergence from the top of the petiole is matched in living leaves having five or more lobes. Some of the fossil leaves, like the living (fig. 2), have conspicuous basilar lobes that sometimes cover the top of the petiole. Lester Ward (1888; 1890) illustrated these features and speculated that they pointed toward the origin of stipules. That stipules arose in this way seems doubtful because it is anomalous that living leaves with basilar lobes have stipules in addition.

When marginal teeth are present the sinuses between them are scalloped, as in living leaves. This combination of features is not, so far as I am aware, matched in any other living genus. A number of fossil species, somewhat like *P. nobilis*, have been described from Eocene and Oligocene strata in the Southern and Western United States.

No authentic seed balls or seeds of *Platanus* have ever been reported from the same strata that contain these Paleocene leaves. The seed balls identified by Bell (1949, p. 58, pl. 43, fig. 1) as belonging to *P. basilobata* are instead the fruiting heads of *Sparganium antiquum* (Newberry) Berry.

Occurrence: Fort Union formation (lower), 8567; (upper), 2414 (fig. 3, reproduction of Ward's type of *Aralia digitata*), 2416 (figs. 1, reproduction of Ward's type of *P. basilobata*, 4), 4984, 5594 (figs. 5, 6), 7695, 9109, 9125, 9322; Coalmont formation, 6103, 6107; Evanston formation, 5539; Ferris formation, 7548, 9531; Middle Park formation, 337; Raton formation, 5134.

Platanus raynoldsi Newberry

Plate 30, figures 1–4; plate 31, figures 1–6; plate 66, figure 8

Platanus raynoldsi Newberry, 1868, p. 69; 1898, p. 109, pl. 35.
 Lesquereux, 1878, p. 185, pl. 27, figs. 1–3.
 Ward, 1887, p. 37, pl. 20, figs. 2, 3.
 Knowlton, 1917, p. 324, pl. 95, fig. 1; 1930, p. 77, pl. 35.
 Bell, 1949, p. 59, pl. 37, fig. 2; pls. 38–41; pl. 34, fig. 3; pl. 60, fig. 3.
Platanus raynoldsi var. *integrifolia* Lesquereux, 1878, p. 185, pl. 26, figs. 4, 5.
Platanus aceroides Göppert. Heer, 1868, p. 111, pl. 12, figs. 1–8; pl. 32, figs. 1, 2; pl. 47, fig. 3; 1883, p. 96, pl. 97, fig. 1.
 Lesquereux, 1878, p. 184, pl. 25, figs. 4–6; 1883, p. 227, pl. 49, fig. 1.
 Knowlton, 1917, p. 321, pl. 63, fig. 4; pl. 97, figs. 2, 3.
Platanus aceroides cuneata Knowlton, 1917, p. 321, pl. 113, fig. 1.
Platanus aceroides latifolia Knowlton, 1917, p. 321, pl. 92; pl. 93, fig. 3; pl. 94.
Platanus coloradensis Knowlton, 1930, p. 82, pl. 37, figs. 1, 2; pl. 38, fig. 1.
Platanus guillelmae Göppert. Lesquereux, 1878, p. 183, pl. 25, figs. 1–3.
 Ward, 1887, p. 37, pl. 20, fig. 1.
 Knowlton, 1930, p. 76, pl. 34, fig. 1.
Platanus haydeni Newberry, 1868, p. 70; 1898, p. 103, pl. 36; pl. 38; pl. 56, fig. 3.
 Knowlton, 1930, p. 79, pl. 36, fig. 1.

Platanus nobilis Newberry, 1898, p. 106, pl. 37, fig. 1 [not pl. 34; pl. 50, fig. 1, which are *Platanus nobilis* Newberry].
Platanus regularis Knowlton, 1917, p. 325, pl. 113, fig. 4.
Acer arcticum Heer. Lesquereux, 1883, p. 234, pl. 49, figs. 7, 9.
Acer gracilens Lesquereux, 1883, p. 234, pl. 49, fig. 7 only.
Acer indivisum Weber. Ward, 1887, p. 66, pl. 29, fig. 5.
Acer trilobatum tricuspidatum (Braun) Heer. Ward, 1887, p. 66, pl. 29, fig. 6.
Acer sp. Knowlton, 1930, p. 101, pl. 45, fig. 6.
Ampelopsis montanensis Cockerell, 1908, p. 103, for *Vitis cuspidata* Ward, 1887, p. 71, pl. 32, fig. 8 only.
Aralia coloradensis Knowlton, 1917, p. 241, pl. 107, fig. 2.
Aralia reesidei Knowlton, 1924, p. 94, pl. 17, fig. 3.
Aralia? *serrata* Knowlton, 1917, p. 341, pl. 108, fig. 4.
Celastrus taurinensis Ward, 1887, p. 79, pl. 34, fig. 5 only.
Cissus grossedentata Knowlton, 1917, p. 340, pl. 104, fig. 1.
Cissus laevigata Lesquereux, 1883, p. 238, pl. 40, fig. 12 only.
Cissus parrotiaefolia Lesquereux, 1878, p. 239, pl. 42, fig. 1 only.
Ficus tiliaefolia (Braun) Heer. Ward, 1887, p. 40, pl. 22, fig. 1.
Grewiopsis platanifolia Ward, 1887, p. 89, pl. 40, fig. 1.
Grewiopsis populifolia Ward, 1887, p. 90, pl. 40, figs. 3–5.
Grewiopsis viburnifolia Ward, 1887, p. 89, pl. 40, fig. 2.
Liquidambar? *cucharas* Knowlton, 1917, p. 320, pl. 91, fig. 6.
Populus balsamoides eximia (Göppert) Lesquereux, 1883, p. 226, pl. 46A, fig. 10.
Populus nervosa Newberry, 1898, p. 48, pl. 27, figs. 2, 3.
Populus subrotundata Lesquereux, 1878, p. 173, pl. 24, figs. 6–8.
Knowlton, 1930, p. 59, pl. 22, fig. 9.
Quercus negundoides Lesquereux, 1878, p. 161, pl. 21, fig. 2.
Quercus platania Heer, 1868, p. 109, pl. 46, fig. 7; 1871, p. 472, pl. 46, fig. 5; pl. 55, fig. 3c; 1883, p. 91, pl. 68, fig. 1.
Lesquereux, 1878, p. 160, pl. 21, fig. 1.
Rhus? *viburnoides* Knowlton, 1917, p. 328, pl. 98, fig. 5.
Sterculia berryana Knowlton, 1917, p. 337, pl. 102, figs. 3, 4.
Sterculia? *heterodonta* Knowlton, 1930, p. 117, pl. 50, fig. 5; pl. 51, figs. 4, 8.
Viburnum antiquum (Newberry) Hollick. Berry, 1925, p. 58, pl. 17, figs. 1, 2 only; pl. 18, figs. A, B.
Viburnum lakesi Lesquereux. Knowlton, 1917, p. 348, pl. 110, fig. 4.
Bell, 1949, p. 78, pl. 14, fig. 3; pl. 37, fig. 1; pl. 58, fig. 1.
Phyllites pellucidus Knowlton, 1930, p. 130, pl. 39, fig. 2; pl. 56, fig. 4.

The somewhat arbitrary synonymy here proposed may seem too inclusive for one species of plane-tree or sycamore. However, after observing the great variation shown by leaves from living species of *Platanus*, I am amazed that paleobotanists have had the temerity to describe as many fossil species as they have. Ward (1888), Berry (1923, p. 157–164), and MacGinitie (1941, p. 126–128) have discussed the frustrating difficulties attending the unraveling of this tangled situation. The synonymy includes the names of many odd-shaped and abnormal specimens, as well as readily recognizable ones, but with some peculiarities. Comment on all or many of these seems unprofitable at this juncture.

The illustration of the type specimen (Newberry, 1898, pl. 35) shows too many teeth and the sinuses between the teeth as angular, whereas they are typically scalloped. The leaves of *P. raynoldsi* are in general not strongly lobed, and they resemble the terminal leaflets of *Cissus marginata* (Lesquereux) Brown so closely that separation of the two species, especially when the specimens are poorly preserved, is virtually impossible. When well preserved and well developed however, both the lobed and the unlobed leaves have strong, basal, lateral veins that usually branch at wide angles from the midrib at a noticeable distance above the base of the blade and top of the petiole, but in *Cissus* the corresponding veins are conspicuously decurrent into the petiole by relatively narrow angles. The surface of *Platanus* leaves also, when well preserved, is distinctly roughened by a minute but prominent quadrangular meshwork pattern. In *Cissus* this feature is subdued or absent. It is not unusual to find characteristic, finely corrugated impressions of the inside layer of *Platanus* bark, but so far no definite seed balls or seeds have been found in the Paleocene strata. However, wood purporting to be that of *Platanus* was collected by Ross Johnson from the Raton formation in SE¼ sec. 24, T. 34 S., R. 68 W., near the mouth of Leon Canyon on the South Fork of Purgatoire River, Colo.

This species doubtless evolved from a Cretaceous ancestor in an as yet unresolved complex of numerous identified forms. It may have been in the ancestral line leading to *P. appendiculata* Lesquereux, in the Eocene of the Sierra Nevada in California, the Cascades of Oregon, and the petrified forests of Yellowstone National Park.

Occurrence: Fort Union formation (lower), 4032 (pl. 31, figs. 1, 5, 6), 4404, 4625, 4661, 5609, 6057, 6113, 6297, 7538, 8199, 8556, 9180 (pl. 66, fig. 8) 9334; (upper), 2414, 2420 (pl. 30, fig. 2, reproduction of Ward's type of *Grewiopsis viburnifolia;* 3, reproduction of Ward's illustration of *Platanus guillelmae*), 2424 (pl. 31, figs. 3, 4, reproduction of Ward's illustration of *Acer trilobatum tricuspidatum*), 4369, 4897, 4910 (pl. 31, fig. 2), 4974, 4979, 8257 (pl. 30, fig. 4), 8774, 8888, 8913, 9109, 9125, 9501, exact locality unknown (pl. 30, fig. 1, reproduction of Newberry's type of *Platanus raynoldsi*); Animas formation 6443, 7463; Coalmont formation, 5994, 6004; Dawson arkose, 5835; Denver formation, 317; Ferris formation, 6417, 6625, 6971; Livingston formation, 8896; Middle Park formation, 337; Puerco formation, 7371; Raton formation, 5134, 5141, 5679, 5700, 5701, 5711, 5713, 5715, 5798, 6535.

Credneria? daturaefolia Ward

Plate 18, figure 14; plate 32, figures 1–5

Credneria? daturaefolia Ward, 1887, p. 97, pl. 42, fig. 4; pl. 43, figs. 1–3; pl. 44, figs. 1–3; pl. 45, figs. 1–3.
Knowlton, 1919, p. 200.
Populus? daturaefolia (Ward) Cockerell. Bell, 1949, p. 56, pl. 24, figs. 2–6.

The identity of these leaves remains as doubtful as when Ward described them. Some or all of those identified by Bell as belonging to this species may be variants of *Platanus raynoldsi* Newberry. The species ranged into the Eocene (pl. 32, fig. 2).

Occurrence: Fort Union formation (lower), 4975 (pl. 32, fig. 4); (upper), 2416 (pl. 32, fig. 1, reproduction of Ward's pl. 44, fig. 3), 8164 (pl. 32, fig. 5), 8205, 8920 (pl. 18, fig. 14). Eocene, 7552, at clay pit, 1 mile south of Dickinson, N. Dak. (pl. 32, fig. 2).

LAURACEAE

Cinnamomum sezannense Watelet

Plate 66, figures 1–3, 6, 9

Cinnamomum sezannense Watelet, 1866, p. 175, pl. 50, fig. 2.
Saporta and Marion, 1878, p. 60, pl. 9, figs. 2–6.
Knowlton, 1930, p. 86, pl. 38, figs. 7 [same as pl. 59, fig. 2], 8.
Cinnamomum affine Lesquereux, 1878, p. 219, pl. 37, figs. 1–4, 7 [not fig. 5, and probably not the lower left-hand leaf on the block with fig. 1, which are *Ficus affinis* (Lesquereux) Brown].
Knowlton, 1922a, p. 145, pl. 8, fig. 4; pl. 17, fig. 6.
Dorf, 1938, p. 60, pl. 9, figs. 3, 4.
Brown, 1939a, p. 250, pl. 53, figs. 1, 2.
Cinnamomum dubium Watelet, 1866, p. 176, pl. 50, fig. 4.
Minnamomum ellipsoideum Saporta and Marion, 1878, p. 61, pl. 9, figs. 7–9.
Cinnamomum formosum Watelet, 1866, p. 175, pl. 50, fig. 5.
Cinnamomum heeri Lesquereux. Newberry, 1898, p. 100, pl. 17, figs. 1–3.
Berry, 1914, p. 118, pl. 21, fig. 8.
Cinnamomum inaequale Watelet, 1866, p. 174, pl. 50, fig. 1.
Cinnamomum lanceolatum (Unger) Heer. Ward, 1887, p. 49, pl. 24, fig. 2.
Cinnamomum larteti Watelet, 1866, p. 173, pl. 49, figs. 9–13.
Cinnamomum middendorfensis Berry, 1914, p. 55, pl. 8, fig. 14; pl. 9, fig. 1.
Cinnamomum newberryi Berry, 1911, p. 150, pl. 16, fig. 3; 1914, p. 54, 117, pl. 9, figs. 12, 13; pl. 21, figs. 9–11; 1916a, p. 860, pl. 71, fig. 6; 1919, p. 118, pl. 21, figs. 6–9; 1925, p. 75, pl. 16, fig. 5.
C. newberryi ellipticum Berry, 1925, p. 77, pl. 16, fig. 7.
C. n. lanceolatum Berry, 1925, p. 76, pl. 16, fig. 4.
C. n. minimum Berry, 1925, p. 77, pl. 16, fig. 6.
Cinnamomum paucinervum Watelet, 1866, p. 176, pl. 50, fig. 3.
Cinnamomum polymorphum (Braun) Heer. Lesquereux, 1878, p. 221, pl. 37, fig. 6 [not fig. 10, which is *Ficus affinis* (Lesquereux) Brown.]
Cinnamomum scheuchzeri Heer. Lesquereux, 1878, p. 220, pl. 37, fig. 8.
Cinnamomum wardi Knowlton, 1898, p. 69.
Cinnamomum sp. Knowlton, 1930, p. 87, pl. 39, fig. 1.
Cinnamomoides buckhami Bell, 1957, p. 491, pl. 35, fig. 1.
Ficus dalmatica Ettingshausen. Lesquereux, 1878, p. 199, pl. 63, figs. 3–5.
Ficus eucalyptifolia Knowlton, 1916, p. 340, pl. 87, fig. 2 only.
Laurus asiminoides Berry. Bell, 1957, p. 50, pl. 36, fig. 4.
Laurophyllum insigne Dawson, 1894, p. 61, pl. 7, figs. 24, 25.
Bell, 1957, p. 51, pl. 26, figs. 1, 2; pl. 37, fig. 1; pl. 65, fig. 3 (upper leaf).
Smilax inquirenda Knowlton, 1922a, p. 118, pl. 4, fig. 5.

In these ovate to elliptic entire leaves the large primary veins normally branch from the midrib at an appreciable distance above the top of the petiole. The few secondaries above the primaries are generally confined to the uppermost part of the leaf. Short branches from the primaries along the margin are numerous and evenly spaced. Thus, these leaves are much like those of *Ficus planicostata* Lesquereux, *Ficus affinis* Lesquereux, and the unlobed leaves of *Sassafras thermale* (Lesquereux) Brown. Distinction between some of these closely similar leaves is practically impossible.

Reference of these leaves to *Cinnamomum* is more than conjectural, for it is now known definitely that one or more species of cinnamon were present during the Cretaceous and Tertiary of the southern and western United States. Berry (1925, p. 77, pl. 16, fig. 7), for example, reported a twig with opposite leaves from the Ripley formation (Upper Cretaceous) in Tennessee; and in 1955, in company with C. A. Repenning, I had the good fortune to find in the Mesaverde formation (Upper Cretaceous) at Black Mountain (Mesa) about 40 miles southeast of Kayenta, Ariz., several twigs of a species of *Cinnamomum* having opposite leaves. One of these is here illustrated (pl. 55, fig. 5). The identification of these leaves as *Ficus* is not indicated because oppositeness in figs is extremely rare and in the extant species, *F. hispida* Linnaeus, the opposite leaves are toothed! On the other hand, in most living cinnamons the leaves are opposite and all are entire. No fruits authentically assignable to cinnamon have been found with the Cretaceous and Paleocene leaves here referred to *Cinnamomum.*

The long synonymy of varied leaves from strata of different ages may be criticized as unrealistic. Does the speciation exemplied by Watelet in the Paleocene of the Paris Basin and by Berry in the Upper Cretaceous of Tennessee, inspire confidence in the validity of their many species, particularly as these came from the same localities? That specific differences between these many species might have been recognized, had one seen the living trees, is granted, but until a workable method, not solely based on segregated areas or strata, appears for detecting recognizable, constant differences in the fossils, it seems more feasible, for descriptive purposes, to regard the specimens as variants of a single species. The species *sezannense* is selected as the name bearer because it is the best known and is geographically descriptive.

The relationship of *Cinnamomum sezannense* Watelet to the ubiquitous *C. polymorphum* (Braun) Heer of Europe, and to *C. dilleri* Knowlton in the Eocene of the Western United States, is unknown.

Occurrence: Fort Union formation (lower), 4571 (fig. 2), 4725 (figs. 6, 9), 8652; Dawson arkose, 5835, 9554; Denver formation, 8426 (fig. 1), 8777 (fig. 3).

Laurophyllum caudatum (Knowlton) Brown, n. comb.

Laurus? *caudata* Knowlton, 1917, p. 316, pl. 89, fig. 1.
Laurus socialis Lesquereux. Knowlton, 1917, p. 317, pl. 91, fig. 5.
Andromeda? *lanceolata* Knowlton, 1917, p. 344, pl. 110, fig. 1 only.
Carapa eolignitica Berry. Knowlton, 1917, p. 327, pl. 69, fig. 2.
Cassia lancifolia (Lesquereux) Berry. Knowlton, 1917, p. 327, pl. 96, fig. 1.
Magnolia angustifolia Newberry, 1883, p. 513.
Knowlton, 1917, p. 309, pl. 79, fig. 1; pl. 80, figs. 1, 2; pl. 81, fig. 1.
Magnolia attenuata Weber. Lesquereux, 1878, p. 250, pl. 45, fig. 6.
Magnolia laurifolia Lesquereux. Knowlton, 1917, p. 309, pl. 106, fig. 2 only.
Nectandra lancifolia (Lesquereux) Berry. Knowlton, 1917, p. 318, pl. 90, fig. 2 only.
Quercus? *ratonensis* Knowlton, 1917, p. 298, pl. 69, fig. 6.
Sapindus caudatus Lesquereux. Knowlton, 1917, p. 330, pl. 100, fig. 2.

As the name *angustifolium*, which this species should take, is preoccupied, *caudatum* seems next in order. The leaves have attenuate apexes, strongly cuneate bases, and somewhat irregular secondary venation, thus simulating those of some species of *Magnolia*. The species apparently did not reach the northernmost areas of the Paleocene terrain. Inclusion of specimens from Eocene strata of the gulf coast may be unjustified.

Occurrence: Fort Union formation (lower) 8677; Evanston formation, 3658; Ferris formation, 8516; Raton formation, 5140, 5142, 5690, 5712, 5714, 5798, 5826, 5830.

Laurophyllum perseanum Brown, n. sp.

Plate 34, figures 3, 5

Asimina eocenica Lesquereux. Knowlton, 1930, p. 94, pl. 40, fig. 4; pl. 43, figs. 1, 2 only.
Nectandra lancifolia (Lesquereux) Berry. Knowlton, 1917, p. 318, pl. 90, fig. 1 only.

Lanceolate leaves with blunt to acute apexes, cuneate bases, entire margins. Petioles 1 to 2 cm long. Secondary veins evenly spaced, branching from the midrib at about 30° and somewhat decurrent on it.

Occurrence: Fort Union formation (lower), 3979, 8567; (upper), 2416 (fig. 5), 4661; Coalmont formation, 5994, 6102; Dawson arkose, 5738; Evanston formation, 3661 (fig. 3); Raton formation, 5236, 5826.

Laurus socialis Lesquereux

Plate 27, figures 6, 7

Laurus socialis Lesquereux, 1878, p. 213, pl. 36, figs. 1-4, 7.
Laurus primigenia Unger. Heer, 1880, p. 12, pl. 3, figs. 8-13; 1883, p. 104, pl. 77, figs. 8-13.
Lesquereux, 1878, p. 214, pl. 36, figs. 5, 6, 8.
Knowlton, 1924, p. 86.
Laurus ratonensis Knowlton, 1917, p. 316, pl. 91, figs. 1-4.
Berchemia multinervis (Braun) Heer. Knowlton, 1917, p. 333, pl. 101, fig. 5.
Cassia puryearensis Berry. Knowlton, 1924, p. 90, pl. 14, figs. 1, 2.
Ficus? *smithsoniana* Lesquereux, 1878, p. 200, pl. 32, fig. 5.
Quercus simplex Newberry. Knowlton, 1917, p. 298, pl. 70, fig. 3.

Lesquereux likened the type of this species to the living *Persea borbonia* (Linnaeus) Sprengel, of the Southeastern United States, but perhaps the best that can be said is that it has a general lauraceous aspect.

Occurrence: Fort Union formation (lower), 4325 (fig. 7), 4696 (fig. 6), 4877, 8551, 8567; (upper), 4974, 8922; Animas formation, 7496; Coalmont formation, 5993; Dawson arkose, 8307; Evanston formation, 3658, 3661, 5555; Raton formation, 5134, 5140, 5711, 5826.

Lindera obtusata (Ward) Brown, n. comb.

Plate 43, figure 1; plate 66, figure 10

Diospyros? *obtusata* Ward, 1887, p. 105, pl. 49, fig. 5.
Diospyros? *ficoidea* Lesquereux. Ward, 1887, p. 105, pl. 49, fig. 3 [not fig. 4, which is *Viburnum antiquum* Lesquereux].
Chrysobalanus coloradensis Knowlton, 1930, p. 95, pl. 43, figs. 5, 7 only.
Cornus studeri Heer. Knowlton, 1924, p. 94, pl. 13, fig. 2; pl. 15, fig. 1.
Oreodaphne pagosensis Knowlton, 1924, p. 87, pl. 15, fig. 5.

Leaves elliptic to ovate, relatively broad, with cuneate bases and attenuate apexes. Margin entire. Secondary veins few, branching from the midrib at about 37°, curving sharply upward near the margin. Second pair of secondaries with conspicuous branches in the marginal area, a characteristic of some lauraceous genera, particularly *Lindera* and *Persea*.

Occurrence: Fort Union formation, (lower), 5720 (pl. 43, fig. 1), 6057, 8666; (upper), 2416, 2420, 4323 (pl. 66, fig. 10), 5618; Animas formation, 5455, 6443; Ferris formation, 6971, 8516.

Persea brossiana Lesquereux

Plate 34, figures 6-8

Persea brossiana Lesquereux, 1874, p. 407.
Knowlton, 1930, p. 85.

Laurus brossiana (Lesquereux) Lesquereux, 1878, p. 216, pl. 36, fig. 9.
Cornus rhamnifolia Ltsquereux, 1878, p. 244, pl. 42, fig. 6.
Magnolia angustifolia Newberry. Knowlton, 1924, p. 88, pl. 16, fig. 5.
Nectandra lancifolia (Lesquereux) Heer. Knowlton, 1917, p. 318, pl. 90, fig. 1 only.
Rhamnus eridani Unger. Heer, 1868, p. 123, 153, pl. 19, figs. 5–7; pl. 49, fig. 10.

These are long, oval or slightly obovate leaves with cuneate bases and abruptly acuminate apexes. The evenly spaced secondary veins curve upward near the margin to the secondaries above.

Occurrence: Fort Union formation (lower), 4661 (fig. 7); (upper) 4582, 5612 (fig. 8); Animas formation, 7496 (fig. 6); Coalmont formation, 5987; Livingston formation, 6767; Middle Park formation, 337; Raton formation, 5236, 5826.

Sassafras thermale (Lesquereux) Brown, n. comb.

Plate 33, figures 4–7; plate 34, figures 1, 2, 4

Juglans thermalis Lesquereux, 1878, p. 287, pl. 56, fig. 3 [not fig. 4, which is *Ficus planicostata* Lesquereux.]
Litsea carbonensis Ward, 1887, p. 48, pl. 24, fig. 1.
Malapoenna carbonensis (Ward) Knowlton, 1919, p. 378.
Malapoenna praecursoria (Lesquereux) Knowlton, 1919, p. 379.
Malapoenna sessiliflora (Lesquereux) Knowlton, 1898, p. 142.
Platanus raynoldsi var. *integrifolia* Lesquereux. Knowlton, 1930, p. 78, pl. 34, fig. 2.
Sassafras ferretianum Massalongo. Heer, 1871, p. 474, pl. 50, figs. 1, 2; 1883, p. 103, pl. 97, fig. 5.
Tetranthera praecursoria Lesquereux, 1883, p. 288, pl. 48, fig. 2.
Tetranthera sessiliflora Lesquereux, 1878, p. 217, pl. 35, fig. 8 only.

These leaves display considerable variation in size, but internally they are fundamentally similar in having a system of venation in which the first strong pair of basal secondaries emerges sharply from the midvein usually at a point 1 cm, more or less, above the top of the petiole. These secondaries are seldom decurrent along the sides of the midvein into the petiole as are the corresponding veins in *Melastomites montanensis* Brown. Further, *S. thermale* has a weaker, sometimes almost invisible, pair of basal secondaries generally close to the margin, as in nearly all Lauraceae, but this pair is lacking in *M. montanesis*, although the latter may have a faint, irregular vein formed from the union of the outer arcs of the branches from the primary veins. For some distance above the first strong secondaries, the midrib of *S. thermale* lacks branches, but at or below the middle of the blade secondaries reappear at regularly spaced intervals to the apex. All these, except those entering lobes, loop near the margin.

The various objects identified by Lesquereux with the leaf, *Tetranthera sessiliflora*, on the block of his plate 35, figure 8, are probably not organically related to the leaf. The four-parted involucre on the petiole of the leaf is, on close inspection, seen not to be attached to the petiole. Moreover, the basal secondaries of the leaf are not accurately depicted, but are opposite one another. Thus, the leaf appears to be a small, entire leaf of *Sassafras thermale*.

Because the margins of all the latest Cretaceous and Paleocene specimens here synonymized are unlobed, I long regarded the species as probably referable to *Cinnamomum*, *Laurus*, *Litsea*, *Malapoenna*, *Oreodaphne*, *Ocotea*, or other lauraceous genera. In January 1944, however, I discovered in a collection from the Fort Union of the Big Horn Basin, a specimen (pl. 33, fig. 4) with two conspicuous lobes well toward the apex of the blade. Oddly, these lobes receive the first secondaries from near the middle of the blade instead of the strong basal secondaries, as is normal for the three-lobed leaves. However, this condition, though rare, sometimes appears in living leaves (pl. 33, fig. 1). I am inclined, therefore, to believe that the fossil leaf is an incipient three-lobed leaf of *Sassafras*, and that all the unlobed leaves in the synonymy are to be referred to *Sassafras*. Lesquereux referred characteristically three-lobed leaves from the Dakota sandstone of Kansas to *Lindera venusta* and a leaf from the same Kansas locality, similar to the lobed specimens from the Fort Union of the Big Horn Basin, to *Cinnamomum sezannense*. The association of entire and lobed leaves of this kind in strata of different ages strengthens my conviction that they represent *Sassafras* or a primitive ancestor of *Sassafras* or *Lindera*. Berry (1902c) discussed the ancestry of *Sassafras*.

Occurrence: Fort union formation (lower), 3852 (pl. 33, fig. 6), 4665 (pl. 33, fig. 4), 4874 (pl. 33, fig. 5), 4876, 5720, 6057, 6083, 8551 (pl. 33, fig. 7), 8928, 9111; (upper), 1502, 5578, 5618, 8887 (pl. 34, fig. 1); Coalmont formation, 5594, 6102, 6105; Evanston formation, 3653 (pl. 34, figs. 2, 4); Ferris formation, 6431; Middle Park formation, 336, 8787.

NYMPHEACEAE

Cabomba inermis (Newberry) Hollick

Plate 35, figures 5, 6

Psilotum inerme Newberry, 1868, p. 38.
Cabomba inermis (Newberry) Hollick. Newberry, 1898, p. 92, pl. 22, fig. 2; pl. 23, fig. 2.
Cabomba gracilis Newberry, 1883, p. 514; 1898, p. 91, pl. 22, fig. 1; pl. 23, fig. 1.
Cabomba grandis Newberry, 1883, p. 514.

Although these specimens suggest *Cabomba*, no entire, peltate leaves attached to the stems bearing these dissected leaves have been found. The foliage may belong to some other aquatic genus, such as *Ceratophyllum*.

Occurrence: Fort Union formation, exact locality unknown (fig. 6, reproduction of Newberry's pl. 22, fig. 1), 4272, 9072 (fig. 5).

Nelumbium montanum Brown, n. sp.

Plate 35, figures 2–4

Nelumbo tenuifolia (Lesquereux) Knowlton. Berry, 1935, p. 37, pl. 7, figs. 2, 3.
Nelumbites protoluteus (Berry) Bell, 1949, p. 64, pl. 63, fig. 5.

Orbicular leaves sometimes 10 cm in diameter. Margin entire or slightly undulate. Radial veins 24 or thereabouts, considerably forked. Fruit receptacle 3 cm or more in diameter.

The folded condition in which most of these leaves are found suggests that in life they were somewhat cupped as is the habit of living species of this genus. Although assumed by Berry to be the same as those formerly called *Nelumbo tenuifolia* (Lesquereux) Knowlton and *N. lakesiana* (Lesquereux) Knowlton from the Denver Basin, Colorado, this species differs in having twice as many radial veins, which are usually four-forked dichotomously, whereas those of the Denver species are few and appear irregularly branched rather than dichotomous. Some variation in number of veins is to be expected in any species, but the wide disparity here seems to indicate more than intraspecific variation. Berry's specimens from the Ravenscrag formation of southern Saskatchewan agree in all respects with *Nelumbian montanum* from the Fort Union formation. The identity of these leaves with *Nelumbo protolutea* Berry, from the Eocene of Mississippi, as averred by Bell, is doubtful.

The fragmentary fruit receptacle found with the leaves at locality 8282 was evidently somewhat squeezed during fossilization, as the casts of the seed cavities are considerably flattened and distorted.

Occurrence: Fort Union formation (lower), 3980, 4315, 6667, 8227 (fig. 4), 8786 (fig. 2), 8897; (upper) 8262 (fig. 3).

Nelumbium tenuifolium Lesquereux

Nelumbium tenuifolium Lesquereux, 1874, p. 402; 1878, p. 253, pl. 46, fig. 3.
Nelumbo tenuifolia (Lesquereux) Knowlton, 1922a, p. 141, p. 26, fig. 7; 1930, p. 92, pl. 41, fig. 2.
Dorf, 1942, p. 141, pl. 10, fig. 10.
Nelumbium lakesianum Lesquereux, 1874, p. 403.
Nelumbium lakesii Lesquereux, 1878, p. 252, pl. 46, figs. 1, 2.
Nelumbo lakesiana (Lesquereux) Knowlton, 1917, p. 308; 1924, p. 88; 1930, p. 91, pl. 41, fig. 1; pl. 42, fig. 2.
Nelumbo crossi Knowlton, 1930, p. 93, pl. 41, fig. 3.

The leaves of this species have 15, more or less, radial veins that are not conspicuously dichotomous but give rise to a few curved lateral branches. The margin may be entire, slightly undulate, or almost lobed. There appears to be a close relationship between this species and *Paleonelumbo macroloba* Knowlton, and the former may be merely a variant of the latter.

Occurrence: Animas formation, 6309; Denver formation, 317.

Nymphaea leei (Knowlton) Brown, n. comb.

Castalia leei Knowlton, 1917, p. 307, pl. 79, fig. 3.

This fragmentary leaf with cordate base is the only one of its kind so far found. As the margin is largely missing, its character, whether entire, sinuate, or toothed, is unknown.

Occurrence: Raton formation, 5679.

Nymphaea pulchella (Knowlton) Brown, n. comb.

Castalia pulchella Knowlton, 1930, p. 94, pl. 42, fig. 1, a restoration of pl. 57, fig. 3.

This specimen is thus far the only one of its kind known from Paleocene deposits. It has a notched base and sinuate margin with moderately large teeth or lobes.

Occurrence: Dawson arkose, 5831.

Paleonelumbo macroloba Knowlton

Plate 35, figure 1

Paleonelumbo macroloba Knowlton, 1930, p. 93, pl. 39, fig. 3; pl. 42, figs. 3, 4 [which is the base of pl. 39, fig. 3].

The specimen figured here is only half the size of the types from the Denver formation but apparently agrees in all other essential respects with them. The number of radial veins varies from 9 to 11.

Occurrence: Fort Union formation (lower), 8673 (fig. 1).

Paleonuphar hesperium Brown, n. sp.

Plate 35, figure 7

Leaves large, 20 cm or more long, 15 cm wide, cordate, with a deep sinus. Margin entire, slightly undulate. Midvein stout. Secondaries widely spaced, once or twice forked toward the margin, the ultimate branches joining to form intramarginal loops.

This species resembles *Paleonuphar inopina* Hollick (1930, p. 75, pl. 40, fig. 5) from the Cretaceous of Alaska, in general outline but is larger. The secondary veins of *P. inopina* fork and loop considerably farther inward from the margin than those of *P. hesperium*.

The living red-disked pond-lily, *Nuphar rubrodiscum* Morong, is comparable to *P. hesperium*.

Occurrence: Fort Union formation (lower), 4877, 7538 (fig. 7).

Paranymphaea crassifolia (Newberry) Berry

Plate 36, figures 1–5

Catalpa crassifolia Newberry, 1868, p. 56.
Aristolochia crassifolia (Newberry) Cockerell, 1908, p. 90.
  Knowlton, 1919, p. 96.
  Berry, 1930a, p. 20, pl. 6, figs. 1–3.
Paranymphaea crassifolia (Newberry) Berry, 1935, p. 39, pl. 7, figs. 4, 5; pl. 9; pl. 10.
  Bell, 1949, p. 68, pl. 50, fig. 3; pl. 52, fig. 5.
Aristolochia cordifolia Newberry, 1898, p. 90, pl. 39; pl. 40, fig. 7; pl. 60, fig. 4.
Cercis borealis Newberry, 1883, p. 162.

There is little to add to previous discussions of these leaves except to note a feature not heretofore reported, namely, that these leaves were minutely hairy, particularly along the veins. This hairiness is best shown on leaves preserved in fine-grained rocks.

Several of the leaves described by Heer (1868, p. 99, pl. 7, figs. 2–4; pl. 50, fig. 9) from Atanekerdluk, Greenland, as *Populus gaudini* Fischer, and that called *Aristolochia pagei* Hollick (1930, p. 74, pl. 40, fig. 3) from Alaska, may also belong with this species.

North of the latitude of mid-Wyoming this species appears to be confined to basal Paleocene strata; but a fragment identified as *Menispermites knightii* Knowlton by Dorf (1942, p. 143, pl. 10, fig. 11) may belong here, and, if so, would indicate that the species was already in existence farther south in late Cretaceous time.

The specimens identified as *Cocculus haydenianus* Ward by Knowlton in collections made by Hewett (1926, p. 28, locs. 6667, 6669), and identified as coming from the Lance formation, 30 and 60 feet, respectively, below the base of the Fort Union formation as mapped by Hewett, were taken, at least at locality 6667, from blocks of talus that had dropped down the slope from the Fort Union formation above, as I verified by a visit there in 1940.

Occurrence: Fort Union formation (lower), 2432 (fig. 1), 4625, 6154, 6667, 6669, 8517, 8519 (figs. 3, 4), 8553 (fig. 2), 8567, 8673, 8678, 8780, 8899, 9334, exact locality unknown (fig. 5, reproduction of Newberry's type of *Aristolochia cordifolia*, pl. 39).

CERCIDIPHYLLACEAE

Cercidiphyllum arcticum (Heer) Brown

Plate 37, figures 1–24; plate 38, figures 1–17; plate 52, figure 9
Cercidiphyllum arcticum (Heer) Brown, 1939, p. 492, pl. 53; pl. 54, figs. 1–7, 12, 13, 17; pl. 56, figs. 1–6a, 10, 11. [Delete from the synonymy *Populus newberryi* Cockerell (for *P. acerifolia* Newberry), *Populus smilacifolia* Newberry, and *Zizyphus meeki* Lesquereux. Ward, fig. 6 only.)
Cercidiphyllum ellipticum (Newberry) Brown, 1939a, p. 491, pl. 52, figs. 10, 11, 12, 14–16; pl. 54, figs. 8–11, 14–16. [Transfer from the synonymy to that of *C. arcticum* the following: *Berrya racemosa* Knowlton, *Carpites lakesi* Knowlton, *Cercis coloradensis* Knowlton, *Leguminosites? arachioides* Lesquereux, *Leguminosites arachioides minor* Berry, *Nyssa? racemosa* Knowlton, *Piper heeri* Lesquereux, *Populus arctica* Heer, *P. glandulifera* Heer, *Sabalites? fructifer* Lesquereux, and *Zizyphus hesperius* Knowlton].
Dolichites deusseni Berry, 1916a, p. 14, pl. 3, fig. 3.
Jenkinsella arctica (Heer) Bell, 1949, p. 57, pl. 44, fig. 1.
Leguminosites? borealis Dawson, 1889, p. 72, pl. 10, fig. 7.
Orites sp. Chandler, 1926, p. 47, pl. 8, fig. 6.
Paliurus? borealis Heer, 1868, p. 122, pl. 19, fig. 1.
Populus nebrascensis Newberry, 1898, p. 47, pl. 27, figs. 4, 5.
Smilax grandifolia Unger. Lesquereux, 1878, p. 94, pl. 9, fig. 5.
Trochodendroides arctica (Heer) Berry. Bell, 1949, p. 56, pl. 20, fig. 3; pl. 44, fig. 2; pl. 45, figs. 1, 2; pl. 46, figs. 1–3 only.
Zizyphoides colombi (Heer) Seward and Conway. Bell 1949, p. 73, pl. 50, fig. 1; pl. 51, fig. 1; pl. 52, figs. 2–4.

Since my publication on *Cercidiphyllum* in 1939, I have collected at many more localities in the lower Paleocene and have found that here and there deltoid leaf forms appear among the abundant elliptic forms generally characteristic of that time. As the emergence and predominance of the deltoid norm was considered indicative of *Cercidiphyllum arcticum*, I now find it difficult to justify the assignment of many Paleocene items to *C. ellipticum* (Newberry) Brown. Therefore, as a workable arbitrary line must be drawn somewhere, I propose that the name *C. ellipticum* be restricted to the elliptic specimens of the Upper Cretaceous and that it retain all of the original synonymy except the items transferred in the present synonymy.

Cercidiphyllum arcticum is characterized by having a leaf norm that is deltoid in outline, with a crenate margin, but, associated with examples of this norm are variants suggesting the norms of *C. ellipticum* (Newberry) Brown and others in its ancestral line. Some of these variants, like those on the living *C. japonicum* Siebold and Zuccarini (Swamy and Bailey, 1949, p. 188), are so astonishingly different from the norms that the possibility for misidentification of single given leaves is very great. Some of the elliptic leaves resemble those of the living *Tetracentron sinense* Oliver, of western China.

The fruits and seeds are little if any different from those of *C. ellipticum* and descendant species.

No twigs with attached leaves and fruits have yet been reported but in the lower Tertiary strata of the London Basin, England, Chandler (1961, p. 70, pl. 6, figs. 4–7; p. 84, pl. 8, figs. 18–20; p. 85, pl. 9, figs. 1–5; p. 113, pl. 12, figs. 8, 9) found among the typical separate remains two fruits (p. 298, pl. 30, figs. 1–7, text fig. 43) that, fortunately and as originally postulated, contained the characteristic winged seeds. In her opinion, however, these fossils do not represent *Cercidiphyllum* but some genus in the Hamamelidaceae.

The item, *Populus nebrascensis* Newberry, was founded on specimens collected by F. V. Hayden from "ferruginous shale, banks of the Yellowstone River." (Newberry, 1868, p. 63, 64.) Both the locality and material from the same collection examined by Newberry is, however, clearly *Cercidiphyllum arcticum* and not the same as the many specimens from the Denver formation called *Populus nebrascensis* (Knowlton, 1930, p. 55–57), which, in the present paper, are assigned to *Ampelopsis acerifolia* (Newberry) Brown.

The item, *Populus wilmattae* Cockerell (1925, p. 3, pl. 2, fig. 8), included in my previous synonymy but from the Green River formation (Eocene), may indeed be a *Populus*, but further collections and study will be necessary to determine this point.

The fossil species of *Cercidiphyllum* have been compared with the living *C. japonicum*, of eastern Asia, which in Shuihsa Valley, Hupeh Province, China, is associated with *Metasequoia glyptostroboides* Hu and Cheng, at 3,000 feet above sea level, where, according to Chu and Cooper (1950, p. 267), frosts and snowfall are rare. As *C. arcticum* was associated with *M. occidentalis* (Newberry) Chaney in the Rocky Mountains and Great Plains region during the early Tertiary, the probability seems strong that the latter region also had a mild climate at that time.

Occurrence: Fort Union formation (lower), 1468, 3852, 3981 (pl. 52, fig. 9), 4625, 4661, 4674, 5063, 5437 (pl. 37, figs. 4, 7, 14), 6131, 6154, 7547, 8188 (pl. 37, fig. 9), 8227 (pl. 37, fig. 5), 8517 (pl. 37, figs. 19, 20, 22–24), 8519 (pl. 37, fig. 15), 8545, 8551, 8567 (pl. 37, figs. 13, 18), 8673 (pl. 37, fig. 3), 8781, 8884, 8893, 8896, 8899, 8928, 9130 (pl. 37, figs. 12, 16), 9334 (pl. 37, figs. 8, 10, 11, 17), 9530; (upper), 2416 (pl. 38, fig. 1), 2420, 4032, 4256 (pl. 38, figs. 5, 6), 4264 (pl. 38, figs. 7, 8, 10, 14, 16), 4881, 4892, 4908, 4909, 4974, 4975, 8167 (pl. 38, fig. 11), 8234 (pl. 38, fig. 2), 8255, 8556 (pl. 38, fig. 12), 8774 (pl. 38, fig. 17), 8885, 8910 (pl. 38, fig. 3, left column), 8913, 8921, 8922, 9056, 9072, 9109, 9125 (pl. 38, figs. 3, 4, 9, 15); Coalmont formation, 5987, 6107, 6110; Denver formation, 317 (pl. 37, fig. 21), 8672 (pl. 37, fig. 6); Evanston formation, 3653 (pl. 37, figs. 1, 2), 3661, 5539, 5555; Ferris formation, 6415, 6420, 6971; Livingston formation, 333, 337; Poison Canyon formation, 5121; Raton formation, 5137, 5140, 5826. Eocene, 8540 (pl. 38, fig. 13).

MAGNOLIACEAE

Magnolia berryi (Knowlton) Brown, n. comb.

Plate 39, figure 1

Juglans berryi Knowlton. Berry, 1916a, p. 183.
Knowlton, 1917, p. 293, pl. 63, fig. 3; pl. 64, fig. 3; pl. 73, fig. 3; 1924, p. 80, pl. 6, figs. 5, 6.
Fagus crossi Knowlton, 1924, p. 81, pl. 19, fig. 2.

These leaves are elliptic to obovate in outline, with long petioles, a feature not characteristic of living species of *Juglans*. Further, they do not seem to be leaflets of compound leaves, but in form and venation they suggest a species of *Magnolia*.

Occurrence: Animas formation, 5455, 7496; Raton formation, 5679 (fig. 1), 5799, 5826, 6535.

Magnolia borealis Brown, n. name

Plate 39, figure 3; plate 66, figure 11

Juglans ungeri Heer. Ward, 1887, p. 33, pl. 14, fig. 6.
Ficus monodon (Lesquereux) Berry. Knowlton, 1924, p. 83, pl. 10, fig. 1.

These are broad ovate to elliptic leaves with cuneate or subcordate bases and acute apexes. Margin entire. Secondary veins few, evenly spaced, regularly curved, and forking well within the margin.

Occurrence: Fort Union formation (middle), 2420, 5579 (pl. 66, fig. 11), 8523 (pl. 39, fig. 3); Livingston formation, 6765.

