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THE LARAMIE FLORA OF THE DENVER BASIN

WITH A REVIEW OF THE LARAMIE PROBLEM

BY

F. H. KNOWLTON

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THE LARAMIE FLORA OF THE DENVER BASIN,

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By F. H. Knowlton.

INTRODUCTION.

In the investigation of the Laramie flora which I began about 1889 it was my original intention to study the flora of the Laramie formation of the entire Rocky Mountain region, over which the formation was then understood and generally accepted as being widely distributed. As a preliminary to this study the older collections, which had served as the basis for the work of Lesquereux, Newberry, and others, were critically reviewed. To this basis was to be added the new material that was becoming available in ever-increasing volume. It very soon became evident, however, that opinion concerning the Laramie formation was undergoing a transition, during which, as will be shown in the historical review which follows, area after area was found to have been incorrectly or unwisely assigned to the Laramie. The work was consequently delayed pending the settlement of these disputed points, and subsequent events have abundantly proved the wisdom of postponement, for otherwise the result would have been a composite picture and open to the same objections as those that fall upon Ward's "Flora of the Laramie group." The revision of the older material, together with the descriptions of such new material as came to hand from time to time, has consequently lain in manuscript for many years, though it has been available and has furnished the basis for numerous tentative considerations of this flora.

In view of the uncertainties as to the ultimate classification of certain of the supposed Laramie areas, it was finally decided to restrict this account to an area about which there is little or no disagreement. The Denver Basin in Colorado offers such an area. The geologic relations of the Laramie as understood in 1895 were set forth by Emmons, Cross, and Eldridge in their monograph on the geology of the Denver Basin.[1]

After the segregation of the Arapahoe and Denver formations from the Laramie, there remained the Laramie unit as now accepted, which is believed to fulfill in all essential particulars the requirements of the original definition by King. When the Denver Basin monograph was published, it was supposed that the coal-bearing Laramie rocks were present throughout the Front Range. Subsequent study has shown, however, that the Laramie is not now known to extend beyond Colorado Springs on the south.

This paper deals with the plants known from the Laramie of the Denver Basin, which is here considered as slightly larger than the limits set in the monograph above mentioned, extending from the vicinity of Greeley to the divide near Palmer Lake on the south. The southernmost exposure of Laramie rocks in the Castle Rock quadrangle is in practical continuity with the Laramie in the Denver Basin and is separated by a covered interval of only about 18 miles from the nearest exposure of Laramie in the Colorado Springs quadrangle. To the east the Laramie extends for varying distances out on the plains, where, however, it is more or less deeply covered by the Arapahoe or Denver formations or the Dawson arkose.

The material on which this paper is based was derived from many sources. Most of the original material on which Lesquereux based his studies is preserved in the United States National Museum and has been freely con-

[1] U. S. Geol. Survey Mon. 27, 1896.

sulted. It was collected in part by F. V. Hayden and in part by Lesquereux or by persons in correspondence with him. The very earliest collection made by Hayden, at Marshall in 1867, is apparently lost. The types of the few species described by J. S. Newberry are also preserved in the United States National Museum. About 1884 an important collection was made for Newberry by N. L. Britton, now of the New York Botanical Garden. The larger part of this collection came from mines near Erie, Colo., from which no additional material has been procured. Other parts of this collection were made at Marshall and on Coal Creek. All this material has been placed at my disposal by Dr. Arthur Hollick. Considerable collections were made by Lester F. Ward in 1883, but heretofore they have only partly been described. During the prosecution of the work which resulted in the publication of the Denver Basin monograph, Emmons, Cross, and Eldridge obtained a number of small collections, and under the instructions of Emmons larger and important collections were made by Arthur Lakes and G. L. Cannon. These collections, made in 1889 and 1890, have not before been described. A small collection from Crow Creek, near Greeley, was made in 1896 by T. W. Stanton and me. The largest collections obtained in recent years were made by A. C. Peale and me in 1908. The material in the museum of the University of Colorado, at Boulder, has been placed at my disposal by the custodian, Judge Junius Henderson. Smaller collections or individual specimens have been communicated by T. D. A. Cockerell, of Boulder; R. D. George, State geologist of Colorado; G. L. Cannon, of Denver; G. B. Richardson and M. I. Goldman, of the United States Geological Survey; and G. I. Finlay, formerly of Colorado Springs. Invaluable data regarding the supposed upper part of the Laramie were obtained by W. T. Lee, of the United States Geological Survey, in 1915. To these men and all others who have contributed to this study the appreciation of the writer is hereby expressed.

Notwithstanding the fact that these very considerable collections have been brought together, the flora is neither large nor very impressive. In the first place, although plants are widely distributed in the Laramie, they are rarely found in any great abundance. The matrix in which they occur is usually a soft, friable sandstone which is not fitted to retain the plant impressions with fidelity, and, moreover, it is difficult to find perfect specimens. In attempting to present as complete a picture as possible of the plant life of the time, it has frequently been necessary to characterize forms on rather slender data. It is hoped, however, that all are figured and described adequately enough to be recognizable in the future.

A word should be said concerning the two styles of plates in this report. Plates XX–XXVIII were made a number of years ago, when it was the custom to make pen drawings of the specimens. These were drawn on an enlarged scale, requiring a one-third reduction to bring them to natural size. The figures on Plates I–XIX were photographed natural size and merely have had the outlines and nervation strengthened. The impossibility of having the two styles of drawings mixed on the same plate accounts for the scattering of the figures.

PART I. HISTORICAL REVIEW OF THE LARAMIE PROBLEM.

EARLY OPINIONS CONCERNING THE COAL-BEARING ROCKS OF THE ROCKY MOUNTAIN REGION.

As this report is the first of what is proposed to be a short series of papers dealing with the stratigraphy and paleobotany of certain late Cretaceous and early Tertiary formations in the Rocky Mountain region it is thought desirable to present rather completely a historical review of opinion which led to the establishment of the term Laramie and to its subsequent application. This review includes not only the Laramie formation in its typical area in the Denver Basin of Colorado, but also various beds at one time considered to be of Laramie age. For more than 60 years what finally came to be known as the "Laramie problem" has been more or less of a storm center in American geology. Its discussion has given rise to an extensive body of literature, and it is only within the last decade that a solution has been arrived at which, at least to me, appears to be logical and, it is hoped, permanent.

