Contributions to Paleontology

A MIDDLE EOCENE FLORA FROM THE CENTRAL SIERRA NEVADA

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INTRODUCTION

The Tertiary continental deposits on the west slope of the Sierra Nevada in California, parts of which have for many years been designated as the "auriferous gravels," contain plant fossils at many localities. The plant beds are fine-grained volcanic and flood-plain sediments of various ages, ranging from Middle Eocene to Lower Pliocene.

The Chalk Bluffs flora, herein described, is the richest of the older floras which have been studied thus far. The name Chalk Bluffs is taken from the type locality, the Chalk Bluffs hydraulic mine just east of You Bet in Nevada County. The flora has also been collected at several other localities along the course of the ancient river channel called the Tertiary Yuba River by Waldemar Lindgren (1911, p. 34). (See map, fig. 1, p. 5.)

The outcrops of the plant-bearing sediments, with few exceptions, have been uncovered by mining activities, either by hydraulic or by "drift" tunneling processes. The "Forty-niners" at first mined the Quaternary gravels along the present stream channels by crude placer methods. These gravels in time became depleted, and as better methods of mining were developed, search for further sources of gold resulted in the discovery of the Tertiary gravels on the interstream divides high above the modern stream beds. These Tertiary gravels were first mined by placer methods along stream courses, but the presence of huge bodies of gravel was the incentive for the evolution and perfecting of the hydraulic method of mining. The water for hydraulicking was often brought from mountain streams at some distance above by an elaborate system of ditches and pipe lines. The gravel was first loosened at the base by tunneling and dynamiting, and then undermined and washed into sluices by the action of streams of water directed under pressure against the face of the gravel from the nozzles of monitors. As the overlying gravel crumbled and was washed away, cliffs were formed which receded by degrees under the mining process. Lenses of fine clays were usually left where they fell, in isolated patches, and these clay deposits are usually richly fossiliferous.

Hydraulic mining was thus first developed in California, and from small beginnings soon grew in magnitude, until the operations for the mining and removal of gravel in the years 1870-1883 took place on what might justly be called a geologic scale. Cubic miles of material were removed and washed into the streams, leaving enormous scars on the flat interstream divides, bordered in some instances by cliffs two hundred feet high. These cliffs often exhibit cross sections of the ancient stream sediments and the overlying deposits that can hardly be excelled in variety and interest.

The miners became, indirectly, fossil collectors, since they piled the silicified logs (Chaney, 1934, p. 124), which occur in abundance, in windrows along the edges of the sluicing channels in order to facilitate the movement of the finer gravel. They also noted the fossil leaf impressions in the clay beds. These were brought to the attention of the United States geologists under J. D. Whitney about 1875. A good collection was made at Chalk Bluffs and sent to Leo Lesquereux for determination, along with other collections from Tuolumne Table Mountain and Bowen's Tunnel in Placer County. Lesquereux (1878b) published the results of his study as a Report on the fossil plants of the Auriferous Gravel deposits of the Sierra Nevada. This report is one of the classic papers in the literature of paleobotany. The clarity of thought and breadth of knowledge displayed call forth the respect and admiration of the reader, although the author's main conclusions concerning the age and relationships of the fossil floras cannot be accepted today as entirely correct. Lesquereux was the great pioneer in the field of paleobotany in America, and for comparisons was forced to depend on the work of European writers. Because of this his interpretation of the American fossil floras was colored by the researches of Heer, Goeppert, Unger, and others. He wrote at the time of the first organized researches in the geology of the western states, when the Tertiary history of the region was still largely unknown. The sequence of floras and faunas had yet to be established, although Cope and Leidy had made great progress in the study of the fossil mammals. Fossil material was sent to Lesquereux as collected, and it was necessary for him to take on faith the stratigraphic relations of the deposits as formulated by the geologists of his day. The plant fossils from the auriferous gravels of

California as collected by members of the Geological Survey under Whitney were treated by him as a group. It is now known, however, that the material came from localities of diverse ages. These localities are: Table Mountain, Tuolumne County: Lower Pliocene; Bowen's Tunnel, Placer County, and North Fork Tunnel, Sierra County: latest Miocene; and Chalk Bluffs, Nevada County: Middle Eocene. A consideration of this mixture of early and late Tertiary plants led Lesquereux to conclude that the age of the flora was late Miocene or Pliocene, and that the closest affinity of the fossil plants was with the living flora of the South Atlantic states. This conclusion appears to have been the only one possible under the circumstances.

T. D. A. Cockerell (1910) discussed the age relations of the Florissant, Yellowstone, and Auriferous Gravels floras and showed that the flora from the gravels was "composed of two sets of plants, one related to living forms, the other to those of the Eocene."

The early collections are preserved in the Paleontology Museum of the University of California. F. H. Knowlton examined this material and wrote a revision of Lesquereux's determinations which, with his preliminary identifications of many species from several localities discovered subsequent to 1878, was published in Lindgren's monograph (1911) on the Tertiary gravels. Knowlton failed to bring out clearly the obvious diversity in the ages of the various floras, and thus his revision contributed little to a comprehension of their relationships, although knowledge of the stratigraphy and paleobotany of the region had been enriched by the experience of more than thirty years since the publication of the original paper.

In 1933 Ralph W. Chaney contributed a brief report (Chaney, 1933) on the floras of the Tertiary gravels which pointed out the diversity of the floras and indicated their relative ages.

A well preserved flora occurring in dacite tuff at the old La Porte hydraulic mine in Plumas County was brought to the attention of Dr. Chaney in 1931. This was studied by Susan S. Potbury under the supervision of Dr. Chaney, and the results of the study were published as a monograph (Potbury, 1935). This paper is notable for its use of modern research methods and of the increased knowledge of stratigraphy and fossil plants accumulated in the previous twenty years. It is the first of a series of monographic reports on the Tertiary floras of the Sierran region, and will be succeeded by Condit's paper on the flora of Table Mountain, the present paper, and reports on the flora of Remington Hill by Condit, the flora of the Valley Springs formation by Axelrod, and the floras of the Susanville district by the writer.

Locations of the Principal Fossil Localities

The fossil plants of the Chalk Bluffs flora have been collected at many localities in the gravel mines along the course of the Tertiary Yuba River, from Iowa Hill, east of Colfax, to Sailor Flat, northeast of Nevada City, and at the Cherokee Mine, north of Oroville. The straight-line distance between Iowa Hill and Cherokee is approximately 50 miles. The chief localities of the Chalk Bluffs flora can be reached from Colfax on the Lincoln Highway, U. S. 40, 56 miles northeast of Sacramento, or from Nevada City, 65 miles northeast of Sacramento on California Highway 49. They are shown on the accompanying map (fig. 1; distances given below are by road, and are approximate). Iowa Hill and Independence Hill (locality 42, 1 mile east of Iowa Hill) are respectively 8 and 9 miles east of Colfax by way of a graveled road which crosses the canyon of the American River. Chalk Bluffs proper (localities P3318, P3324, P3325, P3345) is 2 miles east of the town of You Bet, which is 10 miles northwest of Colfax and easily accessible by a good graveled road. The Buckeye Flat localities (104 and P3320) can be reached by automobile only in the summer months. The temporary road branches right from the You Bet--Nevada City road 2 miles below You Bet and follows the channel of Greenhorn River for about 2 1/2 miles before ascending the right bank of the stream to the Buckeye diggings. Quaker Flat (locality P3346) and its northward extension, Scotts Flat, are on a graded road approximately 8 miles east of Nevada City, via Banner Hill. The Blue Tent Mine lies on the right of the Nevada City--North Bloomfield road, from 3 to 4 miles northeast of Nevada City. Sailor Flat (locality P3347) is a part of this mine, and lies about 4 miles northeast of Nevada City and 1 mile northwest of Quaker Flat. The Cherokee Mine (locality 206) is 8 miles north of Oroville.

The localities, with the possible exception of that at Cherokee, are all considered to fall in the same stratigraphic horizon, both on the basis of the fossil plants and on that of the geological relations. Their elevations vary from 3000 feet at Iowa Hill to 1000 feet at Cherokee.

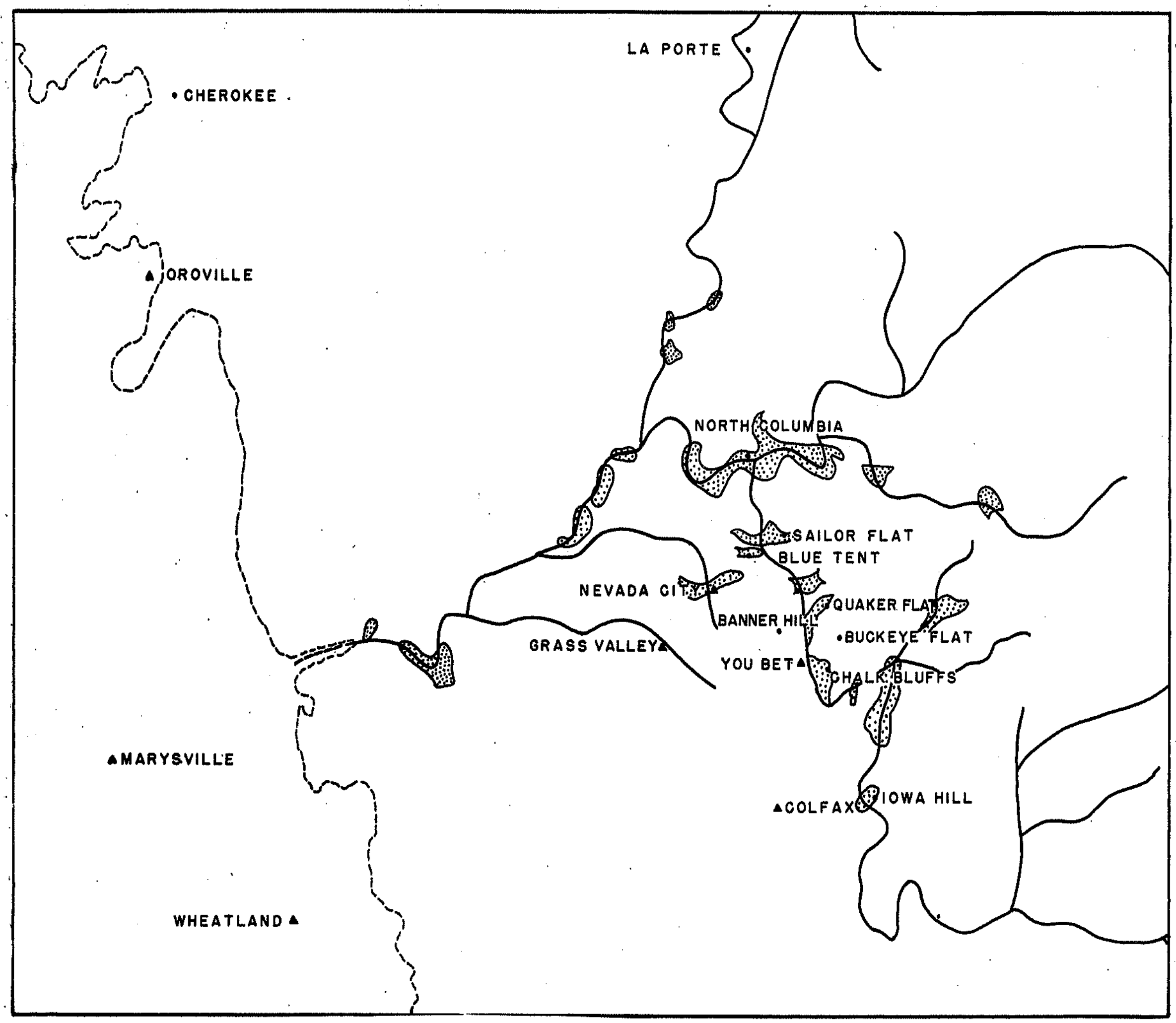


Fig. 1. Map of Chalk Bluffs localities, along the Tertiary Yuba River. Stippled areas indicate gravel deposits.

Field Work

The fossil localities of Chalk Bluffs and vicinity, where collections were first made about 1870, were temporarily lost after the decline of gold mining in the region. In 1931 the fossil deposits at Buckeye Flat were noted by members of the U. S. Forest Service and the information was communicated to Ralph W. Chaney at the University of California, who visited the locality shortly after. Field work was begun by the writer in the summer of 1933, at the suggestion of Dr. Chaney. Collections were first made at Buckeye Flat, but further exploration resulted in the rediscovery of the rich deposits at Chalk Bluffs and other localities. Subsequent collecting and geological work were continued during the summers of 1934-1936 and 1938.

Acknowledgments

It is a pleasure to express my sincere appreciation to the Carnegie Institution of Washington, which has financed the major part of the investigation. The work has been carried on under the direction of Dr. Chaney, to whom I am indebted for advice, encouragement, and helpful criticism. Dr. Roland Brown has given generously of his time in checking identifications and suggesting solutions to taxonomic problems. I wish to thank Davidson German, Carlton Condit, and Beverly Wilder for assistance in the field. I am grateful to Galen Sturgeon for his research on the sediments at Chalk Bluffs. Miss Elizabeth Richardson has been an efficient assistant in the preparation of the manuscript. Other friends have contributed in many ways to the substance of the paper and, although space does not permit listing of names, it is with pleasure that I extend to them my appreciation.

GEOLOGY OF THE REGION

Rock Formations of the Colfax Quadrangle

The rocks underlying the Colfax Quadrangle form roughly northward-trending belts and may be divided into four groups:

1. The strongly folded, steeply tilted, and metamorphosed sediments with associated volcanics which make up the Calaveras group, of Paleozoic age (Ferguson and Gannett, 1932, pp. 3, 6-18; also Lindgren, 1900, pp. 1-7) (Cape Horn formation, Blue Canyon formation, etc.). These form the bedrock over about half the area of the quadrangle, and for the most part are fissile slates with quartzite and chert, accompanied by intrusive amphibolite, peridotite, serpentine, and gabbro.
2. The Lower Mesozoic slates and other metamorphosed sediments of the Sailor Canyon (Triassic) and Mariposa (Jurassic) formations. The first

of these appears as a strip along the northeastern part of the quadrangle; the second as a comparatively small area in the southwestern corner.

3. Several areas of Nevadan intrusives: granite and granodiorite, outliers of the great Sierran batholith which forms the summit of the range.
4. Tertiary volcanics and fluvial sediments. Lindgren divided the Tertiary sediments and pyroclastics of the region as follows, the youngest formation placed at the top:

   Andesitic gravels, tuffs, and tuffaceous breccias
   Rhyolitic tuffs and gravels
   Bench gravels
   Deep or channel gravels

The continental deposits on the west slope of the Sierra represent a long and complex record of river erosion and deposition, accompanied by volcanism and changes in elevation. Correlative with these deposits are Tertiary marine and littoral formations which outcrop along the east side of the Sacramento Valley from near Fresno to the vicinity of Oroville. Since these formations are, in part, dated by invertebrate fossils and directly related to the continental deposits higher in the range, they furnish important evidence concerning the sequence and ages of the "auriferous gravels" and associated volcanics.

Tertiary Formations of the East Side of the Sacramento Valley

The strand-line deposits form a narrow belt, maximum width about 10 miles, of gently dipping beds which flank the older granitic and metamorphic rocks of the Sierra. The same stratigraphic units appear to be present throughout the length of the belt except where they are obscured by local overlap or erosion. The lithology of each formation is remarkably uniform throughout this range. Near Folsom and also in the vicinity of Oroville, Upper Cretaceous beds are found between the Tertiary and the older rocks of the Sierra. This section is summarized as follows:

	Maximum thickness (feet)
Recent	
Flood-plain deposits	50
Pleistocene	
Gravel terrace deposits (Arroyo Seco gravel)	125

	Maximum thickness (feet)
Pliocene	
Laguna formation (Piper, Gale, Thomas, and Robinson, 1939, pp. 57-61). Micaceous silts, clays, and sands.....	400
Latest Miocene to Middle Pliocene	
Mehrten formation (ibid., pp. 61-71). Andesitic series, principally water-laid sands and redeposited mudflows of andesitic origin. Considerable rhyolitic pumice and white rhyolitic mud near base. Latest Miocene, Remington Hill--Forest; Lower Pliocene, Table Mountain and Oakdale floras..	400
Unconformity	
Upper Miocene	
Valley Springs formation (ibid., pp. 71-80). Rhyolitic series. Gray, greenish-gray, and white tuffaceous clays, altered tuff beds, water-laid pumice beds, and some white sand. Valley Springs flora in upper portion.............	200
Unconformity	
Middle Eocene	
Ione formation. Uppermost member (50 feet thick) a white to reddish, massive sandstone, containing anauxite, and characterized by absence of feldspar and ferromagnesian minerals, generally well cemented. Underlain by continental carbonaceous gray, white, and pink clays with lenticular, uncemented, anauxitic, white quartz sand bodies and lignitic coal beds. Generally less than 100 feet exposed. Chalk Bluffs flora................................	500

The Ione formation exhibits a peculiar and characteristic lithology (Allen, 1929, pp. 375-382), and marine invertebrate fossils are found in associated beds at several localities. The faunal group comprises the *Siphonalia sutterensis* zone and is dated as lower Middle Eocene. In California this fauna defines the Capay stage, which has been correlated with the Umpqua formation of Oregon, the lower Claiborne of the Gulf states, and the Ypresian stage of the Paris Basin Eocene (Clark and Vokes, 1936, pp. 858-861).

The Ione formation is of particular interest in connection with the geology of the older plant-bearing deposits in the Tertiary channels, since "The Ione formation is a delta deposit that accumulated simultaneously with the channel deposits and in places it is difficult to decide just where the line of demarcation between them should come" (Allen, 1929, p. 406). Allen also states that "The mineral composition of the white quartz gravels is similar to the Ione, and the gravels were deposited by the same streams which laid down the delta deposits of the Ione" (ibid., p. 402). He gives the following definition of the Ione formation:

While mapping the Jackson quadrangle, Turner made three divisions of the type section, which are in ascending order: (a) white clay and sand containing lignite, well exposed around Ione; (b) white or red sandstone that occurs to the south; (c) clay rock or tuff. In the present paper, it is proposed to restrict the name Ione formation to the beds along the foothills of the Sierra Nevada that have mineral composition and history similar to the lower two members of the type locality. Statements have appeared from time to time that the lower clays of the Ione formation were formed from rhyolitic tuffs. The investigation of the nature of these clays lends no support to this notion, but on the contrary shows that both the clays and the associated sands were derived from a surface that had been subjected to a long period of chemical weathering. Turner mentions the occurrence of pearly scales of a hydrous silicate of aluminum that is characteristic of the sandstones. This mineral is anauxite, and with it are associated quartz and a group of minerals that have withstood the intensive chemical weathering. This assemblage composes the lower two members of the type section, and it is so persistent that it has been traced more than two hundred miles. Therefore it is suggested that the name Ione formation be reserved for this lithologic unit, serviceable in mapping and valuable in correlation (ibid., pp. 353-354).

From Iowa Hill to North Bloomfield, typical Ione sediments are common along the sides of the deep channels and on the benches: sediments showing the extreme of chemical weathering; pink, brown, or white pure clays, quartz-anauxite sands, and limonite layers. There is no lithologic difference between the fine sediments of the channels and the delta deposits of the Ione, and there can be no doubt that the deposits are of essentially the same age. For this reason the leaf-bearing sediments will be called the Ione gravels, and the Chalk Bluffs flora is therefore a flora of Ione or Capay age.

The most important recent contribution to the stratigraphy of the Tertiary deposits along the east side of the Sacramento Valley is the paper by Clark and Anderson (1938) on the Wheatland formation. The outcrop is located about 14 miles north of Lincoln. This paper records the discovery of an Upper Eocene (or Lower Oligocene) marine fauna in a pebble-cobble conglomerate containing abundant pebbles of hornblende-andesite and pyroxene-andesite. A few miles north of the Wheatland locality is another outcrop of nonfossiliferous Tertiary deposits containing andesitic breccia and andesitic cobble gravel overlying the Ione formation. Petrographic and stratigraphic evidence indicates that this andesitic formation, called the Reeds Creek andesites, is not younger than the Wheatland formation. It may be that the Reeds Creek andesites and the andesites of the Wheatland formation are of nearly the same age, namely, Upper Eocene. The discovery of Upper Eocene andesitic rocks shows that there were at least two periods of andesitic eruptions, since the bulk of the Sierran andesites appears to be Upper Miocene to Middle Pliocene in age. At the locality of the Reeds Creek andesites, and apparently lying above them, is a thin layer of rhyolitic pumice tuff which is petrographically related to the "clay rock" of the Sierran rhyolite tuffs. If this rhyolite tuff is of the same age as the rhyolite tuff on the slope of the Sierra, it indicates that the age of the rhyolites is younger than Upper Eocene.

About 55 miles in a direct line northeast of Wheatland is the locality of the La Porte flora. This flora is probably of Upper Eocene age and occurs in a hypersthene dacite tuff. This dacite tuff may then be nearly contemporaneous with the Wheatland formation.

Tertiary Continental Deposits

The Eocene Valleys and Their Gravels

The early Tertiary continental sediments with which this paper is chiefly concerned are found along a part of an ancient river channel which pursued a general north-northwesterly direction from Iowa Hill in Placer County to North Columbia in Nevada County. The direction of the channel was apparently controlled to a large extent by the structures in the underlying Paleozoic bedrock, since it followed a belt of slates just east of a belt of resistant amphibolite schists and diabase. The northerly course of the channel seems to have been everywhere conditioned by this strip of hard schists, which, in Middle Eocene time, evidently formed an irregular ridge of prominent hills, a thousand feet or more above the channel. Banner Hill, southeast of Nevada City, is now the most prominent remnant of the schist belt. This part of the Tertiary Yuba River seems to have been a subsequent branch of the principal stream, which emptied into the Tertiary Gulf near Oroville; it may therefore be called the South Fork of the Tertiary Yuba.

The cross section of the early valley is exceptional (see fig. 2). There is a comparatively steep-sided, V-shaped trough from 200 to 300 feet deep, gradually merging into gently sloping benches which may be 2 miles or more in width. The deep channel is unsymmetrically placed with respect to the benches; the eastern bench is wider and better developed than the western. The whole valley is filled to a depth of 300 feet or more with fluvial deposits ranging from cobble gravels to clays.

This enormous accumulation of gravels can hardly have been a normal episode in a regular process of stream erosion. At least two explanations for the unusual cross section and the valley filling may be suggested. The first was presented by Diller (1892, p. 425). His theory assumes that the deep channels were formed after the cutting of the benches. Fenneman states this theory as follows:

> In the normal process of stream work gravel would not have accumulated to any great depth; its accumulation in this case was aided by moderate tilting of the surface. While on the one hand this would increase the gradient and thereby the transporting power of the stream, it might on the other hand greatly increase the amount of gravel brought to the stream. Under suitable circumstances the latter effect would predominate, at least for a time, and the valleys would aggrade. It is assumed that this was the case with the Sierra streams. The first effect of this tilting was the increase of power, with the resultant cutting of narrow valleys several hundred feet deep within the old wide valleys. These were first filled with the deepening gravel which then spread over the older and broader valley floor, sometimes to a depth of 200 to 300 feet (Fenneman, 1931, p. 414).

The second explanation assumes that the benches are younger than the deep channel. A consideration of the Ione sediments along the east side of the Sacramento Valley makes it clear that they are the result of a rather rapid marine transgression. The lower beds in some places are composed of lagunal deposits--delta clays, sands, and lignite--followed by marine sandstones. At other localities removed from ancient river mouths, the marine sandstone rests directly on the bedrock. It seems reasonable to suppose that the streams were aggraded in their lower courses because of the rise in base level. The encroachment of the sea may possibly have been accompanied by tilting or rotation of the Sierran area which depressed the western portion and elevated the eastern, although such a tilting does not seem necessary to account for the accumulation of gravels. At the beginning of the interruption in the cycle of stream erosion, the region was probably in a mature stage of erosion, the valleys occupied by streams not at grade and possessing considerable transporting power. Aggradation began with rise of base level, and this would be accompanied by loss of down-cutting power and a change to meandering and side-cutting. When grade was finally established, the sea had encroached on the lower end of the valleys several hundred feet above its previous level.

It is not easy to uncover field evidence which will definitely prove one or the other of these theories. The fluvial sediments are marked by many local unconformities and complex minor structures. If the broad river valleys outlined by the benches were formed before the deeper channels and later covered by deposits of gravels, there should be a rather marked contrast, at least in places, between the older and newer gravels. The sides of the V-shaped deep channel should be characterized by fresh, comparatively little weathered bedrock. There is no clear evidence of either of these conditions. The gravels in the central part of the V-shaped channel gradually merge into the strongly weathered typical Ione sediments along the sides. It is only on the bottom of the channel that fresh, unweathered bedrock is present over any considerable area. The slight change in composition of the gravel from the center of the main channel, vertically and laterally, might naturally be expected in the process of aggradation. It is true that the Ione gravels, which cover the benches to a depth of a hundred feet or more, are succeeded by material of different composition, but there is every reason to suppose that this is a much later deposit, separated from the Ione sediments by an erosion interval. If the deep channel had been cut after the benches and afterward filled by sediments which finally overspread the benches, there should be a similarity in composition between the channel gravels and those which succeed the Ione bench gravels. This condition does not exist; the channel gravels are related in composition to those of the benches and not to the gravels below the rhyolite.

Nature of the Basement Rocks and the Contact with the Tertiary Gravels

The underlying rocks along the channel belong to the Cape Horn and Delhi formations of the Calaveras group (Lindgren, 1900, pp. 5-6). At Chalk Bluffs the metamorphic basement rocks strike north to northwest and are steeply tilted from 60° to vertical, the dip being usually toward the west. The rocks are predominantly dark slates with intercalated beds of gray quartzite and greenstone schist. The greenstones associated with the slates are metamorphosed basic igneous rocks, now converted to amphibolite schists, and for the most part appear to have been narrow sills and dikes injected into the slates. The quartzites represent metamorphosed lenses and beds of quartz sandstone and occasionally attain a thickness of 15 feet, although they are commonly not more than a few feet in width. The slate bedrock has been exposed over numerous areas by hydraulic mining. On the bottom of the deep channel it is comparatively fresh and blue-black or gray-black in color; on the sides of the channel and on the benches the bedrock slates are deeply weathered, and light gray to silvery white in color. The weathered material is often completely kaolinized (lithomarge) and crumbles to a powder when disturbed. The intercalated amphibolites are usually chloritized or thoroughly decomposed. The quartzite is highly resistant and commonly projects above the softer rocks as jagged ridges. Boulders of quartzite litter the bedrock surface where it is exposed. Some of them are very large, the maximum dimension reaching 10 feet. On the benches the surface of the bedrock is usually mantled by a layer of nearly pure limonite or lateritic material. In the channel the surface shows no limonite, but there may be an abundance of iron pyrite on the contact and in the cement of the overlying gravel.

Description and Relationships of the Tertiary Deposits

The great Chalk Bluffs hydraulic mine was the source of the original collections of Eocene plants, and, since it is easily accessible and furnishes a complete succession of outcrops, it was chosen as the type locality for the geologic section. The section is much the same from Independence Hill (Iowa Hill) to North Columbia, and therefore the series of beds at Chalk Bluffs may be considered as characteristic of the deposits along the South Fork of the Tertiary Yuba River.

Tertiary beds at the Chalk Bluffs hydraulic mine 2 miles east of You Bet
(Youngest formation at the top)

	Thickness (feet)
Andesitic series	
Andesitic agglomerates, tuffs, and flows with interbeds of gravel, sand, and clay	300+
Rhyolitic series	
Rhyolite tuffs and mudflows with abundant pumice; interbeds of gravel and sand, the gravels largely composed of rhyolite porphyry cobbles	225
Conglomerate	
Massive conglomerate; well rounded cobbles composed of resistant bedrock materials, and various extrusives and intrusives, mainly andesitic in composition	22
Biotite sands	
Quartz-biotite sands with fresh feldspars	100±
Bench gravels	
Loose or poorly consolidated, light-colored or rusty gravels, sands, and clays. Gravels composed of quartzite and white quartz with thoroughly decomposed pebbles of greenstone (?), slate (?), and basic intrusive (?); sands usually 50 per cent or more quartz with various amounts of anauxite and altered feldspar; clays buff to white, leaf-bearing. Ione sediments	300±
Channel gravels	
Massive dark-colored river gravels, well rounded, cobble and boulder sizes interspersed with gravels and sand. Composed mainly of resistant bedrock materials such as quartzite and hornfels, cemented with silica and iron compounds	30-60

Description and Lithology of the Eocene or Ione Gravels

The pronounced central channel is filled to a depth of 40 to 60 feet with cemented blue gravel or channel gravel. This was deposited by the active stream and protected by water from excessive decomposition and oxidation. These gravels, lying below the water table, are well cemented with silica and iron oxides. The iron is in a reduced state resulting from the action of ground water, and this gives the characteristic greenish or bluish color. Nearly all the abundant fossil wood in the lower gravels is carbonized rather than silicified, indicating that it was preserved below the water table. A composition count of the pebbles and cobbles was made at several locations, both in the deep channel and in the gravels at various levels above on the benches. The composition was determined on the spot, the determinations being subject to the unavoidable errors of all field determinations. At Browns Hill, just southeast of You Bet, the channel gravels near the contact occurred in the following compositions and percentages:

	Per cent
White quartz..........................	24
Quartzite.............................	20
Siliceous slate or impure quartzite...	19
Diorite porphyry......................	13
Diorite...............................	6
Andesites (?).........................	5
Lamprophyre dike rocks................	4
Biotite granite.......................	3
Black hornfels or chert...............	3
Indurated pink rhyolite...............	2
Serpentine............................	1

In some places the gravels are so firmly cemented it is necessary to use dynamite before hydraulicking. The thickness of these blue gravels is irregular. They become somewhat finer at a distance of 30 feet or more above the channel. Lenses of clayey, biotitic sandstone containing carbonized twigs and logs are common in the lower gravels and rest directly on the bedrock in places.

Above the blue gravels the material has been thoroughly oxidized and decomposed, and is predominantly rusty yellow or light-colored. The contrast between the lower and upper gravels is apparently caused by the different exposure to oxidation as a function of depth of burial, and not by any pronounced age difference. The higher gravels were deposited by a slower-moving stream on a wider flood plain and were subject to intensive chemical weathering. Along the steep west side of the main channel southeast of You Bet, at Browns Hill diggings, typical Ione sediments may be seen close to bedrock but grading out into the heavier gravels of the main channel. Whereas the basement rocks of the deep main channel are comparatively fresh in many places, along the channel sides and under the bench gravels they are deeply weathered and decomposed. Similar conditions were noted by Allen at the Cherokee pit north of Oroville (Allen, 1929, pp. 398-399). Contrasting the basement surface and deposits of the main channel with the bench deposits, he says:

> ... it seems that both developed during that state of the stream history when the lower part of the channel was filled with 30 or 40 feet of coarse boulders which protected it from weathering.... The closest approach to

the conditions at Cherokee have been reported by Holmes* in Portuguese East Africa, where laterite deposits occur along the sides of small streams, the majority of which dry up during several months of the year. In a cross section of the channel no laterite was shown on the floor of the channel, but the sides are mantled with deposits of laterite, varying in thickness.

*Holmes, A., Laterite deposits of Mozambique, Geol. Mag., vol. 1, p. 531, 1914.

The fact that there is a regular gradation from the characteristic Ione sediments along the channel sides into the gravels of the channel indicates that the channel gravels and the bench gravels, with their typical Ione sediments, were all formed in sequence as the aggrading stream filled its channel and cut wide benches above.

A characteristic feature of the gravels above the cemented zone is the presence of white to gray, kaolinized pebbles and cobbles which completely disintegrate when uncovered and exposed to weathering. The kaolinized gravels superficially resemble intermediate or acid extrusive rocks which have been somewhat altered, but a thorough examination failed to disclose the slightest evidence of the presence of any volcanic products among them. The texture of the original rock is often preserved, but the composition has been entirely altered by strong chemical weathering. These lithomargic pebbles and cobbles often make up a third or more of the total gravel assemblage. On account of their extreme decomposition, it is not possible to determine with accuracy the nature of the rock from which they were derived, but it is evident that the majority of them represent the less resistant bedrock constituents. Slate, amphibolite schist, and porphyritic basic intrusives were probably the original rocks in most cases. Under the effects of hydraulic mining, the lithomargic gravels crumble and disappear, leaving the quartz and quartzite, which thus seem to form a larger proportion of the sediments than the true composition warrants. A count of resistant pebbles in the bench gravels just above bedrock on the east bench showed the following:

	Per cent
Hornfels or siliceous slate............	35
Quartzite............................	33
White quartz.........................	12
Green intrusive......................	8
Cherts, diorite, schist, granodiorite...	12

(The kaolinized pebbles were not counted at this locality.) At another locality 30 to 40 feet above the bedrock on the east bench, a count showed the following:

	Per cent
Kaolinized pebbles................................	27
White quartz......................................	28
Dark slate and hornfels...........................	21
Quartzite...	19
Fine-grained purple andesite, diorite, and sandstone	5

It will be seen from these two counts that white quartz pebbles increase in abundance with distance from the bedrock. The pebbles near the contact contain a greater proportion of material from the underlying slates. In the overlying gravels, the pebbles are more resistant and indicate that they have been transported some distance. The bench gravels as a whole are well rounded except near the contact. There are many lenticular beds of white sands, with hard layers of limonite, rare layers of carbonaceous sand, and extensive beds of light to dark brown "chocolate" clays and shales. The brown clays invariably contain abundant leaf impressions with carbonized films of the leaf substance usually present. In other places the clays contain layers in which the leaf impressions are highly colored with reds or orange-yellows owing to the presence of ferric oxides. In these colored clays, the preservation of the fossil leaf venation is remarkable for its clarity and delicacy. On the outer or east bench, the finer interbeds show a slightly different aspect, ranging from white and red quartz-anauxite sands to pure clays which may be white, or colored light gray, greenish gray, yellow, pink, or red. The quartz-anauxite sand and the accompanying clays are typical Ione sediments which have been described by Allen (1929, pp. 375-382). The sediments on the benches have experienced the extreme of chemical weathering. The anauxite is evidently an alteration product of biotite, derived from the granodiorites higher in the range; and the angular quartz grains probably had the same source. The amount of white quartz pebbles in the gravel increases toward the upper edges of the benches, but there is always a large amount of dark quartzite derived from the Cape Horn formation.

Above the typical Ione sediments deposited on the benches is a thick bed of rusty, cross-bedded sands which differ markedly in their composition from the sands below. Petrographic analyses of the sediments selected at various localities in the channel and in the succeeding deposits were made by Galen Sturgeon, who has placed the appended data at the writer's disposal.

Petrography of channel deposits

By Galen Sturgeon

(See figure 2 for location of samples)

The samples were separated with bromoform and the light and heavy separates studied individually.

The following designations are used for showing the abundance of each heavy mineral with respect to the total of the heavies:

A, flood (also forms large part of the total sediment)
B, very abundant
C, common
D, sparse
E, rare
F, very rare

1. Gray sand, partly stained yellow-brown; angular to subangular

Lights:

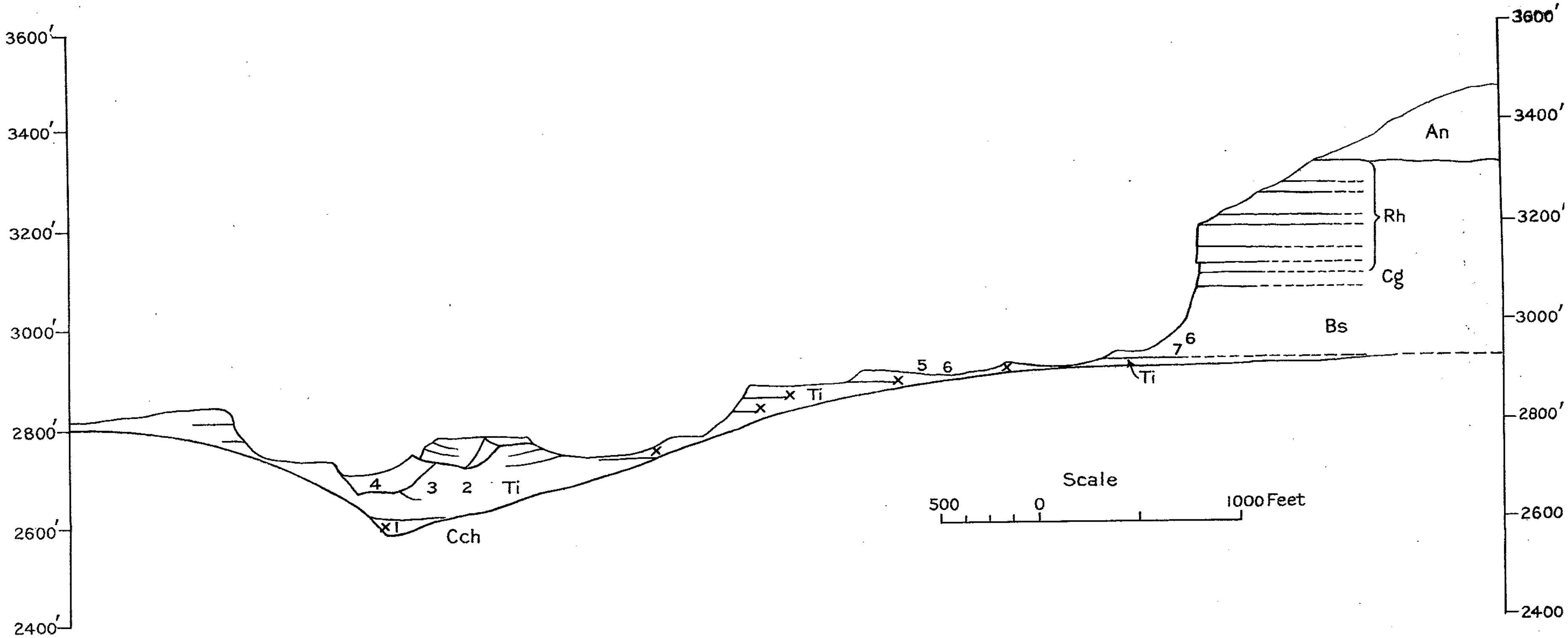
Quartz	68%	
Plagioclase (oligoclase to andesine)	15	Feldspars somewhat altered
Orthoclase	15	

Heavies, 2 per cent of total:
Biotite (some bleached), A, 15 per cent
Chromite or ilmenite, B
Tourmaline, B
Green hornblende, B
Epidote, B
Titanite (short, stubby envelopes with inclusions), C
Zoisite, C
Zircon, C
Andalusite, C
Colorless garnet, D
Tan garnet, D
Strained garnet, D
Tremolite, F

2. Fine greenish-gray sandstone cemented by clay material

Lights:

Quartz	33%	Feldspars fresh to partly altered
Plagioclase (albite)	20	
Microcline	5	
Clay material	40	



Cross section of the channel at Chalk Bluffs. Scale: 5/8 in. = 500 ft. horizontal; 5/8 in. = 200 ft. vertical.

Cch, Cape Horn formation   Cg, conglomerate
Ti, Ione gravels   Rh, rhyolite
Bs, biotite sands   An, andesite
x, shale layers containing fossil plants

Numbers refer to samples analyzed by Galen Sturgeon (see pages 18-22).

Heavies, 2 per cent of total:
- Chromite or ilmenite, B
- Biotite (reddened), B
- Zircon, B
- Barite, B
- Tourmaline, C
- Zoisite, C
- Colorless garnet, D
- Tan garnet, D
- Epidote, E
- Rutile, E

3. A conglomerate of weathered rocks including a purple feldspar porphyry, an acid porphyry with quartz phenocrysts, and a soapy green rock (altered serpentine or talc). The porphyries and other unidentifiable light-colored fragments were crushed to look for volcanic material.

Lights (some fresh, some altered):

Quartz	50%	Some fresh, some altered
Orthoclase	5	
Plagioclase (albite)	44	

Heavies, 1 per cent of total:
- Chromite or ilmenite, B
- Zircon, B
- Barite, D
- Tourmaline, D
- Epidote, D
- Andalusite, E
- Magnetite, E

4. Very fine white flaky material; angular

Lights:

Quartz	45%	Fresh
Plagioclase (albite-oligoclase)	20	
Orthoclase	10	
Kaolinized feldspars	25	

Heavies, 0.5 per cent of total:
- Chromite or ilmenite, B
- Zircon, B
- Magnetie, C
- Tourmaline, C
- Andalusite, D
- Epidote, D
- Rutile, D

5. White, some stained reddish, quartz-anauxite sands; angular

Lights:
- Quartz..... 84%
- Anauxite... 15 (2v = 20)

Heavies, 1 per cent of total:
- Chromite or ilmenite, B
- Tourmaline, B
- Andalusite, B
- Zircon, B
- Biotite (yellow to golden brown, also greenish brown), C
- Epidote, D
- Rutile, D
- Green hornblende, E
- Colorless garnet, E
- Brookite, E
- Zoisite, E
- Hematite, E
- Magnetite, E
- Staurolite, F

6. Light gray sand with biotite-rich layers showing cross-bedding; angular

Lights:

Quartz..........................	73%	Fresh feldspars
Orthoclase..............less than	1	
Plagioclase (basic oligoclase)...	5	

Heavies, 1 per cent of total excepting biotite:
- Biotite (bleached), A (20 per cent of total)
- Chromite or ilmenite, B
- Epidote, B
- Tourmaline, C
- Zoisite, C
- Zircon (with inclusions), C
- Andalusite, C
- Hornblende (green-brown), E
- Hypersthene, E
- Colorless garnet, E
- Tan garnet, E
- Strained garnet, E
- Rutile, E

7. Fine buff sand; angular

Lights:

Quartz..................................	58%	Feldspars fairly fresh
Plagioclase (albite to basic oligoclase)...	15	
Orthoclase / Microcline	5	

Heavies, 2 per cent of total excepting biotite:
- Biotite (golden brown and reddened, 2v = 20), A (20 per cent of total)
- Magnetite, B
- Chromite or ilmenite, B
- Epidote, B
- Zircon, B
- Tourmaline, C

Heavies—Continued
- Zoisite, C
- Andalusite, D
- Colorless garnet, D
- Tan garnet, E
- Rutile, E
- Green spinel, F

Summary of petrographic analysis:

Chalk Bluffs ridge. The inter-rhyolitic gravel (below the top rhyolite layer) is made up mostly of fresh material and contains a light-colored acid lava (rhyolite probably), granodiorite pebbles, some purple and green andesite porphyries, and much quartzite.