Magnolia magnifolia Knowlton

Plate 39, figure 4

Magnolia magnifolia Knowlton, 1917, p. 311, pl. 84.
Magnolia hilgardiana Lesquereux, 1878, p. 249, pl. 44, fig. 4. Knowlton, 1917, p. 310, pl. 79, fig. 2; pl. 85, fig. 1; 1924, p. 89, pl. 16, fig. 4.
Magnolia laurifolia Lesquereux. Knowlton, 1917, p. 309, pl. 85, fig. 2.
Magnolia leei Knowlton, 1917, p. 313, pl. 64, fig. 2; pl. 65, fig. 2; pl. 81, fig. 2.
Magnolia lesleyana Lesquereux, 1878, p. 248, pl. 44, figs. 1–3. Knowlton, 1917, p. 313, pl. 82, figs. 1, 2.
Magnolia tenuinervis Lesquereux, 1878, p. 249, pl. 45, fig. 2.
Chionanthus membranaceus Knowlton, 1917, p. 345, pl. 108, fig. 2.
Ficus aguilar Knowlton, 1917, p. 300, pl. 71, fig. 1.
Ficus denveriana Cockerell. Knowlton, 1917, p. 302, pl. 75, fig. 1.
Ficus puryearensis Berry. Knowlton, 1930, p. 72, pl. 29, figs. 1, 2.
Ficus sp. Knowlton, 1924, p. 84, pl. 7, fig. 3.
Juglans? innominata Knowlton, 1924, p. 80, pl. 7, fig. 2.
Juglans schimperi Lesquereux. Knowlton, 1917, p. 296, pl. 64, fig. 1.
Juglans sapindiformis Knowlton, 1917, p. 295, pl. 65, fig. 3.
Quercus? ratonensis Knowlton, 1917, p. 298, pl. 69, fig. 7.

The species here synonymized are based on large leaves that appear to be magnolialike in form and venation. Many of the illustrations of these fossils look much better than the specimens themselves, for the latter, as a rule, are very poorly preserved, so that more than cursory identification is practically impossible.

Knowlton's name *Magnolia magnifolia* is chosen for the species. It was instituted for *M. tenuinervis* Lesquereux, one original Paleocene specimen of which is preserved in the U.S. National Museum collections (Lesquereux, 1878, pl. 45, fig. 2, from South Table Mountain, Golden, Colo.). As Lesquereux included a mixture of diverse Cretaceous and Tertiary leaves under this name, Knowlton proposed that the term *tenuinervis* be restricted to Lesquereux's plate 45, figure 4, from the Laramie formation at Golden, Colo.

Occurrence: Fort Union formation (lower), 3852, 4665, 4694, 9111; (upper), 4882 (fig. 4), 8196; Animas formation, 5455, 7481, 7496; Denver formation, 317; Raton formation, 5046, 5133, 5137, 5142, 5684, 5690, 5697, 5699, 5798, 5826, 5837.

Magnolia regalis Heer

Plate 39, figure 2

Magnolia regalis Heer, 1877, p. 81, pl. 20.
Knowlton, 1917, p. 314, pl. 87.
Ficus aguilar Knowlton. Knowlton, 1930, p. 65, pl. 24, fig. 4.
Ficus uncata Lesquereux, 1878 ,p. 197, pl. 35, fig. 1 only.
Knowlton, 1917, p. 301, pl. 76, fig. 2.

The leaf identified by Knowlton as *Ficus aguilar* from the Dawson arkose is apparently not conspecific with the type of that species (herein referred to *Magnolia magnifolia* Knowlton) from the Raton formation but seems to be only a small specimen of *Magnolia regalis.* Heer's specimen is fragmentary, thus leaving the original identification somewhat dubious. Perhaps assignment to *Ficus* would be more appropriate.

Occurrence: Dawson arkose, 5839; Denver formation, 317 (fig. 2); Raton formation, 5465, 5689, 5799.

Magnolia rotundifolia Newberry

Magnolia rotundifolia Newberry, 1898, p. 95, pl. 59, fig. 1.
Oreodaphne? *ratonensis* Knowlton, 1917, p. 318, pl. 88, fig. 2.

These leaves have features suggestive of some Lauraceae and Moraceae, but I cannot place them more definitely.

Occurrence: Raton formation, Fisher's Peak, Colo. (type specimen), 5687.

HAMAMELIDACEAE

Hamamelites inaequalis (Newberry) Brown, n. comb.

Plate 40, figures 4–6

Protoficus inaequalis Newberry, 1883, p. 512; 1898, p. 89, pl. 58, fig. 2.
Hamamelites fothergilloides Saporta. Ward, 1887, p. 64, pl. 29, fig. 1.

These leaves resemble those of the witchhazel, *Hamamelis virginiana* Linnaeus, but neither fruits nor seeds have been found to confirm the identification. They compare well with those called *H. fothergilloides* Saporta from Sezanne in the Paris Basin, but differ in being somewhat broader with fewer, more widely spaced cross veinlets between the secondary veins.

Occurrence: Fort Union formation (upper), 2416 (fig. 5), exact locality unknown (fig. 4, reproduction of Newberry's pl. 58, fig. 2), 4977 (fig. 6).

Liquidambar dakotense Brown, n. sp.

Plate 68, figures 23, 24

Winged seeds, 7 mm long, the seed itself about equal to the wing in length, pointed at the proximal end, rounded at the distal end.

The seeds of *Liquidambar* are much like those of the closely related *Exbucklandia*, but no foliage or fruits surely attributable to either genus have been found in association with the Paleocene seeds. *Liquidambar*, however, is found in the Eocene of the Rocky Mountains and Great Plains, and *Exbucklandia* in the Oligocene and Miocene of Oregon and Washington. That *Liqudambar* existed in the Paleocene of North America is further suggested by the presence of a Cretaceous species, *L. fontanella* Brown, from Fontanelle Creek northwest of Kemmerer, Wyo. (Brown, 1933, p. 8, pl. 2, fig. 3, text fig. 2).

Occurrence: Fort Union formation (upper), 9125 (figs. 23, 24).

EUCOMMIACEAE

Eucommia serrata (Newberry) Brown, n. comb.

Plate 44, figures 1–6; plate 45, figures 1–7

Alnus serrata Newberry, 1868, p. 55; 1898, p. 66, pl. 33, fig. 11.
Celastrinites insignis (Heer) Bell, 1949, p. 71, pl. 36, fig. 4 [part]; pl. 53; pl. 54, figs. 1–4; pl. 55, figs. 1, 2; pl. 56, figs. 1, 3, 4.
Celastrus curvinervis Ward, 1887, p. 82, pl. 36, figs. 3, 4.
Celastrus ferrugineus Ward, 1887, p. 78, pl. 34, figs. 1–4.
Celastrus grewiopsis Ward, 1887, p. 81, pl. 36, fig. 2.
Celastrus montanensis Knowlton and Cockerell. Knowlton, 1919, p. 159, for *C. alnifolius* Ward, 1887, p. 80, pl. 35, figs. 1, 2.
Celastrus pterospermoides Ward, 1887, p. 80, pl. 35, figs. 3–6.
Celastrus serratus Knowlton, 1917, p. 329, pl. 98, fig. 3; pl. 99, fig. 4; pl. 100, fig. 1.
Celastrus taurinensis Ward, 1887, p. 79, pl. 34, fig. 6.
Celastrus wardii Knowlton and Cockerell. Knowlton, 1919, p. 160, for *C. ovatus* Ward, 1887, p. 81, pl. 36, fig. 1.
Celastrus sp. Knowlton, 1917, p. 329, pl. 98, fig. 1.
Elaeodendron polymorphum Ward, 1887, p. 84, pl. 38, figs. 1–7.
Elaeodendron serrulatum Ward, 1887, p. 83, pl. 37, figs. 3–5.
Euonymus splendens Berry. Knowlton, 1917, p. 329, pl. 69, fig. 1.
Euonymus xantholithensis Ward, 1887, p. 82, pl. 37, figs. 1, 2.
Grewia celastroides Ward, 1887, p. 86, pl. 39, fig. 2.
Grewia pealei Ward, 1887, p. 87, pl. 39, figs. 3–5.
Ilex insignis Heer. Hollick, 1936, p. 131, pl. 73; pl. 74, fig. 1.
Juglans nigella Heer. Ward, 1887, p. 33, pl. 15, fig. 1.
Magnolia elliptica Newberry, 1898, p. 94, pl. 12, fig. 1.
Monimiopsis amboraefolia Saporta. Ward, 1887, p. 51, pl. 25, fig. 2.
Oreopanax sp. Bell, 1949, p. 76, pl. 59, fig. 3.

Populus anomala Ward, 1887, p. 23, pl. 8, fig. 7.
Populus inaequalis Ward, 1887, p. 24, pl. 9, fig. 2.
Quercus leonis Knowlton, 1930, p. 53, pt. 18, fig. 3.
Viburnum finale Ward, 1887, p. 115, pl. 57, fig. 5.
Berry, 1930b, p. 27, pl. 5, fig. 4.

Although these leaves resemble superficially those of some living species of *Celastrus* and *Prunus*, they compare most strikingly with those of *Eucommia ulmoides* Oliver, a dioecious, monotypic tree of Central China. The characteristic fruits of *Eucommia*, although present in some American Eocene and Oligocene floras (Brown, 1940, p. 349), have, however, not yet been reported from the Paleocene. The fact that they occur in slightly younger strata in the Southern and Western States suggests strongly that a concentrated search for Paleocene examples could be successful. The presence of *Eucommia* in the Paleocene flora of America is not surprising in view of the fact that this flora also contains representatives of other living Asiatic congeners: *Ginkgo*, *Glyptostrobus*, *Metasequoia*, *Pterocarya*, *Zelkova*, *Cercidiphyllum*, *Koelreuteria*, etc.

The species ranged from New Mexico to Canada and probably Alaska during the Paleocene. It may have arisen from the Cretaceous species *Celastrinites alatus* knowlton found in the Laramie formation of the Denver Basin. The leaves of the latter average somewhat smaller in size, with more numerous and more closely spaced secondary veins that emerge from the midrib at a smaller angle and are more conspicuously directed toward the apex of the blade.

Occurrence: Fort Union formation (lower), 2421, (pl. 44, fig. 1), 2423 (pl. 44, fig. 4), 4005, 4565, 4617, 4625, 4626 (pl. 44, fig. 5), 4699, 5388, 5389, 5885, 5889 (pl. 44, fig. 2; pl. 45, fig. 4), 6598, 7004, 8190, 8227, 8239, 8240, 8249, 8253, 8258, 8512, 8530, 8547, 8550, 8552 (pl. 45, fig. 3), 8568, 8677, 9193, 9301; (upper), 2416, 2420 (pl. 44, fig. 3; pl. 45, figs. 2, 5–7), 2422 (pl. 44, fig. 6), exact locality unknown (pl. 45, fig. 1, reproduction from Newberry, 1898, pl. 12, fig. 1), 4369, 4661, 4908, 5480, 5595, 5760, 6156, 6161, 7685, 8206, 8224, 8888, 9239; Coalmont formation, 5994; Dawson arkose, 8881; Ferris formation, 6971; Raton formation, 5140, 5151, 5712, 5798; Ravenscrag formation, Alberta and Saskatchewan.

SAXIFRAGACEAE

Hydrangea antica Brown, n. sp.

Plate 41, figures 3, 5

Leaves lanceolate with rounded-cuneate bases and acute apexes. Margins with low relatively few serrate teeth. Secondary veins widely spaced, camptodrome with short branches into the teeth. Connecting veinlets diagonal, parallel. Petiole 1 cm long.

No calyces identifiable as those of *Hydrangea* have yet been found in the Paleocene strata of the Rocky Mountains and Great Plains, but authentic leaves and calyces have been taken from Eocene and later strata in Alaska, California, Colorado, Oregon, and Washington.

Occurrence: Fort Union formation (lower), 4661 (fig. 5); Middle Park formation, 337 (fig. 3).

ANNONACEAE

Asimina vesperalis Brown, n. sp.

Plate 46, figure 4

Leaves obovate, with entire margins and cuneate bases. Secondary veins widely spaced, slightly decurrent on the midrib and forming loops near the margin. Petiole short, thick.

No seeds characteristic of pawpaw have been found in the strata containing these leaves. The assignment to *Asimina*, therefore, is tentative. Some species of *Magnolia* have leaves that match these fairly closely.

Occurrence: Fort Union formation (upper), 8774 (fig. 4).

ROSACEAE

Cercocarpus ravenscragensis Berry

Cercocarpus ravenscragensis Berry, 1930, p. 23, pl. 5, fig. 6.

This leaf, the only one of its kind so far seen in the Paleocene strata of the Rocky Mountains and Great Plains, purports to be a species of *Cercocarpus*.

Occurrence: Ravenscrag formation, SE$\frac{1}{4}$ sec. 22, T. 7, R. 22 W., third meridian, on north branch of Frenchman River, Saskatchewan, Canada.

Prunus careyhurstia Brown, n. sp.

Plate 42, figures 2, 8

Leaves lanceolate elliptic, but shape of the base and apex not definitely known. Margin finely dentate to serrate with scalloped to angular sinuses between the sharp teeth. Pinnate secondary veins strongly curved distad, sometimes branched near the margin. Connecting veinlets delicate, closely spaced, almost horizontal when leaf is viewed in upright position.

Occurrence: Fort Union formation (lower), 8666 (fig. 2), 8552 (fig. 8).

Prunus coloradensis Knowlton

Plate 42, figures 3, 4, 9

Prunus coloradensis Knowlton, 1917, p. 326, pl. 96, fig. 2.
Prunus denverensis Knowlton, 1930, p. 97, pl. 44, figs. 3, 4, 6, 11.
Juglans acuminata Brown. Knowlton, 1917, p. 292, pl. 65, fig. 1.
Laurus primigenia Unger. Knowlton, 1930, p. 83, pl. 38, figs. 5, 6 [not fig. 3, which is *Laurus socialis* Lesquereux].

These leaves lack the acropetiolar glands usually but not always present on the deciduous, serrate leaves of *Prunus*. Their resemblance to the serrate leaves of other genera, particularly *Carya* and *Salix*, emphasizes caution in accepting them as *Prunus*. The secondaries of this species are less numerous, more widely spaced and irregular than those of *Prunus careyhurstia* Brown. The intersecondaries, however, are more numerous and prominent than in the latter. The leaves identified by Knowlton as *Laurus primigenia* are not entire, as figured, but have minutely serrate margins.

Occurrence: Dawson arkose, 5738 (fig. 3, 4), 5836 (fig. 9), 5838; Raton formation, 5714, 5799.

Prunus corrugis Brown, n. sp.

Plate 67, figures 1–4, 8

Impressions of nuts, broadly elliptic, rounded at one end and rounded to blunt pointed at the other. Length, 1.5 to 4 cm, width to 2.8 cm, diameter about 1 cm. Outer surface slightly concave, pitted and irregularly furrowed; inner surface slightly convex, smooth or reflecting the features of the outer surface, with a smooth flange about 1 mm wide.

Although in some respects these fossils suggest walnuts, their affinity seems more plainly to be with the *Amygdalus* or almond section of *Prunus*. They are somewhat more elliptic in outline than the specimen from the Eocene of Tennessee called *Amygdalus wilcoxiana* Berry (1930a, p. 72, pl. 12, fig. 1). Just what Paleocene foliage belonged with this species is a moot question.

Occurrence: Fort Union formation (lower), 541 (fig. 8), 4984 (figs. 2, 3), 8660, 8668, 9540; (upper), 9132; Almy formation, 9235; Animas formation, 4050 (fig. 4), 5460, 9492 (fig. 1); Coalmont formation, 6005; Ferris formation, 9209.

Prunus mclearni Berry

Prunus mclearni Berry, 1935, p. 41, pl. 11, figs. 1, 2.

These lanceolate, acuminate leaves resemble those of *Prunus careyhurstia* in venational and marginal features, but are more lanceolate and long acuminate.

Occurrence: Ravenscrag formation, sec. 29, T. 3, R. 24 W., second meridian, Saskatchewan, Canada.

Prunus perita Brown, n. sp.

Plate 43, figures 2, 3

Leaves 15 cm long, 4.5 cm wide, elliptic, narrowed at base and apex, which is somewhat attenuate. Margin serrate, with numerous low, blunt regular teeth, separated by angular sinuses. Venation pinnate though obscure, the leaves apparently having had a thick texture. Secondaries evenly spaced, forming loops well within the margin. Some intersecondaries present.

The features of these leaves suggest those of the evergreen section of *Prunus* that includes the laurel-cherries. However, I find no clear evidence of glands within the blade near the midrib, as often seen in living species and in the Oligocene specimens from Oregon called *Prunus pristina* Brown (1950, p. 323, text figs. 1–3). The relationship of *P. perita* to the species described by Heer (1880, p. 16, pl. 6, figs. 2, 3) as *P. scotti* is problematical.

Occurrence: Fort Union formation (middle), 8552 (figs. 2, 3).

LEGUMINOSAE

Bauhinia wyomingana Brown

Plate 43, figure 10

Bauhinia wyomingana Brown, 1956, p. 104, text fig. 1.

The deep sinus and bilobed outline of this leaf, together with the venational details, strongly suggest the assignment to *Bauhinia*. Since this species was published, large pods have been found in the same collection that yielded the leaf, but whether or not the pods, *Leguminosites coloradensis* Knowlton, belong with the leaf is uncertain.

Occurrence: Fort Union formation (lower), 4877 (fig. 10).

Leguminosites coloradensis Knowlton

Plate 68, figures 1, 3–6

Leguminosites? *coloradensis* Knowlton, 1922a, p. 147, pl. 19, fig. 9.

Impressions of the interiors of large capsules which were attached by broad bases to a stout petiole. Valves with broad flanges, blunt pointed at the apex and rounded at the base. Some specimens show cross wrinkles, folds, or striations.

The type specimen, described by Knowlton from the Laramie formation at Marshall, Colo., is only the apical end of what evidently was a large pod. That these pods are leguminous and belong with some one of the described Paleocene legumes, or to some other family of plants such as the Bignoniaceae, is uncertain.

Occurrence: Fort Union formation (lower) 3852, 4877 (figs. 1, 6), 5526 (fig. 3), 5918, 8551 (fig. 4), 8884, 9130, 9221, 9566; Middle Park formation, 336 (fig. 5), 337.

Leguminosites williamsi Berry

Leguminosites williamsi Berry, 1930b, p. 23, pl. 5, fig. 1.

No further specimens assignable to this species have been found, and no new light has been shed on its generic identity.

Occurrence: Ravenscrag formation, SE¼ sec. 22, T. 7, R. 22, W., third meridian, on north branch of Frenchman River, Saskatchewan, Canada.

Mimosites coloradensis Knowlton

Plate 43, figures 12, 13

Mimosites coloradensis Knowlton, 1923, p. 166, pl. 40, figs. 1-3. Brown, 1934, p. 59.

As only two specimens were collected from the Coalmont formation, near Coalmont, Colo., and as these can be matched by specimens from the large collections of *Mimosites coloradensis* Knowlton from the Green River formation, it would seem that they should be assigned to this species.

Occurrence: Coalmont formation, 6440 (figs. 12, 13).

Robinia wardi (Knowlton) Brown, n. comb.

Plate 43, figures 4-6

Acacia wardi Knowlton, 1899, p. 730, pl. 98, fig. 7.
Acacia lamarensis Knowlton, 1899, p. 730, pl. 98, fig. 6.
Acacia macrosperma Knowlton, 1899, p. 729, pl. 98, fig. 8.
Robinia mesozoica Cockerell, 1912, p. 32, text fig. 1.

Of the pods described by Knowlton as *Acacia* from the Eocene of Yellowstone National Park, that called *A. wardi* is represented by the best specimen. Although the specimens here assigned to *Robinia wardi* differ somewhat in size and shape, they can be matched readily in every respect by pods from the living black locust, *R. pseudoacacia* Linnaeus. The leaves described by Knowlton as *Leguminosites lamarensis* and *L. lesquereuxiana* from the same Yellowstone strata may be leguminous, but they are too fragmentary for satisfactory identification and definite assignment to *Robinia wardi.* Likely leaves that might belong to this species are scarce at Paleocene localities, but the fragments here illustrated (pl. 43, figs. 9, 11) may be such.

The specimens described by Cockerell as *Robinia mesozoica* and here refigured (fig. 5) are parts of two pods, slightly different in size, one representing the proximal and the other the distal half of the pods. The proximal half ends in an abruptly tapered symmetrical base somewhat extended to the point where it was attached to the peduncle. The distal half ends more bluntly except that the wide flange running along the upper or placental margin of the pod curves downward at the end to make a sharp projection about on a median line lengthwise through the pod. In the pods of living redbuds, *Cercis*, with which those of fossil *Robinia* might be confused, the upper margin runs almost straight into the apical tip, with little downward curvature, thus giving them the appearance of the blades of carving knives. The lower margin of the pods has a narrower flange.

Cockerell's remark that in his pods "the seeds are placed very obliquely" and that this distinguishes them from those described by Knowlton from Yellowstone National Park, is not strictly correct. In all the pods here synonymized with *Robinia wardi*, the position of the seeds, so far as can be detected from their impressions, is only slightly oblique, but, nevertheless, normal for *Robinia.*

Cockerell assumed that his specimen came from strata of Laramie age, whence the specific term *mesozoica;* but as leaves of *Platanus raynoldsi* Newberry are on the same block and as the containing strata are similar to the Coalmont formation in North Park and the Middle Park formation in Middle Park, the age is Paleocene.

Occurrence: Fort Union formation (upper), 9109 (figs. 4, 6); Coalmont or Middle Park formation, 9445 (fig. 5, Specimen in University of Colorado Museum); Eocene of Yellowstone National Park.

STAPHYLEACEAE

Staphylea minutidens (Knowlton) Brown, n. comb.

Juglans minutidens Knowlton, 1917, p. 293, pl. 55, fig. 3.
Juglans nigella Heer. Knowlton, 1917, p. 292, p. 55, fig. 2; pl. 63, fig. 2.

The long petioles of these leaflets are not harmonious with an assignment to *Juglans*, whose leaflets are generally sessile or nearly so.

Occurrence: Raton formation, 5686, 5714, 5799.

ACERACEAE

Acer fragile Knowlton

Acer fragilis Knowlton, 1917, p. 330, pl. 101, figs. 1, 2.
Quercus fisheriana Knowlton, 1917, p. 297, pl. 68, figs. 3, 4.

These fragmentary specimens, as stated by Knowlton, are at least superficially aceroid in appearance. That they represent a species of *Acer* may be doubted. The reader after inspecting Knowlton's figures of *Acer fragilis* (pl. 101, figs. 1, 2) may question the relationship of the two specimens. Figure 2, unfortunately, was retouched, so that it does not show the well-defined rounded sinus between two lobes in the uppermost portion of the blade to the left of the midrib. All the specimens here synonymized are from the same locality.

Occurrence: Raton formation, 5099.

Acer newberryi Brown, n. name

Plate 46, figures 2, 3, 6, 8

Negundo triloba Newberry, 1898, p. 115, pl. 31, fig. 5.
Aralia triloba Newberry, 1898, p. 123, pl. 40, figs. 4, 5.

The specimens here assigned to a species of boxelder-maple are fragmentary and are not accompanied by appropriate samaras. As an earlier described fossil maple is called *trilobatum* I give the present specimens a new name.

Occurrence: Fort Union formation (upper), 2420 (figs. 2, 6, 8, reproductions from Newberry, 1898, pl. 31, fig. 5; pl. 40, figs. 4, 5), 4871, 8910 (fig. 3).

Acer silberlingi Brown, n. sp.

Plate 46, figure 7

Leaves palmately three-lobed. One specimen shows two pairs of primary veins indicating that there may have been an additional pair of existing or incipient basal lobes, but the margin of the specimen is broken so that this assumption cannot be verified without further material. The lobes are attenuate pointed with margins having large, coarse unequal teeth. No samaras were found with these leaves.

Without samaras it seems futile to suggest the modern affinities of these leaves. There may be some relationship between this species and *Acer disputabilis* Hollick (1936, p. 134, pl. 74, fig. 4) from the Tertiary of Alaska. No undoubted leaves and fruits of *Acer* are known from the Paleocene deposits of Greenland, but Heer described such remains from other areas and ages in the Arctic regions.

The specific term honors A. C. Silberling of Harlowton, Mont., whose labors as a collector of fossil mammals in the Crazy Mountain region contributed greatly to knowledge of Paleocene vertebrates. In 1936 he guided me to the plant locality where *Acer silberlingi* was found.

Occurrence: Fort Union formation (lower), 8567 (fig. 7).

Acer sp.

Plate 46, figure 5

Samara 3 cm or more in length, with greatest width of the wing 7 mm. Only half of the seed portion is present, the point of attachment not being preserved. The only maple leaves found at the locality that supplied this fruit are those assigned to a boxelder type, *Acer newberryi*, but the fruit may not belong to that species.

Occurrence: Fort Union formation (upper) 8910 (fig. 5), 9532.

Acer sp.

Plate 46, figures 9, 10

Samaras up to 5 cm in length, with large elliptical seed heads 1.3 cm long. Wing slightly constricted just behind the seed head. In life the twin samaras diverged at an angle of about 160°. No leaves were found with these seeds and no modern affinities are therefore suggested.

Occurrence: Fort Union formation, 9109 (figs. 9, 10).

SAPINDACEAE

Sapindus affinis (Newberry) Brown, n. comb.

Plate 47, figures 1–8

Sapindus affinis Newberry, 1868, p. 51; 1898, p. 116, pl. 30, fig. 1; pl. 40, fig. 2.
Ward, 1887, p. 67, pl. 30, figs. 1, 2.
Sapindus alatus Ward, 1887, p. 68, pl. 31, fig. 3 only.
Sapindus angustifolius Lesquereux. Ward, 1887, p. 68, pl. 31, figs. 5–7.
Sapindus berryanus Knowlton, 1930, p. 101, pl. 46, figs. 1, 2.
Sapindus glendivensis Knowlton, 1919, p. 579.
Sapindus grandifoliolus Ward, 1887, p. 67, pl. 30, figs. 3–5; pl. 31, figs. 1, 2.
Sapindus? membranaceus Newberry, 1878, p. 117, pl. 30, fig. 2 only.
Sapindus obtusifolius Lesquereux, 1878, p. 266, pl. 49, figs. 8–11; 1883, p. 235, pl. 48, figs. 5–7.
Laurus resurgens Saporta. Ward, 1887, p. 47, pl. 23, fig. 7.

The large amount of variable material found at each locality yielding these leaflets makes the distinction of more than one species difficult or impossible. On such fairly complete compound leaves as have been found, the leaflets are alternate, opposite, or mixed. Despite all appearances it is still uncertain that this foliage represents *Sapindus*. Suggestive comparisons can be made with *Bursera*, *Phellodendron*, *Rhus*, and *Xanthoxylum*.

Occurrence: Fort Union formation (lower), 3728, 4315, 8517, 8519, 8523 (figs. 2, 5), 8654, 8678 (figs. 7, 8); (upper), 1502, 2416 (figs. 4, 6), 2422, 5578, 8206, 8920, 8921, 9180, exact locality unknown (figs. 1, 3, reproduction from Newberry, 1898, pl. 30, figs. 2, 1); Dawson arkose, 5839, 8188.

Koelreuteria annosa Brown

Plate 59, figures 8, 9

Koelreuteria annosa Brown, 1956, p. 107, text fig. 3.

The leaflet (fig. 8) here assigned to this species was not found with the capsule (fig. 9), but at a locality on the Little Powder River, near Biddle, Mont. It, however, seems to be an authentic *Koelreuteria* leaflet.

Occurrence: Fort Union formation (lower), 9253 (fig. 8); (upper), 9344 (fig. 9).

ILICACEAE

Ilex artocarpidioides (Lesquereux) Brown, n. comb.

Celastrinites artocarpidioides Lesquereux, 1878, p. 268, pl. 35, fig. 3.
Celastrinites populifolius Knowlton, 1930, p. 100, pl. 40, fig. 1; pl. 45, fig. 11.
Celastrus gaudini Lesquereux, 1888, p. 54.
Knowlton, 1930, p. 99, pl. 45, fig. 3; pl. 45, figs. 3, 4 [not fig. 9, which is *Cissus marginata* (Lesquereux) Brown].
Ilex? ovata Knowlton, 1930, p. 102, pl. 46, fig. 4.
Quercus celastrifolia Lesquereux. Knowlton, 1930, p. 54, pl. 18, fig. 5.
Quercus leonis Knowlton, 1930, p. 53, pl. 18, fig. 3 only.

These leaves resemble the smaller leaves of *Eucommia serrata* (Newberry) Brown, but differ in having conspicuously cuneate bases and more open secondary venation which, in the better preserved specimens, has connecting loops between the secondaries well within the margin.

Occurrence: Denver formation, 317, 318.

RHAMNACEAE

Paliurus? sp. Berry

Paliurus? sp. Berry, 1930a, p. 25, pl. 5, fig. 7.

This specimen was described as a disklike fruit resembling that of some living species of *Paliurus*. If correctly identified it is the earliest good evidence of *Paliurus* in the Tertiary strata of the Rocky Mountains and Great Plains.

Occurrence: Ravenscrag formation (part of which was formerly called Estevan on the Souris River) in SW¼ sec. 6, T. 8, R. 3, W., fourth meridian, Alberta, Canada.

Rhamnus cleburni Lesquereux

Plate 42, figures 1, 5–7

Rhamnus cleburni Lesquereux, 1878, p. 280, pl. 53, figs. 1–3.
  Knowlton, 1930, p. 104, pl. 40, fig. 6 only.
Rhamnus? *discolor* Lesquereux, 1878, p. 280, pl. 52, fig. 17.
Rhamnus inaequalis Lesquereux, 1878, p. 279, pl. 52, fig. 16.
Cornus denverensis Knowlton, 1930, p. 119, pl. 13, fig. 1.
Cornus impressa Lesquereux. Knowlton, 1930, p. 118, pl. 51, fig. 1 only.
Cornus lakesii Knowlton, 1930, p. 119, pl. 50, fig. 1.
Cornus neomexicana Knowlton, 1917, p. 342, pl. 109, fig. 1.
Cornus studeri Heer. Lesquereux, 1878, p. 244, pl. 42, fig. 5 [not fig. 4, which is *Rhamnus goldiana* Lesquereux].
  Ward, 1887, p. 55, pl. 26, fig. 1.
Ficus coloradensis Cockerell, 1910, p. 223.
  Knowlton, 1922, p. 134, pl. 22, fig. 1.
Ficus crossii Ward, 1887, p. 39, pl. 21, fig. 2.
  Dorf, 1938, p. 56, pl. 7, fig. 3.
Ficus denveriana Cockerell, 1910, p. 224.
  Knowlton, 1930, p. 64, pl. 24, figs. 2, 3 only.
Ficus irregularis Lesquereux, 1878, p. 196, pl. 34, figs. 4–7; pl. 63, fig. 9.
  Ward, 1887, p. 38, pl. 20, fig. 4 only.
Ficus rhamnoides Knowlton, 1916, p. 339, pl. 87, fig. 3.
Ficus spectabilis Lesquereux, 1878, p. 199, pl. 33, figs. 4–6.
  Ward, 1887, p. 38, pl. 21, fig. 1.
Ficus uncata Lesquereux, 1878, p. 197, pl. 35, fig. 2 only.
Populus ungeri Lesquereux, 1878, p. 175, pl. 24, fig. 5.

Lesquereux's types of this species, like those of *R. goldiana*, came from the Denver formation that crops out on the slopes of South Table Mountain near Golden, Colo. Except that they have a cuneate base, the leaves of *R. cleburni* are much like those of *R. goldiana*, and it is probable that both kinds may have come from the same species of tree or shrub. For the present, however, I shall regard them as having originated from distinct species. That these were in fact species of *Rhamnus* is uncertain. The leaves of *R. cleburni* have some of the aspects of those borne by living species of Cornaceae, and particularly of *Camptotheca acuminata* Decaisne, of western China.

Included in the foregoing synonymy are some items representing Upper Cretaceous specimens. Dorf's synonymy (1938, p. 67; 1942, as *Dillenites cleburni*, p. 146) included other Upper Cretaceous items such as *R. rectinervis* Heer, *R. brittoni* Knowlton, and *R. marshallensis* Knowlton. These three, however, in my opinion, after comparison of the types with those of *R. salicifolia* Lesquereux, also from the Upper Cretaceous, should be referred to the latter species, for some of the specimens of all these species have definitely toothed margins. Thus far I have seen no leaf, authentically comparable to the types of *R. cleburni*, with a toothed margin.

Occurrence: Fort Union formation (lower) 8901; (upper), 5863; Denver formation, 317 (figs. 5, 7), 6145, 8672 (figs. 1, 6), 8777; Dawson arkose, 5838; Ferris formation, 6431; Raton formation, 5464, 5687, 5826.

Rhamnus goldiana Lesquereux

Plate 48, figures 2, 5–7

Rhamnus goldianus Lesquereux, 1878, p. 281, pl. 53, figs. 4–8.
  Knowlton, 1924, p. 91.
Rhamnus cleburni Lesquereux. Knowlton, 1924, p. 90, pl. 17, fig. 4.
Berchemia multinervis (Braun) Heer. Lesquereux, 1878, p. 277, pl. 52, figs. 9, 10.
  Ward, 1887, p. 73, pl. 33, fig. 2 [not fig. 1, which is *Juglans taurina* Brown].
Cornus studeri Heer. Lesquereux, 1878, p. 244, pl. 42, fig. 4 [not fig. 5, which is *Rhamnus cleburni* Lesquereux].
Ficus irregularis Lesquereux. Ward, 1887, p. 38, pl. 20, fig. 5.

The distinguishing feature of these leaves is the conspicuous cordate base. Of perhaps minor importance is the presence of short branches from the first secondary veins above the base. In other respects, particularly the spacing, delicacy, and regularity of the veinlets connecting the secondaries, the leaves of *R. goldiana* and *R. cleburni* are closely comparable. Living species of *Rhamnus* may have leaves with entire margins, but in general the margins are serrate or serrulate. No species, however, so far as I am aware, has leaves with strongly cordate bases and incipient palmate venation.

Occurrence: Animas formation, 7481, 7496; Denver formation, 317 (fig. 5), 8774 (figs. 2, 6, in Chicago Nat. History Mus., 7); Raton formation, 5291.

Rhamnus hirsuta Brown, n. sp.

Plate 49, figures 1–10

Leaves elliptic in outline, long and narrow, or short and wider through the middle. Base cuneate, apex blunt pointed. Petiole short. Margin entire to coarsely serrate. Surfaces rough hairy. Venation pinnate with evenly spaced curved secondaries that may or may not be forked near the margin.

There is some doubt that these leaves represent *Rhamnus*. However, they resemble in many respects those called *Rhamnus marginatus* var. *apiculatus* Berry (1922, p. 15, pl. 11, figs. 2, 3) from the Wilcox group in Louisiana, except that the latter are described as having entire margins and attenuate apexes.

Occurrence: Fort Union formation (lower), 8519 (figs. 1–10), 8677, 8897.

Zizyphus fibrillosus (Lesquereux) Lesquereux

Plate 50, figures 5, 6, 10, 11

Ceanothus fibrillosus Lesquereux, 1873, p. 381.
Zizyphus fibrillosus (Lesquereux) Lesquereux, 1878, p. 276, pl. 52, figs. 1–6.
Knowlton, 1917, p. 335, pl. 102, fig. 1; 1924, p. 91; 1930, p. 108, pl. 46, figs. 6, 9.
Zizyphus beckwithii Lesquereux, 1883, p. 125, pl. 19, fig. 5.
Knowlton, 1930, p. 110, pl. 47, fig. 3.
Zizyphus corrugatus Knowlton, 1922, p. 158, pl. 17, fig. 3.
Zizyphus daphnogenoides Knowlton, 1924, p. 91; 1930, p. 109, pl. 48, figs. 5, 6.
Zizyphus distortus Lesquereux, 1878, p. 275, pl. 51, fig. 7 only.
Knowlton, 1930, p. 110, pl. 47, fig. 2; pl. 52, fig. 1.
Zizyphus hendersoni Knowlton, 1922a, p. 157, pl. 15, figs. 1, 2.
Ficus pseudopopulus Lesquereux. Knowlton, 1924, p. 83, pl. 7, fig. 4; 1930, p. 66, pl. 26, fig. 3.
Ficus wardi Knowlton, 1917, p. 266, pl. 42, fig. 2.
Paliurus zizyphoides Knowlton, 1917, p. 334, pl. 104, fig. 2.
Phyllites trillioides Dorf, 1938, p. 78, pl. 17, fig. 3.

So far as I can see, the unusually fine specimens I found in 1939 in the upper strata of the Vermejo formation (Upper Cretaceous) on the south side of the Cuchara River, 1.2 miles west of Walsenburg, Colo., cannot be distinguished from those called *Zizyphus fibrillosus* Lesquereux, occurring in the Denver formation (Paleocene). Inasmuch as the Vermejo, is, in large part at least, equivalent to the Laramie formation, it seems highly probable that the poorly preserved leaves from the Laramie assigned to *Z. corrugatus*, and *Z. hendersoni* also belong with *Z. fibrillosus*.

The identification of these leaves as *Zizyphus* is, in my estimation, somewhat dubious.

Occurrence: Fort Union formation (lower) 8928; Animas formation, 7496; Denver formation, 317 (fig. 11), 8774 (figs. 5, 6); Raton formation, 5690, 5712; Vermejo formation (Upper Cretaceous), 8776 (fig. 10).

Zizyphoides mackayi Bell

Zizyphoides mackayi Bell, 1949, p. 74, pl. 19, figs. 2, 3; pl. 20, figs. 2, 4.

These elliptic remotely dentate leaves, described by Bell as coming from the Post-Brazeau Paleocene strata in Alberta, Canada, do not seem to be matched by any found in the Paleocene rocks of the United States. Some in the latter that bear a superficial resemblance to *Zizyphoides mackayi* and were formerly referred to *Paliurus* or *Zizyphus* have been found to be variants of *Cercidiphyllum arcticum* (Heer) Brown. The closest comparable specimens from strata in the United States are those called *Zizyphus cinnamomoides* Lesquereux from the Eocene Green River formation in Wyoming. Is it possible that the Canadian specimens are from Eocene rather than Paleocene strata?

VITACEAE

Ampelopsis acerifolia (Newberry) Brown, n. comb.

Plate 51, figures 1–18; plate 52, figures 1–8, 10; plate 59, figures 6, 11; plate 66, figure 7

Populus acerifolia Newberry, 1868, p. 65; 1898, p. 37, pl. 28, figs. 5–8. [Cockerell in 1906 changed the name to *P. newberryi*, but *acerifolia* is here retained because that term has not been used with *Ampelopsis*.]
Acer articum Heer. Bell, 1949, p. 71, pl. 48, fig. 2.
Ampelopsis bruneri carbonensis (Ward) Cockerell, 1908, p. 103.
Ampelopsis montanensis Cockerell, 1908, p. 103.
Ampelopsis xantholithensis (Ward) Cockerell, 1908, p. 103.
Cercidiphyllum ellipticum (Newberry) Brown, 1939a, p. 491, pl. 52, figs. 13, 17 only.
Cissus? cannoni Knowlton, 1930, p. 113, pl. 47, fig. 5.
Cissus lesquereuxi Knowlton, 1930, p. 114, pl. 48, figs. 3, 4.
Cissus lobato-crenata Lesquereux, 1878, p. 240, pl. 41, figs. 1–3 [fig. 1, from Upper Cretaceous strata at Black Buttes, Wyo.]
Cissus tricuspidata Heer. Lesquereux, 1878, p. 240, pl. 41, figs. 4–7. [Fig. 4, Middle Park formation; figs. 5, 6, Denver formation; fig. 7, Upper Cretaceous, Black Buttes, Wyo.]
Dombeyopsis nebrascensis (Newberry) Bell, 1949, p. 62, pl. 2, figs. 1, 4; pl. 9, figs. 1–3; pl. 10, fig. 1; pl. 12, figs. 9, 10; pl. 19, fig. 1; pl. 20, fig. 1; pl. 22, fig. 6; pl. 46, fig. 4; pl. 48, fig. 1.
Populus craspedodroma Ward, 1887, p. 21, pl. 8, fig. 3.
Populus lacoeana Knowlton, 1930, p. 60, pl. 22, fig. 5.
Populus smilacifolia Newberry, 1898, p. 53, pl. 29, fig. 5.
Populus whitei Ward, 1887, p. 22, pl. 8, fig. 4.
Populus zaddachi Heer. Knowlton, 1930, p. 60, pl. 22, fig. 8.
Populus sp. Knowlton, 1930, p. 57, pl. 21, fig. 9.
Trochodendroides nebrascensis (Newberry) Dorf, 1938, p. 61, pl. 11, figs. 1, 4, 6, 7. [Include entire synonymy, except *Populus nebrascensis* Newberry, 1898, p. 47, pl. 27, figs. 4, 5, which is *Cercidiphyllum arcticum* (Heer) Brown.]
Viburnum anceps Lesquereux, 1878, p. 227, pl. 38, fig. 11.
Viburnum lakesii Lesquereux. Bell, 1949, pl. 61, fig. 1; pl. 62, figs. 3, 4.
Viburnum trinervis Berry. Bell, 1949, pl. 61, figs. 2, 3.
Vitis bruneri Ward, 1887, p. 69, pl. 32, figs. 1, 2.
Vitis carbonensis Ward, 1887, p. 70, pl. 32, fig. 3.
Vitis cuspidata Ward, 1887, p. 71, pl. 32, figs. 6, 7 [not fig. 8, which is *Platanus raynoldsi* Newberry.]
Vitis xantholithensis Ward, 1887, p. 71, pl. 32, figs. 4, 5.
Zizyphus distortus Lesquereux, 1878, pl. 51, figs. 8, 9 [not fig. 7, which is *Z. fibrillosus* (Lesquereux) Lesquereux.]

These leaves or leaflets, as the case may be in some instances, have large, rounded, sometimes notably unequal marginal teeth, separated by more or less concave to slightly angular sinuses. In appearance the better leaves are maplelike. (See *Acer arcticum* Heer, 1876, p. 86, pls. 22, 23, 24, figs. 1, 2; pl. 25, figs. 1–3.) The primary veins are in general fairly straight but may, in the more elliptic specimens, be somewhat curved. As evolution proceeded, the tendency toward lobation became more marked, the later leaves being distinctly more maplelike than those from the early Paleocene.

The variants among these leaves suggest those of the living *Parthenocissus* (*Ampelopsis*) *tricuspidata* (Siebold and Zuccarini) Planchon and *Ampelopsis brevipedunculata* Koehne, of China, and the early leaflets on seedlings of the Virginia creeper, *Parthenocissus quinquefolia* (Linnaeus) Planchon. Some also resemble strongly those of a number of species of *Viburnum*, particularly *V. acerifolium* Linnaeus, a shrub of the Northeastern United States and Canada.

Because some of these leaves are strikingly like variants of *Cercidiphyllum arcticum* (Heer) Brown, there is likelihood that they may be misidentified as the latter and vice versa, particularly when both are found together. Thus, a number of specimens formerly assigned to *Cercidiphyllum* are here reassigned.

Occurrence: Fort Union formation (lower), 4625, 4699 (pl. 51, fig. 10; pl. 52, fig. 7), 4877, 5063, 5437, 5718, 6154, 8163, 8227 (pl. 52, fig. 1), 8240, 8517 (pl. 52, figs. 2, 3, 6, 10), 8545, 8673, 8780, 8884, 8893, 8899, 8928, 9104, 9130 (pl. 51, fig. 17), 9301, 9334, 9502, 9530; (upper), 2420 (pl. 51, figs. 8, 15, 18; pl. 52, fig. 4; pl. 59, fig. 11), 2432, 4974 (pl. 51, figs. 3, 7, 12), 5333, 6359, 7659, 8225, 8255, 8521 (pl. 51, figs. 2, 13), 8523 (pl. 51, figs. 1, 16), 8552 (pl. 59, fig. 6), 8774 (pl. 51, figs. 4, 11), 8922 (pl. 51, figs. 5, 6, 9, 14), 9085, 9092, 9477; Coalmont formation, 5994; Dawson arkose, 5837, 8188; Denver formation, 317 (pl. 52, figs. 5, 8; pl. 66, fig. 7), 8447; Evanston formation, 3653, 3658; Livingston formation, 4311, 6767; Middle Park formation, 333, 337.

Cissus marginata (Lesquereux) Brown, n. comb.

Plate 53, figures 1–4, 6; plate 54, figures 1–4; plate 55, figures 4, 6, 7

Viburnum marginatum Lesquereux, 1873, p. 395; 1878, p. 223, pl. 37, fig. 11; pl. 38, figs. 1–4 [not fig. 5, which is a small leaf of *Ficus planicostata* Lesquereux.]

Dorf, 1938, p. 73, pl. 15, figs. 3, 5; pl. 17, figs. 4, 5; 1942, p. 150, pl. 14, fig. 3; pl. 15, figs. 1, 5.

Brown, 1939b, p. 252, pl. 59, fig. 7.

Acer collieri Hollick, 1930, p. 99, pl. 78, fig. 5.

Alnus auraria Knowlton and Cockerell. Knowlton, 1930, p. 49, pl. 15, fig. 6.

Alnus carpinifolia Lesquereux. Knowlton, 1930, p. 49, pl. 15, fig. 2.

Betula beatricina conformis Hollick, 1930, p. 68, pl. 35, fig. 4.

Betula brongniarti Ettingshausen. Heer, 1883, p. 81, pl. 96, fig. 3 only.

Betula fallax Lesquereux. Knowlton, 1930, p. 50, pl. 15, figs. 7–10; pl. 16, figs. 1, 2.

Betula schimperi Lesquereux. Knowlton, 1930, p. 49, pl. 15, figs. 3, 4.

Celastrus gaudini Lesquereux. Knowlton, 1930, p. 99, pl. 45, fig. 9 only.

Cissus corylifolia Lesquereux. Knowlton, 1930, p. 113, pl. 47, fig. 4; pl. 48, fig. 1, pl. 49, fig. 1.

Cissus grossedentata Knowlton, 1930, p. 112, pl. 48, fig. 2; pl. 51, fig. 10.

Cissus hesperia Knowlton, 1930, p. 112, pl. 47, fig. 1.