The history of the Laramie formation, as already intimated, is long and complicated, and the literature is widely scattered through a series of papers and reports in a manner that is very confusing to one who attempts to gain a comprehensive knowledge of it. A number of articles have been published dealing more or less completely with the historical development of the Laramie problem. One of the most complete for its time was that by Lester F. Ward,[2] published in 1886. Five years later C. A. White [3] again reviewed the subject as it finally appeared to one who had taken a large part in shaping it, and in 1906 George P. Merrill [4] devoted a special chapter to the Laramie question, which he ranked with the well-known "Taconic question." The "Index to the stratigraphy of North America," by Bailey Willis,[5] also contains valuable data on the Laramie formation, especially as regards certain of the later phases of opinion regarding it.

[2] Ward, L. F., Synopsis of the flora of the Laramie group: U. S. Geol. Survey Sixth Ann. Rept., pp. 399-557, 1886.

[3] White, C. A., Correlation papers—Cretaceous: U. S. Geol. Survey Bull. 82, 1891.

[4] Merrill, G. P., Contributions to the history of American geology: U. S. Nat. Mus. Rept. for 1904, pp. 647-658, 1906.

[5] U. S. Geol. Survey Prof. Paper 71, 1912.

Although the term Laramie first appeared in print in 1875, it is essential, to understand the conditions which led up to the use of the term and made it necessary, to go back at least as far as 1854, the date which marks the beginning of F. V. Hayden's explorations in the Missouri River region. As Ward [6] says:

> From the circumstance that at nearly all places where it has been recognized it consists to a greater or less extent of deposits of lignite or coal, this condition was for a time inseparably associated with it to such an extent that there was a disposition to regard all the lignitic deposits of the West as belonging to the same geological formation.

Prior to the work of Hayden the presence of coal in the upper Missouri River region had been noted by Lewis and Clark in 1804–1806, by Nicollet in 1839, by Audubon and Harris in 1843, and by John Evans in 1849 and 1853, but very little was recorded by these observers concerning the geology. In 1853 F. B. Meek and F. V. Hayden were employed by James Hall, then and for many years thereafter State geologist of New York, to visit the badlands of White River for the purpose of making collections of Cretaceous and Tertiary fossils in that region. They brought back extensive collections of vertebrates and invertebrates, the latter especially from the vicinity of Sage Creek and several localities on Missouri River, mainly below Fort Pierre. Subsequently Hayden spent two years in exploration and in collecting fossils in the same general region, and in 1856 he again visited this country in connection with an expedition under the direction of Lieut. G. K. Warren.

The data acquired on these expeditions resulted in the publication of a series of valuable papers in the paleontology and geology of the Missouri River region, or Nebraska Territory, as it was then called. The first of these papers was written by Hall and Meek,[7] and although it was concerned mainly with

[6] Ward, L. F., Synopsis of the flora of the Laramie group: U. S. Geol. Survey Sixth Ann. Rept., p. 406, 1886.

[7] Hall, James, and Meek, F. B., Description of new species of fossils from the Cretaceous formation of Nebraska, etc.: Am. Acad. Arts and Sci. Mem., vol. 5, pt. 2, pp. 379-411, 1855.

the description of new species of invertebrates it contains (p. 405) a geologic section under the heading "Section of the members of the Cretaceous formation as observed on the Missouri River and thence westward to the Mauvaises Terres." The stratigraphic units of this section, which practically correspond to those accepted at the present day, were numbered in ascending order from 1 to 5, but they were not then named. Above the Cretaceous portion of the section was recorded the Eocene Tertiary, which was given a maximum thickness of 250 feet.

In 1856 the elaboration of the invertebrates was continued by Meek and Hayden,[8] who quoted the geologic section from Hall and Meek without change, except that the Tertiary was given a thickness of 400 to 600 feet and was said to be composed of "beds of clay, sandstone, lignite, etc., containing remains of vertebrates and in places vast numbers of plants, with land, fresh-water, and sometimes marine or estuary Mollusca." As regards the Cretaceous portion of the section they stated:

> It is worthy of note that some of the species contained in the collection from the most recent Cretaceous beds of the upper Missouri country appear referable to genera which, according to high European authority, date no further back than the true chalk, while many of them are closely analogous to Tertiary forms—so close, indeed, that had they not been found associated in the same bed with *Ammonites*, *Scaphites*, and other genera everywhere regarded as having become extinct at the close of the Cretaceous epoch, one would have considered them Tertiary species.

On subsequent pages in the same journal Leidy[9] began the publication of the results of his study of the vertebrate remains from the Judith River badlands. He did not discuss the age of the beds, but in the description of the final species, which was named in honor of the collector, he said: "This species is named in honor of Dr. Hayden * * * and which remains, I suspect, indicate the existence of a formation like that of the Wealden of Europe."[10]

In their second paper[11] Meek and Hayden took up the invertebrates that were believed to be of Tertiary age and incidentally briefly described the lithology and areal extent of the great lignite-bearing formation (=Fort Union) of the region as then known to them. They showed that it occupies a vast area, "chiefly between the forty-sixth and forty-ninth parallels of north latitude and the one hundredth and one hundred and eighth degrees of longitude." As their adumbrations, even in this first venture, regarding the age of this lignite-bearing formation are so nearly in accord with the modern interpretation, it may be of interest to quote their statement (p. 113) in full:

> Although there can be no doubt that these deposits hold a rather low position in the Tertiary system, we have as yet been able to arrive at no very definite conclusion as to their exact synchronism with any particular minor subdivision of the Tertiary, not having been able to identify any of the Mollusca found in them with those of any well-marked geological horizon in other countries. Their general resemblance to the fossils of the Woolrich and Reading series of English geologists, as well as to those of the great Lignite formations of the southeast of France, would seem to point to the lower Eocene as their position.

In the following year, however, Hayden appears to have modified his opinion regarding the age of the lignite-bearing formations, for in a short paper[12] accompanying a colored geologic map of the country bordering Missouri River, he said, in discussing the "Great Lignite deposit)":

> The collections of fossils now obtained show most conclusively that it possesses the mixed character of a fresh-water and estuary deposit and that it can not be older than the Miocene period. It is composed mostly of clays, sands, sandstones, and lignites and has yielded numerous animal as well as vegetable fossils of great perfection and beauty. It is chiefly remarkable, however, for the evidence that it reveals to us of the variety and luxuriance of the flora of that period.