The gravels below the massive cliff rhyolite layer are fresh except for granodiorite pebbles. A count here showed a dark basic lava (andesite?) 32, quartzite 20, hornfels (dark, dense, and fine) 8, acid porphyry 5, vein quartz 3, hard sandstone 5, purple andesite porphyry 3, metavolcanic 1, gray schist 1.

The gravels associated with the quartz-anauxite sands or the so-called bench gravels average about 1 inch in diameter and may attain 6 inches. There are also some large fragments and boulders several feet across. The main constituent is quartzite, including metamorphosed and rolled sandstones and pebble conglomerate.

Below You Bet. The gravels from the deepest part of the channel appear somewhat coarser than the bench gravels above. They average about 2 inches and may measure as much as 1 foot. There is more fresh material from the bedrock, but still a large proportion of them are greatly weathered.

In the section below You Bet, all samples show effects of chemical weathering. The heavy separates, which contain the susceptible ferromagnesian minerals, show impoverishment by their small quantity. Nevertheless, all the samples are appreciably feldspathic, some of the feldspars being quite fresh. No volcanic glass was found.

The extreme of chemical weathering is found in the quartz-anauxite sand above in the bench gravels, in which not only are the heavies depleted to the most resistant minerals, but no feldspars appear in the lights, leaving only quartz and the alteration product, anauxite. No volcanic glass was found here. It might be argued that if rhyolitic glass had been present, it would have been destroyed by weathering as were the feldspars.

In the gray sands above these and below the cliff rhyolite, however, fresh feldspars are abundant, and the character of the sand has completely changed. In the three samples analyzed only one particle of glass was found, seeming to indicate that any eruptions during the time of the formation of that layer were insignificant, and probably none preceded it. The gravel just below the rhyolite layer shows evidence of various types of eruptives (and irruptives) both acid and basic, which are probably the main beginnings of volcanic activity.

The rhyolitic period, then, was preceded by a decided change in climate.

There can be no doubt that the contact of the cross-bedded sands with the Ione gravels is an erosional disconformity or unconformity. Above the contact, there is an abundance of practically unaltered biotite and there may be as much as 25 per cent of fresh feldspars. This indicates a marked difference in weathering. A similar relation is seen in the Gladding McBean clay pit at Lincoln. "Here the gently dipping layers of the Ione are terminated abruptly by a disconformity. On this erosion surface, gravels were deposited in the lowest depressions and these grade upward into sands, often with much biotite, or into clays" (Allen, 1929, p. 413).

Although the relations are somewhat obscure, it appears certain that the Capay stage fauna from the vicinity of Oroville occurs in beds just underlying the Ione. These marine beds were called the Dry Creek formation by Allen. They are very similar in composition to the rusty, biotite sands which overlie the Ione gravels. The same relations are found on the west side of the Marysville Buttes where the Ione sediments overlie the Marysville formation (similar in lithology to the Upper Cretaceous beds), containing a marine fauna of Capay age (Williams, 1929, p. 127). It was at one time believed that the Butte gravels, which unconformably succeed the Ione at Marysville Buttes, were also of Capay age, but there is a strong probability that this formation is much younger. The age was determined by a fauna reported from a sandstone "700 feet above the Ione." This sandstone is in reality a part of the Marysville formation, instead of a member in the Butte gravels, and lies 700 feet above the Cretaceous, not the Ione, since there are <u>two</u> zones of white sands exposed in the Buttes, the lower of which is Upper Cretaceous. The Butte gravels appear to underlie the Sutter formation and may be a product of the uplifts which preceded the volcanism of the later Miocene and Pliocene.

There remains to be found a satisfactory explanation for the occurrence of the Ione type of sediments sandwiched between arkosic and biotitic sediments. If the conditions of deposition are the same, the chemical nature of the sediments largely depends on three factors: (1) the chemical composition of the source rocks; (2) the climate; (3) the rate of removal of the products of weathering. In the later Cretaceous (or earlier), and probably throughout the whole of the Paleocene and Eocene, the nature of the bedrock exposures in the region of the Sierra must have remained essentially the same, although a slow increase of intrusives exposed in the area would be expected. At least there can have been no marked change in the composition of the source rocks. Except for some indication of cooler climates during a part of the Paleocene, there is no indication of any important climatic fluctuations in this time interval. The climate was, for the most part, subtropical, with abundant rainfall. In looking for an explanation of the lithologic changes in sediments during the Eocene, if we assume factors (1) and (2) above to have been fairly constant, we have left only (3) as a major factor producing chemical changes in the sediments under the same conditions of deposition.

During uplift, there may be rapid removal of the products of weathering, and deposition of comparatively unresistant materials in a relatively fresh state, even under conditions of subtropical weathering. During periods of quiescence, the rock mantle would accumulate and sufficient time would be available for the complete alteration of the minerals more susceptible to chemical decay, and for penetration of weathering into the bedrock surface. In other words, the time element must be considered, as well as the temperature and humidity.

A long period of crustal stability producing an erosion surface of low relief, followed by a period of renewed uplift, should produce a characteristic sedimentary sequence under conditions of subtropical, humid weathering. There would result a gradual change from arkosic sediments, at the beginning of the erosion interval, to white quartz gravels, quartz sands, and pure clays toward the close, followed by a return to arkosic, less chemically differentiated products, after uplift had removed the accumulated mantle. The most rapid period of deposition of the Ione type of sediments would be at the beginning of the period of uplift. Under these conditions, the change from arkosic to pure quartz sands must be very slow, whereas the reverse change might be comparatively rapid.

The sharp break above the Ione gravels at Cherokee and Chalk Bluffs can only be explained as a disconformity, and the field evidence for this seems conclusive. The rapid transition from the Dry Creek beds and Marysville formation to the overlying Ione sands also strongly indicates a disconformity. One way to explain the observed relations is to postulate a period of crustal stability of sufficient length to produce the conditions essential for the formation of the advanced residual weathering products of the Ione. This period must be included between two periods of uplift and rapid erosion. The arkosic sediments imply fairly rapid erosion and removal of the rock mantle, whereas the extreme weathering indicated by the Ione sediments required a period of crustal quiet and slow transport. According to this theory, the deposition of the Dry Creek and Marysville formations must have been followed by a long period of erosion, a period of sufficient length to produce an old-age erosion surface. This introduces a problem of great difficulty, since under any conditions the formation of such an old-age surface would mean a time interval of too great length to be contained in the Capay stage.

This problem may be solved by a consideration of the lithology of the Ione gravels. First, it is necessary to remember the obvious fact that the gravels are a product of stream deposition; they were laid on bedrock originally scoured by stream action, and were subjected to the changing conditions of the flood-plain environment. Second, the presence of a relatively large proportion of rotten, kaolinized pebbles indicates that the sediments were subjected to intensive chemical weathering <u>after</u> deposition. The pebbles crumble at the touch when exposed to present weathering conditions, and soon disintegrate completely, leaving only the resistant quartz and quartzite. The gravels have been protected from weathering since the deposition of the overlying sediments and volcanics. The bedrock below the gravels, except in the bottom of the channels, is deeply weathered, and the Cape Horn slates have been, in places, completely kaolinized and changed to lithomarge to a depth of several feet.

The fact that part of the chemical weathering of the Ione gravels took place after deposition gives an explanation of the sequence of sediments. Since the time element is as important as the climate in the production of such sediments, we have here a mechanism for long-continued subaerial weathering of flood-plain material. Under conditions of rapid erosion, the sediments are transported to the final place of deposition in a comparatively short interval, and little time is available for the action of weathering processes en route. If a rise in base level occurs, and the lower part of the stream valleys becomes aggraded, transport to the final marine site of deposition is greatly retarded. The sediments are spread out over the flood plain in thin layers, exposed to alternate wetting and drying and the full effects of chemical weathering. Under the climate of the early Tertiary, arkosic and biotitic sediments fed into the main stream by the more active tributaries were transformed into quartz-anauxite sands and pure clays. The lower part of the stream valleys thus became, in a sense, areas where the sediments were completely digested and slowly fed to the delta regions along the land border. Where the rise in base level was slow enough, the accumulation of several hundred feet of chemically weathered sediments in the lower stream courses was a natural consequence. The Ione sediments thus are a normal result of the Middle Eocene marine transgression.

The Sierra of that time formed a distinct range of low mountains draining into a bordering sea. Under moderately active conditions of erosion induced by uplift, incompletely weathered sediments like those of the Marysville and Dry Creek formations would result.

The deposition of the Ione was followed by a period of uplift which removed part of that formation and which caused a withdrawal of the sea from the adjacent portions of the Sacramento Valley. As far as the sedimentary record can be interpreted, continental conditions prevailed until the deposition of the shallow-water, marine Wheatland formation in the Upper Eocene. The layer of biotite sands overlying the Ione was doubtless a product of this uplift.

Overlying the biotite sands is a massive bed of coarse cobble gravel which appears everywhere below the rhyolite series along the South Fork of the Tertiary Yuba. Several composition counts were taken in this gravel which gave the following approximate percentages:

	Per cent
Basalt or andesite................	42-51
Gray quartzite....................	22-25
Various metamorphic intrusives...	8-11
Hornfels..........................	5-10
Gray sandstone....................	5- 7
White quartz......................	4- 5
Quartz porphyry...................	3- 4

The basic igneous rocks vary from a purplish andesite porphyry to dark pyroxene andesite and basalt (?). The composition of this conglomerate appears to be similar to that of the basal conglomerate of the Wheatland formation. There is a strong probability, however, that it is later in age and a result of the uplifts preceding the rhyolitic eruptions. It may be a correlative of the Butte gravels.

The succeeding volcanic deposits, the Rhyolitic and Andesitic series, have been so carefully and adequately treated by Lindgren (1911, p. 137) that only a brief description of their occurrence at Chalk Bluffs will be given. One of the best exposures of the light gray to white tuffs of the Rhyolitic series is seen at Chalk Bluffs, where they form the capping of the "Bluffs." At the base is a layer of sandy, brownish-gray tuff about 20 to 25 feet thick; then follows a massive bed of white, sandy-textured tuff in which abundant pumice fragments are embedded. This is approximately 70 feet in thickness and presents a striking appearance on account of its brilliant white color and great thickness. Above the massive tuff is a series of agglomeratic and tuffaceous beds overlain by gravel approximately 10 feet in thickness, largely made up of cobbles of rhyolite lava. This is followed by a complex succession of rather thin beds of rhyolitic sandy tuffs interbedded with gravel (Lindgren, 1900, p. 6). The lower tuffs are the result of great explosive eruptions in the higher part of the range, and the succeeding group of beds present a record of declining volcanic activity, during which time the pyroclastics resulting from minor eruptions were interbedded with river gravels. The massive tuffs originated as mudflows somewhere in the range east of Blue Canyon, since they can be traced from that point down the east branch of the South Fork of the Tertiary Yuba to Alta and thence northward through the Chalk Bluffs deposits to Quaker Flat. At Alta the tuffs attain a maximum thickness of nearly 300 feet.

Apparently the rhyolitic mudflows followed channels which transected the older channels. This relation is seen in the cliffs made by hydraulicking, notably at Independence Hill and at the Dardanelles Mine near Forest Hill. These channels were directed down the slope of the range and follow, in a general way, the same lines of flow as the succeeding great flows of andesitic breccia. They were a result of a westward tilting of the range which continued, with interruptions, into the Quaternary. There is much field evidence to support the suggestion that the Rhyolitic

Table 1

Correlation of Tertiary deposits on the west slope of the northern Sierra

Horizon	Generalized California section	East side of Great Valley of California	Chalk Bluffs	Marysville Buttes	Wheatland region	Cherokee Pit and Oroville Table Mountain	Fossil flora
Pleistocene	Tulare	Flood-plain deposits Arroyo Seco gravel	Terrace Gravels				You Bet[4]
Pliocene	Etchegoin Jacalitos	Laguna formation Andesitic series or Mehrten formation	Andesites			Basalt[3]	Tuolumne Table Mountain and Bowen's Tunnel
Miocene	San Pablo[1] Monterey Temblor Vaqueros	Rhyolitic series or Valley Springs formation[2]	Rhyolitic tuffs Massive gravels	Sutter beds Butte gravels[3]	Rhyolitic pumice tuff	Tuffaceous yellow clay	Remington Hill--Forest Upper Cedarville Valley Springs[5]
Oligocene	San Lorenzo Gaviota				Cross-bedded yellow sands		Lower Cedarville
Upper Eocene Middle Eocene	Tejon Domengine Capay	Ione formation	Biotite sands Ione formation; bench and channel gravels	Ione formation Marysville formation	Wheatland formation Red and white clays, quartz-anauxite sand	Biotite sands Ione formation Dry Creek	La Porte Chalk Bluffs

[1]Upper part of the San Pablo is probably Lower Pliocene.

[2]It has not yet been established that all the rhyolitic deposits are of the same age.

[3]The stratigraphic position is not yet quite certain.

[4]Unpublished manuscript by H. Mason.

[5]Manuscript in preparation by D. I. Axelrod.

and Andesitic series were phases of the same period of volcanism, and that the time interval separating them was of comparatively short duration. If this be so, then the age of the Valley Springs formation (Rhyolitic series) is not older than Upper Miocene. There are exposures which show that some erosion of the acid tuffs took place before the advent of the andesitic volcanics, and these latter eruptives in some places follow stream channels cut in the rhyolite. These erosion effects were not produced on a scale that indicates a long interval of time.

The Mehrten formation (Andesitic series) comprises massive mudflows of tuff breccia interbedded with stream gravels. The thickness exceeds 300 feet in many places between Forest Hill and the Blue Tent mine. The entire quadrangle at one time was buried under a thickness of these volcanics which may have reached 1000 feet (Lindgren, 1911, p. 137).

Topography

"The dominant feature of the western slope of the Sierra is an approximate uniformity of summit altitudes giving the appearance of a widely extended and deeply trenched plateau" (Fenneman, 1931, p. 403). From any slight elevation, the line of the horizon presents a remarkably flat plane. This plane represents a former erosion surface which slopes gently upward toward the summit of the range. In the Colfax Quadrangle the elevation of the southwestern corner is about 2200 feet, and thence there is a rise of 6000 feet along the margin of the upland summits in the northeastern part of the quadrangle, a gradient of about 130 feet per mile. The slope is trenched by the deep canyons of consequent streams, such as the American River and the North and South forks of the Yuba, whose channels are cut as much as 2500 feet below the upland level. There is the sharpest possible physiographic contrast between the nearly level or gently rolling interstream divides, with their small meandering streams in shallow valleys, and the surprisingly abrupt and youthful canyons, with their powerful and rapidly eroding rivers.

The upland plateau, between elevations of approximately 2000 and 5000 feet, is largely covered by the andesitic breccias and flows which, to a certain extent, filled in and smoothed out the irregularities in the earlier topography. The smooth surface of the summit plain, however, is in part due to erosion subsequent to the andesitic eruptions, since it cuts across intrusives, metamorphics, and andesite breccias alike. The andesitic eruptions occurred during the interval Upper Miocene-Middle Pliocene, according to paleontological evidence. This dates the age of the erosion surface as later than Middle Pliocene, and indicates that it was formed during the Upper Pliocene. A similar erosion surface was developed at about the same time over the region now occupied by the southern Klamath Mountains and northern Coast Ranges (MacGinitie, 1937, pp. 103-106).

CLIMATE AND VEGETATION OF THE CHALK BLUFFS AREA

The Chalk Bluffs region lies in the climate of Mediterranean type characteristic of the lower Sierra toward the north. According to the Koppen classification, the climate is defined by the symbols **Csa** for elevations below 2500 feet and **Csb** for elevations between 2500 and 4000 feet. These symbols are defined as follows: **C**, temperate, average temperature of the coldest month between 64.4° and 26.6° F. (18° to -3° C.); **s**, dry season in the summer; **a**, average temperature of the warmest month above 71.6° F. (22° C.); **b**, average temperature of the warmest month below 71.6° F., at least four months above 50° F. (10° C.). The annual precipitation averages exceed 50 inches. More than three-fourths of the total amount falls in the five winter months, November to March. Over a large part of the region there is less than one inch of precipitation in the three summer months, June to August. Minimum temperatures in the winter vary between 5° and 10° F. The maximum temperatures of the summer exceed 100° F.; and the average daily maximum temperatures vary between 80° and 90° F. for the different Weather Bureau stations in the area during the summer months, June to August. The frostless season varies in length from somewhat less than six months to over seven months, depending on the latitude. Snowfall at elevations below 4000 feet is moderate, varying from a little over 2 feet on the average at Colfax to over 4 feet average annual fall at North Bloomfield. Higher on the slope of the Sierra east of the area covered in this report, the snowfall is extraordinarily heavy, annual averages of from 20 to 35 feet being commonly reported. The most striking factor of the climate is the extended period of nearly rainless weather in the summer. The days are remarkably similar, with clear skies, high temperatures from 11 a.m. to 4 p.m., and low humidity. This latter factor favors a large daily temperature range and cool nights. The winters are cloudy, rainy, and cool.

In summary it may be said that the climate is temperate, characterized by short, cool winters with heavy precipitation, and long, warm, dry summers.

The vegetation of the area in which the fossil flora occurs is typical of the Transition life zone, sometimes called the Sierra Transition life zone. The dominant forest trees (Jepson, 1925, p. 7),[1] in the order

[1]The common and botanical names of the modern plants are as follows:

Common name	Botanical name
Azalea	Rhododendron occidentale Gray
Big-leaf maple	Acer macrophyllum Pursh
Black cottonwood	Populus trichocarpa Torrey and Gray
Black oak	Quercus kelloggii Newberry
Canyon live oak	Quercus chrysolepis Liebmann
Chinquapin	Castanopsis sempervirens Dudley
Chokecherry	Prunus demissa (Nuttall) Dietrich
Coffeeberry	Rhamnus rubra Greene
Creambush	Holodiscus discolor (Pursh) Maximowicz
Deer brush	Ceanothus integerrimus Hooker and Arnott
Dogwood	Cornus nuttallii Audubon
Douglas fir	Pseudotsuga taxifolia (Lambert) Britton
Elk clover	Aralia californica Watson
Gooseberry	Ribes roezlii Regel
Hazelnut	Corylus rostrata Aiton
Incense cedar	Libocedrus decurrens Torrey
Knobcone pine	Pinus attenuata Lemmon
Labrador tea	Ledum glandulosum Nuttall
Madrone	Arbutus menziesii Pursh
Mahala mat	Ceanothus prostratus Bentham
Manzanita	Arctostaphylos patula Greene
Mountain mahogany	Cercocarpus betuloides Nuttall
Mountain misery	Chamaebatia foliolosa Bentham
Pigeonberry	Rhamnus californica Eschscholtz
Poison oak	Rhus (Toxicodendron) diversiloba Torrey and Gray
Red alder	Alnus rubra Bongard
Serviceberry	Amelanchier alnifolia Nuttall
Sugar pine	Pinus lambertiana Douglas
Sumac	Rhus trilobata Nuttall
Tan oak	Lithocarpus densiflora (Hooker and Arnott) Rehder
Thimbleberry	Rubus parviflorus Nuttall
Tobacco brush	Ceanothus velutinus Douglas
White fir	Abies concolor Lindley and Gordon
Wild grape	Vitis californica Bentham
Wild rose	Rosa spp.
Willow	Salix spp.
Yellow pine	Pinus ponderosa Douglas

of abundance, are: Douglas fir, yellow pine, incense cedar, sugar pine, and white fir. Black oak, tan oak, and madrone are commonly associated with the coniferous trees in the more open parts of the forest. Canyon live oak is abundant on open, dry canyon sides. California wild grape, big-leaf maple, red alder, black cottonwood, and willow are common in the moister situations. There are occasional scattered groves of knobcone pine on barren or rocky slopes.

Many shrubs occupy favorable situations on the forest border and along the streams: hazelnut, thimbleberry, gooseberry, dogwood, azalea, elk clover, coffeeberry, deer brush, chokecherry, creambush, serviceberry. A different group of shrubs is dominant on dry, open hillsides. The typical plant of these locations is mountain misery, which forms dense colonies under open groves of yellow pine. The pungent odor of this plant on hot summer afternoons is peculiarly characteristic of the lower Transition life-zone region in the Sierra. In addition there are extensive colonies of manzanita, which sometimes form impenetrable thickets on cut-over land. Mahala mat, tobacco brush, pigeonberry, poison oak, sumac, mountain mahogany, and chinquapin also frequent the drier areas.

COMPOSITION OF THE FLORA AND RELATIONSHIPS OF THE FOSSIL SPECIES

The Chalk Bluffs flora is distributed in 20 orders, 44 families, 66 genera, and 77 species. One varietal form is included. Fifty of the species are new or are established as new combinations. Where the relation of the fossil form to any one living genus could not be established, a genus such as Platanophyllum or Laurophyllum was used, indicating the general relationship of the fossil.

Systematic List of the Chalk Bluffs Flora[2]

Pteridophyta
  Filicineae
    Filicales
      Schizaeaceae
        Lygodium kaulfussii
      Cyatheaceae
        Hemitelia pinnata

Spermatophyta
  Gymnospermae
    Cycadales
      Cycadaceae
        Zamites californica

[2]Arrangement after Willis, 1925, supp., pp. ii-xlix.

- Spermatophyta—Continued
  - Angiospermae
    - Monocotyledones
      - Palmales
        - Palmae
          - Sabalites californicus
      - Liliales
        - Liliaceae
          - Smilax labidurommae
    - Dicotyledones
      - Salicales
        - Salicaceae
          - Salix ionensis
        - Juglandales
          - Juglandaceae
            - Carya sessilis
            - Engelhardtia nevadensis
        - Fagales
          - Betulaceae
            - Alnus operia
          - Fagaceae
            - Castanopsis longipetiolatum
            - Quercus distincta
            - Quercus eoxalapensis
            - Quercus nevadensis
        - Urticales
          - Ulmaceae
            - Chaetoptelea pseudo-fulva
          - Moraceae
            - Artocarpus lessigiana
            - Ficus densifolia
            - Ficus goshenensis
        - Ranales
          - Nymphaeaceae
            - Nelumbium lacunosum
          - Cercidiphyllaceae
            - Cercidiphyllum elongatum
          - Menispermaceae
            - Hyperbaena diforma
          - Magnoliaceae
            - Magnolia dayana
          - Lauraceae
            - Cinnamomum acrodromum
            - Cinnamomum dilleri
            - Cryptocarya praesamarensis
            - Laurophyllum fremontensis
            - Laurophyllum litseaefolia
            - Neolitsea lata
            - Persea praelingue
            - Persea pseudo-carolinensis
        - Rosales
          - Saxifragaceae
            - Hydrangea californica
          - Hamamelidaceae
            - Hamamelites voyana
            - Liquidambar californicum
          - Platanaceae
            - Platanophyllum angustiloba
            - Platanophyllum angustiloba var. serrata
            - Platanophyllum whitneyi
            - Platanus appendiculata
            - Platanus coloradensis
          - Rosaceae
            - Chrysobalanus eoicaco
            - Vauquelinia exigua
          - Leguminosae
            - Dalbergia rubra
            - Desmodium indentum
            - Inga ionensis
            - Pongamia ovata
            - Strongylodon falcata
            - Vouapa geminifolia
        - Geraniales
          - Burseraceae
            - Canarium californicum
          - Simarubaceae
            - Ailanthus lesquereuxi
          - Meliaceae
            - Cedrela eolancifolia
          - Euphorbiaceae
            - Acalypha aequalis
            - Mallotus riparius
        - Sapindales
          - Celastraceae
            - Celastrus preangulata
          - Icacinaceae
            - Phytocrene sordida
          - Anacardiaceae
            - Rhus mixta
          - Aceraceae
            - Acer aequidentatum
          - Sapindaceae
            - Cupania oregona
            - Thouinopsis myricaefolia
          - Sabiaceae
            - Meliosma truncata
        - Rhamnales
          - Rhamnaceae
            - Rhamnidium chaneyi
            - Rhamnus calyptus
            - Rhamnus plenus
          - Vitaceae
            - Cissus pyriformis
        - Parietales
          - Theaceae
            - Gordonia egregia

Spermatophyta--Continued
  Angiospermae--Continued
    Dicotyledones--Continued
      Myrtiflorae
        Myrtaceae
          Calyptranthes myrtifolia
        Nyssaceae
          Nyssa californica
        Combretaceae
          Terminalia estamina
      Umbelliflorae
        Cornaceae
          Cornus kelloggii
      Ebenales
        Ebenaceae
          Diospyros retinervis
      Contortae
        Oleaceae
          Fraxinus yubaensis
        Apocynaceae
          Nerium hinoidea
          Tabernaemontana chrysophylloides
        Asclepiadaceae
          Asclepiadites laterita
      Rubiales
        Caprifoliaceae
          Viburnum variabilis
      Campanulatae
        Compositae
          Calycites mikanoides
      Incertae sedis
          Carpites egregia
          Phyllites cordiaefolia
          Phyllites daturaefolia
          Phyllites laurinea
          Quercophyllum platanoides

The modern relationships of 67 of the fossil angiosperm species are sufficiently clear to permit a determination of their habit. On this basis 36 species, or 54 per cent, were trees; 24, or 36 per cent, were shrubs or small trees; and 7, or 10 per cent, were vines. The ratio of trees to shrubs is high in comparison with that found in other early Tertiary floras of the same general region, as is shown in the following table.

	Trees (per cent)	Shrubs (per cent)	Vines (per cent)
Chalk Bluffs.......	54	36	10
La Porte...........	46	41	13
Goshen.............	40	51	9
Weaverville........	33	39	16

The tree-shrub ratio of the Chalk Bluffs flora approximates the ratio found in living tropical forests. There is more chance for the leaves of a tree to enter the fossil record than there is for the leaves of a shrub, since the trees are larger, bear more leaves, and reach farther up into the path of the wind. This advantage in favor of the trees is partly compensated for by the habitat of many shrubs along the edge of the forest adjacent to the streams.

The family Lauraceae, with 8 species, is the largest; the Leguminosae, with 6, and the Fagaceae and Platanaceae, with 4 each, are next in order. The Moraceae and Rhamnaceae each contain 3 species. The remaining families are represented by only 1 or 2 species each. There are 2 pteridophytes, 1 gymnosperm, and 2 monocotyledons, leaving 72 species of dicotyledons, in addition to which there are several angiosperms represented by the undescribed leaves and fruits figured.

Of the two ferns in the flora, Lygodium is a climbing fern of present-day lowland subtropical or tropical regions, and Hemitelia appears to be the leaf of a tree fern similar to several living Central American species. The tree fern was either rare or an inhabitant of the higher tributary valleys, judging from the scarcity of its remains. The leaflets referred to Zamites were doubtless those of a cycad which grew on the upland slopes. The two monocotyledons offer little of interest. The species of Sabalites is founded on fragments of a small fan palm which appears to have been an upland form related to a living Asiatic species. There are rare leaf impressions of Smilax, similar to the leaves of several living species of Asia and America.

In the dicotyledons, the family Salicaceae is represented by one species of willow founded on three leaf impressions. This rare species resembles the leaves of certain willows common in the southern states, such as Salix nigra Marshall.

The family Juglandaceae includes a species of Carya, founded on impressions of the leaflets, and a species of Engelhardtia whose identity is made certain by the numerous impressions of winged fruits. The Carya leaflets are similar to those of Carya (Hicoria) cordiformis K. Koch, the familiar swamp hickory or pignut of the eastern states. This tree, although it is found on rocky hillsides, usually frequents low woods and swamps, and grows from Minnesota and Quebec southward to Florida and eastern Texas. The fossil fruits of Engelhardtia nevadensis differ in some respects from those of any living species, although they show a general correspondence, except in size, to the winged seeds of the living Neotropical forms. Three species have been described from the American tropics: E. pterocarpa (Oersted) Standley, of Costa Rica; E. mexicana Standley, of Tabasco; and E. guatemalensis Standley, from central Guatemala. The Neotropical Engelhardtias are striking endemics growing in the upland rain forests of Central America from Costa Rica to northern Guatemala (and perhaps into southern Mexico) at elevations of from 2500 to 4500 feet or, rarely, higher. They can be distinguished from the Asiatic species by the much larger, strongly three-veined wings of the fruits and by the greater size and prominence of the basal or fourth lobe. About ten existing species of the genus inhabit the warm-temperate to tropical parts of southern and southeastern Asia, from China to the Philippines and westward through the East Indies and Indo-China to India. They are upland trees, and in the warmer parts of their range grow at elevations of 6000 feet or more, but farther north they descend to lower elevations. The Asiatic species should probably not be considered tropical plants, but rather warm-temperate or possibly subtropical, living in the equable climate of tropical uplands. The common occurrence of the winged fruits in connection with the extreme rarity of the leaflets in the Chalk Bluffs flora strongly indicates that the fossil _Engelhardtia_ was an upland tree. It is evident that the genus was widely distributed during the Tertiary in the now temperate portions of Europe, Asia, and North America. Characteristic fruits closely similar to the fruits of existing Asiatic species of _Engelhardtia_ have been found in many European fossil floras from the Eocene into the Upper Miocene. Berry figures fruits of _E_. _mississippiensis_ which are apparently little different from those of the European _E_. _brongniarti_ Saporta, recorded from several localities of Middle and Upper Tertiary age. Fruits of _Engelhardtia_ similar to those of the Asiatic _E_. _colebrookiana_ Lindley have recently been discovered in the Oligo-Miocene Crooked River shales of Oregon. These are similar to _E_. _olsoni_ Brown (1940, p. 349), found in the Miocene Latah formation of Idaho. The present limited distribution of the living American species furnishes one of the best illustrations of the restriction of early Tertiary plants to the rain forests of tropical Mexico and Central America.

The family Betulaceae is not usually represented in the earlier Tertiary floras, but there are a few leaf impressions from scattered localities which are clearly identified with alder leaves. The leaf impressions are similar to the leaves of the living _Alnus formosana_ (Burkhill) Makina and _A_. _maritima_ Nuttall. These species are closely related and have a strange distribution. _Alnus formosana_ is restricted to Formosa; _A_. _maritima_ is found in two isolated areas in the United States, one near the seacoast in Delaware and Maryland and the other along the Red River where it forms the boundary between Oklahoma and Texas. These two species, like the species of *Hamamelis*, flower in the autumn, and appear to have a subtropical climatic adaptation. The present distribution indicates a long geological history. *Alnus relatus* (Knowlton) Brown from the Miocene Latah formation is probably the late Tertiary descendant of *A. operia*, since it also is similar to the leaves of the living species mentioned.

Four species of the family Fagaceae have been identified, three species of oak and a *Castanopsis*. One of the oaks, *Quercus distincta*, is clearly related to the live-oak types of western America and Mexico. Another species, *Q. nevadensis*, is more like the foliage of certain Asiatic species of oak such as *Q. glauca* Thunberg or *Q. hainanensis* Merrill, or of some of the Oriental species of *Castanopsis*. The third, *Q. eoxalapensis*, is similar to a living species in southeastern Mexico. These three species, judging from their occurrence, evidently were not abundant along the stream channels, but were more characteristic of high-ground situations. The *Castanopsis* (*Dryophyllum*), originally described from Yellowstone Park basic breccia, is much closer to the leaves of various living Oriental species of *Castanopsis* than to the early Tertiary *Dryophyllum*, which is supposed to represent the foliage of trees ancestral to the oaks and chestnuts. *Castanopsis fissa* Rehder and Wilson and *C. calathiformis* Rehder and Wilson have foliage most similar to the fossil leaves. These species inhabit the subtropical rain forests on the southern slopes of the mountains facing the China Sea from Kwangtung to Yünnan. The genus *Castanopsis* shows close relations to *Castanea*, one difference being the evergreen habit of *Castanopsis*. There are about twenty-five species in southeastern Asia, the greater number of which are confined to the subtropical or tropical regions of southern China. Several species are known from the East Indies, the Philippine Islands, and the southern part of the continent west to India; one species occurs in Japan, one in Korea; two species are native to California.

Chaetoptelea pseudo-fulva is one of the most characteristic fossils of the Chalk Bluffs flora. It closely resembles the living *C. mexicana* Liebmann both in foliage and in fruit. This tree is also a native of that haven for early Tertiary plants, the subtropical hill country of southeastern Mexico and Central America, from Vera Cruz to Costa Rica. Its range extends southward to the highlands of Colombia.

The family Moraceae illustrates the curious intermingling of species related to plants now found in southeastern Asia or southern Mexico and Central America. *Ficus goshenensis* is most similar to a Mexican species, and *F. densifolia* closely resembles the foliage of *F. pisocarpa* Wallich, inhabiting the subtropical and tropical regions of southern Asia. *Artocarpus lessigiana*, related to forms once common from Greenland to California, appears to be represented by the cultivated breadfruit, *A. incisa* Förster, originally native to tropical southeastern Asia, but now widely planted in the tropics. The breadfruit is typical of the *tierra caliente* (see p. 58) in the American tropics, although it is occasionally grown in places of higher elevation. It is killed by frost.

The order Ranales includes five families. The genus *Nelumbium* is represented by an impression of the top of a characteristic swollen receptacle. *Cercidiphyllum* furnishes another instance of a genus once nearly holarctic in its distribution but now confined to southern Japan and southwestern China, where a single species (and perhaps a variety) is now living. *Cercidiphyllum* leaves and the characteristic fruits are particularly abundant in the early Tertiary floras of North America, such as the "Fort Union" group; the late Cretaceous and early Tertiary floras of the Rocky Mountain front known variously as Laramie, Denver, Vermejo, Raton, Animas, etc.; the Tertiary floras of Alaska; and the Chalk Bluffs, Steel's Crossing, and Lower Cedarville floras of the Pacific slope. It appears to have been one of the most common stream-side types in the time of equable climates and high rainfall from the late Cretaceous to the beginning of the Miocene. The leaves were variously assigned to *Grewiopsis*, *Populus*, *Zizyphus*, and other genera by the older paleobotanists, and the fruits were called *Leguminosites* (?) *arachioides*, *Nyssidium*, and *Berrya*. Roland W. Brown first recognized the relation between the fossil fruits and leaves, and thus was able to begin the systematic revision of the whole complex (Brown, 1939). The existing *Cercidiphyllum japonicum* Siebold and Zuccarini is said to be the largest deciduous tree of southwest China (Hupeh, Szechwan, Shensi) and warm-temperate Japan. It is a common stream-side type and thrives in moist, rich soils.

The genus *Hyperbaena* now comprises about a dozen species of large, woody vines inhabiting the Neotropics. The Chalk Bluffs species also occurs in the La Porte flora and is most similar to two living species in the hill country of eastern British Honduras, *H. smilacina* Standley and *H. hondurensis* Standley. The former species is also found in the forests of the Atlantic coast of Costa Rica between elevations of about 1000 and 3700 feet. *Hyperbaena hondurensis* Standley grows at somewhat lower elevations in Honduras and British Honduras.

The genus *Magnolia* is well represented in early Tertiary floras. In the present instance there are impressions of *Magnolia* leaves closely similar to those of *M. tripetala* Linnaeus, the umbrella tree or cucumber tree of the eastern and southern states. This is a small tree which is found from Pennsylvania to Georgia and westward to Arkansas. It inhabits the rich, moist soil of stream valleys or sheltered intervales, but is nowhere common.

An abundance of genera belonging to the Lauraceae is characteristic of early Tertiary floras, and there are in the Chalk Bluffs flora eight distinct species belonging to the family. It is often impossible to assign the leaf impressions of the laurels to any one genus, since certain species of *Nectandra*, *Persea*, *Litsea*, and *Machilus* have leaves remarkably similar in character. The form genus *Laurophyllum* is used to indicate a member of the Lauraceae where it is not possible to make an assignment to any one genus. The Chalk Bluffs species of *Laurophyllum* exhibit characters of both *Persea* and *Litsea* leaves. The *Cryptocarya*, the *Neolitsea*, and the two species of *Cinnamomum* resemble living Asiatic species, and the two species of *Persea* are founded on leaf impressions similar to the foliage of living American trees. *Persea pseudo-carolinensis* in particular is much like the leaves of the common swamp red bay of the southeastern states. The fossil species seems to have been common in the Tertiary floras of the Pacific slope as late as the Lower Pliocene. It was evidently a tree adapted to a wet substratum, judging from its common occurrence with species such as *Platanus*, *Magnolia*, *Gordonia*, *Liquidambar*, and other moisture-loving trees. The red bay of the southeastern states usually inhabits the borders of streams and swamps in rich, moist soil; this was apparently the case with the fossil species.

There are five families in the Rosales. The genus _Hydrangea_, of the family Saxifragaceae, was identified through the presence of leaves and a sterile flower. This is one of the earliest occurrences of the genus. It has not been reported from the Tertiary floras east of the Rocky Mountains, but ranges from Middle Eocene to Upper Miocene in the western floras. It has been identified in the Florissant, Weaverville, Goshen, Latah, Mascall, and Alaskan Tertiary floras. There are about forty living species of _Hydrangea_, approximately twenty-five of which are known from southern China. The fossil seems closest to _H. strigosa_ Rehder and similar Asiatic species. Four species are found in the eastern states from New York southward and westward. These shrubs are especially plentiful in the southern Appalachians. Several species are known from Mexico and Central America, and one species occurs in Panama and northern South America. A climbing form, _H. oerstedii_ Briquet, is of common occurrence in the mountains of Costa Rica between elevations of 3500 and 9000 feet. Two or three species are also known from the eastern Sierra Madre of Mexico. The great majority of the species of _Hydrangea_ are adapted to a humid, warm-temperate climate.

The family Hamamelidaceae today has a curiously discontinuous distribution: two genera in eastern North America, seven in eastern and southern Asia, one genus in eastern and southern Africa, and one in Persia. This distribution indicates a great antiquity for the group. The family is now typically eastern Asiatic, considering the number of genera and species native there. _Hamamelites voyana_ resembles equally the foliage of the American _Hamamelis virginiana_ Linnaeus and the Asiatic _H. mollis_ Oliver. There are about six existing species of _Hamamelis_: the common witch hazel of the eastern states, and four or five species in China and Japan. The American witch hazel is a small tree or shrub inhabiting low woods and moist hillsides from Ontario to north Florida and Texas. It is one of the few woody plants of the eastern states which bloom in the winter. _Hamamelis mollis_, an abundant shrub in the mountains of Chekiang and Hupeh, has similar habitat requirements. Hollick (1936) has described the single occurrence of fossil _Hamamelis_ leaves in the Tertiary of Alaska. Wood of the genus occurs in the Miocene of western Nebraska (Chaney and Elias, 1938, p. 10). _Hamamelites_ was reported by Ward from the Fort

Union. Leaves called Fagus and Betula in the Raton and Denver floras may also be those of Hamamelis. In contrast with the occurrence of Hamamelis is the wide Tertiary distribution of Liquidambar. It is abundantly represented in the Tertiary floras of Europe, and in America is found in the Wilcox, Jackson, Bridge Creek, La Porte, Latah, Mascall, and Alaskan floras. There are three (or four) living species: one in the United States, Mexico, and Central America, one in southern China, and one in Asia Minor. This again illustrates the present restriction of a Holarctic Tertiary genus. The American species of Liquidambar, in areas where it is the dominant tree of forest communities, inhabits two entirely different situations. Toward the north, in the central and southeastern states, the tree forms nearly pure stands on low swampy bottom lands subject to flooding. Farther south, in Mexico and Central America, the Liquidambar is a tree of the uplands, flourishing on steep mountain sides at elevations of from 1000 to 5000 feet in the humid eastern Sierra Madre. Similarly, the Asiatic L. formosana Hance toward the south, in northern Yünnan and southwestern Szechwan, is a tree of the rainy hill country. The Tertiary history of the genus indicates a similar contrast of habitats. In the Chalk Bluffs and Wilcox floras, the Liquidambar was a tree of wet lowlands. In the Upper Eocene and Oligocene it practically disappeared from the lowland floras of middle latitudes and evidently retreated to the uplands. Later, as a result of the gradual cooling of the climate, Liquidambar again became one of the dominant forms in the riparian floras. Liquidambar californicum differs from the living species in the more shallow lobing of the leaves, in the finer serrations of the margins, and in the type of fruit, which apparently was borne in clusters.