Cissus lobato-crenata Lesquereux. Knowlton, 1930, p. 114, pl. 49, figs. 3, 4.

Dorf, 1942, p. 153, pl. 16, fig. 3.

Crataegus myricoides Lesquereux. Knowlton, 1930, p. 96, pl. 44, figs. 7, 10.

Fagus papyracea Knowlton, 1917, p. 297, pl. 68, fig. 1.

Ficus? *lakesi* Knowlton, 1930, p. 60, pl. 28, fig. 1.

Fraxinus sp. Knowlton, 1930, p. 124, pl. 58, fig. 7.

Grewiopsis tenuifolia Lesquereux, 1878, p. 258, pl. 40, fig. 14.

Knowlton, 1930, p. 116, pl. 50, fig. 3.

Negundo decurrens Lesquereux. Knowlton, 1930, p. 100, pl. 45, fig. 10.

Phyllites denverensis Knowlton, 1930, p. 130, pl. 59, fig. 5.

Phyllites herbacea Knowlton, 1924, p. 97, pl. 15, fig. 4.

Phyllites leei Knowlton, 1917, p. 280, pl. 49, fig. 8.

Phyllites pellucidens Knowlton, 1930, p. 130, pl. 39, fig. 2; pl. 56, fig. 4.

Platanus aceroides latifolia Knowlton, 1924, p. 86, pl. 13, fig. 3; pl. 14, fig. 4; 1930, p. 76, pl. 33, fig. 1.

Platanus affinis Lesquereux. Bell, 1957, p. 52, pl. 37, fig. 5; pl. 39, figs. 1, 4, 5; pl. 42, fig. 6.

Platanus guillelmae Göppert. Heer, 1883, p. 96, pl. 97, fig. 6; pl. 98, figs. 1, 2; pl. 99, fig. 1; pl. 103, fig. 4.

Knowlton, 1917, p. 322, pl. 93, fig. 1; 1930, p. 76, pl. 33, fig. 2.

Platanus quillelmae heeri Knowlton, 1917, p. 323, pl. 96, fig. 5; pl. 97, fig. 1; pl. 98, fig. 2.

Platanus heeri Lesquereux. Ward, 1887, p. 37, pl. 15, figs. 3, 4.

Platanus marginata (Lesquereux) Heer, 1883, p. 97, pl. 98, figs. 3–5; pl. 99, figs. 2, 3; pl. 101, fig. 5.

Knowlton, 1930, p. 81, pl. 36, figs. 2, 3.

Platanus? *newberryana* Heer. Hollick, 1930, p. 83, pl. 46 figs. 2, 3; pl. 47, fig. 3.

Platanus? *newberryana conditionalis* Hollick, 1930, p. 83, pl. 47 fig. 4.

Platanus platanoides (Lesquereux) Knowlton, 1917, p. 323 pl. 95, fig. 4; 1922a, p. 146, pl. 13, fig. 1; 1930, p. 82 pl. 36, fig. 5.

Platanus rhomboidea Lesquereux, 1878, p. 186, pl. 26, figs. 6, 7.

Knowlton, 1930, p. 75, pl. 32, fig. 3.

Platanus sp. Knowlton, 1930, p. 83, pl. 38, fig. 2.

Populus denverensis Knowlton, 1930, p. 61, pl. 23, fig. 5.

Populus knowltoni Berry. Knowlton, 1930, p. 61, pl. 23, figs. 1–4.

Quercus celastrifolia Lesquereux. Knowlton, 1930, p. 54, pl. 18, figs. 4, 6, 7 [not fig. 5, which is *Ilex artocarpoides* (Lesquereux) Brown].

Quercus purdonensis Knowlton, 1930, p. 52, pl. 17, fig. 2.

Quercus viburnifolia Lesquereux, 1878, p. 159, pl. 20, figs. 11, 12.
Knowlton, 1930, p. 50, pl. 16, figs. 3–8; pl. 17, fig. 1.
Dorf, 1938, p. 53, pl. 6, figs. 3, 5, 7; 1942, p. 154, pl. 16, figs. 5, 7, 8.
Quercus whitei Lesquereux. Knowlton, 1930, p. 53, pl. 17, fig. 3; pl. 18, fig. 1.
Rhamnus cleburni Lesquereux. Knowlton, 1917, p. 332, pl. 113, fig. 3.
Rhus? viburnoides Knowlton, 1917, p. 328, pl. 98, fig. 5.
Sophora puryearensis Berry. Knowlton, 1930, p. 98, pl. 45, fig. 8.
Ulmus quercifolia Unger. Knowlton, 1930, p. 62, pl. 23, fig. 10.
Viburnum antiquum (Newberry) Hollick. Knowlton, 1924, p. 96, pl. 18, figs. 1–3.
Bell, 1949, p. 77, pl. 61, fig. 4.
Viburnum contortum Lesquereux. Knowlton, 1917, p. 346, pl. 108, fig. 3; 1930, p. 127, pl. 55, fig. 1.
Viburnum crassum Knowlton, 1917, p. 277, pl. 52, figs. 3, 4.
Viburnum dichotomum Lesquereux, 1878, p. 225, pl. 38, fig. 6.
Viburnum lakesi Lesquereux, 1878, p. 226, pl. 37, fig. 13.
Knowlton, 1917, p. 348, pl. 110, fig. 3 [not fig. 4, which is *Platanus raynoldsi* Newberry]; 1930, p. 128, pl. 55, fig. 3.
Viburnum magnum Knowlton, 1917, p. 347, pl. 110, fig. 2.
Viburnum marginatum ravenscragensis Berry, 1935, p. 58.
Viburnum melaenum Knowlton and Cockerell. Knowlton, 1930, p. 128, pl. 55, fig. 5.
Viburnum montanum Knowlton, 1900, p. 73, pl. 19, figs. 1, 2; 1917, p. 276, pl. 52, fig. 2.
Dorf, 1938, p. 75, pl. 17, fig. 2; 1942, p. 150, pl. 15, figs. 2, 3.
Viburnum platanoides Lesquereux, 1878, p. 224, pl. 38, figs. 8, 9.
Viburnum? problematicum Knowlton, 1900, p. 71, pl. 19, fig. 4; 1917, p. 276, pl. 49, fig. 9.
Viburnum richardsoni Knowlton, 1930, p. 126, pl. 52, fig. 8; pl. 53, figs. 1, 3–5; pl. 54, figs. 2, 3.
Viburnum rotundifolium Lesquereux, 1878, p. 225, pl. 37, fig. 12; pl. 38, fig. 10; pl. 61, fig. 22.
Knowlton, 1924, p. 96, pl. 16, fig. 1.
Viburnum simile Knowlton, 1917, p. 277, pl. 49, fig. 3.
Viburnum speciosum Knowlton, 1917, p. 347, p. 111, figs. 1–5; 1924, p. 96, pl. 16, fig. 3.
Viburnum whymperi Heer. Lesquereux, 1878, p. 225, pl. 38, fig. 7; pl. 61, fig. 23.
Knowlton, 1900, p. 72, pl. 17, fig. 1; pl. 18, fig. 1; pl. 19, fig. 3.
Viburnum sp. Knowlton, 1917, p. 278, pl. 44, fig. 3.
Vitis? platanifolia Knowlton, 1917, p. 339, pl. 103, fig. 2.
Vitis stantoni (Knowlton) Brown. Bell, 1949, p. 75, pl. 3, fig. 3; pl. 9, fig. 5.
Winchellia triphylla Lesquereux, 1893, p. 209, pl. 8, fig. 1.

The well-preserved ternate or trifoliate leaf (pl. 53, fig. 4), called by Lesquereux *Winchellia triphylla* in a posthumous publication, adds new information on the mixture of many-named Cretaceous and Paleocene leaves variously assigned, as seen from the synonymy, to the alders, birches, beeches, maples, grapes, sycamores, viburnums, and others. This fine compound leaf, it now appears, is not the only one of its kind known, others being *Negundo decurrens* Lesquereux (Knowlton, 1930, pl. 45, fig. 1), *Platanus guillelmae* Göppert (Knowlton, 1930, pl. 33, fig. 2, in which the right-hand leaflet is obscure), and some not hitherto figured (pl. 54, figs. 3, 4). One unfigured specimen, collected by me in 1930 from the Aspen shale on Fontanelle Creek north of Kemmerer, Wyo., is also now in the U.S. National Museum collections.

The normal terminal leaflets of this species have the appearance of partly opened fans and are incipiently to strongly three-lobed like some maples and viburnums. However, many of the figured single leaves, purporting to have been terminal leaflets, may in reality have been simple leaves, for they show no evidence of leaflet scars on their long petioles. Moreover, some of the assumed ancestral, simple, Cretaceous specimens (pl. 55, fig. 2) have remains of narrow acute stipules. It seems evident, therefore, that *C. marginata* had both simple and compound leaves.

Associated at all localities with the characteristic terminal leaflets are the more or less asymmetric, petioled, lateral leaflets, of great variety in shape, venation, and marginal features, causing much diversity of identification as illustrated by the extensive synonymy here proposed. Perhaps I have included in this species some aberrant specimens that properly belong elsewhere, for I have no infallible method of classifying such disputable material.

The venation of these leaves is fundamentally pinnate, but the tendency toward palmateness is unmistakable, the first pair of basal secondaries being, in many specimens, especially strong, so that they should probably be called primaries. These veins have numerous lateral branches from the lower side but sometimes give off a strong branch or two from the upper side. Most veins and their branches terminate in marginal teeth that differ greatly in size in different leaves. The prominent, fairly straight primaries are decurrent at acute angles into the top of the petiole, or, if they appear to branch from the midvein a little higher, are decurrent on the midvein into the petiole. This feature helps to distinguish these leaves from the normal leaves of *Platanus raynoldsi* Newberry in which the curved or bowed primaries branch from the midvein at greater angles and at a centimeter, more or less, within the blade above the top of the petiole. Otherwise, the general venational pattern, the overall outline, and the teeth, separated by smoothly scalloped sinuses, are very similar in both species. The teeth of this species, however, are, with few transitional exceptions, sharp pointed and are thus in contrast with the blunt, rounded teeth of an associated vitaceous species, *Ampelopsis acerifolia* (Newberry) Brown.

A canvass of the possibilities among plant families having species with features comparable to those here described suggests that this species most likely belongs in the grape family, Vitaceae, rather than in the Caprifoliaceae or Platanaceae. Among living Vitaceae, *Rhoicissus usambarensis* Gilg, from South Africa, is a fair match for this species, but difficulty in explaining the wide breach in distribution makes an assignment to *Rhoicissus* seem like stretching a point. Choice of *Ampelopsis* or *Vitis* also seems less appropriate than *Cissus*. Further, although these leaves are here called *Cissus*, their resemblance in many particulars to those of *Platanus* prompts the needed caution of looking for examples of compound leaves in the ancestry of *Platanus*. So far, after examining many seedlings, suckers, and young shoots of living species of *Platanus*, I have found no compound specimens that could be regarded as possible atavistic throwbacks.

Lesquereux saw a resemblance between *Winchellia triphylla* and the deerfoot or vanilla-leaf, *Achlys triphylla* DeCandolle, of the barberry family, found in the Pacific Coast region from California to British Columbia. Except for the trifoliateness, however, the two are in other features not closely comparable, and the assignment to the Berberidaceae is deemed far-fetched. It seems remarkable that Lesquereux did not detect the striking similarity in every respect between the terminal leaflet of *Winchellia triphylla* and the Cretaceous leaves he had called *Viburnum marginatum*.

After exhaustive comparisons between Cretaceous and Paleocene assemblages of these leaves, I have found no unfailing features that clearly distinguish them. At some localities the Cretaceous leaves appear to average smaller in size and may be somewhat rounder in outline, with the apical lobe less pronounced. The terminals of some Paleocene specimens show a stronger lobing or tendency to be aceroid or platanoid in outline.

Closely similar to this species is the Upper Cretaceous *Vitis stantoni* (Knowlton) Brown, which differs chiefly in having leaves that are broad rounded, and usually with cordate bases. Perhaps this species should also be reassigned to *Cissus*, although no compound examples have been reported.

The more distant ancestors or relatives of this species may possibly be found among the many described forms of *Aspidiophyllum*, *Betulites*, *Cissites*, *Crataegus*, *Grewiopsis*, *Hedera*, *Platanus*, *Populites*, and *Viburnum*. These occur in the Cretaceous of Greenland and Alaska, and notably in the Dakota sandstone of Kansas, Nebraska, and Minnesota. A few are figured here (pl. 55, figs. 1–3) for comparison in shape, venation, and marginal dentition with the corresponding features of the later species. The specimen (pl. 55, fig. 7) from the Cretaceous at Parowan Gap, Utah, is noteworthy in showing a rounded base with a perfoliate petiole, thus simulating some leaves of fossil and living *Platanus*.

Occurrence: Fort Union formation (lower), 4280, 4976, 6297, 8551, 9193, 9252 (pl. 53, fig. 4), 9334; (upper), 8774; Animas formation, 5455, 6309, 6443, 7485, 7498, 9565; Coalmont formation, 6107; Dawson arkose, 331, 5783, 5835–5840, 8187, 8307; Denver formation, 317 (pl. 53, fig. 1; pl. 54, fig. 3), 5738, 8672; Ferris formation, 3852, 4369, 5494, 6416 (pl. 53, fig. 6; pl. 54, fig. 2), 6431 (pl. 53, figs. 2, 3), 8516, 8528, 8660; Puerco formation, 7495 (pl. 54, figs. 1, 4); Raton formation, 5154, 5679, 5683, 5701, 5711, 5714, 5802, 5826. Cretaceous localities: Pl. 55, fig. 4, Mesaverde formation, south of Gallup, N. Mex.; pl. 55, fig. 6, Hell Creek formation, east of Glendive, Mont.; pl. 55, fig. 7, Kaiparowitz formation, Parowan Gap, Utah.

Cissites rocklandensis Brown, n. sp.

Plate 27, figure 8

Large ovate three-lobed leaf, the two lateral lobes relatively small or incipient. Venation with two large primary veins that rise from the top of the petiole and run toward the lateral lobes; and secondary veins, widely spaced from the middle of the blade to the apex. Margin entire. Base somewhat cordate.

Superficially this leaf resembles those called *Ficus planicostata* Lesquereux, but I have never seen any lobed specimens of the latter among the abundant material in the collections of the U.S. National Museum. Cretaceous species that may have been ancestral to *Cissites rocklandensis* are *Cissites colgatensis* Brown, *C. lobatus* Dorf, *Dombeyopsis obtusa* Lesquereux, *D. trivialis* Lesquereux, *Phyllites dombeyopsoides* Knowlton, *P. populoides* Knowlton, and *P. trinervis* Knowlton.

Occurrence: Raton formation, 5679 (fig. 8).

Parthenocissus ursina Brown, n. sp.

Plate 48, figures 1, 3, 4

Leaflets 12 cm or more long, 5 cm wide, narrow elliptic in outline, blunt pointed at the apex, and cuneate, more or less asymmetric, at the base. Secondary veins relatively few, widely spaced, with some intersecondaries, slightly undulant and forming loops but with small branches into the marginal teeth. Margins serrate with large teeth and angular sinuses. Texture apparently thin.

No complete leaflet or compound leaf was found. The fragments, however, suggest comparison with the leaves of the living *Parthenocissus quinquefolia* (Siebold and Zuccarini) Planchon, of the Eastern United States. The species seemingly was larger and coarser than the delicate *P. tertiaria* (Lesquereux) Knowlton from the Eocene Green River formation in Wyoming.

Occurrence: Early Paleocene, 8547 (figs. 1, 3, 4), in the Bear of Simpson, Crazy Mountain area, Montana.

Vitis lobata (Knowlton) Brown, n. comb.

Plate 56, figures 3, 7, 10

Aralia lobata Knowlton, 1924, p. 93, pl. 17, figs. 1, 2.
Aralia sp. Knowlton, 1924, p. 94, pl. 6, fig. 4.

The specimens from Montana figured here resemble closely those called *Aralia* by Knowlton from southern Colorado, except that the lobes of the latter are apparently not sharply toothed. This may be a local variation, but it may also mean that two species are involved. The Montana specimens, under magnification, show some evidence of having been glandular or at least somewhat hairy. There is a suggestion of relationship between this species and the Upper Cretaceous *Cissites panduratus* Knowlton (1917, p. 274, pl. 49, fig. 10) from the Vermejo formation in Colorado. Leaves of the living *Vitis rubra* Michaux [or *V. palmata* Vahl] match those of *V. lobata* fairly well.

Occurrence: Fort Union formation (lower) 8519 (figs. 3, 7, 10); Animas formation, 7483.

Vitis olriki Heer

Plate 27, figure 10; plate 59, figure 10

Vitis olriki Heer, 1868, p. 120, pl. 48, fig. 1.
  Lesquereux, 1878, p. 241, pl. 41, fig. 8.
  Knowlton, 1930, p. 115, pl. 49, fig. 6; pl. 50, fig. 4.
Vitis arctica Heer, 1868, p. 120, pl. 48, figs. 2, 2c; 1871, p. 478, pl. 55, fig. 1.
Vitis inominata Knowlton, 1917, p. 339, p. 107, fig. 1.
Vitis leei Knowlton, 1917, p. 338, pl. 66, fig. 4.
Vitis sp. Heer, 1871, p. 478, pl. 55, figs. 5d, 6 (seed).
Ficus denveriana Knowlton, 1930, p. 64, pl. 24, fig. 1.
Populus cordata Newberry, 1868, p. 60; 1898, p. 38, pl. 29, fig. 6.
Populus richardsoni Heer. Knowlton, 1930, p. 62, pl. 23, figs. 6, 8.
Tilia speciosissima Knowlton, 1917, p. 336, pl. 67.

These are relatively large leaves with cordate bases and entire or toothed margins. Between the rounded teeth are smooth concave sinuses. The seed *Vitis* sp., figured by Heer and found associated with a leaf of that genus at Atanekerdluk, Greenland, probably belongs with this species.

Occurrence: Fort Union formation (lower) 8517 (pl. 27, fig. 10), 8899, 9104 (pl. 59, fig. 10); (upper) 2414, 8921; Dawson arkose, 331, 5837, 5840, 8447; Evanston formation, 3653; Middle Park formation, 337; Raton formation, 5679, 5684.

Vitis sp.

Plate 53, figure 5

This rounded seed with the two prominent adjacent cavities clearly belongs with the Vitaceae. As such it is the first to be reported from the Paleocene strata of the Rocky Mountains and Great Plains. However, as no leaves were found with the specimen, it cannot be plausibly assigned to any one of the vitaceous leaf species here listed.

Occurrence: Fort Union formation (upper) 9132 (fig. 5).

STERCULIACEAE

Dombeyopsis magnifica Knowlton

Dombeyopsis magnifica Knowlton, 1930, p. 125, pl. 54, fig. 4; pl. 55, fig. 4; pl. 57, fig. 1; pl. 58, fig. 8.
Dombeyopsis grandifolia Unger. Lesquereux, 1878, p. 255, pl. 47, fig. 6.
Dombeyopsis? sedaliensis Knowlton, 1930, p. 126, pl. 56, fig. 5; pl. 59, fig. 1.
Ficus sp. Knowlton, 1930, p. 72, pl. 29, fig. 5.
Phyllites aristolochioides Knowlton, 1930, p. 129, pl. 57, fig. 2 only.

The implication that these leaves are related to living *Dombeya* seems to me farfetched. They are somewhat like *Cissites steenstrupi* Heer (1883, p. 118, pl. 81, fig. 1) from Greenland.

Occurrence: Dawson arkose, 325, 5831, 5839; Denver formation, 317.

Pterospermites cordatus Ward

Plate 41, figures 1, 2, 4

Pterospermites cordatus Ward, 1887, p. 93, pl. 41, fig. 4.
Ficus berthoudi Lesquereux, 1888, p. 49.
  Knowlton, 1930, p. 65, pl. 25, figs. 1, 2, 6.
Ficus ratonensis Knowlton, 1917, p. 306, pl. 74, fig. 4.

These large, entire-margined, heart-shaped leaves resemble some described as *Ficus*, *Paranymphaea*, *Coccolobis*, *Dombeyopsis*, *Catalpa*, and others, but differ in venational and other features from all these. The regular parallel interconnecting tertiary veins are particularly coarse and widely spaced. I doubt that this species is allied with the genus *Pterospermum* but have no better suggestion to make.

Occurrence: Fort Union formation (lower), 4625 (fig. 4), 6892, 8678 (fig. 1); (upper) 2416, 7776 (fig. 2), 8190, 8774, 8921, 9109; Dawson arkose, 325; Denver formation, 317; Raton formation, 5140.

DILLENIACEAE

Dillenites garfieldensis Brown, n. sp.

Plate 57, figures 2, 5

Leaves large, elliptic, with cuneate to rounded bases and acute apexes. Length of petiole unknown. Margin beset with mammilately rounded to pointed, unequal, serrate teeth separated by angular sinuses. Venation pinnate, the numerous equally spaced secondaries curving gracefully away from the midvein into the larger marginal teeth and sending inconspicuous branches into the subsidiary teeth. Secondaries connected by closely spaced diagonal parallel veinlets.

This species differs from *Dillenites microdentatus* (Hollick) Berry in the Wilcox group of the Southeastern States and in the Tertiary of Alaska by having subsidiary teeth in addition to the main teeth and in having the teeth rounded instead of acute. A further study of Hollick's four species of *Dillenites* from the Tertiary of Alaska may prove that they are only a single species, as he himself intimated.

Occurrence: Fort Union formation (upper), 8774 (figs. 2, 5; specimens in Chicago Nat. History Mus.).

MYRTACEAE

Myrtophyllum torreyi (Lesquereux) Dorf

Plate 50, figures 1–4, 7–9

Myrica torreyi Lesquereux. Dorf, 1938, p. 49, pl. 6, figs. 1–3.
Myrtophyllum torreyi (Lesquereux) Dorf, 1942, p. 146. [See synonymy.]
Apocynophyllum wilcoxensis Berry. Knowlton, 1924, p. 95, pl. 14, fig. 5.
Myrica sp. Knowlton, 1930, p. 44, pl. 11, fig. 7.

Except that the intramarginal vein is more subdued and sometimes absent, these Paleocene leaves with eucalyptoid venation are scarcely distinguishable from their Cretaceous predecessors. Their reference to the family Myrtaceae may be appropriate in respect to venation, but the general absence of marginal teeth in leaves of that family is discordant, thus raising doubts about the present reference.

I have not seen the specimens called *Celastrophyllum benedini* by Saporta and Marion (1873, p. 67, pl. 10, fig. 6; pl. 12, figs. 1, 2; 1878, p. 86, pl. 14, fig. 2) from the Paleocene at Gelinden, Belgium, and am not certain that the venation is accurately drawn, but there is a strong suggestion of resemblance between them and the leaves of *Myrtophyllum torreyi.* The leaves described by Heer as *Rhus holbölliana* (1883, p. 134, pl. 59, fig. 7) from Atanekerdluk, Greenland, are also similar, and favorable comparison can be made with *Myrica wilcoxensis* Berry (1916a, p. 188, pl. 18, fig. 1) from the Eocene at Grenada, Miss. The illustration of the leaf called *Apocynophyllum wilcoxensis* Berry by Knowlton is retouched and is inaccurate in showing numerous regular, evenly spaced secondary veins; but these veins are irregular and unevenly spaced and they unite near the margin to form an obscure intramarginal vein.

Occurrence: Fort Union formation (lower) 8196, 8551 (figs. 2, 7), 8666, 8677 (figs. 3, 4), 8899, 9210 (fig. 1); Animas formation 7483; Dawson arkose, 5738, 8188 (fig. 8), 8881 (fig. 9).

TRAPACEAE

Trapa angulata (Newberry) Brown, n. comb.

Plate 58, figures 1–12

Neuropteris angulata Newberry *in* Ives, 1861, p. 131, pl. 3, fig. 5.
Trapa? cuneata Knowlton, 1900, p. 64, pl. 5, fig. 6.
Trapa? microphylla Lesquereux, 1878, p. 295, pl. 61, figs. 16–17a.
  Dawson, 1887, p. 31, pl. 2, figs. 19, 19a.
  Ward, 1887, p. 64, pl. 28, figs. 2–5.
  Knowlton, 1899, p. 661, pl. 77, figs. 3, 4; 1900, p. 62, pl. 5, fig. 7; 1919, p. 627.
  Hollick, 1930, p. 109, pl. 84, fig. 4.
  Berry, 1935, p. 61, pl. 19, figs. 1–11.
  Brown and Houldsworth, 1939, p. 336–339, text figs. 1–9.
Fucus lignitum Lesquereux, 1878, p. 42, pl. 61, figs. 24, 24a.
  Ward, 1887, p. 549, pl. 1, fig. 1 only.
  Knowlton, 1900, p. 17, pl. 3, fig. 4.
Nelumbites striata Berry, 1935, p. 38, pl. 8, figs. 1–3.
Nymphaeites angulatus (Newberry) Bell, 1949, p. 64, pl. 17, figs. 4, 7.
Nymphaeites striatus (Berry) Bell, 1949, p. 67, pl. 17, figs. 1–3, 5, 6.

Berry (1935, p. 61) and Bell (1949, p. 64) have summarized the history and information concerning this species, but Bell did not cite the report by Brown and Houldsworth (1939) of fruit-bearing specimens from the Ravenscrag formation in southern Saskatchewan, Canada. These fruits have been found at nearly all localities that have also yielded the characteristic leaves.

Nelumbites striata Berry from the Whitemud formation (Upper Cretaceous) in Canada has all the features of the typical compound foliage of *Trapa angulata* except that the leaflets tend to be eccentrically peltate, the blade being attached to the petiole near the margin or some distance inward. Such leaflets, wherever reported, as at Point of Rocks, Wyo., are found associated with the typical floating foliage of *Trapa angulata*, thus, together with the similarities in anatomy, arousing the suspicion of close relationship, if not identity.

The National Museum's collection of *Trapa angulata* includes many almost perfect rosettes of this plant both from Upper Cretaceous and Paleocene strata. Inspection of these rosettes shows that the leaflets near the center tend to be reniform, rounded, and peltate, and those farther out, spatulate, rounded, truncated, cuneate, and attached basally. The margins are serrate with sharp teeth. The secondary veins or their branches do not, as a superficial glance might indicate, enter the marginal teeth but run into glands at the bases of the teeth at the angle of the sinus.

The affinity of this species with living *Trapa* may well be questioned, and comparison with water-cress, although attractive so far as habit is concerned, is otherwise untenable.

The fruits lack the conspicuous "horns" of the living species.

Occurrence: Fort Union formation (lower), 2421, 3980, 5438, 6360, 8229, 8673, 8678, 8677, 9180; (upper) 2420 (figs. 3–5, 7–12), 8550; Ravenscrag formation, sec. 4, T. 2, R. 22 W., second meridian, Saskatchewan, Canada (figs. 1, 2).

Trapa paulula (Bell) Brown, n. comb.

Plate 58, figure 13

Adiantum? *paululum* Bell, 1949, p. 41, pl. 1, figs. 2, 4, 6, 10.
Leguminosites stagnum Bell, 1949, p. 68, pl. 1, figs. 8, 9.

This species differs from *Trapa angulata* (Newberry) Brown in being notably smaller, with floating rosettes not distinctly four-parted and with cuneate leaflets throughout. The submerged foliage is many times dichotomously forked into filiform divisions. No definite midvein is discernible. Most of the veins arise from the top of the petiole and fork several times, thus simulating roughly the venation of some ferns. The marginal dentition is blunter than that in *T. angulata* and is confined to the apical half of the leaflet.

The figured specimen shows the thickened subsurface portion of the stem that bore the floating rosette of leaves. Farther down the stem are remains of the filiform submerged foliage.

Occurrence: Fort Union formation (lower), 7004 (fig. 13); (upper), 4896.

MELASTOMACEAE

Melastomites montanensis Brown, n. sp.

Plate 56, figures 1, 2, 5, 6

Leaves ovate lanceolate, attaining a length of 15 cm. Apex acute, base cuneate. Margin entire. Venation composed of a strong midvein flanked by one pair of strong primaries that arise from the top of the petiole or from the midrib a short distance above the top of the petiole and upward, extending to the very apex of the blade. Branches from the primaries coalesce near the margin to form a minor pair of intramarginal veins. Midvein, primaries, and intramarginal vein connected by closely spaced, more or less horizontal veinlets and secondaries, as in *Sassafras* and *Cinnamonum*. Surfaces of the better preserved leaves display minute dots, about 300 per sq cm, that were probably glandular. Petioles 2 to 3 cm long.

These leaves are somewhat larger than but resemble those of *Melastomites verus* (Berry) Berry, originally *Cinnamomum vera* Berry, from the Eocene of the Southeastern States. They may be compared favorably with those of a number of species of *Tococa* from South America.

Occurrence: Fort Union formation (lower), 5716, 7005 (fig. 6), 7662 (fig. 5), 8519 (figs. 1, 2), 8897; Ferris formation, 6420.

CORNACEAE

Cornus hyperborea Heer

Plate 59, figure 1

Cornus hyperborea Heer, 1871, p. 476, pl. 50, figs. 3, 4.

Leaves ovate, with cuneate to rounded bases and acute to blunt apexes. Margin entire. Secondary veins usually four on each side of the midvein, curved strongly upward toward the apex. For more than half the length of the leaf, no secondaries branch from the midvein, and there are no branches from the secondaries toward the margin. The tertiary venation is composed of more or less parallel veinlets, 1 or 2 mm apart and at or nearly at right angles to the midvein and secondaries and practically horizontal as viewed by the observer when holding the leaf upright.

These specimens have all the earmarks of being an authentic species of *Cornus*. However, no flowers or seeds of *Cornus* have yet been found in the Paleocene strata of the Rocky Mountain region. The flower described by Knowlton as *Cornus speciosissima* (1922a) from Converse County, Wyo., although superficially comparable, is very likely not that of a dogwood. Moreover, the locality is in the Lance formation (Upper Cretaceous) and is in T. 34 N., not T. 33 N., as cited.

Numerous fossil species of *Cornus*, based chiefly on leaves, have been described—some authentic but most of them probably spurious. As the colored involucral bracts of the flower-heads fall separately, it is most unlikely that the usual four-parted flower head would be preserved intact. If it should be preserved, the center, composed of a number of flowers, would add a characteristic identifying feature. Most so-called fossil dogwood flowers lack this conspicuous center and hence seem unconvincing to me.

This species resembles *Cornus platyphylla* Saporta (1868, p. 391, pl. 11, figs. 8, 9) from Sezanne in the Paris Basin.

Occurrence: Fort Union formation (upper), 4871 (fig. 1), 9109, and an inexact locality in Montana; Middle Park formation, 337.

Cornus nebrascensis Schimper

Plate 59, figures 2–5, 7, 12

Cornus acuminata Newberry, 1868, p. 71.
Cornus nebrascensis Schimper, 1874, v. 3, p. 54.
Cornus impressa Lesquereux, 1878, p. 243, pl. 42, fig. 3.
Cornus newberryi Hollick. Newberry, 1898, p. 124, pl. 37, figs. 2, 3 [not fig. 4, which after cleaning shows prominent teeth and is *Ficus artocarpoides* Lesquereux].

This species differs from *Cornus hyperborea* Heer in having somewhat smaller leaves with more secondaries in the apical halves.

Occurrence: Fort Union formation (lower), 3980, 4626 (fig. 5), 5389 (fig. 12), 5720, 6765, 8567 (figs. 2, 3, 7), 8781, exact locality unknown (Hollick's specimens of *Cornus newberryi*); (upper), 8195 (fig. 4), 8920; Middle Park formation, 337.

Nyssa alata (Ward) Brown, n. comb.

Plate 60, figures 1–4, 6

Sapindus alatus Ward, 1887, p. 68, pl. 31, fig. 4 [not fig. 3, which is *Sapindus affinis* Newberry].
Andromeda scripta Knowlton, 1917, p. 344, pl. 112, figs. 1, 2.
Apeibopsis neomexicana Knowlton, 1917, p. 336, pl. 101, fig. 3.
Chrysobalanus coloradensis Knowlton, 1930, p. 95, pl. 40, figs. 2, 3; pl. 43, figs. 3, 8, 9 [not other figures]; pl. 44, figs. 1, 2.
Chrysobalanus? lanceolatus Knowlton, 1930, p. 96, pl. 44, fig. 5.
Cornus emmonsi Ward, 1887, p. 55, pl. 26, fig. 2 only.
Cornus impressa Lesquereux. Knowlton, 1930, p. 118, pl. 51, fig. 2 only.
Diospyros brachysepala Braun. Ward, 1887, p. 104, pl. 49, figs. 1, 2.
Knowlton, 1930, p. 121, pl. 51, figs. 5–7, 9; pl. 52, fig. 3.
Ficus? alata Knowlton, 1930, p. 64, pl. 23, fig. 9.
Ficus occidentalis (Lesquereux) Lesquereux. Knowlton, 1930, p. 68, pl. 27, fig. 4.
Ficus ovalis Lesquereux, 1878, p. 198, pl. 30, fig. 2.
Inga heterophylla Knowlton, 1917, p. 327, pl. 54, fig. 5.
Laurus socialis Lesquereux. Knowlton, 1930, p. 85, pl. 38, fig. 4.
Nyssa lanceolata Lesquereux. Knowlton, 1917, p. 343, pl. 108, fig. 1; pl. 113, fig. 2; 1930, p. 120, pl. 52, fig. 2.
?*Sapindus obtusifolius* Lesquereux. Knowlton, 1930, p. 102, pl. 46, fig. 3 [same specimen as *Ficus occidentalis*, pl. 27, fig. 4].
Sophora richardsoni Knowlton, 1930, p. 97, pl. 45, fig. 7.
Phyllites calhanensis Knowlton, 1930, p. 130, pl. 56, fig. 1.

The assignment of these leaves to *Nyssa* is unconfirmed by any authentic seeds suggestive of the genus. The leaf identified by Lesquereux (1878, p. 245, pl. 35, fig. 5) as *Nyssa lanceolata*, from the Denver formation at Golden, Colo., is a leaflet of *Fraxinus eocenica* Lesquereux; and the seed, identified with the leaf (renamed by Knowlton, 1930, p. 120, as *Nyssa denveriana*), is so poorly preserved and the artist's drawing of it (Lesquereux, 1878, pl. 35, fig. 6) so idealized that only confusion can result from retaining it as a named object.

The leaves of *Nyssa alata* can be matched by the smaller leaves of the black tupelo, *Nyssa sylvatica* Marshall, of the Eastern United States.

Occurrence: Fort Union formation (upper) 2416 (figs. 2, 4, 6), 5388, 5609, 8224 (fig. 3), 8250, 8257, 8542 (fig. 1), 8774; Dawson arkose 325, 5837, 5838, 8672; Denver formation, 317; Ferris formation, 5971; Raton formation, 5679, 5683, 5704.

Nyssa borealis Brown, n. sp.

Plate 61, figure 4

Leaves elliptic, with entire margins. Secondary veins widely spaced, branching from the midrib almost at right angles and joining the secondaries above in conspicuous loops well within the margin.

These leaves resemble those of the water tupelo, *Nyssa aquatica* Marshall, of the Southeastern United States.

Occurrence: Fort Union formation, 4981 (fig. 4); Ferris formation, 8516.

Nyssa? obovata Knowlton

Nyssa? obovata Knowlton, 1930, p. 121, pl. 54, fig. 1.

No further light on the identity of this specimen has appeared.

Occurrence: Denver formation, 317.

ERICACEAE

Kalmia elliptica Brown, n. sp.

Plate 40, figure 3

Leaves elliptic, with entire margins. Secondary veins conspicuously decurrent at the thick midrib, somewhat undulant or irregular, forking and looping near the margin.

These leaves compare fairly well with those of the mountain laurel, *Kalmia latifolia* Linnaeus of the Eastern United States.

Occurrence: Fort Union formation, 4661 (fig. 3); Denver formation, 317.

OLEACEAE

Fraxinus eocenica Lesquereux

Plate 57, figure 4; plate 62, figures 1–7

Fraxinus eocenica Lesquereux, 1878, p. 229; 1883, p. 123, pl. 20, figs. 1–3.
Knowlton, 1930, p. 123, pl. 52, figs. 4–6.
Aralia alexoensis Bell, 1949, p. 76, pl. 56, figs. 2, 5 [upper leaf]; pl. 59, fig. 1.
Celastrinites insignis (Heer) Bell, 1949, p. 71, pl. 58, fig. 3; pl. 59, fig. 4.
Juglans denveriana Knowlton, 1930, p. 44, pl. 12, figs. 1, 2; pl. 13, figs. 2–4.
Juglans rugosa Lesquereux, 1878, p. 286, pl. 54, figs. 5, 14; pl. 55, figs. 1–9.
Knowlton, 1930, p. 46, pl. 14, fig. 1.

Juglans sp. Knowlton, 1930, p. 48, pl. 14, fig. 5; pl. 15, fig. 1.
Nyssa lanceolata Lesquereux, 1878, p. 245, pl. 35, fig. 5.
Knowlton, 1930, p. 120, pl. 52, fig. 2.
Pterocarya? retusa Lesquereux. Knowlton, 1930, p. 48, pl. 14, figs. 2–4; pl. 15, fig. 5.
Quercus leonis Knowlton, 1930, p. 53, pl. 18, fig. 2 [not fig. 3, which is *Eucommia serrata* (Newberry) Brown].
Quercus straminea Lesquereux, 1878, p. 151, pl. 19, fig. 6.
Quercus whitmani Knowlton, 1930, p. 52, pl. 17, fig. 5.
Sapindus caudatus Lesquereux, 1878, p. 264, pl. 48, fig. 6.
Knowlton, 1930, p. 101.

The leaflets of this species are entire or remotely toothed, asymmetric, ovate lanceolate, elliptic, or oblanceolate in outline, petioled, with acute or attenuated apexes and cuneate to rounded bases. Fragments of the compound leaves with three leaflets still attached have been found, but no seeds attributable to *Fraxinus* have been recovered.

Some of the specimens here assigned to *Fraxinus eocenica* were originally identified by Lesquereux as *Juglans rugosa* and came from a locality doubtfully considered to be Evanston, Wyo. The complicated history of *J. rugosa* was discussed by Knowlton (1930, p. 46). Other correlative specimens, however, were identified simultaneously by Lesquereux as *Fraxinus eocenica*, from the Denver formation at Golden, Colo. This seems to be a more satisfactory allocation.

Occurrence: Fort Union formation (lower), 4626 (pl. 62, fig. 7), 4661, 8165; (upper), 5760, 8234 (pl. 62, fig. 1), 8774 (pl. 62, figs. 3–5; pl. 57, fig. 4); Coalmont formation, 6105 (pl. 62, fig. 6); Denver formation, 317 (pl. 62, fig. 2); Evanston formation, 3658; Middle Park formation, 337.

APOCYNACEAE

Apocynophyllum lesquereuxi Ettingshausen

Apocynophyllum lesquereuxi Ettingshausen, 1883, p. 132.
Knowlton, 1917, p. 345.
Apocynophyllum linifolium Knowlton, 1917, p. 346, pl. 104, fig. 3.
Apocynophyllum wilcoxensis Berry. Knowlton, 1917, p. 345, pl. 103, fig. 3; pl. 105, figs. 1, 2; pl. 106, fig. 1.
Quercus neriifolia Brown. Lesquereux, 1878, p. 150, pl. 19, fig. 5 only.

The published illustrations of these leaves are for the most part unsatisfactory and misleading. In actuality the secondary veins are numerous and fairly closely spaced but are unequally parallel, and with the intersecondaries, are quite irregular and variously branched or interconnected, and are united to form an intramarginal vein. As remarked by nearly all students dealing with these leaves, their affinity is more probably with the Myrtaceae than with the Apocynaceae, but, lacking suggestive fruits as evidence, doubt about their correct allocation will continue to be entertained.

Occurrence: Raton formation, 5611, 5684, 5701, 5798.

CAPRIFOLIACEAE

Viburnum antiquum (Newberry) Hollick

Plate 63, figures 1–8; plate 64, figure 4

Tilia antiqua Newberry, 1868, p. 52.
Viburnum antiquum (Newberry) Hollick. Newberry, 1898, p. 128, pl. 33, figs. 1, 2.
Berry, 1935, p. 58, pl. 17, fig. 3 only.
Viburnum betulaefolium Ward, 1887, p. 114, pl. 57, fig. 4.
Viburnum dakotense Lesquereux, 1883, p. 231, pl. 46A, fig. 9.
Viburnum dentoni Lesquereux, 1883, p. 231, pl. 49, figs. 2, 3.
Viburnum elongatum Ward, 1887, p. 112, pl. 54, figs. 4, 5.
Viburnum limpidum Ward, 1887, p. 110, pl. 53, figs. 3–6.
Viburnum macrodontum Ward, 1887, p. 110, pl. 53, fig. 2.
Viburnum nordenskioldi Heer. Lesquereux, 1883, p. 230, pl. 49, fig. 4.
Viburnum oppositinerve Ward, 1887, p. 112, pl. 55, figs. 1, 2.
Viburnum perfectum Ward, 1887, p. 109, pl. 52, figs. 3, 4; pl. 53, fig. 1.
Viburnum perplexum Ward, 1887, p. 111, pl. 54, figs. 2, 3.
Viburnum whymperi Heer, 1869, p. 475, pl. 46, fig. 1b.
Ward, 1887, p. 111, pl. 54, fig. 1.
Alnus serrata Newberry. Bell, 1949, p. 52, pl. 33, fig. 6.
Corylus macquarrii (Forbes) Heer. Lesquereux, 1883, p. 223, pl. 49, fig. 4.
Diospyros ficoidea Lesquereux. Ward, 1887, p. 105, pl. 49, fig. 4 only.
Ficus viburnifolia Ward, 1887, p. 42, pl. 22, figs. 4–8.
Grewia obovata Heer. Ward, 1887, p. 88, pl. 39, fig. 7 only.
Hedera parvula Ward, 1887, p. 57, pl. 26, fig. 4.
Monimiopsis fraterna Saporta. Ward, 1887, p. 52, pl. 25, fig. 3.
Populus grewiopsis Ward, 1887, p. 23, pl. 9, fig. 1.

In this synonymy I have grouped those viburnum-like leaves having a broad-ovate, elliptic, or cordate outline; a margin with large, rounded, dentate to serrate teeth; and secondaries widely spaced, somewhat irregular and undulating and conspicuously branched. Exceptions to this general statement appear to be *Diosypros ficoidea*, *Ficus viburnifolia*, and *Hedera parvula*. These I regard as extreme or abnormal variants from the general average. *Diosypros ficoidea* was figured as an entire-margined leaf. The type specimen, however, is not as perfect as the sketch, much of the margin being missing, but on that which is preserved, undulations may be seen which suggest rudimentary teeth. *Ficus viburnifolia* (Ward's fig. 8) has an entire margin and resembles *Hedera parvula*. Both seem to me to be abnormal or malformed leaves. The normal leaves of *V. antiquum* find matches among those of several living species.

The seeds found at locality 4264 in association with typical leaves of this species appear to be more clearly referable to *Viburnum* than those identified by Ward as *V. tilioides*. These seeds were flattened and had four longitudinal furrows.

Occurrence: Fort Union formation (upper), 2414 (pl. 63, figs. 1–7), 2416, 4264, 4974, 8166 (pl. 63, fig.

8), 8230, 8255, 8523, 8774, 9071 (pl. 64, fig. 4), 9125; Ferris formation, 6971.

Viburnum asperum Newberry

Plate 64, figures 1–3, 5, 7–11

Viburnum asperum Newberry, 1868, p. 54; 1898, p. 129, pl. 33, fig. 9.
  Ward, 1887, p. 113, pl. 55, figs. 4–9.
  Berry, 1935, p. 56, pl. 16, figs. 1–4.
  Bell, 1949, p. 79, pl. 62, fig. 2; pl. 67, figs. 4, 6.
Viburnum castrae Knowlton and Cockerell. Knowlton, 1919, p. 641, for *V. lanceolatum* Newberry, 1898, p. 131, pl. 33, fig. 10.
  Berry, 1935, p. 56, pl. 15, fig. 5.
Viburnum erectum Ward, 1887, p. 112, pl. 55, fig. 3.
Viburnum newberrianum Ward, 1887, p. 113, pl. 56, figs. 1–6.
Viburnum nordenskioldi Heer. Ward, 1887, p. 114, pl. 57, figs. 1–3.
Viburnum antiquum mut. *trinervum* Berry, 1935, p. 60, pl. 7, fig. 6; pl. 15, fig. 6.
Alnus nostratum Unger. Heer, 1868, p. 103, pl. 47, figs. 12a, b.
Amelanchier similis Newberry, 1898, p. 111, pl. 40, fig. 6.
Cornus denverensis Knowlton. Bell, 1949, p. 76, pl. 56, fig. 5 [part.]
Ficus limpida Ward, 1887, p. 42, pl. 22, fig. 3.
Rhamnites concinnus Newberry, 1898, p. 118, pl. 33, figs. 7, 8.
Rhamnus goldianus Lesquereux. Knowlton, 1917, p. 332, pl. 112, fig. 5.
Tilia weedi Knowlton, 1902, p. 706, text fig. 1.
Ulmus praecursor Dawson, 1886, p. 28, pl. 2, fig. 11.

The striking features of these leaves are the remarkable smoothness and grace in the curvature of the many secondary veins; the numerous closely spaced connecting veinlets; the regular, rounded to pointed, crenate-serrate teeth; the tendency to have strong basal secondaries with many branches; and the lanceolate-pointed shape with rounded or cordate sometimes slightly asymmetric base.