In a paper immediately following that one Meek and Hayden[13] continued the description

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[8] Meek, F. B., and Hayden, F. V., Description of new species of gastropods from the Cretaceous formation of Nebraska Territory: Acad. Nat. Sci. Philadelphia Proc., vol. 8, p. 63, 1856.

[9] Leidy, Joseph, Notice of extinct reptiles and fishes, discovered by Dr. F. V. Hayden in the badlands of the Judith River, Nebraska Territory: Acad. Nat. Sci. Philadelphia Proc., vol. 8, p. 72, 1856.

[10] This is the beginning of the so-called Judith River problem, which is considered on pp. 77-78 of the present paper.

[11] Meek, F. B., and Hayden, F. V., Descriptions of new species of Acephala and Gastropoda from the Tertiary formations of Nebraska Territory, with some general remarks on the geology of the country about the source of the Missouri River: Acad. Nat. Sci. Philadelphia Proc., vol. 8, p. 111, 1856.

[12] Hayden, F. V., Notes explanatory of a map and section illustrating the geologic structure of the country bordering on the Missouri River, from the mouth of Platte River to Fort Benton: Acad. Nat. Sci. Philadelphia Proc., vol. 9, p. 109, 1857.

[13] Meek, F. B., and Hayden, F. V., Description of new species and genera of fossils collected by Dr. F. V. Hayden in Nebraska Territory, etc.: Acad. Nat. Sci. Philadelphia Proc., vol. 9, p. 117, 1857.

of the invertebrates of the upper Missouri River region, but before beginning the technical part of the paper they again went over the geology of the region, reaffirming their conclusion that the lignite-bearing beds are of Miocene age.

The next paper of importance dealing with the geology of this region was another by Meek and Hayden [14] published in 1861. In a "general section of the Cretaceous rocks of Nebraska" (p. 419) the stratigraphic units previously known only by number first received the names by which they are now so widely recognized. These are as follows:

No. 5=Fox Hills.
No. 4=Fort Pierre.
No. 3=Niobrara.
No. 2=Fort Benton.
No. 1=Dakota.

Meek and Hayden also presented in this paper (p. 433) the first complete section of Tertiary rocks of the upper Missouri River region, given in the following sequence:

Loup River beds.
White River group.
Wind River deposits.
Fort Union or Great Lignite group.

As we are concerned in the present connection only with the lower of these divisions, the others may be passed over. Their description of the Fort Union is as follows:

> Beds of clay and sand, with ferruginous concretions and numerous beds, seams, and local deposits of lignite; great numbers of dicotyledonous leaves, stems, etc., of the genera *Platanus*, *Acer*, *Ulmus*, *Populus*, etc., with very large leaves of fan palms; also *Helix*, *Melania*, *Vivipara*, *Corbicula*, *Unio*, *Ostrea*, *Pholadomomya*, and scales of *Lepidotus*, with bones of *Trionyx*, *Emys*, *Compsemys*, *Crocodilus*, etc., occupy the whole country around Fort Union, extending north into the British possessions to unknown distances, also southward to Fort Clark. Seen underneath the White River group on North Platte River. Also on west side of Wind River Mountains.

Their conclusion as to the age of the Fort Union was not very definite, owing largely to the difficulty of interpreting the somewhat conflicting plant and invertebrate evidence, but the facts that it had been observed beneath the White River deposits (regarded by them as of Miocene age but now assigned to the Oligocene) and that it contains certain vertebrate remains not known in Europe above the Eocene "strengthen the impression that this Fort Union lignite group probably represents the Eocene of Europe."

For a number of years succeeding the publication of the last-mentioned paper, or during the years covered by the Civil War, there was little scientific activity in the vast and then almost unknown Western Territories, but in the spring of 1867 Hayden secured an appropriation from Congress for the geologic investigation of Nebraska. His report on this area [15] was submitted from the field on July 1, 1867. In this he quoted without change the general sections of the Cretaceous and Tertiary rocks of Nebraska, from the paper of 1861, above mentioned. The area supposed to be covered by the "Fort Union or Great Lignite group" was greatly extended, occupying not only all the country along the Missouri from Heart River to the Musselshell, most of the valley of the Yellowstone, and northward into the British possessions, but southward as far as the North Platte and "coming to the surface again at Pikes Peak, Colorado, and extending to Raton Pass, in New Mexico." The coal near Denver and Golden, in the Denver Basin, as well as what is now known as the Canon City field and thence southward to the Raton Pass district, was considered to be of Tertiary age, and this view was affirmed the following year.[16] In Hayden's third annual report,[17] which embraced Colorado and New Mexico, the area over which the coal-bearing rocks are distributed was greatly extended. "I regard all the coal beds of the West as lower Tertiary" (p. 189) is his final word at this time.

At this point a brief review may be given of the reasons which up to this time had led Hayden and others to regard the "Great Lignite deposits" of the West as of Tertiary age. These beds had been first studied in the upper Missouri River region, where their position above the marine Cretaceous section was plainly marked. Although they were not known to be separated from the marine Cretaceous by a discordance of any kind, they were obviously above it. The paleontologic evidence, at least so far as concerned the

[14] Meek, F. B., and Hayden, F. V., Description of new Lower Silurian, Jurassic, Cretaceous, and Tertiary fossils, collected in Nebraska, * * * with some remarks on the rocks from which they were obtained: Acad. Nat. Sci. Philadelphia Proc., vol. 13, p. 415, 1861.

[15] Hayden, F. V., U. S. Geol. Survey Terr. First Ann. Rept., pp. 1-64, 1867; reprint, 1873.

[16] Hayden, F. V., Notes on the lignite deposits of the West: Am. Jour. Sci., 2d ser., vol. 45, p. 198, 1868; U. S. Geol. Survey Terr. Second Ann. Rept., 1868; reprint, 1873.

[17] U. S. Geol. Survey Terr. Third Ann. Rept., 1869; reprint, 1873.

vertebrates and invertebrates, had been found somewhat conflicting, though it favored the Tertiary side. It was the fossil plants, of which great numbers were found, that proved of most value in influencing opinion. The material, especially that obtained by Hayden while on the Raynolds expedition of 1859-60, was studied by the well-known paleobotanist J. S. Newberry. Although Newberry's report was evidently prepared and submitted as early as 1867, it was not published until 1869, when it appeared as an appendix to Hayden's account of the geology.[18] Newberry argued strongly for the Tertiary (Miocene) age of the "Fort Union or Great Lignite series." The preliminary paper in which the Fort Union plants were first described by Newberry was published in 1868,[19] though the final publication in which they were fully described and adequately illustrated was not published until 1898.[20]

The fossil plants obtained by Hayden in Colorado and Wyoming in 1867 and 1868 were studied by Leo Lesquereux, and his preliminary report on them was printed in the form of a letter to Hayden.[21] They included plants from the Laramie Plains, Wyoming, the Denver Basin of Colorado, and the Raton Mountains of southern Colorado and northern New Mexico. Lesquereux regarded the plants from all these localities as of Miocene age, a conclusion which of course confirmed Hayden in his opinion held at that date (1869) that all the coal of the West was of Tertiary age.