The Chalk Bluffs flora contains two species of Platanus, one a large ovate leaf found elsewhere only in the Denver flora. The other species, P. appendiculata, appears to be identical with the species of Platanus in several Eocene floras of the Rocky Mountain region. The geological history of the genus has been adequately treated by Berry (1923b, pp. 157-164). Since the sycamore is a characteristic stream-side type with resistant leaves, it has been one of the common fossil angiosperms since the first appearance of the class in the Cretaceous. Leaves of the genus are especially abundant in the Cretaceous-Eocene floras of the Rocky Mountain region, and in the Chalk Bluffs flora, the Weaverville flora, and many later Tertiary floras. The evolutionary tendency in leaf form seems to have been from wide, shallow-lobed shapes toward more slender, deeply lobed leaves. From five to nine living species are recognized: P. orientalis Linnaeus, the only Old World species; P. racemosa Nuttall and P. wrightii Watson of California, Arizona, New Mexico, and adjacent Mexico; P. occidentalis Linnaeus of the eastern states from Nebraska to Maine and south to Florida and Texas; and about five species in Mexico. The Mexican species listed by Standley, in addition to those above, are: mexicana Moricand, glabrata Fernald, chiapensis Standley, lindeniana Martius and Galeotti, and oaxacana Standley. Platanus mexicana appears to be only a geographical variety of P. occidentalis. Platanus racemosa and wrightii are also closely related. Perhaps the most distinctive Mexican species is P. lindeniana, which, in some respects, is closer to the Eocene forms than any other of the living species. Platanus racemosa and orientalis may be considered the most specialized. Many of the handsome, large fossil leaves assigned to "Aralia" have characters which justify their inclusion in the Platanaceae. The numerous impressions of large, palmate leaves which are typical of the Chalk Bluffs fossil beds and which were formerly called Aralia whitneyi and A. angustiloba have been assigned to the genus Platanophyllum, not only on the basis of their outline and more obvious features of venation, but also on the basis of the correspondence of the minute details of the tertiary venation and areolation to those of the leaves of the living Platanus lindeniana. The leaves of Platanus from the Upper Eocene of Texas, recently described by Ball as P. rileyi (1939, pls. 9, 10), form a connecting link in leaf form between the "Aralias" and the modern leaves of Platanus lindeniana. The platanoid leaves of this group are conspicuous in the warm-temperate floras of the Lower Tertiary and later Cretaceous, and the trees which bore them must have formed an important part of the riparian forests. In the floras east of the Sierra which indicate a subtropical climate, such as the Wilcox and Laramie, the aralioid leaf type is absent or rare, in contrast with the profusion of Platanophyllum leaves in the cooler flora of the Yellowstone. The deeply lobed form called Platanophyllum angustiloba is, however, of common occurrence in the Comstock and Steel's Crossing floras on the west coast, and these are apparently subtropical in character.

Two genera are included in the Rosaceae. Of these, the genus Vauquelinia has not hitherto been reported as a fossil. The living genus, with about five species distributed from western Texas and northwestern Mexico to the California border, is a plant of mountain canyons in this warm, semiarid region. Chrysobalanus occurs in the Wilcox flora, from which two species, one founded on fruits, the other on leaves, have been reported. They doubtless represent one botanical entity. Chrysobalanus lacustris from the Green River flora is closely similar to the Chalk Bluffs form. The only other occurrence of the genus in the North American Tertiary is in the Goshen flora. (Knowlton's Chrysobalanus from the Esmeralda formation was wrongly identified; see Axelrod, 1940, p. 171.) Chrysobalanus as usually known is sometimes divided into two genera, the additional genus being called Geobalanus. There are two (or perhaps three) living species. The Chalk Bluffs fossil leaf is similar to the leaves of the cocoa plum, Chrysobalanus icaco Linnaeus, which grows along the coast of eastern tropical America and western Africa.

Like the Lauraceae, species of the family Leguminosae are usually abundant in Lower Tertiary floras. Of the six genera in the Chalk Bluffs flora, two are lianas, Strongylodon and Desmodium; the others are trees or large shrubs. All the genera present are characteristic of warm-temperate to tropical regions of today. Strongylodon is confined to the Paleotropics, Vouapa to the Neotropics. There are approximately a hundred and twenty species of Dalbergia in the warm climates of the world. Many of them are valuable timber trees; others are shrubs or vines. Dalbergia densa Bentham and D. laevigata Standley occupy similar ecological situations in the subtropical to tropical rain forests of southern China and Central America respectively. One species of Dalbergia (Amerimnon) grows in southern peninsular Florida; about four species are common in the subtropical hill forest of Mexico from Oaxaca to Vera Cruz; and many species have been reported from the tropical forests of Central and South America. Dalbergia or Dalbergites appears in one of the oldest known angiosperm floras, the Lower Cretaceous of Greenland, and is widely distributed in the Upper Cretaceous and Eocene floras, but becomes uncommon in the later

Tertiary. The species of *Inga* is closely similar to a leaf form in the Wilcox flora. The living species are confined to the Neotropics, where approximately a hundred and fifty species are found. The Chalk Bluffs leaflets are most similar to a species from southeastern Mexico. *Pongamia* is a monotypic genus of forest trees now inhabiting the Indo-Malayan region. *Vouapa bifolia* Aublet (*Macrolobium bifolium* Persoon) is a small tree of the moist forests in tropical South America. There are about forty-five species of the genus in the tropics of America and Africa, mostly small trees with habitats similar to those of the species mentioned above. The living species of *Desmodium* whose leaflets correspond to the fossil *Desmodium* grow in the subtropical forests of southwest Szechwan and Yünnan. *Strongylodon coeruleus* Merrill is native to the forests of the Philippines and the southern border of Asia.

The genus *Canarium* is here first reported from the Tertiary. There are about eighty species of *Canarium* in tropical Asia and Africa, and a few species have been erroneously reported from the American tropics, where they are cultivated. There are about sixty species of the related genus *Protium*, also widely distributed in the tropics. The absence of any adequate record in the Lower Tertiary, notwithstanding the apparently ideal climate and environment, suggests that the leaflets of this plant may have been confused with *Juglans* or some other familiar genus. *Juglans denveriana* Knowlton (1930, pl. 12) is probably an instance of this.

The genus *Ailanthus* at the present time is confined to eastern Asia, where about eight species have been recognized in the area from northern China to Australia. The genus appears to have been common in the Tertiary period in western North America, since impressions of the characteristic samaras have been found in several fossil floras, notably in the Florissant and Green River floras.

Cedrela and a closely related or equivalent genus, *Toona*, in southeastern Asia, have an extensive geologic record. The earliest authenticated appearance is in the Wilcox flora, where four nominal species were found. Another species occurs in the Jackson. One of the surprising additions to paleobotanical knowledge in recent years is the discovery of abundant remains of *Cedrela* in the western Miocene. Fossil fruits and leaves are found in the Florissant, Latah, Sucker Creek, Trout Creek, Upper Cedarville, and other floras. It appears contradictory that a genus now confined to tropical America and tropical to warm-temperate Asia should be found associated with the predominantly temperate plants of the Miocene, but this contradiction disappears when it is seen that the Miocene species of Cedrela closely resembles C. (Toona) sinensis A. de Jussieu of China. This species is more hardy than the American Cedrela, since it grows in central and western China and as far north as Manchuria; it is naturalized in Golden Gate Park in the cool, foggy climate of the central California coast, and is planted as a street tree in Santa Barbara, where it bears fruit abundantly. In addition to C. (Toona) sinensis, there are seven other species ranging from India and Australia to the Philippines and Yünnan. Standley lists ten species of Cedrela in his flora of Mexico (1922-1926, pp. 561-563), and several times that number have been reported from other parts of tropical America. Although Cedrela is of common occurrence in the humid forests of the tropics, there are species in the northern part of the range which inhabit altitudes where the climate is in no sense tropical.

The Euphorbiaceae is a large family, comprising about two hundred and twenty living genera and four thousand species. Many woody plants of this family are common in subtropical and tropical regions, but only comparatively recently have various genera been recognized in the fossil state. Aleurites and Drypetes (Euphorbiophyllum) are known from the La Porte flora, Mallotus from the Chalk Bluffs, Comstock, and Steel's Crossing, and Alchornea from the Clarno. About three hundred and twenty species of Acalypha are found in the tropics and in South Africa. The genus Mallotus is confined to southeastern Asia, where there are approximately a hundred and twenty species, growing from southern Japan on the north, through southern China to Malaysia, the East Indies, and the Philippines. Acalypha schlechtendaliana Mueller, which ranges from Vera Cruz to Costa Rica, is a shrub prevalent in the upper tierra caliente. Mallotus japonicus Mueller and the closely related M. tenuifolius Pax are common in warm-temperate Japan and on the continent from Chekiang to western Hupeh and Szechwan, growing to altitudes of 3000 feet.

The order Sapindales includes six families. The related genera Celastrus and Euonymus are both abundantly represented in the fossil state.

Celastrus appears in the Patoot beds of Greenland, and several species are known from the Upper Cretaceous and Eocene. *Euonymus* is common in the Eocene floras of the Gulf states and in the Miocene of the western states. The Chalk Bluffs *Celastrus* is represented by striking, large leaves, unlike those of any previously recorded fossil species, but closely similar to the foliage of *C. angulata* Maximowicz, now growing in southern China.

The family Icacinaceae is now confined to the tropics, where about two hundred species have been recorded in thirty-eight genera. Many of these are lianas, often of huge size, among which is *Phytocrene*, whose characteristic large, heavy-textured, palmately veined leaves are found as impressions in the Chalk Bluffs clays. One other species of *Phytocrene* (or *Palaeophytocrene*), described from pyritized fruits, is reported in the Lower Eocene London Clay flora. There are seven existing species in south China and Indo-Malaysia, which frequent moist flats and stream valleys at low or moderate elevations.

Only one species of the Anacardiaceae, *Rhus mixta*, has been recognized in the flora. The fossil leaf impressions are similar to the leaves of the living American *R. glabra* Linnaeus, or *R. typhina* Torner (Barclay, 1937, p. 287). A related fossil species is *R. longepetiolata* (Lesquereux) Brown from the Green River. This genus is particularly abundant in the later Tertiary and is represented in nearly every known Miocene flora. Approximately a hundred and thirty living species of *Rhus* have been reported from warm-temperate and subtropical regions. Such a large proportion of these are from Mexico that this may well be called the center of distribution of the genus. *Rhus typhina* and *R. glabra* are shrubs or small trees widely distributed in the United States east of the Cascade-Sierra ranges. In the western part of their range these plants usually frequent the moist soil of watercourses (*R. cismontana* Green), but farther east they are often found on high ground. The occurrence of the fossil species indicates a river-bank habitat, since it is associated with typical riparian forms.

Acer aequidentatum is abundant in the form of leaf and fruit impressions at only one locality; elsewhere it is extremely rare. The leaves resemble those of the eastern red maple or those of an Asiatic species, *A. davidii* Franchet.

There are two species in the Sapindaceae, both related to Neotropical forms. The Cupania leaflets are matched by those of C. vernalis Cambessedes of South America. There are about thirty-two living species of the genus, inhabiting the warmer parts of the Americas from Mexico to Argentina. Cupania vernalis is native to South America, and is especially common in the warm-temperate hill country of northern Argentina. Leaves, leaflets, and fruits of Thouinopsis, preserved as impressions, are the most widespread and abundant of the plant fossils in the Ione gravels. The leaflets resemble those of Thouinidium, and the associated winged fruits are like those of Thouinia. All the evidence indicates that this fossil genus, related to several modern genera of the Sapindaceae, is now extinct. Thouinidium with four species, and Thouinia with fifteen species, are restricted to the American tropics, growing from the West Indies to Central America.

Meliosma truncata is a species founded on rare leaf impressions. The fossil leaves are matched exactly by those of M. cuneifolia Franchet, a small tree or shrub very common in the hill country of southwestern China at altitudes of 3000 feet or more. Three species were reported from the Goshen flora, one also occurring in the La Porte flora. There are about fifty-five living species of the genus, restricted to the warmer parts of southeast Asia and America. The family Sabiaceae consists of but four genera and some sixty-five species, which occupy the range indicated for Meliosma. The geologic history of the family is as yet unknown, although its present distribution implies a much wider distribution in the early Tertiary.

Rhamnidium, one of the two genera included in the Rhamnaceae, is confined at present to tropical South America and the West Indies, where five species are known. The Chalk Bluffs species was first identified in the La Porte flora, and these are the only occurrences reported in the fossil floras of North America. The leaf impressions correspond to the leaves of Rhamnidium elaeocarpum Reisseck from tropical South and Central America. The resemblance of the fossil leaves to leaves identified as Rhamnus in the latest Cretaceous and early Tertiary of the southern Rocky Mountains and Gulf states suggests a rather extended geologic history for Rhamnidium. Two well marked species of Rhamnus occur in the Chalk Bluffs flora. The leaf impressions called Rhamnus calyptus are matched by the leaves of R. nipalensis Wallich, native to the subtropical hill country of the central and eastern Himalayan region. The leaves of R. crenatus Siebold and Zuccarini correspond to the fossil leaves named Rhamnus plenus. The living species has a wide range, from southern Japan to western Yünnan.

The leaves of Vitis and Cissus are closely similar and the two genera cannot always be separated on the basis of leaf characters. In the present instance, the variability of form in the fossil impressions is matched only in the leaves of Cissus. The fossil Cissus resembles living species in the tropics of both Asia and America. Cissus sicyoides Linnaeus is a variable species of wide occurrence in tropical America, from central Mexico and the West Indies to Colombia. This large vine also has a great altitudinal range, growing from the tropical coasts to the tierra templada (see p. 58) of the central plateaus. Cissus assamica (Laws) Craib grows in much the same situations from northern India to Kwangtung, China.

The family Theaceae now includes about twenty-two genera and three hundred and fifty species, restricted to the tropics and subtropics. The species of the most important genera, such as Gordonia, Thea, Ternstroemia, and Camellia, are so abundant in southeastern Asia that this region may be considered the modern haven of the family, although the Theaceae are also well represented in tropical America. There are five endemic genera in the Americas, as contrasted with ten in Asia. No living woody species of the family are found in western North America north of tropical Mexico. Two genera, Stewartia and Gordonia, are found in the southern Atlantic coastal region from Virginia to Florida. Some taxonomists subdivide these, recognizing two additional genera, Franklinia and Malachodendron. Two other genera, Taonoba (Ternstroemia) and Eurya, grow in tropical Mexico. Gordonia egregia is one of the dominants in the Chalk Bluffs flora. The leaf impressions occur at all localities, although more abundantly toward the main channel. Capsules, calyces, and calyx fragments are also not uncommon. Associated seeds like those of Stewartia and Franklinia are named Carpites egregia. Gordonia hesperia Berry occurs in the Latah formation. Eight species of Ternstroemites have been identified by Berry in the Tertiary deposits of the Gulf coast from the Wilcox to the top of the Claiborne formation. Not all of these are distinct botanical entities. Some of them doubtless represent the modern genera *Eurya*, *Ternstroemia*, etc. *Ternstroemites ovatus* Berry from the Wilcox is closely similar to the Chalk Bluffs species and might well be a *Gordonia*. The abundance of the leaf impressions of some of these Wilcox *Ternstroemites* in beds indicating lagoonal or swamp-border conditions suggests a similarity of habitat adaptation to that of the living *Gordonia lasianthus* Elliot in the southeastern states and of the fossil *G. egregia*. There are about fifteen living species of *Gordonia* in subtropical and tropical Asia, and two in the South Atlantic states. They are commonly evergreen, although occasionally deciduous, and vary in size from shrubs to small trees. *Gordonia lasianthus*, the loblolly bay, grows from southeastern Virginia to Florida and westward to southern Mississippi, and frequents shallow swamps and moist depressions.

A few leaf impressions showing characters of the Myrtaceae were found at a single locality at Buckeye Flat, and these are assigned to *Calyptranthes*, since they match the leaves of the living *C. chytraculia* (Linnaeus) Swartz, which inhabits moist coastal districts in southern Florida and the West Indies. The fossil remains of *Nyssa* are found in a large proportion of the Tertiary floras of the southern and western states, as would be expected from the stream-side habitat of the living species. The Chalk Bluffs species must have been rare in the contemporary forest, judging from the scarcity of seeds and leaf impressions. It was most similar to the living *N. aquatica* Linnaeus of the southeastern states. The remaining family of the order Myrtiflorae, the Combretaceae, contains the interesting genus *Terminalia*. The fossil leaves are most similar to those of a living species in southern China, *T. hainanensis* Excell. There are about a hundred and twenty species of the genus, confined to the tropics or subtropics. They are commonly large trees which usually frequent moist, low ground, either the flood plains of rivers near the sea or the adjacent coastal plains. Seven species have been reported from the Tertiary of the Gulf states, some of which might be found similar to the California species, were adequate material available for comparison.

Lesquereux founded *Cornus kelloggii* on a single leaf, incomplete at the base. The venation is so characteristic, however, that the identification may be considered valid. Only a few fragments have been found during recent collecting. The species was either extremely rare or an upland form. There are several living species of dogwood in both Asia and America which have similar foliage; C. florida Linnaeus, the flowering dogwood of the eastern states, and C. nuttallii Audubon are perhaps the most similar in foliage characters.

The genus Diospyros is abundantly represented in the fossil state. Some dozen species have been reported from the Tertiary of the western and southern states, but some of these are probably not valid. The leaves of Diospyros are easily confused with those of Banisteria, Chionanthus, Heteropterys, and Nyssa, and the leaflets of various legumes, and so abundant fossil material is necessary to insure a reliable identification. The leaves from Chalk Bluffs appear to be more like those of Diospyros virginiana Linnaeus, the common persimmon of the eastern states, than of any other species examined. There are about two hundred living species of the genus, predominantly of humid tropical or subtropical habitats, although a few species, such as D. virginiana or D. lotus Linnaeus, extend into temperate regions as far north as latitude 40°.

The genus Fraxinus is represented by a characteristic samara and many leaflets similar to those of the common black ash tree of the eastern states. There are about sixty living species of Fraxinus, of common occurrence in temperate or warm-temperate regions, especially in the eastern United States and the Mediterranean area. Only a few species extend into the subtropical regions of Mexico and southeastern Asia. Fraxinus schiedeana Schlechtendal and Chamisso and F. berlandieriana A. de Candolle are both found at moderate elevations in eastern Vera Cruz. Two fossil species of Fraxinus were reported from the Wilcox flora and another from the Green River flora.

The genera Nerium and Tabernaemontana of the family Apocynaceae are at present found in tropical or subtropical regions, with the exception of one species of Nerium which extends into temperate regions of southeastern Asia. This latter genus has not hitherto been recorded as fossil in North America, although the genus Apocynophyllum may represent the living genus Nerium in some instances. Nerium hinoidea is similar to the foliage of N. indicum Linnaeus, which is found in wet soils in southern

Asia. A species of Phyllites from the Wilcox flora appears to be identical with the Chalk Bluffs Nerium. Oleanders have been cultivated since ancient times and have been disseminated by man to such an extent that it is difficult to delimit accurately the species and their natural ranges. They are probably native to the Mediterranean region and areas eastward to India and possibly Japan. Three living species have been recognized. Nerium is a plant of moist ground, and in the wild state frequents river beds and the neighborhood of watercourses in warm-temperate or subtropical climates. The species of the genus Tabernaemontana range throughout the tropics. The shrubs are popular in cultivation on account of their wealth of fragrant blossoms. About a hundred and sixty species are known, of which fifty occur in tropical America. Three of these are known from the eastern Sierra Madre of Mexico, ranging from near sea level into the lower part of the tierra templada. The fossil leaves are matched by those of Tabernaemontana rupicola Bentham of Central America and T. bufalina Loureiro of tropical southern China. The genus is widely distributed in the Paleotropics from Africa to the oceanic islands. These leaf impressions are not uncommon in the La Porte collection, but only a few specimens are known from Chalk Bluffs.

The family Asclepiadaceae is a large one, comprising about three hundred and twenty living genera and over seventeen hundred species. The great majority of the genera are tropical in their distribution, and for the most part are climbing shrubs or lianas. In the Chalk Bluffs flora the leaf impressions have been assigned to the form genus Asclepiadites, since it is not practicable to differentiate such genera as Cynanchum, Tylophora, and Gonolobus on the basis of their similar leaves. The only other occurrence of the family in the Tertiary of North America is the presence of Gonolobus (or Vincetoxicum) in the Trout Creek flora. Species of fossil leaves referred to Acerates may represent either the family Apocynaceae or the Asclepiadaceae; this is true of Acerates wilcoxiana Berry. Two valid species of the Asclepiadaceae have been described from the Bembridge flora.

The leaves of Viburnum are abundant at the Independence Hill and Buckeye Flat localities. Similar fossil leaves of the genus are particularly common in the Fort Union and related Paleocene formations such as the Ravenscrag, and in the northern Eocene floras of Canada and Alaska. The leaves of living species of Viburnum exhibit considerable variability, and there is no doubt that there has been much overspeciation of the fossil forms. Other fossil leaf impressions referred to Viburnum are probably related to Platanus, or represent some extinct genus of the Platanaceae. After mistakes in taxonomy have been given due weight, however, it is apparent that Viburnum was common in the warm-temperate Paleocene and early Tertiary Arctic floras. There are approximately a hundred and ten living species of Viburnum, distributed through the cool to warm-temperate regions of eastern North America and Eurasia. The climatic adaptations of the genus explain its absence from the Wilcox flora and render somewhat questionable the identifications of Viburnum in the subtropical late Cretaceous floras. The fossil leaves from Independence Hill are best matched by the leaves of V. microcarpum Schlechtendal and Chamisso, a common, large shrub growing in the humid tierra templada in the eastern Sierra Madre of Mexico from Vera Cruz to Oaxaca. There are, however, several Asiatic species, such as Viburnum erosum Thunberg and V. tomentosum Thunberg, the leaves of which are also much like the fossil leaves.

The family Compositae is sparsely represented in the fossil state, although it is now the largest family of flowering plants, including about nine hundred genera and some thirteen thousand species. The great majority of the species are herbaceous; probably less than 2 per cent are woody, and this largely accounts for the rarity of fossil leaf impressions. The varied and efficient mechanisms for seed dispersal which are a distinguishing character of the members of this family should furnish frequent opportunities for preservation of the seeds. The practically complete absence of Compositae in the fossil record of North America may result from failure to recognize the identity of seed fossils, or from the character of the fossil matrix, or may be due to an actual scarcity of such plants in the vicinity of sites of deposition. The Chalk Bluffs fossils are small calyces found at all localities, and were probably derived from a shrub or woody vine, related to Mikania or Eupatorium. The genus Mikania is restricted to the tropics and comprises about a hundred and seventy-five species, a large proportion of which occur in America. Carpolithus *hyoseritiformis* Berry is most certainly a fossil achene belonging to the Compositae, but, aside from this record, there is no other fossil occurrence of the family in North America.

Silicified wood is abundant in the deposits of the Tertiary Yuba River. The greater part of the fossil wood is not well enough preserved to permit identification, although occasionally dark, agatized material is found in which the preservation of the wood structure is excellent. A large collection of this material is deposited at the University of California, and when identifications are complete, a report will be made on the fossil woods of the Chalk Bluffs deposits.

In 1907, Paul Platen presented a doctor's dissertation to the University of Leipzig on fossil woods from the western United States (Platen, 1907). In this paper, the author described woods from Nevada County, California. Part of these woods appear to be from Miocene deposits, but some of them undoubtedly came from the Chalk Bluffs deposits and were probably collected by Whitney. Unfortunately Platen is somewhat vague concerning localities, and in some cases there is much uncertainty with regard to the exact source of the fossil material. None of the species were recorded as coming from either Chalk Bluffs or Independence Hill. It is of interest to note the following species by Platen, founded on wood from the general locality "Nevada County" (ibid., pp. 72-84):

Anacardioxylon magniporosum	Platinium pacificum
Aralinium excellens	Quercinium anomalum
Aralinium multiradiatum	Quercinium lesquereuxi
Aralinium parenchymaticum	Simarubinium crystallophorum
Ebenoxylon speciosum	Simarubinium engelhardti
Perseoxylon californicum	

The fossil wood genera may correspond to the genera *Diospyros*, *Persea*, *Platanus*, *Quercus*, and *Ailanthus* of the Chalk Bluffs flora.

The relations of the fossil species to living species can only be established by a comparison of the fossil and living material. The final validity of the comparisons depends, among other things, on the adequacy of herbarium material, on the time available for extensive examination and checking, and on the amount and quality of fossil material. It is generally true that many of the plant species of the Miocene and Pliocene, perhaps the majority of them, are represented in the living flora by identical or closely related species. These can always be located by diligent search, and, the living "equivalents" or most similar living species once recognized, the ecology and relationships of the fossil flora are thereby established. The modern relationships of Eocene and earlier plants are more difficult to determine, and in many cases composite resemblances to several living species or even genera will be found. There is no certainty that any of the Chalk Bluffs species are still extant, and the evidence is strong that practically all of them, and also certain of the genera, are no longer to be found in the living flora of the world. Such species as Chaetoptelea pseudo-fulva and Celastrus preangulata, bearing close similarity to living material, may yet be in existence. Engelhardtia nevadensis, Cercidiphyllum elongatum, and Liquidambar californicum exemplify fossil species which differ in some respects from all living forms, although the correspondences are sufficiently close to make the relationships clear. Platanophyllum whitneyi, Laurophyllum litseaefolia, and Thouinopsis myricaefolia are examples of fossil species which show composite relations to several genera. In the case of forms like Quercophyllum platanoides, both the genus and the family may be extinct. In all these cases the term "modern equivalent" cannot be used, and the best that can be done is to establish the closest living species, which in some cases may be a rather subjective proceeding. Thus a reconstruction of the environmental conditions under which an early Tertiary flora existed, based on analogies with similar living species, cannot be so precise as such a reconstruction for a flora of late Tertiary age. It is fortunate that there is a comparatively large number of species in the Chalk Bluffs flora, since the testimony of a large number of forms, all in substantial agreement with regard to the environment, is more to be trusted than that of a few. Table 2 (pp. 56-57) has been prepared to show the distribution of the most similar living species. It should be noted that some of the temperate species, such as Liquidambar styraciflua Linnaeus, which grows below elevations of 1000 feet in the coastal mountains of Honduras, extend into tropical regions, but their common habitat is at elevations in keeping with their warm-temperate (and not tropical) adaptations. In a few instances, the divisions are somewhat arbitrary. This is the case with Mallotus, which grows in the tropics but has its best development in warm-temperate China and Japan. Although the numerical values are given for each group, also the relative percentage of the entire flora which each comprises, in view of what has been said in the preceding paragraph these figures should be taken as qualitative rather than strictly quantitative. The figures, nevertheless, give a satisfactory analysis of the fossil flora in terms of the distribution of the most similar living species.

ENVIRONMENT OF THE FOSSIL FLORA

Geographical Distribution of Similar Living Species

The species of the Chalk Bluffs flora may be divided into five groups on the basis of their relations to existing species:

1. Species related to existing forms in the subtropical regions of eastern Mexico, and Central America: the Neotropical element. 21 species or 27 per cent.
2. Species related to existing forms in subtropical southeastern Asia: the Paleotropical element. 19 species or 25 per cent.
3. Species related to existing forms in the warm-temperate regions of southeastern Asia and southeastern United States. 27 species or 36 per cent.
4. Species related to existing forms on the southern Pacific slope of North America. 2 species or 3 per cent.
5. Species which are extinct or whose relationships are uncertain. 7 species or 9 per cent.

There is a remarkable similarity in climate and physiography between the two regions now inhabited by groups 1 and 2.[3] In southern Mexico, along the Atlantic slope of the eastern Sierra Madre, between latitudes 20° and 25° north (and also to the south in Guatemala and Honduras), there is a regular altitudinal succession of forest belts, beginning with a lowland tropical flora at elevations below 2000 feet and ending with cold-temperate coniferous forests at 10,000 feet. The lowest zone is popularly

[3] For vegetation of the area, see Standley, 1922-1926, 1930, 1931, 1936, 1937, 1940a, 1940b.

Table 2

The species of the Chalk Bluffs flora, showing the most similar living species, and their geographic distribution*

Fossil species	Living species	Genus extinct, or living representatives uncertain	Southeastern Asia, Paleotropics	Mexico, Central America	Warm-temperate China, Japan	Southeastern United States	California and northwestern Mexico
Acalypha aequalis	Acalypha schlechtendaliana	...	...	x	...	...	...
Acer aequidentatum	Acer ginnala, davidii	...	...	...	x	...	...
Ailanthus lesquereuxi	Ailanthus altissima	...	...	...	x	...	...
Alnus operia	Alnus formosana, maritima	...	...	...	x	o	...
Artocarpus lessigiana	Artocarpus incisa	...	x	...	...	...	...
Asclepiadites laterita	Tylophora, Cynanchum spp	...	x	...	...	...	...
Calycites mikanoides	Mikania spp	x	...	...	...	...	...
Calyptranthes myrtifolia	Calyptranthes chytraculia	...	...	x	...	...	...
Canarium californicum	Canarium album	...	x	...	...	...	...
Carpites egregia	Franklinia, Stewartia spp	...	...	...	...	x	...
Carya sessilis	Carya cordiformis	...	...	...	o	x	...
Castanopsis longipetiolatum	Castanopsis fissa	...	x	...	...	...	...
Cedrela eolancifolia	Cedrela odorata	...	...	x	...	...	...
Celastrus preangulata	Celastrus angulata	...	...	...	x	...	...
Cercidiphyllum elongatum	Cercidiphyllum japonicum	...	...	...	x	...	...
Chaetoptelea pseudo-fulva	Chaetoptelea mexicana	...	...	x	...	...	...
Chrysobalanus eoicaco	Chrysobalanus icaco	...	...	x	...	...	...
Cinnamomum acrodromum	Cinnamomum mercadoi	...	x	...	...	...	...
Cinnamomum dilleri	Cinnamomum or Lindera sp	...	x	o	...	...	...
Cissus pyriformis	Cissus sicyoides, assamica	...	o	x	...	...	...
Cornus kelloggii	Cornus florida, urbiniana, controversa	...	...	...	o	x	...
Cryptocarya praesamarensis	Cryptocarya samarensis	...	x	...	...	...	...
Cupania oregona	Cupania vernalis	...	...	x	...	...	...
Dalbergia rubra	Dalbergia densa, laevigata	...	x	o	...	...	...
Desmodium indentum	Desmodium dasylobum, sequax	...	x	...	...	...	...
Diospyros retinervis	Diospyros virginiana, lauii	...	...	...	o	x	...
Engelhardtia nevadensis	Engelhardtia guatemalensis, pterocarpa	...	...	x	...	...	...
Ficus densifolia	Ficus pisocarpa, parietalis	...	x	...	...	...	...
Ficus goshenensis	Ficus bonplandiana	...	...	x	...	...	...
Fraxinus yubaensis	Fraxinus nigra, inopinata	...	...	...	o	x	...
Gordonia egregia	Gordonia alatamaha, fragrans	...	...	...	x	o	...
Hamamelites voyana	Hamamelis virginiana, mollis	...	...	...	o	x	...
Hemitelia pinnata	Hemitelia grandifolia	...	...	x	...	...	...
Hydrangea californica	Hydrangea strigosa	...	...	...	x	...	...
Hyperbaena diforma	Hyperbaena smilacina	...	...	x	...	...	...
Inga ionensis	Inga xalapensis, jinicuil	...	...	x	...	...	...
Laurophyllum fremontensis	Persea spp	...	...	x	...	...	...
Laurophyllum litseaefolia	Litsea spp	...	x	...	...	...	...
Liquidambar californicum	Liquidambar styraciflua, formosana	...	...	...	o	x	...

*x indicates the most similar species; o indicates a second, similar species.

(Continued on following page)

Table 2 - *Continued**

Fossil species	Living species	Genus extinct, or living representatives uncertain	Southeastern Asia, Paleotropics	Mexico, Central America	Warm-temperate China, Japan	Southeastern United States	California and northwestern Mexico
Lygodium kaulfussii	Lygodium circinnatum	...	x	...	...	...	...
Magnolia dayana	Magnolia tripetala	...	...	...	...	x	...
Mallotus riparius	Mallotus japonicus, tenuifolius	...	...	...	x	...	...
Meliosma truncata	Meliosma cuneifolia	...	...	...	x	...	...
Nelumbium lacunosum	Nelumbo lutea	...	...	...	o	x	...
Neolitsea lata	Neolitsea chuii, ferruginea	...	x	...	...	...	...
Nerium hinoidea	Nerium indicum	...	...	...	x	...	...
Nyssa californica	Nyssa sylvatica, sinensis	...	...	...	o	x	...
Persea praelingue	Persea lingue	...	...	x	...	...	...
Persea pseudo-carolinensis	Persea borbonia, podadenia	...	...	x	...	...	...
Phyllites cordiaefolia	....	x	...	...	...	...	...
Phyllites daturaefolia	....	x	...	...	...	...	...
Phyllites laurinea	....	x	...	...	...	...	...
Phytocrene sordida	Phytocrene blancoi	...	x	...	...	...	...
Platanophyllum whitneyi	Platanus spp.	x	...	...	...	...	...
Platanus appendiculata	Platanus occidentalis, mexicana	...	...	...	...	x	...
Platanus coloradensis	Platanus sp.	x	...	...	...	...	...
Pongamia ovata	Pongamia pinnata	...	x	...	...	...	...
Quercophyllum platanoides	....	x	...	...	...	...	...
Quercus distincta	Quercus agrifolia	...	...	...	...	...	x
Quercus eoxalapensis	Quercus xalapensis	...	...	x	...	...	...
Quercus nevadensis	Quercus glauca	...	...	...	x	...	...
Rhamnidium chaneyi	Rhamnidium elaeocarpum	...	...	x	...	...	...
Rhamnus calyptus	Rhamnus nipalensis	...	x	...	...	...	...
Rhamnus plenus	Rhamnus crenatus, Rhamnella franguloides	...	...	...	x	...	...
Rhus mixta	Rhus typhina, glabra	...	...	...	o	x	...
Sabalites californicus	Rhapis flabelliformis	...	x	...	...	...	...
Salix ionensis	Salix nigra	...	...	...	o	x	...
Smilax labidurommae	Smilax pumila	...	...	...	o	x	...
Strongylodon falcata	Strongylodon coeruleus, macrobotrys	...	x	...	...	...	...
Tabernaemontana chrysophylloides	Tabernaemontana lanceolata, bufalina	...	o	x	...	...	...
Terminalia estamina	Terminalia hainanensis	...	x	...	...	...	...
Thouinopsis myricaefolia	Thouinia, Thouinidium spp.	...	...	x	...	...	...
Vauquelinia exigua	Vauquelinia spp.	...	...	...	...	...	x
Viburnum variabilis	Viburnum microcarpum, erosum	...	...	...	o	x	...
Vouapa geminifolia	Vouapa bifolia	...	...	x	...	...	...
Zamites californica	Zamia, Ceratozamia spp.	...	...	x	...	...	...
Totals		7	19	21	12	15	2
					27		
Percentages		9	25	27	16	20	3
					35		

*x indicates the most similar species; o indicates a second, similar species.

known as the *tierra caliente*. Above this is the *tierra templada* or temperate belt, bounded approximately by elevations of 2000 and 5500 feet. The lower part of the *tierra templada* contains an association having a close parallelism with the grouping of plants in the Chalk Bluffs flora. Between elevations of 2500 and 4000 feet there is a luxuriant rain forest whose dominants are *Chaetoptelea* (*Ulmus*) *mexicana* and *Liquidambar styraciflua*. The Mexican elm is more numerous in the lower part of this forest belt, where it reaches a great size and towers above the remaining forest trees; *Liquidambar* becomes more abundant in the upper part, where it forms over half the total number of tree individuals in many places. Associated with these two dominants are many laurels (*Nectandra*, *Ocotea*, *Persea*), legumes (*Cassia*, *Dalbergia*, *Erythrina*, *Lonchocarpus*, *Pithecolobium*, etc.), figs and other Moraceae, Burseraceae, Meliaceae, Sapindaceae, Dilleniaceae, and also many shrubs belonging to the Piperaceae, Melastomaceae, and Compositae. Oaks are common from the tropical lowlands to elevations of 9000 feet. Cycads (especially *Ceratozamia mexicana* Brongniart), palms, and tree ferns are locally abundant. *Viburnum*, *Carya*, and *Fraxinus* are found in the upper part of the *tierra templada* at elevations of 4500 to 6000 feet. Sycamores are numerous along the stream courses in the upper part of the tropical zone and lower temperate zone. *Thouinidium decandrum* is locally abundant along stream courses in the upper *tierra caliente*, where it grows in company with huge figs, laurels, *Cordia*, and various Tiliaceae, Meliaceae, Leguminosae, Anacardiaceae, etc. *Engelhardtia* has been reported from southern Mexico, but it reaches its best development in the lower *tierra templada* in the mountains of eastern British Honduras and Guatemala. Approximately thirty-five genera of the Chalk Bluffs flora are to be found within an altitudinal range of 4000 feet in the state of Vera Cruz. Among these genera are some of the living representatives of the characteristic dominants in the fossil flora, such as *Chaetoptelea*, *Liquidambar*, *Platanus*, and *Thouinopsis*. The living species representing the genera *Hyperbaena*, *Rhamnidium*, *Tabernaemontana*, and *Vouapa* are more characteristic of the lowland tropical zone and are not commonly found in the lower part of the *tierra templada*. This rather anomalous group is similar ecologically to the lowland tropical assemblage comprising a part of the living Asiatic representatives of the fossil species (see p. 60).

The living species of group 2, the Paleotropical element, are found in a region extending from southern China to northern Indo-China, Siam, and the Philippines. Many of these species grow at moderate elevations, between 1000 and 5000 feet, in southern and southwestern China, in a region of considerable topographic diversity. The climate is warm-temperate to tropical, with comparatively dry winters, and heavy summer rainfall brought by the southeast monsoon.

Little careful ecological work has been done on the forests of southeastern Asia. A fair idea, however, of the composition of the forests in various districts and at various altitudes may be obtained by consulting works by Wilson (1913), Sargent (1911-1917), Handel-Mazzetti (1927), Chun (1922), and Merrill (Merrill and Chun, 1930).

The Nan Shan (or Nanling) complex of mountain ranges extends eastward from the plateau of western Szechwan and Yünnan, roughly parallel to the coast, along the north boundaries of Kwangsi and Kwangtung and through the west edge of Fukien to central Chekiang. This mountainous region faces the summer monsoon from the China Sea, and the southern slopes support a subtropical hardwood forest at moderate elevations. Above this is a zone of temperate hardwoods grading into coniferous forests at higher altitudes.

Another forested mountain region extends southeastward from the eastern Himalayas, from western Szechwan and Yünnan along the east border of Upper Burma into western Indo-China. At the north the lower parts of these ranges bear a luxuriant warm-temperate hardwood forest, perhaps richer in species than any other such region in the world. Toward the south, this forest merges into tropical hardwoods which extend up the mountain slopes for several thousand feet. Chekiang and western Szechwan are at latitude 30° north, the same as northern Florida and the Gulf coast; Tonkin and southern Yünnan are at latitude 22° north, which corresponds to that of northern Vera Cruz, Mexico.

In western Szechwan and northern Yünnan below altitudes of 6000 feet, the forests contain some thirty of the Chalk Bluffs genera: Acer, Ailanthus, Canarium, Castanopsis, Cedrela, Cercidiphyllum, Cinnamomum, Cissus, Cornus, Cryptocarya, Dalbergia, Desmodium, Diospyros, Engelhardtia, Ficus, Fraxinus, Gordonia, Hydrangea, Liquidambar, Litsea, Magnolia, Mallotus, Meliosma, Neolitsea, Pongamia, Quercus, Rhamnus, Rhus, Terminalia, and Viburnum. In addition, Engelhardtia, Gordonia, Cercidiphyllum, and Liquidambar are found in association in the middle forest zone of southern Yünnan. In the mountains of Chekiang and Kiangsi, Carya, Celastrus, Cercidiphyllum, Hamamelis, Liquidambar, and Nyssa are particularly common.

The temperate and subtropical species which comprise the living Asiatic representatives of the fossil species may thus be found within an altitudinal range of a few thousand feet in the same general region. There are, however, a few living species such as Artocarpus incisa Förster, Ficus pisocarpa Wallich, Phytocrene blancoi (Azaola) Merrill, and Strongylodon coeruleus Merrill which are lowland tropical forms not native to the hill country of southern China. These occur in the Philippine Islands, the East Indies, or the adjacent lowlands of the continent in Malaysia. The tropical forms appear to be out of place in the ecological group of modern species, but, as stated on page 58, there is a similar Neotropical group. In a succeeding division of this paper, a discussion of the meaning of this strictly tropical element will be given.

Many of the warm-temperate genera include species occurring in both Asia and the southeastern states which are similar to the fossil species. This is particularly true of Alnus, Cornus, Diospyros, Fraxinus, Gordonia, Hamamelis, Liquidambar, Nyssa, and Viburnum. Important genera of this group not found in the southeastern states are Ailanthus, Castanopsis, and Mallotus. The living forests of the southern Appalachians and the adjacent Atlantic coastal plain from North Carolina to Georgia contain a significant element of the living representatives of the flora. This indicates a certain similarity of ecological conditions, but the absence of such typical fossil genera as Chaetoptelea, Engelhardtia, and Terminalia implies essential differences.

Two of the modern species inhabit the semiarid region of southwestern North America: Quercus agrifolia Née in southern and central California, and Vauquelinia corymbosa Correa in northwestern Mexico and the adjoining parts of Arizona and New Mexico.