The leaf called *Amelanchier similis* Newberry is apparently somewhat abnormal, and this, together with the fact that it was incorrectly illustrated in critical details, almost masks its relationship to *Viburnum asperum.* Its venational and marginal features, however, on close examination are distinctive. The leaf described as *Tilia weedi* Knowlton (fig. 11) is an unusually large example of *V. asperum.*

These leaves resemble those of the hamamelidaceous species *Corylopsis sinensis* Hemsley, but particularly those of the cornaceous *Davidia involucrata* Baillon, of western China.

The species, with other associates, is a fairly reliable index for the Paleocene of the Rocky Mountains and Great Plains. At only one Upper Cretaceous locality, about 4 miles east of Reed Point, Mont., have I found probable ancestral specimens (pl. 64, fig. 6) that simulate the leaves of this species, except that they are smaller and somewhat more asymmetrical.

Occurrence: Fort Union formation (lower) 8519, 8558, 8654, 8673, 8678 (figs. 7, 8), 9056 (figs. 9, 10); (upper), 607 (fig. 11), 2417 (figs. 1, 3), 2422, 4871, 5194, 5882, 6377, 8166, 8192, 8213, 8222, 8520 (fig. 5), 8885 (fig. 2), 8921, 8922, 9322.

Viburnum cupanioides (Newberry) Brown, n. comb.

Plate 46, figure 1; plate 57, figure 1; plate 65, figures 1–8

Phyllites cupanioides Newberry, 1868, p. 74; 1898, p. 135, pl. 41, figs. 3, 4.
Pterospermites cupanioides (Newberry) Knowlton, 1893, p. 35, pl. 2.
Celtis rugosa Newberry, 1883, p. 510.
Celtis lingualis Knowlton and Cockerell. Knowlton, 1919, p. 160.
Phyllites carneosus Newberry, 1898, p. 134, pl. 41, figs. 1, 2.
Phyllites carneosa (Newberry) Bell, 1949, p. 55, pl. 35, figs. 1–3; pl. 36, figs. 1–6.
Phyllites venosus Newberry, 1898, p. 136, pl. 30, fig. 4.
Pterospermites minor Ward, 1887, p. 95, pl. 42, figs. 1–3.
  Berry, 1935, p. 48, pl. 11, fig. 4.
Pterospermites whitei Ward, 1887, p. 94, pl. 41, figs. 5, 6.
  Bell, 1949, p. 69, pl. 4, fig. 3.
Rhamnites marginatus (Lesquereux) Bell, 1949, p. 73, pl. 61, fig. 5.
Sapindus? membranaceus Newberry, 1878, p. 117, pl. 30, fig. 3 only.
Viburnum paucidentatum Newberry, 1883, p. 511.

The general outline, marginal dentition, and venation of these leaves can be matched most readily in *Viburnum.* Indeed, several specimens assigned to this species might serve as connecting links with *Viburnum antiquum* (Newberry) Hollick.

The leaf described by Newberry as *Celtis rugosa*, renamed *C. lingualis* by Knowlton and Cockerell, and that called *Viburnum paucidentatum* were never illustrated or again referred to by Newberry; nor is the present location of the specimens known. The descriptions, however, suggest their assignment to this species.

Occurrence: Fort Union formation (lower) 4514, 4625 (pl. 65, fig. 6), 5885 (pl. 57, fig. 1), 5889 (pl. 65, figs. 5, 7), 6050 (pl. 65, fig. 2), 8519, 8521, 8627, exact locality unknown (pl. 65, fig. 1, reproduction of Newberry, 1898, pl. 30, fig. 4); (upper), 2420 (pl. 65, figs. 3, 4), 5324, 8190 (pl. 46, fig. 1), 8774, 8910, 8920, 9322; Paskapoo formation, Alberta, Canada.

Viburnum tilioides Ward

Plate 67, figures 18, 19, 24, 25, 30, 31

Viburnum tilioides Ward, 1887, p. 107, pl. 51, figs. 4–8 [not other figures, which are *V. antiquum* (Newberry) Hollick].
Carpites sulcatus Knowlton, 1924, p. 96, pl. 19, figs. 3, 4.

As at least two authentic species of *Viburnum* and one species of *Nyssa* are represented by leaves from the same strata at or near the same locality that yielded the types of these seeds, there is reasonable doubt concerning the relationship of the leaves and seeds. The seeds may not even be those of *Viburnum* or *Nyssa.* Some may well be mistaken for those of *Trapa angulata* (Newberry) Brown. Others bear considerable resemblance to the cornaceous seeds assigned by Kirchheimer to *Mastixia,* from the brown coal deposits of Germany.

Occurrence: Fort Union formation (lower) 4626, 5509, 5619, 8519, 8554 (fig. 25); (upper), 2414 (fig. 19), 2424, 8196 (figs. 18, 24), 8225 (fig. 31), 8774 (fig. 30); Animas formation, 7496.

OBJECTS OF UNCERTAIN CLASSIFICATION

Macclintockia kanei (Heer) Seward and Conway

Macclintockia kanei (Heer) Seward and Conway, 1935, p. 24, pl. 2, figs. 16, 17, 20, text fig. 9.
Cocculus kanii (Heer) Saporta and Marion, 1873, p. 63, pl. 10, fig. 1.
Daphnogene kanii Heer, 1868, p. 112, pl. 14; pl. 16, fig. 1. Saporta and Marion, 1873, p. 65, pl. 10, figs. 2, 3.
Macclintockia dentata Heer, 1868, p. 115, figs. 3, 4.
Macclintockia lyallii Heer, 1868, p. 115, pl. 15, figs. 1a, 2; pl. 16, figs. 7a, 7b; pl. 17, figs. 2a, 2b; pl. 47, fig. 13; pl. 48, fig. 8.
Macclintockia trinervis Heer, 1868, p. 115, pl. 15, figs. 7–9; 1883, p. 95, pl. 77, fig. 8.

The spelling *kanei* for this species is here used as being more appropriate to the dedicatee, Dr. Elisha Kane.

Heer, in my opinion, was not justified in defining three species of dentate-leaved *Macclintockia* from the same locality; and for defining entire leaves, having the same texture and internal architecture as the dentate leaves, as a species in a different genus and family. All these leaves appear to be variants of a single species.

No authentic Paleocene *Macclintockia* foliage has been reported from the mainland of North America. *Daphnogene kanii* Heer, reported from the Eocene of Alaska by Hollick (1936, p. 121, pl. 67, fig. 11), although somewhat like Heer's types, differs by having its pair of primary veins arise from the midrib at a considerable distance above the top of the petiole. Similar leaves occur in the Eocene lignitic strata of Washington. The *Cocculus kanii* specimen reported by Berry (1926, p. 111, pl. 16, fig. 2) from the Eocene at Kitsilano, British Columbia, appears to have the form of *Macclintockia kanei,* but venational details are missing, so that no definite conclusion can be drawn.

Heer, on the basis of fragments, reported two species of *Macclintockia* from the Upper Cretaceous of Greenland at Igdlokunguak on Disko Island: *M. cretacea* (1880, p. 70, pl. 36, figs. 1, 2a; pl. 37, figs. 2–4), and *M. appendiculata* (1880, p. 71, pl. 37, fig. 1). If these fragments, as illustrated, are authentic, they may represent forerunners of the Paleocene *M. kanei.*

Macclintockia kanei differs little from *M. heersiensis* Saporta and Marion (1878, p. 55, pl. 9, fig. 1) from the Paleocene at Gelinden, Belgium.

No satisfactory conclusion has been reached about the botanic classification of this species. Comparisons often made with *Cocculus laurifolius* DeCandolle, though suggestive, are not completely convincing.

Occurrence: Atanekerdluk, Greenland.

Phyllites demoresi Brown, n. sp.

Plate 61, figures 5–8

Leaves ovate to ovate lanceolate, with rounded bases and acuminate apexes. Margin entire. Petiole slender, more than 3 cm long. Venation pinnate, with secondaries widely spaced, forming conspicuous, closed loops well within the margin. Intersecondaries common.

Named for the Marquis DeMores, who founded the town of Medora, N. Dak.

Occurrence: Fort Union formation (upper), 4264 (figs. 5, 6, 8), 4879, 4892, 8196 (fig. 7).

Phyllites disturbans Brown, n. sp.

Plate 60, figures 5, 7–10

Leaves elliptic, with acute apexes and cuneate bases. Secondary veins evenly spaced, camptodrome. Margin entire or very obscurely, distantly, and minutely toothed.

Occurrence: Fort Union formation (upper) 4262 (fig. 7), 6342 (fig. 8), 7659 (fig. 5), 8563 (figs. 9, 10).

Phyllites pagosensis Knowlton

Plate 18, figure 10

Phyllites pagosensis Knowlton, 1924, p. 97, pl. 16, fig. 2.
Ulmus sp. Knowlton, 1917, p. 300, pl. 70, fig. 4.

The leaf fragments here cited and figured seem to be closely related morphologically. Their margins have large double teeth, and their slightly arched secondary veins enter the major marginal teeth. Branchlets from the secondaries enter the subsidiary teeth.

Ulmaceous affinities may be indicated here, but some rosaceous genera also have leaves displaying somewhat similar features. Somewhat comparable leaves called *Ulmus sorbifolia* Göppert (Hollick, 1936, p. 106, pl. 57, figs. 3–5) occur in the Tertiary floras of Alaska.

Occurrence: Animas formation, 7496; Denver formation, 317 (fig. 10); Raton formation, 5695.

Calycites hexaphylla Lesquereux

Plate 4, figure 11

Calycites hexaphylla Lesquereux, 1873, p. 402.

Diospyros hexaphylla (Lesquereux) Knowlton, 1919, p. 238.
Diospyros wodani Unger. Lesquereux, 1878, p. 233, pl. 59, fig. 13.

The lobes of *Calycites hexaphylla* differ from those of *C. polysepala* Newberry in being longer, slightly spatulate, and finely striate. The unlobed portion is smaller and has a central, craterlike depression. No remains of stamens or pistils are present.

Lesquereux's figured specimen of *Diospyros wodani* fortunately retains a long peduncle. Excavation of the upper part of the peduncle and the bases of the six lobes shows a true six-parted calyx underneath, 8 mm in diameter, and having short pointed lobes that alternate with those of the "corolla" above. The specimens, therefore, are gamopetalous flowers, with the 6 petals and 6 sepals, respectively, united near their bases. The affinity of these flowers is uncertain but may be with the Lauraceae, species of which are represented by leaves in the Paleocene flora.

Occurrence: Fort Union formation (lower), 9248 (fig. 11), 9249; Evanston formation, 1471.

Calycites polysepala Newberry

Plate 4, figure 5

Calycites polysepala Newberry, 1898, p. 139, pl. 40, fig. 3.

Newberry's type has seven lobes. Other specimens in the collection have six, seven, and eight lobes. The sinuses between the lobes are rounded, not sharply angular, but there are no discernible definite markings on the lobes. The unlobed central portion of the specimens shows a broad, shallow, saucerlike depression, with no apparent diagnostic features. No peduncle has been seen but a central pit or scar may represent the point of attachment of a peduncle.

Superficially, except for the rounded sinuses, these specimens resemble species of earthstar puffballs (*Geaster*) somewhat like the doubtful *Geaster florissantensis* Cockerell from Oligocene lakebeds at Florissant, Colo. Smaller specimens bearing the names *Antholithes browni* Berry (1930, p. 77, pl. 15, fig. 3) and *A. fremontensis* Berry (1930, p. 78, pl. 15, fig. 2), which are clearly synonymous, are known from the middle Eocene of the Wind River Basin in Wyoming. Other and more suggestive comparisons could perhaps be made, but the true affinity of these "calyces" remains for the present unknown.

Occurrence: Fort Union, exact locality unknown (fig. 5). One specimen from an unspecified locality near Dickinson, N. Dak., was collected by R. L. Coville.

Carpolithes spinosus Newberry

Carpolithes spinosus Newberry, 1898, p. 138, pl. 68, figs. 2, 3.

Occurrence: ?Raton formation, North Fork of the Purgatoire River, Colo.

Nordenskioldia borealis Heer

Plate 67, figures 13, 45

Nordenskioldia borealis Heer, 1871, p. 65, pl. 7, figs. 1–13; 1880, p. 13, pl. 6, fig. 8.
Bell, 1949, p. 80, pl. 18, fig. 2; pl. 21, fig. 3.
Carpites cocculoides (Heer) Schimper. Lesquereux, 1878, figs. 32–35.
Carpites cocculoides var. *major* Lesquereux, 1878, p. 307, pl. 60, p. 307, pl. 60, figs. 38, 39.
Carpolithes cocculoides Heer, 1871, p. 484, pl. 52, figs. 9, 9b.
Diospyros brachysepala Alexander Braun. Heer, 1868, p. 117, pl. 47, figs. 4b, 5, 5f, 5g.

The surface markings of these lunate impressions are veinlike, diagonal, and forked. Thus, there is a superficial resemblance between *Nordenskioldia* and the capsules of *Cercidiphyllum*, and inasmuch as both are found together at many localities, there is likelihood of confusion if the specimens are not carefully examined. In outline, *Nordenskioldia* impressions resemble seeds of persimmon, *Diosypros*, with one side practically straight and the remainder of the border arched. The seeds of *Nordenskioldia*, however, were packed around a central axis like those of *Malva*, and the fruits were sessile, alternate, and opposite (fig. 45), at intervals on a long rachis. There seems as yet no inkling as to the correct botanical affinity of *Nordenskioldia.*

Occurrence: Fort Union formation (lower), 4661, 5509, 5918, 8240, 8654, 9130; (upper) 2420, 4870, 4892, 5618, 8167, 8234, 8236, 8887 (fig. 45), 8910, 8913 (fig. 13), 8917, 9125; Coalmont formation, 6110.

Palmocarpon commune Lesquereux

Palmocarpon commune Lesquereux, 1878, p. 119, pl. 13, figs. 4–7.
Palmocarpon mexicanum (Lesquereux) Lesquereux, 1878, p. 119, pl. 11, fig. 5.

The identifying feature of these roundish flattened seeds is the somewhat narrow elliptic scar (perhaps a raphe) with a nipple in the middle of the broader end, well illustrated in Lesquereux's plate 13, figure 7. What species of living palm, if any, produces seeds of this kind?

Occurrence: Denver formation, 317; Raton formation, exact locality uncertain.

Palmocarpon compositum Lesquereux

Palmocarpon compositum Lesquereux, 1878, p. 119, pl. 11, fig. 4.
Euphorbocarpum richardsoni Knowlton, 1917, p. 328, pl. 96, figs. 3, 4.

The assignment of these specimens to either the Palmaceae or Euphorbiaceae is unconfirmed by convincing evidence.

Occurrence: Raton formation, 5046, and an uncertain locality.

Palmocarpon lineatum Lesquereux

Palmocarpon lineatum Lesquereux, 1888, p. 44.
Knowlton, 1930, p. 42, pl. 11, fig. 5.

Assignment of these seeds to the Palmaceae is dubious.

Occurrence: Denver formation, 317.

Palmocarpon subcylindricum Lesquereux

Plate 67, figure 37

Palmocarpon subcylindricum Lesquereux, 1878, p. 121, pl. 11, fig. 12.
Knowlton, 1930, pl. 52, fig. 3b.

Lesquereux said of his specimens that they were split in two at the top. Careful excavation of these objects, however, shows that the tops are three-parted and that the bottoms have a well-defined roundish attachment scar. Knowlton's plate 52, figure 3b, illustrates a specimen with a broad cuplike base or a thick peduncle. Something about these objects suggests that they are empty calyces of some flower. That they belonged to palms seems doubtful.

Occurrence: Fort Union formation, 4901, 5918; Denver formation, 317 (fig. 37).

Palmocarpon truncatum Lesquereux

Palmocarpon truncatum Lesquereux, 1878, p. 120, pl. 11, figs. 6–9.
Ginkgo? *truncata* (Lesquereux) Knowlton, 1930, p. 34, pl. 9, fig. 3.

The long peduncle (see Knowlton's pl. 9, fig. 3) of these specimens seems to rule out assignment to the palms; and the "fleshy cup" referred to by Knowlton seems on examination of the specimen itself to be a remnant of a once larger enclosing sheath or calyx, thus casting doubt on the assignment to *Ginkgo*. Moreover, no foliage attributable to *Ginkgo* has yet been found at the plant localities in the Denver formation on South Table Mountain near Golden, Colo. It is probable that these objects belong with *Palmocarpon subcylindricum* Lesquereux.

Occurrence: Denver formation, 317, 325.

Viburnum goldianum Lesquereux

Viburnum goldianum Lesquereux, 1878, p. 227, pl. 60, figs. 2, 2a–c.

Nothing new has been learned about the true identity of these seeds, but reference of them to *Viburnum* is questionable.

Occurrence: Denver formation, 317.

Viburnum solitarium Lesquereux

Plate 67, figures 33, 34

Viburnum solitarium Lesquereux, 1878, p. 227, pl. 60, fig. 3.
Carpites rhomboidalis Lesquereux, 1878, p. 306, pl. 60, figs. 28, 29.

These small seeds had ovate kernels, apparently enclosed in a bivalved shell whose suture in fossilization made a wide flange, squarish at the top. The assignment to *Viburnum* is dubious.

Occurrence: Denver formation, 317 (figs. 33, 34); Laramie formation (Upper Cretaceous) for *C. rhomboidalis.*

Ophiomorpha nodosa Lundgren

Ophiomorpha nodosa Lundgren. Häntzschel, 1952, p. 148, pls. 13, 14. [See synonymy and discussion.]
Halymenites major Lesquereux. Brown, 1939b, p. 253, pl. 62, figs. 1–7; pl. 63, figs. 1, 2.

Thus far the only specimens of this kind found in the Paleocene of the Rocky Mountains and Great Plains were taken from the sandy facies of the Cannonball member of the Fort Union formation by T. W. Stanton in 1913 in the right bank of Heart River, one-half a mile south of Mandan, N. Dak. They are fragmentary but characteristic. In Europe, Watelet (1866, p. 24, pl. 4, fig. 1) reported a specimen from the upper Paleocene of the Paris Basin, which he called *Phymatoderma dienvalii*, now synonymized by Häntzschel, with *Ophiomorpha nodosa.*

As stated in my study of *Halymenites major* in 1939 and by Häntzschel in his review of *Ophiomorpha* in 1952, there is strong evidence that this supposed alga represents the burrow of a marine animal, probably a crustacean. As yet, however, no remains of the purported burrowers themselves have been found in or directly connected with the burrows. Field geologists and collectors should keep this problem in mind and be on the lookout for such conclusive evidence.

Occurrence: Fort Union formation (lower), 6525.

MISCELLANEOUS LEAVES, FRUITS, SEEDS, FLOWERS, ROOTS, AND PROBABLE ANIMAL REMAINS

Plate 57, figure 3

Leaves large, ovate, with cuneate bases and rounded or blunt apexes. Margin with minute scattered sharp-pointed teeth. Venation pinnate, the secondaries evenly spaced, camptodrome. Intersecondaries common. Veinlets connecting the secondaries subparallel, oblique. Fort Union formation, 8774.

Plate 66, figure 4

Palmately veined leaf, with cordate base, and a few coarse marginal teeth. Fort Union formation, 8920.

Plate 66, figure 5

Narrow elliptic leaves or leaflets with undulate to toothed margins, but teeth few, blunt, and serrate. Venation obscure, but apparently palmate with the veins extending well toward the apex. These may be leaflets of *Trapa angulata* (Newberry) Brown. Fort Union formation, 6215.

Plate 67, figure 5

A five-loculed fruit, pentagonal in outline, simulating the seed case of an apple after the flesh has been removed. A somewhat similar fruit was described by Reid and Chandler (1933, p. 469, pl. 26, figs. 31–38) as *Sapoticarpum latum*, from the Eocene London clay. Fort Union formation, 8247.

Plate 67, figures 6, 7

Winged, maplelike samaras, but with long peduncles, thus suggesting some genera in the soapberry family, Sapindaceae. Fort Union formation, 9125.

Plate 67, figures 9, 14, 15, 16, 20, 22, 23, 27

Ovate seeds with a thin shell or skin whose outer surface was fairly smooth but whose inner surface was marked by closely packed papillae, squarish protuberances, or cavities as the case may be. Seeds of *Actinidia* might leave such impressions. Fort Union formation, 4031, 4320, 4896, 4901, 5438, 6215 (figs. 15, 22, 23, 27), 8519, 8550 (figs. 9, 14) 8910, 9109, 9236 (figs. 16, 20); Denver formation, 317.

Plate 67, figure 10

A flattened carbonized specimen, elliptical in outline and showing irregular angular divisions as though it represented a multiple fruit. The surface of each division is marked by two overlapping depressions, one smooth and shallow, the other with a central pit. Whether this object was originally round before being flattened is unknown. Fort Union formation, 6382.

Plate 67, figures 11, 12, 17

Narrow wrinkled specimens, blunt rounded at one end and squarish, fringed at the other. Possibly a fruit, topped by the remnants of a calyx. Fort Union formation, 4626 (fig. 11), 8547 (fig. 17), 8566 (fig. 12), 8917.

Plate 67, figure 21

A spike or catkin of seedlike bodies that are somewhat lunate in shape with two or three concentric folds. As these catkins were found with matted palm leaves, there is some suspicion that they may have been parts of a flowering palm spadix. Fort Union formation, 8519 (fig. 21); Evanston formation, exact locality unknown.

Plate 67, figure 26

Ovate seeds with longitudinal rows of pits. Fort Union formation, 4618 (fig. 26), 8551.

Plate 67, figures 28, 29

Oval seeds with five or more conspicuous longitudinal ridges and furrows with scattered glandlike marks on the surface of the furrows. Fort Union formation, 4264.

Plate 67, figure 32

Flat heart-shaped apparently two-lobed fruits, occurring in clusters. Fort Union formation, 8519 (fig. 32), 8775.

Plate 67, figure 35

An elliptic flat object, divided into two equal halves by a median, longitudinal line. Numerous fine hairs radiate from the margin. The specimen is somewhat like the Upper Cretaceous *Carpolithus hirsutus* Newberry. Fort Union formation, 4977, 8522 (fig. 35).

Plate 67, figure 36

An oval fruit, which, according to the longitudinal ridges, may have been multilocular. Fort Union formation, 8167.

Plate 67, figure 38

Oval seeds with wide flanges, rounded at both ends. Animas formation, 5667.

Plate 67, figures 39–42, 47

These are apparently burs, with a few relatively stout, sometimes branched, sharp-pointed spines. In figure 47 the burs are definitely associated with round fruitlike bodies. They may be the fruits of a sandburgrass, *Cenchrus*. Fort Union formation, 2427, 7538 (figs. 39–42), 9109 (fig. 47).

Plate 67, figure 43

An elliptic body covered with roundish projections. This object may be the fertile cone of a species of *Equisetum*. Fort Union formation, 6905.

Plate 67, figure 44

This fragment appears to have been a cylindrical object originally, and is now studded with bilobed projections. Fort Union formation, 9130.

Plate 67, figure 46

Small calyces, with five blunt slightly unequal lobes. These resemble the calyces and corollas of elderberry, *Sambucus*. Fort Union formation, 5194, 8774 (fig. 46).

Plate 68, figures 2, 7–11

Roots, with rootlet scar pits in three or more longitudinal rows. Specimens have been taken from nearly every formation from the Upper Cretaceous to the Eocene, but to what plant they belonged is unknown. Fort Union formation (lower), 5614; (upper) 8668 (fig. 10); Animas formation, 5458, 5461, 8669 (fig. 2); Ferris formation, 3963; Livingston formation 6765 (fig. 11); Middle Park formation, 337; Raton formation, 5129. Upper Cretaceous, Fruitland formation, 4468 (fig. 7); Eocene, Wind River formation, 9533 (fig. 9); Fossil Forest Ridge, Yellowstone National Park, 750 (fig. 8).

Plate 68, figures 17–22

Two-winged seeds, simulating those of catalpa and other Bignoniaceae. A seed similar to these was described for Göppert by Weber (1851, p. 233, pl. 25, fig. 5) and called *Dipterospermum bignonioides*, from Oligocene lignitic strata near Bonn in the Rhineland. Reid and Chandler (1926, p. 129, pl. 8, fig. 20) also described a similar seed, *Radermachera pulchra*, from the Bembridge beds (Oligocene) of the Isle of Wight. Fort Union formation, 8910.

Plate 68, figure 25

This small roundish square-beaked seed is probably a stone-fruit of some kind. Fort Union formation, 8913.

Plate 68, figure 26

This boat-shaped object resembles the glumes or bracts of some grasses. Fort Union formation, 8913.

Plate 68, figures 27–29

Small pedicelled fruit or flowerlike objects. Fort Union formation, 5595 (fig. 29), 9109 (fig. 27), 9125 (fig. 28).

Plate 69, figure 1

Feather of an unknown bird. This feather is preserved in the pinkish baked shale from above a burned coal bed about 10 miles north of Glendive, Mont. It was found about 1930 by John S. Larimer, former jeweler at Glendive, and given to me by his son in 1950. Bird feathers and down have sometimes been mistaken for plant remains, as for example Lesquereux's supposed moss, *Fontinalis pristina* (1883, p. 135, pl. 21, fig. 9), from Oligocene lakebeds at Florissant, Colo., and Cziffery-Szilagyi's *Donacites erdobenyensis* (1955, p. 164, fig. 7, on p. 31) from the Miocene of Hungary.

Plate 69, figures 15–19

Ropy striated concretions blunt pointed at both ends when perfect. These are found with others that are more irregular, warty, and without striations. Figures 16–19 represent specimens from a clayey, silty stratum in the Fort Union formation, 8 miles south of Rhame, N. Dak. They are composed of limonite and are rusty brown on the surface. That they were chiefly siderite before they were oxidized to limonite is inferred from the fact that the comparable specimen, figure 15, from Miocene strata (Roberts, 1958, p. 35) on Cedar Creek, a tributary of Salmon Creek, Wash., is still largely siderite, without discernible organic matter, like most of its kind at that locality. These come from a bluish clay containing some woody material and, locally, well-preserved leaves and seeds. Speculation has ranged widely in attempts to account for these objects, but the most persistent hypothesis, based on their shape and their occurrence in fluvial deposits, is that they are coprolites, perhaps of large fishes, turtles or other reptiles.

OTHER OBJECTS OF UNCERTAIN OR MISTAKEN IDENTITY

Besides the foregoing illustrated objects of uncertain though most likely of organic affinity, the Paleocene collections contain many other seeds, fruits, flowers, and problematica not here described or illustrated. Many of these are not well preserved, are not good subjects for photography, and, although exciting curiosity and stimulating much thought without definite classificatory results, are here deemed best to remain temporarily nameless.

Some objects hitherto thought to be seeds, fruits, or other parts of plants, are now known to be of inorganic origin. Thus, for example, Ward (1887, p. 14, pl. 1, fig. 3) described a specimen he identified as an alga, *Spiraxis bivalvis*. This is a concretion, showing the original bedding planes of the sandstone that gave Ward the mistaken impression that these were spirally alined. On revisiting the locality I found similar specimens and verified their identity as concretions.

Stainbrook (1924) described an object he thought might be a fossil fruit, from Chimney Butte in SW¼ sec. 29, T. 139 N., R. 102 W., North Dakota. At this locality on September 7, 1949, I found numerous similar specimens. All are concretions, the centers of which in many instances are somewhat septarian thus giving the deceptive appearance of being locular fruits.

THE MICROSCOPIC PLANTS

Although plant microfossils from Paleozoic coal seams and associated strata have received considerable attention, those from Mesozoic and Cenozoic strata have, until recently, been more or less neglected. Led by the investigation of the pollens and spores in Pleistocene and Recent peat bogs and the microfossils of the middle Eocene Green River formation, the trend now seems strong toward a comprehensive study of the Mesozoic and Cenozoic microscopic flora. E. L. Miner (1935) found numerous spores in the Cretaceous coals of Montana and one species, *Selaginellites mirabilis* (now *Triletes mirabilis* (Miner) Schopf, Wilson, Bentall), in the Paleocene coal at the Homer mine, Bear Creek, Mont. Subsequently, Wilson and Webster (1946) reported the following species from the Kolarich coal mine (Paleocene) in sec. 25, T. 7 S., R. 20 E., 2 miles east of Red Lodge, Mont.:

Alnus speciipites Wodehouse. Wilson and Webster (1946, p. 275, figs. 10, 11).
Betula claripites Wodehouse. Wilson and Webster (p. 275, fig. 12).
Brachysporium sp. Wilson and Webster (p. 271, fig. 1).
Carya veripites Wilson and Webster (p. 276, fig. 14).
Carya viridifluminipites (Wodehouse) Wilson and Webster (p. 276, fig. 13).
Cycadopites follicularis Wilson and Webster (p. 274, fig. 7).
Deltoidospora diaphana Wilson and Webster (p. 273, fig. 3).
Laevigatosporites gracilis Wilson and Webster (p. 273, fig. 4).
Laevigatosporites ovatus Wilson and Webster (p. 273, fig. 5).
Momipites coryloides Wodehouse. Wilson and Webster (p. 275, fig. 15).
Picea grandivescipites Wodehouse. Wilson and Webster (p. 275, fig. 8).
Quercus priscipites Wilson and Webster (p. 276, fig. 16).
Sequoia lapillipites Wilson and Webster (p. 275, fig. 9).
Sparganium globipites Wilson and Webster (p. 276, fig. 18).
Sphagnum antiquasporites Wilson and Webster (p. 273, fig. 2).
Taxodium hiatipites Wodehouse. Wilson and Webster (p. 275, fig. 6).
Typha latifolipites Wilson and Webster (p. 276, fig. 17).

Study of the Mesozoic and Cenozoic plant microfossils may prove helpful in checking the identification of the megafossils and in the correlation of strata, but the writer, for a number of cogent reasons, has not attempted this study. No diatoms have been reported from Paleocene strata in America.

FOSSIL WOOD

Silicified and carbonized woods are locally abundant in the Paleocene strata, the silicified material being found chiefly in the shales and sandstones and the carbonized material in or near coal seams. In the vicinity of Medora, N. Dak., in the badlands along the course of the Little Missouri River, and also in the right bank of the Missouri River between Elbowoods and Sanish, N. Dak., silicified stumps and logs are plentiful. (See illustrations on pl. 21 of U.S. Geol. Survey Bull. 726, 1922, and pl. 4 of North Dakota Geol. Survey Second Bienn. Rept., 1902.) Most of the Paleocene wood is in prostrate position, but at some localities, as in Roosevelt State Park, just east of Medora, and near Sully Springs station on the Northern Pacific Railway, southeast of Medora, upright stumps of swamp forests may be seen in place.

The uninitiated traveler may sometimes be deceived by objects that look like prostrate logs when seen from a distance. Thus, along and on the east side of U.S. Highway 85, south of the bridge over the Little Missouri River, south of Watford City, N. Dak., and also on the hillside east of Seven Mile Creek about 6 miles north of Stipek, Mont., long gray loglike sandstone concretions, simulating fossil wood in appearance, may seem to the observer to resemble, except in color, the prostrate trunks in parts of the Petrified Forest National Monument near Holbrook, Ariz.

Most of the Paleocene wood is coniferous, but occasionally pieces of palms and dicotyledons may be found. One undescribed piece of a sycamore (*Platanus*), for example, was found in the Raton formation on the South Fork of the Purgatoire River, Colo., by Ross Johnson in 1950.

The following woods have been described, but it should be noted that some of their names have since been changed by Kräusel (1949):

Cupressinoxylon breverni Mercklin. Cramer *in* Heer, 1868, p. 167, pl. 42, figs. 11–17. Sinikfik, on east coast of Disko Island.

Cupressinoxylon dawsoni Penhallow, 1903, p. 46, figs. 9–11. The describer concluded that this wood represents a species of cypress (*Cupressus*), probably related to *C. macrocarpa* Hartweg. No cones suggesting the presence of *Cupressus* in the Paleocene strata have yet been found. Southern Saskatchewan, Canada.

Cupressinoxylon elongatum Knowlton, 1888, p. 7, pl. 3, figs. 1–4. Knowlton cited the locality for this wood as "Tiger Buttes, Dawson County, Mont." and concluded that "its age is, without doubt Laramie, as it is not far from Glendive from which come typical Laramie plants." The term Laramie as used by Knowlton means Laramie group in the old sense of Great Lignite. As I have not been able to relocate this locality to determine its stratigraphic position, there must remain some doubt as to the source of this wood and its age, whether Cretaceous or Paleocene.

Cupressinoxylon ucranicum Göppert. Cramer, *in* Heer, 1868, p. 168, pl. 34, fig. 5; pl. 38, figs. 7–12. Atanekerluk, Greenland.

Palmoxylon cannoni Stevens. Knowlton, 1930, p. 43. Denver formation, 317, South Table Mountain, Colo. Much palm wood occurs in the Paleocene of the Denver and adjacent basins, but I have made no attempt to study and classify it. In 1939, near the mammal locality on South Table Mountain (Brown, 1943a) I found a small palm stump in place, with roots penetrating the clay that was once the soil in which the tree grew.

Pityoxylon krausei Felix, 1886, p. 48, pl. 12, figs. 1, 2. A radial section shows two or three pits on the side walls of the ray tracheids. A tangential section shows rays nine or more cells high and one resin canal. The transverse section is not illustrated, but the description of it records the presence of numerous resin canals and parenchyma cells. The name was changed to *Coniferoxylon krausei* (Felix) Beck (1945, p. 69, 94).

Fort Union formation, northeast of Medora, N. Dak.

Pityoxylon sp. Torrey, 1923, p. 65. The specimen was said not to be well preserved and was not illustrated. It was cited as coming "from Cretaceous Laramie deposits at Sentinel Butte, North Dakota." As there are no Cretaceous outcrops at Sentinel Butte, the wood if the locality citation is correct, must be Tertiary in age, and presumably Paleocene.

Podocarpoxylon dakotense Torrey, 1923, p. 73. Not illustrated. Torrey is "inclined to believe that this twig may have belonged to one of the many 'sequoias'" described from the Great Lignite. Tertiary (not Cretaceous Laramie, as cited), Sentinel Butte, N. Dak.

Pseudotsuga miocena Penhallow, 1903, p. 47, figs. 12–13. The describer regarded *Taxoxylon* sp. Dawson (1875, p. 331) as synonymous with this species. Southern Saskatchewan, Canada.

Rhamnacinium porcupinianum Penhallow, 1903, p. 48, figs. 14–16, 21, 22. The describer compared this wood with that of the Salicaceae but concluded that its relationship is with *Rhamnus*. Southern Saskatchewan, Canada.

Rhamnacinium triseriatim Penhallow, 1903, p. 54, figs. 17–20. The describer separated this species from *R. porcupinianum* by alleged differences in the rays as seen in tangential section. Southern Saskatchewan, Canada.

Sequoia langsdorfi (Brongniart) Heer. Penhallow, 1903, p. 41, figs. 2–4. This wood was probably misidentified for that of *Metasequoia occidentalis* (Newberry) Chaney, whose twigs, cones, and seeds are common at many Paleocene localities in Canada and Montana. Southern Saskatchewan, Canada.

Sequoioxylon burgessi (Penhallow) Torrey, 1923, p. 79, for *Sequoia burgessi* Penhallow, 1903, p. 42, figs. 5–8. Penhallow, because the bordered pits in this wood are chiefly in two rows instead of one, concluded that its affinity "appears to be in the direction of *Sequoia gigantea*." The presence of fusiform rays, seen in the tangential section, raises doubt about the reference of this wood to *Sequoia*. Penhallow's material is from southern Saskatchewan, Canada; Torrey's is from a lignite mine, locality unspecified, near Colorado Springs, Colo. The latter may, therefore, be from Cretaceous rather than Paleocene strata.

Sequoioxylon dakotense Torrey, 1923, p. 77, pl. 10, fig. 24; pl. 11, figs. 25–28. Fort Union formation (not Cretaceous Laramie, as cited), Wilton, N. Dak.

Sequoioxylon laramense Torrey, 1923, p. 78, pl. 11, figs. 29–31. This is said to differ from *S. dakotense* in having far more abundant wood parenchyma and in lacking the small pits that characterize the tracheids of *darkotense*. Fort Union formation (not Cretaceous Laramie, as cited), Plentywood, Mont.

Sequoioxylon montanense Torrey, 1923, p. 74, pl. 10, figs. 19–23. This species was considered not to be identical with *Sequoia langsdorfi* (Brongniart) Heer. Fort Union formation (not Cretaceous Laramie, as cited), bank of the Missouri River, Culbertson, Mont.

Taxodium distichum (Linnaeus) Richard. Penhallow, 1903, p. 36, fig. 1. As both *Taxodium* and *Glyptostrobus* are represented in the Paleocene strata by twigs, cones, and seeds, respectively, there is some doubt about the correct assignment of this wood. Southern Saskatchewan, Canada.

SUGGESTED REJECTION OF SOME NAMES

Because they are poorly preserved and sometimes badly illustrated or because they were named but never illustrated or because they are now probably lost, the following leaves, fruits, and seeds are herein disregarded as name bearers:

Ficus evanstonensis Knowlton and Cockerell. Knowlton, 1919, p. 276, for *F.* (*Protoficus*) *nervosa* Newberry, 1883, p. 512. Said to have come from Evanston, Wyo., but no specimen corresponding to Newberry's description is now in the Evanston collection of the U.S. National Museum.

Ilex microphyllina Cockerell, 1911, p. 264, for *I. microphylla* Newberry, 1883, p. 510. No specimen.

Laurus palaeophila Knowlton and Cockerell. Knowlton, 1919, p. 347, for *L. acuminata* Newberry, 1883, p. 511. No specimen.

Rhamnus newberryi Knowlton and Cockerell. Knowlton, 1919, p. 548, for *Rhamnus parvifolius* Newberry, 1883, p. 511. No specimen.

Ulmus grandifolia Newberry, 1883, p. 508. No specimen.

Viburnum grandidentatum Newberry, 1883, p. 511. No specimen.

Viburnum paucidentatum Newberry, 1883, p. 511. No specimen.

Carpites coffeaeformis Lesquereux, 1878 (p. 303, pl. 60, figs. 6, 7).

C. coryloides Knowlton, 1930 (p. 132, pl. 58, figs. 3–6).

C. costatus Lesquereux, 1878 (p. 303, pl. 60, fig. 5).

C. laurineus Lesquereux, 1878 (p. 304, pl. 60, figs. 20, 21).

?*Carpites lineatus* Newberry. (Lesquereux, 1878, p. 302, pl. 60, figs. 1b–1d; Newberry, 1898, p. 138, pl. 40, fig. 1).

C. minutulus Lesquereux, 1878 (p. 305, pl. 60, fig. 25).

C. myricarum Lesquereux, 1878 (p. 303, pl. 60, figs. 8–11).

C. oviformis Lesquereux, 1878 (p. 302, pl. 30, fig. 6a).

C. rostellatus Lesquereux, 1878 (p. 303, pl. 60, figs. 12, 13). To this probably belongs *Palmocarpum corrugatum* Lesquereux, 1878, p. 121, pl. 11, fig. 11. This irregular, angular object may be an inorganic effect.

C. triangulosus Lesquereux, 1878 (p. 302, pl. 60, fig. 4 [USNM 496]). The numbered specimen does not seem to be that illustrated by Lesquereux, but is a fruit of *Cercidiphyllum arcticum* (Heer) Brown from the Denver formation, 317, at Golden, Colo. The other specimens, plate 62, figures 19, 20, said by Lesquereux to have come from the Upper Cretaceous strata at Point of Rocks, Wyo., are missing from the U.S. National Museum collections.

C. utahensis Lesquereux, 1878 (p. 305, pl. 60, fig. 22).

Nyssa lanceolata Lesquereux, 1878 (p. 245, pl. 35, fig. 6).

Tetranthera sessiliflora Lesquereux, 1878 (p. 217, pl. 34, figs. 1c, 1d only).

See rejected names for palms (p. 53).

COMPOSITION AND ECOLOGIC SIGNIFICANCE OF THE PALEOCENE FLORA

Some of the named and described items in the list (p. 38) and foregoing systematic treatment of about 170 species of the Paleocene flora are not classified with certainty. The remainder are considered to be placed fairly closely, at least generically, and show that a respectable variety of seedless and seed plants was present in the Rocky Mountains and Great Plains region over the span of some 10 million years. During this interval there were noticeable changes in the flora, so that a good collection from a given locality in the early part of the epoch can be distinguished from a similarly satisfactory one in the later part.

Formerly, in various publications, the number of species in the Paleocene (that is, Fort Union as then understood) flora was given as about 500—a too-generous estimate based on overspeciation and guesswork about the known specimens. Nevertheless, the present list of about 170 is doubtless too small, for, had a botanist been present to take a complete census of the actual flora, the total would, by comparison with the floras of assumed similar areas and environments today, be very much larger. It is interesting, but perhaps futile, to speculate about what species were present or should have been present in the flora, though not now represented in the fossil record. Formerly, also, it was thought that there was an almost complete floral break at the close of the Late Cretaceous. Now it is apparent that many early Paleocene plants cannot, with assurance, be distinguished from their Late Cretaceous predecessors; and that species thought to be restricted to the Paleocene must be cited with cautious reservations. Among the latter the following, not singly but in combinations of two or more, are characteristic and common enough to be useful for tentative age determinations: *Lygodium coloradense*, *Isoetites horridus*, *Ginkgo adiantoides*, *Glyptostrobus nordenskioldi*, *Metasequoia occidentalis*, *Taxodium olriki*, *Thuja interrupta*, *Sabal grayana*, *Carya antiquorum*, *Pterocarya glabra*, *Pterocarya hispida*, *Betula stevensoni*, *Corylus insignis*, *Castanea intermedia*, *Quercus greenlandica*, *Quercus sullyi*, *Ulmus rhamnifolia*, *Platanus nobilis*, *Sassafras thermale*, *Paranymphaea crassifolia*, *Eucommia serrata*, *Sapindus affinis*, *Rhamnus goldiana*, *Fraxinus eocenica*, *Viburnum antiquum*, *Viburnum asperum*, and *Viburnum cupanioides*. Some of these, it should be stated, ranged into the early Eocene, or at least had very close relatives in the flora of that epoch.

Inspection of the items in the Paleocene list shows that the seedless plants include algae, fungi, liverworts, mosses, ferns, and fern allies; and that the seed plants include cycads, ginkgo, conifers, waterweeds, palms, willow, hickories, walnuts, birch, hazel, chestnut, oaks, hackberries, elm, zelkova, breadfruit, figs, mulberry, sycamores, cinnamon, laurels, sassafras, waterlilies, katsura, magnolias, witchhazel, sweetgum, hydrangea, cherries, legumes, maples, koelreuteria, buckthorns, grapes, dogwood, black tupelo, ash, and viburnums. Suggestions about the possible relationship or likeness to modern species have been made in the discussion of each item, but these must be taken with the customary grains of salt, for no human observer was there to note some of the significant and perhaps evanescent features of the now extinct plants that, if known, would be most helpful in making comparisons with the assumed comparable living species. Many of the species, it will be noted, have counterparts, or similar relatives, in the temperate floras of the Eastern United States and eastern Asia, thus reflecting the similar aspects of these modern floras. A glance at the dicotyledonous leaves of the Paleocene flora shows that those with toothed margins far outnumber those with entire margins—a significant indication of adaptation to a temperate climate. Intermingled with the temperate species, however, are some ferns, palms, breadfruit, and figs (if they are figs) that were relics or adaptations from a warmer, subtropical flora.

The Paleocene flora was essentially a lowland flora that extended for hundreds of miles inland from the open sea to the foothills and mountains that were the sources of the sediments in which the plant debris was entombed. Most of the fossils, it should be noted, were collected from strata that were formed at or near sea level; and there are very few, if any, that can be singled out as having been collected from strata formed at higher elevations. That such strata, however, may have been in existence for a time, but were removed by erosion, is quite probable. From the aspect of the flora it would appear that many species were adapted to drier hillsides at some distance back from the swampy lowlands and that their leaves, fruits, seeds, and wood were borne by streams to the burial ground in the lower areas of deposition. Some of the trees, particularly the conifers, were of large size, as shown by the remains of their 4- to 6-foot silicified trunks and stumps that may be seen, for example, in and around Roosevelt State Park, east of Medora, N. Dak. Some of the stumps are still upright and, from the fact that they rest on clays or carbonaceous strata associated with coal seams, are without much doubt relics of a swamp forest like that of the bald cypress areas around the Dismal Swamp in Virginia and North Carolina.

Comparing the Paleocene plants from the several areas, north and south, one is struck by the fact that some climatic zoning is clearly evident. For example, the remains of breadfruit (*Artocarpus*) and cinnamon (*Cinnamomum*) are limited to central Wyoming and southward. Nevertheless, palms are present as far north as the Yellowstone River in Montana. On the other hand, the ginkgos, birches, hazels, maples, and viburnums are limited to the areas north of the Colorado-Wyoming border or to what were presumably high areas near the headwaters of the southern terrain. Taking a broad view of the situation, the flora may be said fairly to have been a mesophytic one in a warm temperate environment with a medium amount of precipitation well distributed through the year.

This flora and its environment were similar to those that existed in the Paris Basin in France at the same time, if one may rely on the description of the geology and the reports on the fossils of that area. Comparison with the Paleocene situation in Greenland is somewhat obscured by the lack of detailed geologic information about the strata and by the numerous probable misidentifications of species. Precise comparisons of the plants with those of the American Paleocene are not always possible, but in their larger aspects the two floras seem to be closely comparable.