Up to this time there had apparently been practical unanimity as to the Tertiary age of the lignite series, "the only varying evidence being found in what Dr. Leidy considered the Wealden type of the Judith River vertebrates." The first dissenting voice to this general current belief appears to have been raised by John L. Le Conte, who had accompanied an expedition for the survey of an extension of the Union Pacific Railroad from Smoky Hill River, Kans., to the Rio Grande. The first announcement is an extract from a letter dated Fort Craig, N. Mex., October 3, 1867, published in the American Journal of Science for January, 1868.[22] In this letter he stated that he had been enabled to make an examination and determine the age of a bed of anthracite near Old Placer Mountain, 25 miles southwest of Santa Fe, N. Mex.[23] The data upon which the Cretaceous age was predicated were not given at this time but were set forth in his full report [24] published later in 1868. At a number of localities, but notably in the canyon of Purgatoire River and near Trinidad, he found undoubted Cretaceous invertebrates associated with the coal, and in the higher beds he collected plants which Lesquereux pronounced of Tertiary age. Although Le Conte's paper bears date of February, 1868, it evidently was not published on that date, for in the paper he speaks of having seen Hayden's article on "Lignite deposits of the West" in the March number of the American Journal of Science for that year. In fact, he devotes several pages (pp. 65-68) to disproving Hayden's contention that all the coal of the West was of Tertiary age. In addition to studying the rocks of the Raton-Trinidad area, Le Conte made a journey from Trinidad to Denver, noting the coal near Colorado City and in the Denver Basin at Marshall, Golden, and other places. All this coal he considered to be of Cretaceous age, in spite of the evidence for Tertiary age adduced by Hayden and Lesquereux.

Without unduly anticipating it may be pointed out that subsequent study in the Raton-Trinidad area has shown that both Le Conte and Lesquereux were right—that is, the beds which yielded the *Inoceramus* are now known to be separated by marked unconformity from those above which supplied most of the plants studied by Lesquereux. (See pp. 18-19.)

[18] Hayden, F. V., Geological report of the exploration of the Yellowstone and Missouri rivers, under the direction of Capt. W. F. Raynolds, in 1859-60, 1869. Newberry's "Report on the Cretaceous and Tertiary plants" occupies pp. 145-174.

[19] Newberry, J. S., Notes on the later extinct floras of North America, with descriptions of some new species of fossil plants from the Cretaceous and Tertiary strata: New York Lyceum Nat. Hist. Annals. vol. 9, pp. 1-76, 1868.

[20] Newberry, J. S., The later extinct floras of North America (a posthumous work, edited by Arthur Hollick): U. S. Geol. Survey Mon. 35, 1898.

[21] Am. Jour. Sci., 2d ser., vol. 45, pp. 205-208, 1868; reprinted in U. S, Geol. Survey Terr. Third Ann. Rept., pp. 195-197, 1873.

[22] Cretaceous coal in New Mexico: Am. Jour. Sci., 2d ser., vol. 45, p. 136, 1868.

[23] Two years later F. V. Hayden visited this region and reported that the coal beds were above Cretaceous rocks containing *Ostrea congesta*, *O. larva*, *Inoceramus*, etc. The anthracite he explained as being due to the presence of an enormous dike. (See Preliminary field report of the United States geological survey of Colorado and New Mexico [U. S. Geol. Survey. Terr. Third Ann. Rept.], pp. 66-68, 1869.)

[24] Le Conte, J. L., Notes on the geology of the survey for the extension of the Union Pacific Railway from the Smoky Hill River, Kans., to the Rio Grande, pp. 1-117, 1868.

In 1869 Cope [25] published an elaborate paper on American fossil vertebrates in which he laid the foundation at least for a possible reference of certain of the localities of the Missouri River region to the Cretaceous. In discussing *Ischyrosaurus antiquus* Leidy (p. 40), which came from Moreau River in what is now South Dakota, he said that the horizon may be "perhaps of Cretaceous age," and under *Hadrosaurus? occidentalis* Leidy (p. 98) he recorded the horizon as "? Cretaceous beds of Nebraska, between Moreau and Grand rivers." In the same paper he refers the badlands of the Judith River to the upper Jurassic.

About this time the United States Geological Exploration of the Fortieth Parallel, under the direction of Clarence King, had reached that stage of its work which permitted the publication of the first to appear of its final reports.[26] To this volume King contributed a number of chapters, among them one on the geology of the Green River Basin of Wyoming, in which he held that the coal-bearing strata are of Cretaceous age and are unconformably overlain by fresh-water deposits of Tertiary age. On this point he says (p. 453):

Near the summit of the 9,000 feet a looser texture begins, and this change is rendered very noticeable by the introduction of beds of coal, which for an unknown distance upward, probably several thousand feet, reappear through a zone of constantly changing sand and mud rocks. The fossil life, which clearly indicates a Cretaceous age for the deepest members up to and including the first two or three important coal beds, from that point gradually changes with a corresponding alternation of sediments, indicating a transition to a fresh-water period. The coal continued to be deposited some time after the marine fauna had been succeeded by fresh-water types. The species of fossils are in no case identical with the California Cretaceous beds, which occupy a similar geological position on the west of the Sierra Nevadas. Their affinities decidedly approach those of the Atlantic slopes, while the fresh-water species, which are found in connection with the uppermost coal beds, seem to belong to the early Tertiary period.

Regarding the unconformable relations of the beds above mentioned to the overlying Tertiary, he said (p. 455):

Whatever may be the relation of these beds in other places, it is absolutely certain that within the region lying between the Green River and the Wasatch and bounded on the south by the Uintah Range there is no single instance of conformity between the coal beds and the horizontal fresh-water strata above them.