Relative abundance of fossil species

Species	Locality P3345		Locality P3325		Locality P3320		Locality P3318		Locality P3324	
	No. specimens	Per cent	No. specimens	Per cent	No. specimens	Per cent	No. specimens	Per cent	No. specimens	Per cent
Acalypha aequalis	...	...	...	...	...	...	7	2.0	...	...
Acer aequidentatum	...	...	...	...	71	3.0	...	...	...	...
Calyptranthes myrtifolia	...	...	...	...	3	0.1	...	...	...	...
Canarium californicum	...	...	...	...	2	0.1	...	...	...	...
Celastrus preangulata	...	...	11	2.0	4	0.2	...	...	...	...
Cercidiphyllum elongatum	397	21.3	54	9.9	121	5.2	55	15.8	7	4.8
Chaetoptelea pseudo-fulva	254	13.6	84	15.3	50	2.1	...	...	...	...
Chrysobalanus eoicaco	...	...	1	0.2	12	0.5	...	...	...	...
Cinnamomum acrodromum	...	...	...	...	2	0.1	...	...	...	...
Cinnamomum dilleri	7	0.4	...	...	...	...	3	0.9	...	...
Cissus pyriformis	...	...	...	...	2	0.1	...	...	...	...
Cupania oregona	...	...	...	...	...	...	2	0.6	...	...
Dalbergia rubra	2	0.1	...	...	...	...	...	...	...	...
Desmodium indentum	...	...	...	...	3	0.1	...	...	...	...
Diospyros retinervis	...	...	...	...	...	...	10	2.9	...	...
Engelhardtia nevadensis	44	2.4	2	0.4	81	3.5	14	4.0	...	...
Fraxinus yubaensis	...	...	...	...	...	...	14	4.0	...	...
Gordonia egregia	395	21.2	10	1.8	102	4.4	...	...	...	...
Hamamelites voyana	...	...	...	...	...	...	7	2.0	...	...
Hydrangea californica	14	0.8	...	...	2	0.1	...	...	...	...
Hyperbaena diforma	6	0.3	...	...	...	...	...	...	...	...
Inga ionensis	...	...	...	...	2	0.1	...	...	...	...
Laurophyllum litseafolia	...	...	...	...	...	...	...	...	21	14.5
Liquidambar californicum	73	4.0	...	...	124	5.3	4	1.2	...	...
Magnolia dayana	...	...	11	2.0	2	0.1	1	0.3	...	...
Mallotus riparius	...	...	26	4.7	63	2.7	2	0.6	25	17.2
Neolitsea lata	...	...	5	0.9	...	...	...	...	...	...
Nyssa californica	...	...	...	...	6	1.3	...	...	...	...
Persea praelingue	...	...	6	1.1	...	...	14	4.0	...	...
Persea pseudo-carolinensis	36	1.9	56	10.0	151	6.5	43	12.4	18	12.4
Phyllites cordiaefolia	13	0.7	...	...	...	...	...	...	...	...
Phyllites daturaefolia	...	...	...	...	4	0.2	...	...	...	...
Phytocrene sordida	...	...	...	...	...	...	3	0.9	...	...
Platanophyllum angustiloba	...	...	...	...	...	...	...	...	16	11.0
Platanophyllum whitneyi	243	13.4	66	12.0	122	5.2	6	1.7	2	1.4
Platanus appendiculata	5	0.3	71	13.0	34	1.5	40	11.5	21	14.5
Pongamia ovata	...	...	...	...	...	...	15	4.3	3	2.1
Quercus distincta	...	...	23	5.3	...	...	19	5.5	...	...
Quercus nevadensis	...	...	6	1.1	46	2.9	3	0.9	...	...
Rhamnidium chaneyi	7	0.4	5	0.9	9	0.4	...	...	...	...
Rhamnus calyptus	...	...	...	...	...	...	...	...	1	0.7
Rhamnus plenus	2	0.1	...	...	...	...	3	0.9	...	...
Rhus mixta	97	5.2	3	0.5	4	0.2	15	4.3	...	...
Salix ionensis	2	0.1	...	...	...	...	...	...	...	...
Strongylodon falcata	...	...	...	...	7	0.3	...	...	...	...
Terminalia estamina	30	1.6	...	...	...	...	...	...	...	...
Thouinopsis myricaefolia	206	11.1	99	18.0	1275	54.6	81	23.3	31	21.4
Vauquelinia exigua	2	0.1	...	...	...	...	...	...	...	...
Viburnum variabilis	...	...	...	...	3	0.1	...	...	...	...
Zamites californica	19	1.0	5	0.9	15	0.6	...	...	...	...
Totals	1856		544		2322		347		124	

Relative Abundance of the Fossil Species

Counts were made of the fossils at several localities (see table 3). These counts include only 50 of the species, since collections were made at a score or more of localities. The counts also omit such forms as *Carpites* and *Calycites*, although these are common. Considering the percentage representation at each locality and the number of localities at which the species occurs, the first ten numerical dominants of the flora, in terms of leaf, leaflet, or fruit impressions, and approximately in the order of their abundance are:

Thouinopsis myricaefolia	Mallotus riparius
Cercidiphyllum elongatum	Chaetoptelea pseudo-fulva
Persea pseudo-carolinensis	Gordonia egregia
Platanophyllum whitneyi	Liquidambar californicum
Platanus appendiculata	Rhus mixta

Thouinopsis and *Rhus* occur as leaflets and thus the actual abundance of the living plants was much less, perhaps as little as a tenth of the abundance indicated by the counts. This would place the *Thouinopsis* well in the lower part of the first ten dominants and bring either *Engelhardtia nevadensis* or *Quercus nevadensis* into the first ten.

There are general resemblances between the plant associations at the various localities, but significant differences may be observed which are doubtless related to physiographic factors at the time of deposition.

Ecological Considerations

In deriving conclusions with regard to the habitat of the fossil plants, there are several useful sources of evidence. These may be outlined as follows:

1. A comparison with the habitat of similar living species. Where the modern relationships are clear and definite, this furnishes the most accurate information.
2. The mode of occurrence of the fossils.
   a. The location of the fossil locality with reference to ancient stream channels or to hillsides or uplands.
   b. The relative abundance of the fossil forms. The more abundant the remains, the greater the probability that they grew near the site

of deposition. If all the localities indicate deposition under flood-plain conditions, marked changes in relative abundance of the various species indicate admixtures of different associations controlled by local physiographic and edaphic conditions. Where a form occurs in about the same relative abundance at several localities which show marked differences in composition, this indicates an independence of local conditions and thus either a distant, common source or a wide range of adaptability for the particular species.

c. The nature and texture of the fossils. Winged seeds, cones, and wood will sustain much transport, and it is only in these forms that upland species are usually preserved. Thin-textured leaves can normally be preserved only near the place where they grew; heavy-textured leaves may be transported for a considerable distance.

An obvious fact, sometimes overlooked, is that fossil floras, with rare exceptions, are preserved in low ground and usually in lowland situations (Chaney, 1936a, pp. 318-319; 1940, pp. 472-473). Thus the remains of upland plants are extremely scanty, in contrast with the ample representation of stream-side, lakeside, and coastal species.

The wide flood plains developed during the aggradation of the river valleys of Ione time were ideally suited to the development of a rich bottom-land flora similar in luxuriance and variety to the flora of the lower Wabash valley in southern Indiana. Although a large proportion of the species in the fossil flora are now extinct and presumably differed in various degrees from similar living species in their habitat requirements, yet there are close links with existing species and from these we may infer the environmental requirements of other associated species whose relationships are not so clear. It is certain, for instance, that Persea pseudo-carolinensis and Platanus appendiculata were stream-side types. This conclusion is founded on their mode of occurrence in the Chalk Bluffs flora, on their association in other fossil floras with Taxodium, Nyssa, Liquidambar, and similar moisture-loving trees, and on the habitat of the existing species of Persea and Platanus. It is also a logical deduction that a majority of the other dominants in the flora associated with these two species were also adapted to a riparian habitat. Included in this group are *Cercidiphyllum*, *Chaetoptelea*, *Ficus*, *Gordonia*, *Hyperbaena*, *Liquidambar*, *Mallotus*, *Nyssa*, *Platanophyllum*, *Rhamnidium*, *Rhus*, *Terminalia*, *Thouinopsis*, and *Viburnum*. The common habitat of *Liquidambar* in the United States is on rich river bottoms from southern Indiana south to the Gulf coast. In these situations the red gum reaches its best development. It occasionally forms pure stands, but usually is mixed with *Acer rubrum*, *Nyssa sylvatica*, *Quercus nigra*, *Magnolia*, *Persea*, etc. To the botanist accustomed to this river-bottom forest, the hill forest of Vera Cruz is a distinct surprise. Between elevations of 3000 and 5000 feet on the extremely rugged mountain fronts facing the Gulf coast there are luxuriant forests of *Liquidambar*. *Gordonia*, a tree of swamps and river bottoms in the southeastern states, likewise becomes a tree of the uplands in subtropical and tropical southern China. The association of *Gordonia*, *Liquidambar*, and *Chaetoptelea* in the Chalk Bluffs flora, and their present upland habitats in the tropics, or subtropics, raises the question whether or not they were upland types in the Eocene forest of Chalk Bluffs. All the evidence indicates that they were riparian forms. In regions where at present they are upland trees, the riparian forest is much more tropical in character than that of the Chalk Bluffs flora. In going from north to south along the Atlantic and Gulf coasts, the riparian forests of more northern localities successively become the upland forests of regions to the south. Thus the lowland forests of the southern states become the hill forests of Vera Cruz. On the basis of the fossil association it is clear that the warmer climates and increased rainfall of the Eocene were not of sufficient degree to bring in tropical forests at low elevations and relegate the *Liquidambar*-*Gordonia*-*Chaetoptelea* association to the uplands. The leaf impressions of these species are too abundant and well preserved for the leaves to have been transported any considerable distance.

The flood plain of the Tertiary Yuba supported a rich mesic forest in which the species listed above were dominants, with an admixture of other less common species of laurels, figs, legumes, and woody climbers such as *Desmodium*, *Phytocrene*, and *Lygodium*. The species of *Platanophyllum*, with their huge palmate leaves, must have been a striking element in this flood-plain flora.

The locality at Buckeye Flat (P3320) is located near the eastern edge of the ancient flood plain, and locality P3318 at Chalk Bluffs is near a side channel. There are several species which are relatively abundant at each of these localities and comparatively rare elsewhere. These undoubtedly were plants that grew either along the edges of the flood plain or beside the tributary streams reaching back to the higher elevations. They include *Acer aequidentatum*, *Fraxinus yubaensis*, *Hamamelites voyana*, *Pongamia ovata*, *Quercus nevadensis*, and *Quercus distincta*.

The composition of the upland forest is not clear, but certain inferences can be made. The occurrence of many of the resistant winged fruits of *Engelhardtia* and their rather uniform representation at various localities, in connection with the absence of leaflets which may certainly be attributed to the same species, at once suggests an upland habitat for this tree, a conclusion substantiated by the habitat of the living trees. In view of the abundance of the fruits, the tree must have been a dominant on higher ground. Other trees or shrubs which, from the texture of their leaves, mode of occurrence, and scarcity of their remains, might also be regarded as belonging to the hill forest are: *Carya*, *Cedrela*, *Diospyros*, *Fraxinus*, *Hamamelites*, *Laurophyllum*, *Neolitsea*, *Persea praelingue*, *Quercus*, *Sabalites* (*Rhapis*), *Vauquelinia*, and *Zamites*. There is thus an incomplete picture of a mesic, upland forest characterized by abundant *Engelhardtia* and with oaks, laurels, witch hazel, small palms, cycads, hickory, and persimmon. A curious feature of this forest is the entire absence of pines, since not a scrap of vegetative remains referable to this genus has been found. The same condition was noted in the Shanwang flora (Chaney and Hu, 1940, pp. 93, 99). There is, however, one indication of the presence of a coniferous tree: the fossil illustrated on plate 26, figure 3, appears to be a cross section of a cypress cone. The absence of pines is a strong indication of a humid upland forest composed of broad-leafed hardwoods, and, according to analogies with the middle-altitude forests of Vera Cruz and Yünnan, one in which laurels and oaks were dominant. The rainfall, then as now, must have increased with elevation up to a certain limit, and may have reached 100 inches or more on the western slopes of the Eocene Sierra between altitudes of 4000 and 7000 feet.

Two florules from beds of Capay age in the Mount Diablo range[4] indicate the character of the contemporary strand vegetation. The fossil plants are found near the base of the Middle Eocene formation (Tesla formation) above sandstones containing a brackish-water invertebrate fauna (Smith, 1937; Huey, 1940). The matrix is much the same at the two localities: chocolate shales and silts with rusty, fine-grained quartz sandstone. The beds were evidently deposited under lagoonal or estuarine conditions. Leaf impressions are abundant but not well preserved. Only about a dozen well marked species are found at either locality. The fossils are a segregate of the most resistant leaves of the plants which grew along the strand.

The collections were studied with a view to determining the relations of the florules to the Chalk Bluffs flora, and provisional determinations of the species were made. At least three-fourths of the species at each locality occur at the other. Only four species are not found in the Chalk Bluffs flora, although intensive study might alter this number somewhat. The most abundant forms are *Castanopsis longipetiolatum*, *Cinnamomum acrodromum*, *Persea pseudo-carolinensis*, *Phytocrene sordida*, *Rhamnidium chaneyi*, and *Rhamnus calyptus*, together with fragments of palm leaves, many twigs of a taxodiaceous conifer, an unidentified laurel, and a strange, bilobed, Y-shaped leaf.

The Chalk Bluffs flora, although it shows close similarities in composition to living subtropical floras, contains some ecological inconsistencies. Thus, although it is predominantly subtropical in character, there are certain genera, such as *Artocarpus*, *Rhamnidium*, and *Tabernaemontana*, which are tropical in habitat at the present time. On the other hand, there are a few genera--*Acer*, *Carya*, and *Fraxinus*, for instance--which appear to be wholly temperate in character. None of these latter genera, however, are entirely confined to the temperate regions. A few species of each extend into tropical areas, although usually at moderate altitudes. The bulk of the plants in the fossil flora would be perfectly at home in the subtropical rain forests of Vera Cruz, Honduras, or Yünnan,

[4]Tesla Quadrangle, north bank of Corral Hollow Creek, Sec. 25, T. 3 S., R. 3 E. Carbona Quadrangle, north bank of Lone Tree Creek, Secs. 16 and 21, T. 4 S., R. 5 E.

but the association of such genera as Acer, Fraxinus, and Artocarpus would not normally be found in existing forests. This apparent contradiction requires an explanation.

A solution of these inconsistencies might be found in any one of the following statements or in a combination of them:

1. The identifications are in error.
2. The requirements of the genera have changed since the Eocene.
3. Our knowledge of the present distribution and climatic requirements of the genera and species is inadequate.
4. The florules collected at various localities are not all of the same geologic age.
5. Differences in elevation of the Chalk Bluffs region at the time of deposition of the fossil flora were great enough to support temperate forests on uplands adjacent to subtropical or even tropical lowlands.

Consideration of these statements in order brings first the question of the validity of the identifications. The genera Acer and Fraxinus are each represented by both leaves and fruits, and their presence is thus proved beyond any doubt. Artocarpus was identified on the basis of its characteristic leaves. The preservation of the fossil leaves is excellent, and they were compared microscopically with leaves of the existing species of Artocarpus and with fossil material in the United States National Museum. The writer is convinced that the identification of the Chalk Bluffs material, as well as of the fossils from the Wilcox and Raton floras, is correct. Fossil fruits characteristic of the breadfruit have been found associated with this or a similar leaf species in the warm-temperate Cretaceous floras of western Greenland and western Europe. There may be some reasonable doubt as to the actual identity with modern genera of such leaf forms as those assigned to Tabernaemontana and Rhamnidium, but if the identification of either of these could be proved to be in error, the association of Acer, Fraxinus, and Artocarpus would still have to be accounted for.

It is entirely likely that environmental adaptation or requirements have changed to a greater or less degree in the case of many species since their first appearance in the fossil record. Although the earliest angiosperm floras were already comparatively advanced and not primitive, unspecialized members of the class, it is certain that they had not in any sense acquired their present complex and varied specializations. Much evidence points to an isolated Arctic land mass in the neighborhood of Greenland as the place of origin of the modern plants. Their evolution appears to have taken place during the long interval of equable climates in the Upper Triassic and Jurassic. This being so, there was no impetus for marked temperature and moisture specializations in the equable, humid climate of these northern lands in the Middle Mesozoic. The great radiation of the angiosperms and their colonization of the earth took place after the beginning of the Cretaceous. We should, then, expect an apparently inconsistent mingling of generalized forms in the earliest floras, for the reason that some of these have since become specialized for varied edaphic and climatic situations, from the tropical to the temperate, and the humid to the dry. This is illustrated by the presence of <u>Artocarpus</u> in the warm-temperate Cenomanian flora of west Greenland. Such inconsistencies, <u>in terms of modern adaptations</u>, are doubtless real and not apparent. They should gradually become less noticeable as we examine progressively younger floras, and should finally disappear in the late Miocene and Pliocene floras.

It is true that much remains to be learned about the climatic tolerances of tree species, but this factor can hardly be of much weight in the present discussion. Minimum temperatures are the limiting factors in the poleward extension of tropical species, but the actual amount of heat during the growing season is also important. Certain plants which are popularly supposed to be tropical in their temperature requirements can tolerate a comparatively low average temperature if the minima are not too low, particularly if the extreme minimum for the year does not fall below a few degrees above freezing. Many species of orchids illustrate this point. It may be that nowhere on earth at present is there an exact duplication of Eocene climatic conditions in the now temperate regions of North America, yet those conditions must be closely approached in the existing temperate or subtropical rain forests in the mountains of the tropics. It is not necessary to cultivate the particular species under investigation at successive distances north of the tropics; an observation of its altitudinal range in the tropics is usually sufficient. The equable climate of the tropical rain forests allows the intermingling of species of rather widely varying tolerances, giving the impression of a mixture of tropical and temperate kinds. The lowland tropical forest types, however, of which the breadfruit is one, rarely extend into the cooler montane zone, or _tierra templada_.

The statement that the florules are not all of the same age, or very nearly the same age, can be refuted with confidence. All the collections were made at the same stratigraphic horizon, in sediments having the same composition and, with the exception of the florule at Cherokee, along the course of a Tertiary channel which has been carefully traced from Iowa Hill to North Columbia. In addition to this, the florules are all tied together by a large number of characteristic species in common.

The unevenness of the Eocene land surface accounts for considerable diversity in the Eocene flora. The Chalk Bluffs area was a region of moderate to strong relief at the time of deposition of the Ione gravels. The summit of Banner Hill west of Buckeye Flat rises about 900 feet above the upper surface of the Eocene gravels now uncovered by hydraulicking. Moody Ridge, just east of Gold Run, is more than 1000 feet above the gravels on the west. These elevations represent portions of the old bedrock surface which has been protected from erosion by deposits of the andesitic epoch, and they are therefore older than Upper Miocene. These parts of the bedrock surface were subjected to continuous erosion from the Middle Eocene until they were covered by the andesites, and thus must have been much higher above the river channels during the Eocene than they are at present. It is impossible to estimate accurately the amount of erosion during this time interval. The valley deposits in many places were protected by the covering of rhyolite tuffs and have suffered little degradation. There was a period of uplift after the deposition of the Ione, and the sediments of the Upper Eocene and Miocene were deposited, for the most part, farther to the west instead of along the foothills, so their thickness is not known. An assumption that the prominent elevations were reduced in height by 2000 to 3000 feet during the long period of erosion seems moderate. Lindgren remarks that "The evidence available shows conclusively that at the time when the oldest gravels, probably of Eocene age, began to accumulate, the Sierra Nevada was a mountain range as distinct, if not as high, as at present" (1911, p. 37). There was ample opportunity for the remains of at least a few of the upland plants to be preserved in company with the flood-plain flora. The accessibility of the various sites of deposition to side streams draining near-by elevations accounts satisfactorily for the variation in composition of the florules at Buckeye Flat, Chalk Bluffs, and Cherokee. The abundance of the small, resistant oak leaves known as _Quercus_ _nevadensis_, as well as the presence of _Acer_ and _Fraxinus_, at a locality on the outer edge of the east bench at Buckeye Flat, 2 miles from the main channel, is an illustration of this.

The possibility of the mingling of lowland and upland species satisfactorily explains the presence of certain of the more temperate species, and mitigates but does not entirely remove the difficulties connected with the presence of _Artocarpus_. The riparian flora of the Chalk Bluffs, separated from the upland elements, is in no sense a lowland tropical flora like that associated with the existing breadfruit tree.

To summarize, it may be said that the association of _Artocarpus_ with temperate types can only be satisfactorily explained as due in part to different habitat requirements of the breadfruit in the Eocene, since altered by evolutionary changes, and in part to the marked relief of the time, which resulted in the mingling of upland species with a riparian flora.

Climatic Indications

Analysis of Leaf Characters

The method of analyzing leaf characters according to size, nervation, margin, etc., in their relation to environment, as developed by Bailey and Sinnott (1915a, 1915b, 1916) and by Chaney and his students (Chaney and Sanborn, 1933, pp. 18-23; Potbury, 1935, pp. 51-53; MacGinitie, 1937, pp. 112-113; Dorf, 1938, pp. 25-27), yields significant results. Briefly stated, some of the original conclusions of Bailey and Sinnott may be summarized as follows: (1) The characters of large size, entire margin, pinnate venation, and compound organization occur most frequently in the tropics and decrease proportionately to the temperate zones. (2) Palmate leaves are more primitive than pinnate. The relation between leaf margin and climate appears to be the most direct, and thus the percentage of dicotyledons with entire leaves may be a reliable indication of the climatic environment. This is illustrated by the percentage of woody species with entire leaves in these areas: Panama forest, 88; Florida Keys, 83; upper Gangetic plain, 71; Simla Hills, 57; southeastern United States, 39; Muir Woods, 23. In using results obtained from analysis of the leaf characters of fossil floras, evolutionary trends must also be considered. In a flora of early Tertiary or late Cretaceous age there should be a somewhat larger proportion of palmate leaves and perhaps also of compound leaves. Table 4

Table 4
Analysis of leaf characters
(Percentages)

Locality	Margin		Length		Organization		Nervation	
	Entire	Non-entire	Over 10 cm.	Under 10 cm.	Simple	Compound	Pinnate	Palmate
Chalk Bluffs..........	46	54	59	41	79	21	76	24
La Porte..............	71	29	35	65	85	15	65	35
Goshen................	61	39	53	47	88	12	82	18
Weaverville...........	47	53	60	40	81	19	60	40
Medicine Bow..........	67	33	45	55	83	17	60	40
Laramie...............	71	29	45	55	87	13	64	36
Muir Woods............	23	77	27	73	77	23	77	23
Panama forest.........	88	12	56	44	85	15	83	17

gives the analysis of four leaf characters for six fossil and two living floras. The figures are percentages of the total number of woody species of dicotyledons which fall in each division. In the Chalk Bluffs flora the percentage of species with entire leaves lies between the figure for the southeastern states and that for the Simla Hills, and is almost exactly the same as that for the Weaverville flora. The leaves were large, like those of the Weaverville and Goshen floras and the Panama forest. The percentage of palmate-nerved leaves is low considering the age of the flora, and the percentage of compound leaves is again similar to that in the Weaverville flora. On the basis of these leaf characters, the Chalk Bluffs flora is most similar to the Weaverville, except for the smaller proportion of palmate leaves. A tentative conclusion may be drawn that the climate was warmer than in the southeastern states, but not so tropical as in the Simla Hills area. This supports the conclusion arrived at elsewhere in the paper, that the majority of the species in the flora indicate a subtropical environment.

The Chalk Bluffs flora contains a somewhat larger proportion of species related to living tropical or subtropical species than does the Weaverville flora. The close resemblance in leaf characters is therefore rather surprising.

There are other factors, such as age of the flora, physiographic environment, and amount of sunshine, which must affect the data, but these cannot as yet be correctly evaluated. Further extensive field work with both living and fossil floras will be necessary before the method of leaf-character analysis can be used to the best advantage.

The Eocene Climate in Terms of Living Plant Associations

The _Chaetoptelea_-_Liquidambar_ association in the lower part of the _tierra templada_ suggests a similarity between the climate of the Middle Eocene in Nevada County and the present climate of the lower slopes of the Sierra Madre in the state of Vera Cruz, Mexico. Climatic data from Jalapa and Orizaba (at elevations of approximately 4000 feet) were furnished by the Servicio Meteorológico Mexicano. The data from Orizaba are here presented and, as a matter of interest, are contrasted with similar data from Nevada City, California (figs. 3, 4, pp. 74, 75). Certain aspects of the climate of Orizaba are of particular interest: (1) According to Köppen's classification, it is a temperate or C climate. The average temperature of the coldest month is below 18° C. (December, with an average temperature of 14.8° C.). In fact, there are four months, November to February, whose average temperature falls below 18° C. (2) It is a frostless climate. The extreme minimum temperature recorded is 1.5° C. or 34.7° F. (3) It is an equable or truly "temperate" climate, since the average temperatures of the warmest and coldest months differ by less than 12° F. (4) Although no month is rainless, there is a dry season from December to April. (5) There is a pronounced summer maximum of rainfall: four months, June to September, experience nearly 70 per cent of the total precipitation. The annual rainfall is heavy, 84.6 inches average. (6) The warmest season is in April and May, at the end of the dry season.

There is much confusion in scientific literature in the use of the terms "warm-temperate" and "subtropical." The writer suggests that the term "temperate" be restricted to climates where frost occurs. Characteristic warm-temperate climates are those of the Gulf states, excluding Florida, or of the Central Valley of California. The type of climate exemplified by the frostless climate of Orizaba was apparently widespread in the Eocene. There is need for another symbol in the Köppen classification to designate such a frostless, subtropical climate with heavy rainfall in the warm season and a well marked dry season.

These subtropical fossil floras appear on superficial examination to be more tropical than they really are. On careful analysis it is seen that such a flora is a mingling of tropical and temperate types easily differentiated from such an authentically tropical flora as that which grows in the lowlands of Central America or the Amazon Basin. In the type of climate postulated for the Middle Eocene, chemical weathering becomes far advanced, owing to warmth, heavy rainfall, and the ease of oxidation under alternating wet and dry seasons. It is probable that the Ione sediments, with their quartz-anauxite sands, white and pink clays, and lithomargic pebbles, were accumulated in a climate which differed in no important respects from that of Orizaba at present.

The region in southwestern and southern China inhabited by the Paleotropic element is essentially similar in physiography and climate to the lower tierra templada of southeastern Mexico. No reliable climatic data are available from stations at moderate altitudes in this region. The rainfall is generally heavy. There is a summer maximum, with June the rainiest month of the year. The winters are cool, comparatively dry, and sunny.

The climate described above offers a marked contrast to the present climate of the Chalk Bluffs region, as shown by the climatic data from Nevada City. The rainfall regime is exactly reversed. The difference between the average temperature of the coldest and of the warmest months is near 30° F. at Nevada City and 10° F. at Orizaba. The difference between the extremes in temperature for any month varies from 70° F. to

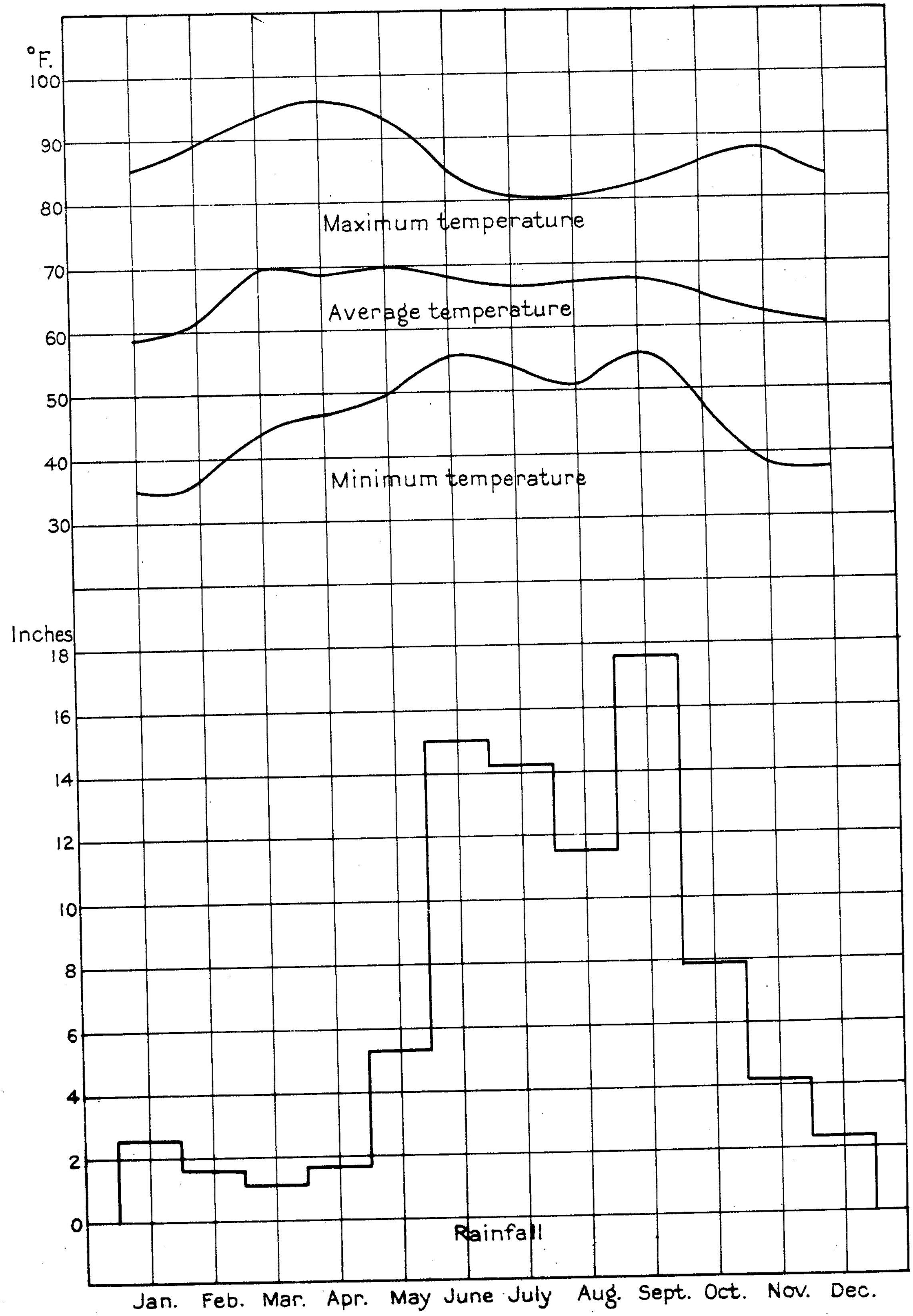


Fig. 3. Rainfall and temperature for Orizaba, Mexico, elevation 4025 feet.

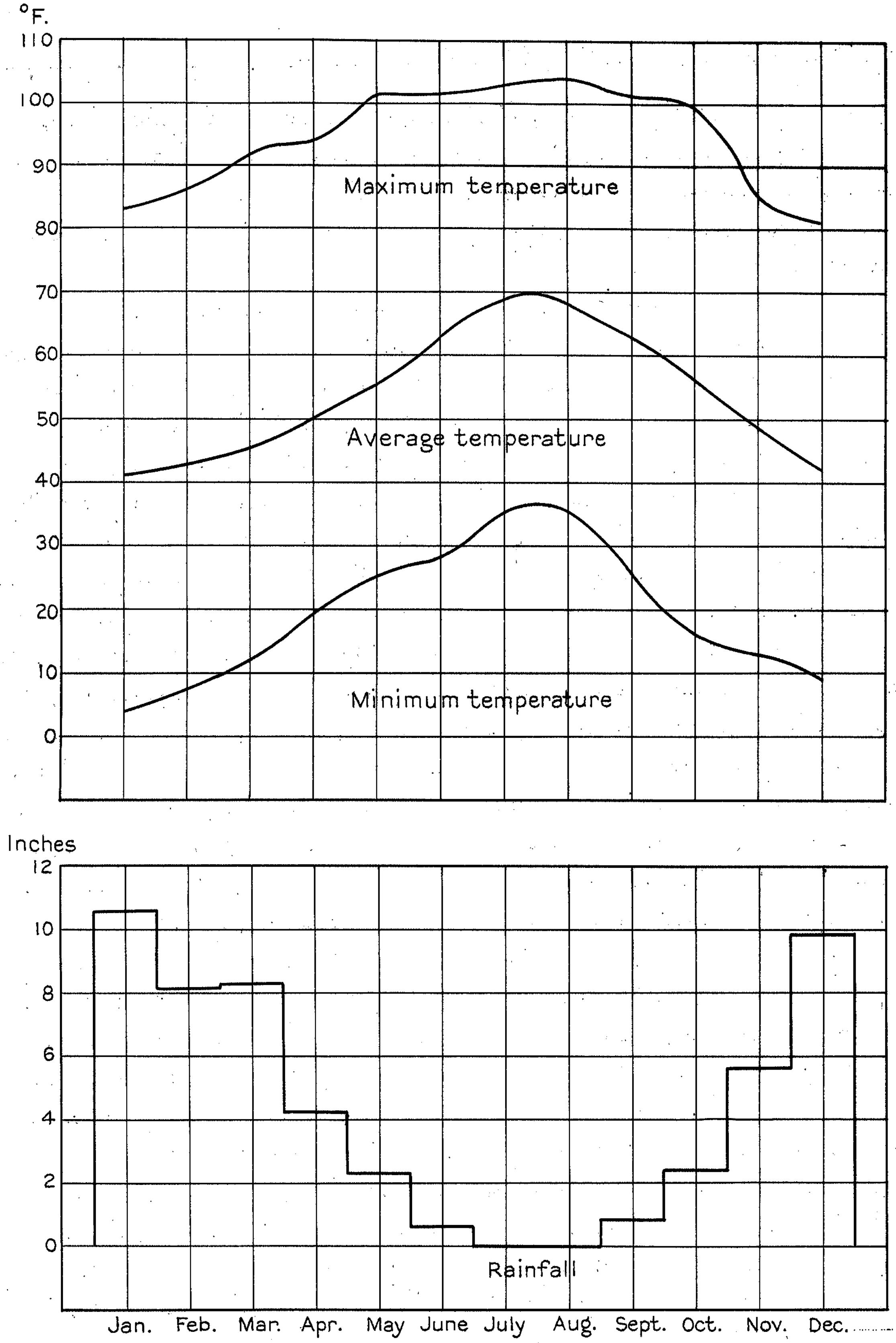


Fig. 4. Rainfall and temperature for Nevada City, California, elevation 2580 feet.

80° F. at Nevada City, whereas in Orizaba the greatest monthly range is 50° F. One of the essential differences between the present climate and that of the Eocene appears to be the reduction, in the latter, of annual temperature ranges, shown particularly in an elevation of the minimum temperatures.

These facts present a striking picture of the indicated climatic changes between the Eocene and the present. The causes of these changes are as yet imperfectly known. The writer wishes to emphasize statements made in an earlier paper (MacGinitie, 1937, pp. 125-127) that geographical causes alone cannot furnish a satisfactory explanation. Changes in the distribution of land and water may cause local climatic changes over a comparatively large area, it is true, but no geographical changes alone could have produced the widespread Eocene climate indicated by the floras of western and central North America, Greenland, Siberia, and Europe. Neither is an adequate explanation to be found by taking liberties with the position of the poles or the continents. It is impossible to prove that changes in solar radiation have occurred, but it is true that an increase in solar radiation would account in large part for the indicated Eocene climates. Such an increase would result in increased humidity and cloudiness, less vigorous interzonal circulation, higher ocean temperatures, and a diminution or loss of the polar ice caps. This condition would favor increased precipitation, a decrease in temperature variations, and a rise in the temperature minima. It can also be shown that with increased humidity and cloudiness, and a decrease in the temperature difference between polar and tropical regions, the so-called belts of Mediterranean climate would shrink and become much less pronounced. Nearly every pre-Pliocene Tertiary flora of the west coast which has been thus far studied gives a definite indication of warm-season rainfall in a region where the summers are now comparatively dry.

The present dry summers of the coast of California and Oregon are due to the temperature contrast between the heated interior of the continent and the cool north Pacific. Air from the north Pacific "high" in its journey toward the low-pressure area over the southwestern states is inherently stable, because of its transfer to progressively warmer regions. The passage across the cold California current increases this stability. Convectional showers along the coast are practically unknown in the summer, and become important as sources of precipitation only along the summit of the Sierra and the interior mountains of southern California.

Warm-season precipitation in the coastal areas would be increased by a rise in the temperature of the bordering ocean without a corresponding rise in land temperature. An increase in ocean temperature would result in greater absolute humidity and greater cloudiness, and thus a decrease in warm-season temperature differences between sea and land and a decrease in the seasonal extremes over the land.

It is possible to arrive at an estimate of the relative sea and land temperatures in the Middle Eocene by considering the temperature tolerances of the living representatives of fossil plants and invertebrates. A recent paper by Durham (1940) furnishes some positive evidence on the ocean temperature of northwestern Washington during this age. The Middle Eocene Crescent formation is found in the neighborhood of Port Crescent, on the north side of the Olympic Peninsula at latitude 48° north. The following genera of corals have been found in these beds: *Astreopora*, *Colpophyllia*, *Leptophyllastrea*, *Madracis*, and *Montipora*. Durham concludes: "It appears probable therefore that this coral assemblage did not live in temperatures lower than about 20° C." (68° F.). This represents the minimum, not the average, temperature of the sea, and implies an increase of not less than 13° F. over the temperature of the present ocean. On this basis the temperature of the ocean off the California coast at the latitude of Chalk Bluffs, 39° north, must have been at least 70° F.

The present climate of Orizaba is a close approximation to the climate of the Middle Eocene in Nevada County, California, in terms of the fossil plants. The average annual temperature at Orizaba is 65° F.; at Nevada City 54° F., at Redding 62° F., and at Sacramento 60° F. This represents an increase of 10° F. or less in the Eocene over the present land temperatures, and leads to the significant conclusion that the average temperature of the ocean waters in the Middle Eocene off the California coast was higher than the land temperature by 5° F. or more. The annual change in temperature over the land in temperate latitudes is greater than that of the ocean waters. Where the average ocean temperature is greater than that of the land, there results a dry, cool winter season, produced by the seaward transport of air from the colder land, and a humid warm season when the maritime air flows landward. Such a condition is entirely sufficient to account for the indicated amount and seasonal distribution of rainfall in the Eocene.

This discussion refers only to the convectional or tropical type of rainfall and neglects the effects of cyclonic disturbances. It is evident that the temperature differences between the tropics and the arctic regions were much less in the Eocene than they are today. The "polar front" must have been weakened and displaced far to the north. The most important source of precipitation in the middle latitudes may therefore have been convectional showers, with the cyclonic storms reduced to infrequent winter visitants or to occasional incursions of tropical storms in the fall.

The following summary statements concerning the climate of the Middle Eocene in northern California are based on estimates but are probably close approximations to the actual conditions.

1. Average annual temperature of the land at low altitudes, 65° F.
2. Average annual temperature of the sea, 70° F.
3. Annual temperature ranges over the land much reduced.
4. Frost rare or absent at low elevations.
5. Average annual rainfall at least 60 inches at lower altitudes, increasing to 80 inches or more at higher elevations.
6. Maximum precipitation in the warm season; cool season comparatively dry.

DISTRIBUTIONAL CONSIDERATIONS

The composition of the Chalk Bluffs flora, when studied in connection with floras of earlier and later date, throws some light on the plant migrations and plant geography of the Tertiary (see table 5, p. 83).

One of the most characteristic elements of the flora is formed by the group of plants related to species in the late Cretaceous and early Paleocene floras of the Rocky Mountain province. <u>Artocarpus</u> <u>lessigiana</u>, Cercidiphyllum elongatum, Cinnamomum dilleri, Cornus kelloggii, Magnolia dayana, Phyllites daturaefolia, Platanophyllum whitneyi, Platanus appendiculata, Rhamnidium chaneyi, Viburnum variabilis, Zamites (?) sp., and a few others appear to be either little-changed survivals from the earlier floras or linear derivatives of the older species. Some of these conservative forms doubtless persisted longer in the Eocene of the Pacific slope for the same reason that the redwoods survive there today. The coastal area must always have been a region of more equable climates and greater humidity than areas farther toward the interior of the continent. Prominent in this group are genera and species comprising the Paleotropical element, such as Artocarpus, Cercidiphyllum, Cinnamomum, Mallotus, and Phytocrene, which no longer grow in the New World but are restricted to the floral refuge of southeastern Asia.

Another element is composed of genera which appear to have originated in the American tropical or subtropical areas in later Cretaceous or early Tertiary time and slowly migrated northward during the Eocene. This element is also conspicuous in the Wilcox flora. In the western states it becomes increasingly important in the younger floras and reaches a maximum in the La Porte and Goshen floras, where it comprises at least half the number of species. Typical genera of this group are: Cedrela, Cupania, Hyperbaena, Meliosma, Rhamnidium, Tabernaemontana, Vouapa, and perhaps Thouinopsis. The increasing prominence of this tropical or subtropical element toward the close of the Lower Tertiary indicates a general increase of temperature which seems to have culminated in the latest Eocene or Lower Oligocene. After this began the swing to the cooler and drier conditions of the late Tertiary. This is in harmony with the observations made by Berry concerning the climatic tendency indicated by the early Tertiary floras of the southeastern states: "... the conclusion is reached that physical conditions, particularly climatic conditions, did not show much change throughout Jackson, Catahoula and Vicksburg time, such change as is apparent being a gradual approach to more nearly tropical conditions" (Berry, 1924, p. 137), and "... the lower Jackson flora is distinctly more tropical than that of the Wilcox" (ibid., p. 25). This Neotropical group, since its members were adapted to a humid, subtropical climate, did not extend so far north as the next group to be discussed, and there is little evidence of them in the "Arctic Miocene" (Upper Eocene) floras of the far north. The most northerly occurrence on the Pacific coast is in the flora from Kupreanof Island on the southern Alaska coast, latitude 58° north. With the onset of less favorable conditions in the later Tertiary, the direction of migration must have been reversed, and at present the survivors of the group are restricted to tropical America.