PALEOCENE ANIMALS OF THE ROCKY MOUNTAINS AND GREAT PLAINS

The Paleocene sedimentary strata of the Rocky Mountains and Great Plains are mostly nonmarine, but about 400 feet—the Cannonball member of the Fort Union formation—is marine, with a few brackish tongues. The fauna of the Cannonball, consisting of foraminifers, corals, mollusks, crabs, and sharks, has been described by Stanton (1921), Fox and Ross (1940, 1942), and Holland and Cvancara (1958). It was a fauna of an epicontinental sea that was open ocean probably to the north or northeast, and perhaps also toward the southeast Midway invasion of the gulf coast.

The fauna from the nonmarine strata includes mollusks, insects, crustaceans, fishes, amphibians, reptiles, birds, and mammals.

The fresh-water mollusks have been described in part by Meek (1876), White (1883, 1886), Russell (1931), Henderson (1935), Yen (1946, 1948), and Tozer (1956).

Remains of insects, usually not well preserved, have been found at many localities, chiefly in carbonaceous shales. Although amber is sometimes present in these shales, I have never found any that contained insects or plants. Of the Paleocene insects only the wing of a cockroach has been previously figured (Brown, 1957, p. 341, fig. 1). Those illustrated here are listed by common names only (pl. 69, figs. 2, 3, 4). Wings of beetles are perhaps the most common insect remains found.

Scattered occurrences of ostracodes, some not identified (Lemke, 1960, p. 30), are known. Other crustaceans include some crabs from the Cannonball marine member reported by Holland and Cvancara (1958).

Fishes are represented by scales (pl. 69, figs. 7, 8, 14), teeth, separate bones, and partial skeletons.

Amphibians, apparently, left only footprints, such as *Ammobatrachus montanensis* (Gilmore (1928).

Reptiles such as turtles and the crocodilelike *Champsosaurus* left abundant remains (pl. 69, figs. 11–13).

One feather (pl. 69, fig. 1), not identified, is at present all that represents the birds.

Locally, mammals left relatively numerous remains (see p. 7ff; and pl. 69, figs. 9, 10). These have been treated by Russell (1932b), Matthew (1937), Simpson (1937b), Patterson (1939), Jepsen (1940), Gazin (1941a, b, 1942; 1956a, b, c), and Van Houten (1945b).

Problematic objects (pl. 69, figs. 15–19) that may be coprolites are the bizarre and perhaps only traces of some unidentified aquatic or land vertebrate.

From this survey of Paleocene life in the Rocky Mountains and Great Plains, one may draw several inferences. First, the number of species now known must be only a fraction of the total that actually existed. It is clearly not reasonable to conclude that because one feather was found only one kind of bird existed at that time! The great number and thickness of the coal beds, however, does not mean that the number of species of plants that contributed to the formation of the coal must necessarily have been large. A few species may have been so luxuriant as to have supplied most of the material. Second, most of the species now known must have been adapted by individual qualities or by favorable habitats for getting into the fossil record. This perhaps is more particularly true of the plants than of the land animals.

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INDEX

PLATES 1–69

[For locality details corresponding to numbers see list on page 30. All figures on plates 4–69 are natural size unless otherwise indicated]

PLATE 1

FIGURE 1. Looking north at the western outcrops of the type locality of the Fort Union formation, Snowden, Mont. 1931 (p. 3, 12, 19).

2. South face of clinker-capped Pretty Butte, 6 miles north of Marmarth, N. Dak. Arrow indicates Cretaceous-Paleocene contact. 1931 (p. 1, 11).

3. Looking east at the unconformable Cretaceous-Paleocene contact indicated by arrow at the base of the white sandstone in the center of the photograph, 2 miles southeast of Black Buttes station, Wyo. 1938 (pp. 11, 13).

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VIEWS OF CRETACEOUS AND PALEOCENE STRATA

PLATE 2

FIGURE 1. Looking west at Cretaceous-Paleocene contact indicated by arrow, 13 miles south of Fort Peck dam, Montana. 1948 (p. 1, 11).

2. Pick rests on oyster bed of the Cannonball member of the Fort Union formation, 150 feet above the Little Missouri River, left bank, 3 miles southwest of Yule, N. Dak. 1936 (p. 8, 12).

3. Right bank of Little Missouri River at Phelan ranch, 1 mile southeast of locality shown in fig. 2. Below the coal seam in the middle of the bank and river level is the lowest known tongue of the Cannonball member of the Fort Union formation. It contains species of *Corbula* and *Corbicula*. 1936 (p. 8, 12).

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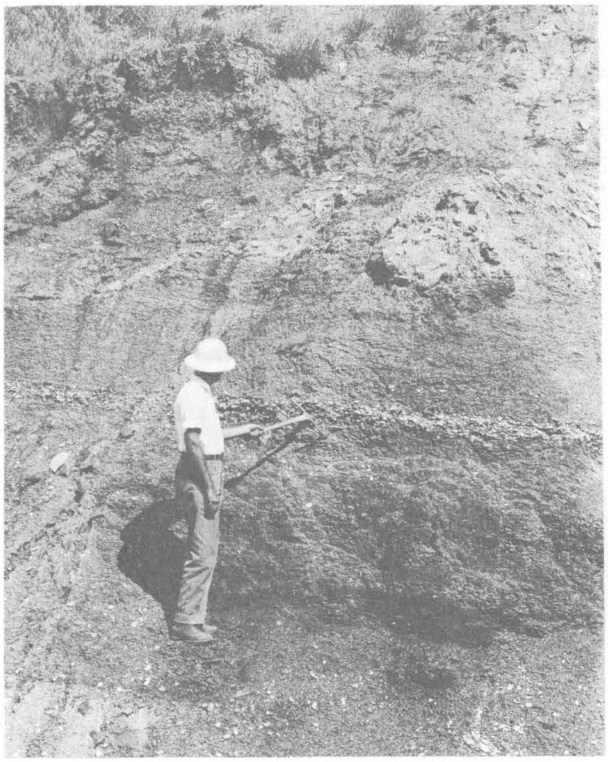

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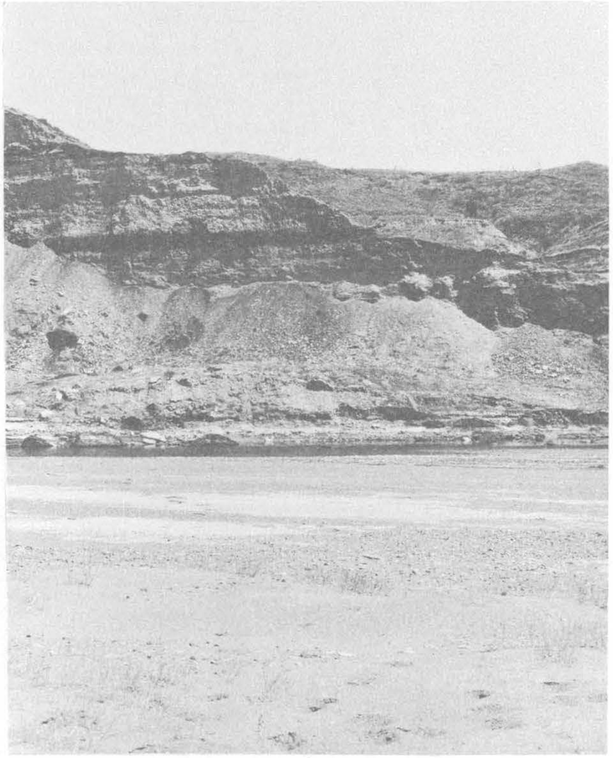

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VIEWS OF CRETACEOUS AND PALEOCENE STRATA

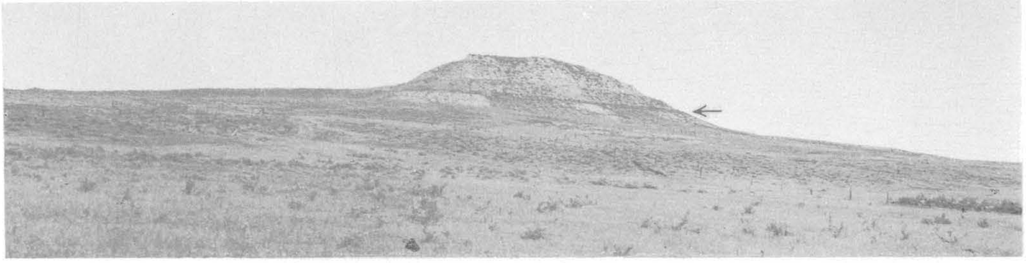
PLATE 3

FIGURE 1. Looking west at Cretaceous-Paleocene contact indicated by arrow, west side of Powder River 8 miles south of Powderville, Mont. 1946 (pp. 11, 16).

2. Looking west at Cretaceous-Paleocene contact indicated by arrow, 5 miles southeast of Glendive, Mont. 1941 (pp. 6, 11, 14).

3. Looking north at Cretaceous-Paleocene contact indicated by arrow, at base of whitish beds in south face of butte, 10 miles north of Baker, Mont. 1941 (pp. 11, 15).

4. Looking northeast at Cretaceous-Paleocene contact indicated by arrow, 4 miles south of Rock Springs, Wyo. 1941 (p. 11, 22).



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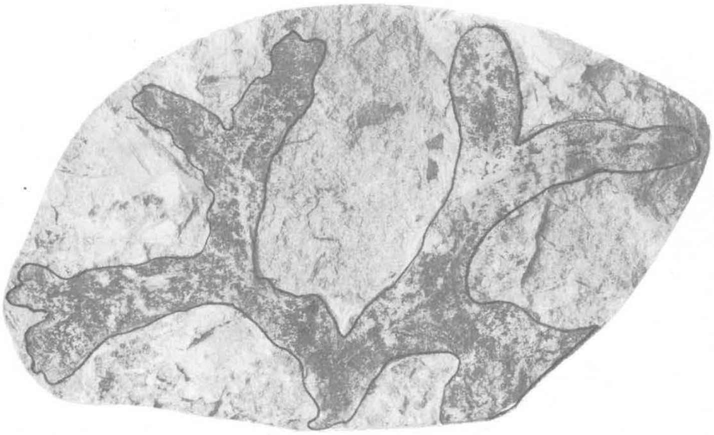
VIEWS OF CRETACEOUS AND PALEOCENE STRATA

PLATE 4

FIGURES 1, 10. *Marchantia pealei* Knowlton (p. 40). 1, loc. 8517; 10, loc. 4293.
2, 3, 8. *Selaginella collieri* Knowlton (p. 46). 2, loc. 2420; 3, 8 (× 2), loc. 7004.
4, 6. *Marchantia lignitica* (Ward) Brown, n. comb. (p. 40). Loc. 2420, 6 (× 3).
5. *Calycites polysepala* Newberry (p. 89). Exact locality unknown.
7. *Preissites wardi* Knowlton (p. 40). Loc. 2420.
9. *Selaginella berthoudi* Lesquereux (p. 46). Loc. 8779.
11. *Calycites hexaphylla* Lesquereux (p. 88). Loc. 9248.
12, 13. *Selaginella monstrosa* (Hollick) Brown, n. comb. (p. 46). 12, loc. 8249; 13, loc. 4031.



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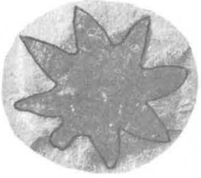

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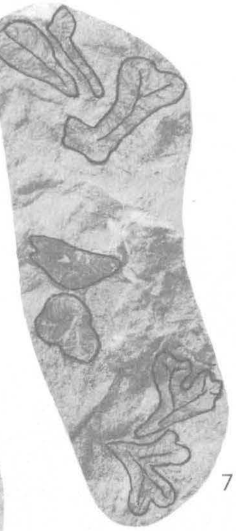

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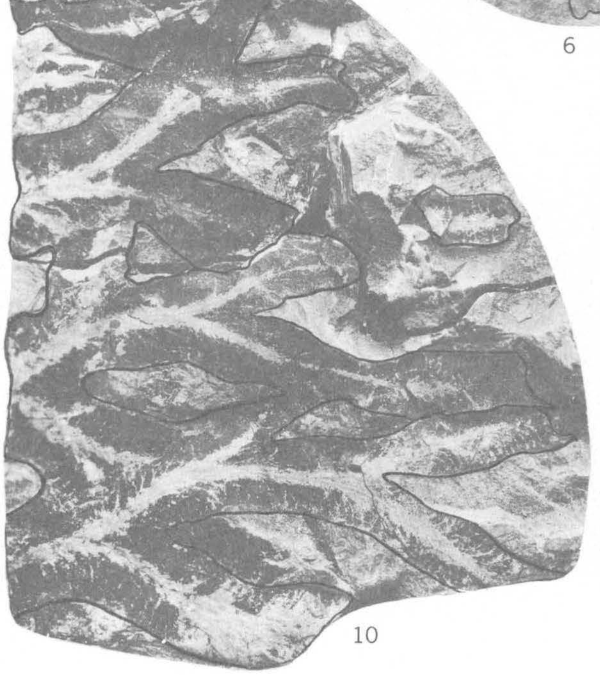

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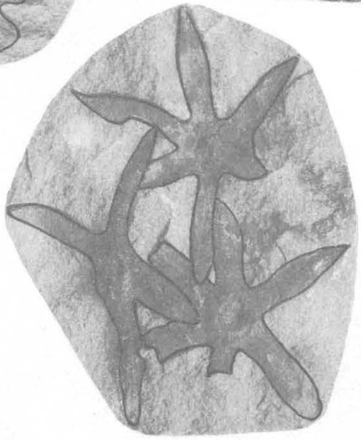

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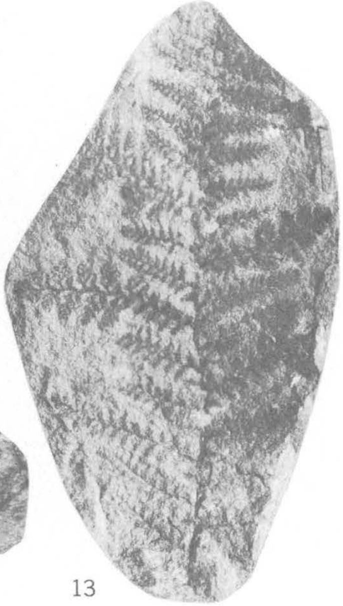

13

MEGASCOPIC PALEOCENE PLANTS

PLATE 5

FIGURES 1–6. Oogonia of *Chara* spp. (p. 39). × 15. 1, loc. 229; 2, 3, loc. 9204; 4–6, loc. 9205.
7. *Hypnum coloradense* Brown, n. sp. (p. 41). Loc. 5738.
8. *Osmunda greenlandica* (Heer) Brown, n. comb. (p. 45). Loc. 317.
9–11, 18. *Lastrea goldiana* (Lesquereux) Lesquereux (p. 47). 9, 10, loc. 325; 11, loc. 6105; 18 (× 2) loc. 8258.
12. *Mnium montanense* Brown, n. sp. (p. 41). Loc. 8519.
13–16. *Allantodiopsis erosa* (Lesquereux) Knowlton and Maxon (p. 41). 13, loc. 318; 14, loc. 6105; 15, loc. 317; 16 (fertile), loc. 325.
17. *Dryopteris meeteetseana* Brown, n. sp. (p. 42). Loc. 4694.
19. *Saccoloma gardneri* (Lesquereux) Knowlton (p. 42). Loc. 8897.


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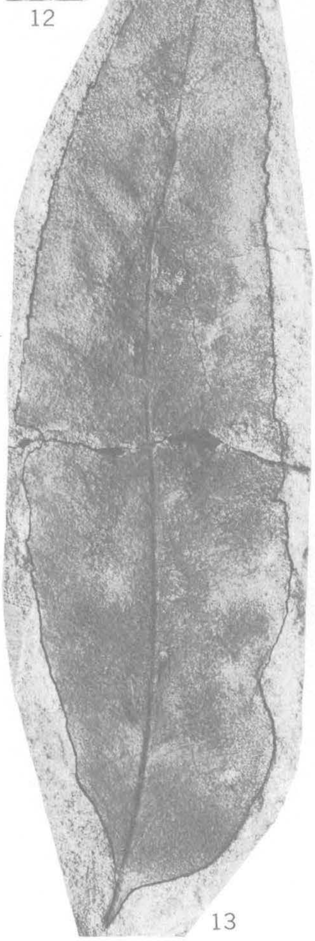
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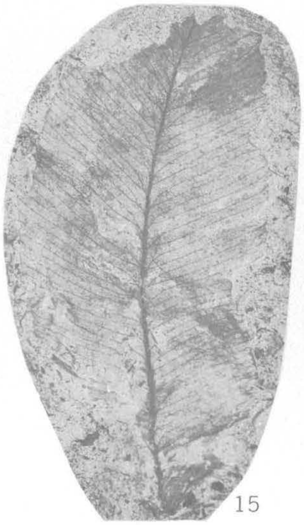
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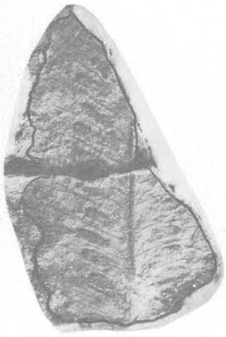
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MEGASCOPIC PALEOCENE PLANTS

PLATE 6

FIGURES 1, 2, 5–7. *Dennstaedtia americana* Knowlton (p. 42). 1, loc. 4273; 2, 5, loc. 8222; 6, loc. 8231; 7, loc. 5029.

3, 4. *Blechnum anceps* (Lesquereux) Brown, n. comb. (p. 41). loc. 8678.

8. *Anemia elongata* (Newberry) Knowlton (p. 44). Loc. 6084.

9. *Hymenophyllum confusum* Lesquereux (× 3) (p. 41). Loc. 317.

10, 11. *Osmunda macrophylla* Penhallow (p. 45). Loc. 8519.

12, 13. *Saccoloma gardneri* (Lesquereux) Knowlton (p. 43). 12, loc. 8678; 13, loc. 4029.

14, 15. *Osmunda greenlandica* (Heer) Brown, n. comb. (p. 45). Loc. 8519.


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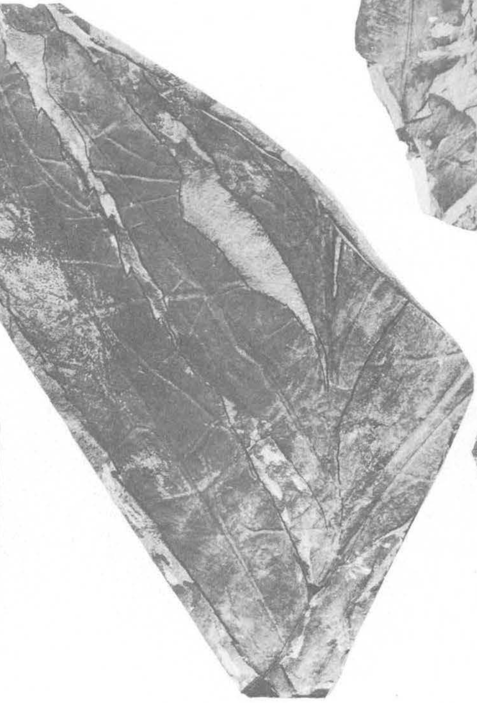
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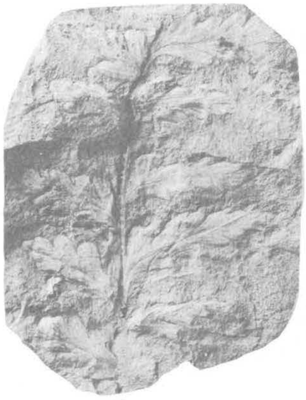
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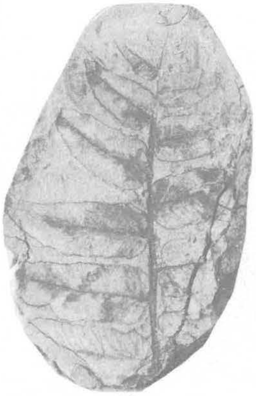
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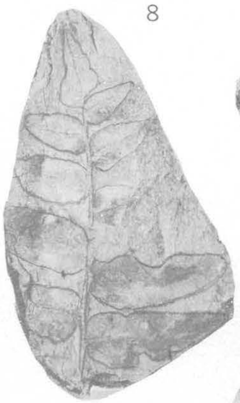
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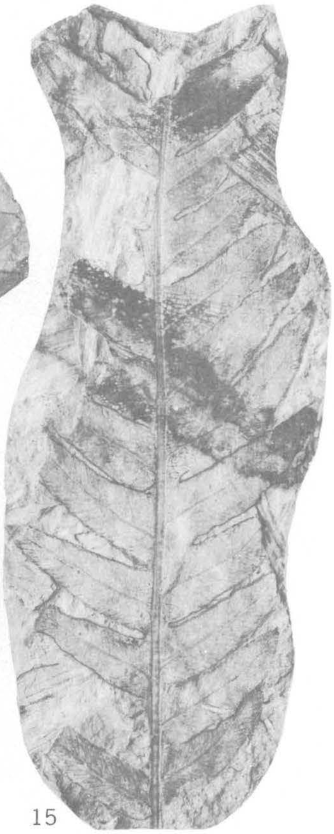
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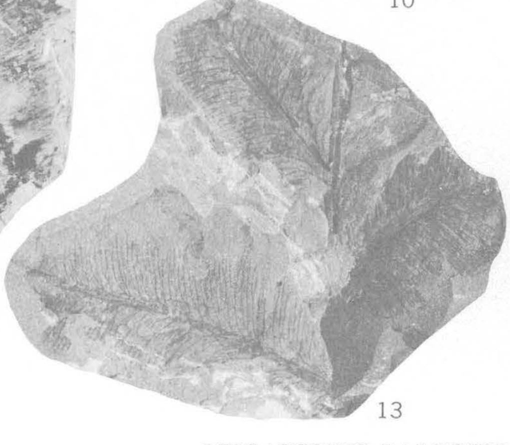
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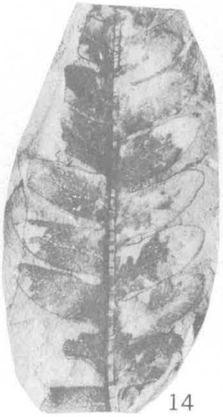
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MEGASCOPIC PALEOCENE PLANTS

PLATE 7

FIGURES 1, 4. *Onoclea hesperia* Brown, n. name (p. 43). 1, exact locality unknown; 4, loc. 7004.

2, 3, 5. *Woodwardia arctica* (Heer) Brown, n. comb. (p. 43). 2, loc. 5030; 3, 5, loc. 8519.

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MEGASCOPIC PALEOCENE PLANTS

PLATE 8

FIGURES 1–6. *Equisetum* spp. (p. 45), showing underground tubers (1, 2, 5), and stems with sheaths (3, 4, 6). 1, loc. 2417; 2, 5, loc. 2414; 3, loc. 7538; 4, loc. 8240; 6, loc. 8164.

7, 8, 13, 14. *Osmunda macrophylla* Penhallow (p. 45). 7, 14, loc. 9085; 8, loc. 9084; 13, loc. 8248.

9, 10. *Lygodium coloradense* Knowlton (p. 45). 9 (fertile pinnule), loc. 6105; 10 (sterile pinnule), loc. 8678.

11, 12, 16. *Gleichenia hesperia* Brown, n. sp. (p. 44). 11, loc. 8897; 12 (× 2), 16, loc. 8519.

15. *Dryopteris lakesi* (Lesquereux) Knowlton (p. 42). Loc. 317.

17. *Dryopteris serrata* Brown, n. sp. (p. 42). Loc. 8678.


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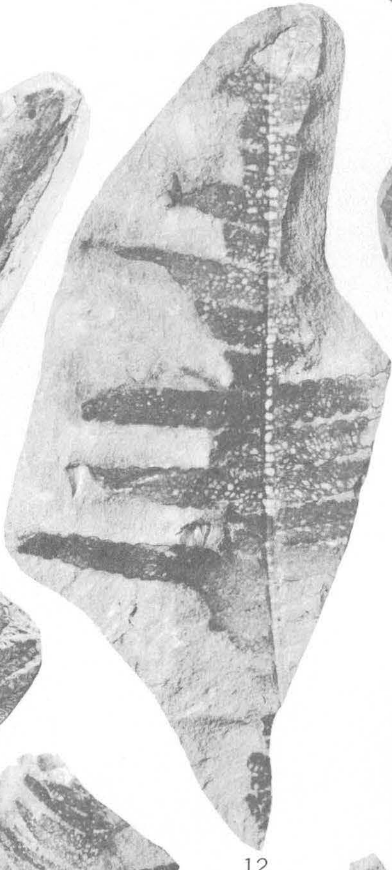
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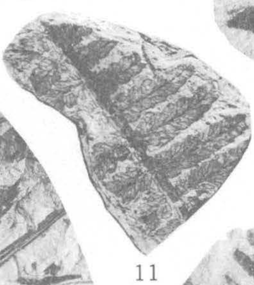
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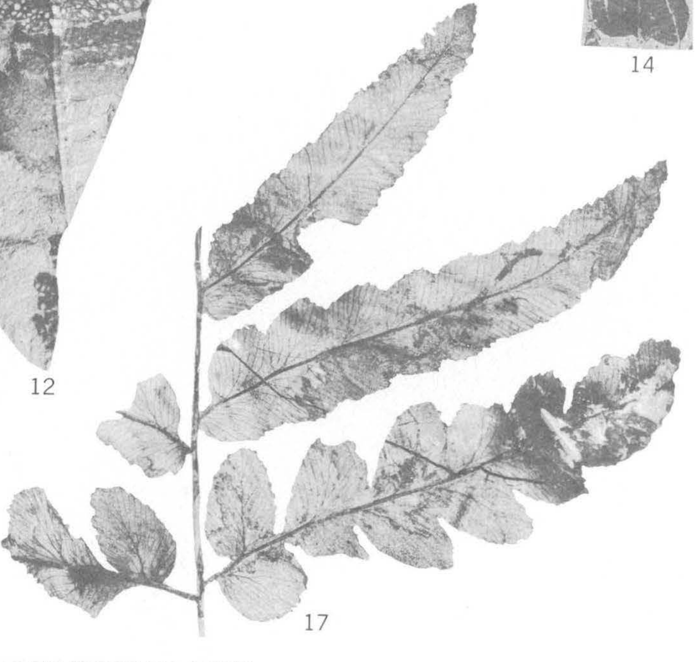
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MEGASCOPIC PALEOCENE PLANTS

PLATE 9

FIGURES 1–8. *Isoetites horridus* (Dawson) Brown (p. 46). 1, corm with sporangia tipped by ligules, loc. 8548; 2, detached sporangia, loc. 8881; 3 (× 3), corm with circle of sporangia containing megaspores and microspores, loc. 8535; 4, corm with rosette of leaves, 5, tip of leaf, 6 (× 15), surface pattern of leaf, loc. 2420; 7, corm with leaf scars, loc. 5255; 8, corm with rosette of leaves showing rectangular depressions, the external indications of collapsed internal air spaces, loc. 2432.

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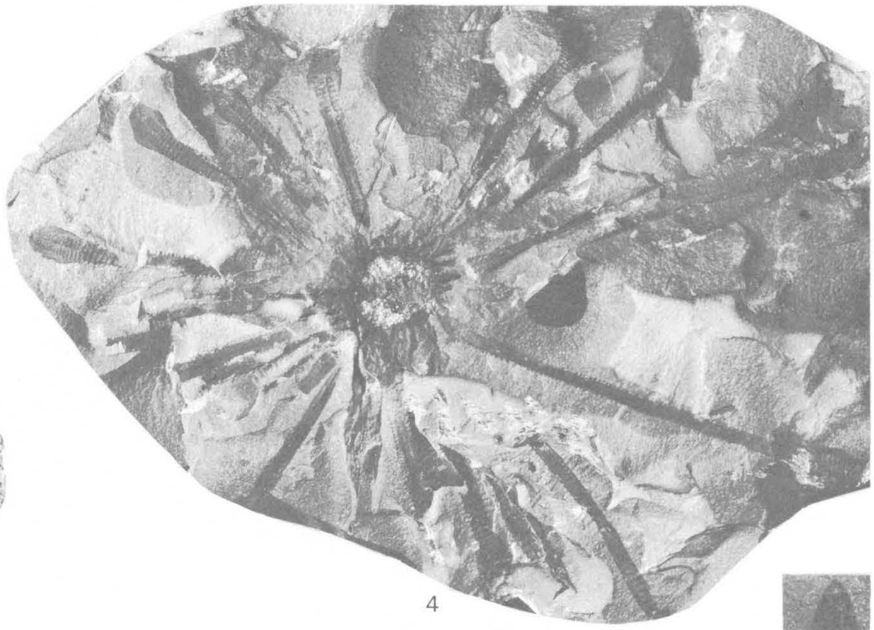

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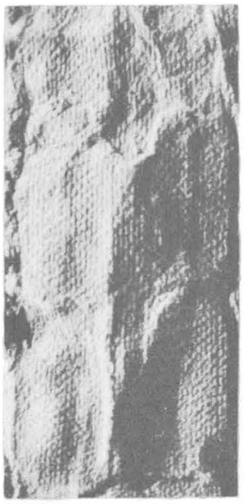

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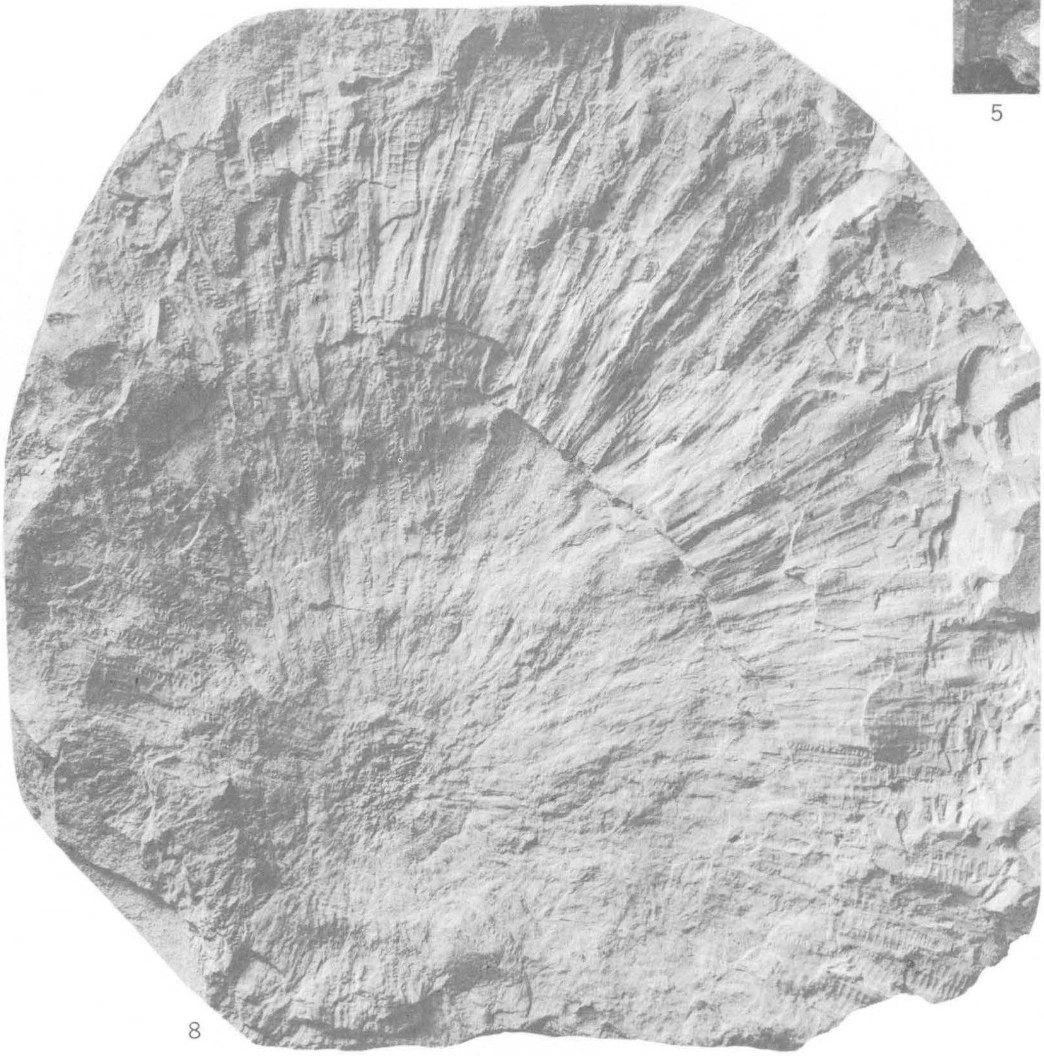

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MEGASCOPIC PALEOCENE PLANTS

PLATE 10

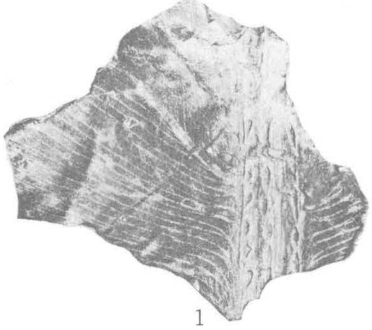
Figure 1. *Zamia wyomingensis* Brown, n. sp. (p. 47). Loc. 5911.

2–5, 8. *Ginkgo adiantoides* (Unger) Heer (p. 47). 2, loc. 8256; 3, loc. 8786; 4 (× 5), 5, loc. 2416; 8, loc. 9109.

6, 9, 12, 13. *Zamia coloradensis* (Knowlton) Brown, n. comb. (p. 47). Loc. 8551.

7, 11, 15. *Taxodium olriki* (Heer) Brown, n. comb. (p. 50). 7, 11, loc. 2420; 15, loc. 8549.

10, 14, 16. *Thuja interrupta* Newberry (p. 51). 10, loc. 5030; 14, loc. 8897; 16, loc. 7989.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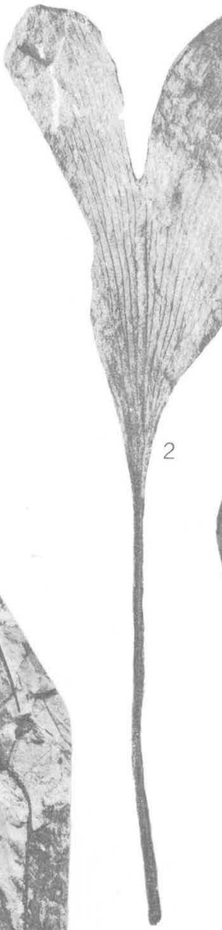
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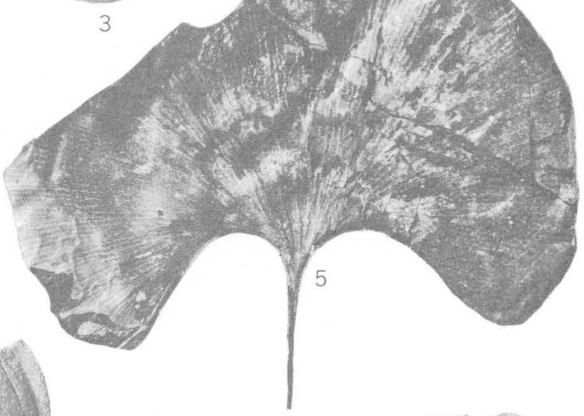
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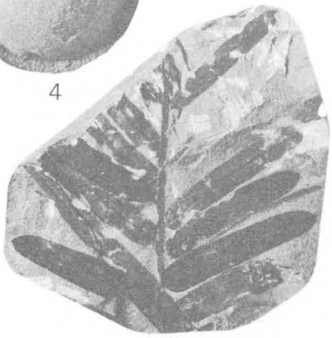
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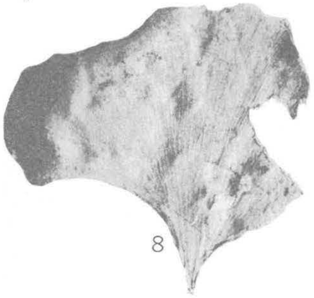
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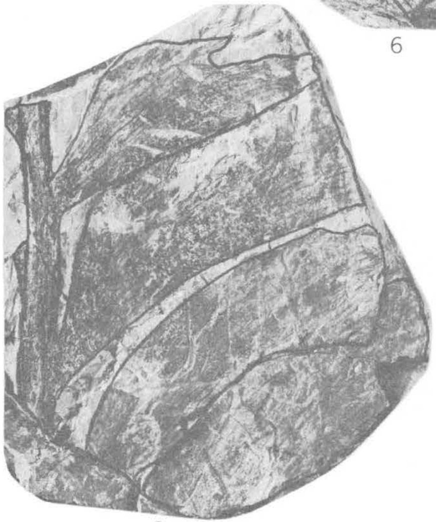
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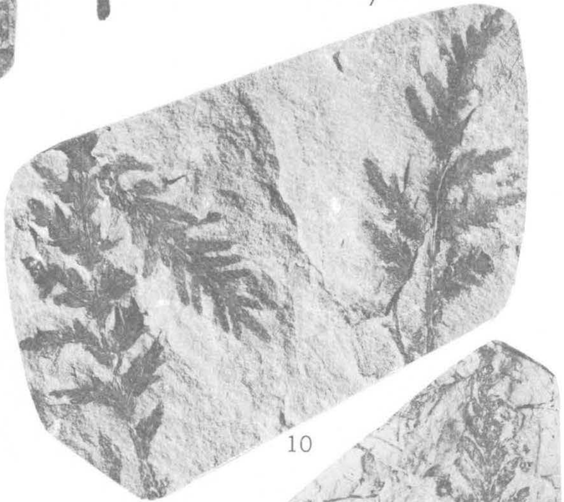
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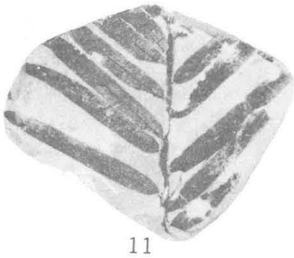
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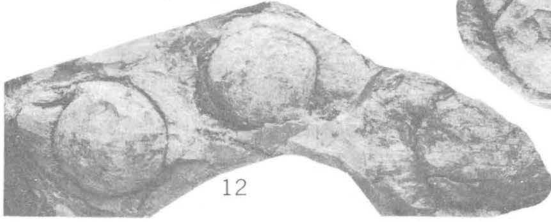
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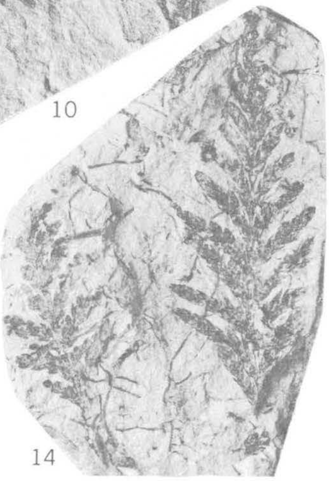
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MEGASCOPIC PALEOCENE PLANTS

PLATE 11

FIGURES 1, 2. *Fokienia catenulata* (Bell) Brown, n. comb. (p. 50). Loc. 7548.

3, 7–22. *Glyptostrobus nordenskioldi* (Heer) Brown, n. comb. (p. 49). 3, loc. 8552; 7, 13 (seed), loc. 8786; 8, loc. 8203; 9, loc. 9192; 10, 18 (cone scales), loc. 8224; 11 (seed), 16 (cone scale), loc. 8193; 12 (seed), loc. 8549; 14 (cone scale), loc. 8677; 15, 19 (cone scales), loc. 8212; 17 (seed and cone scale), loc. 8245; 20, loc. 8249; 21, loc. 8206; 22, exact locality unknown.

4–6. *Taxodium olriki* (Heer) Brown, n. comb. (p. 50). 4, loc. 2416; 5, loc. 7548; 6, loc. 8549.


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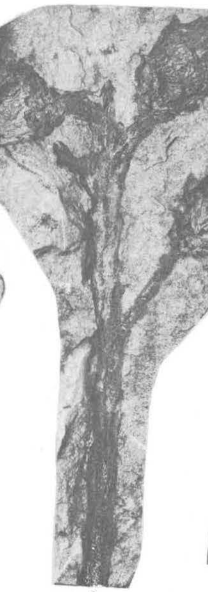
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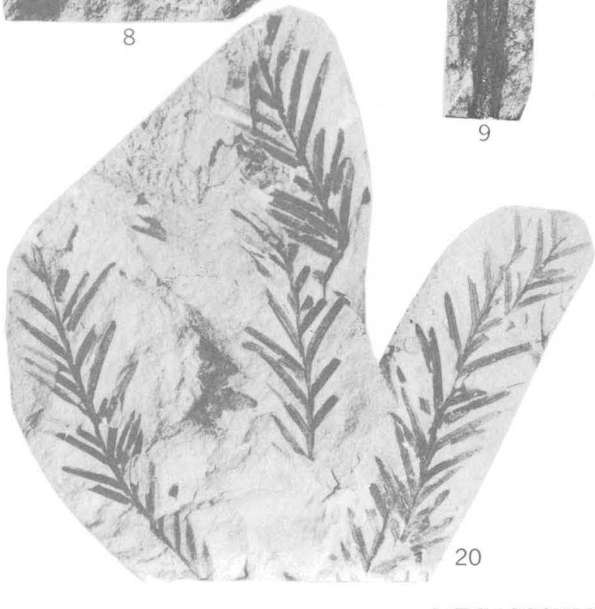
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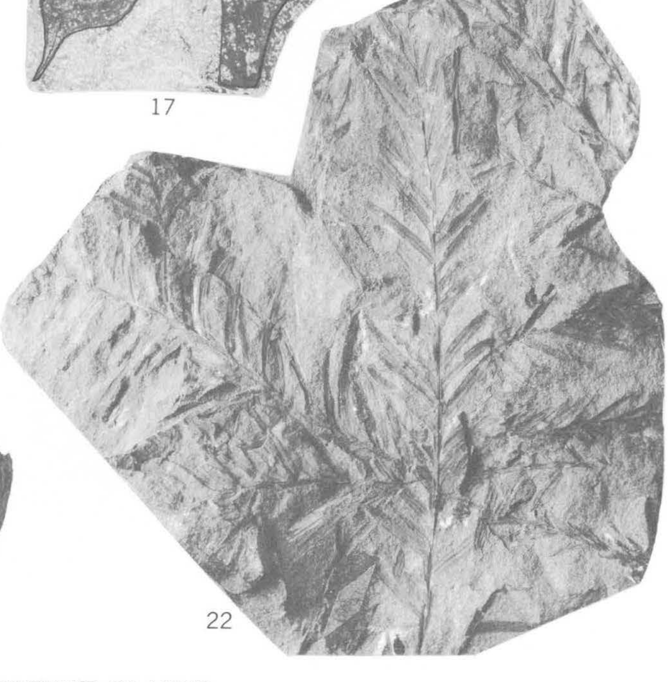
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MEGASCOPIC PALEOCENE PLANTS

PLATE 12

Figures 1–14. *Metasequoia occidentalis* (Newberry) Chaney (p. 49). 1, 8 (cones), 10 (foliage and seeds, × 2), loc. 8521; 2, loc. 4984; 3, loc. 8238; 4, 7, loc. 8550; 5, loc. 4264; 6, loc. 4582; 9, loc. 8551; 11, loc. 8165, 12 (staminate aments), loc. 8212; 13, 14, loc. 2420.


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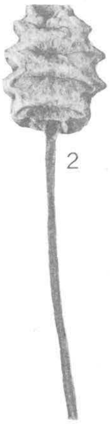
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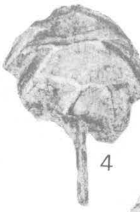
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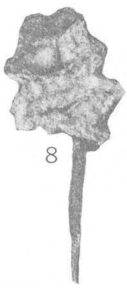
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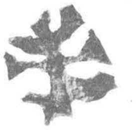
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MEGASCOPIC PALEOCENE PLANTS

PLATE 13

Figures 1–7. *Araucaria longifolia* (Lesquereux) Brown, n. comb. (p. 48). 1–5 (cones and foliage), loc. 8519; 6, 7 (stomata, × 10, on lowest left-hand needle of fig. 6), loc. 5886.