This same chapter contains a report by F. B. Meek on the fossil invertebrates of the region, in which he made the following guarded statement:

With the exception of the genus *Inoceramus*, which is certainly represented by two or three species, and perhaps *Anchura*, all of these fossils, so far as their characters can be made out, appear to be just such forms as might be referred with about as much propriety to the Tertiary as to the Cretaceous. In fact, it is probable, from the general absence of characteristic Cretaceous types among them (with the exceptions mentioned) that, if submitted to almost any paleontologist not aware of the fact that the specimens of *Inoceramus* and *Anchura?* occurred in the same beds, the whole would be unhesitatingly referred to the Tertiary. * * * From all the facts now known, I can therefore scarcely doubt that you are right in referring these beds to the Cretaceous.

In this report Meek also discussed the age of the so-called "Bear River Estuary beds," a series of fresh-water beds contiguous to Bear River in western Wyoming and eastern Utah. A complete historical review of the Bear River controversy, together with an enumeration of its invertebrate fauna, was given by C. A. White in 1895.[27] A brief exposition of this matter will be found on page 78 of this report.

The Fourth Annual Report of the Geological Survey of the Territories, for 1870 (published in 1871), was devoted to Wyoming and portions of contiguous territories. In a brief review of the geology of the Missouri River region, which forms Chapter VII of this report (pp. 85–98), Hayden again insisted upon the Tertiary age of the "Fort Union or Great Lignitic," and in support of this contention quoted from Newberry's report on the fossil plants as published in the Raynolds report already mentioned. (See p. 6.) That Hayden had come to realize the possibility that the coals of the West might not all be of Tertiary age is shown by the following remark (p. 94):

The area which it [Fort Union] occupies is not yet known, but every year it is extended north, south, and west. It is also characterized by numerous beds of coal, or lignite as it was formerly called, and, so far as the upper Missouri is concerned, most of the coal is true lignite. It is quite probable that the coal-making period began in the later portion of the Cretaceous era and extended up into the Tertiary. The observations of

[25] Cope, E. D., Synopsis of the extinct Batrachia, Reptilia, and Aves of North America: Am. Philos. Soc. Trans., vol. 14, pp. 1–252, 1869–70.

[26] U. S. Geol. Expl. 40th Par. Rept., vol. 3, Mining industry, Washington, 1870.

[27] White, C. A., The Bear River formation and its characteristic fauna: U. S. Geol. Survey Bull. 128, 1895.

geologists in New Mexico and Utah point to the conclusion that large deposits of excellent coal occur in the upper Cretaceous.

In the same report (p. 165) in discussing conditions on the Laramie Plains, he said:

That there is a connection between all the coal beds of the West I firmly believe, and I am convinced that in due time that relation will be worked out and the links in the chain of evidence joined together. That some of the older beds may be of upper Cretaceous age I am prepared to believe, yet until much clearer light is thrown upon their origin than any we have yet secured I shall regard them as belonging to my transition series or beds of passage between the true Cretaceous and the Tertiary.

Lesquereux also contributed a short paper to this same report in which (pp. 381–385) he gave a list of all the supposed Tertiary plants of the region known at that date. This list includes 30 species from the "Eo-lignitic" (now Wilcox formation) of Mississippi, 8 species from the Raton Pass region (now Raton formation) of New Mexico and Colorado, 9 species from Marshall, Colo. (now Laramie formation), 2 species from Golden, Colo. (now Denver formation), and 6 species from Rock Creek, Laramie Plains, Wyo. (now "Upper Laramie").[28]

In the Fifth Annual Report of the U. S. Geological Survey of the Territories, for 1871, which was published in 1872, Lesquereux has a long report on new plants from localities in Wyoming and Montana, all of which he considered to be of Tertiary age. He also attempted an important generalization in dividing the several localities among the stages of the Tertiary. This may be summarized as follows:

To the Eocene he referred the localities of Mississippi ("Eo-lignitic"); of Raton Pass, Purgatoire Canyon, and Marshall mine, near Denver, Col.; of Washakie Station, Evanston both above and below the coal, and Snake River just below [south of] the Yellowstone Park, all in Wyoming; and 6 miles above Spring Canyon, Mont. To the lower Miocene he referred the Fort Union and Yellowstone, Mont.; Rock Creek, Medicine Bow, Junction Station, and Carbon Station, Wyo.; to the middle Miocene Henrys Fork, Muddy Creek, and Barrell's Springs, Wyo., and Elko Station, Nev. The following localities were not at this time definitely placed stratigraphically: Green River, Point of Rocks, Sage Creek, and mouth of Spring Canyon.

In the following year (1872) Lesquereux himself spent several months in the study of this general field, undertaken at the direction of Hayden, as he somewhat naïvely remarks, with the "view of positively ascertaining the age of the lignite formations, either from data obtainable in collecting and examining fossil vegetable remains, or from any geological observations which I should be able to make."

During this investigation Lesquereux visited and collected from the coal fields of Marshall and Golden in the Denver Basin, Colorado Springs, Canon City, Trinidad, and Raton, and also along the line of the Union Pacific Railroad from Cheyenne to Evanston, Wyo. His results[29] were considered as confirmatory of his previous conclusions, namely, that the beds at these localities are of Tertiary age and constitute what he called the American Eocene

The same year Meek and Bannister, who were also conducting investigations along the line of the Union Pacific Railroad, made a discovery at Black Buttes which, in the opinion of many, had a very definite bearing on the age of the coal of the region. This was the finding of the remains of a huge dinosaur which was named by Cope[30] *Agathaumas sylvestris*. In his paper Cope said:

From the above description it is evident that the animal of Black Buttes is a dinosaurian reptile. * * * It is thus conclusively proven that the coal strata of the Bitter Creek basin of Wyoming Territory, which embraces the greater area yet discovered, were deposited during the Cretaceous period, and not during the Tertiary, though not long preceding the latter.

In a short paper published later in the same year Cope,[31] in commenting on the discovery of *Agathaumas*, said: "This discovery places this group [the so-called Bitter Creek series] without doubt within the limits of the Cretaceous period, and to that age we must now refer the great coal area of Wyoming."

In commenting on the age of the "Bitter Creek series," as the beds at Black Buttes and vicinity were then designated, Meek[32] expressed himself with extreme caution, saying:

[28] With the exception of that at the Marshall locality, all the collections above enumerated as Tertiary by Lesquereux are accepted as such at the present day, though for some of them it has required 40 years to establish the truth of Lesquereux's assignment.