The temperate element of the Chalk Bluffs flora, exemplified by Acer, Fraxinus, Hydrangea, Liquidambar, Nyssa, Rhamnus, Rhus, etc., nearly disappears in the Upper Eocene and Lower Oligocene floras, but reappears and later becomes dominant in the Miocene floras. Many of the genera of this element or genera directly ancestral to them appear at the beginning of the Upper Cretaceous in the Dakota and Raritan floras. The flora of the Dakota group, in contrast to the subtropical facies of the late Cretaceous Lance and Laramie floras, is indicative of a temperate climate. Before generic comparisons between Tertiary and Cretaceous floras are made, it should be noted that the taxonomy of the Cretaceous angiosperms is encompassed by extreme difficulties (Dorf. 1938, pp. 38–40). The application of modern generic names to plant species of the late Middle and Upper Cretaceous is to be questioned in many instances. It is true, however, that marked similarities to living plants do exist in numerous cases, and it is probable that many of the Cretaceous genera are either identical with or directly ancestral to the living genera indicated. The following genera from the Dakota flora comprise a group ancestral to the temperate element of the Chalk Bluffs flora:

Alnites	Liquidambar	Rhamnus
Celastrophyllum	Magnolia	Rhus
Cinnamomum	Nyssa	Salix
Diospyros	Persea	Smilax
Hamamelites	Platanus	Viburnum
	Quercus	

A similar group is found in the Magothy flora:

Acer	Magnolia	Rhus
Celastrophyllum	Persea	Salix
Cinnamomum	Platanus	Smilax
Cornus	Quercus	Viburnum
Diospyros	Rhamnus	

The presence of this temperate element in western floras of at least three ages, basal Upper Cretaceous, Middle Eocene, and Miocene, suggests that the association may have been continually present in the region and that its appearances and disappearances were due to altitudinal migrations (Chaney, 1936b, p. 65). On the other hand, it is evident that north-and-south migrations as well as vertical movements took place, since most of the species in the temperate element of the Chalk Bluffs flora show close relations to existing species in both eastern North America and southeastern Asia. During the period of most favorable climates, the genera of the temperate element formed a part of the forests of Arctic regions, and with the lowering of temperature which came to pass in the Upper Tertiary, migrated southward from an approximately continuous region accessible to both eastern North America and eastern Asia.

The reason for the similarities between the Middle Eocene flora and the living flora of subtropical southeastern Asia cannot be given satisfactorily until more complete additional Eocene floras are known from southern Asia. It may be that there was a much greater similarity between the floras on opposite sides of the Pacific during the early Tertiary. The great seaway of Upper Cretaceous time which separated eastern and western North America would tend to produce such a similarity. If the angiosperms originated in the far north and migrated southward, that would be another factor tending to create floristic similarities between western North America and eastern Asia. This leaves unexplained the extinction of many genera of the Paleotropical group which once existed in western North America but are now found only in eastern Asia.

The Chalk Bluffs flora is thus seen to comprise three groups:

1. An older group related to Cretaceous and Paleocene species whose living representatives are now, for the most part, restricted to eastern Asia.
2. A group which appears to have originated in the American tropics, migrated northward during the Lower Tertiary, and finally become restricted again to the American tropics at the close of the Tertiary.
3. A group of temperate species derived from the Dakota and related floras which became restricted to the far north or to the uplands during the warmth of the Lower Tertiary, and, through subsequent migration south-

ward and downward, is now found in both eastern Asia and eastern North America.

AGE OF THE FLORA

As stated in the section on the geology of the deposits, the Chalk Bluffs flora is preserved in the continental facies of the Ione formation. Its age is therefore lower Middle Eocene, on the basis of the Capay invertebrate fauna. Thus it is of approximately the same age as the lower Claiborne of the Gulf states or the Ypresian of the Paris Basin (Clark and Vokes, 1936, pp. 860-861). It is worth while to check this determination by comparing the Chalk Bluffs flora with other Lower Tertiary floras.

There are several pre-Miocene floras in the region from northern California to Puget Sound, known either from recent monographs or from large collections at the University of California. These range in age from Lower Eocene to latest Eocene or Lower Oligocene. Five of these floras, the Comstock, Steel's Crossing, La Porte, Clarno, and Goshen, listed in the approximate order of their decreasing ages, contain species in common with the Chalk Bluffs flora. In order to establish a provisional basis for a comparison of the relative ages and stages of development, the species of the respective floras have been divided into four groups: (1) the temperate Holarctic element: species which are closely related to species in temperate or warm-temperate southeastern North America and/or southeastern Asia; (2) the Neotropical element: species whose closest living relatives are confined to subtropical and tropical America; (3) the Paleotropical element: species whose closest living relatives are found only in subtropical or tropical southeastern Asia; (4) species extinct or of doubtful affinities. Such a grouping is not of much value unless the floras occupied a similar environment.

Considering the floras as arranged in table 5 from the Chalk Bluffs to the Goshen, there is seen to be a progressive increase in the importance of the Neotropical element and diminution in the prominence of group 3, the Paleotropical element. There is some indication of an increase in temperature which culminated in the Upper Eocene or Lower Oligocene. The Steel's Crossing and Clarno floras are omitted from the table because taxonomic work on them is still in progress.

The Weaverville flora has been added as a matter of interest, since it shows the beginning of the floristic change which ushered in the later Tertiary. It should be noted that the percentage under group 3 for this flora represents plants from the warm-temperate regions of central and southern China rather than any subtropical element. One Chalk Bluffs species, Rhamnus plenus, is found in the Weaverville flora, but this flora differs markedly in facies and composition, and is so much younger than

Table 5

Present relationships of fossil floras

Element	Weaverville		Goshen		La Porte		Comstock		Chalk Bluffs	
	No. species	%	No. species	%	No. species	%	No. species	%	No. species	%
1. Temperate to warm-temperate..........	20	62.0	7	14.3	4	10.6	7	31.8	27	35.5
2. Neotropical..........	7	22.0	31	63.3	24	63.0	8	36.6	21	27.6
3. Paleotropical........	5	16.0	7	14.3	7	18.4	5	22.7	19	25.0
4. Doubtful or extinct..	0	0.0	4	8.2	3	8.0	2	9.0	7	9.2

the Chalk Bluffs that a discussion of its aspects would not be relevant to the problem of the age of the older flora. (See table 6.)

Approximately 20 of the Chalk Bluffs genera occur in the Tertiary floras of Alaska as monographed by Hollick, but less than half of these are represented by species at all closely allied to species in the California flora. There is no certainty that the floras from the various Alaskan localities are of the same age, although there is some evidence to indicate that the majority of them are of Upper Eocene age. The flora from Kupreanof Island is definitely warm-temperate (or even subtropical) in its facies, containing Dioon, Ceratozamia, Flabellaria, Castanopsis longipetiolatum, Magnolia, Ocotea, Rhamnus, and Dillenites. The floras from a large majority of the localities contain abundant remains of Salix, Betula, Corylus, Alnus, Fagus, Quercus, etc., associated with Sequoia, indicating a humid, temperate climate similar to that of southwestern England. The Alaskan flora is largely composed of the temperate Holarctic element which probably occupied its most northerly position during the warm climates of the Upper Eocene.

The Comstock and Steel's Crossing floras are both of Upper Eocene age, according to the associated marine invertebrate faunas. The Comstock

Correlation with other fossil floras*

Species	Middle Eocene Mt. Diablo Range	La Porte	Comstock	Steel's Crossing	Clarno	Yellowstone	Wind River	Wilcox	Denver-Animas-Raton	Probable derivatives of Paleocene--late Cretaceous species
Acalypha aequalis	...	x	...	...	...	...	...	...	...	...
Artocarpus lessigiana	...	...	...	...	...	o	...	x	x	o
Calyptranthes myrtifolia	...	...	...	...	...	...	...	o	...	...
Canarium californicum	x	...	...	...	...	...	...	...	o	o
Castanopsis longipetiolatum	x	x	...	x	...	x	...	...	...	...
Cercidiphyllum elongatum	...	...	o	...	...	...	o	...	...	o
Chaetoptelea pseudo-fulva	...	x	...	x	...	...	...	...	...	...
Cinnamomum acrodromum	x	x	...	x	...	...	...	o	...	...
Cinnamomum dilleri	x	x	x	x	x	...	...	...	...	...
Cornus kelloggii	...	x	...	...	...	...	...	...	...	...
Cryptocarya praesamarensis	...	...	x	...	...	...	...	...	...	...
Engelhardtia nevadensis	x	...	...	...	...	...	...	o	...	...
Ficus densifolia	...	...	...	...	...	x	...	...	...	...
Ficus goshenensis	...	x	x	...	...	...	...	...	...	...
Gordonia egregia	x	...	...	...	...	...	...	o	...	...
Hamamelites voyana	...	...	...	...	...	...	...	...	o	o
Hyperbaena diforma	...	x	...	...	...	...	...	...	...	...
Inga ionensis	...	...	...	...	...	...	...	o	...	...
Laurophyllum fremontensis	...	...	...	...	...	x	x	...	...	...
Liquidambar californicum	...	x	...	...	...	...	...	o	...	...
Lygodium kaulfussii	...	...	...	x	x	x	x	...	...	...
Magnolia dayana	...	...	...	...	...	...	...	o	o	...
Neolitsea lata	...	...	...	...	...	o	...	o	...	...
Nerium hinoidea	...	...	...	...	...	...	...	x	...	...
Nyssa californica	...	...	x	...	...	o	...	...	...	...
Persea praelingue	x	x	x	...	...	...	...	...	...	...
Persea pseudo-carolinensis	x	x	x	...	...	x	...	...	...	...
Phyllites daturaefolia	...	...	...	...	...	...	...	...	...	o
Phytocrene sordida	x	...	...	...	...	...	...	o	...	o
Platanophyllum angustiloba	...	...	x	x	x	...	...	...	...	o
Platanophyllum angustiloba serrata	...	...	...	...	...	...	o	...	...	o
Platanophyllum whitneyi	...	...	...	...	...	x	x	...	...	o
Platanus appendiculata	...	...	x	...	...	x	...	...	...	o
Platanus coloradensis	...	...	...	...	...	...	...	...	x	...
Quercophyllum platanoides	...	...	...	...	...	...	...	...	...	o
Quercus nevadensis	x	x	...	...	...	...	...	...	...	...
Rhamnidium chaneyi	x	x	...	o	...	...	...	o	o	o
Rhamnus calyptus	x	...	x	...	...	o	...	...	...	o
Rhus mixta	...	...	x	...	x	...	...	...	...	...
Sabalites californicus	...	x	...	x	...	...	...	...	...	...
Strongylodon falcata	...	...	...	o	...	...	...	...	...	...
Tabernaemontana chrysophylloides	...	x	...	...	...	...	...	...	...	...
Terminalia estamina	...	...	...	...	...	...	o	...	...	...
Thouinopsis myricaefolia	x	...	...	...	...	...	...	...	...	...
Viburnum variabilis	...	...	x	...	...	...	...	...	...	o
Zamites californica	...	...	...	x	...	x	...	...	...	...
Totals	13	15	11	8	4	8	3	2	2	...

*x, most similar species present; o, closely similar species present.

formation overlaps strata containing a Cowlitz-Tejon fauna. They are both subtropical lowland floras. Approximately one-third of the Comstock species and about one-fourth of the Steel's Crossing species are found in the Chalk Bluffs flora. Platanophyllum angustiloba, Cinnamomum dilleri, Persea pseudo-carolinensis, Rhus mixta, and Chaetoptelea pseudo-fulva are among the most characteristic of these common species. The Asiatic element is conspicuous in both the Comstock and Steel's Crossing floras, and the Neotropical element is correspondingly reduced. Among the typical lowland species of the Chalk Bluffs which are absent from these floras are: Artocarpus lessigiana, Canarium californicum, Celastrus preangulata, Ficus densifolia, Gordonia egregia, Pongamia ovata, and Liquidambar californicum. Many temperate and upland species of the Chalk Bluffs are not represented. Liquidambar, which is so abundant at all the Chalk Bluffs localities, is either extremely rare or entirely absent in the later floras. It is possible that Liquidambar retreated to the uplands, with the indicated trend toward more tropical conditions in the Upper Eocene.

A few Clarno species are found in the Chalk Bluffs flora. All of these occur in one or more of the other floras mentioned and appear to be persistent forms without much stratigraphic significance. The Clarno flora is apparently of late Eocene age.

The La Porte flora of Plumas County, 30 miles east of Cherokee and 30 miles north of Chalk Bluffs, occurs in a dacite tuff which was deposited in one of the northern branches of the Tertiary Yuba River. There is an erosional break between the sedimentary formation containing the fossiliferous tuff and the underlying white quartz gravels of the Ione formation. Fifteen species, or 36 per cent of the total number known from La Porte, occur in the Chalk Bluffs flora, although only 4 of the common species, Chaetoptelea pseudo-fulva, Liquidambar californicum, Persea pseudo-carolinensis, and Quercus nevadensis, are abundant in the Chalk Bluffs flora. The La Porte flora shows a considerable evolutionary advance beyond the Chalk Bluffs flora, notwithstanding the comparatively large number of common species. The early Tertiary relicts such as Artocarpus, Castanopsis, Mallotus, Phyllites daturaefolia, Viburnum, etc. form an inconspicuous element, and their place is taken by Neotropical plants which give the La Porte flora a more modern and at the same time a more tropical aspect than that of the Chalk Bluffs flora.

The Goshen flora also contains a conspicuous Neotropical element and indicates the most nearly tropical climate of the six floras discussed. Apparently it is the most advanced in floral composition, showing the culmination of the northward migration of Neotropical plants, and the peak of the trend to warmer climates. On this basis it is, therefore, the youngest of the group of six floras. Two or three Goshen species are found in the Chalk Bluffs flora. One of these, Cupania oregona, has thus far been noted only in these two floras.

It is not always easy to evaluate the significance of species correlation between two floras in terms of their relative ages. Although there is a comparatively large species correlation between the Chalk Bluffs and the La Porte floras, it does not necessarily follow that they are of the same age. There is no indication of any striking climatic changes in the California province during the Eocene, and therefore large floristic differences between the Middle and Upper Eocene forests would not be expected. Such floristic changes as did occur probably represent a slow evolution in a comparatively stable environment. Climatic fluctuations then, as now, must have been tempered by the proximity of the Pacific Ocean. The specific correlation between the La Porte and the Chalk Bluffs flora is of the same order as that between the Middle Eocene Claiborne and Upper Eocene Jackson floras, since 39 per cent of the Claiborne species are found in the Jackson (Berry, 1924, p. 34). The age difference between the Chalk Bluffs and La Porte floras is probably as great as, or greater than, that between the Claiborne and the Jackson floras. The Chalk Bluffs flora, considering evolutionary trends, is clearly the oldest of the six floras discussed. This evidence is consistent with an age assignment to the Middle Eocene.

Two floras of the mid-continent, the flora of the Yellowstone Park basic breccias and the flora of the Wind River Basin of western Wyoming, show relations to the Chalk Bluffs flora. The general facies, composition, and stage of evolution of the Yellowstone basic breccia flora are closely similar to those of the California flora, and there are between 7 and 9 specifically identical or closely related species. Among these are certain of the abundant and characteristic Chalk Bluffs forms such as Castanopsis longipetiolatum, Ficus densifolia, Persea pseudo-carolinensis, *Platanophyllum whitneyi*, and *Platanus appendiculata*. This evidence warrants the statement that the two floras are of approximately the same age. Several floras of Wasatch age have recently been collected by Roland W. Brown from the central Rocky Mountain region, and similarities between these floras and that of the Yellowstone basic breccia suggest that the Yellowstone flora is of Wasatch age. This evidence indicates that the Wilcox flora and the Yellowstone flora are of nearly the same age. The Wind River flora was correlated by Berry with the Green River flora; 21 of the 41 species identified are indicated as conspecific with Green River species. An examination of the list of common species shows that approximately 12 out of the 21 are based on fragmentary or otherwise doubtful material, thus substantially reducing the supposed close similarity between the Wind River and Green River floras. The general facies and composition of the Wind River flora is notably different from that of the true Green River, as this formation occurs in northwestern Colorado (Garfield and Rio Blanco counties). Only a few of the typical Green River species, such as *Ampelopsis tertiaria*, *Juglans alkalina*, and *Sapindus dentoni*, are found in the Wind River. The latter flora is composed for the most part of conservative, warm-temperate or subtropical, lowland species, in contrast with the rather specialized, temperate or warm-temperate, largely endemic Green River plants. It is improbable that the Wind River flora was contemporaneous with the Green River, and the available evidence indicates an older age. Three Wind River species are found in the Chalk Bluffs flora, and in addition there are a few forms which closely resemble Chalk Bluffs species, although they are probably not identical. This is illustrated by the following group:

Wind River	Chalk Bluffs
Aralia browni	Platanophyllum angustiloba serrata
Ficus mississippiensis	Phytocrene sordida
Ficus ungeri	Canarium californicum
Ficus wyomingiana	Cinnamomum dilleri
Cercidiphyllum arcticum	Cercidiphyllum elongatum

Only one or two Chalk Bluffs species are found in the Green River flora, and the two floras show more contrasts than similarities. If the Green River flora is Middle Eocene, according to all the evidence it must belong to the latest stage of that time division. The typical Green River flora apparently occupied an enclosed basin in an upland region, and the unique character of the flora is probably a reflection of its physical isolation. The only flora which shows marked similarities to the Green River is the Florissant. This much younger flora contains approximately 25 species identical with or closely related to characteristic Green River plants.

The Upper Eocene Jackson and (late) Middle Eocene Claiborne floras of the Gulf coast show no close relations to the Chalk Bluffs flora. Nineteen Jackson genera and 13 Claiborne genera are found in the Chalk Bluffs flora, but since all but one of these are also found in the Wilcox flora, the generic resemblance is more indicative of certain climatic than of age similarities. The majority of these genera belong to the Neotropical element which occupies a prominent place in the Jackson and Claiborne floras. The Claiborne seems to embrace a rather wide time interval. The known flora comes from the upper Claiborne deposits, but if a fossil flora could be obtained from the lower Claiborne, this might show a much closer resemblance to the Chalk Bluffs flora.

There are between 27 and 29 genera common to the Wilcox and Chalk Bluffs floras:

Artocarpus	Diospyros	Magnolia
Calyptranthes	Dryophyllum cf. Castanopsis	Nyssa
Carya	Engelhardtia	Oreodaphne cf. Ocotea
Cedrela	Ficus	Persea
Celastrus	Fraxinus	Platanus
Cercidiphyllum	Juglans	Rhamnus
Chrysobalanus	Laurophyllum	Sabalites
Cinnamomum	Leguminosites	Smilax
Cryptocarya	Liquidambar	Zamia?
Dalbergia	Lygodium	

This list represents about 40 per cent of the Chalk Bluffs genera, but the comparison loses some of its significance when it is seen that 10 of these genera also occur in both the Claiborne and the Jackson floras, and that 5 additional genera are found in either the Claiborne or the Jackson. This reduces to 14 (or less) the number of genera shared between the Chalk Bluffs and Wilcox which do not occur in the later Gulf floras. The similarity, however, is probably greater than the number of common genera would indicate. The following list shows identical or related species of the two floras:

Wilcox	Chalk Bluffs
Artocarpus lessigiana	Artocarpus lessigiana
Cercidiphyllum arcticum	Cercidiphyllum elongatum
Cinnamomum postnewberryi	Cinnamomum acrodromum
Dalbergites ovatus	Dalbergia rubra
Dryophyllum tennesseensis	Castanopsis longipetiolatum
Engelhardtia puryearensis	Engelhardtia nevadensis
Ficus mississippiensis	Phytocrene sordida
Ficus myrtifolius	Calyptranthes myrtifolia
Fraxinus wilcoxensis	Fraxinus yubaensis
Inga or Canavalia spp	Inga ionensis
Liquidambar wilcoxianum	Liquidambar californicum
Magnolia leei	Magnolia dayana
Phyllites sp	Nerium hinoidea
Rhamnus marginatus	Rhamnidium chaneyi
Zamia (?) wilcoxensis	Zamites californica

The Wilcox flora was deposited in a more typically lowland environment than the Chalk Bluffs flora, which grew along the western margin of a mountainous area. This would tend to produce a different facies, and thus the significance of floristic similarities between the two floras is heightened. The most striking differences between the Wilcox and Chalk Bluffs floras consist in the presence in the Wilcox of abundant Proteaceae and such genera as *Capparis*, *Metopium*, *Myrcia*, *Apocynophyllum*, and *Sterculia*; and in the Chalk Bluffs of *Chaetoptelea*, *Platanophyllum whitneyi*, *Thouinopsis*, and *Viburnum*. The Wilcox forest might be designated, rather superficially, as a palm-oak(*Dryophyllum*)-soapberry-laurel association with abundant legumes (Berry, 1930a, p. 19). This plant grouping would be characteristic of low, damp, littoral flats. The Chalk Bluffs dominants are *Thouinopsis*, *Cercidiphyllum*, *Platanophyllum*, *Platanus*, and *Liquidambar*, an association more characteristic of river bottoms subject to flooding.

Thus the Chalk Bluffs flora shows a closer resemblance to the Wilcox flora than to the later Claiborne and Jackson floras both in floristic composition and in the stage of evolution, and the differences appear to be due to variation in habitat.

Berry states that "the Wilcox ... finds its closest parallel in the Ypresian floras of southern England and the Paris basin, although it also shows some rather less close affinities with the flora found in the Sparnacian of French geologists, ..." and also, "I suppose that in a general way the Wilcox flora may be correlated with that known as the Fort Union, ..." (ibid., pp. 29-30). These two statements are contradictory. The Wilcox flora is clearly Lower Eocene, although probably not oldest Lower Eocene. The stratigraphic position and composition of the Fort Union flora indicate that it is considerably older than the Wilcox and of Paleocene age.

The large Fort Union flora is now being revised and monographed by Roland W. Brown, of the U. S. Geological Survey, and until his work is available, comparisons based on previous publications must be considered as tentative. A few Chalk Bluffs species appear to be derived from Fort Union forms:

Fort Union	Chalk Bluffs
Celastrus ferrugineus................	Rhamnus calyptus
Cercidiphyllum ellipticum............	Cercidiphyllum elongatum
Credneria (?) daturaefolia...........	Phyllites daturaefolia
Platanus guillelmae..................	Platanus appendiculata
Viburnum antiquum....................	Viburnum variabilis

A small percentage of the Chalk Bluffs species seem to be descended from forms occurring in the late Cretaceous or Cretaceous-Eocene floras of the central and southern Rocky Mountain province, as suggested in the following lists:

Denver-Raton	Chalk Bluffs
Artocarpus lessigiana................	Artocarpus lessigiana
Castanea intermedia..................	Castanopsis longipetiolatum
Cercidiphyllum ellipticum............	Cercidiphyllum elongatum
Cinnamomum sezannense................	Cinnamomum acrodromum
Cissus corylifolia...................	Hamamelites voyana
Ficus planicostata, neoplanicostata..	Mallotus riparius
Juglans denveriana...................	Canarium californicum
Magnolia leei........................	Magnolia dayana
Platanus coloradensis................	Platanus coloradensis
Platanus guillelmae..................	Platanus appendiculata
Rhamnus and Ficus spp................	Rhamnidium chaneyi
Viburnum richardsoni.................	Viburnum variabilis

Medicine Bow	Chalk Bluffs
Cercidiphyllum ellipticum............	Cercidiphyllum elongatum
Ficus planicostata...................	Mallotus riparius
Grewiopsis saportana.................	Viburnum variabilis

The conclusions regarding the age of the flora, reached by means of comparisons with other older Tertiary floras, may be summarized as follows:

1. The Chalk Bluffs flora is shown by its composition and state of evolution to be the oldest of the six well known older Tertiary floras of the Pacific slope.

Table 7

Approximate ages of the floras

Horizon		West coast	Rocky Mountains	Gulf coast
Oligocene	Upper	Bridge Creek Lower Cedarville	Florissant	Vicksburg
	Lower	Weaverville Goshen		
Eocene	Upper	Clarno La Porte Comstock and Steel's Crossing		Jackson
	Middle	Chalk Bluffs	Green River Wind River Yellowstone basic breccia	Claiborne
	Lower		Wasatch	Wilcox
Paleocene			Fort Union Denver-Raton-Animas	Midway
Cretaceous	Upper		Lance-Laramie	

2. The Chalk Bluffs flora exhibits a stronger similarity to the Wilcox flora than it does to the Claiborne or Jackson.
3. There is a slight resemblance to the Wind River flora, but no significant relations with the Green River flora.
4. There is a marked correspondence to the flora of the basic breccias of Yellowstone Park.
5. The flora contains a few species which are closely related to species

found in the late Cretaceous and early Tertiary floras of the central and southern Rocky Mountains.

The Chalk Bluffs flora is therefore older than the middle part of the Upper Eocene, and the evidence indicates that it is older than the Claiborne flora.

There is thus nothing in the relationships of the flora to contradict the assignment of the Ione formation to the Capay stage of the Middle Eocene, and much to substantiate this age determination.

The time differences between various parts of the Tertiary are less than those of preceding ages, and since plants are relatively conservative and do not tend to change rapidly in geologic time, it is usually impracticable to employ a single plant species as an index fossil. The group of dominant species offers a much more certain age indication. Chaetoptelea pseudo-fulva, Persea pseudo-carolinensis, Platanus appendiculata, Quercus nevadensis, Rhus mixta, and Viburnum variabilis are examples of widespread and common forms which are of no value in separating Middle from Upper Eocene floras.

The riparian group comprising Artocarpus lessigiana, Canarium californicum, Ficus densifolia, Gordonia egregia, Phytocrene sordida, Platanophyllum whitneyi, and Thouinopsis myricaefolia may be used as an indicator of the Middle Eocene. In the brackish-water or strand deposits, Castanopsis longipetiolatum, Cinnamomum acrodromum, Phytocrene sordida, Rhamnidium chaneyi, and Rhamnus calyptus as a group mark the Middle Eocene. The Upper Eocene floras are distinguished by abundant Cinnamomum dilleri, Platanophyllum angustiloba, and Pterospermum obliquum, with Cryptocarya praesamarensis, Polyalthia chaneyi, ovate forms of Cercidiphyllum, Tetracera, and Meliosma.

BOTANIC PROVINCES OF THE EOCENE

A comparison of the known Middle Eocene floras of North America gives some evidence concerning the physiographic and botanical provinces of this time. It is a curious fact that there is a greater similarity between the Chalk Bluffs flora and the basic breccia flora of the Yellowstone than there is between the latter flora and the near-by Green River flora. The

Yellowstone flora is either upper Lower Eocene or lower Middle Eocene; it is not younger than the Chalk Bluffs and may be older. It is a typical early Tertiary riparian flora with *Asplenium*, *Lygodium*, *Sequoia*, *Taxodium*, and large leaves of *Castanopsis* (*Dryophyllum*), *Cercidiphyllum*, *Ficus*, *Magnolia*, several species of the Lauraceae and Leguminosae, *Platanus*, *Platanophyllum*, etc. This assemblage denotes a climate similar to that of the Chalk Bluffs, but a little more humid and somewhat cooler. There is little or no evidence of upland, continental conditions. The facts at hand do not warrant any general conclusions, yet it is probable that the warm, humid climate indicated by the Chalk Bluffs flora extended eastward, with some modification, as far as the Yellowstone region.

The flora of the Wind River basin, by reason of the presence of numerous palm leaves, has a warmer aspect than the Yellowstone flora discussed above. It contains *Asplenium*, *Lygodium*, *Ampelopsis*, *Cercidiphyllum*, *Platanus*, *Rhamnus*, etc. This flora is younger than the Yellowstone flora; many of the species of the common genera are different, and related to Green River species, although the presence of "*Aralia*" *notata*, *Ficus mississippiensis*, and *Platanophyllum whitneyi* indicate that it is somewhat older than the Green River.

The Wind River flora has a few elements in common with the Chalk Bluffs, but the composition and general character of the flora are distinct. It shows the beginning of the change toward the specialization and endemism of the Green River flora.

The latter flora is the most individual of the known American Eocene floras. Its most characteristic phase comes from the oil shales of northwestern Colorado, mainly in Garfield County. This appears to be the youngest part of the Green River flora and, as stated in the section on the age of the Chalk Bluffs flora, it may be as young as the lower part of the Upper Eocene. The Green River flora, including the pollen species of Wodehouse, comprises 136 species of spermatophytes assigned to definite genera. Less than a half-dozen of these species are found in other Eocene floras. There are, however, some 25 species closely allied to or identical with species in the Florissant flora. It is a warm-temperate flora, mainly of stream-side and lakeside types, although the work of Wodehouse has shown the presence of many genera of predominantly upland habitat: Abies, Cunninghamia, Engelhardtia, Ephedra, Liriodendron, Pinus, Tsuga, and two genera of the Ericaceae. Approximately 20 of the genera recorded from the Jackson and Claiborne floras are found in the Green River; these are typical stream-side types. Since the Gulf floras include many plants characteristic of coastal plains which would not be found in the Green River flora, the common genera indicate a similarity in composition between the riparian elements of the Gulf coast and Green River floras.

Approximately 15 of the Chalk Bluffs genera occur in the Green River flora, but these are largely from the temperate element of the California flora and form a different group from the genera common to the Green River and Gulf floras. Thus the riparian element of the Green River flora shows a greater correspondence to the Claiborne and Jackson floras. The floristic evidence shows that the Green River flora grew in a warm-temperate basin adjacent to highlands, and that there were either dry periods or near-by dry areas. Species such as Banksites lineatulus, Celtis mccoshii, Eucalyptus ? americanus, Koelreuteria viridifluminis, Lomatia coloradensis, Planera nervosa, Rhus balli, and others, which persisted, with some evolutionary modifications, into the Oligocene or Lower Miocene, form a peculiar element which appears first in this flora. Such a group indicates a certain amount of geographic isolation and the onset of less favorable upland or continental conditions.

About a dozen of the Claiborne genera are found in the Chalk Bluffs flora; nearly all of these are of subtropical coastal-plain or riparian habitat, plants such as are now growing on the Gulf coast, and are also found in the Wilcox and Jackson floras. The Claiborne and Chalk Bluffs floras exhibit significant contrasts in composition, due in part to the coastal strand character of the Claiborne and in part to its later age.

The west coast floras of the Upper Eocene, the Comstock, La Porte, and Steel's Crossing, are conspicuously provincial in character. The absence of marked similarities to the Green River and the contemporary Gulf coast floras indicates the presence of an effective barrier.

The Tertiary floras of Alaska as described by Hollick may include floras whose ages vary from late Cretaceous to Upper Eocene. The flora of Kupreanof Island contains a few species similar to species in the Steel's

Crossing flora, and this fact, taken in connection with the warm-temperate or subtropical affinities of the Kupreanof flora, suggests an extension of the Upper Eocene west coast flora northward to latitude 58°.

Many of the Tertiary florules from the Alaskan mainland and others from western Canada are temperate in aspect, containing a forest association whose dominants are redwood, swamp cypress, alder, hazelnut, elm, and katsura (Chaney, 1936b, pp. 60-62). These floras are in such a state of confusion, both stratigraphically and botanically, that little definite information can be gained by a study of the published material. There is a clear indication, however, of a distinct botanical province in the northwestern part of North America during part or all of the lower Tertiary. This formed a part of the area occupied by the temperate, Holarctic forest made known by the researches of Heer, although the continuity and homogeneity of this northern forest have perhaps been overemphasized. It formed the reservoir from which were drawn the later Tertiary and modern forests of Eurasia and North America. The similarity of the living forests of eastern Asia and the eastern United States testifies to the uniformity of the ancestral forest in northern North America and northeastern Asia.

A provisional statement can now be made concerning the botanical provinces of the Eocene. In the first half of the period, the Pacific coast and Gulf coast were distinct botanical provinces, although there were many common genera. The Rocky Mountain region was a subprovince of the Pacific coast. In the later half of the period, regional differences became more pronounced, and at least four botanical provinces can be discerned: the Gulf coast, the central Rocky Mountain area, the Pacific coast as far north as Kupreanof Island, and a northern area in continental Alaska and western Canada.

SYSTEMATIC DESCRIPTIONS

No key for plant identification has yet been developed which will satisfactorily serve the needs of the paleobotanist. All identifications must be made by laborious comparisons. Naturally, the wider the acquaintance the investigator has with modern and fossil plants, the easier identification becomes. Enough has been said on the subject to convince the most skeptical that, in most cases, satisfactory identifications can be made by means of foliar characters. The additional presence of fruiting material or wood often helps to confirm identification based on leaves. The identification of fruiting material is often extremely difficult, however, particularly where only impressions are available. It is generally true that foliar organs are more stable or conservative in form than fruiting organs, and the difficulty of identifying fossil seeds or fruits is enhanced by the rapid changes in those organs in geological time. Identification of the Chalk Bluffs flora has been in progress for a period of over six years, yet a few forms still remain to be classified.

The writer has striven not to overspeciate and perhaps has erred in the other direction. The present trend in paleobotany is away from the philosophy of classification held by Knowlton and Hollick, who believed that fossil forms should be given specific rank on the basis of small variations in character, and who paid little attention to corresponding variations in living material. Wherever possible, the writer has tried to make the species a botanical entity rather than a paleobotanic form. This is illustrated by the _Acer_ leaves and fruits, of each of which only one kind was found. Since both fruits and leaves have a general similarity to the corresponding organs of the living _Acer rubrum_, and since only one form of each is present, it is safe to conclude that they represent only one botanic species rather than two.

Identifications were based only on comparisons with living or fossil material. In no case were ecological considerations given weight in the choice between two living forms as modern representatives of fossil plants. One of the most important contributions made by the paleobotanist is the reconstruction of past environments. If identifications are based on ecology, and then ecology is deduced from identified species, the result is a kind of cyclic reasoning which may lead to considerable error.

Ecological considerations were, however, of help in identification in the following way. It was seen at first, on the basis of a few obvious forms identified, that the fossil flora indicated a humid, subtropical climate. This ruled out all the cool-temperate and dry modern floras, in the search for corresponding living forms. As identification progressed, it was seen that the existing representatives of the fossil plants inhabited two areas: southeastern North America, including Mexico and Central America, and southeastern Asia. Comparisons were then practically confined to the floras of these two regions, omitting Africa, Australia, the Pacific Islands, and other areas.

Family SCHIZAEACEAE

Genus **LYGODIUM** Swartz

Lygodium kaulfussii Heer

Lygodium kaulfussii Heer, Beiträge zur nähern Kenntniss der sächsisch-thüringischen Braunkohlen Flora, p. 3, pl. 8, fig. 21; pl. 9, fig. 1, 1861.

Berry, U. S. Geol. Surv. Prof. Paper 92, p. 39, pl. 3, figs. 1, 5, 1924.

Berry, U. S. Geol. Surv. Prof. Paper 165, p. 64, pl. 7, figs. 2, 3, 1931.

This characteristic Eocene fossil fern is abundant at Buckeye Flat, although the material is fragmentary. The species is also abundant in the Wind River Basin flora. The fossil leaves with their 3 to 5 slender, elongate lobes exhibit a close similarity to the leaves of Lygodium circinnatum Swartz, now growing in southern China and adjacent subtropical and tropical regions.

Occurrence. Buckeye Flat, locality 104.

Collection. U. C. Mus. Pal., Paleobot. Ser., no. 2142.

Family CYATHEACEAE

Genus **HEMITELIA** Brown

Hemitelia pinnata, new species

(Plate 10, figure 1)

Description. A portion of a pinna 8 cm. in length, 3.5 cm. in width; pinnatifid, cut into alternate, rhomboid-ovate pinnules or lobes; the dissection deeper toward the rachis; pinna inequilateral, lobes 2.2 cm.

in length below, 1.7 cm. above, width of lobes about 1 cm.; nervation of lobes consisting of a strong midrib and 10 to 14 pairs of lateral nerves originating at an angle of 40° and dividing into two equal branches 1 mm. or less beyond the midrib; texture coriaceous.

Discussion. This fossil appears to be part of the frond of a large tree fern. It is quite similar to the pinnae of certain species of the Cyatheaceae, particularly *Hemitelia grandifolia* Sprengel and *Cyathea divergens* Kunze from the American tropics. There are also resemblances to the common cinnamon fern of the eastern states, *Osmunda cinnamomea* Linnaeus. The fossil from Chalk Bluffs resembles *Asplenium magnum* Knowlton reported from the early Tertiary flora of Yellowstone Park (Knowlton, 1899, pp. 667-668, pl. 79, figs. 5-8), although the pinnules of *Asplenium magnum* are not so large as those of the California specimen and are more deeply pinnatifid. In other ways the leaves are very similar.

Occurrence. Buckeye Flat, locality P3320.

Collection. U. C. Mus. Pal., Paleobot. Ser., holotype, no. 2143.

Family CYCADACEAE

Genus **ZAMITES** Brongniart

Zamites californica, new species

(Plate 10, figures 2, 3, 5)

Magnolia ? *pollardi* Knowlton, U. S. Geol. Surv. Mon. 32, pt. 2, p. 721, pl. 81, figs. 9, 10, 1899.

Description. Leaflets ovate-lanceolate; length 9 to 14 cm., width 2.5 to 3.5 cm.; apex contracted and prolonged into a slender point; base truncate, slightly oblique and concave; sessile; venation parallel; marked by 6 to 8 strong veins irregularly spaced and converging at the apex, these interspersed with more slender veins which disappear toward the point; leaflets usually curved or wrinkled; texture leathery.

Discussion. Although these fossils bear some resemblances to various fossil forms identified as monocotyledonous leaves, the complete absence of a midrib, the form of the base, and the leathery texture strongly suggest the leaflets of various cycads such as *Ceratozamia mexicana* Brongniart or *C. miqueliana* Wendland. The leaflets have never been found attached to a central rachis. This fact might be explained by considering the habitat of living cycads, which are predominantly upland forms, so that an opportunity for fossil preservation of the complete leaf would rarely occur. Although there is some resemblance to the leaves of Agathis alba Foxworthy and certain species of Podocarpus, in these forms the base is constricted to a petiole quite unlike the base of the fossil. The venation and leaf shape also correspond in a general way to those of several species of Iris and certain epiphytic monocotyledons.

The fossils show a marked resemblance to several species of Podozamites, such as P. marginatus Heer (Berry, 1919, p. 55, pl. 6, fig. 1) from the Tuscaloosa formation and P. lanceolatus Braun (Hollick, 1930, p. 46, pl. 8, figs. 2, 4-8) from the Alaskan Tertiary. They also strongly resemble the figures of P. oblongus Lesquereux (1883, p. 28, pl. 1, figs. 10, 11) from the Dakota flora. Berry has described Zamia (?) wilcoxensis from the Wilcox flora (Berry, 1916, p. 169, pl. 114, fig. 2), a form like Zamites californica, and a similar species, Zamia (?) sp. (Potbury, 1935, p. 60, pl. 1, figs. 5, 6), occurs in the La Porte flora.

Occurrence. All localities.

Collection. U. C. Mus. Pal., Paleobot. Ser., cotypes, nos. 2144, 2145, 2146.

Family PALMAE

Genus **SABALITES** Saporta

Sabalites californicus Lesquereux

Sabalites californicus Lesquereux, Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, p. 1, pl. 1, fig. 1, 1878.
Sabalites rhapifolius Potbury, Carnegie Inst. Wash. Pub. 465, II, p. 61, pl. 1, fig. 9, 1935.

Although only fragments of palm leaves have been found at La Porte and Chalk Bluffs, the venation and other characters render it certain that the two species given above are identical. Potbury says, "The most satisfactory match for the fossil is the modern Asiatic species Rhapis flabelliformis L'Heritier; in this species the secondaries and primaries, as well as the character of the cross nervilles, indicate a close relationship."

Occurrence. Buckeye Flat, locality P3320.

Collection. U. C. Mus. Pal., Paleobot. Ser., no. 2147.

Family LILIACEAE

Genus **SMILAX** (Tournefort) Linnaeus

Smilax labidurommae Cockerell

Smilax labidurommae Cockerell, Torreya, vol. 14, p. 135, text fig., 1914.

Impressions of Smilax leaves from Icwa Hill appear to be conspecific with the Florissant species. It is impossible, in many cases, to determine the modern species of Smilax on leaf characters only, and the same is doubtless true of the fossil species. The leaves in the Chalk Bluffs flora are from 6 to 10 cm. in length, broadly ovate, and with cordate or rounded bases, like the leaves of S. pumila Walters, the sarsaparilla vine of the southern states.

Occurrence. Buckeye Flat, locality P3320; Chalk Bluffs, locality P3318.

Collection. U. C. Mus. Pal., Paleobot. Ser., no. 2148.

Family SALICACEAE

Genus **SALIX** (Tournefort) Linnaeus

Salix ionensis, new species

(Plate 12, figure 3)

Description. Leaves lanceolate; length 10 to 14 cm., width 1.7 to 2 cm.; margin finely serrate with apically directed glandular teeth; apex acuminate; base cuneate; petiole heavy, 8 mm. in length; midrib stout, tapered; 12 or more pairs of irregularly spaced secondaries, arising at acute angles, ascending and looping along the margin; a few intersecondaries looping with branches from the secondaries; tertiary venation mainly reticulate but with percurrent crossties perpendicular to the midrib; areolation a fine, reticulate mesh; texture firm.

Discussion. The fossil leaves resemble those of many species of willow, particularly Salix fragilis Linnaeus, native to western Europe, and S. nigra Marshall, the common black willow of the central states.

Salix ionensis differs from all the fossil species noted in the more remote spacing of the secondaries. It is similar to S. cockerell Brown from the Green River (1934, p. 53, pl. 9, figs. 6-10), although that species has more numerous and more closely spaced secondaries.

Occurrence. Buckeye Flat, locality 104; Chalk Bluffs, locality P3345.