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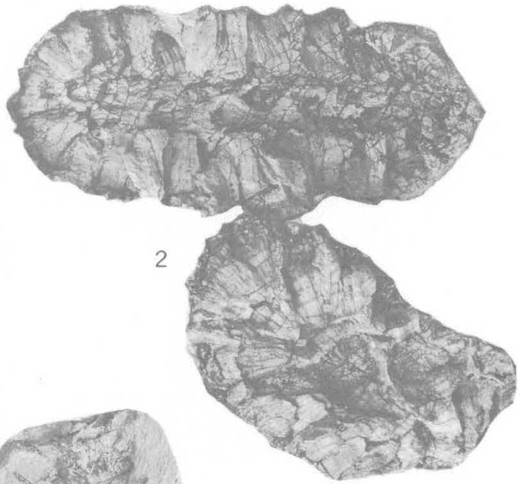
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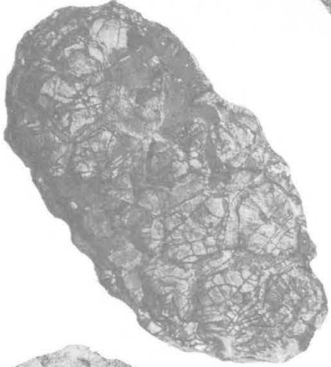
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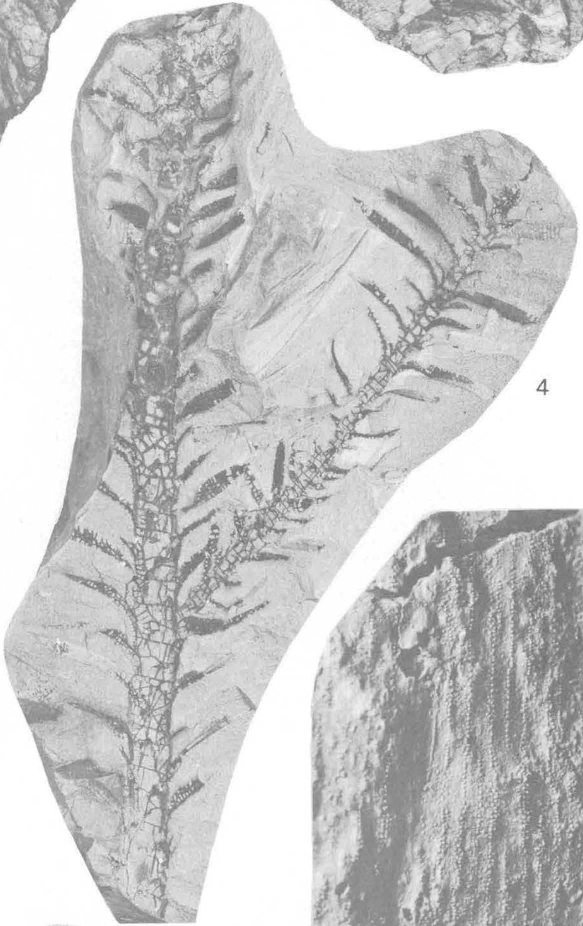
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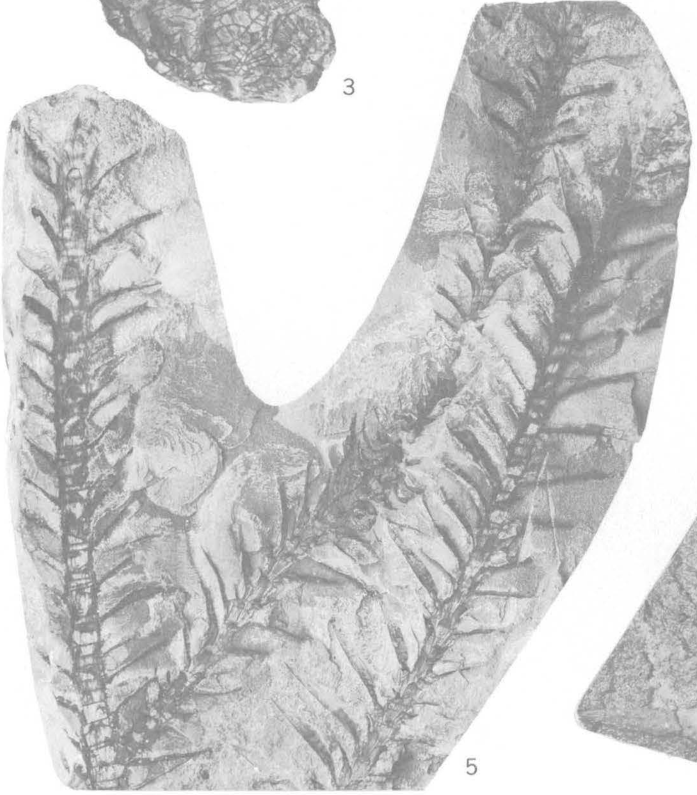
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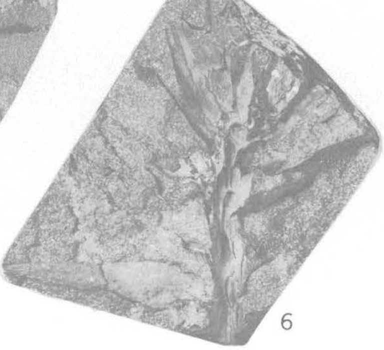
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MEGASCOPIC PALEOCENE PLANTS

PLATE 14

Figure 1. *Thrinax dorfi* Brown, n. sp. (p. 55). Loc. 8256.

2, 6. *Sabal imperialis* Dawson (p. 54). 2 (× ½), loc. 5886; 6, 8188.

3. Monocotyledonous leaf (p. 53). Loc. 2417.

4, 5. *Sparganium antiquum* (Newberry) Berry (p. 51). 4, loc. 8230; 5, loc. 2416.

7, 8. *Amentotaxus campbelli* (Gardner) Florin (p. 48). 7, loc. 9109; 8, loc. 4696.

MEGASCOPIC PALEOCENE PLANTS

PLATE 15

FIGURES 1, 4, 6. *Alismaphyllites grandifolius* (Penhallow) Brown, n. comb. (p. 52). **1, 4,** loc. 8206; 6, loc. 8227.

2. *Canna? magnifolia* Knowlton (p. 55). Loc. 9200.

3, 7. *Paloreodoxites plicatus* (Lesquereux) Knowlton (p. 54). 3, loc. 8188; **7,** loc. 317.

5. *Sabal grayana* Lesquereux (p. 54). Loc. 8672.

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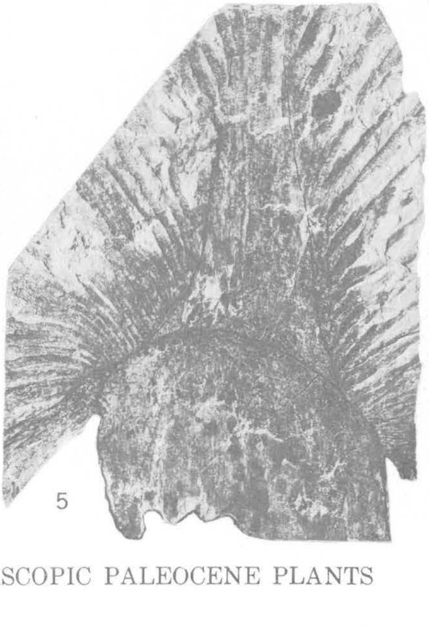

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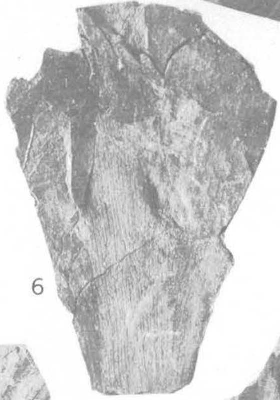

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MEGASCOPIC PALEOCENE PLANTS

PLATE 16

FIGURES 1, 3, 8–11. *Hydromystria expansa* (Heer) Hantke (p. 52). 1, loc. 4897; 3, loc. 8212; 8, loc. 2420; 9, 11, loc. 8191; 10, loc. 5512.

2, 5, 6. *Sabal powelli* Newberry (p. 55). Loc. 8519.

4. *Sabal grayana* Lesquereux (p. 54). Loc. 317.

7. Monocotyledonous rootstock (p. 53). Loc. 8678.


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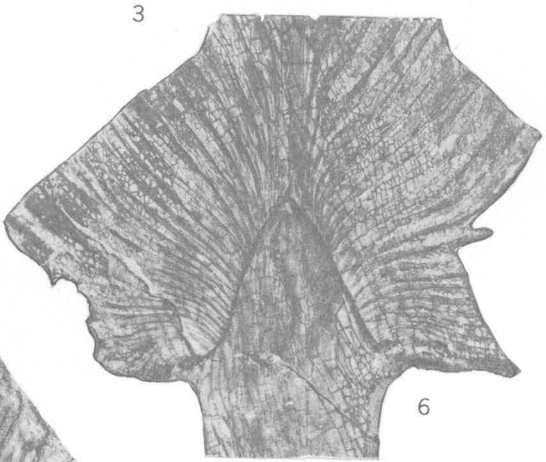
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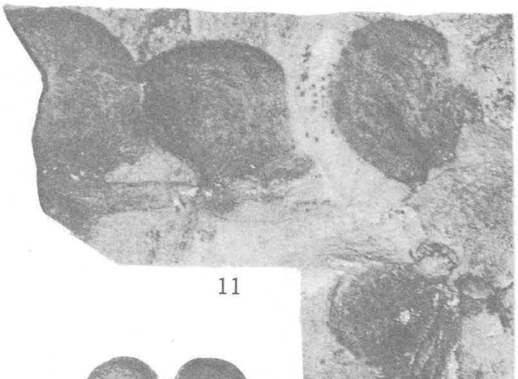
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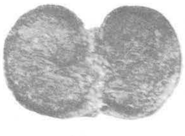
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MEGASCOPIC PALEOCENE PLANTS

PLATE 17

FIGURES 1–7. *Carya antiquorum* Newberry (p. 55). 1, loc. 541; 2, loc. 8206; 3, 6, loc. 8224; 4, exact locality unknown; 5, loc. 8523; 7, exact locality unknown.

MEGASCOPIC PALEOCENE PLANTS

PLATE 18

FIGURES 1–3, 5–9, 13. *Pterocarya glabra* Brown, n. sp. (p. 57). Loc. 8921.
4. *Carya antiquorum* Newberry (p. 55). Loc. 5711.
10. *Phyllites pagosensis* Knowlton (p. 88). Loc. 317.
11, 12. *Pterocarya hispida* Brown, n. sp. (p. 57). Loc. 8920.
14. *Credneria? daturaefolia* Ward (p. 66). Loc. 8920.


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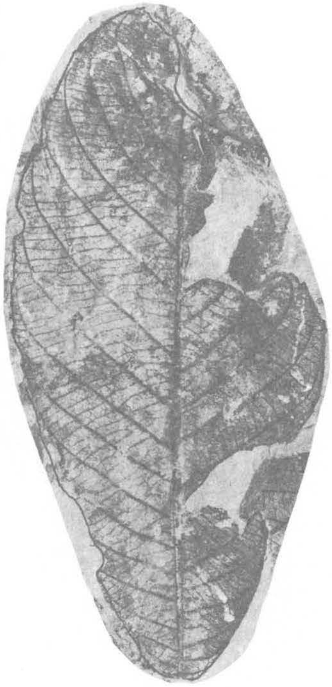
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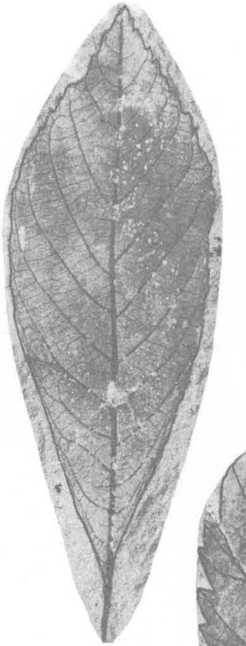
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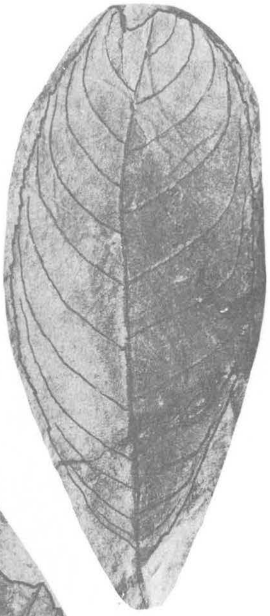
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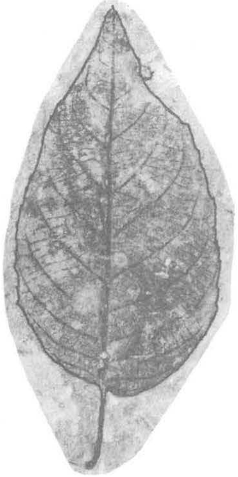
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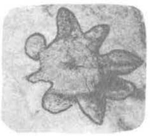
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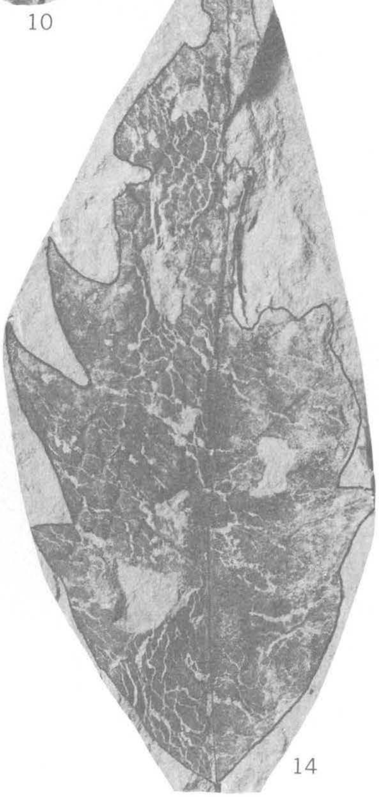
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MEGASCOPIC PALEOCENE PLANTS

PLATE 19

FIGURE 1. *Pterocarya hispida* Brown, n. sp. (p. 57). Loc. 8910.
2. *Quercus macneili* Brown, n. sp. (p. 58). Loc. 8239.
3, 6, 12. *Quercus greenlandica* Heer (p. 58). 3, loc. 4010; 6, loc. 4878; 12, loc. 6171.
4. *Quercus yulensis* Brown, n. sp. (p. 59). Loc. 8239.
5, 7–11. *Juglandicarya* spp. (p. 56). 5, 10, loc. 5917; 7, loc. 8910; 8, loc. 9198; 9, 11, loc. 9112.


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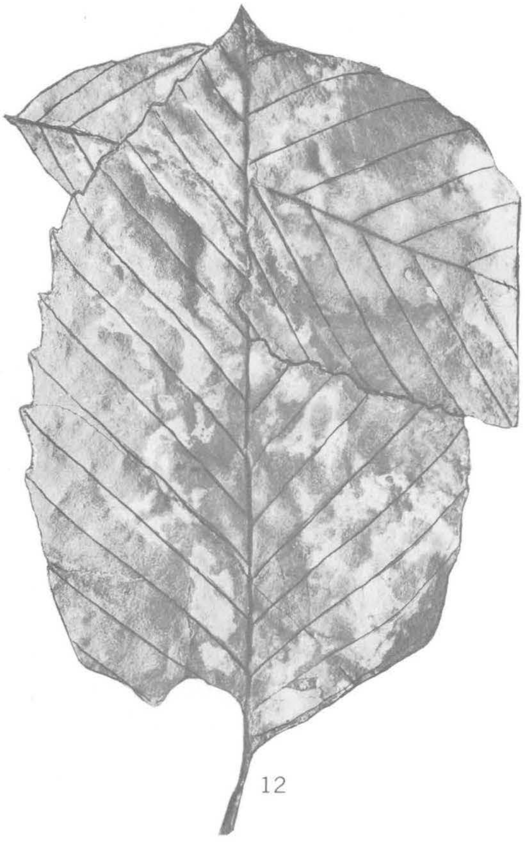
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MEGASCOPIC PALEOCENE PLANTS

PLATE 20

FIGURES 1–5, 7–9. *Betula stevensoni* Lesquereux (p. 57). 1, 3 (catkin), loc. 4661; 2, 4, loc. 8893; 5, loc. 3661; 7 (catkins), loc. 9109; 8, loc. 4984; 9, loc. 9199.

6. *Celtis peracuminata* Brown, n. sp. (p. 60). Loc. 7688.

10. *Morus montanensis* Brown, n. sp. (p. 64). Loc. 4032.


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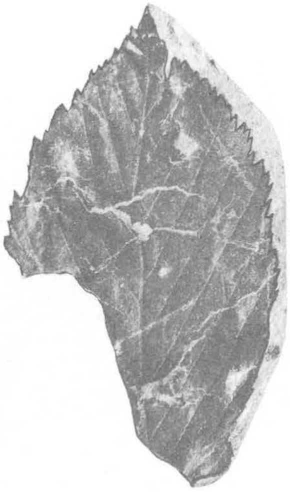
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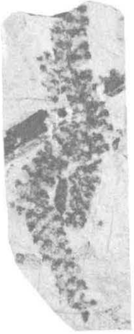
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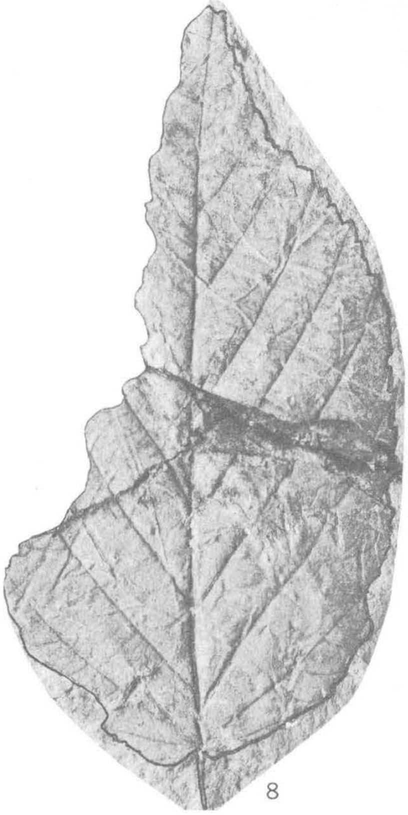
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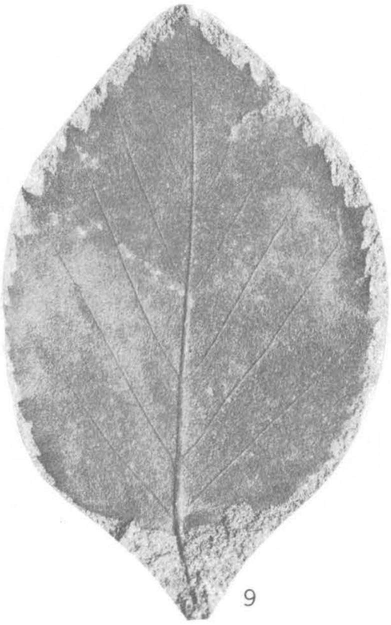
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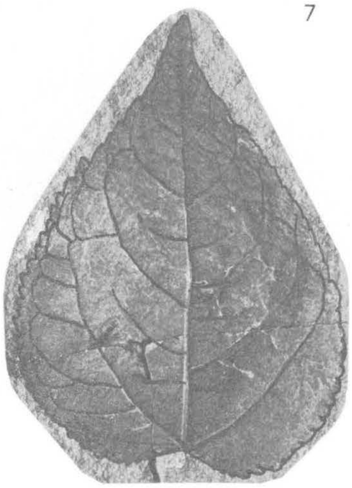
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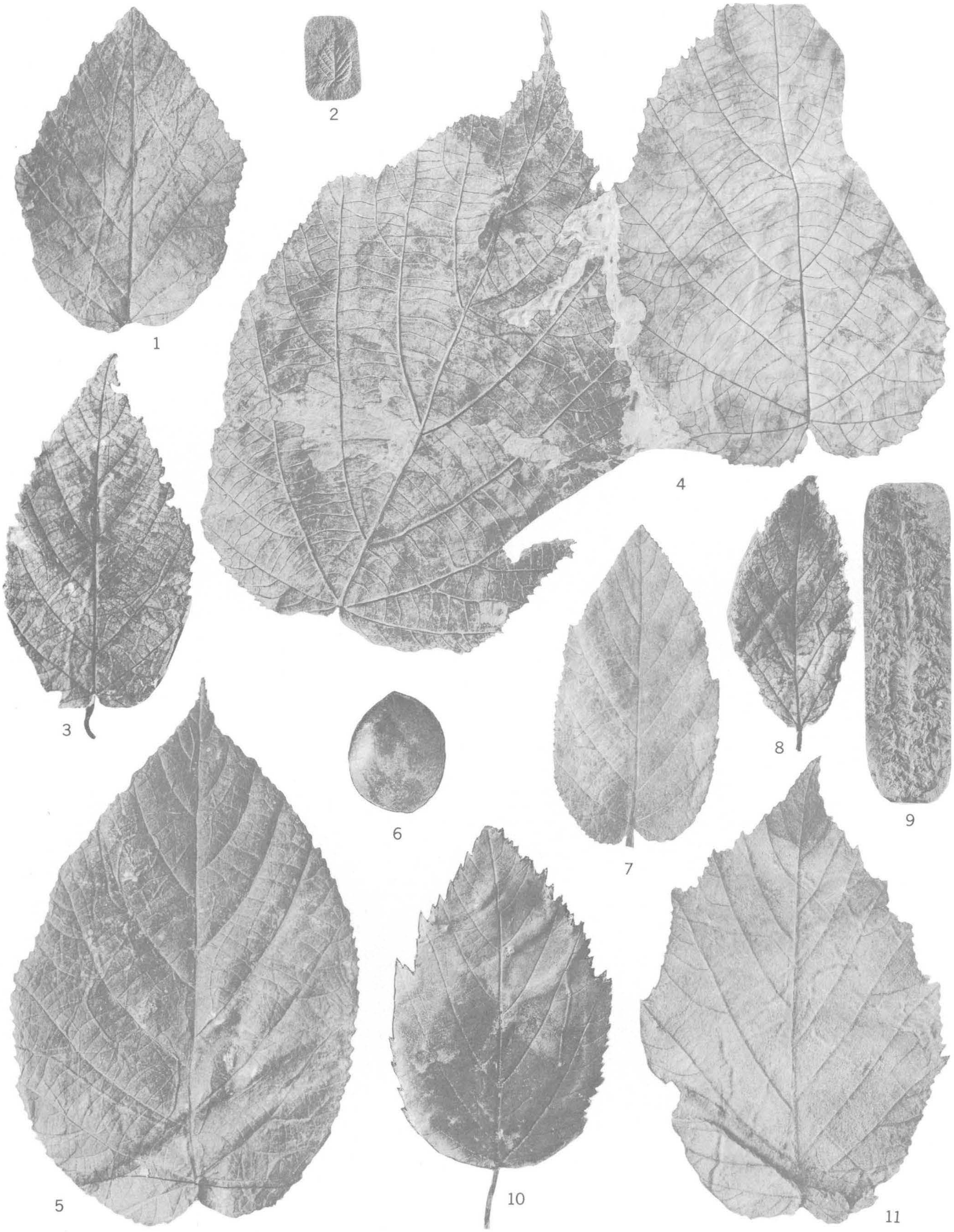
MEGASCOPIC PALEOCENE PLANTS

PLATE 21

Figures 1–11. *Corylus insignis* Heer (p. 57). 1, 6 (× 3) (nut), 11, loc. 2416; 2, 3, 8, loc. 9072; 4, loc. 8255; 5, loc. 2414; 7, loc. 9202; 9 (× 2) (catkin), 10, loc. 8519.



MEGASCOPIC PALEOCENE PLANTS

PLATE 22

FIGURE 1. *Quercus asymmetrica* Trelease (p. 58). Exact locality unknown.
2. *Zelkova planeroides* (Ward) Brown, n. comb. (p. 60). Exact locality unknown.
3, 4, 6, 7–10. *Castanea intermedia* Lesquereux (p. 58). 3, 4, 6, loc. 8928; 7, loc. 541; 8, loc. 9203; 9, loc. 5836; 10, loc. 5495.
5. *Quercus greenlandica* Heer (p. 58). Loc. 6000.

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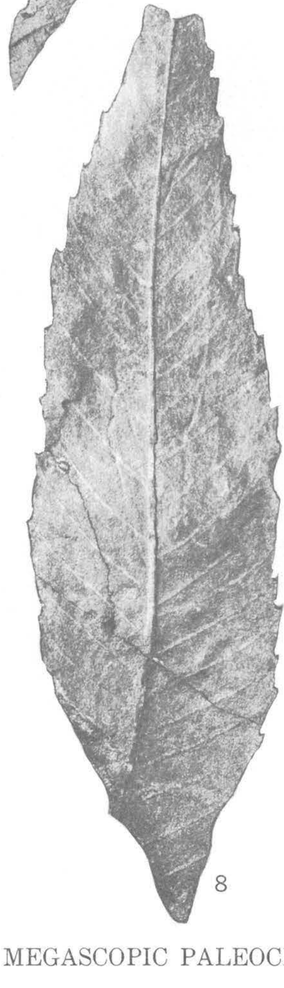

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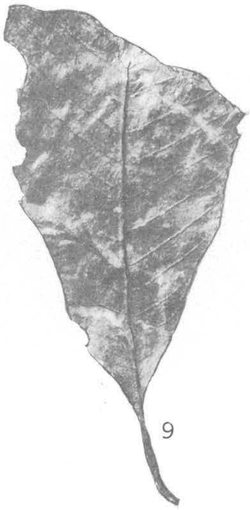

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MEGASCOPIC PALEOCENE PLANTS

PLATE 23

Figures 1–7. *Quercus sullyi* Newberry (p. 59). 1, loc. 436; 2, exact locality unknown; 3, loc. 8552; 4, loc. 8239; 5, loc. 2414; 6, 7, loc. 8886.

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MEGASCOPIC PALEOCENE PLANTS

PLATE 24

FIGURES 1–11, 13, 15, 16. *Planera microphylla* Newberry (p. 60). 1, 2, loc. 8885; 3–5, 8, 9, 13, loc. 4264; 6, exact locality unknown; 7, 11, loc. 8206; 10, loc 5885; 15, loc. 8166; 16, exact locality unknown.

12, 14, 19, 20. *Zelkova planeroides* (Ward) Brown, n. comb. (p. 60). 12, loc. 4035; 14, 20, loc. 2414; 19, exact locality unknown.

17, 18, 21–23. *Ulmus rhamnifolia* Ward (p. 60). Seeds (17, 18). 17, loc. 9207; 18, 23, loc. 8910; 21, loc. 2414; 22, loc. 9109.


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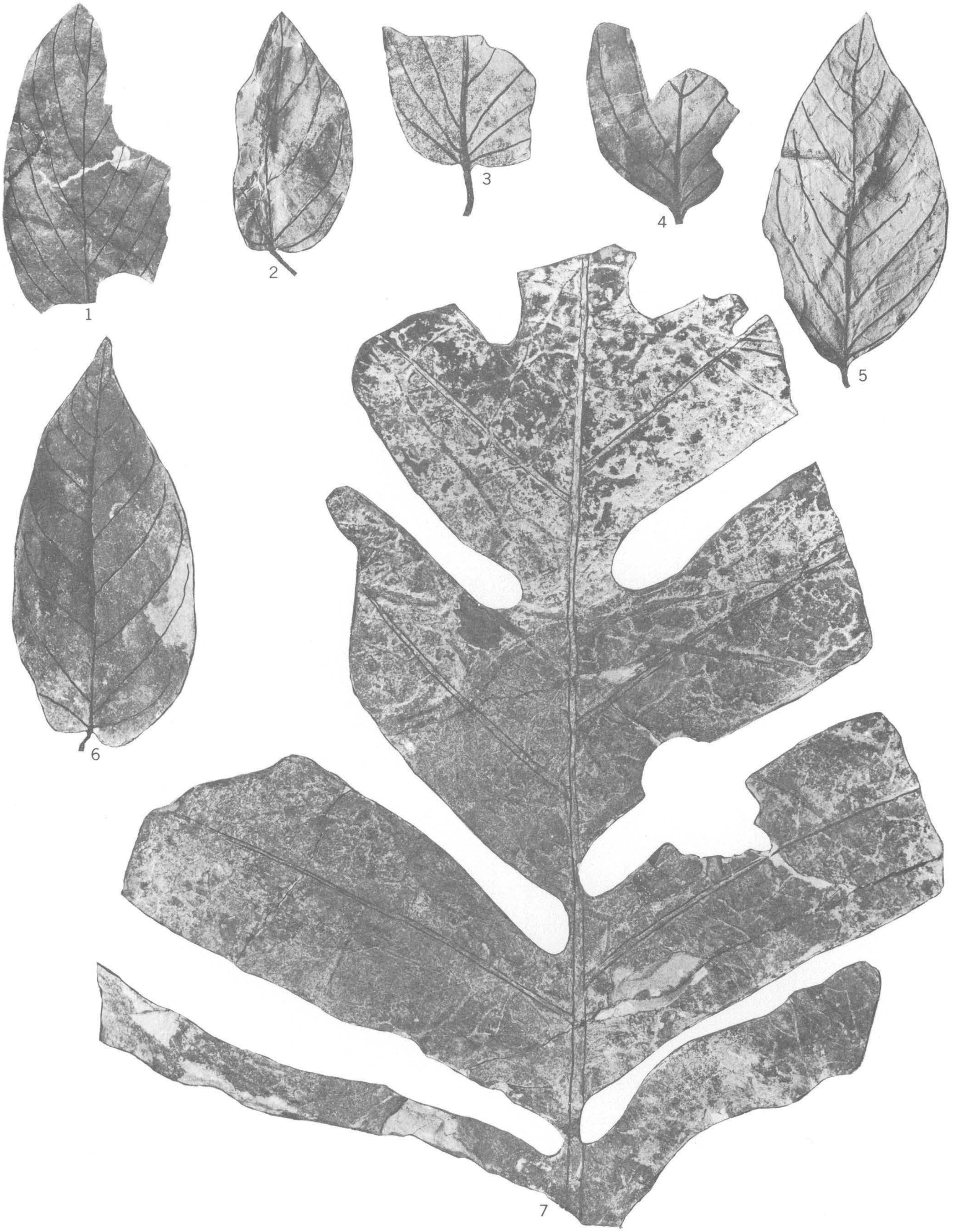
MEGASCOPIC PALEOCENE PLANTS

PLATE 25

FIGURES 1–6. *Ficus subtruncata* Lesquereux (p. 63). 1, 4, loc. 8227; 2, loc. 8551; 3, loc. 8516; 5, loc. 8901; 6, loc. 317.

7. *Artocarpus lessigiana* (Lesquereux) Knowlton (p. 60). Loc. 317.



MEGASCOPIC PALEOCENE PLANTS

PLATE 26

Figures 1–8. *Ficus planicostata* Lesquereux (p. 62). 1, loc. 317; 2, 5, 7, 8, loc. 8774; 3, loc. 7481; 4, loc. 8188; 6, loc. 4876.

MEGASCOPIC PALEOCENE PLANTS

PLATE 27

FIGURES 1, 2, 5. *Ficus affinis* (Lesquereux) Brown, n. comb. (p. 61). 1, 2, loc. 317; 5, loc. 7481.

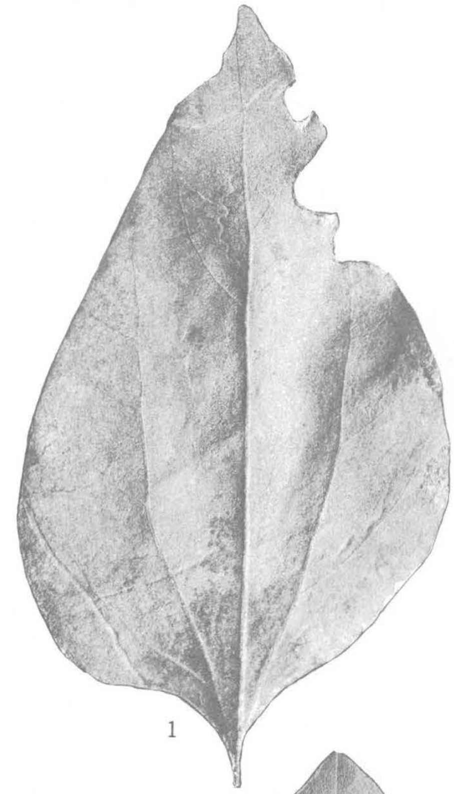
3, 4. *Celtis newberryi* Knowlton and Cockerell (p. 59). 3, exact locality unknown; 4, loc. 9109.

6, 7. *Laurus socialis* Lesquereux (p. 67). 6, loc. 4696; 7, loc. 4325.

8. *Cissites rocklandensis* Brown, n. sp. (p. 81). Loc. 5679.

9. *Quercus sullyi* Newberry (p. 59). Loc. 8253.

10. *Vitis olriki* Heer (p. 82). Loc. 8517.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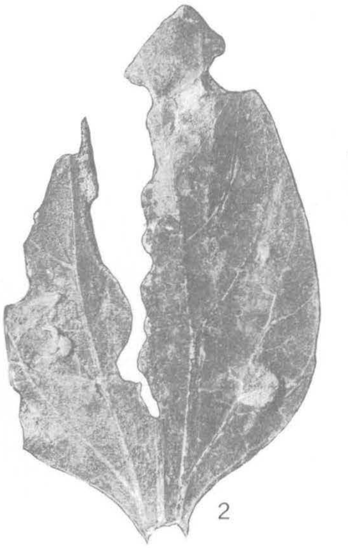
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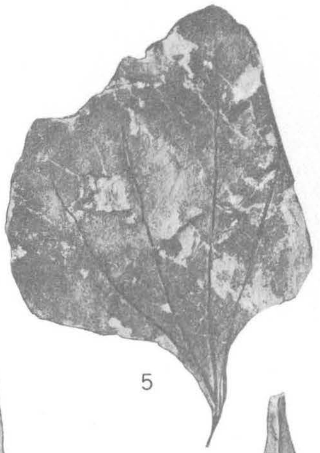
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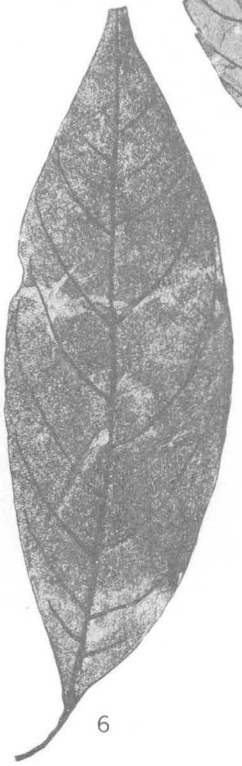
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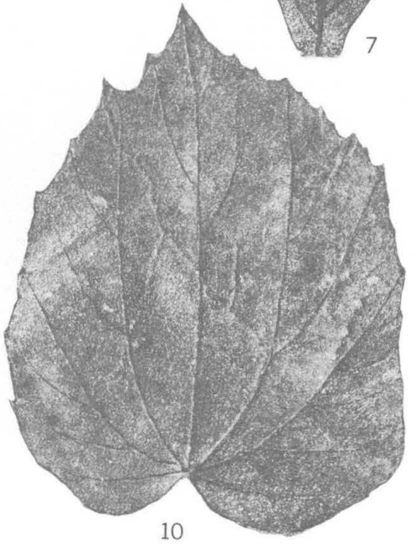
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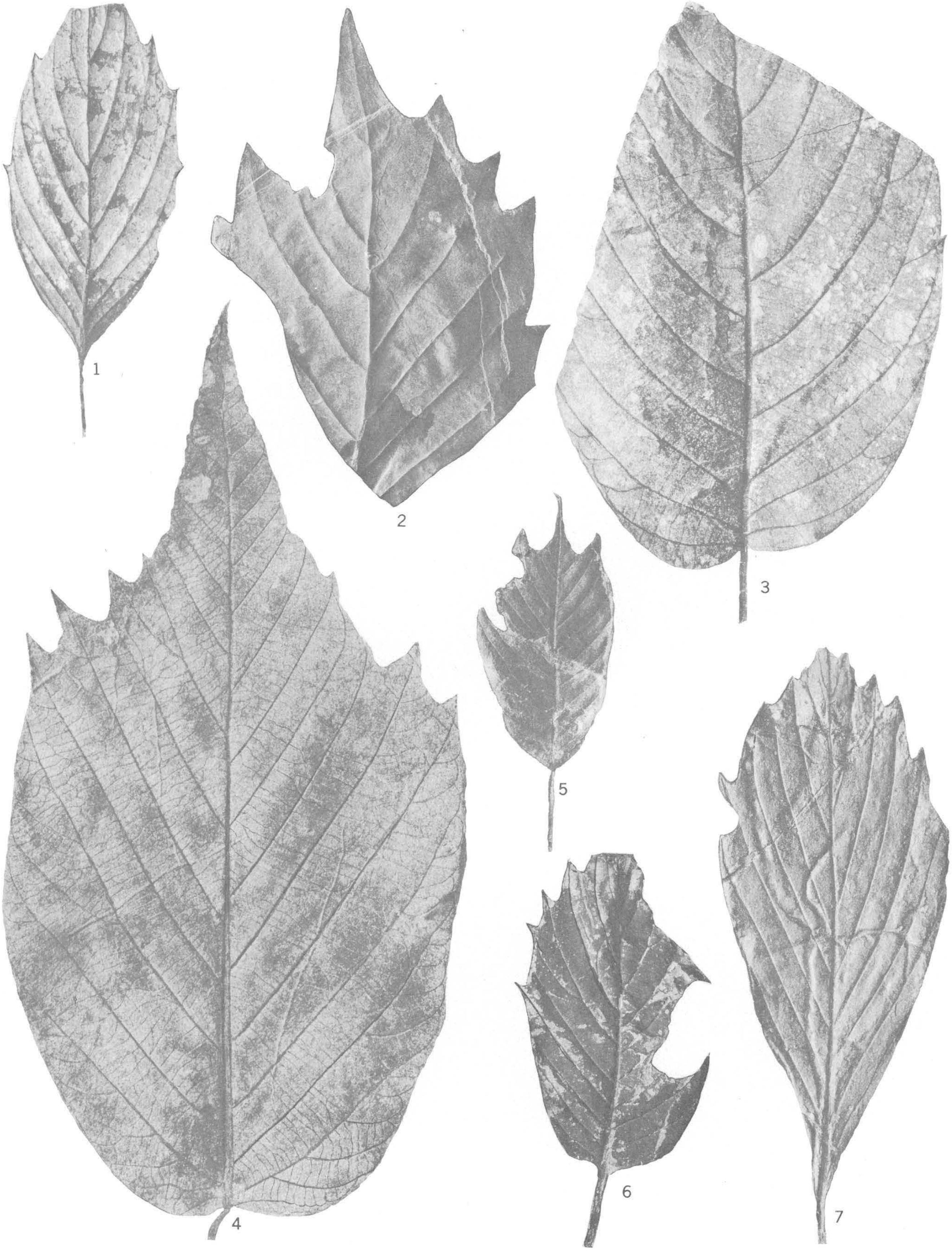
MEGASCOPIC PALEOCENE PLANTS

PLATE 28

FIGURES 1–7. *Ficus artocarpoides* Lesquereux (p. 61). 1, exact locality unknown; 2, loc. 8910; 3, loc. 4369; 4, loc. 8261; 5, loc. 2416; 6, loc. 4625; 7, exact locality unknown.

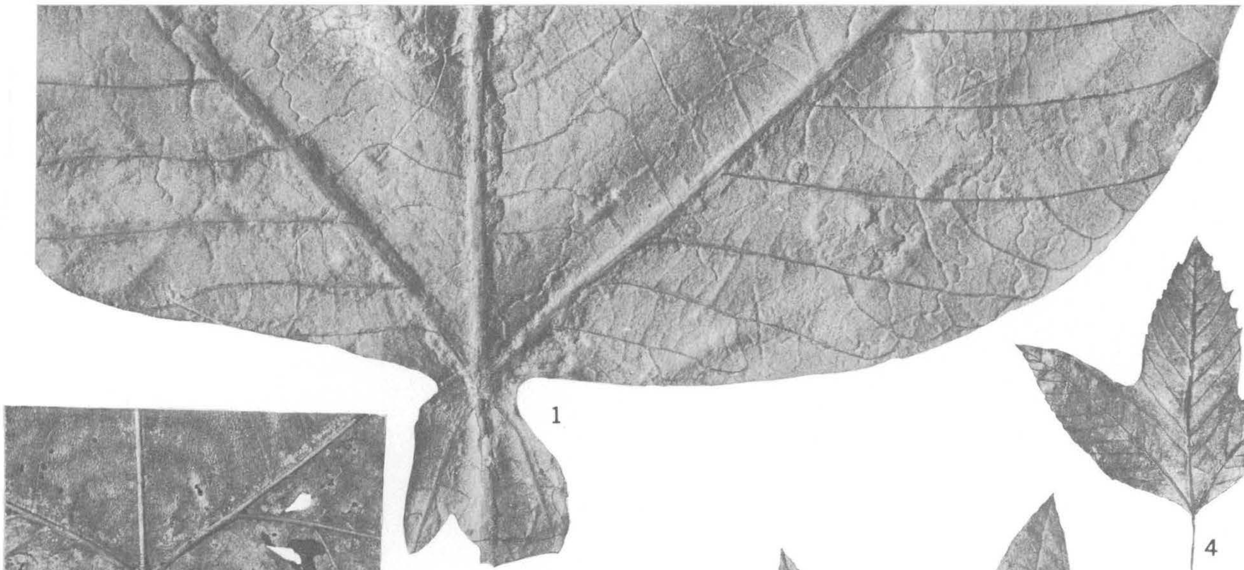


MEGASCOPIC PALEOCENE PLANTS

PLATE 29

FIGURES 1, 3–6. *Platanus nobilis* Newberry (p. 64). 1, 4, loc. 2416; 3, loc. 2414; 5, 6, loc. 5594.

2. Leaf of the existing *Platanus occidentalis* Linnaeus, showing basilar lobes (p. 64).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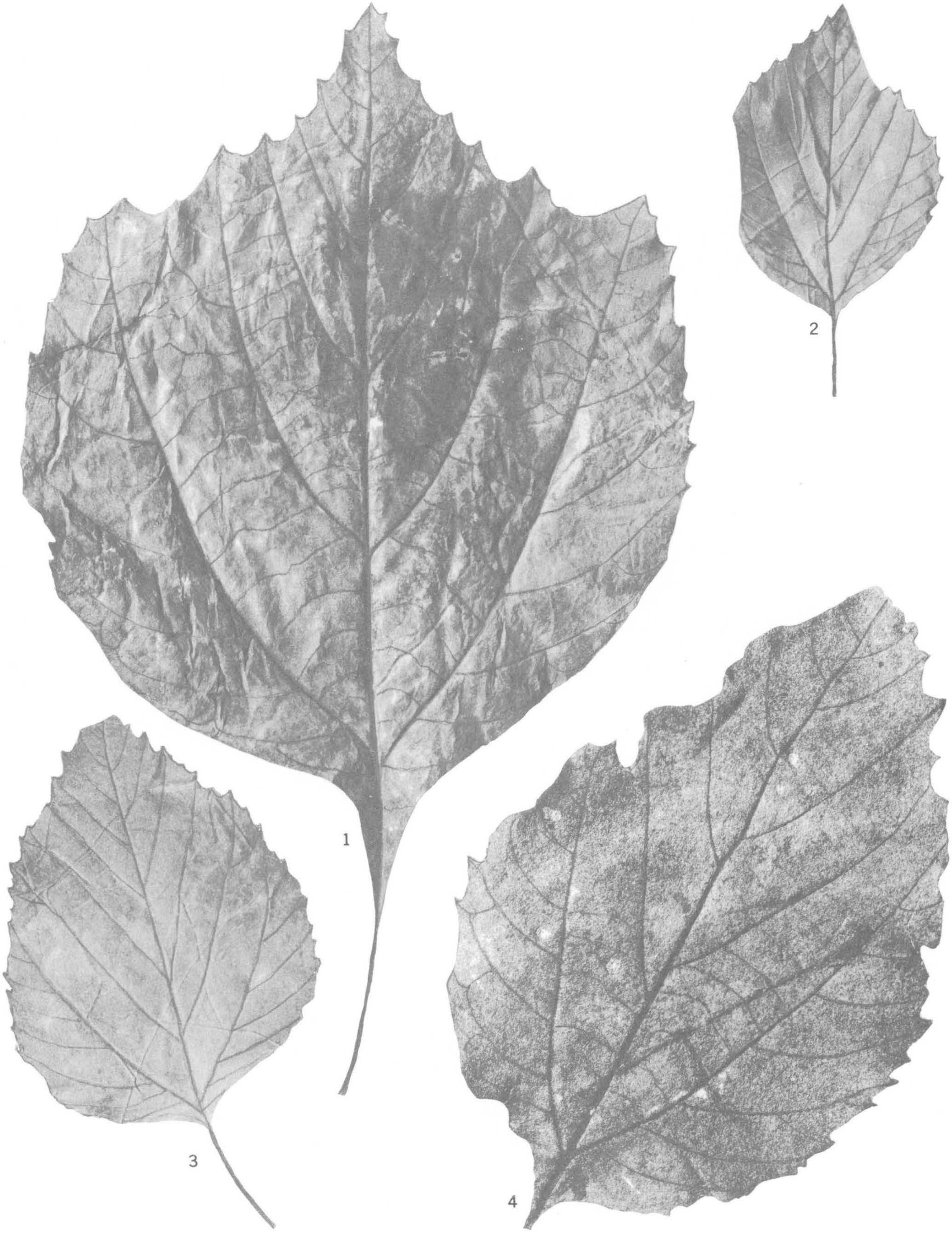
MEGASCOPIC PALEOCENE PLANTS

PLATE 30

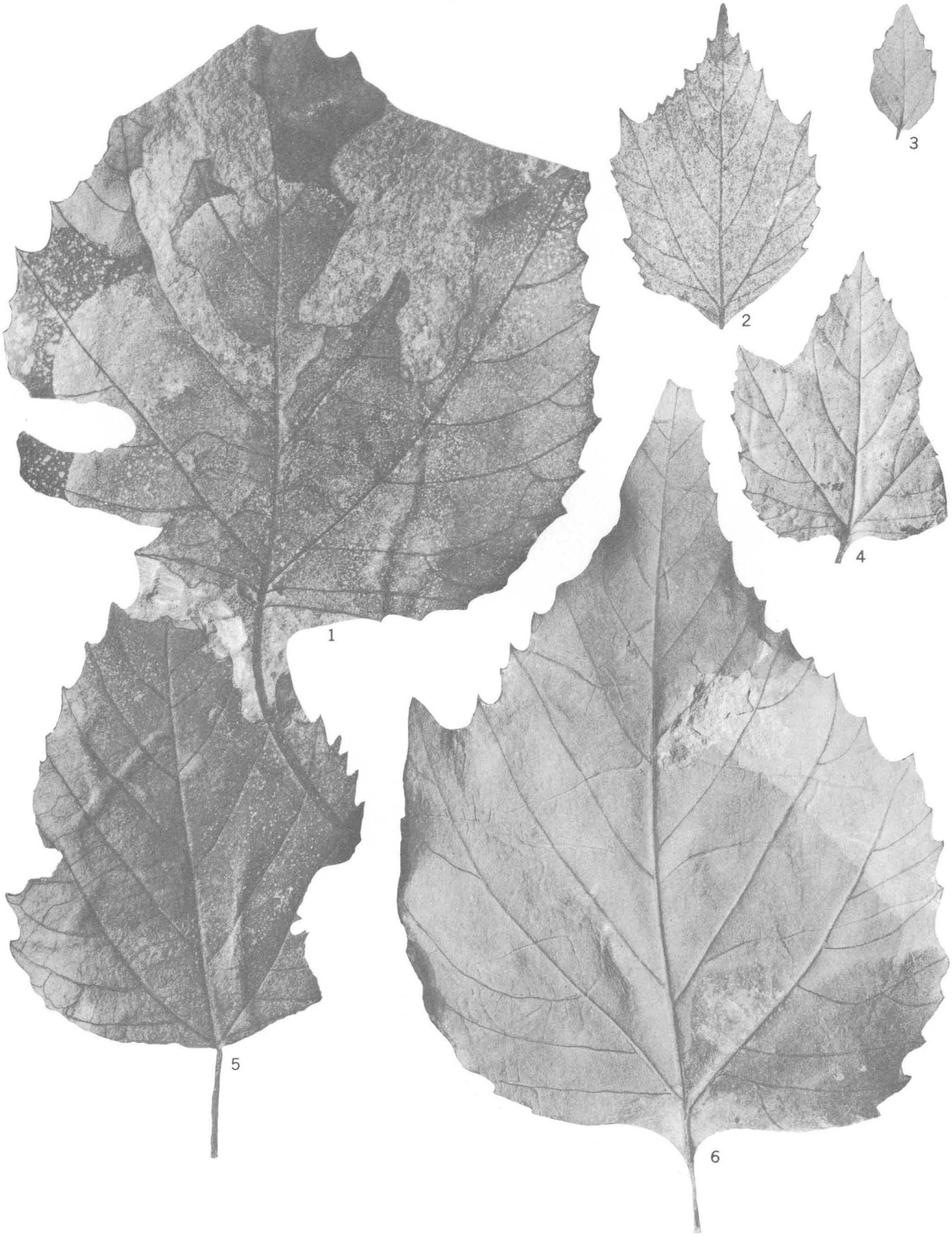
FIGURES 1–4. *Platanus raynoldsi* Newberry (p. 64). 1, exact locality unknown; 2, 3, loc. 2420; 4, loc. 8257.