[29] Lesquereux, Leo, Lignitic formations and fossil flora: U. S. Geol. Survey Terr. Sixth Ann. Rept., for 1872, pp. 317–427, 1873.

[30] Cope, E. D., On the existence of Dinosauria in the transition beds of Wyoming: Am. Philos. Soc. Proc., vol. 12, p. 481, 1872.

[31] Cope, E. D., The geological age of the coal of Wyoming: Am. Naturalist, vol. 6, p. 669, 1872.

[32] Meek, F. B., U. S. Geol. Survey Terr. Sixth Ann. Rept., for 1872, pp. 458, 461, 1873.

The reptilian remains found at Black Butte, near the top of the series, have, as elsewhere stated, been investigated by Prof. Cope and by him pronounced to be decidedly dinosaurian and therefore indicative of Cretaceous age. On the other hand, the fossil plants from the same beds have been studied by Prof. Lesquereux, who informs me that they are unquestionably Tertiary types. My own investigations having been confined to the invertebrates, it is of these chiefly that I will speak here. In the first place, it will be seen that all of these yet known belong to a few genera of mollusks, represented by 12 or 14 species. And just here it may be stated that, although partly committed in favor of the opinion that this formation belongs to the Cretaceous and still provisionally viewing it as most probably such, I do not wish to disguise or conceal the fact that the evidence favoring this conclusion to be derived from the mollusks alone, as now known, is by no means strong or convincing. The genera are probably all common both to the Cretaceous and Tertiary, as well as to the present epoch. * * * The entire absence among the fossils yet known from this formation of *Baculites, Scaphites, Ancyloceras, Phychoceras, Ammonites, Gyrodes, Inoceramus,* and all of the other long list of genera characteristic of the Cretaceous or in part also extending into older rocks, certainly leaves its molluscan fauna with a strong Tertiary facies. * * * It thus becomes manifest that the paleontological evidence bearing on the question of the age of this formation, so far as yet known, is of a very conflicting nature; though aside from the dinosaurian, the organic remains favor the conclusion that it is Tertiary.

It is plain that Meek was very much confused by the data then available, especially by the invertebrates, for he declared in another place that they might with almost equal propriety be referred to the Tertiary or the Cretaceous, and as the vertebrate evidence was interpreted to mean undoubted Cretaceous, only the fossil plants were left to sustain unfalteringly the Tertiary side of the argument. It was immediately pointed out, as it is occasionally even to the present day, that the error made by Oswald Heer in referring plants of the Dakota "group" to the Miocene [33] weakened the evidence of fossil plants and gave added weight to the dictum of the vertebrate paleontologist, namely, that the presence of dinosaurian reptiles in a formation was positive proof of Cretaceous age. Thus Cope was so firmly convinced that the presence of *Agathaumas* at Black Buttes proved the Cretaceous age of the "Bitter Creek series" that in 1874 he proceeded to refer the "Great Lignitic" of the upper Missouri to the same period. In discussing the age of certain vertebrate-bearing beds in northern Colorado, he said: [34]

Believing, as I do, that the evidence derived from the vertebrate remains requires the reference of the Bitter Creek coal series to the Cretaceous period, and having pointed out on similar grounds that the horizon of the Great Lignite from which vertebrate remains have been procured on the Missouri River is undoubtedly Mesozoic, although usually regarded as Tertiary, I suspect that the corresponding strata in Colorado will be found to pertain to the same section of geologic time.

In another bulletin of this series Cope [35] had an extensive article on the fossil vertebrates then recognized from the Cretaceous of the West. In this paper vertebrates from the localities on Moreau River and between Moreau and Grand rivers, S. Dak.; at Long Lake, N. Dak.; north of Big Horn River, Mont.; and in Colorado, now mainly referred to the Lance formation, he for the first time definitely referred to the Cretaceous. In alluding to the studies of the flora of these beds by Lesquereux and Newberry, he said (p. 16):

They have, as is well known, pronounced this whole series of formations as of Tertiary age, and some of the beds to be as high as Miocene. The material on which this determination is based is abundant, and the latter must be accepted as demonstrated beyond all doubt. I regard the evidence derived from the mollusks in the lower beds, the vertebrates in the higher, as equally conclusive that the beds are of Cretaceous age. There is, then, no alternative but to accept the result, *that a Tertiary flora was contemporaneous with a Cretaceous fauna, establishing an uninterrupted succession of life* across what is generally regarded as one of the greatest breaks in geologic time.

The above statement by Cope has often been quoted during the 48 years since it was written, and it is only recently that its converse—that is, that a fauna of Cretaceous type may be contemporaneous with a Tertiary flora—has been admitted as even possible.

This conclusion was further elaborated by Cope in Hayden's annual report for 1873, in a paper that was more or less in the nature of a reply to the article by Newberry already men-

[33] Those who are interested in this reference of the Dakota sandstone to the Miocene may be instructed by reading Lesquereux's account of the conditions under which the error was made (U. S. Geol. Survey Terr. Sixth Ann. Rept., for 1872, p. 343, 1873). From this account it appears that Heer never saw specimens of the Dakota plants, for only outline drawings of a few species were submitted to him. They were mostly dicotyledonous leaves and wholly unlike any then (1857) known from the Cretaceous of Europe, and the drawings were without the essential details of nervation. As soon as the specimens themselves were seen by Newberry he recognized their correct characters.

[34] Cope, E. D., Report on the stratigraphy and Pliocene vertebrate paleontology of northern Colorado: U. S. Geol. and Geog. Survey Terr. Bull. [1st ser.], No. 1, p. 10, 1874.

[35] Cope, E. D., Review of the Vertebrata of the Cretaceous period found west of the Mississippi River: U. S. Geol. and Geog. Survey Terr. Bull. [1st ser.], No. 2, pp. 1-51, 1874.

tioned. In the same report Marvine [36] had an elaborate paper on the results of his studies in Middle Park, Colo., in which he considered among many other things, the age of the lignite-bearing formations of Colorado. After alluding to the weakness of the invertebrate evidence for the Cretaceous age and the apparent strength of the evidence derived from the terrestrial vertebrates, he said:

> It must be supposed, then, that either a Cretaceous fauna extended forward into the Eocene period and existed contemporaneously with an Eocene flora, or else that a flora, wonderfully prophetic of Eocene times, anticipated its age and flourished in the Cretaceous period to the exclusion of all Cretaceous plant forms. * * * In either case the fact remains that here the physical and other conditions were such that one of the great kingdoms of life, in its progress of development, either lost or gained upon the other, thus destroying relations and associations which existed between them in those regions from which were derived the first ideas of life boundaries of geologic time, causing here apparent anomalies.