Collection. U. C. Mus. Pal., Paleobot. Ser., holotype, no. 2149.

Family JUGLANDACEAE

Genus **CARYA** Nuttall

Carya sessilis, new species

(Plate 10, figures 4, 6)

Description. Leaves odd-pinnate, number of leaflets unknown. Lateral leaflets lanceolate; maximum length 12.5 cm., maximum width 3.5 cm.; margin coarsely serrate except at the base; apex acuminate; sessile; base unequally cuneate, midrib strong, slightly curved; 12 or more pairs of subopposite secondaries, originating at an angle of about 70°, curving upward and looping at the margin, tertiary branches entering the teeth; intersecondaries prominent; tertiary venation percurrent; areolation a reticulate network; surface of leaf characterized by uniformly distributed fine dots; texture firm. Terminal leaflets obovate; maximum length 10 cm., maximum width 4 cm.; base narrowly cuneate with a short petiolule 2 to 3 mm. in length; secondaries near the base originating nearly at right angles with the midrib.

Discussion. The form of the lateral leaflets, the large, short-petioled terminal leaflet with its narrowly cuneate base, and the characters of the secondary venation place these fossils in the genus Carya (or Hicoria) rather than Juglans. They are similar to Carya cordiformis K. Koch (Hicoria minima [Marsh] Britton) and also resemble Carya pallida Ashe (Hicoria villosa [Sargent] Ashe).

Carya sessilis is like C. typhinoides (Lesquereux) Condit from Table Mountain, California, but differs in its much larger size and coarser marginal serrations.

Many fossil species of the genus have been recognized from the Tertiary of North America. Some of these have been established on extremely scanty material and others might well be transferred to Juglans. LaMotte has reported abundant fossil leaves of Carya from the Upper Cedarville beds of northeastern California (LaMotte, 1936, p. 116). None of the fossil species described appear to be closely similar to Carya typhinoides with the exception of Hicoria jacksoniana Berry (1924, p. 155, pl. 34, figs. 6, 7; pl. 50, figs. 1, 2) from the Jackson flora and *Carya elaenoides* Heer (1855-1859, vol. 3, p. 92, pl. 131, fig. 3) from the "Swiss Miocene," which have several points of resemblance.

Occurrence. Buckeye Flat, locality P3320; Chalk Bluffs, locality P3318.

Collection. U. C. Mus. Pal., Paleobot. Ser., cotypes, nos. 2150, 2151.

Genus **ENGELHARDTIA** Leschenault

Engelhardtia nevadensis, new species

(Plate 13, figures 5-7, 9, 10)

Description. Winged fruits with large, deeply four-parted involucre and ovoid nutlets; lobes of the involucre arranged in bilateral symmetry, a large median lobe flanked by two lateral lobes in trident shape with the fourth lobe at the base; median lobe lanceolate-spatulate, apex rounded, length 3 to 6 cm., width 6 to 12 mm.; lateral lobes deviating from the median at an average angle of 50°, oblong to linear, length 2 to 3 cm., width 3 to 6 mm., apex bluntly pointed; basal lobe broadly ovate, truncate below, partly surrounding the nutlet, length 0.9 to 1.4 cm., width (at base) 7 to 13 mm.; venation of the three upper lobes similar, a strong midrib flanked by a pair of weaker, straggling primaries, connected with the midrib by a series of branching secondaries, weak secondaries branching from the lateral primaries and looping along the margin; tertiary venation reticulate; areolation a fine, straggling, reticulate web; nervation of basal lobe a series of short primaries, 5 to 7 or more, arising from the base, branching and looping at the margin, a strong median primary often present; nutlet 4 to 8 mm. in length.

Discussion. The fruits of this species are rather common at all localities except Cherokee Pit. They differ in some degree from the fruits of any of the living species. Various species of *Engelhardtia* inhabit the tropical regions of Asia and North America. The American species are distinct from the Asiatic, since the fruits of the Neotropical species are, on the average, about four times as large as those of the Paleotropical species, and are prominently triveined with a large fourth lobe at the base. Only a few are found in each raceme, in contrast with the large number (up to 40 or 50) in the racemes of the Asiatic species. These differences have led some taxonomists to place the American species in a separate genus called Oreomunnea, but present-day botanists are inclined to combine them under the genus Engelhardtia, a practice which the writer follows. In size these fossil fruits are about halfway between those of the living American and Asiatic species, but the shape of the lobes and their venation definitely relate them to the American forms.

Closely similar winged fruits from the Wilcox flora, Engelhardtia puryearensis Berry (1916, p. 185, pl. 17, figs. 6, 7), have been combined in an interesting restoration (ibid., p. 185, pl. 19, figs. 1-3, 5) with associated fossil leaflets called E. ettingshauseni Berry (1930a, p. 61). The type specimen of E. puryearensis in the U. S. National Museum strongly resembles the California fossils, and if it were well preserved, the identity of this species with the California form might be established. As it is, the imperfect nature of the Wilcox fossil renders a definite correlation uncertain. A somewhat different type of Engelhardtia fruit which is also found in the Wilcox, E. mississippiensis Berry (1916, p. 183, pl. 17, fig. 1), is more like the living Asiatic forms. Similar to this is E. jacksonensis Berry (1924, p. 153, pl. 28, fig. 5) from the Upper Eocene Jackson flora. The latest appearance of the genus in the American Tertiary consists of fruits which have been recently discovered in the Bridge Creek flora of Upper Oligocene age, and in the Latah formation of Idaho (Brown, 1940, p. 349, fig. 10).

Fossil fruits of the genus, similar to those of living Asiatic species, are common in the earlier Tertiary of Europe (Reid and Chandler, 1926, pp. 87-92), but none of these closely resemble the California fossils. Berry has likened E. puryearensis to E. macroptera (Brongniart) Saporta, but this latter species is much closer to E. mississippiensis.

Occurrence. All localities.

Collection. U. C. Mus. Pal., Paleobot. Ser., cotypes, nos. 2155, 2156, 2157, 2158, 2159.

Family BETULACEAE

Genus **ALNUS** (Tournefort) Linnaeus

Alnus operia, new name

(Plate 12, figure 7)

Quercus goepperti Lesquereux (not Alnus goepperti [Unger] Goeppert), Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, p. 7, pl. 2, fig. 11, 1878.

Description. Leaves oblong to lanceolate; length 4.3 to 9 cm., width 1.2 to 3.5 cm.; margin doubly serrate, widely spaced primary dentations at the extremities of the secondaries, 3 to 5 small, irregular dentations between; apex acute, broadly cuneate; petiole strong, maximum length 1.2 cm.; midrib strong; 9 pairs of subopposite to alternate secondaries, diverging at varying angles, from 70° at the base to 50° in the middle of the leaf, nearly straight, often bifurcated near the margin, craspedodrome to the primary dentations or looping when bifurcated; tertiary venation composed of percurrent crossties except near the margin, where the tertiary veins loop and form a coarse reticulation; areolation a fine network; texture firm.

Discussion. Only three recognizable specimens of this species have been found, and these are from the Chalk Bluffs area. There is a close similarity between the fossil leaf impressions and the leaves of the living Alnus formosana (Burkhill) Makina from Formosa and A. japonica Siebold and Zuccarini from Japan and adjacent China. There is also an interesting resemblance to the leaves of the American A. maritima Nuttall, which is now restricted to two isolated areas, one along the Red River in southern Oklahoma and adjoining Texas, and the other in Delaware. Alnus formosana and A. maritima are closely related and some botanists consider them the same species. Alnus relatus (Knowlton) Brown (1937, p. 170, pl. 49, figs. 1-6) from the Latah formation is similar to the Chalk Bluffs Alnus and is doubtless the later Tertiary descendant of the California species.

Occurrence. Chalk Bluffs, localities P3325, P3345.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotype, no. 2167.

Family FAGACEAE

Genus **CASTANOPSIS** Spach

Castanopsis longipetiolatum, new combination

(Plate 11, figures 1, 2)

Dryophyllum longipetiolatum Knowlton, U. S. Geol. Surv. Mon. 32, pt. 2, p. 710, pl. 88, figs. 6, 7, 1899.
Hollick, U. S. Geol. Surv. Prof. Paper 182, p. 104, pl. 42, fig. 5, 1936.

Description. Leaves long-lanceolate; length 9 to 16 cm., width 2.5 to 4 cm.; margin entire or broadly crenate in the lower third of the leaf, becoming strongly dentate apically; apex acute; base narrowly cuneate; petiole of medium strength, 1.2 to 3 cm. in length; midrib strong; 12 to 20 pairs of secondaries, commonly opposite or subopposite, originating at an angle of approximately 60° in the central part of the leaf, more acutely disposed basally, regularly convex and subparallel, camptodrome in the lower part of the leaf, entering the marginal dentations apically; tertiary venation quadrangular-reticulate with scattered percurrent cross-ties, intersecondaries well marked; areolation a fine, polygonal network; texture coriaceous.

Discussion. In the collection of fossil plants from Yellowstone Park at the University of California there are impressions of "Dryophyllum" leaves which exhibit no characters by which they can be distinguished from the Chalk Bluffs fossils. This species is abundant at Iowa Hill and Cherokee Pit and rare or absent at other localities. The fossil leaves are so similar to the leaves of several living oriental species of Castanopsis, such as C. fissa Rehder and Wilson, C. calathiformis Rehder and Wilson, C. indica A. de Candolle, and C. fargesii Franchet, from southern China, that the original generic assignment has been changed.

Castanopsis longipetiolatum appears to be intermediate between Dryophyllum tennesseensis Berry (1916, p. 191, pl. 19, fig. 6; pl. 20, figs. 1-3; pl. 22, fig. 2. 1930a, p. 19), one of the dominants in the Wilcox flora, and D. brevipetiolatum Berry (1924, pp. 157-158, pl. 28, fig. 11; pl. 31) from the Jackson and Claiborne floras, in number and spacing of secondaries, length of petiole, and length of lamina. It is not possible to decide, without examining the original material, just how many of the nominal species of Dryophyllum would be more appropriately designated as Castanopsis or Quercus.

Castanopsis longipetiolatum is much like Quercus bockéei Dorf (1933, p. 84, pl. 9, figs. 1-3) from the California Pliocene, the only consistent difference being the greater length and more narrow form of the Eocene species.

Many species of Dryophyllum have been described from the Eocene of Europe, of which D. dewalquei Saporta and Marion (1873, p. 37, pl. 2, figs. 1-6; pl. 3, figs. 1-4; pl. 4, figs. 1-4), D. curticellense (Watelet) Saporta and Marion (ibid., p. 42, pl. 1, fig. 5), and D. palaeocastanea Saporta (1868, p. 61 [349], pl. 5, figs. 4-6) appear to be the most common. At the majority of localities at which the leaves of this genus are found, the associated plants indicate that Dryophyllum (in part Castanopsis?) was a lowland type, frequenting the banks of streams and littoral sands (Berry, 1916, p. 81). The deposits at Cherokee were not far from the mouth of the ancient stream, and the dominance of Castanopsis at that locality parallels the occurrence of Dryophyllum in the Wilcox flora.

Occurrence. All localities.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotypes, nos. 2152, 2153.

Genus QUERCUS Linnaeus

Quercus distincta Lesquereux

(Plate 11, figures 3, 5)

Quercus distincta Lesquereux, Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, pp. 6-7, pl. 2, figs. 7-9, 1878.

Description. Leaves ovate; length 5.5 to 9 cm., width 3 to 5 cm.; margin remotely sinuate-dentate, except near the base; apex acute or rounded; base rounded; petiole 2 cm. in length in the larger specimens; midrib strong; 6 or 7 pairs of irregularly spaced secondaries, originating at angles of 40° to 45° in the central part of the leaf, pursuing a comparatively straight course to the margin, where they enter the teeth, the first one or two secondaries above the base at wide angles, thin, straggling, and camptodrome, the stronger secondaries above usually with several abaxial camptodrome branches; tertiary venation irregularly percurrent; areolation a coarse reticulate network of quaternary veins enclosing a fine, even mesh of small veinlets; texture coriaceous.

Discussion. Lesquereux's figures show the larger characters of the fossils clearly. The leaves of Quercus distincta are like those of the California live oak, Q. agrifolia Née. The only noticeable difference is the more definitely percurrent nature of the tertiary venation and the straighter secondaries in the fossil leaves. Quercus distincta was evidently an evergreen oak with heavy-textured leaves and probably similar in its habitat requirements to the living live oaks Q. wislizenii A. de Candolle and Q. agrifolia.

Occurrence. Buckeye Flat, locality P3320; Independence Hill, locality 42; Chalk Bluffs, localities P3345, P3318.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotypes, nos. 2160, 2161.

Quercus eoxalapensis, new species

(Plate 12, figures 2, 6)

Description. Leaves lanceolate to ovate-lanceolate; length 7 to 12 cm., width 2.5 to 4 cm.; margin coarsely spinose-dentate; apex acuminate or acute; base narrowly rounded to cuneate; petiole slender, midrib slender; 10 to 12 pairs of opposite to alternate secondaries originating at angles of 55° to 65°, proceeding straight to the marginal dentations, often exhibiting a strong marginal branch which loops with tertiaries from the secondary above; tertiary venation percurrent to quadrangular-reticulate; areolation a strong quadrangular mesh; texture coriaceous.

Discussion. These impressions of oak leaves are similar to the fossils called Quercus pregrahami from the Weaverville formation. They differ in their much more conspicuous dentation and the closer spacing of the secondaries. The fossil oak appears to have been related to the Acutifoliae group of Mexican living oaks as outlined by Trelease (1924, p. 197), since the leaves show so many similarities to the foliage of Q. canbyi Trelease, Q. grahami Bentham, and Q. xalapensis Hooker and Bentham.

Occurrence. Buckeye Flat, locality P3320.

Collection. U. C. Mus. Pal., Paleobot. Ser., cotypes, nos. 2165, 2166.

Quercus nevadensis Lesquereux

(Plate 12, figure 1)

Quercus nevadensis Lesquereux, Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, p. 5, pl. 2, figs. 3, 4, 1878.
Potbury, Carnegie Inst. Wash. Pub. 465, II, p. 62, pl. 1, figs. 4, 8, 11, 1935.

These fossils are particularly abundant at Buckeye Flat, where they are associated with Chaetoptelea pseudo-fulva, Thouinopsis myricaefolia, and Liquidambar californicum. They are similar to the leaves of the living Quercus glauca Thunberg and Q. hainanensis Merrill now living in southeastern Asia, but differ in minor characters from the leaves of any of the living oaks so far examined. They are closely similar to the leaves of certain Asiatic species of Castanopsis and may possibly represent fossils of that genus.

Occurrence. All localities.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotype, no. 2162.

Family ULMACEAE

Genus **CHAETOPTELEA** Liebmann

Chaetoptelea pseudo-fulva, new combination

(Plate 14, figures 4-10)

Ulmus pseudo-fulva Lesquereux, Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, p. 16, pl. 4, fig. 3, 1878.

Description. Leaves oblong-ovate, widest below the middle; length 5 to 14 cm., width 2.5 to 6 cm.; margin commonly single-serrate, but rarely biserrate or triserrate; apex inequilateral; petiole slender, 1 to 1.5 mm. in length; midrib strong; secondaries numerous, subparallel, craspedodrome, sometimes bifurcating near the margin, originating at an angle of approximately 45°; tertiary venation reticulate, tertiaries thin but dense; areolation an extremely fine network; texture coriaceous.

Discussion. Lesquereux likened the leaf impressions to the leaves of Ulmus fulva Michaux. In reality they differ considerably from the leaves of that species. The fossil impressions are comparatively slender and nearly equilateral, with rather fine serrations, and are similar in many ways to the leaves of Chaetoptelea mexicana Liebmann (Ulmus mexicana Planchon), the only perceptible difference consisting in the somewhat wider spacing of the secondaries in the fossil. The resemblance is heightened by the presence of numerous small wingless fruits, tipped with remnants of the two-pronged style, which are exactly like fruits of Chaetoptelea mexicana.

Occurrence. All localities.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotypes, nos. 2168, 2169, 2170, 2171, 2172, 2173, 2174.

Family MORACEAE

Genus **ARTOCARPUS** Forster

Artocarpus lessigiana (Lesquereux) Knowlton

(Plate 15; plate 16, figure 1)

Artocarpus lessigiana (Lesquereux) Knowlton, Science, vol. 21, no. 519, p. 24, 1893.
Ball, Bull. Agric. and Mech. Coll. Texas, ser. 4, vol. 2, no. 5, pp. 52-56, 1931.
Artocarpus californica Knowlton, Science, vol. 21, no. 519, pp. 24-25, 1893.
Artocarpus pungens (Lesquereux) Hollick, Louisiana Geol. Surv., Rept. for 1899, special rept. 5, p. 281, pl. 38, figs. 1, 2, 1899.

This species was referred by Knowlton to Artocarpus californica with the statement that it might be identical with A. lessigiana (Lesquereux) Knowlton. With the additional material now at hand it is clear that the relationship of this fossil species is with both A. pungens and A. lessigiana. The specimens from Independence Hill correspond to the figure of A. pungens given by Berry in his paper on the Wilcox flora (1916, pl. 25). The writer follows Ball in his belief that the two fossil species mentioned are not distinct. This is rendered the more certain by consideration of the great variation in the leaves of the living Artocarpus incisa Förster (A. communis), which shows a marked similarity to the fossil species. The difficulty experienced by paleobotanists in the separation of *A. lessigiana* and *A. pungens* is illustrated by the variety of leaf forms referred to each species. The correspondences of the fossils from Nevada County to those ascribed to *A. pungens* from the Wilcox (Berry, 1930a, pl. 9, figs. 1-3), Animas (Knowlton, 1924, pl. 12), and Denver (Knowlton, 1930, pl. 31) floras do not warrant their separation as a new species.

Occurrence. Independence Hill, locality 42.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotypes, nos. 2175, 2176.

Genus **FICUS** (Tournefort) Linnaeus

Ficus densifolia Knowlton

(Plate 16, figures 3-5)

Ficus densifolia Knowlton, U. S. Geol. Surv. Mon. 32, pt. 2, p. 712, pl. 89, fig. 1; pl. 90, figs. 1, 2; pl. 91, fig. 1, 1899.

Description (modified from Knowlton). Leaves ovate to oblong-lanceolate; length 8 to 20 cm., width 3.5 to 5 cm.; inequilateral; apex acute; base rounded-cuneate to incipiently cordate; petiole short, heavy, length 0.5 to 1.5 cm.; margin entire or undulate; midrib heavy; a lower pair of secondaries occasionally present just above the base, arising at an angle of approximately 40° and curving upward just within the margin; 7 to 9 pairs of secondaries, opposite at the base, varying to alternate above, irregularly spaced and at varying angles, the angle becoming larger toward the apex, strongly curved upward and looping along the margin, sometimes branching at right angles to form broad loops; tertiary venation irregular, scattered crossties and varied branching producing large quadrangular meshes; areolation a strong quadrangular network; texture coriaceous.

Discussion. Leaf impressions of *Ficus densifolia* in association with those of *Viburnum* and *Platanus* are common at Buckeye Flat and at Iowa Hill. This species furnishes one of the links between the Yellowstone and Chalk Bluffs floras, since it is a common form in both, and particularly characteristic; known only from these two floras.

The leaves of the existing Ficus pisocarpa Wallich, native to tropical southeastern Asia, correspond to the fossil impressions in all the characters of venation and leaf form. A related living species from the same region, F. parietalis Blume, is also closely similar to the fossil in leaf characters.

Occurrence. Buckeye Flat, locality 104; Chalk Bluffs, locality P3318.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotypes, nos. 2179, 2180, 2181.

Ficus goshenensis Chaney and Sanborn

(Plate 17, figure 3)

Ficus goshenensis Chaney and Sanborn, Carnegie Inst. Wash. Pub. 439, p. 66, pl. 6, figs. 1, 3, 4, 1933.
Potbury, Carnegie Inst. Wash. Pub. 465, II, p. 64, pl. 2, fig. 1, 1935.

Fragmentary leaves of this species are common in association with leaves of Platanus and Viburnum at Buckeye Flat and Iowa Hill.

Occurrence. Independence Hill, locality 42; Buckeye Flat, locality 104.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotype, no. 2182.

Family NYMPHAEACEAE

Genus **NELUMBIUM** Jussieu

Nelumbium lacunosum, new species

(Plate 12, figure 5)

Description. An impression of the upper surface of the fruiting receptable, ovoid in outline, 3 cm. in maximum diameter, marked by irregular concentric rows of depressions.

Discussion. This fossil appears to be the impression of an immature receptable similar to that of Nelumbo lutea (Willdenow) Persoon of the eastern states, the common yellow pond lily.

Occurrence. Independence Hill, locality 42.

Collection. U. S. Nat. Mus., holotype, no. 40237.

Family CERCIDIPHYLLACEAE

Genus **CERCIDIPHYLLUM** Siebold and Zuccarini

Cercidiphyllum elongatum Brown

(Plate 12, figure 4; plate 13, figures 1-4; plate 14, figures 1-3)

Cercidiphyllum elongatum Brown, Jour. Paleontol., vol. 13, no. 5, pp. 494-495, pl. 55, figs. 1-5, 1939.
?Trochodendroides zaddachi (Heer) Sanborn, Carnegie Inst. Wash. Pub. 465, I, pp. 16-17, pl. 3, fig. 2, 1935.
Populus zaddachi Heer; Lesquereux, Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, p. 11, pl. 8, figs. 1-8, 1878.
Zizyphus microphyllus Lesquereux (Zizyphus californicus Knowlton and Cockerell), ibid., p. 28, pl. 8, fig. 9.
Zizyphus piperoides Lesquereux, ibid., p. 28, pl. 8, figs. 10, 11.
Zizyphus sp. Knowlton, Jour. Geol., vol. 4, p. 890, 1896.

This species is one of the dominants in the Chalk Bluffs flora. It occurs wherever leaf fossils are found and forms about one-eighth of all the leaf impressions collected. Impressions of the characteristic fruits (Leguminosites [?] arachioides Lesquereux) and tiny winged seeds are also known from all the localities which furnish leaf impressions. Apparently the same species has been reported from the Upper Eocene Comstock flora, and a closely similar species is also common in the Steel's Crossing flora. It is probable that the species from Steel's Crossing is distinct from that at Chalk Bluffs, since the leaves are commonly ovate rather than elongate-ovate and the marginal dentations display a considerable variation not shown in the numerous leaves from the Chalk Bluffs flora. Brown has shown that leaves of Cercidiphyllum or a closely related genus are among the most common and widespread fossils in the Tertiary floras of North America, from the Eocene to Lower Miocene, where it has been variously known as Populus, Zizyphus, Grewiopsis, or Trochodendroides. A similar leaf form appears in the Wind River Eocene and was named Grewiopsis wyomingensis Berry (1930b, pp. 73-74, pl. 13, figs. 1, 2) and probably also Zizyphus wyomingensis Berry (ibid., pl. 11, figs. 6, 7). This or a closely similar leaf form appears in the Yellowstone flora, where it is called Populus xantholithensis Knowlton (1899, p. 695, pl. 85, figs. 1, 2) and Zizyphus serrulatus Ward (ibid., p. 740, pl. 101, figs. 4, 5).

Grewiopsis tennesseensis Berry (1930a, p. 106, pl. 16, figs. 1-4) from the Wilcox flora also appears to be closely similar to Cercidiphyllum elongatum.

Occurrence. All localities.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotypes, nos. 2183, 2184, 2185, 2186, 2187, 2188, 2189.

Family MENISPERMACEAE

Genus **HYPERBAENA** Miers

Hyperbaena diforma Potbury

(Plate 17, figures 1, 2)

Hyperbaena diforma Potbury, Carnegie Inst. Wash. Pub. 465, II, p. 65, pl. 4, figs. 1-4, 1935.

A comparison of material from Chalk Bluffs with the type specimens of the La Porte flora shows that Hyperbaena diforma is present in the Chalk Bluffs flora. Some of the impressions from Chalk Bluffs differ in that the outer pair of primaries is more weakly developed. In other respects the correspondence is exact. The fossil leaves are similar to those of H. smilacina Standley, now living in Central America, and to H. hondurensis Standley from the eastern hill country of Honduras. There is also a marked similarity to the leaves of various species of Abuta.

Hyperbaena diforma has a superficial resemblance to Mallotus riparius and Phytocrene sordida, both ovate, palmately veined leaves, but the character of the nervation is distinct in these forms. Hyperbaena may be distinguished by the following combination of characters: the weak outer pair of primaries; strongly curved secondaries and lateral primaries; not more than 3 secondaries on midrib; usually 4 widely spaced, looping, abaxial secondaries on the lateral primaries; widely spaced, percurrent tertiaries; percurrent crossties between the stronger tertiaries.

Occurrence. Chalk Bluffs, localities P3318, P3345; Independence Hill, locality 42.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotypes, nos. 2191, 2192.

Family MAGNOLIACEAE

Genus **MAGNOLIA** Linnaeus

Magnolia dayana Cockerell

(Plate 18, figure 1)

Magnolia dayana Cockerell, Amer. Naturalist, vol. 44, p. 35, 1910.
Magnolia lanceolata Lesquereux, Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, pp. 24-25, pl. 6, fig. 4, 1878.

Description. Leaves oblong-lanceolate or obovate-lanceolate; length 15 to 22 cm., width 6 to 8 cm.; margin entire; apex acute or obtuse; base narrowly cuneate; petiole stout, 2 to 3 cm. in length; midrib stout; 17 to 20 pairs of subopposite secondaries, originating at an angle of 65° in the middle portion of the leaf, the angle decreasing from base to apex; secondaries branched near the margin or occasionally at about half their length, and anastomosing, forming prominent marginal loops; tertiary venation irregularly percurrent with sinuous crossties; areolation obsolete; texture membranaceous.

Discussion. The impressions of the large leaves of Magnolia are rarely encountered in the fossiliferous clays. Lesquereux likened them to the leaves of M. acuminata Linnaeus, but the resemblance is closer to the leaves of M. tripetala Linnaeus, the umbrella tree of the Appalachians. The fossil impressions differ from the leaves of M. acuminata in the tendency to oblanceolate forms and in the strongly decurrent base and sinuously percurrent tertiaries.

Magnolia dayana has a close resemblance to M. leei Knowlton as described from the Raton (Lee and Knowlton, 1917, p. 313, pl. 81, fig. 2) and Wilcox (Berry, 1916, p. 215, pl. 43, figs. 1, 2) floras.

Occurrence. Chalk Bluffs, locality P3318.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotype, no. 2193.

Family LAURACEAE

Genus **CINNAMOMUM** (Tournefort) Linnaeus

Cinnamomum acrodromum Potbury

Cinnamomum acrodromum Potbury, Carnegie Inst. Wash. Pub. 465, II, p. 65, pl. 5, figs. 6, 8, 1935.

This characteristic species from La Porte, Plumas County, occurs sparingly at Buckeye, Chalk Bluffs, and Iowa Hill, where it is associated with Viburnum, Platanus, Persea, Platanophyllum, and Rhus. It is easily distinguished by its ovate-lanceolate shape and striking acrodrome primaries extending to the apex.

Occurrence. Buckeye Flat, localities 104, P3320; Chalk Bluffs, locality P3318; Independence Hill, locality 42.

Collection. U. C. Mus. Pal., Paleobot. Ser., no. 2194.

Cinnamomum dilleri Knowlton

(Plate 21, figure 6; plate 23, figure 1)

Cinnamomum dilleri Knowlton, U. S. Geol. Surv. 20th Ann. Rept., pt. 3, p. 47, pl. 4, fig. 1, 1900; U. S. Geol. Surv. Bull. 204, p. 59, 1902.
Potbury, Carnegie Inst. Wash. Pub. 465, II, p. 66, pl. 5, figs. 4, 5, 1935.
Sanborn, Carnegie Inst. Wash. Pub. 465, I, pp. 18-19, pl. 4, figs. 1, 3, 4, 6-8, 1935.

Cinnamomum dilleri occurs at all the localities but is rare in every case. The more ovate leaves with curved secondaries well developed along the abaxial side of the lateral primaries, as in Potbury's (1935) plate 4, figure 1, do not correspond to leaves from living species, and it is probable that this form should be referred to some genus of the Menispermaceae or Tiliaceae. The larger leaves have some resemblance to those of Hyperbaena, but they may be easily distinguished by the acrodrome primaries, the initial upward curve of the veins of tertiary order along the midrib, and the reticulate character of the tertiary nervation.

This species is an abundant and characteristic form in the Comstock, La Porte, and Steel's Crossing floras, all of which are of Upper Eocene age.

Occurrence. All localities.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotypes, nos. 2196, 2197.

Genus **CRYPTOCARYA** R. Brown

Cryptocarya praesamarensis Sanborn

(Plate 21, figure 4)

Cryptocarya praesamarensis Sanborn, Carnegie Inst. Wash. Pub. 465, I, pp. 19-20, pl. 5, figs. 4, 6, 1935.

This characteristic species from the Comstock flora is represented by a perfect leaf and several fragmentary specimens found at Chalk Bluffs.

The fossil leaves have been likened to Cryptocarya samarensis Merrill, now growing in the tropics of southeastern Asia.

Occurrence. Chalk Bluffs, locality P3318.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotype, no. 2198.

Genus **LAUROPHYLLUM** Goeppert

Laurophyllum fremontensis, new combination

(Plate 19, figure 3; plate 20, figure 1)

Laurus fremontensis Berry, U. S. Geol. Surv. Prof. Paper 165b, p. 74, pl. 13, fig. 3, 1930.

Laurus grandis Lesquereux; Knowlton, U. S. Geol. Surv. Bull. 696, p. 345, 1919; U. S. Geol. Surv. Mon. 32, pt. 2, p. 725, pl. 95, fig. 1, 1899 (?)

Although synonymies based on comparisons with figures are subject to error, the relation between the California and Wind River species seems to be particularly well founded. One of the figures of the California species shows more complex marginal looping of the secondaries than in Berry's illustration; otherwise there is no apparent difference. Laurus fremontensis was likened to the leaves of the living Sassafras of the eastern states by its author, but there are such close resemblances to the leaves of other genera of the Lauraceae, such as Cryptocarya, Machilus, and Nectandra, that the noncommittal name Laurophyllum is more appropriate. It is probable, although not certain, that this species also occurs in the Yellowstone flora.

Laurophyllum fremontensis is entirely distinct from Persea pseudo-carolinensis. Distinguishing characters are the strong, closely spaced secondaries and the percurrent tertiary venation. This species is not common at any locality in the Chalk Bluffs flora, although it is widespread.

Occurrence. Buckeye Flat, locality P3320; Chalk Bluffs, locality P3318.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotypes, nos. 2204, 2205.

Laurophyllum litseaefolia, new species

(Plate 18, figures 2, 3; plate 19, figures 1, 2; plate 22, figure 2)

Description. Leaves obovate; length 20 to 22 cm., width 8 to 10 cm.; margin entire; apex acute; base cordate or rounded-cuneate; petiole stout, length 4 to 5 cm.; midrib heavy; 10 to 12 pairs of secondaries originating at angles of 50° in the middle of the lamina, subopposite in the upper part of the leaf, usually irregularly spaced below, occasionally bifurcating at or near the midrib, curving upward and approaching parallelism with the margin, with which they nearly merge, becoming lost in a series of fine loops with tertiary branches from the secondary above; secondaries often bearing several abaxial branches in their outer half which curve sharply upward and loop along the margin; tertiary venation percurrent or angularly reticulate, the crossties zigzag rather than sinuous; areolation a coarse net of sharply angular meshes enclosing a finer network; texture coriaceous.

Discussion. The characters of the fossil leaves described above recall those of the leaves of *Magnolia*, *Fissistigma*, *Polyalthia*, *Uvaria*, *Artocarpus*, and *Persea*. The combination of foliar characters, however, is found only in the leaves of the Lauraceae. The large size, cordate base, and coarse, angular areolation distinguish these fossils from *Persea pseudo-carolinensis* Lesquereux. They have characters in common with the leaves of *Cryptocarya*, *Litsea*, and *Persea*. The bifurcating, irregularly placed secondaries with prominent abaxial branches are often found in the leaves of *Persea*, but the cordate base and coarse areolation are not at all typical of that genus. However, *Phoebe* (*Persea*) *nectandroides* Mez (University of California Herbarium sheet 277989) of southern Mexico shows the greatest similarity in all the details of foliar characters. Species of both *Litsea* and *Cryptocarya* show the cordate base, peculiar areolation, and close approach of the secondaries to the margin. The heavy petiole is characteristic of *Cryptocarya* and *Persea* spp. The sum of all the leaf characters may also be found in the leaves of *Cryptocarya* spp., but not in any one species. The foliage of *C. multipaniculata* Elmer of the Philippines is most similar to the fossil impressions.

Occurrence. Chalk Bluffs, locality P3324; Buckeye Flat, locality P3320.

Collection. U. C. Mus. Pal., Paleobot. Ser., cotypes, nos. 2199, 2200, 2201, 2202, 2203.

Genus **NEOLITSEA** Merrill

Neolitsea lata, new species

(Plate 20, figures 2, 3)

Description. Leaves ovate; length 11 to 14 cm., average width 6 cm.; margin entire; apex acute or blunt; base cuneate; petiole stout, length 1.3 cm.; triple-ribbed, a strong midrib flanked by a pair of acrodrome secondaries arising about 1 cm. above the base at angles of 40°, ascending through two-thirds the length of the lamina, and forming multiple marginal loops with branches from the secondaries next above; 4 additional pairs of distantly spaced, opposite to alternate secondaries arising at angles of 45° to 60°, ascending and looping along the margin; each basal secondary carrying 6 or more irregularly spaced veins on the marginal side which arise nearly perpendicular to midrib, gradually curve upward, and form prominent loops along margin; tertiary venation percurrent; areolation a fine-meshed, reticulate network; texture coriaceous.

Discussion. These leaf fossils were named from their striking resemblance to the leaves of two living species of Neolitsea, N. chuii Merrill and N. ferruginea Merrill, from southern China. They also resemble, to a lesser extent, the entire leaves of the American Sassafras and of Cinnamomum camphora.

There is a similarity between Neolitsea lata and Ocotea eocernua Chaney and Sanborn, but the Goshen fossil is more slender, is generally obovate rather than ovate, lacks the prominent loops on the marginal side of the acrodrome secondaries, and shows a coarser areolation.

Occurrence. Buckeye Flat, locality P3320.

Collection. U.C. Mus. Pal., Paleobot. Ser., cotypes, nos. 2208,2209.

Genus **PERSEA** (Plumier) Gaertner

Persea praelingue Sanborn

(Plate 19, figures 4, 5)

Persea praelingue Sanborn, Carnegie Inst. Wash. Pub. 465, I, p. 20, pl. 6, fig. 1, 1935.
Potbury, Carnegie Inst. Wash. Pub. 465, II, p. 68, pl. 6, fig. 4, 1935.

Leaf impressions of this species occur at Buckeye Flat but are not abundant. They are apparently from a tree closely related to the modern

Persea lingue Nees, since they show all the characters and variation of the leaves of the living species.

Occurrence. Buckeye Flat, locality P3320.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotypes, nos. 2210, 2211.

Persea pseudo-carolinensis Lesquereux

(Plate 21, figures 1-3, 5)

Persea pseudo-carolinensis Lesquereux, Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, p. 19, pl. 7, figs. 1, 2, 1878.
Knowlton, U. S. Geol. Surv. Mon. 32, pt. 2, p. 725, pl. 95, fig. 4, 1899.
Potbury, Carnegie Inst. Wash. Pub. 465, II, pp. 68-69, pl. 6, figs. 2, 3, 1935.
Sanborn, Carnegie Inst. Wash. Pub. 465, I, pp. 20-21, pl. 5, fig. 3, 1935.
Persea princeps Schimper; Condit, Carnegie Inst. Wash. Pub. 476, V, p. 261, 1938.
Persea dilleri Lesquereux, Proc. U. S. Nat. Mus., vol. 11, p. 27, pl. 13, figs. 2-4, 1888.
Laurus similis Knowlton, U. S. Geol. Surv. 20th Ann. Rept., pt. 3, p. 48, pl. 5, figs. 1-4, 1900.

Persea pseudo-carolinensis is one of the abundant species in the flora. The fossil leaves are very similar to the leaves of P. borbonia Sprengel (P. carolinensis Nees) and show all the foliar variations of that species. The leaves are lanceolate to long-lanceolate and vary in length from 6 to 14 cm. The petioles are usually stout and from 1 to 1.6 cm. in length, but rarely they may be extremely short, not more than 5 mm. in length. Potbury has called attention to the resemblance of the fossil to P. podadenia Blake from the living flora of southern Mexico.

Persea pseudo-carolinensis, under various names, has been reported from many western floras, ranging in age from Middle Eocene to Upper Miocene. It is doubtful if the same species really had such a wide distribution in time and space. Some of the later Tertiary forms probably represent another fossil species similar to P. hartwegii Meissner of western Mexico.

Occurrence. All localities.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotypes, nos. 2212, 2213, 2214, 2215.

Family SAXIFRAGACEAE

Genus **HYDRANGEA** (Gronovius) Linnaeus

Hydrangea californica, new species

(Plate 23, figures 2, 3)

Description. Leaves ovate; length 10 to 11 cm., width 4.5 to 5 cm. (apices missing); base broadly cuneate; petiole short, 5 mm. in length; midrib prominent, flexuose; margin finely and regularly dentate; 9 pairs of opposite to alternate secondaries, slender, flexuose, angle of origination varying from 45° near the base to nearly 90° at the apex, strongly convex toward the base, extended along the margin in a series of fine loops; one or more intersecondaries present between each pair of secondaries, originating at right angles and anastomosing with strong tertiaries from the secondary below; tertiary venation flexuous-percurrent; areolation a fine, reticulate network; texture firm.

A sterile flower of Hydrangea, the opposite pairs of sepals unequal; sepals 1.3 to 1.5 cm. long. 1.1 to 1.3 cm. wide; pinnately veined from a strong midrib; incipiently petiolate.

Discussion. Hydrangea californica is most similar to H. fraxinifolia (Lesquereux) Brown from Florissant, Colorado (Brown, 1937, p. 176, pl. 53, figs. 5, 6). The flowers are not distinguishable, but the leaves of the California species are much larger and not so tapered basally, and the marginal dentations are more numerous and uniform. The leaf venation is much the same, and all together the resemblances indicate a rather close relationship. Several fossil occurrences of Hydrangea have been noted from the western Miocene deposits, most of which have been assigned to H. bendirei (Ward) Knowlton, which differs in many details from H. californica. The modern relationships appear to be with such Asiatic species as H. strigosa Rehder.

Occurrence. Chalk Bluffs, locality P3345.

Collection. U. C. Mus. Pal., Paleobot. Ser., cotypes, nos. 2217, 2218.

Family HAMAMELIDACEAE

Genus **HAMAMELITES** Saporta

Hamamelites voyana, new combination

(Plate 11, figure 6; plate 20, figure 4; plate 23, figures 4-6)

Quercus voyana Lesquereux, Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, p. 8, pl. 2, fig. 12, 1878.

Description. Leaves rhombic or broad-ovate in outline, often inequilateral; length 5 to 9 cm., width 4 to 6 cm.; margin crenate or broadly dentate with one to several irregular lobes, unsymmetrically placed; apex rounded or acute; base broadly cuneate to cordate; petiole 5 to 10 mm. in length, of medium strength, expanded toward the base; midrib slender; 5 to 6 pairs of irregularly placed secondaries, originating at an angle of 50° in the middle of the lamina, the two or three lower pairs much stronger than the upper pairs; sometimes one or more weak secondaries at the base; secondaries entering the larger dentations, and with strong, mostly abaxial branches toward their extremities which enter the smaller marginal dentations; tertiary venation reticulate, the tertiary branches leaving the secondaries nearly at right angles; areolation a well-defined network of polygonal meshes; texture coriaceous.

Discussion. The smaller leaf impressions are similar in shape to the leaflets of several species of Rhus diversiloba Torrey and Gray or Ampelopsis cantonensis Planchon, yet the petiole indicates that they are leaves rather than leaflets. They are also similar to the leaves of Cordia alba Roemer and Schultes in shape, margin, and secondary venation, but the tertiary venation and areolation are quite different. The fossils are oaklike in character, with the short, expanded petiole, the irregular lobing, and certain details of venation which match those in the leaves of the California live oaks and related Mexican oaks. It is only to the leaves of Hamamelis, however, that a close correspondence is found. The leaves of H. virginiana Linnaeus are practically identical in all respects with the exception of the petiole, which is heavier in the fossil leaf, and the more reticulate tertiary venation of the fossils. Hamamelis mollis Oliver from warm-temperate China also bears closely similar leaves. Hollick (1936, pp. 122-123) has described a Hamamelis from the Alaskan

Tertiary which has only a slight resemblance to the species from California. In the same publication, however, are figured leaves closely similar to *Hamamelites voyana* under the names *Grewiopsis grandiculus* Hollick (ibid., pl. 87, fig. 1), *Grewiopsis alaskana* Hollick (ibid., pl. 85, fig. 1), and *Quercus platania* Heer (ibid., pl. 44, figs. 5, 6).

Occurrence. Chalk Bluffs, locality P3318; Buckeye Flat, locality P3320.

Collection. U. C. Mus. Pal., Paleobot. Ser., holotype, no. 1897 (Lesquereux's pl. 2, fig. 12); plesiotypes, nos. 2219, 2220, 2221, 2222, 2223.

Genus **LIQUIDAMBAR** Linnaeus

Liquidambar californicum Lesquereux

(Plate 24, figures 2, 3, 6)

Liquidambar californicum Lesquereux, Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, pp. 14-15, pl. 6, fig. 7c; pl. 7, figs. 3, 6, 1878. Potbury, Carnegie Inst. Wash. Pub. 465, II, pl. 6, fig. 5, 1935.