MEGASCOPIC PALEOCENE PLANTS

PLATE 31

FIGURES 1–6. *Platanus raynoldsi* Newberry (p. 64). 1, 5, 6, loc. 4035; 2, loc. 4910; 3, 4, loc. 2424.



MEGASCOPIC PALEOCENE PLANTS

PLATE 32

FIGURES 1–5. *Credneria? daturaefolia* Ward (p. 66). 1, 3, loc. 2416; 2, loc. 7552; 4, loc. 4975; 5, loc. 8164.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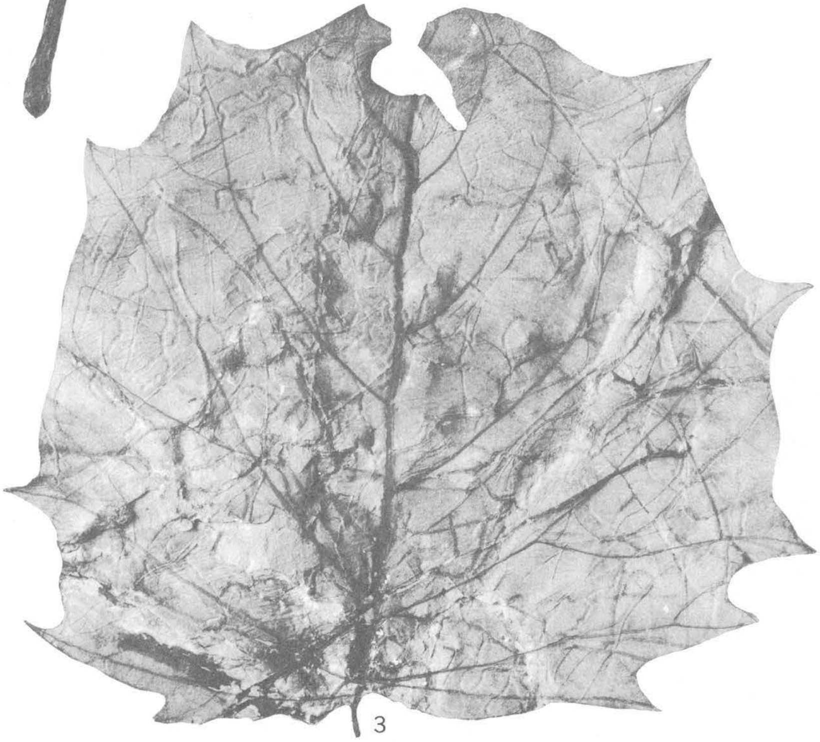
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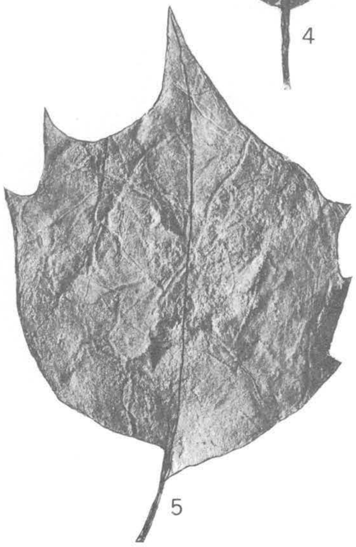
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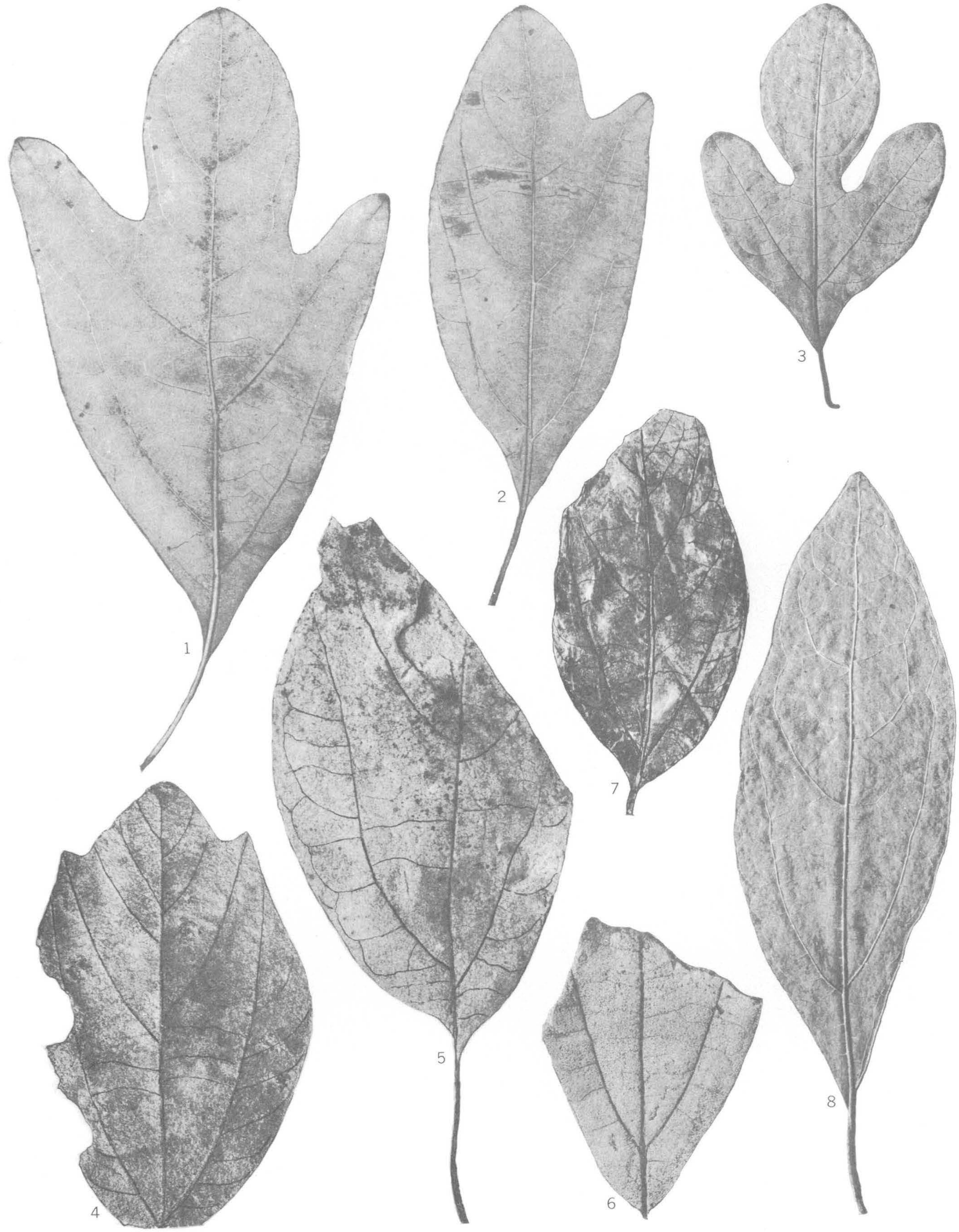
MEGASCOPIC PALEOCENE PLANTS

PLATE 33

FIGURES 1–3, 8. Variant leaves of the existing *Sassafras albidum* (Nuttall) Nees (p. 68).

4–7. *Sassafras thermale* (Lesquereux) Brown, n. comb. (p. 68). 4, loc. 4665; 5, loc. 4874; 6, loc. 3852; 7, loc. 8551.



MEGASCOPIC PALEOCENE PLANTS

PLATE 34

FIGURES 1, 2, 4. *Sassafras thermale* (Lesquereux) Brown, n. comb. (p. 68). 1, loc. 8887: 2, 4, loc. 3653.

3, 5. *Laurophyllum perseanum* Brown, n. sp. (p. 67). 3, loc. 3661; 5, loc. 2416.

6–8. *Persea brossiana* Lesquereux (p. 67). 6, loc. 7496; 7, loc. 4661; 8, loc. 5612.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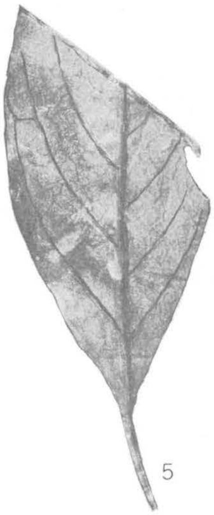
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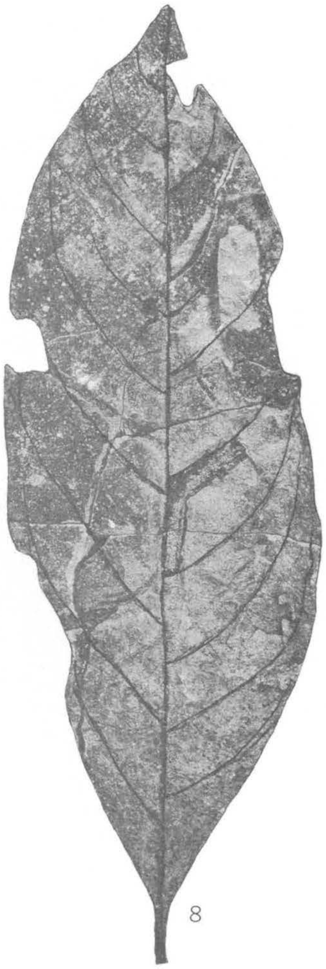
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MEGASCOPIC PALEOCENE PLANTS

PLATE 35

FIGURE 1. *Paleonelumbo macroloba* Knowlton (p. 69). Loc. 8673.

2–4. *Nelumbium montanum* Brown (p. 69). 2, loc. 8786; 3 (fruit), loc. 8262; 4, loc. 8227.

5, 6. *Cabomba inermis* (Newberry) Hollick (p. 68). 5, loc. 9072; 6, exact locality unknown.

7. *Paleonuphar hesperium* Brown, n. sp. (p. 69). Loc. 7538.


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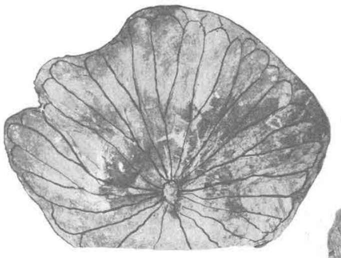
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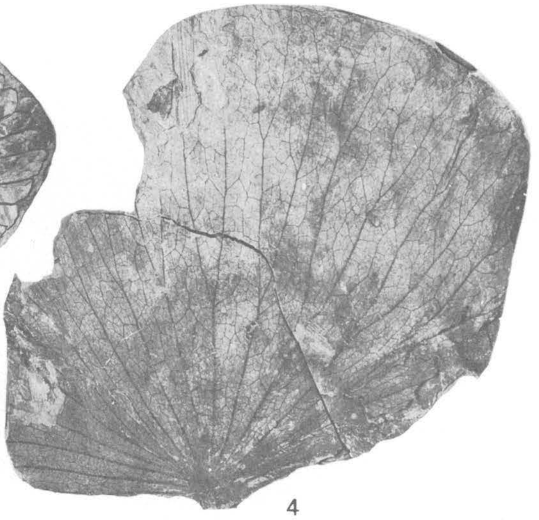
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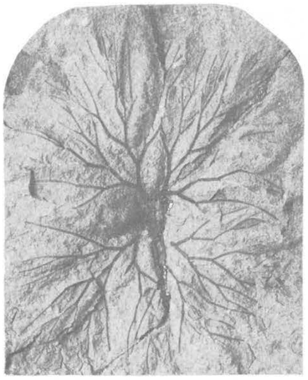
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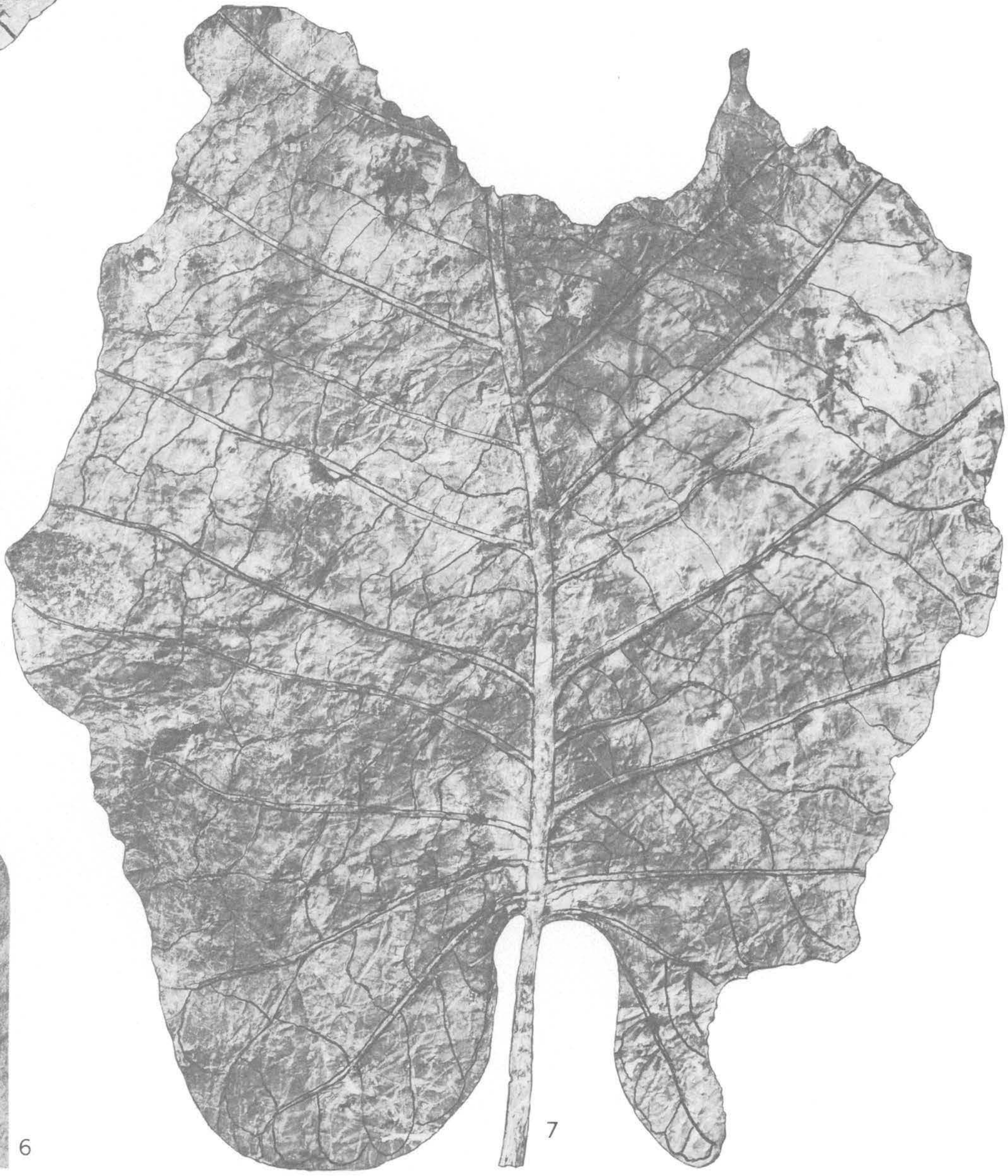
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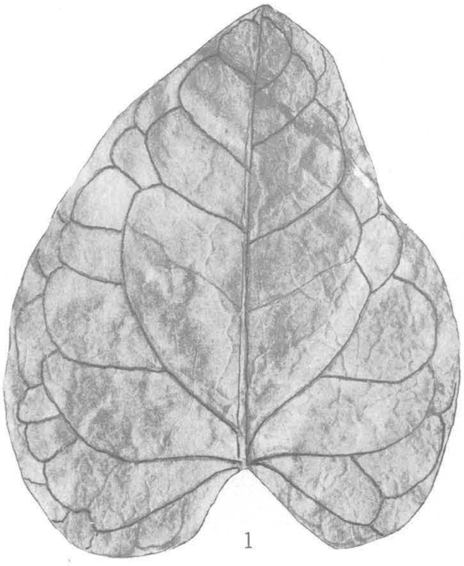
MEGASCOPIC PALEOCENE PLANTS

PLATE 36

Figures 1–5. *Paranymphaea crassifolia* (Newberry) Berry (p. 70). 1, loc. 2432; 2, loc. 8553; 3, 4, loc. 8519; 5, exact locality unknown.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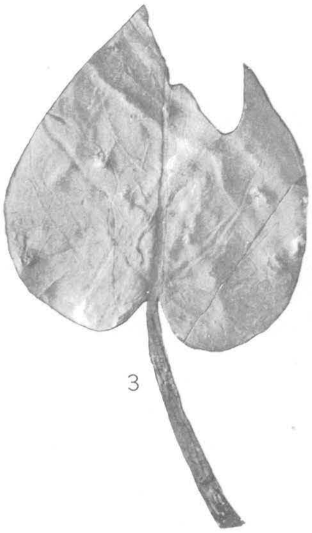
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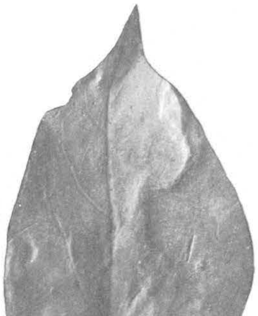
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MEGASCOPIC PALEOCENE PLANTS

PLATE 37

FIGURES 1–24. *Cercidiphyllum arcticum* (Heer) Brown (p. 70). Leaves (8–11, 13, 15, 17, 18, 20, 22); fruits (1, 14, 23, 24); seeds (2–7, 12, 16, 19). 1, 2, loc. 3653; 3, loc. 8673; 4, 7, 14, loc. 5437; 5, loc. 8227; 6, loc. 8672; 8, 10, 11, 17, loc. 9334; 9, loc. 8188; 12, 16, loc. 9130; 13, 18, loc. 8567; 15, loc. 8519; 19, 20, 22–24, loc. 8517; 21, loc. 317.


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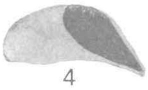
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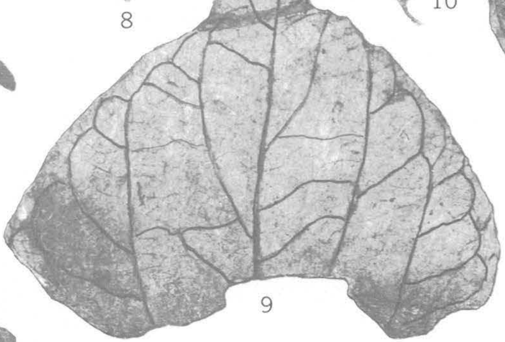
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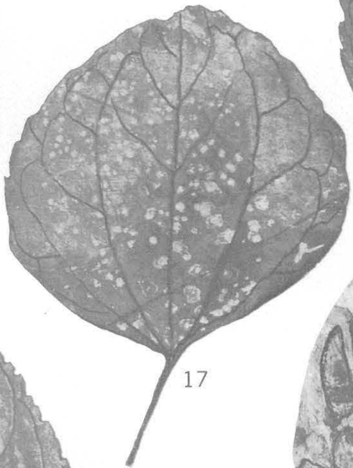
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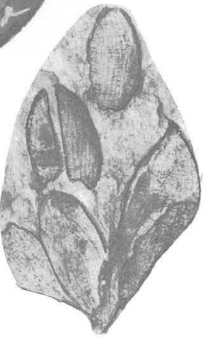
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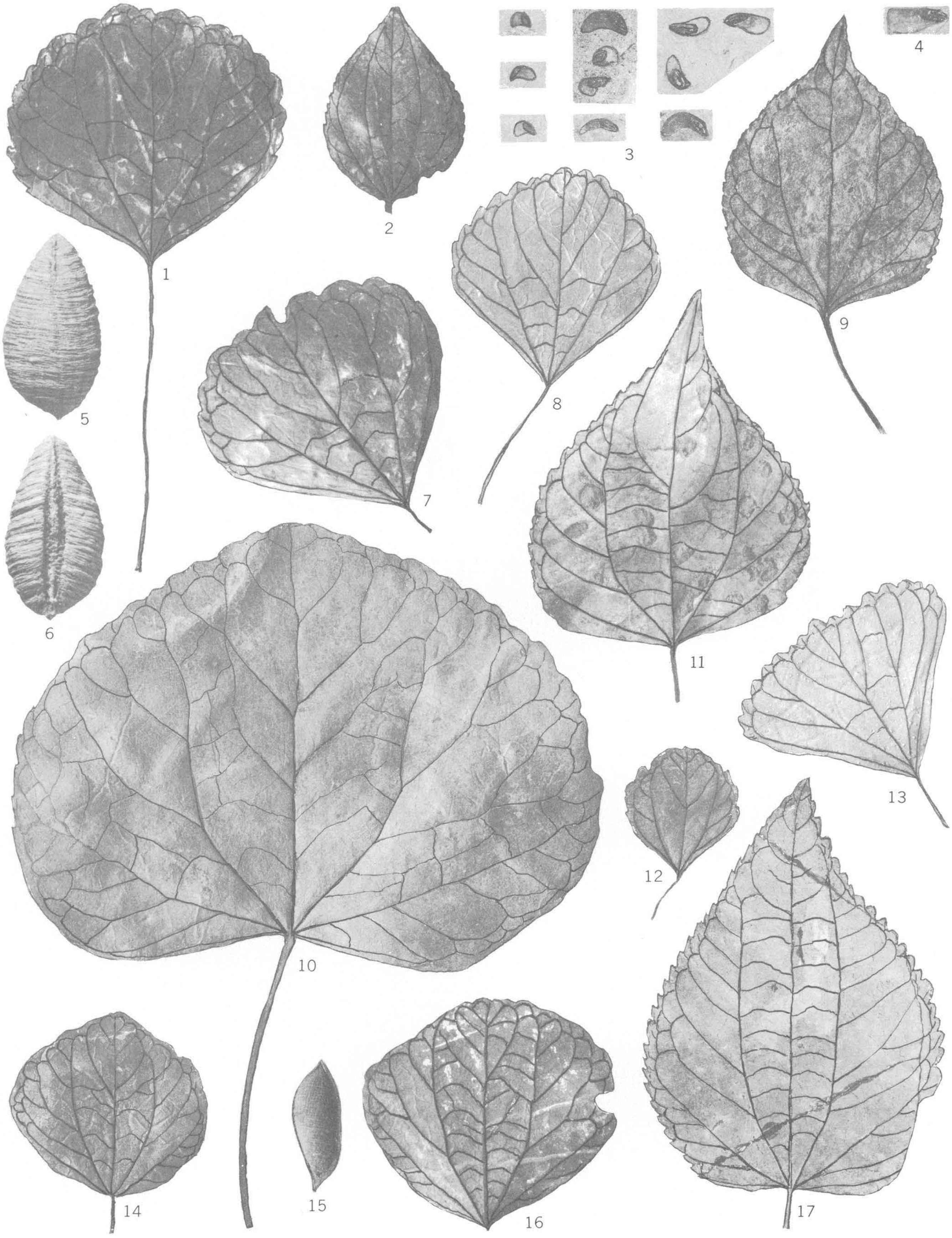
MEGASCOPIC PALEOCENE PLANTS

PLATE 38

Figures 1–17. *Cercidiphyllum arcticum* (Heer) Brown (p. 70). Leaves (1, 2, 7–14, 16, 17); fruits (5, 6, 15); seeds (3, 4). 1, loc. 2416; 2, loc. 8234; 3 (left column in 3, loc. 8910), others, loc. 9125; 4, 9, 15, loc. 9125; 5, 6, loc. 4256; 7, 8, 10, 14, 16, loc. 4264; 11, loc. 8167; 12, loc. 8556; 13, loc. 8540; 17, loc. 8774.



MEGASCOPIC PALEOCENE PLANTS

PLATE 39

FIGURE 1. *Magnolia berryi* (Knowlton) Brown, n. comb. (p. 71). Loc. 5679.
2. *Magnolia regalis* Heer (p. 72). Loc. 317.
3. *Magnolia borealis* Brown, n. name (p. 71). Loc. 8523.
4. *Magnolia magnifolia* Knowlton (p. 71). Loc. 4882.

MEGASCOPIC PALEOCENE PLANTS

PLATE 40

FIGURES 1, 2. *Quercus greenlandica* Heer (p. 58). Loc. 5526.
3. *Kalmia elliptica* Brown, n. sp. (p. 85). Loc. 4661.
4–6. *Hamamelites inaequalis* (Newberry) Brown, n. comb. (p. 72). 4, exact locality unknown; 5, loc. 2416; 6, loc. 4977.

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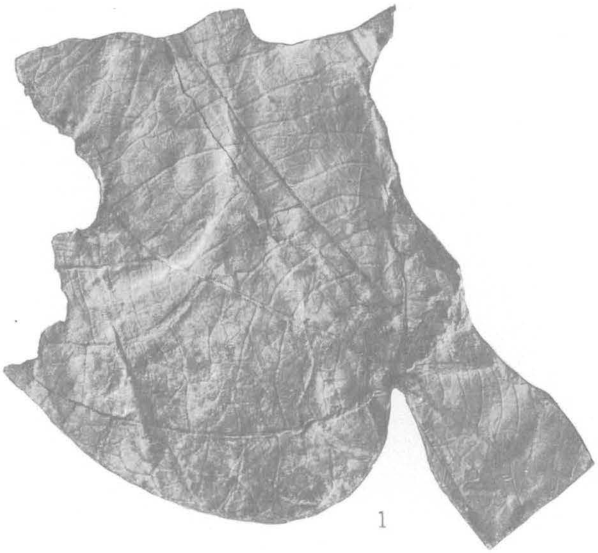
MEGASCOPIC PALEOCENE PLANTS

PLATE 41

Figures 1, 2, 4. *Pterospermites cordatus* Ward (p. 82). 1, loc. 8678; 2, loc. 7776; 4, loc. 4625.

3, 5. *Hydrangea antica* Brown, n. sp. (p. 73). 3, loc. 337; 5, loc. 4661.



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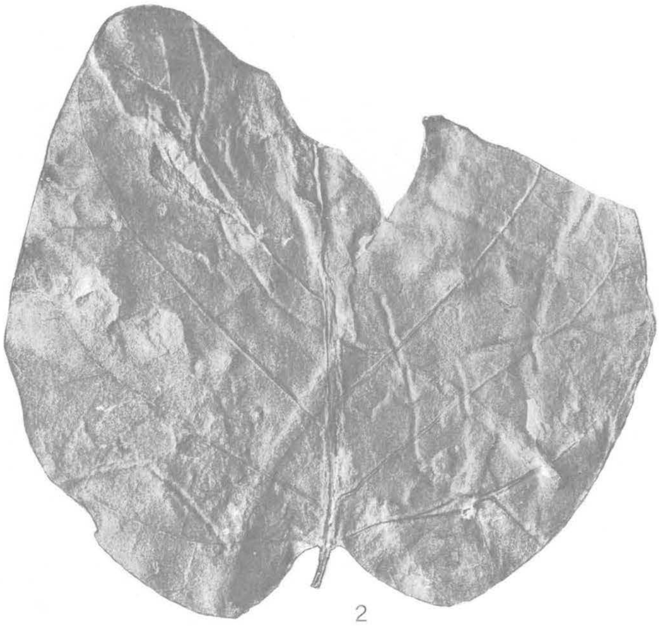

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MEGASCOPIC PALEOCENE PLANTS

PLATE 42

FIGURES 1, 5–7. *Rhamnus cleburni* Lesquereux (p. 77). 1, 6, loc. 8672; 5, 7, loc. 317.
2, 8. *Prunus careyhurstia* Brown, n. sp. (p. 73). 2, loc. 8666; 8, loc. 8552.
3, 4, 9. *Prunus coloradensis* Knowlton (p. 73). 3, 4, loc. 5738; 9, loc. 5836.

MEGASCOPIC PALEOCENE PLANTS

PLATE 43

FIGURE 1. *Lindera obtusata* (Ward) Brown, n. comb. (p. 67). Loc. 5720.

2, 3. *Prunus perita* Brown, n. sp. (p. 74). Loc. 8552.

4–6. *Robinia wardi* (Knowlton) Brown, n. comb. (p. 75). 4, 6, loc. 9109; 5, loc. 9445.

7, 8. *Ficus affinis* (Lesquereux) Brown, n. comb. (p. 61). 7, loc. 5796; 8, loc. 4625.

9. Probably a leaflet of *Robinia wardi* (Knowlton) Brown (p. 75). Loc. 6440.

10. *Bauhinia wyomingana* Brown (p. 74). Loc. 4877.

11. Probably a leguminous leaflet (p. 75). Loc. 8556.

12, 13. *Mimosites coloradensis* Knowlton (p. 75). Loc. 6440.


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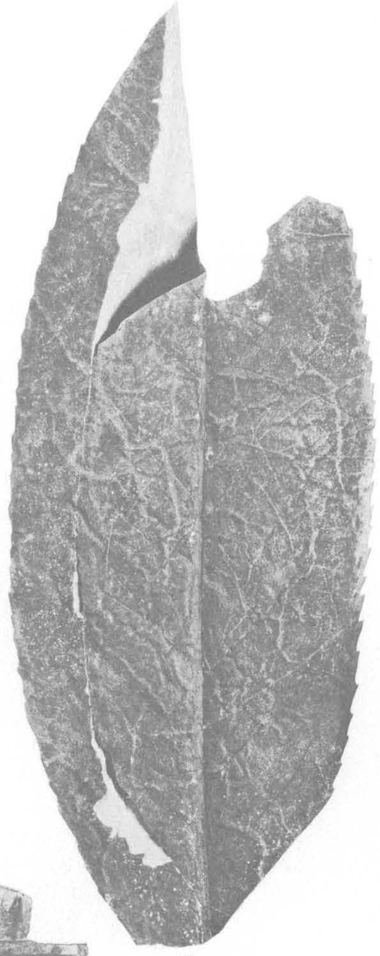
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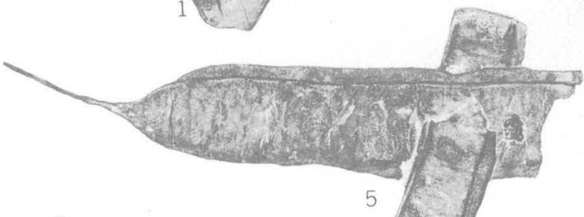
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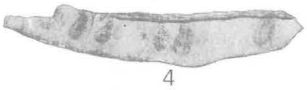
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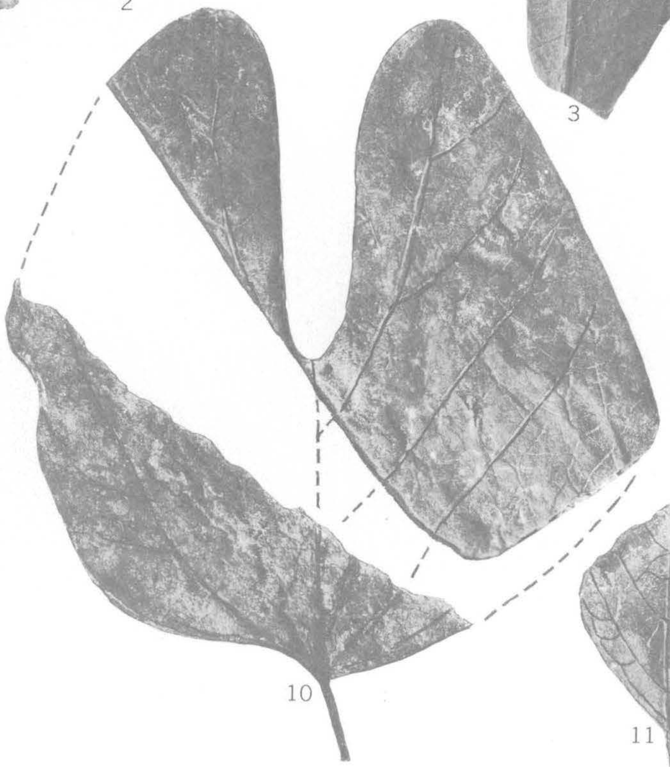
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MEGASCOPIC PALEOCENE PLANTS

PLATE 44

FIGURES 1–6. *Eucommia serrata* (Newberry) Brown, n. comb. (p. 72). 1, loc. 2421; 2, loc. 5889; 3, loc. 2420; 4, loc. 2423; 5, loc. 4626; 6, loc. 2422.


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MEGASCOPIC PALEOCENE PLANTS

PLATE 45

FIGURES 1–7. *Eucommia serrata* (Newberry) Brown, n. comb. (p. 72). 1, exact locality unknown; 2, 5–7, loc. 2420; 3, loc. 8552; 4, loc. 5889.


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MEGASCOPIC PALEOCENE PLANTS

PLATE 46

FIGURE 1. *Viburnum cupanioides* (Newberry) Brown, n. comb. (p. 87). Loc. 8190.
2, 3, 6, 8. *Acer newberryi* Brown, n. name (p. 75). 2, 6, 8, loc. 2420; 3, loc. 8910.
4. *Asimina vesperalis* Brown, n. sp. (p. 73). Loc. 8774.
5. *Acer* sp. (p. 76). Loc. 8910.
7. *Acer silberlingi* Brown, n. sp. (p. 76). Loc. 8567.
9, 10. *Acer* sp. (p. 76). Loc. 9109.


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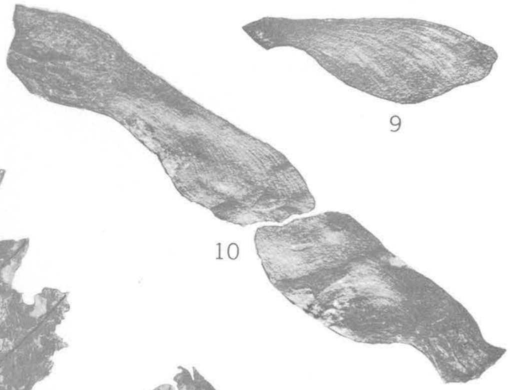
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MEGASCOPIC PALEOCENE PLANTS

PLATE 47

FIGURES 1–8. *Sapindus affinis* Newberry (p. 76). 1, 3, exact locality unknown; 4, 6, loc. 2416; 2, 5, loc. 8523; 7, 8, loc. 8678.

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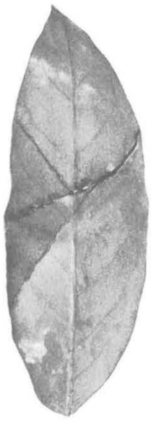

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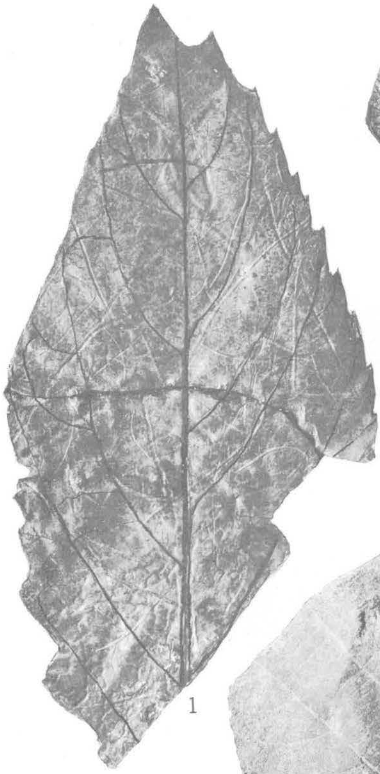
MEGASCOPIC PALEOCENE PLANTS

PLATE 48

FIGURES 1, 3, 4. *Parthenocissus ursina* Brown, n. sp. (p. 81). Loc. 8547.
2, 5–7. *Rhamnus goldiana* Lesquereux (p. 77). 2, 6, 7, loc. 8774; 5, loc. 317.
8. *Ficus minutidens* Knowlton (p. 62). Loc. 7496.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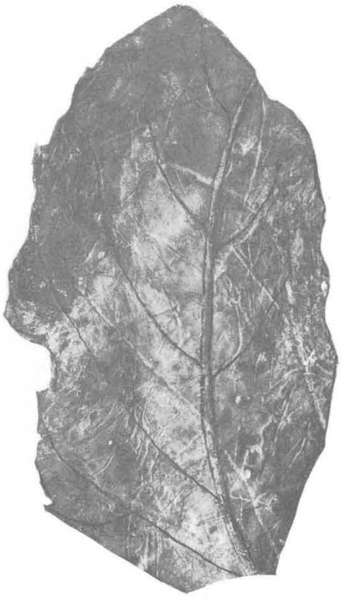
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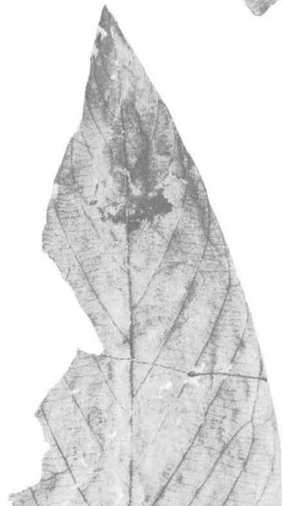
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MEGASCOPIC PALEOCENE PLANTS

PLATE 49

FIGURES 1–10. *Rhamnus hirsuta* Brown, n. sp. (p. 77). Loc. 8519.

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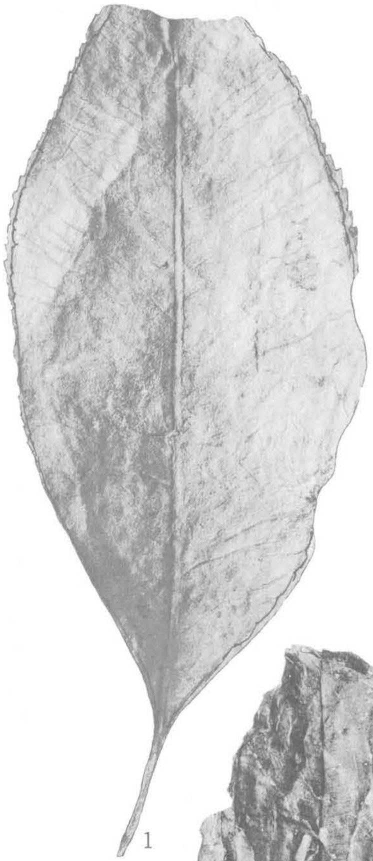
MEGASCOPIC PALEOCENE PLANTS

PLATE 50

FIGURES 1–4, 7–9. *Myrtophyllum torreyi* (Lesquereux) Dorf (p. 83). 1, loc. 9210; 2, 7, loc. 8551; 3, 4, loc. 8677; 8, loc. 8188; 9, loc. 8881.

5, 6, 10, 11. *Zizyphus fibrillosus* (Lesquereux) Lesquereux (p. 78). 5, 6, loc. 8774; 10, loc. 8776; 11, loc. 317.



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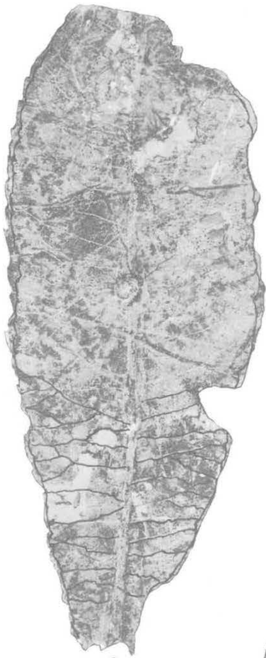

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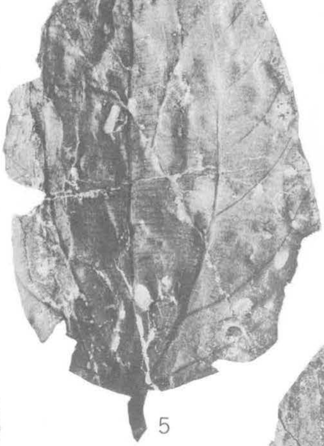

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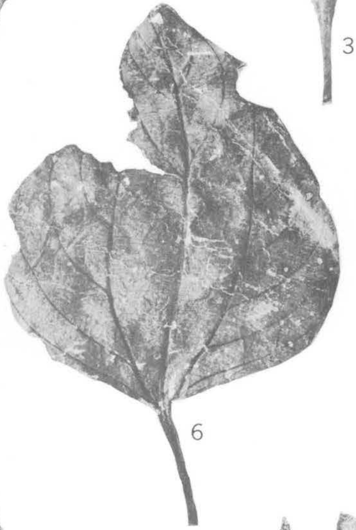

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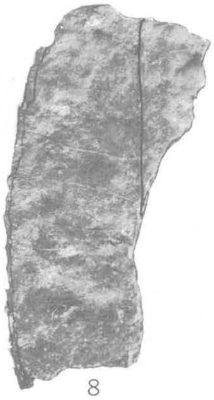

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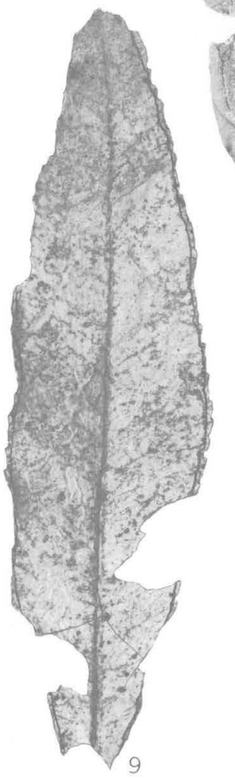

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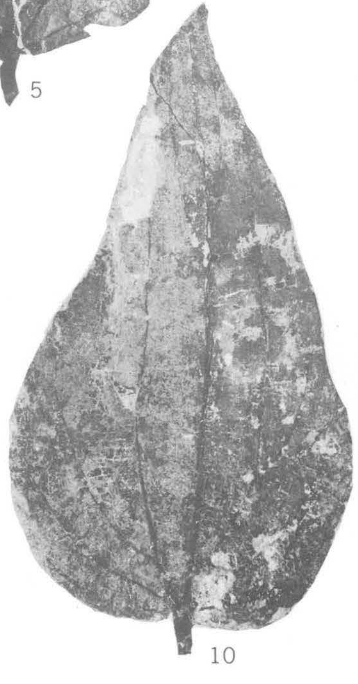

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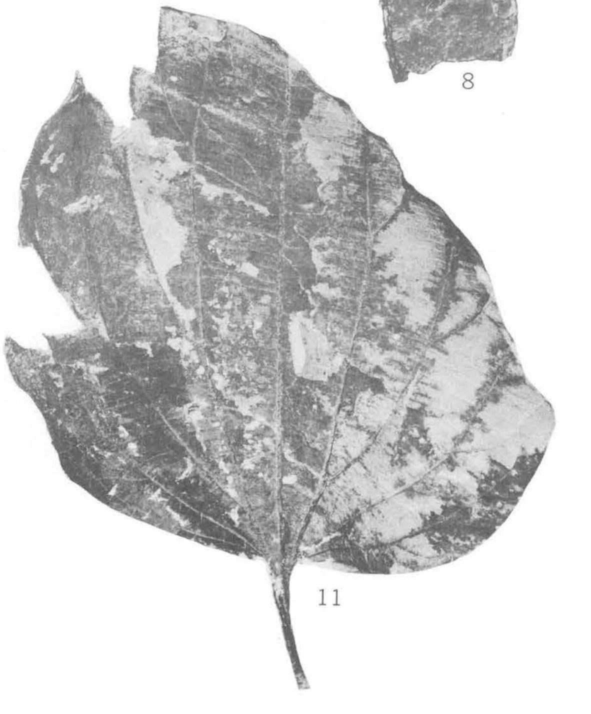

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MEGASCOPIC PALEOCENE PLANTS

PLATE 51

Figures 1–18. *Ampelopsis acerifolia* (Newberry) Brown, n. comb. (p. 78). 1, 16, loc. 8523; 2, 13, loc. 8521; 3, 7, 12, loc. 4974; 4, 11, loc. 8774; 5, 6, 9, 14, loc. 8922; 8, 15, 18, loc. 2420; 10, loc. 4699; 17, loc. 9130.