As a probable explanation of these apparent discrepancies, Marvine wisely concludes as follows: "Much of the confusion and discrepancy has, in my opinion, arisen from regarding different horizons as one and the same thing."

In his report for 1873 Lesquereux had a further paper on the "Lignitic" flora in which he of course argued still more strongly for its Tertiary age. He also revised the several "groups" into which he divided the section of lignite-bearing rocks and presented full lists of the species of plants found in each.

In Hayden's original description of the Fort Union formation he predicted that it would be found extending into Canadian territory, and this prediction was verified in 1874 by George M. Dawson,[37] who published an article in which he accepted the views of Hayden and Lesquereux and referred the Fort Union to the Eocene. In discussing the views of Cope he said:

> The evidence does not appear to show that the Cretaceous species were of themselves becoming rapidly extinct, but that over the western region, now forming part of this continent, the physical conditions changing drove the Cretaceous marine animals to other regions, and it is impossible at present to tell how long they may have endured in oceanic areas in other parts of the world. This being so, and in view of the evidence of the preponderant animal and vegetable forms, it seems reasonable to take the well-marked base of the Lignite series as that of the lowest Tertiary, at least at present. The formation described belongs to this lowest Tertiary, being, in fact, an extension of Hayden's Fort Union group, and from analogy may be called Eocene.

The work upon which Dawson's views were based was done in connection with the British North American Boundary Commission, of which he was geologist. In a report of progress for 1873, published in 1874, he affirmed his original statement in the following language:[38]

> The formation is, however, undoubtedly an extension of the Great Lignite or Fort Union group of strata of Hayden, as developed in the Western States and Territories. * * * These strata immediately succeeding the Cretaceous rocks are the lowest American representatives of the Tertiary series and have been called, for this reason, Eocene.

In the final report of the Boundary Commission, published in 1875, the same views were expressed.

About this time John J. Stevenson, who was then associated with the Wheeler Survey, published a number of papers on the geology of portions of Colorado and New Mexico in which he argued strongly for the Cretaceous age of the lignite-bearing beds, especially along the Front Range. In a chapter on the age of the Colorado lignites[39] he reviewed the opinions of Hayden, Lesquereux, and others and concluded that the presence of the supposed fucoid *Halymenites major* was an indication of Cretaceous rather than Eocene age, as advocated by Lesquereux. Subsequent study has shown that Stevenson was correct in referring the beds containing *Halymenites* to the Upper Cretaceous, but he failed to note the presence of the profound unconformity that has since been demonstrated by Whitman Cross and W. T. Lee to occur in the midst of this supposedly continuous coal-bearing section.

In the annual report of the Hayden Survey for 1874, published in 1876, there are three very important papers dealing more or less completely with this subject. The first of these is one by Hayden, in which he summed up his understanding of the lignite group at that date. He gave a brief history of the group and pointed out that the evidence for its age, as interpreted by different geologists and paleontologists, is very conflicting. He said:

[36] Marvine, A. R., Report of the Middle Park division: U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1873, p. 107, 1874.

[37] Dawson, G. M., The Lignite formations of the West: Canadian Naturalist, vol. 7, p. 241, 1874.

[38] Dawson, G. M., Report on the Tertiary Lignite formation in the vicinity of the 49th parallel, British North Am. Boundary Com., 1874.

[39] U. S. Geog. and Geol. Surveys W. 100th Mer. Rept., vol. 3, pp. 404-410, 1875.

One fruitful source of difference of opinion has been in the misunderstanding in regard to the different horizons of coal strata of the West. That there are important coal beds in rocks of well-defined Cretaceous age can not be disputed, and I have long since yielded that point. What we wish to show more clearly is that there exists in the West a distinct series of strata which we have called the Lignite group, and that it is entirely separate, paleontologically and geologically, from a great group of strata in the lower Cretaceous, and perhaps extending down into the Jurassic, which contains a great number of thick and valuable beds of coal. It is not necessary to discuss the question whether the term Lignitic shall be applied to the coal of either or both groups. I have used the term Lignitic for the upper group without reference to the quality of its fuel, simply to distinguish it from the other great groups of older date, the ages of which are not questioned.

From the above statement it is clear that Hayden was entirely willing to admit the existence of coal in the Cretaceous of the Rocky Mountain region, and from this it of course followed that the term "Lignitic" was not applicable to all the coal-bearing strata; in fact, he distinctly stated that the term was to be applied only to the upper coal-bearing series. He still argued, however, for the connection of the coal-bearing beds of the Laramie Plains and Colorado with the vast group to the northwest.

The same report contained a long paper by A. C. Peale on the geology of portions of Colorado, in which he presented a series of tables illustrating the progress of opinion regarding the "Lignitic group." He discussed the different opinions at length and reached the following conclusions:

1. The lignite-bearing beds east of the mountains in Colorado are the equivalent of the Fort Union group of the upper Missouri and are Eocene Tertiary; also, that the lower part of the group, at least at the locality 200 miles east of the mountains, is the equivalent of a part of the lignitic strata of Wyoming.

2. The Judith River beds have their equivalent along the eastern edge of the mountains below the Lignite or Fort Union group and also in Wyoming and are Cretaceous, although of a higher horizon than the coal-bearing strata of Coalville and Bear River, Utah. They form either the upper part of the Fox Hills group (No. 5) or a group to be called No. 6.

Also in this report for 1873 Lesquereux had an extensive paper under the title "On the Tertiary flora of the North American Lignitic, considered as evidence of the age of the formation." He again took up the objections that had been urged against his interpretation and answered each in detail as the evidence appeared to him. His opinion remained unchanged.

The historical review of opinion which preceded the introduction of the term Laramie has now been presented in sufficient detail to make clear the necessity for a convenient, usable, common appellation. Those who had approached the subject from a study of the northern areas—that is, of the upper Missouri River region and contiguous territory—were naturally impressed with the strength of the argument for the Tertiary age of the lignite-bearing beds, while those who had first become familiar with the more southern areas were quite as strongly of the opinion that the beds they studied were of Cretaceous age. Subsequent study has shown that both these views contained a measure of truth.