The leaf impressions of *Liquidambar* are everywhere abundant in the fossiliferous clays of the Eocene gravels along the Tertiary Yuba. At Independence Hill the 3-lobed form predominates; at the other localities, 5-lobed forms are most common. The fossils have their modern counterpart in the leaves of *L. styraciflua* Linnaeus, although they are more finely and sharply serrate and less deeply lobed than the foliage of any living species. The leaves were broadly lobed, with wide, shallow sinuses, the length of the lobes beyond the body of the leaf rarely exceeding 3 cm. The 3-lobed forms are like *Liquidambar* leaves from southern Mexico or the juvenile leaves of the Chinese *L. formosana* Hance. The presence of abundant 3-lobed leaf forms directly relates the fossil species to the living variety in Mexico.

The associated fruits differ in some respects from those of the living species. The globose fruiting heads appear to have been borne in loose racemes instead of singly as in the modern forms. The modern *Liquidambar* bears only the staminate flowers in racemes. The characteristic winged seeds, however, are no different from those of the existing American species.

A comparison of fossil specimens shows that occurrences of the early Tertiary California species reported from various western Miocene floras by Berry (1929, p. 235) and others are in error. The Miocene species of Liquidambar are distinct from L. californicum.

The leaves of Acanthopanax ricinifolius (Schlechtendal and Chamisso) Seemann are much like those of Liquidambar, but may be distinguished by their characteristic areolation network and the lack of marginal serrations near the petiole.

Occurrence. All localities.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotypes, nos. 2224, 2225, 2226.

Family PLATANACEAE

Genus **PLATANOPHYLLUM** Fontaine

Platanophyllum angustiloba, new combination

Aralia angustiloba Lesquereux, Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, p. 22, pl. 5, figs. 4, 5, 1878.
Sanborn, Carnegie Inst. Wash. Pub. 465, I, p. 27, pl. 9, fig. 6, 1935.

This species occurs in a small lens at Chalk Bluffs, and rarely at Independence Hill. It is abundant in the Comstock, Clarno, and Steel's Crossing floras, where Platanophyllum whitneyi is absent, and thus may be used as an indicator of the Upper Eocene.

Occurrence. Chalk Bluffs, locality P3324; Independence Hill, locality 42.

Platanophyllum angustiloba serrata, new variety

(Plate 25, figure 2; plate 27, figure 1)

Description. Similar in all characters to Platanophyllum angustiloba except for marginal serrations, numerous but irregularly spaced; secondaries not craspedodrome.

Discussion. Similar variations may be seen in the leaves of Platanus racemosa Nuttall, which may be entire, remotely toothed, or finely serrate, all gradations occurring on the same tree. Another platanoid fossil leaf, Aralia browni, has been described by Berry (1930b, p. 75, pl. 3, fig. 5) from the Wind River Eocene. This differs from the Chalk

Bluffs species in having 5 instead of 9 lobes and in the entire base and sinuses. Berry suggests that _A_. _browni_ may represent the same botanic species as "_Aralia_" _angustiloba_. A comparison of specimens from the two localities, however, indicates that the species are distinct. This variety is also found in the Steel's Crossing flora.

Occurrence. Chalk Bluffs, locality P3345.

Collection. U. C. Mus. Pal., Paleobot. Ser., cotypes, nos. 2227, 2228.

Platanophyllum whitneyi, new combination

(Plate 25, figures 1, 3; plate 26, figure 4; plate 27, figures 2–4)

Aralia whitneyi Lesquereux, Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, pp. 20-21, pl. 5, fig. 1, 1878.
Knowlton, U. S. Geol. Surv. Mon. 32, pt. 2, p. 748, pl. 99, fig. 3, 1899.
Berry, U. S. Geol. Surv. Prof. Paper 165b, p. 76, 1930.

Description. Leaves of large size, nearly equidimensional, ranging in size from a length and width of 8 cm. to 30 cm. in length and 34 cm. in width, average length approximately 20 cm.; fan-shaped in outline, with 5 to 9 symmetrical lobes separated by shallow, V-shaped sinuses not deeper than one-third the length of the leaf, the central lobes rarely bearing one or more pairs of small triangular lobes; base broadly cuneate; petiole short and stout, from one-fourth to three-tenths the length of the lamina; base of leaf usually decurrent for a short distance along the sides of the petiole and occasionally showing a peltate point or the development of two appendiculate bracts, or pseudo-stipular lobes; 3 primary veins, the lateral primaries branching dichotomously from one to three times, the inner and stouter branches of the dichotomy diverging at angles of from 20° to 30° and proceeding straight to the apex of the lobes in outward succession; secondary veins numerous, more closely spaced toward the base of the leaf, originating at an angle of approximately 55° in the central part of the leaf, curving upward and anastomosing by complex loops with secondaries from the adjacent primaries; secondaries in the lobes and along the lateral edges curved nearly parallel with the margin and forming a series of loops with tertiary branches from the succeeding vein; tertiary venation distinct, irregularly percurrent in the lobes and distal portion of the leaf, elsewhere reticulate; areolation a quadrangular mesh of quaternary veins, enclosing an even-meshed, quadrangular network of fifth-order veinlets; texture coriaceous.

Discussion. The original assignment of these leaf impressions to the genus Aralia was prompted by the general correspondence of the shape and lobing to such fossil species as A. affinis and A. notata (Lesquereux, 1878a, p. 237, pl. 34, figs. 2-4), whose reference to the genus in turn was doubtless inspired by their supposed resemblance to the leaves of certain genera of the Araliaceae, since separated as Oreopanax, Tetrapanax, etc. Although the leaves known as Aralia whitneyi have a general resemblance in shape and primary venation to the leaves of Tetrapanax spp., for instance, the finer details of venation are unlike anything found in the Araliaceae. The fossil leaves correspond much more closely to the leaves of certain species of Platanus, particularly Platanus lindeniana Martius and Galeotti and Platanus oaxacana Standley. The characters of the secondary and finer venation are exactly matched by those of Platanus lindeniana. The writer is convinced that "Aralia whitneyi" as well as the other two species of "Aralia" included in the Chalk Bluffs flora are extinct species of Platanus or a closely related genus.

Other species of "Aralia" which appear to be related to Platanus are A. notata Lesquereux, A. coloradensis Knowlton (Lee and Knowlton, 1917, p. 341, pl. 107, fig. 2), A. serrata Knowlton (ibid., pl. 108, fig. 4), A. notata denticulata Berry (1930b, p. 75, pl. 15, fig. 5), and A. wyomingensis Knowlton and Cockerell (Newberry, 1898, p. 121, p. 67, fig. 1).

In discussing Aralia digitata, Ward remarked:

> Recalling the peculiar basal lobes described in one species of Platanus (P. basilobata) and comparing the general character of these leaves with those we are now considering, it is impossible to resist the conviction that the two forms have a close natural relationship. The obvious affinity ... seems to link all the forms having this character into one correlated group ... the presence of basal lobes argues strongly for the reference ... to the Platanaceae ... it may be thought best to distinguish these forms from true Platanus and establish a new genus of that family to be called Protoplatanus ... (Ward, 1887, p. 63).

The characters of the fossil leaves assigned to Platanophyllum whitneyi are allied to those of the living species of Platanus mentioned by a series of intermediate forms. O. M. Ball has recently described a species of Platanus from the Jackson formation of Texas, Platanus rileyi

Ball (1939, figs. 84-88), which shows several features in common with the entire-margined leaves of the existing Platanus lindeniana and with the leaves of Platanophyllum whitneyi and Platanophyllum angustiloba. The pointed stipular lobes, the peculiar dichotomous branching of the primaries, and the characteristic secondary venation are well shown. Platanus basilobata Ward (1885, p. 552, pl. 42, figs. 1-4; pl. 43, fig. 1. 1887, p. 35, pl. 17, fig. 1; pl. 18, figs. 1-3; pl. 19, fig. 1) also has basal lobes similar to those of Platanophyllum whitneyi, according to the figures in Berry's flora of the Whitemud and Ravenscrag formations (1935). The exact systematic position of the plant bearing the leaves called "Aralia" whitneyi must remain in doubt, however, until supplementary evidence of attached fruits is obtained. For that reason the name Platanophyllum is used. These large leaves are one of the abundant and characteristic forms in the Chalk Bluffs flora. They are sometimes matted together in countless numbers in the more carbonaceous clay lenses, and their association with the leaves of Persea and Platanus appendiculata indicates a stream-side habitat.

This typical Chalk Bluffs species is found at several localities in the "basic breccia" flora of Yellowstone Park and is reported by Berry from Crow Heart Butte in the Wind River basin of western central Wyoming. A similar 5-lobed leaf called Aralia republicensis Brown (1937, p. 183, pl. 55, fig. 7) has been identified in the Lower Miocene flora from Republic, Washington.

Occurrence. All localities.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotypes, nos. 2229, 2230, 2231, 2232, 2233, 2234.

Genus **PLATANUS** (Tournefort) Linnaeus

Platanus appendiculata Lesquereux

(Plate 28, figure 4; plate 29, figures 1, 2)

Platanus appendiculata Lesquereux, Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, p. 12, pl. 3, figs. 1-6; pl. 6, fig. 7b, 1878.
Acer vitifolium Al. Braun; Lesquereux, ibid., pl. 7, figs. 4, 5.
Platanus guillelmae Goeppert; Knowlton, U. S. Geol. Surv. Mon. 32, pt. 2, p. 727, pl. 46, fig. 1; pl. 47, fig. 5, 1899.

Lesquereux founded the species appendiculata on the presence of appendiculate bracts, but these are hardly a specific character, since they

occur on the foliage of more than one living species and several extinct species. The leaves of existing species of the genus are extremely variable, on the same tree, and from tree to tree in different situations. There is no reason for believing that the foliage was any more uniform in the past. This variability has resulted in an unfortunate multiplication of fossil species and great uncertainties concerning the characters of various species. Thus the treatment of the genus Platanus in the Cre-

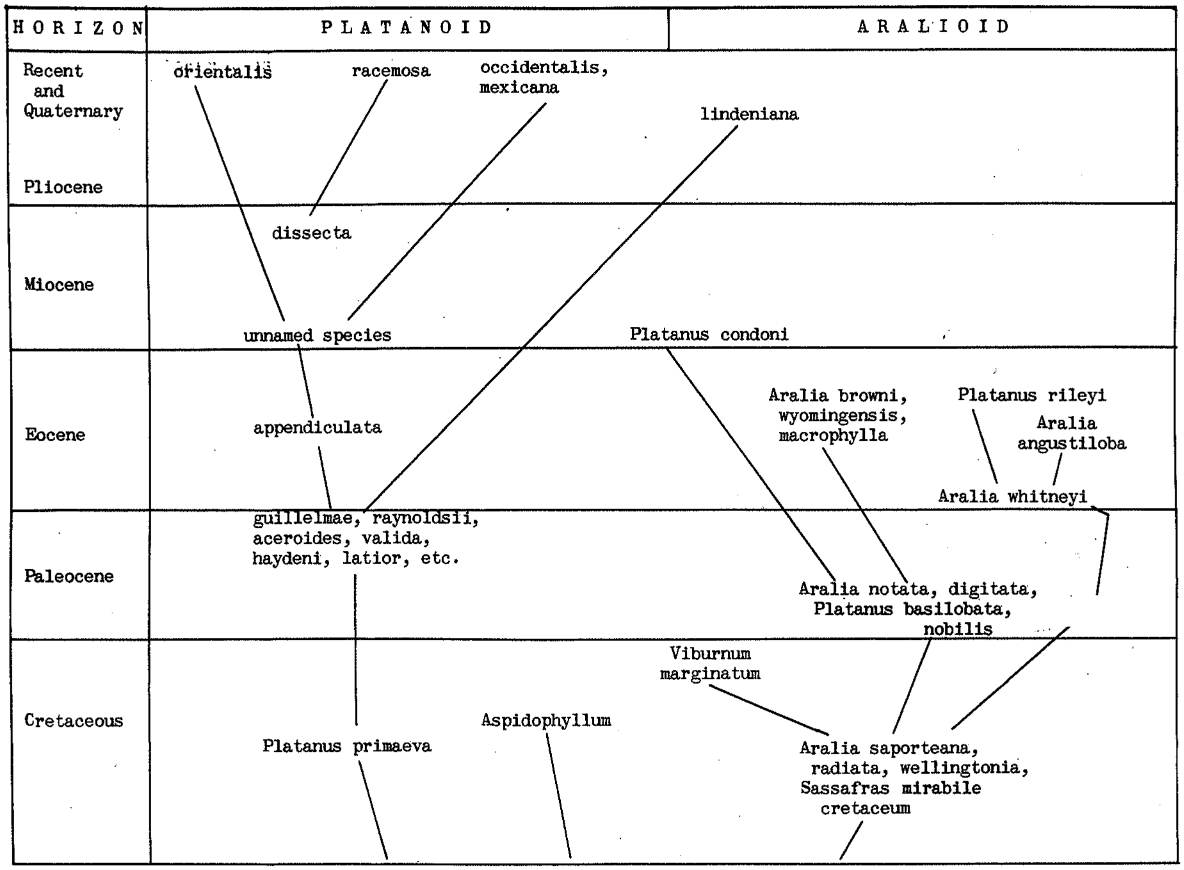


Fig. 5. Foliar relationships of fossil Platanaceae

taceous and Tertiary suffers from apparently unsurmountable difficulties in taxonomy. If any progress is to be made in the naming of fossil leaf species, the variability of the leaves of Platanus must be taken into account and the number of fossil species correspondingly reduced. The only consistent characters which are common to the numerous leaf impressions of Platanus in the Chalk Bluffs flora are a strong tendency to 3-lobed forms, the uniform presence of a cuneate or rounded, rather than cordate, base, and the wide spacing of the marginal dentations. Five-lobed leaves have been found but they are rare. The abundant leaves of Platanus from the "basic breccia" flora of the Yellowstone are like the California specimens in every detail and appear to represent the same

botanic species. There is also a striking resemblance to the fossil leaves of a late Cretaceous and early Tertiary species which is abundant in the Denver, Raton, Arapahoe, Animas, and related formations and variously named by Knowlton as *P. guillelmae*, *P. aceroides*, *P. raynoldsii*, *P. coloradensis*, etc., with varieties. The California species is apparently closely related to this older species from the Denver-Raton floras of the southern Rockies. An examination of the original descriptions and plates and a study of the associated flora show that the specific names *guillelmae* and *aceroides*, which have been widely used for the sycamore leaves of the early Tertiary in North America, should be dropped. Goeppert (1852, p. 492) described four species from the same flora, *rugosa*, *oeynhausiana*, *aceroides*, and *guillelmae*, which, on close study, prove to be the same, and the names must be synonymized as *P. aceroides*. Dominant in the associated flora are *Betula*, *Ulmus*, *Populus*, *Salix*, *Zelkova*, *Taxodium* or *Sequoia*, *Quercus*, *Ceanothus*, etc., a temperate or even cool-temperate assemblage which, according to the sequence of evolution in the western European fossil floras, cannot be older than Upper Miocene. The fossil *Platanus* is modern in aspect and very similar to the living *P. occidentalis* Linnaeus. It appears extremely improbable that a late Tertiary European species associated with a modern, temperate flora could be identical with a late Cretaceous and early Tertiary American species, associated with a generalized, subtropical flora.

Occurrence. All localities.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotypes, nos. 2235, 2236, 2237.

Platanus coloradensis Knowlton

(Plate 27, figure 5; plate 28, figures 1-3)

Platanus coloradensis Knowlton, U. S. Geol. Surv. Prof. Paper 155, pp. 82-83, pl. 37, figs. 1, 2, 1930.

Several examples of this peculiar leaf have been found at Chalk Bluffs, one of which is 20 cm. in length. Their assignment to the genus *Platanus* is not definitely confirmed. The leaves of the oriental teakwood, *Tectona grandis* Linnaeus, have a strong resemblance to *Platanus coloradensis*.

Occurrence. Chalk Bluffs, locality P3318.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotypes, nos. 2238, 2239, 2240, 2241.

Family ROSACEAE

Genus **CHRYSOBALANUS** Linnaeus

Chrysobalanus eoicaco, new species

(Plate 24, figures 4, 5)

Description. Leaves orbicular or round-obovate; length 4 to 6 cm., width 4 to 5.5 cm.; margin entire; apex obtuse or retuse; base cuneate; petiole short, stout, not longer than 2 mm.; midrib stout at the base, gradually narrowed to the apex; 6 to 7 pairs of subopposite to alternate secondaries, originating at angles of 50° to 55° in the central part of the leaf; tertiary venation reticulate, forming a coarse, polygonal network whose individual meshes are elongated and roughly aligned parallel to the secondaries; areolation a fine, reticulate mesh; texture coriaceous.

Discussion. Although they bear a resemblance to certain species of Dalbergia, Mimusops, Canavalia, and Bumelia, the fact that the fossil leaves described above are matched by those of the existing Chrysobalanus icaco Linnaeus in all their characters indicates a close relation to that species. Berry (1916, p. 220, pl. 44, figs. 4, 5) has described a Chrysobalanus from the Wilcox which closely resembles the living Chrysobalanus oblongifolius Michaux, but is different from the California fossil. Chrysobalanus lacustris Brown (1929, pl. 72, fig. 8) from the Green River flora is more similar to the California species.

Occurrence. Chalk Bluffs, locality P3318; Buckeye Flat, locality P3320.

Collection. U. C. Mus. Pal., Paleobot. Ser., cotypes, nos. 2242, 2243.

Genus **VAUQUELINIA** Correa

Vauquelinia exigua, new species

(Plate 30, figures 4, 6)

Description. Leaves ovate-lanceolate; length 3 to 4.2 cm., width 0.5 to 0.6 cm.; margin irregularly serrate or dentate with strong, spinetipped teeth; apex acuminate; base cuneate; petiole slender, 5 to 8 mm. in length; midrib strong; venation streaming reticulate, secondaries and intersecondaries numerous, interlocking with tertiary branches and forming a fine, complex network of meshes elongated parallel to the stronger secondaries (about 8 to 16 pairs), the stronger branches entering the marginal teeth; tertiary network buried in an areolation of fine polygonal meshes; texture coriaceous.

Discussion. This species is founded on three well preserved specimens found at Chalk Bluffs. The fossil resembles the smaller leaves of Vauquelinia corymbosa Correa and V. pauciflora Standley. There is also a likeness to the leaves of Kageneckia spp., although the apex and petiole of leaves of this genus are considerably different. No similar fossil leaves have previously been described.

Occurrence. Chalk Bluffs, locality P3345.

Collection. U.C. Mus. Pal., Paleobot. Ser., cotypes, nos. 2247,2248.

Family LEGUMINOSAE

Genus **DALBERGIA** Linnaeus

Dalbergia rubra, new species

(Plate 30, figure 3)

Description. Leaflet ovate; length 5.5 cm., width 2 cm.; apex extended to a mucronate tip; base cuneate; petiolule stout, 4 mm. in length; margin entire, undulate; midrib moderately strong, prominent on the lower side of the leaf; secondaries numerous, subparallel, closely but irregularly spaced, arising at angles of 60° to 70°, interspersed with numerous intersecondaries, forming a series of complex, elongate loops well within the margin; tertiary venation streaming reticulate, the meshes elongated parallel to the secondaries; areolation a fine reticulate network; texture firm.

Discussion. Dalbergia rubra is known from only three specimens collected at Chalk Bluffs. No previously described fossil species from the Tertiary of North America shows a strong likeness to these leaflets unless it be Dalbergites ovatus Berry from the Wilcox flora. This leaflet differs from *Dalbergia rubra* in the more acute angle of the secondaries and their much closer spacing.

The leaflets of three living species, *Dalbergia densa* Bentham, *D. hupeana* Hance from southern China, and *D. laevigata* Standley from Honduras, show marked resemblances to the fossil leaflets.

Occurrence. Chalk Bluffs, locality P3345.

Collection. U. C. Mus. Pal., Paleobot. Ser., holotype, no. 2249.

Genus DESMODIUM Desvaux

Desmodium indentum, new species

(Plate 30, figure 2)

Description. Leaves trifoliate, the terminal leaflet obovate to rounded-cuneate, the lateral leaflets inequilateral ovate-elliptical. Lateral leaflets 3.5 to 5 cm. in length, 1.5 to 2 cm. in width, terminal leaflet 5 to 8 cm. in length, 4 to 9 cm. in width; apex truncate, retuse or blunt; base wedge-shaped; petiolule abruptly thickened and distinctly villose or shaggy, 0.5 to 0.6 cm. in length; margin, from the mid-point of the leaf upward, sinuate or with small, crenate lobes; midrib stout; 4 pairs of opposite or subopposite secondaries originating at 35° to 55° (the larger angles occurring in the larger leaflets), the lower pair of secondaries seldom branched, the second pair usually stronger, and, with the succeeding pairs, dividing into angular branches distally, the branches entering the sinuses or lobes, or looping within the margin; tertiary venation with widely spaced sinuous crossties in combination with a quadrangular mesh; areolation quadrangular; texture firm.

Discussion. No fossils of this genus have previously been described from the North American Tertiary, although Berry has reported a *Meibomia* (Berry, 1922, p. 11) from the Pleistocene in Tennessee. The fossils here described greatly resemble *Desmodium dasylobum* Miquelon, now living in tropical southeastern Asia, and *D. sequax* Wallich, common in southern China.

Occurrence. Buckeye Flat, locality P3320.

Collection. U. C. Mus. Pal., Paleobot. Ser., holotype, no. 2250.

Genus **INGA** Scopoli

Inga ionensis, new species

(Plate 32, figure 4)

Description. Leaflets oblong-lanceolate, slightly inequilateral; length 5 cm., width 1.7 cm.; apex acute; margin entire; base cuneate; petiolule stout, length 1 mm.; midrib strong, curved; 6 pairs of opposite to alternate secondaries, remotely spaced, originating at angles of 35° to 50°, directly ascending, curved upward and looped just within the margin; tertiaries sparse, percurrent for the most part; areolation obsolete; texture firm.

Discussion. A few of these small leaflets were found at Buckeye Flat. They resemble the leaflets of various genera of legumes native to warm-temperate and tropical America, such as *Cassia*, *Lonchocarpus*, and *Inga*. *Inga ionensis* is similar to *I. puryearensis* Berry (1916, pl. 51, fig. 12) from the Wilcox flora and *I. arkansensis* Berry (1924, p. 62, pl. 10, fig. 13) from the Claiborne flora. There is also a close similarity to *Lonchocarpus oregonensis* Sanborn (1935, p. 21, pl. 6, fig. 8) from the Comstock flora of Oregon. The Chalk Bluffs leaflets differ from the Comstock fossils in the fewer and more remote secondaries, but it is probable that the two forms are closely related.

Occurrence. Buckeye Flat, locality P3320.

Collection. U. C. Mus. Pal., Paleobot. Ser., holotype, no. 2253.

Genus **PONGAMIA** Ventenat

Pongamia ovata, new species

(Plate 30, figures 1, 7, 8)

? *Magnolia californica* Lesquereux, Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, p. 25, pl. 6, fig. 7 only, 1878.

Description. Leaflets ovate; length 7 to 12.5 cm., width 4 to 7 cm.; margin entire; apex acute to obtuse or incipiently mucronate; petiolule short, 4 to 6 mm. in length, stout, inflated, and with horizontal ridges; base rounded or wedge-shaped, usually inequilateral; midrib slender, striated toward the base; 5 to 7 pairs of subopposite or alternate secondaries, slender, flexuose, strongly convex proximad, forming strong marginal loops with branches from the next succeeding secondary; tertiary venation reticulate and anastomosing, forming a mesh whose spaces are elongated perpendicular to the midrib, scattered sinuous crossties present; areolation an irregular, reticulate coarse mesh; texture firm.

Discussion. The peculiar reticulate tertiary venation, in connection with the inflated and ridged petiolule, indicates that these impressions are leaflets of a legume. They resemble most closely the leaflets of Pongamia pinnata (Linnaeus) Merrill from southern China, although there are also correspondences with the leaflets of Dalbergia (Amerimnon), Lonchocarpus, and Ormosia. Dalbergia ovata MacGinitie (1937, p. 142, pl. 8, fig. 4) from the Weaverville flora of Trinity County is the only previously described fossil species which shows a likeness to Pongamia ovata, but it differs from the Chalk Bluffs species in the heavier midrib and more numerous and more closely spaced secondaries.

The leaf called Magnolia californica Lesquereux appears to be a leaf of this species, but the inferior preservation of the original specimen does not warrant its use as a type, or the use of the species name in a new combination. The leaves from the Comstock flora identified as Magnolia californica (Sanborn, 1935, p. 17, pl. 2, figs. 2-5) differ in length of petiole, behavior of the secondaries, and character of the tertiary venation, and cannot be the same species. They will be renamed in the monograph on the Steel's Crossing flora now in preparation.

Occurrence. Chalk Bluffs, locality P3318.

Collection. U. C. Mus. Pal., Paleobot. Ser., cotypes, nos. 2254, 2255, 2256.

Genus **STRONGYLODON** Vogel

Strongylodon falcata, new species

(Plate 31, figures 1, 3)

Description. Leaflets ovate, bluntly falcate in outline, inequilateral; length 7 to 10 cm., width 4 to 5 cm.; the part of the leaf on the outer side of the midrib approximately twice as wide as that on the inner side; margin entire; apex acute or rounded; base rounded, asymmetric; petiolules not preserved; midrib prominent, slightly bowed; pseudo-palmately 3-veined; 2 lateral secondaries arising at angles of 30°

near the base of the leaf; 4 additional secondaries on the wider side, parallel with the basal secondaries on the narrow side of the lamina; tertiary venation reticulate, forming a coarse quadrangular network; areolation an even-textured reticulate mesh; texture firm.

Discussion. These leaf impressions are obviously the leaflets of a trifoliate legume, such as *Desmodium*, *Pueraria*, *Apios*, or *Calopogonium*. They correspond in every respect to the lateral leaflets of a large climbing legume, *Strongylodon*, inhabiting the tropics of southeastern Asia. There is also a strong resemblance between the fossil leaflets and those of *Calopogonium coeruleum* (Bentham) Hemsley, a tall vine common in the American tropics. The foliage of *Strongylodon macrobotrys* Gray is most similar, but the leaflets of *S. coeruleus* Merrill are also closely similar.

Occurrence. Chalk Bluffs, locality P3318; Buckeye Flat, locality P3320.

Collection. U. C. Mus. Pal., Paleobot. Ser., cotypes, nos. 2257, 2258.

Genus **VOUAPA** Aublet

Vouapa geminifolia, new species

(Plate 31, figures 5, 6)

Description. Leaves bifoliate, composed of two ovate leaflets; length 9 cm., maximum width 3 cm. in the middle of the lamina; leaflets slightly curved or falcate, approximately symmetrical; apex contracted to a bluntly pointed, acuminate tip; base cuneate; petiolule short, stout, 2 mm. in length; margin entire; midrib prominent, smoothly curved; 10 or more pairs of secondaries originating at an average angle of 60°, subparallel, looping well within the margin, interspersed and anastomosing with numerous subsecondaries, forming elongated meshes parallel with the secondaries comprising a reticulate-looped network with complex looping along the margin; areolation a fine reticulate mesh; texture coriaceous.

Discussion. *Hymenaea eocenica* Berry (1930a, pl. 13, fig. 1) resembles these fossils, but the base and shape of the leaflets are quite different, and, since the finer details of venation are not preserved, further comparisons are not possible. There are many living genera which show bifoliate leaflets like the fossils. Among these are *Cynometra*, *Vouapa* (*Macrolobium*), *Cassia*, *Hymenaea*, *Peltogyne*, *Acacia*, and *Leucaena*. The fossils show striking correspondences to species of both *Cynometra* and *Vouapa*, but are closer to *Vouapa bifolia* Aublet. In *Cynometra* the leaflets are rarely as curved as in the fossil, the bases of the leaflets are more inequilateral, and the venation does not show the peculiar reticulate-streaming character of the fossil leaves.

Occurrence. Buckeye Flat, locality P3320.

Collection. U. C. Mus. Pal., Paleobot. Ser., cotypes, nos. 2259, 2260.

Family BURSERACEAE

Genus **CANARIUM** (Rumphius) Linnaeus

Canarium californicum, new combination

(Plate 32, figures 3, 6, 8)

Juglans californica Lesquereux, Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, p. 34, pl. 9, fig. 14; pl. 10, figs. 2, 3, 1878.
Juglans leonis Cockerell, Amer. Jour. Sci., ser. 4, vol. 26, p. 543, 1908.

Description. Leaflets ovate; length 4.5 to 10 cm., width 3 to 4.5 cm.; margin entire or rarely with remote dentations; apex abruptly rounded and prolonged to an acute tip; base asymmetric, rounded on one side, cuneate on the other; petiolule short, stout; midrib strong; 6 to 7 pairs of slender opposite to alternate secondaries, more ascending on the side of the leaf having the cuneate base, originating at angles of 50° to 60° in the middle portion of the lamina, curved upward near the margin, branching and looping with the adjacent secondaries; the lowest pair of secondaries just within and parallel to margin; tertiary venation reticulate, forming small quadrangular meshes, intersecondaries prominent; areolation a quadrangular network of quaternary branches enclosing a fine, reticulate web of veinlets; texture firm.

Discussion. These fossil leaflets are not abundant but are widely distributed in the deposits. They are most similar to the leaflets of *Canarium album* Raeusch now living in southern China (Kwangtung, Hainan, etc.). There is also a strong resemblance to the leaflets of *C. pimela* Koenig from southeastern Asia and *C. laciniatum* Elmer from the Philippines.

The genus has not been recorded as a fossil previously, although certain species of *Juglans*, such as *Juglans denveriana* Knowlton (1930, pl. 12, fig. 2; pl. 13, fig. 2), are closely similar and should probably be referred to the genus *Canarium*.

Occurrence. All localities.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotypes, nos. 2263, 2264, 2265.

Family SIMARUBACEAE

Genus **AILANTHUS** Desfontaines

Ailanthus lesquereuxi Cockerell

(Plate 32, figure 5)

Ailanthus longipetiolata Lesquereux, Rept. U. S. Geol. Surv. Terr., vol. 8, p. 197, pl. 40, fig. 7, 1883.
Ailanthus lesquereuxi Cockerell, Torreya, vol. 27, p. 95, 1927. Brown, U. S. Geol. Surv. Prof. Paper 185c, p. 59, 1934.

The impression of a characteristic fruit of *Ailanthus* which is figured is little, if any, different from the Green River species. The fossil called *Ailanthus americana* Cockerell (1908, p. 539, fig. 3) from the Florissant beds also appears to be identical with the two Eocene species. No leaflets of *Ailanthus* have yet been found in any of these floras. If these are found, it may be possible to differentiate the species, but no separation is possible on the basis of the fruits alone.

Occurrence. Buckeye Flat, locality P3320.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotype, no. 2266.

Family MELIACEAE

Genus **CEDRELA** P. Browne

Cedrela eolancifolia, new species

(Plate 32, figure 2)

Description. Leaflets elongate-ovate; length 9.5 to 11 cm., width 3 cm.; margin entire; apex acuminate; base inequilateral, rounded; petiolule strong, 8 mm. in length; midrib stout; 12 to 13 pairs of subopposite secondaries, originating at angles of 60° to 70°, regularly curved, camptodrome with simple looping along the margin, a few well marked intersecondaries; tertiary venation finely reticulate, merging into a delicate areolation; texture firm to coriaceous.

Discussion. It may be questioned whether a separation of the genera Cedrela and Sapindus can be satisfactorily made in all cases without the presence of fruits or flowers. In general the leaflets of Sapindus differ from those of Cedrela in having: (1) a shorter, stouter petiolule; (2) more numerous secondaries; (3) more numerous and regularly developed intersecondaries; (4) more complex marginal looping of the secondaries. The fossils under discussion correspond to those of Cedrela and cannot be assigned to Sapindus. There is also some resemblance to the leaflets of certain genera of the Burseraceae, but in the leaflets of trees of this family the secondaries are more complexly looped, and the tertiary venation is stronger and more angular. The closest modern form seems to be Cedrela odorata Linnaeus.

Among fossil species the resemblance is closest to C. odoratifolia Berry (1916, p. 255, pl. 57, fig. 7) and C. lancifolia (Lesquereux) Brown (1937, p. 178, pl. 60, fig. 5). There are differences in details between either of these species and the Chalk Bluffs form, although in some respects the latter is intermediate between the two.

Occurrence. Chalk Bluffs, locality P3318.

Collection. U. C. Mus. Pal., Paleobot. Ser., holotype, no. 2267.

Family EUPHORBIACEAE

Genus ACALYPHA Linnaeus

Acalypha aequalis, new combination

(Plate 32, figure 7)

Acalypha serrulata Potbury, Carnegie Inst. Wash. Pub. 465, II, p. 72, pl. 7, fig. 7, 1935.
Betula aequalis Lesquereux, Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, p. 2, pl. 1, figs. 2-4, 1878.

Several well preserved leaves of this species, associated with Platanophyllum whitneyi, Mallotus riparius, and Cercidiphyllum elongatum, were collected from a small clay lens at Chalk Bluffs. Potbury related the fossil leaves to the leaves of Acalypha schlechtendaliana Mueller, a shrub now growing in southern Mexico and Central America from Vera Cruz and Chiapas to Costa Rica.

Occurrence. Chalk Bluffs, locality P3318.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotype, no. 2268.

Genus **MALLOTUS** Loureiro

Mallotus riparius, new name

(Plate 16, figure 2; plate 31, figures 2, 4; plate 33, figures 1-3)

Ficus tiliaefolia (Al. Braun) Heer (not Mallotus tiliaefolia Mueller); Lesquereux, Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, p. 18, pl. 4, figs. 8, 9, 1878.

Description. Leaves variable in size and shape, commonly oval or ovate, often strongly asymmetric; length 4 to 18 cm., width 3 to 14 cm.; margin entire or rarely with one or two pointed lobes as in the leaves of Catalpa; apex acute or extended-acuminate; base broadly cuneate to cordate; petiole long, slender, maximum length 6 cm.; palmately veined, with 3 to 7 primaries; midrib prominent; where 5 to 7 primaries are present, the outer pair usually parallel with the margin, unbranched, the succeeding pair with 7 to 8 abaxial branches, subparallel; the inner pair of primaries often with 2 or more abaxial branches at their outer extremities; 3 to 7 pairs of opposite to subopposite secondaries, parallel to the inner primaries, originating at about 40°, with one or more branches; primaries and secondaries straight except near the margin, where the extremities abruptly curve upward just within the margin and merge with it or loop; tertiary venation strongly percurrent; areolation a quadrangular mesh of quaternary crossties enclosing a finer polygonal mesh of higher-order veinlets; texture firm.

Discussion. The great variability of these leaves would suggest the presence of two species, but such a separation would be purely arbitrary, since the extreme variants are connected by all manner of intermediate forms. The figures illustrate the range of variation in leaf shape. The usual form is the nearly symmetrical nonlobed, ovate leaf. Some of the strongly inequilateral leaves of Mallotus resemble the leaflets of Strongylodon, but the percurrent tertiary venation, close approach of the secondaries to the margin, and long petiole of *Mallotus* allow a separation to be made in all cases. They may be distinguished from *Phytocrene sordida* by the percurrent tertiary venation, and the close approach of the stronger nerves to the margin.

The fossil leaves correspond exactly in all their variations to the leaves of the existing *Mallotus japonicus* Mueller, a small tree widely distributed in the warmer parts of southeastern Asia. They are also similar to the leaves of *M. philippinensis* Mueller, although this latter species does not show the marginal lobes. *Trewia nudiflora* Linnaeus (a genus related to *Mallotus*) bears foliage similar to the fossil leaves, but the tertiary venation is different.

There is a variety of fossil leaf forms variously known as *Ficus planicostata* Lesquereux (Knowlton, 1930, pl. 28, figs. 4, 5), *F. neoplanicostata* Knowlton (Lee and Knowlton, 1917, pl. 74, fig. 3), *F. occidentalis* Lesquereux (1878a, pl. 32, fig. 4), etc., which Berry has synonymized with *F. mississippiensis* Lesquereux (Berry, 1923a, pp. 9-11). These species range from the Laramie (?) to the Green River, but are more common in the Wilcox, Denver, Raton, and related floras. A comparison of the published figures with the Chalk Bluffs fossils and with leaves of the existing *Mallotus* spp. leads to the impression that some of these leaf forms might also be *Mallotus* and not *Ficus*.

Certain figures of *Ficus mississippiensis* (Berry, 1930a, pl. 23) differ considerably from the other forms noted in the synonymy given by Berry, and appear to be much more like leaves of certain genera of the Verbenaceae or Menispermaceae. Dorf has noted this and removed *F. mississippiensis* from the synonymy (Dorf, 1938, pp. 53-55), and all available evidence is in support of his procedure.

Mallotus oregonensis Sanborn (1935, p. 23, pl. 8, fig. 6) is closely similar and may represent the same species. The absence of inequilateral and lobed forms in the Comstock flora indicates that the Chalk Bluffs species is distinct.

Occurrence. All localities.

Collection. U. C. Mus. Pal., Paleobot. Ser., cotypes, nos. 2269, 2270, 2271, 2272, 2273, 2274.

Family CELASTRACEAE

Genus **CELASTRUS** Linnaeus

Celastrus preangulata, new species

(Plate 34; plate 35, figure 3)

Description. Leaves subrotund to broadly cordate; length 11 to 15 cm., width 10 to 15 cm.; margin regularly crenate; apex obtuse; base cordate; petiole comparatively slender, approximately 2 cm. in length; midrib stout, prominent on the lower side of the leaf; 6 to 8 pairs of subopposite to alternate secondaries arising at angles of 70° in the middle part of the leaf, strongly bowed proximad, curving upward and approaching parallelism with the margin in a series of loops formed by tertiary crossties to the next inner secondary; tertiary venation irregularly percurrent, the crossties nearly everywhere perpendicular to the secondaries, tertiary branches forming complex loops within the margin; areolation a reticulate network of various-sized meshes; texture firm.

Discussion. These large leaves from Buckeye Flat are remarkably similar to the leaves of the living Celastrus angulata Maximowicz (C. latifolius Hemsley), a scandent shrub inhabiting western and central China. They are unlike any of the various species of Celastrus described from the American Tertiary.

Occurrence. Buckeye Flat, locality P3320.

Collection. U. C. Mus. Pal., Paleobot. Ser., cotypes, nos. 2276, 2277.

Family ICACINACEAE

Genus **PHYTOCRENE** Wallich

Phytocrene sordida, new combination

(Plate 35, figure 2; plate 36, figure 3)

Ficus sordida Lesquereux, Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, p. 17, pl. 4, figs. 6, 7, 1878.

Description. Leaves round-ovate; length 9 to 13.5 cm., width 9 to 12 cm.; margin shallowly crenate, with small, scattered, apiculate dentations; apex rounded or with a small, obtuse elongation; base rounded or cordate, petiole strong, length unknown; palmately 5-veined from the base; midrib strong throughout its length, not much tapered to the apex, bearing 2 or 3 pairs of subopposite secondaries at angles of approximately 30°, which curve smoothly upward and approach close to the margin, where they branch and form prominent marginal loops; inner pair of lateral primaries prominent, forming an angle of 30° to 40° with the midrib, bearing 3 to 5 abaxial secondary branches nearly at right angles to the midrib which loop along the margin; outer pair of primaries at angles of 75° to 90° with the midrib, curving parallel with the margin and bearing several looping abaxial branches; tertiary venation irregularly percurrent, or reticulate, forming quadrangular meshes; scattered tertiary branches from the marginal loops enter the small marginal dentations; quaternary venation a coarse network of angular, mostly quadrangular meshes; areolation a fine network of fifth- and higher-order veinlets; texture coriaceous.

Discussion. Lesquereux recognized that these fossils were distinct from "*Ficus tiliaefolia*," the larger leaves of which they resemble in shape and in the primary and secondary venation characters. They may readily be distinguished by the crenate margin and the coarse quadrangular or angular polygonal meshes of the tertiary and quaternary venation. Reid and Chandler have reported the fruits of *Phytocrene* from the Lower Eocene London Clay flora (Reid and Chandler, 1933, pp. 333-336, pl. 15, figs. 24-34). This is the only other Tertiary record of the genus known to the writer.

The fossil impressions correspond in every detail to the leaves of *Phytocrene blancoi* (Azaola) Merrill from the Philippines. They are also similar to the leaves of *Hyperbaena hondurensis* Standley, a large vine which grows in the temperate rain forests of Guatemala. The only differences consist in the more quadrangular pattern of the tertiary venation and the scattered apiculate marginal teeth of the fossil leaf.

Occurrence. Chalk Bluffs, locality P3318; Buckeye Flat, locality 104; Independence Hill, locality 42.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotype, no. 2278; Calif. Acad. Sci. Paleo. Type Coll., plesiotype, no. 7777.

Family ANACARDIACEAE

Genus **RHUS** (Tournefort) Linnaeus

Rhus mixta Lesquereux

(Plate 35, figures 1, 4; plate 36, figure 1)

Rhus mixta Lesquereux, Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, p. 30, pl. 9, fig. 13, 1878.
Astronium oregonum Chaney and Sanborn; Sanborn, Carnegie Inst. Wash. Pub. 465, I, p. 24, pl. 9, figs. 2, 3, 1935.