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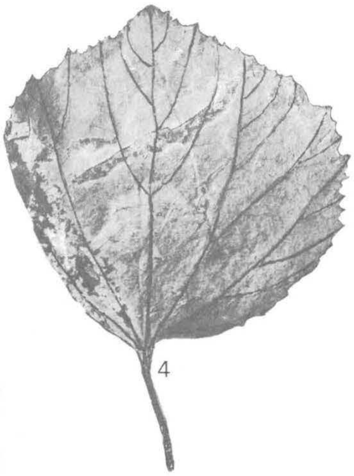
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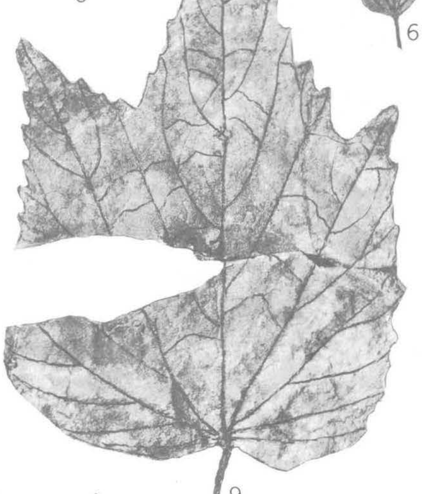
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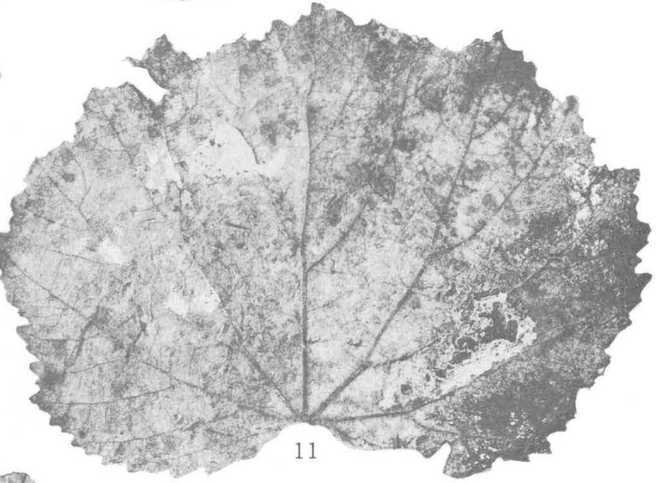
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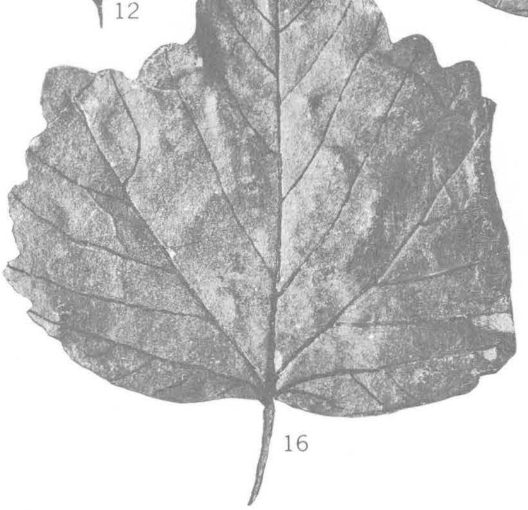
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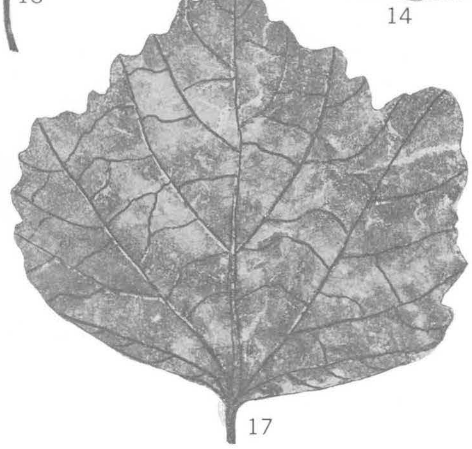
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MEGASCOPIC PALEOCENE PLANTS

PLATE 52

FIGURES 1–8, 10. *Ampelopsis acerifolia* (Newberry) Brown, n. comb. (p. 78). 1, loc. 8227; 2, 3, 6, 10, loc. 8517; 4, loc. 2420; 5, 8, loc. 317; 7, loc. 4699.

9. *Cercidiphyllum arcticum* (Heer) Brown (p. 70). Loc. 3981.


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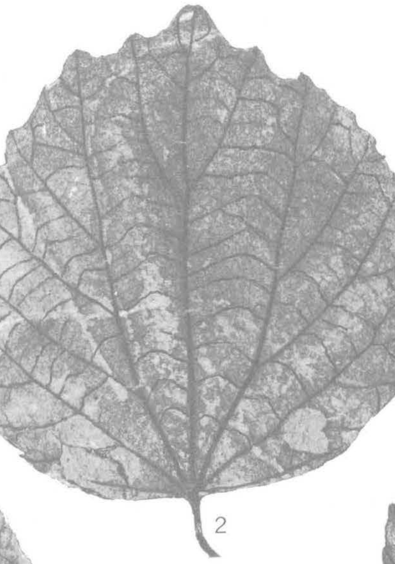
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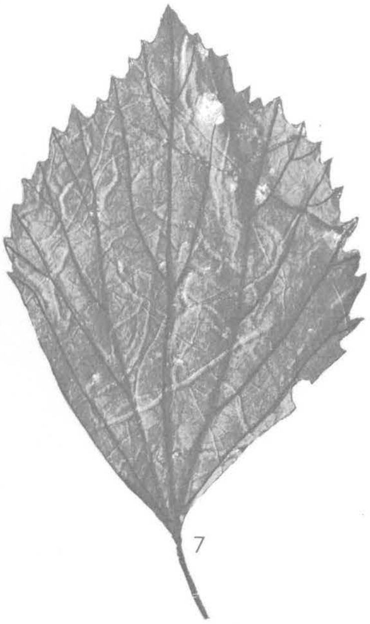
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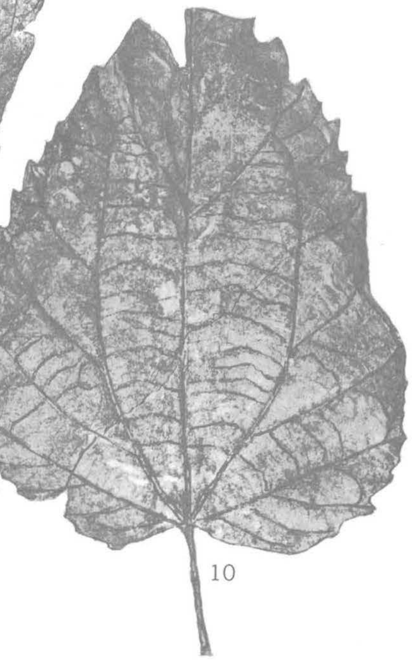
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MEGASCOPIC PALEOCENE PLANTS

PLATE 53

FIGURES 1–4, 6. *Cissus marginata* (Lesquereux) Brown, n. comb. (p. 79). 1, loc. 317; 2, 3, loc. 6431; 4, loc. 9252; 6, loc. 6416.

5. Seed of *Vitis* sp. (p. 82). Loc. 9132.

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MEGASCOPIC PALEOCENE PLANTS

PLATE 54

Figures 1–4. *Cissus marginata* (Lesquereux) Brown, n. comb. (p. 79). 1, 4, loc. 7495; 2, loc. 6416; 3, loc. 317.

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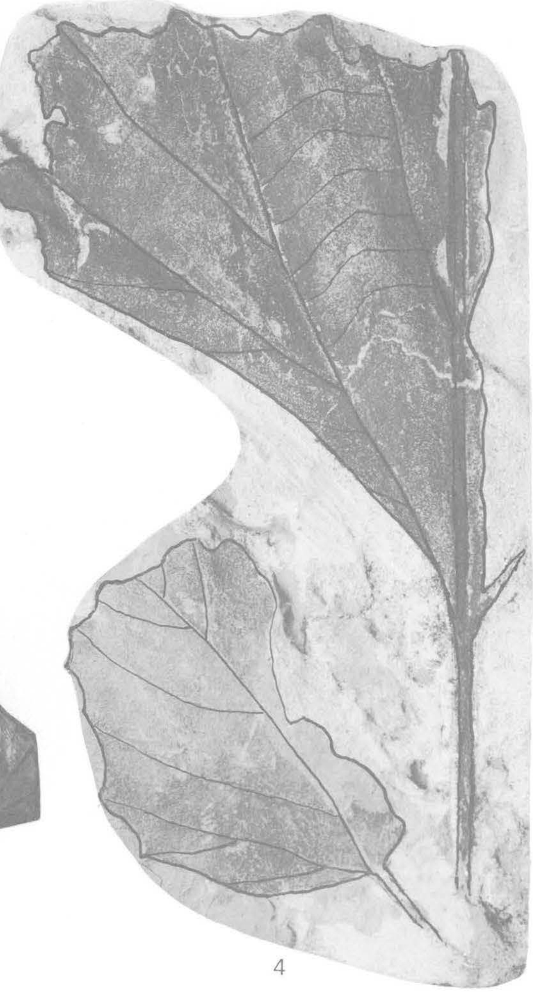

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MEGASCOPIC PALEOCENE PLANTS

PLATE 55

FIGURES 1–3. *Betulites* sp. Lesquereux, (pp. 80, 81), from the Dakota sandstone (Upper Cretaceous), Ellsworth County, Kans., for comparison with *Cissus marginata*.

4, 6, 7. *Cissus marginata* (Lesquereux) Brown, n. comb. (p. 79). 4, from the Mesaverde formation (Upper Cretaceous), south of Gallup, N. Mex.; 6, from the Hell Creek formation (Upper Cretaceous), east of Glendive, Mont.; 7 (× ½), from the Kaiparowitz formation (Upper Cretaceous) at Parowan Gap, Utah. The petiole is perfoliate.

5. Twig of *Cinnamomum* sp. (p. 66) with opposite leaves, from the Mesaverde formation (Upper Cretaceous) at Black Mesa, south of Kayenta, Ariz.


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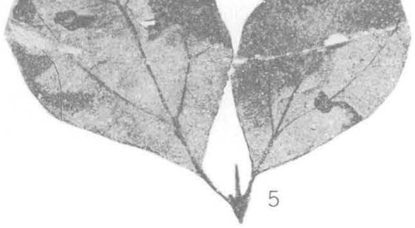
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MEGASCOPIC PALEOCENE PLANTS

PLATE 56

FIGURES 1, 2, 5, 6. *Melastomites montanensis* Brown, n. sp. (p. 84). 1, 2, loc. 8519; 5, loc. 7662; 6, loc. 7005.

3, 7, 10. *Vitis lobata* (Knowlton) Brown, n. comb. (p.82). Loc. 8519.

4, 8, 9. *Juglans taurina* Brown, n. sp. (p. 56). 4, 9, loc. 2423; 8, loc. 4262.

MEGASCOPIC PALEOCENE PLANTS

PLATE 57

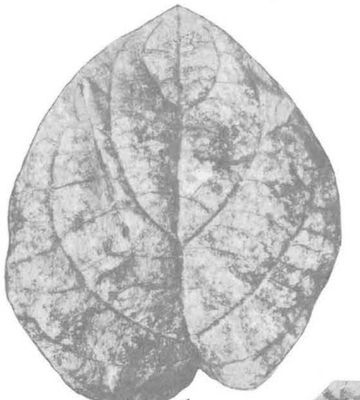
FIGURE 1. *Viburnum cupanioides* (Newberry) Brown, n. comb. (p. 87). Loc. 5885.

2, 5. *Dillenites garfieldensis* Brown, n. sp. (p. 82). Loc. 8774.

3. Leaf with minute teeth (p. 90). Loc. 8774.

4. Probably a small leaflet of *Fraxinus eocenica* Lesquereux (p. 85). Loc. 8774.

6, 7. *Quercus sullyi* Newberry (p. 59). Loc. 8239.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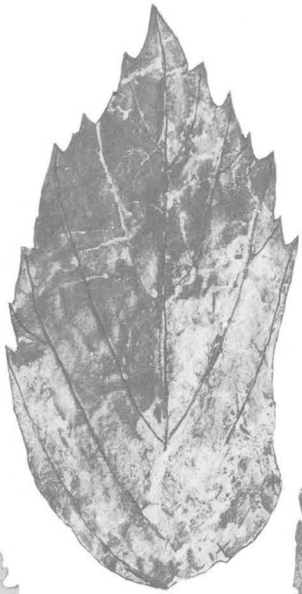
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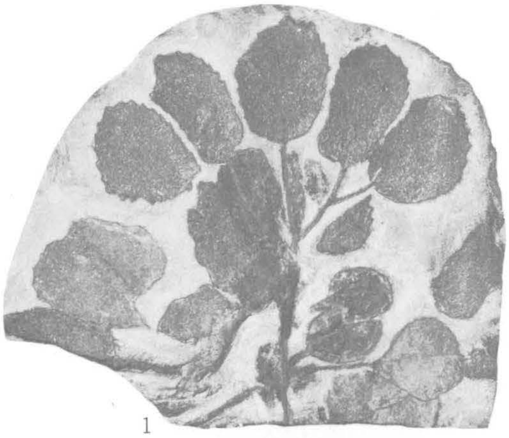
MEGASCOPIC PALEOCENE PLANTS

PLATE 58

FIGURES 1–12. *Trapa angulata* (Newberry) Brown, n. comb. (p. 83). 1, 2, with purported fruits at centers of the rosettes, Ravenscrag formation, Saskatchewan, Canada; 3–5, rosette and separate leaves, 7–12, fruits, loc. 2420; 6, rosette showing fimbriated submerged foliage, from the Meeteetse formation (Upper Cretaceous) in SE¼ sec. 10, T. 46 N., R. 98 W., Wyoming.

13. *Trapa paulula* (Bell) Brown, n. comb. (p. 84). Loc. 7004.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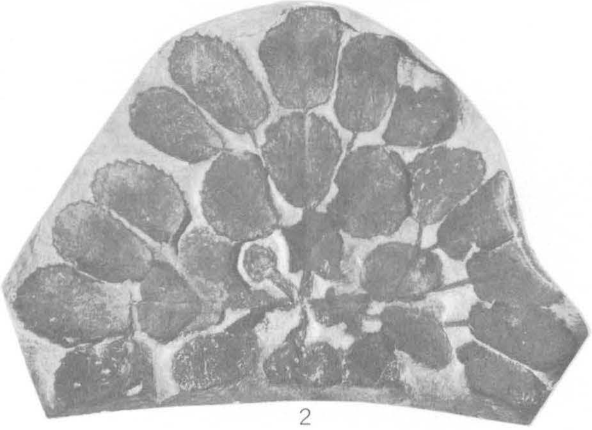
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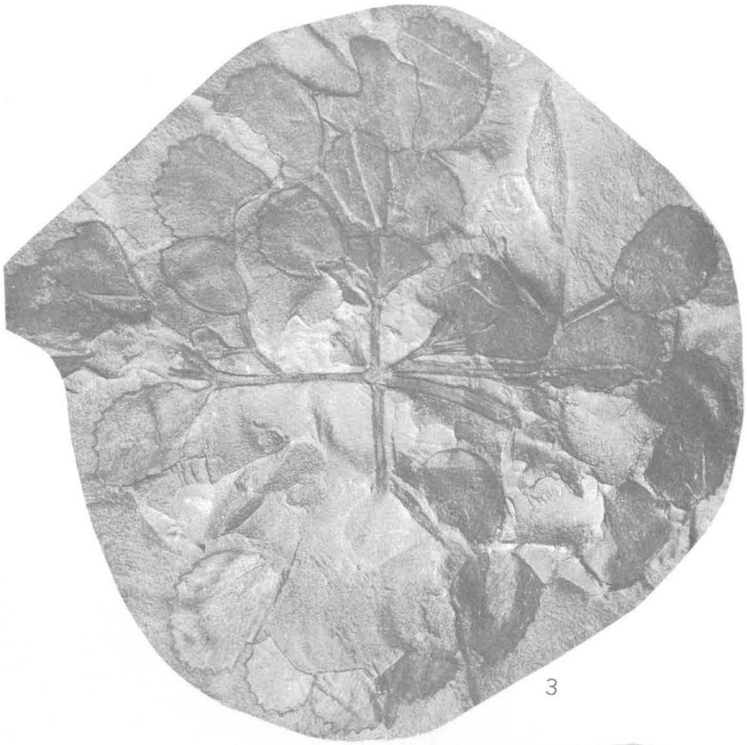
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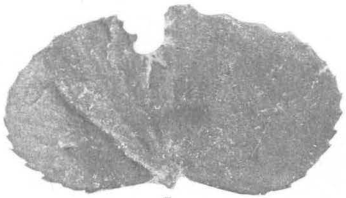
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MEGASCOPIC PALEOCENE PLANTS

PLATE 59

FIGURE 1. *Cornus hyperborea* Heer (p. 84). Loc. 4871.

2–5, 7, 12. *Cornus nebrascensis* Schimper (p. 85). 2, 3, 7, loc. 8567; 4, loc. 8195; 5, loc. 4626; 12, loc. 5389.

6, 11. *Ampelopsis acerifolia* (Newberry) Brown, n. comb. (p. 78). 6, loc. 8552; 11, loc. 2420.

8, 9. *Koelreuteria annosa* Brown (p. 76). 8, loc. 9253; 9, loc. 9344.

10. *Vitis olriki* Heer (p. 82). Loc. 9104.


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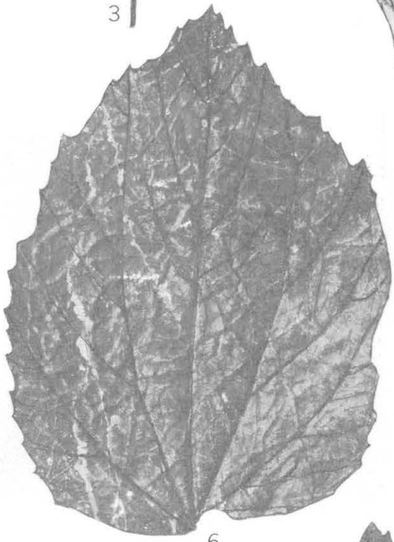
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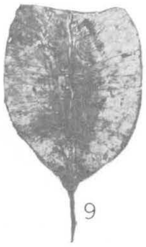
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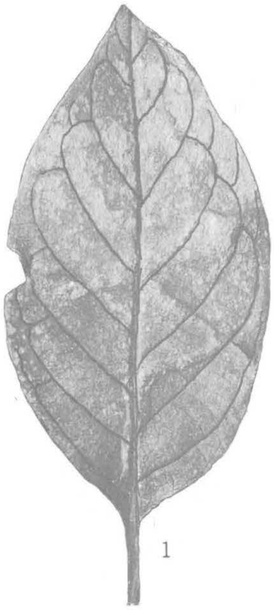
MEGASCOPIC PALEOCENE PLANTS

PLATE 60

FIGURES 1–4, 6. *Nyssa alata* (Ward) Brown, n. comb. (p. 85). 1, loc. 8542; 2, 4, 6, loc. 2416; 3, loc. 8224.

5, 7–10. *Phyllites disturbans* Brown, n. sp. (p. 88). 5, loc. 7659; 7, loc. 4262; 8, loc. 6342; 9, 10, loc. 8563.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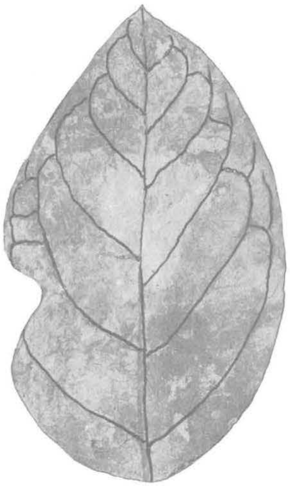
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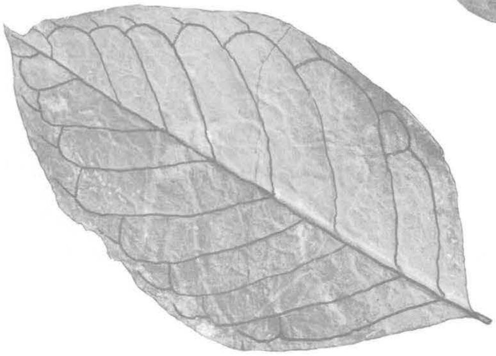
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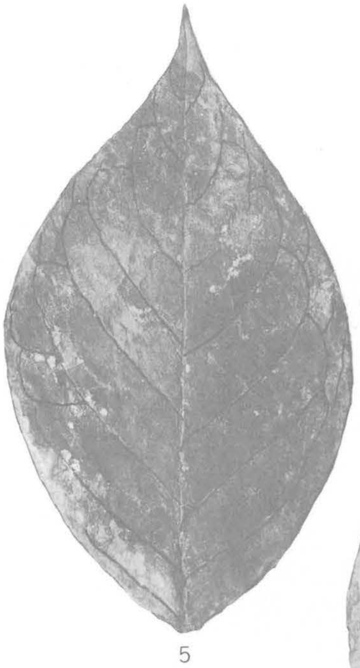
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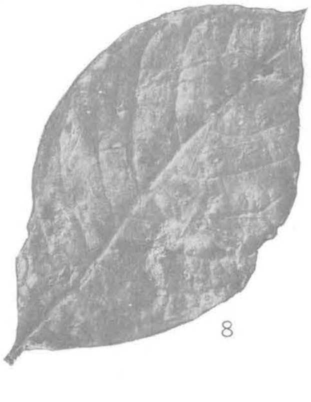
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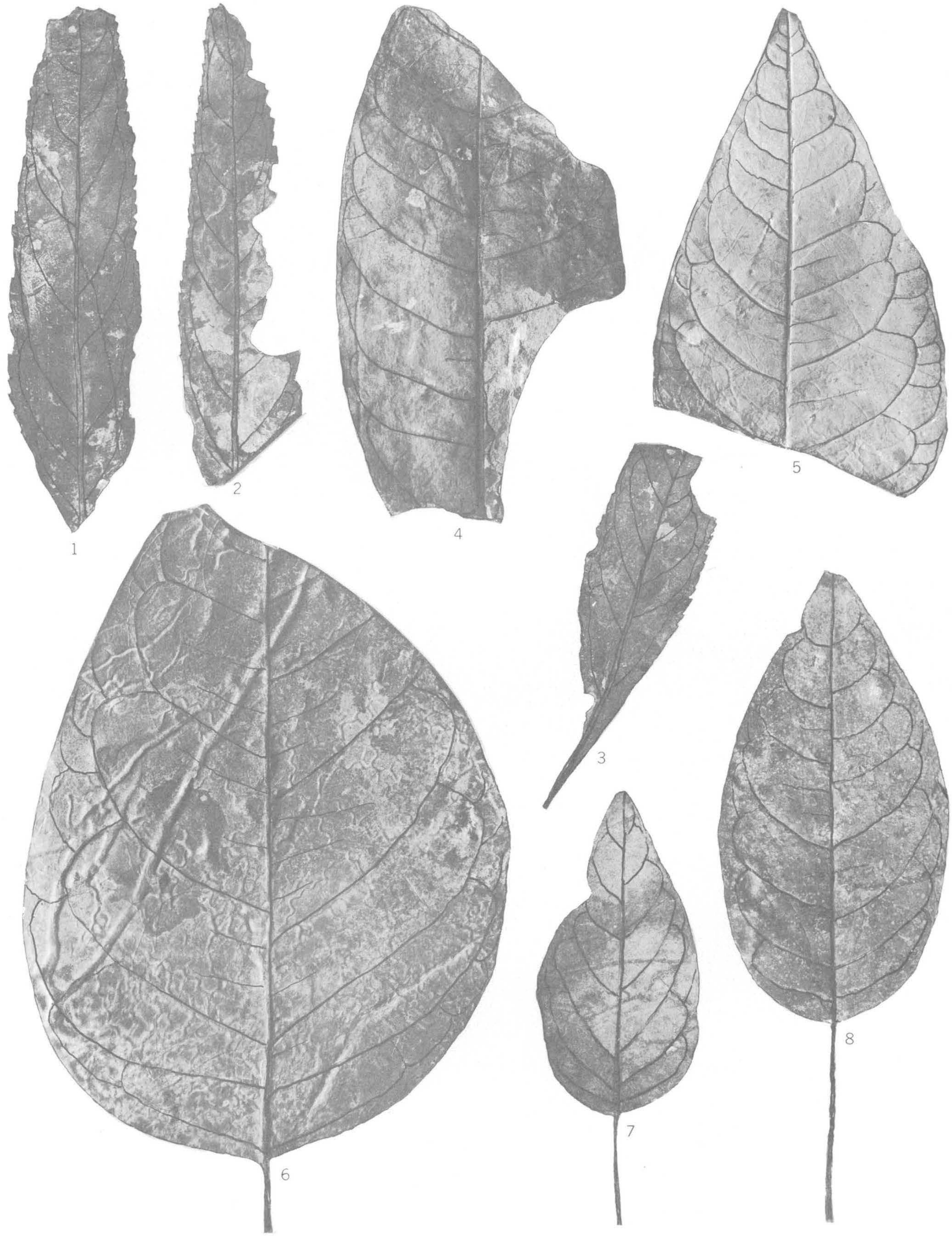
MEGASCOPIC PALEOCENE PLANTS

PLATE 61

FIGURES 1–3. *Salix aquilina* Brown, n. sp. (p. 55). Loc. 9322.
4. *Nyssa borealis* Brown, n. sp. (p. 85). Loc. 4981.
5–8. *Phyllites demoresi* Brown, n. sp. (p. 88). 5, 6, 8, loc. 4264; 7, loc. 8196.



MEGASCOPIC PALEOCENE PLANTS

PLATE 62

FIGURES 1–7. *Fraxinus eocenica* Lesquereux (p. 85). 1, loc. 8234; 2, loc. 317; 3–5, loc. 8774; 6, loc. 6105; 7, loc. 4626.

MEGASCOPIC PALEOCENE PLANTS

PLATE 63

Figures 1–8. *Viburnum antiquum* (Newberry) Hollick (p. 86). 1–7, loc. 2414; 8, loc. 8166.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MEGASCOPIC PALEOCENE PLANTS

PLATE 64

FIGURES 1–3, 5, 7–11. *Viburnum asperum* Newberry (p. 87). 1, 3, loc. 2417; 2, loc. 8885; 5, loc. 8520; 7, 8, loc. 8678; 9, 10, loc. 9056; 11, loc. 607.

4. *Viburnum antiquum* (Newberry) Hollick (p. 86). Loc. 9071.

6. A probable ancestor of *Viburnum asperum* (p. 87) from the Upper Cretaceous, 4 miles east of Reed Point, Mont.

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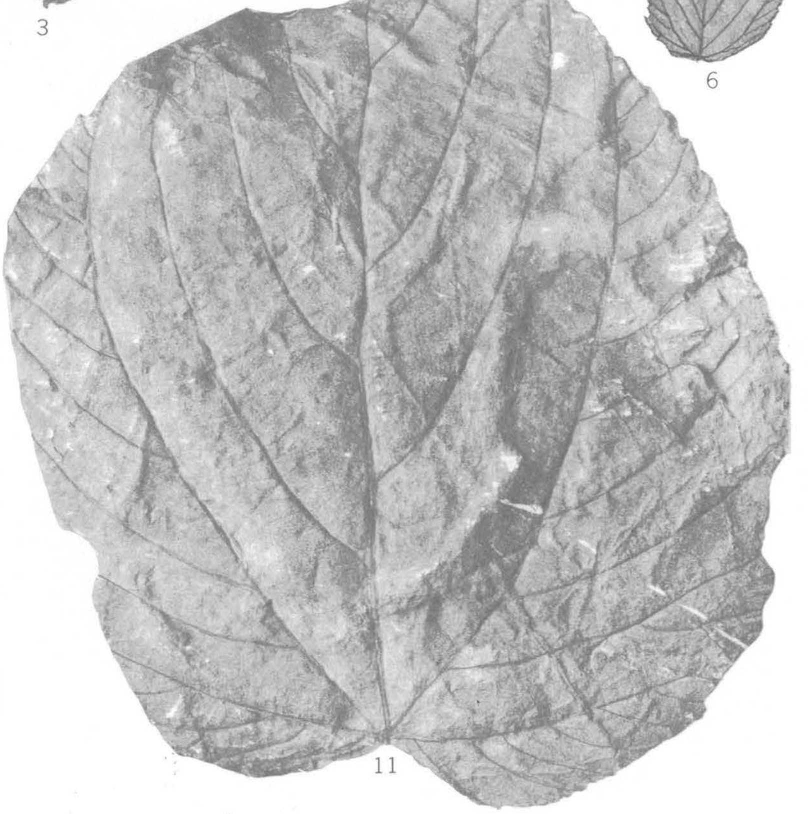

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MEGASCOPIC PALEOCENE PLANTS

PLATE 65

Figures 1–8. *Viburnum cupanioides* (Newberry) Brown, n. comb. (p. 87). 1, exact locality unknown; 2, loc. 6050; 3, 4, loc. 2420; 5, 7, loc. 5889; 6, loc. 4625; 8, exact locality unknown.

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MEGASCOPIC PALEOCENE PLANTS

PLATE 66

Figures 1–3, 6, 9. *Cinnamomum sezannense* Watelet (p. 66). 1, loc. 8426; 2, loc. 4571; 3, loc. 8777; 6, 9, loc. 4725.

4. Palmately veined leaf, (p. 90). Loc. 8920.
5. Serrate leaf, (× 2) (p. 90). Loc. 6215.
7. *Ampelopsis acerifolia* (Newberry) Brown, n. comb. (p. 78). Loc. 317.
8. Small leaf of *Platanus raynoldsi* Newberry (p. 64). Loc. 9180.
10. *Lindera obtusata* (Ward) Brown, n. comb. (p. 67). Loc. 4323.
11. *Magnolia borealis* Brown, n. name (p. 71). Loc. 5579.


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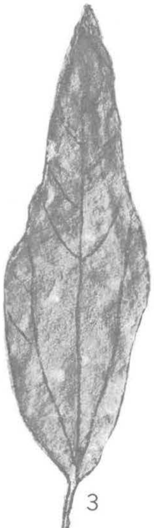
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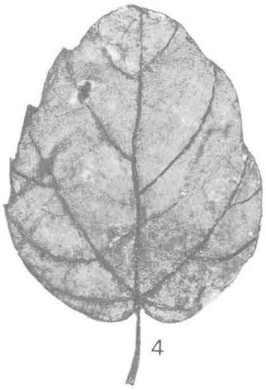
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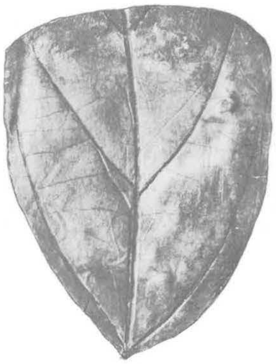
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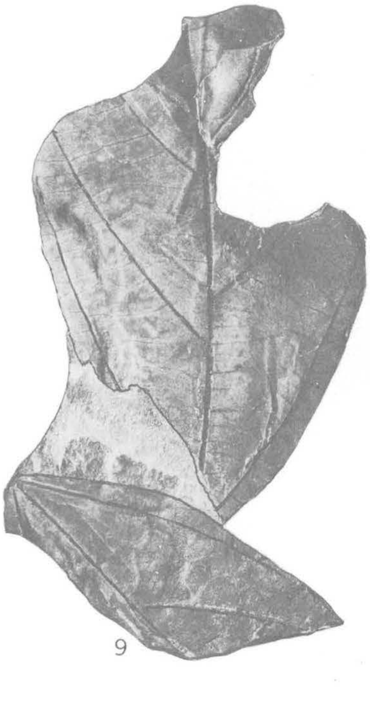
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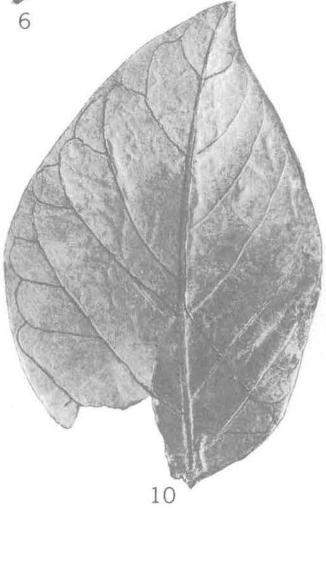
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MEGASCOPIC PALEOCENE PLANTS

PLATE 67

FIGURES 1–4, 8. *Prunus corrugis* Brown, n. sp. (p. 74). 1, loc. 9492; 2, 3, loc. 4984; 4, loc. 4050; 8, loc. 541.

5. A five-loculed fruit (× 2) (p. 91). Loc. 8247.

6, 7. Maplelike samaras, but probably of sapindaceous affinity (p. 91). 6, loc. 9201; 7, loc. 9125.

9, 14–16, 20, 22, 23, 27. Seeds with papillose inner surface (p. 91). 9, 10 (× 2), loc. 8850; 15, 22 (× 2) with small snail at left, 23 (× 3) same as fig. 15, 27 (× 2), loc. 6215; 16, 20 (× 2), loc. 9236.

10. Flattened, carbonized fruit with scars (p. 91). Loc. 6382.

11, 12, 17. Probably fruits with remnants of calyces (p. 91). 11, loc. 4626; 12, loc. 8566; 17, loc. 8547.

13, 45. *Nordenskioldia borealis* Heer (p. 89). 13 (× 3), loc. 8913; 45, loc. 8887.

18, 19, 24, 25, 30, 31. *Viburnum tilioides* Ward (p. 87). 18, 24, loc. 2416; 19, loc. 2414; 25, loc. 8554; 30, loc. 8774; 31, loc. 8255.

21. Spike or catkin of seeds (p. 91). Loc. 8519.

26. Impression of a seed (× 2) showing pits arranged in longitudinal rows (p. 91). Loc. 4618.

28, 29. Seeds with ridges and scattered glands (p. 91). Loc. 4264.

32. Heart-shaped fruits or seeds (p. 91). Loc. 8519.

33, 34. *Viburnum solitarium* Lesquereux (× 5) (p. 90). Loc. 317.

35. Elliptic fruit with a fringe of hairs or filaments (p. 91). Loc. 8522.

36. Oval fruit with several locules (× 2) (p. 91). Loc. 8167.

37. *Palmocarpon subcylindricum* Lesquereux (p. 90). Loc. 317.

38. Oval seeds like figs. 33 and 34 but rounded at the top, not squarish (p. 91). Loc. 5667.

39–42, 47. Burlike objects (p. 91). 39–42, loc. 7538; 47, loc. 9109.

43. Probably the fertile cone of an *Equisetum* (p. 46, 91). Loc. 6905.

44. Longitudinal hollow studded with bilobed projections (p. 91). Loc. 9130.

46. Calyx of a flower (× 10) (p. 91). Loc. 8774.


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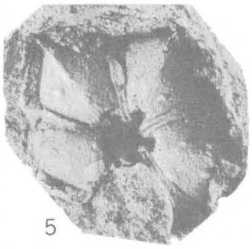
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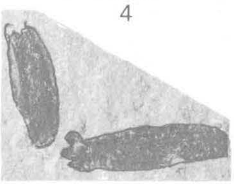
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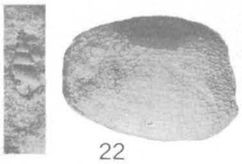
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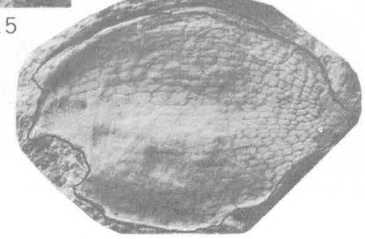
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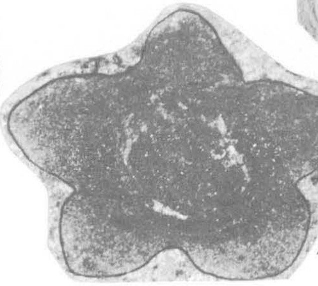
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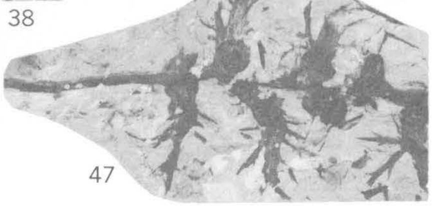
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MEGASCOPIC PALEOCENE PLANTS

PLATE 68

FIGURES 1, 3–6. *Leguminosites coloradensis* Knowlton (p. 74). 1, 6, loc. 4877; 3, loc. 5526; 4, loc. 8551; 5, loc. 336.

2, 7–11. Roots with rootlets (p. 91). 2, loc. 8669; 7, loc. 4468; 8, loc. 750; 9, loc. 9533; 10, loc. 8668; 11, loc. 6765.

12, 13. *Pterocarya hispida* Brown, n. sp. (p. 57). 12, loc. 8910; 13, loc. 6839.

14–16. *Sagittaria megasperma* Brown, n. sp. (p. 52). 14, loc. 4268; 15, 16, loc. 9129.

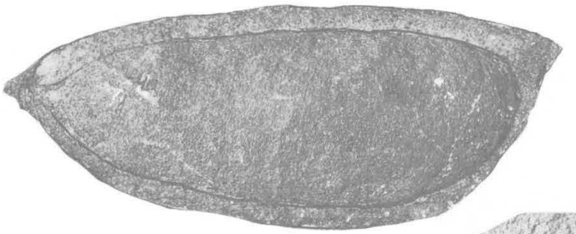
17–22. Two-winged seeds (p. 92). Loc. 8910.

23, 24. *Liquidambar dakotense* Brown, n. sp. (p. 72). Loc. 6384.

25. Probably a stone fruit (× 2) (p. 92). Loc. 8913.

26. Probably the glume of a grass (× 2) (p. 92). Loc. 8913.

27–29. Pedicelled flowers or fruits (× 2) (p. 92). 27, loc. 9109; 28, loc. 9125; 29, loc. 5595.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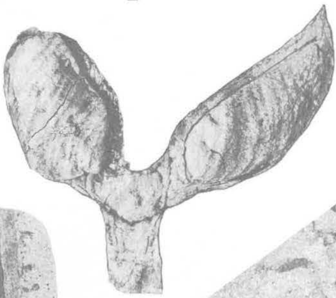
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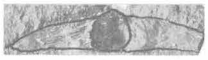
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MEGASCOPIC PALEOCENE PLANTS

PLATE 69

FIGURES 1. Feather of an unknown bird (p. 92, 96). From a locality of clinkered shale about 10 miles north of Glendive, Mont.

2. Dragonfly (p. 96). Loc. 8190.

3. Wing of a cockroach (p. 96). Loc. 8556.

4. Wing of a caddisfly (× 2) (p. 96). Loc. 4976.

5, 6. Views of a *Champsosaurus* vertebra (p. 96). From a locality south of Watford City, N. Dak.

7, 8. Gar scales (p. 96). Loc. 9342.

9, 10. Tooth at left in fig. 9, *Aphronorus*, from Donnybrook, N. Dak. Third tooth from left, *Tricentes*, and all the remaining teeth in figs. 9 and 10, *Claenodon*, from 8 miles west of Medicine Lake, Mont. (p. 96).

11, 12, 13. Reptilian remains (p. 96). Teeth, 11, 12; claw, 13. Loc. 9342.

14. Scale of *Amia* (p. 96). Loc. 8519.

15–19. Probably fish or reptile coprolites (p. 92). 15, from the Miocene on Salmon Creek, Wash.; 16–19, from the Paloecene at loc. 9564, 8 miles south of Rhame, N. Dak.


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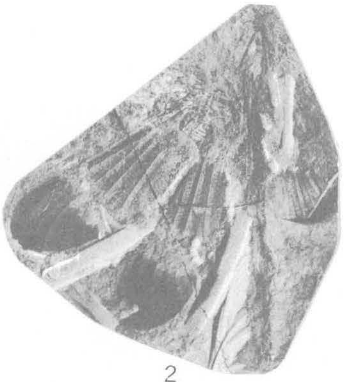
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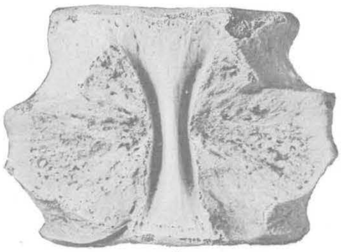
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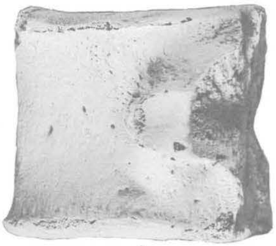
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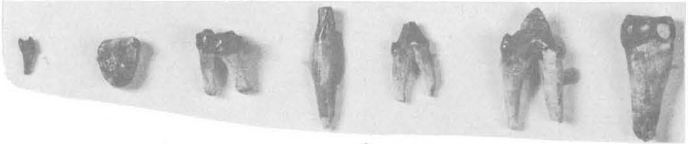
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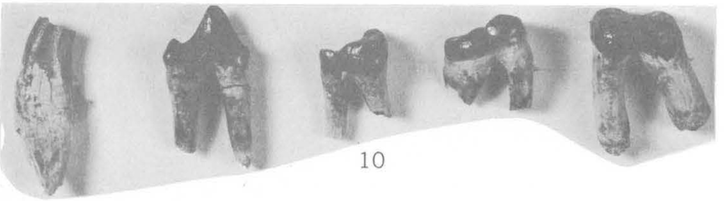
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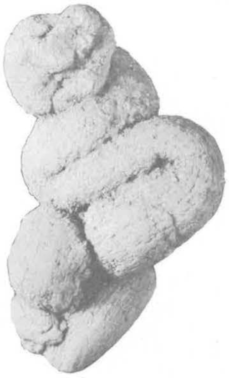
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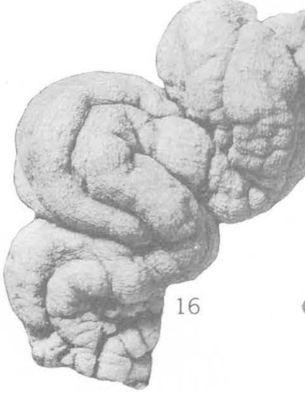
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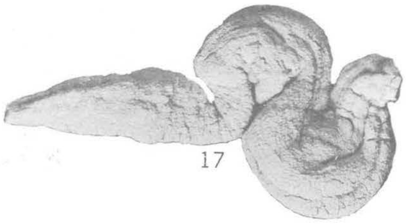
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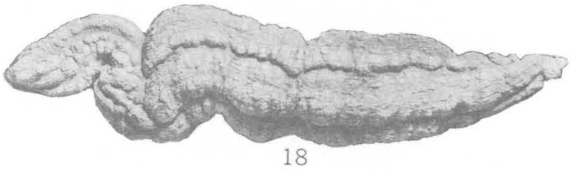
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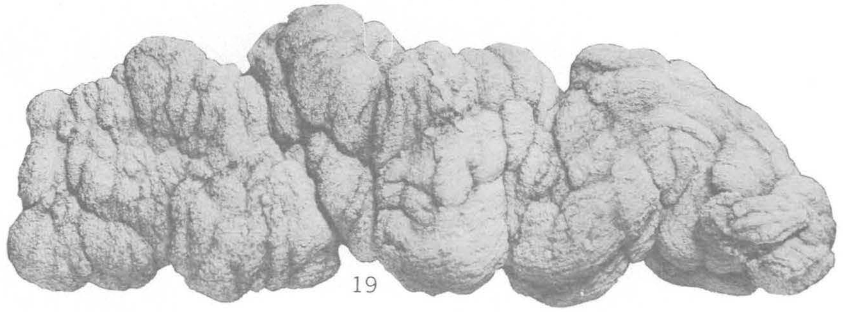
19

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