Description. Leaves pinnately compound, nine or more leaflets; 20 cm. or more in length, 15 to 20 cm. in width. Terminal leaflet long-ovate; length 5 to 8 cm., width 2 to 2.5 cm.; margin coarsely serrate with triangular teeth directed toward the apex, the distal margin of the tooth nearly perpendicular to the midrib; extremity of leaflets often entire; apex extended to an acute point; base rounded. Lateral leaflets ovate-lanceolate, straight or slightly curved toward the base of the leaf; length 5 to 10 cm., width 1.5 to 2.5 cm.; base often somewhat inequilateral, broadly cuneate to rounded; midrib of leaflets strong, longitudinally ridged; secondaries numerous, usually craspedodrome, the extremities convex proximad, originating at angles of 55° to 65°, sometimes bifurcating near the margin, one branch entering a marginal dentation, the other disappearing in the sinus below; intersecondaries about half the length of the secondaries commonly present; tertiary venation reticulate, the branches from the secondaries rapidly diminishing in size, branching and anastomosing in the intersecondary space; areolation an irregular reticulate network; texture firm.

Discussion. The leaves of Rhus glabra Linnaeus and R. typhina Torner correspond to the fossil leaves in every detail. Similar leaflets have been likened to those of Astronium (Sanborn, 1935, p. 24), but in that species the leaflets are ovate with the apex abruptly attenuate, the secondaries form camptodrome loops instead of craspedodrome terminations, and the finer details of venation differ considerably from those of Rhus mixta. Rhus longepetiolata (Lesquereux) Brown (Knowlton, 1923, p. 168, pl. 37, fig. 9. Brown, 1929, p. 287, pl. 73, fig. 19; 1934, p. 60) from the Green River flora, and R. coriarioides Lesquereux (1883, p. 193, pl. 41, fig. 3) from the Florissant beds are also much like R. mixta, the only consistent difference being the much larger size of the California impressions.

Occurrence. All localities.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotypes, nos. 2279, 2280, 2281.

Family ACERACEAE

Genus **ACER** (Tournefort) Linnaeus

Acer aequidentatum Lesquereux

(Plate 37, figures 1-4)

Acer aequidentatum Lesquereux, Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, p. 26, pl. 7, figs. 4, 5, 1878.

Description. Leaves shallowly 3- or 5-lobed, broadly cuneate or rounded at the base, the apical lobe marked by two prominent lateral lobes midway and one or more pairs of smaller lobes toward the apex; length 3.5 to 8 cm., width 3 to 7 cm.; margin serrate except at the base; petiole slender, 7 to 9 cm. in length; 3 primary veins, the midrib finely tapered apically, the lateral veins slender throughout, diverging from the midrib at 50°, bearing 8 or more craspedodrome secondary branches on the outer sides; 6 or 7 pairs of secondaries branching from the midrib, roughly parallel to the lateral primaries, the lower pair looping around the sinus, the remainder craspedodrome; tertiary venation reticulate, the tertiaries repeatedly branching to form a delicate reticulate mesh of fourth- or higher-order veinlets; texture firm.

Discussion. (1) *Acer aequidentatum* closely resembles *A. trilobatum productum* Heer in both leaf and fruit forms, although the European species is larger and more deeply lobed. (2) There is also a marked similarity to *A. florissanti* Kirchner, although that species is usually 5-lobed.

The leaves of *Acer aequidentatum* resemble certain shallowly lobed, elongate leaves of the living *A. rubrum* Linnaeus, particularly of the variety *tridens* Wood. There is also a striking resemblance to the leaves of *A. ginnala* Maximowicz. The smaller fruits are like those of *A. rubrum*, but the larger forms are matched exactly by the fruits of *A. davidii* Franchet. The fossil species is obviously extinct, having characters now found in more than one living species.

Occurrence. Buckeye Flat, locality P3320; Chalk Bluffs, locality P3318.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotypes, nos. 2283, 2284, 2285, 2286.

Family SAPINDACEAE

Genus **CUPANIA** Linnaeus

Cupania oregona Chaney and Sanborn

(Plate 37, figure 5)

Cupania oregona Chaney and Sanborn, Carnegie Inst. Wash. Pub. 439, pp. 82-83, pl. 25, figs. 1, 3, 5, 1933.

Fossil leaves of Cupania oregona Chaney and Sanborn occur at both Chalk Bluffs and Buckeye Flat. These are most similar to the leaflets of C. vernalis Cambessedes, a small tree widely distributed in South America. The species is known only from the Goshen and Chalk Bluffs floras.

Occurrence. Buckeye Flat, locality P3320; Chalk Bluffs, locality P3318.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotype, no. 2287.

Genus **THOUINOPSIS** MacGinitie

Thouinopsis myricaefolia, new combination

(Plate 36, figures 2, 4; plate 37, figures 6-9; plate 45, figure 9)

Rhus myricaefolia Lesquereux, Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, p. 31, pl. 1, figs. 5-7, 1878.

Description. Leaves large, odd-pinnately compound; 20 or more cm. in length, 12 cm. or more in width; 9 to 15 (or more) leaflets, opposite to subopposite, rachis angled or ridged longitudinally; terminal leaflet equilateral, ovate-lanceolate, 6 to 11 cm. in length, 1.5 to 2 cm. in width, extended to an acute tip, base narrowly cuneate, petiolule strong, 0.5 to 1.7 cm. in length; lateral leaflets inequilateral, lanceolate, length 7 to 15 cm., width 1 to 2.5 cm., gradually narrowed to an extended, acuminate tip, base asymmetric, rounded above, cuneate below, petiolule 3 to 5 mm. in length. Leaflets finely and regularly serrate except at the base, with forward-pointing, spinose teeth; midrib prominent; numerous (35 or more pairs) subopposite to alternate secondaries, subparallel, originating at angles of from 65° to 75°, the angle fairly constant from base to apex, mostly camptodrome, curving upward near the margin, bifurcating and looped with succeeding secondary branches along the margin, the stronger branch rarely craspedodrome, the weaker branches lost in the base of the marginal sinuses; intersecondaries regularly alternating with the secondaries, originating at larger angles, and resolving into the tertiary network two-thirds of the distance toward the margin; tertiary venation an even-textured, reticulate areolation; many veins of tertiary size arranged along the midrib, perpendicular to it; texture firm.

Winged fruits, oval, 7 mm. in length, 4 mm. in width, comprising a tiny nutlet or seed 2 mm. in length supporting a stout wing, the wing veined longitudinally as in the samaras of *Acer*, with 5 to 7 or more parallel veins. Apex of the seed with a small down-curved beak, indicating the former point of attachment.

Discussion. Both leaflets and winged seeds are closely similar to those of *Thouinidium decandrum* (Humboldt and Bonpland) Radlkofer, a shrub or small tree common in southern Mexico from Sinaloa to Oaxaca and eastward to Vera Cruz. The leaves of the living plant are odd-pinnate, and the leaflets larger and more irregularly serrate. The fruits are somewhat more elongate than those of the fossil species but otherwise identical. The fruits of *Thouinia acuminata* S. Watson are similar to the fossil fruits, but the leaves of this species are trifoliate. Another genus of the Sapindaceae, *Arytera*, represented by about 20 species in eastern Asia and Australia, bears leaves which correspond closely to the fossil leaves, especially *Arytera lautererianum* (Bailey) Radlkofer. Since the fossil plant shows a composite of features from several related genera of the Sapindaceae, it seems best to designate it by the name *Thouinopsis*, or *Thouinia*-like. Its relation to *Thouinidium* is, however, comparatively close.

Brown has described a leaflet of *Thouinia* (Brown, 1929, p. 289, pl. 74, fig. 4) from the Green River flora, but this species has no strong resemblance to the Chalk Bluffs *Thouinopsis* leaflets.

Occurrence. All localities.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotypes, nos. 2289, 2290, 2291, 2292, 2293, 2294, 2360.

Family SABIACEAE

Genus **MELIOSMA** Blume

Meliosma truncata, new species

(Plate 38, figure 1)

Description. Leaf obovate; length 8 cm., width 5 cm.; margin dentate in the upper two-thirds, the teeth rounded or apiculate; apex truncate or mucronate; base cuneate; petiole slender, approximately 2 cm. in length; midrib slender; 8 to 10 pairs of secondaries, opposite to alternate, originating at an angle of 50° in the central part of the leaf, increasing to 60° near the base, the first two or three pairs curved upward and looping along the margin, the remainder nearly straight, dichotomously branched one to three times, the branches entering the marginal teeth; tertiary venation quadrangular-reticulate with irregular crossties; areolation a fine, polygonal mesh; texture firm.

Discussion. No similar leaf form has been described from the American Tertiary. The leaves of Meliosma cuneifolia Franchet, which is common at moderate elevations in western Hupeh and Szechwan, are an exact match for the fossil impressions. There is also a similarity to the leaves of M. myriantha Siebold and Zuccarini and M. pendens Rehder and Wilson from the same region. One nearly complete leaf and several fragments of this species were found at Independence Hill; it is not known from other localities.

Three species of Meliosma (Chaney and Sanborn, 1933, pp. 84-85, pls. 27-30) were described from the Goshen flora, and one of these, M. goshenensis Chaney and Sanborn, is found in the La Porte flora (Potbury, 1935, p. 74, pl. 11, fig. 7). Meliosma aesculifolia Chaney and Sanborn is similar to the Chalk Bluffs fossil in the character of the margin and tertiary venation.

Occurrence. Independence Hill, locality 42.

Collection. U. C. Mus. Pal., Paleobot. Ser., holotype, no. 2296.

Family RHAMNACEAE

Genus **RHAMNIDIUM** Reissek

Rhamnidium chaneyi Potbury

(Plate 38, figures 6-8)

Rhamnidium chaneyi Potbury, Carnegie Inst. Wash. Pub. 465, II, p. 75, pl. 11, figs. 1, 3-5, 1935.

The distinguishing features of these leaves are the closely spaced, abruptly camptodrome secondaries, the numerous fine tertiaries nearly at right angles to the midrib, and the flattened, heavy petiole. Some of the specimens from the Chalk Bluffs flora show bifurcation of the ends of the secondaries, a character not found in the leaves of the living species, Rhamnidium elaeocarpum Reissek, to which the fossil leaves have been likened. There is a marked resemblance to the leaves of the living Bridelia montana Willdenow or Bridelia stipularis Blume, small trees or shrubs native to southeastern Asia and belonging to the family Euphorbiaceae. There are also similarities to the leaves of Anona and Davilla.

Rhamnus marginatus Lesquereux (Berry, 1916, pp. 282, 283, pl. 69, fig. 1; pl. 71, fig. 1; pl. 72, fig. 1) from the Wilcox flora, and Rhamnus cleburni Lesquereux from the Animas (Knowlton, 1924, pl. 17, fig. 4), Raton, and Denver formations, are so much like Rhamnidium chaneyi as to leave some doubt of their separate identity.

Occurrence. Buckeye Flat, localities 104, P3320; Chalk Bluffs, localities P3318, P3345.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotypes, nos. 2297, 2298, 2299.

Genus **RHAMNUS** (Tournefort) Linnaeus

Rhamnus calyptus, new species

(Plate 38, figure 3)

(?) Celastrus ferrugineus Ward; Sanborn, Carnegie Inst. Wash. Pub. 465, I, p. 24, pl. 9, fig. 1, 1935.

Description. Leaf oval; length 10 cm., width 5 cm.; apex acute; base rounded-cuneate; margin uniformly serrate-crenate, with numerous small, rounded teeth except near the petiole; petiole slender, 1 cm. in length; midrib slender; approximately 10 pairs of opposite to alternate secondaries arising at angles of from 70° to 80°, strongly convex toward the base, branching and forming strong, simple loops along the margin; tertiary venation composed of strong, sinuous crossties, or reticulate near the midrib; areolation finely reticulate; texture coriaceous.

Discussion. These fossil leaves resemble the foliage of both Celastrus and Rhamnus, but are closer to Rhamnus, particularly R. nipalensis Wallich of southeastern Asia. They are also more remotely like the leaves of Celastrus hookeri Prain from the same region, but differ especially in the character of the percurrent tertiaries.

Occurrence. Chalk Bluffs, locality P3345; Buckeye Flat, locality P3320.

Collection. U. C. Mus. Pal., Paleobot Ser., holotype, no. 2301.

Rhamnus plenus MacGinitie

(Plate 38, figure 2)

Rhamnus plenus MacGinitie, Carnegie Inst. Wash. Pub. 465, III, p. 146, pl. 12, fig. 4, 1937.

A single perfect leaf and a few fragments of this species were discovered at Chalk Bluffs. They were associated with Cercidiphyllum, Hamamelites, Dalbergia, Quercus distincta, and Platanus. There is no significant difference in the specimens from the two floras unless the more acute angle of the secondaries in the specimen from Nevada County is considered such. This furnishes another illustration of a type remaining practically unaltered for a period of time measured in tens of millions of years, since the leaves of the living Rhamnus crenatus Siebold and Zuccarini of southern China are strikingly similar to the fossils.

Occurrence. Chalk Bluffs, locality P3345.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotype, no. 2300.

Family VITACEAE

Genus **CISSUS** Linnaeus

Cissus pyriformis, new species

(Plate 39, figures 1-4, 11)

Description. Leaves ovate to broadly rounded-ovate, complete or 3- to 5-lobed; length 4 to 5 cm., width 2.3 to 4.5 cm.; margin serrate-dentate;

apex acute to elongate-acuminate; base cordate or rarely broadly rounded; petiole slender (incomplete in all specimens); midrib slender, flanked by one or two pairs of lateral primaries, the lower pair, when present, deviating at right angles; 5 or 6 pairs of opposite secondaries arising from the midrib at angles of 45° to 55°, paralleling the upper pair of lateral primaries and craspedodrome, the outer primaries bearing 4 or 5 secondaries on their lower sides which curve outward and enter the marginal teeth; tertiary venation percurrent; areolation quadrangular; texture firm.

Discussion. The fossil leaf impressions are variable in outline and the lobed forms are hardly distinguishable from the leaves of *Vitis*. The variation in shape is found in the leaves of two living species of *Cissus*, *C. sicyoides* Linnaeus from the American tropics, and *C. assamica* (Laws) Craib, native to the Paleotropics from India to Kwangtung, China. No closely similar leaf fossil has been described from the American Tertiary, although *Grewiopsis cissifolius* Brown (1929, pl. 74, fig. 8) from the Green River flora shows considerable similarity.

Occurrence. Chalk Bluffs, locality P3345; Buckeye Flat, locality P3320.

Collection. U. C. Mus. Pal., Paleobot. Ser., cotypes, nos. 2302, 2303, 2304, 2305. U. S. Nat. Mus., cotype, no. 40238.

Family THEACEAE

Genus **GORDONIA** Elliot

Gordonia egregia, new combination

(Plate 39, figures 5, 7, 9, 10, 12, 13; plate 40, figure 1)

Juglans egregia Lesquereux, Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, p. 36, pl. 9, fig. 12, 1878.

Description. Leaves oblanceolate; length 10 to 25 cm., width 3.5 to 9 cm., the larger leaves more common; margin serrate, except near the base of the leaf, usually with numerous shallow forward-pointing teeth, occasionally remotely serrate, dentate, or finely crenate; apex obtuse; base narrowly cuneate; petiole stout, 1.5 to 3 cm. long, base of the petiole somewhat dilated; midrib stout, striated; 12 to 15 pairs of opposite to alternate, relatively thin secondaries originating at an angle of 60°, somewhat flexuous, forming prominent loops well within the margin; tertiaries mainly percurrent, nearly parallel with the midrib in the basal part of the leaf, tertiary branches from the marginal loops forming loops just within the margin or entering the marginal teeth; areolation a reticulate, polygonal mesh; texture firm.

Discussion. In Lesquereux's *Fossil plants of the Auriferous Gravel deposits* (1878b), two different forms are labeled *Juglans egregia*. Plate 9, figure 12 is *Gordonia*. Plate 10, figure 1 is a leaf of doubtful affinity.

The leaves of *Gordonia* are abundant at Chalk Bluffs and are one of the characteristic species in the flora. There are also impressions of the fruiting capsules and coriaceous sepals. The evidence indicates that the fossil seeds called *Carpites egregia* represent the seeds of *Gordonia egregia*. The fossil leaves are closely similar to the leaves of *Gordonia alatamaha* Sargent, or *Franklinia alatamaha* Marsh, now known only in cultivation, and *G. fragrans* Merrill, from southeastern Asia and the East Indies. The texture of the fossil leaves was thinner than that of the common *Gordonia* of the eastern states, *G. lasianthus* Elliot or loblolly bay, which grows from southeastern Virginia to Florida and westward to southern Mississippi.

No species of *Gordonia* have been described from the living Neotropical floras, but a closely related genus, *Haemocharis* (*Laplacea*), is found in the West Indies, Central America, and probably southern Mexico (Chiapas). *Laplacea brenesii* Standley, for example, has leaves and fruiting capsules similar to those of the fossil.

This is the second record of the genus *Gordonia* in the fossil state. Brown figures a leaf, a seed, and a fruiting capsule of *Gordonia hesperia* Berry (Brown, 1937, p. 183, pl. 52, figs. 5-8) from the Middle Miocene. It is possible that some of the leaves referred to *Ternstroemites* in the Eocene floras of the southeastern states may belong to this genus, and some of the figures show similarities to the leaf impressions of *Gordonia egregia*. *Ternstroemites ovatus* Berry (1916, pl. 77, figs. 2-4) from the Lagrange formation (Wilcox) appears to be most similar to *Gordonia egregia*, but differs in the characters of the tertiary nervation and areolation.

Occurrence. All localities.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotypes, nos. 2307, 2308, 2309, 2310, 2311, 2312, 2313.

Family MYRTACEAE

Genus **CALYPTRANTHES** Swartz

Calyptranthes myrtifolia, new species

(Plate 40, figure 3)

Description. Leaves ovate-lanceolate; length 6 to 8 cm., width 2 to 2.5 cm.; apex gradually extended, with acuminate tip; base rounded or broadly cuneate; margin entire; petiole not preserved; midrib stout; secondaries numerous, subparallel, 18 or more opposite to alternate pairs (alternating with strong intersecondaries), arising at angles of 70° to 80°, somewhat convex toward the base, branched just within the margin, the branches anastomosing to form an undulating marginal hem 1 to 1.5 mm. from the edge of the leaf; tertiaries forming a streaming reticulate network whose meshes are much elongated perpendicularly to the midrib; areolation obsolete; texture firm.

Discussion. A few fragmentary specimens of these leaves were found at Buckeye Flat. They resemble the leaves of both Myrcia and Calyptranthes, and correspond so well to the leaves of the living C. chytraculia (Linnaeus) Swartz (University of California Herbarium sheet 491354) that there can be no doubt concerning their assignment to that genus.

The fossils from Buckeye Flat recall C. arbutifolia Chaney and Sanborn from the Goshen and Weaverville floras. They differ from that species in their smaller size and more ovate form and in the rounded or broadly cuneate rather than asymmetrically cordate base. Calyptranthes eocenica Berry (1916, p. 319, pl. 90, fig. 5) from the Wilcox flora is a broader leaf with more closely spaced secondaries. The fossil leaves are also closely similar to Ficus myrtifolius Berry (ibid., p. 205, pl. 30, figs. 1-3) from the Wilcox flora, but differ in the broader base and in the fewer and more prominent secondaries.

Occurrence. Buckeye Flat, locality P3320.

Collection. U. C. Mus. Pal., Paleobot. Ser., holotype, no. 2314.

Family NYSSACEAE

Genus **NYSSA** (Gronovius) Linnaeus

Nyssa californica, new species

(Plate 40, figures 2, 4, 6; plate 43, figure 5)

Description. Leaves ovate; length 5 to 8 cm., width 2.5 to 5.5 cm.; margin entire; apex acute; base cuneate; petiole not preserved; midrib slender; 6 to 8 pairs of slender opposite to subopposite secondaries, originating at angles of 50° in the middle of the leaf, curving upward and bifurcating at their extremities and anastomosing with adjacent secondary branches, forming a series of marginal loops; several strong but irregularly spaced intersecondaries; tertiary venation reticulate, forming a coarse mesh; areolation a fine-textured reticulate mesh; texture thin.

Fruits of Nyssa, prominently ribbed, length 15 mm., width 8 mm.

Discussion. The fossil leaves are much like those of Nyssa sylvatica Marshall, a small tree common on swampy soils from Maine to Florida and westward to Texas. The fruit, however, is larger than is usually found in this species, and approaches in size the fruits of N. aquatica Linnaeus.

Occurrence. Buckeye Flat, locality P3320; Chalk Bluffs, locality P3318; Independence Hill, locality 42.

Collection. U. C. Mus. Pal., Paleobot. Ser., holotype, no. 2315; paratypes, nos. 2316, 2322. U. S. Nat. Mus., no. 40239.

Family COMBRETACEAE

Genus **TERMINALIA** Linnaeus

Terminalia estamina, new species

(Plate 42, figures 1, 2; plate 43, figures 2, 4)

Description. Leaves ovate to obovate; length 6 to 11 cm., width 2.5 to 5 cm.; margin entire; apex cuspidate or obtuse-acuminate, rounded and terminating abruptly in a point; base cuneate; petiole comparatively slender, incomplete in all specimens, length over 1.5 cm.; midrib slender; 6 to 9 pairs of thin secondaries, usually alternate, arising at angles of 40° to 50°, arched upward and tortuous within the margin, anastomosing by numerous successively smaller loops; tertiary venation of many flexuous, percurrent or branching nervilles, roughly perpendicular to the midrib; areolation a complex, reticulate network, the meshes rhombic or polygonal and elongated roughly parallel to the tertiary nervilles; texture firm.

Fruits elongate, petiolate, elliptical; length 2 to 2.5 cm., width 1 to 2.3 cm.; doubly bialate, the wings scarious, finely parallel-veined, the veins perpendicular to the seed axis, truncate at the base, emarginate at the apex; seed cavity fusiform, 1.3 cm. in length.

Discussion. The characters of the fossil fruits and leaves are matched by those of the living *Terminalia hainanensis* Excell from southern China. There are also correspondences with fruits and leaves of several Neotropical species, such as *T. triflora* Grisebach of South America. The fruits of *Combretum* are closely similar to those of certain species of *Terminalia*; in general, however, the seed cavity in *Combretum* is much more expanded and longer relative to the wings than in *Terminalia*.

There are four species of *Terminalia* in the Wilcox flora (Berry, 1930a, pp. 119-121), two based on seeds and two on leaves. Two leaf species are described from the Claiborne flora, one of which continues into the Jackson flora. Ball has identified a species from the Indio (Ball, 1931, p. 98) formation. These are the only previously described North American fossil forms, unless an extremely doubtful occurrence in the Alaskan Tertiary (Hollick, 1936, p. 155) is included. It is impossible to make a satisfactory comparison between the California species and any of the Gulf coast forms, since the illustrations are incomplete and no mention is made in the descriptions of the characteristic tertiary nervation of the leaves.

Occurrence. Chalk Bluffs, localities P3345, P3318.

Collection. U. C. Mus. Pal., Paleobot. Ser., cotypes, nos. 2317, 2318, 2320, 2321.

Family CORNACEAE

Genus **CORNUS** Linnaeus

Cornus kelloggii Lesquereux

(Plate 46, figure 1)

Cornus kelloggii Lesquereux, Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, pp. 23-24, pl. 6, fig. 3, 1878.
Potbury, Carnegie Inst. Wash. Pub. 465, II, p. 77, pl. 11, fig. 3, 1935.

Only four specimens of this species are known, and none are complete, but the leaf is so characteristic that its generic reference is hardly open to question. The fossil species is most similar to the leaves of Cornus nuttallii Audubon, a small tree ranging from British Columbia to southern California, but there are also resemblances to the leaves of several other species of dogwood native to the southern states and to Mexico. Cornus studeri Heer, figured by Ward (1887, p. 55, pl. 24, fig. 1) from Point of Rocks, Wyoming, has a general resemblance to the California species.

Occurrence. Chalk Bluffs, locality P3325.

Collection. U. C. Mus. Pal., Paleobot. Ser., holotype, no. 1816.

Family EBENACEAE

Genus **DIOSPYROS** Linnaeus

Diospyros retinervis, new species

(Plate 43, figures 1, 6)

Description. Leaf ovate to broadly ovate; length 7 to 11 cm., width 2.5 to 5 cm.; margin entire; apex acute or acuminate; base cuneate; petiole strong, 1 cm. in length; 6 to 10 pairs of irregularly disposed secondaries, curved upward, becoming nearly parallel with the margin and forming many loops with tertiary branches from the succeeding secondary; tertiary venation polygonal-reticulate, markedly irregular; areolation a fine-textured, polygonal network; texture firm.

Discussion. Approximately a dozen species of Diospyros have been identified in North American Tertiary floras, but the only form similar to D. retinervis is D. brachysepala Al. Braun as figured by Berry from the Wilcox and Claiborne floras (Berry, 1916, p. 333, pl. 51, figs. 3, 4; pl. 57, fig. 6). The Chalk Bluffs leaf impressions differ from those of the Wilcox in the wider spacing and greater irregularity of the secondaries; otherwise there is a fairly good correspondence of characters.

The fossil leaves resemble the leaves of D. virginiana Linnaeus more closely than those of any other living species, although there are similarities between D. retinervis and the foliage of several species inhabiting tropical America and southeastern Asia, such as D. conzatti Standley from Mexico, and D. lauii Merrill or D. morriseana Hance from southern China.

Occurrence. Chalk Bluffs, localities P3318, P3345.

Collection. U. C. Mus. Pal., Paleobot. Ser., holotype, no. 2323; paratype, no. 2319.

Family OLEACEAE

Genus **FRAXINUS** (Tournefort) Linnaeus

Fraxinus yubaensis, new species

(Plate 45, figures 4, 6)

Description. Leaflets ovate, tending to be inequilateral; length 4 to 8 cm., width 1.5 to 2.2 cm.; apex acuminate; base broadly cuneate; sessile; margin dentate, the teeth widely spaced and curved toward the apex; midrib slender; 8 to 11 pairs of opposite or subopposite secondaries originating at 60° to 70°, with a pronounced upward curve, branching and looping along the margin, the stronger divisions entering the sinuses; tertiary venation finely reticulate; areolation an even-textured reticulate mesh; texture firm.

Fruit 2.5 cm. in length, 0.4 cm. in width, with linear samara, the apex contracted and blunt; seed 7 by 2.5 mm., terminating in an elongated acuminate tip.

Discussion. The fossil species which show the closest resemblance to Fraxinus yubaensis are F. inordinata Hollick (1936, p. 163, pl. 100, fig. 4; pl. 101, figs. 1-7) and F. juglandina Saporta (1867, p. 89, pl. 7, fig. 6; pl. 9, figs. 13-16a. Hollick, 1936, p. 163, pl. 42, fig. 4b; pl. 101, figs. 8-10), as figured by Hollick in his Tertiary floras of

Alaska. Differences in the margin and venation, however, render it probable that the species are distinct, although the similarities are close. Fraxinus mespilifolia Lesquereux (1883, p. 169, pl. 33, figs. 7-12) from Florissant was compared to F. inordinata by Hollick, but it is highly probable that these are Carya leaflets.

The fossil leaflets are similar to those of F. nigra Marshall, a common tree of low ground from Nova Scotia and Manitoba to Virginia and Arkansas.

Occurrence. Chalk Bluffs, locality P3318.

Collection. U. C. Mus. Pal., Paleobot. Ser., cotypes, nos. 2324, 2325.

Family APOCYNACEAE

Genus **NERIUM** Linnaeus

Nerium hinoidea, new species

(Plate 44, figures 1-3)

Description. Leaves lanceolate; length 15 cm. or more; width 2 to 3 cm.; margin entire; apex acute; base narrowly cuneate; petiole stout, 1 to 1.5 cm. in length; midrib wide, heavy, 2 mm. in width near the base of the leaf, straight, gradually tapered to the apex; secondaries numerous, parallel, originating at angles of 70° to 85°, the smaller angle toward the apex; slightly curved upward except at the extremities, which abruptly bend upward and merge with the margin of the leaf, often bearing numerous small, anastomosing, abaxial branches just within the margin; tertiary venation reticulate with quadrangular meshes roughly perpendicular to the secondaries; areolation a peculiar spongy reticulation with rounded meshes; texture coriaceous.

Discussion. Fossil leaves showing resemblances to these have usually been assigned to the genus Apocynophyllum. In this case, the correspondences between the fossil impressions and the leaves of the living Nerium are so exact as to warrant assignment to that genus. The fossils occur only at Chalk Bluffs, and but three specimens were found there. The similarity between the fragmentary leaf impressions from the Lagrange formation of Wilcox age designated Phyllites by Berry (1916, p. 353, pl.

104, fig. 2) and Nerium hinoidea indicates that they may be specifically identical. Apocynophyllum tabelarum (Lesquereux) Berry (ibid., p. 343, pl. 52, figs. 2-5; pl. 53, fig. 5) of the same flora also shows several resemblances.

Occurrence. Chalk Bluffs, locality P3325.

Collection. U. C. Mus. Pal., Paleobot. Ser., cotypes, nos. 2327, 2328, 2329.

Genus **TABERNAEMONTANA** Linnaeus

Tabernaemontana chrysophylloides, new combination

(Plate 44, figure 5)

Castanopsis chrysophylloides Lesquereux, Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, p. 9, pl. 2, fig. 10, 1878.

Tabernaemontana intermedia Potbury, Carnegie Inst. Wash. Pub. 465, II, pp. 78-79, pl. 13, figs. 1, 3, 4, 1935.

Only one perfect specimen, Lesquereux's type, of this species has been found in the Chalk Bluffs flora, but more abundant material occurs in the La Porte flora. The fossil leaves were likened to the leaves of Tabernaemontana lanceolata Miers and T. rupicola Bentham.

Occurrence. Chalk Bluffs, locality P3325.

Collection. U. C. Mus. Pal., Paleobot. Ser., holotype, no. 1854.

Family ASCLEPIADACEAE

Genus **ASCLEPIADITES** MacGinitie

Asclepiadites laterita, new species

(Plate 44, figure 6)

Description. Leaf ovate; length 6 cm., width 3.5 cm.; margin entire; apex blunt; base incipiently auriculate; petiole short, stout; midrib thin; 6 pairs of thin, irregularly spaced secondaries, arising at angles of 40° with the midrib, flexuous, widely looped within the margin; tertiary venation a coarse angular-polygonal network; areolation obsolete; texture firm.

Discussion. The fossil leaves resemble the leaves of several genera of the Asclepiadaceae, Calotropis, Cynanchum, Gonolobus, and Tylophora.

They appear to be most similar to the leaves of Cynanchum, but the ovate-auriculate leaves of these genera are so similar that a specific differentiation among them by leaf characters is impossible. The generic name Asclepiadites is therefore employed. The species of Cynanchum, Gonolobus, etc. are vigorous, woody climbers native to tropical or warm-temperate regions.

The only similar fossil previously described from the Tertiary of the western states is Vincetoxicum (Gonolobus) trinervata MacGinitie (1933, p. 66, pl. 15, fig. 1) from the Miocene Trout Creek flora of southeastern Oregon.

Occurrence. Chalk Bluffs, locality P3345.

Collection. U. C. Mus. Pal., Paleobot. Ser., holotype, no. 2330.

Family CAPRIFOLIACEAE

Genus VIBURNUM Linnaeus

Viburnum variabilis, new species

(Plate 41, figures 1, 4-7; plate 42, figures 3-5)

Aralia taurinensis Sanborn, Carnegie Inst. Wash. Pub. 465, I, p. 27, pl. 10, fig. 4 (only), 1935.
Diospyros orientalis Sanborn, ibid., p. 26, pl. 10, fig. 3.
Mallotus comstocki Sanborn, ibid., p. 23, pl. 6, fig. 9.

Description. Leaves ovate; length 5 to 11.5 cm., width 3 to 7.5 cm.; apex acute; base broadly rounded to cuneate or rounded-decurrent; margin, except near the base, sinuate-dentate, the dentations apiculate; petiole stout, 2.5 to 3.5 cm. in length; midrib stout at the base but rapidly tapered apically; 5 to 8 pairs of irregularly spaced secondaries, the third pair above the base usually the strongest, originating at variable angles, the angle decreasing from 60° near the base to 25° near the apex; secondaries with from 1 to 3 abaxial branches which also branch dichotomously, the branchlets entering the marginal dentations; tertiary venation percurrent or coarsely reticulate; areolation a polygonal mesh; texture coriaceous.

Discussion. The leaf impressions called Viburnum variabilis are characteristic of the brown clays at Buckeye Flat and Iowa Hill. They are closely similar to V. antiquum (Newberry) Hollick, and reflect all the variations of that species, which is extremely common at some of the Fort Union localities. Ward's illustrations (1887) of the Fort Union species, for example plate 40, figure 1, plate 53, figure 1, and plate 54, figures 1, 4, and 5, illustrate this resemblance, as do also Berry's figures in his paper on the Ravenscrag and Whitemud floras (Berry, 1935, pp. 58-59, pls. 17, 18b). The California fossil differs from *Viburnum antiquum* only in the characters of the margin, *V. antiquum* having a sharply crenate margin, whereas *V. variabilis* has a dentate margin with shallow, pointed teeth. There is a strong resemblance between *V. variabilis* and certain species of "*Grewiopsis*," particularly *G. saportana* Lesquereux (Dorf, 1938, p. 70, pl. 13, figs. 1, 5, 6) from Upper Cretaceous formations of the Rocky Mountain region, and *G. congerminalis* Hollick (1936, p. 149, pl. 85, figs. 5, 6) from the Alaskan Tertiary flora.

Viburnum microcarpum Schlechtendal and Chamisso, living in the mountains of Vera Cruz and Oaxaca, bears leaves much like the fossil species although they rarely show the peculiar cuneate base of some of the fossil impressions. Certain species of *Viburnum* inhabiting southeastern Asia, such as *V. wrightii* Miquel, *V. tomentosum* Thunberg, and *V. erosum* Thunberg, are also similar to *V. variabilis* in leaf characters.

Occurrence. Buckeye Flat, locality P3320; Independence Hill, locality 42.

Collection. U. S. Nat. Mus., holotype, no. 40241. U. C. Mus. Pal., Paleobot. Ser., paratypes, nos. 2331, 2332, 2333, 2335, 2336. U. S. Nat. Mus., paratypes, nos. 40240, 40242.

Family COMPOSITAE

Genus **CALYCITES** Massalongo

Calycites mikanoides, new species

(Plate 41, figures 2, 3; plate 46, figures 2-4)

Description. Tiny, scarious, prismatic, five-sided calyces; average length 5 mm., average width 3 mm.; the connate, ridged sides of the calyces extended to an acute point; the base smooth and ovoid and showing a basal scar indicating the attachment of the petiolule.

Discussion. The impressions of these small calyces are found at all the occurrences of fossil leaves at Chalk Bluffs and Buckeye Flat.

They appear to be the scarious calyces of a woody composite such as Adenostyles, Eupatorium, Mikania, or Senecio. The resemblance is greatest to the calyces of several Mexican species of Mikania, hence the specific name.

Occurrence. Chalk Bluffs, locality P3345; Buckeye Flat, locality P3320; Quaker Flat, locality P3346.

Collection. U. C. Mus. Pal., Paleobot. Ser., cotypes, nos. 2339, 2340, 2341, 2342, 2343.

INCERTAE SEDIS

Genus **CARPITES** Schimper

Carpites egregia, new species

(Plate 38, figures 4, 5; plate 39, figures 6, 8)

Description. Seeds thin, spatulate; rounded at the base, truncate at the apex, often with a pronounced median convexity; length 5 to 7 mm., width 4 mm.; surrounded, except at the apex, by a thin, narrow, entire rim which is usually unsymmetrical, rounded on one side of the base but with a prominent angulation opposite.

Discussion. The seeds described above are among the most common fossils of the flora and are found at all localities, although never abundantly. They resemble the seeds of various genera of the Asclepiadaceae. Those of Tylophora are perhaps the most similar, but the seeds of Asclepias, Gomphocarpus, Cynanchum, and Gonolobus are also like the fossils. The seeds of Stewartia pentagyna L'Heritier (Malachodendron pentagynum Small) have a greater similarity to the fossil seeds than do those of any genera of the Asclepiadaceae, although it is difficult to find a constant difference in any one character between the seeds of this species and those of Tylophora, for example. Gordonia (Franklinia) alatamaha has wingless seeds which also resemble the fossil forms. This contrasts with the seeds of other species of Gordonia, which are winged. The Franklinia was discovered as a single tree in 1765 by the brothers Bartram, on the Altamaha River in the coastal plain of Georgia. It has never been found since, although preserved in cultivation. It was either a remarkable mutation or a hybrid between Gordonia lasianthus Elliot and Stewartia. The resemblance of the fossil seeds to those of Stewartia and Franklinia, and their constant association with the leaves identified by the writer as Gordonia egregia, strongly indicate that the seeds and leaves were associated on the same plant. If this be true, there is a probability that another generic name should be used, although the leaves and capsules are those of Gordonia.

A fossil seed like these at Chalk Bluffs, Tylophora antiqua Reid and Chandler (1926, pp. 123-124, pl. 8, fig. 23), was identified in the Bembridge flora of the Isle of Wight.

Occurrence. All localities.

Collection. U. C. Mus. Pal., Paleobot. Ser., cotypes, nos. 2344, 2345, 2346, 2347.

Genus **PHYLLITES** Brongniart

Phyllites cordiaefolia, new species

(Plate 44, figure 4)

Description. Leaves ovate to obovate; length 5.5 to 8 cm.; width 3.5 to 4.5 cm.; apex acuminate; base rounded-cuneate; margin entire in the lower half of the leaf, crenate to shallowly dentate above; petiole short, stout, 2 to 3 mm. in length; midrib strong; 7 pairs of secondaries, usually opposite, originating at angles of 40° to 55°, smoothly curved upward and bifurcating from one to three times near the margin, the branches craspedodrome except toward the base; tertiary venation irregularly percurrent; areolation quadrangular-reticulate, with meshes of two orders; texture firm.

Discussion. These leaf impressions have characters found in the leaves of both Premna and Cordia, but constant differences prevent their assignment to either genus. There are also resemblances to the leaves of various species of Actinidia. No similar fossil species are known to the writer.

Occurrence. Chalk Bluffs, locality P3345.

Collection. U. C. Mus. Pal., Paleobot. Ser., holotype, no. 2349.

Phyllites daturaefolia, new species

(Plate 45, figures 1-3)

Description. Leaves ovate to elongate-ovate; length 5 to 9 cm., width 4 to 6 cm.; apex acute; base truncate or widely cuneate; petiole slender, elongate, flattened, 3.5 to 4.5 cm. in length; margin incised, with irregularly spaced acute lobes and narrow rounded sinuses; 10 or more sinuous, irregularly spaced secondaries in each half of the leaf, at variable angles with the midrib, 60° to 80°, craspedodrome, occasionally with craspedodrome branches; tertiary venation sinuous-percurrent; areolation quadrangular; texture coriaceous.

Discussion. These fossils are similar to those called Credneria ? daturaefolia Ward (1885, pls. 57, 58), from Sevenmile Creek, Montana, and they may be closely related. Their systematic position is conjectural. They resemble the leaves of certain genera of the Proteaceae, Araliaceae, Solanaceae, and Euphorbiaceae, particularly those of Jatropha and Datura.

Occurrence. Buckeye Flat, locality P3320.

Collection. U. C. Mus. Pal., Paleobot. Ser., holotype, no. 2351; paratypes, nos. 2352, 2353.

Phyllites laurinea, new combination

(Plate 45, figure 8)

Juglans laurinea Lesquereux, Harvard Mus. Comp. Zool., Mem., vol. 6, no. 2, p. 35, pl. 9, fig. 11, 1878.

Description. Leaf elongate-ovate; length 11 cm., width 4.5 cm.; apex acute; base broadly cuneate; petiole slender, total length not preserved; margin regularly serrate; midrib slender, tapered, sinuous toward the apex; 10 to 11 pairs of slender secondaries, irregularly placed and arising at varying angles averaging about 70° in the middle of the lamina, the basal secondaries arising as pseudo-primaries near the base of the leaf at an angle of 30°; secondaries thin and straggling toward their extremities, looped along the margin; tertiary venation finely reticulate with a few stronger sinuous crossties; areolation a delicate reticulate mesh; texture firm.

Discussion. The character of the basal secondaries shows that the fossil leaf cannot be assigned to Juglans. No satisfactory match among modern leaves has been found, although there are resemblances to the leaves of Croton and Aristotelia.

Occurrence. Chalk Bluffs, locality P3318.

Collection. U. C. Mus. Pal., Paleobot. Ser., plesiotype, no. 2350.

Genus **QUERCOPHYLLUM** Fontaine

Quercophyllum platanoides, new species

(Plate 43, figures 3, 7)

Description. Leaf ovate to obovate; length 7 to 9 cm., width 4.5 to 6 cm.; apex acute; base cuneate; margin sinuate-dentate, entire proximad; midrib strong; petiole 1.5 to 2.5 cm. in length, slender, expanded at the base; approximately 6 pairs of secondaries arising 1.5 to 2 cm. above the base at angles of 45° to 50°, curved upward and craspedodrome, basal secondaries at angles of from 55° to 70°, sinuous and usually camptodrome, the strong pair of secondaries succeeded by 3 pairs of subparallel, craspedodrome secondaries; tertiary venation straggling percurrent, numerous irregular craspedodrome tertiaries branching from the marginal sides of the secondaries toward their extremities; areolation reticulate; texture coriaceous.

Discussion. These leaf impressions are oaklike in many characters, but differ in various respects from all oak leaves examined. The strong pair of secondaries originating at some distance above the base suggests the leaves of Platanus, but this character is also found in such oak leaves as those of Quercus marylandica Muenchhausen. They may be the leaves of some extinct oak, or possibly of some extinct genus of the Platanaceae.

Occurrence. Sailor Flat, locality P3347.

Collection. Calif. Acad. Sci. Paleo. Type Coll., cotypes, nos. 7778, 7779.

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