As A. C. Peale was at that time actively engaged in geologic work in the Rocky Mountain area, his recollection of the conditions then current, as set forth in a recent article,[40] is of interest:

As a member of the Hayden Geological Survey at the time the term "Laramie" was first proposed and used by both the Hayden and King organizations, and as one of those who first used it, a statement of my recollection may be of some interest here. Just at the time the work of the Exploration of the Fortieth Parallel, under Clarence King, was approaching completion, and their geologic maps were being colored, the work of the United States Geological and Geographical Survey of the Territories had also reached the stage when it became necessary to color the maps of Colorado, upon which field work was begun in 1873 and finished in 1876. As two of the maps of the former organization adjoined the work of the Hayden Survey along the northern line of Colorado, it was deemed desirable that there should be some correlation, in terms at least, where the work joined. There was substantial agreement as to most of the formations, about the only difference being as to the age of the beds resting conformably upon the Fox Hills Cretaceous of Hayden as exposed along the line of the Union Pacific Railway and to the westward of the foothills of the Front Range of Colorado, where they were usually designated by Hayden and the members of his Survey as the Lignitic beds of eastern Colorado or the lignitic coal group of the eastern slope. These beds were considered by King to be of Cretaceous age, while Hayden was inclined to consider them as belonging to the Tertiary. At this time Clarence King wrote to Dr. Hayden asking him to propose a name for these debatable beds—debatable only as to age, for both agreed as to their stratigraphic position. In reply to this letter Hayden suggested the name Laramie, which was accepted by King, as indicated by him on page 331

[40] Peale, A. C., On the application of the term Laramie: Am. Jour. Sci., 4th ser., vol. 27, p. 45, July, 1909.

of the volume on systematic geology,[41] where he says: "During the slow gathering of the evidence which shall finally turn the scale I proposed to Dr. Hayden that we adopt a common name for the group and that each should refer it to whatever age his data directed. Accordingly, it was amicably agreed between us that this series should receive the group name of Laramie and that it should be held to include that series of beds which conformably overlies the Fox Hills."

It may be of interest to point out that, so far as now known, the word Laramie used as a geologic formational term first appeared in an author's proof of geologic map No. II of the Fortieth Parallel Survey, by Clarence King and S. F. Emmons. This map was dated November 15, 1875, and was noticed in the American Journal of Science for February, 1876, but in neither place was there any definition of the term. The first printed description of the Laramie was apparently that given by Arnold Hague [42] in volume 2 of the final reports of the Fortieth Parallel Survey, in which he presented a very small and relatively unimportant section that claims distinction only on the ground that it was the first section ever published of the Laramie. It was measured on the Denver Pacific Railroad 5 or 6 miles west of Carr station and about 18 miles southeast of Cheyenne, Wyo. Peale [43] stated that "this section, if any should be so considered, would be the typical Laramie section."

Hayden first used the term Laramie in an article published in 1877.[44] In this article he followed the coloring on King's map above mentioned, which he undoubtedly had before him at the time.

King and the members of his Survey frankly and, as he says, "cheerfully" adopted the classification and nomenclature of the Upper Cretaceous section as defined by Hayden. After describing the Cretaceous rocks of their area up to and including the Fox Hills, King said:[45]

Here, with those who follow Hayden, the Cretaceous series comes to an end. Conformably over this (Fox Hill) lies the group which Hayden and I have agreed to call the Laramie, which is his Lignitic group and is considered by him as a transition member, between Cretaceous and Tertiary. There is no difference between us as to the conformity of the Laramie group with the underlying Fox Hill. It is simply a question of determination of age upon which we differ.

King was in error, however, in stating that the Laramie was the equivalent of Hayden's Fort Union "group," or indeed that it included all of the so-called Lignitic, and it was undoubtedly the assumption by subsequent writers that this was so that led to much of the discussion and difference of opinion that speedily arose. Hayden's last published word on this point [46] occurs in the letter transmitting Lesquereux's "Tertiary flora" to the Secretary of the Interior and is as follows:

If objection is made to the use of the term "Lignitic" group, I would say that in this work it is restricted to a series of coal-bearing strata lying above the Fox Hills group, or Upper Cretaceous, and these are embraced in the divisions Laramie and Fort Union groups. It is well known that there are in various parts of the West, especially along the fortieth parallel and southwestward, very thick beds of coal in the various divisions of the Cretaceous, extending down even into the upper Jurassic. Had this not been the case, the more general term Lignitic would not have been retained by the Survey in preference to any other.

On the succeeding page of this letter he summed up his conclusion in the following words:

The facts as we understand them at the present time would seem to warrant this general division, viz, a marine series, Cretaceous; gradually passing up into a brackish-water series, Laramie; gradually passing up into a purely fresh-water series, Wasatch. It is also probable that the brackish-water beds on the upper Missouri must be correlated with the Laramie, and that the Wasatch group as now defined and the Fort Union group are identical as a whole, or in part at least.

The Laramie was by that time fairly launched, and the literature devoted to it became increasingly voluminous and scattered. It is not possible nor perhaps desirable in the present connection to follow all the intricate ramifications of the discussion, and only an outline of the salient features will be attempted. The two points that attracted most attention were the areal distribution of the Laramie and of course its age. As so frequently happens in discussions of this kind, the pendulum when once started was permitted to swing too far, with the result that beds were included in the Laramie that subsequent study has proved have little or no intimate connection with

[41] U. S. Geol. Expl. 40th Par. Rept., vol. 1, 1878.
[42] Idem, vol. 2, pp. 60, 61, 1877.
[43] Am. Jour. Sci., 4th ser., vol. 27, p. 49, 1909.
[44] Notes on some artesian borings along the line of the Union Pacific Railroad in Wyoming Territory: U. S. Geol. and Geog. Survey Terr. Bull., vol. 3, pp. 181-185, April 5, 1877.
[45] U. S. Geol. Expl. 40th Par. Rept., vol. 1, p. 348, 1878.
[46] U. S. Geol. Survey Terr. Rept., vol. 7, p. iv, 1878.

this formation, at least on the basis of the original definition by King. Some phases of this history will be set forth in the following pages.

One of the first to take up the study of the Laramie from both the geologic and the paleontologic sides was Charles A. White. In the first paper in which he employed the term Laramie [47] the use was relatively unimportant and the term was not defined. He gave two generalized sections—one of the Green River region, in which he placed the Laramie in its proper position between the Fox Hills and the Wasatch beds, and within the larger grouping of post-Cretaceous, which also includes the lower part of the Wasatch; and the other of the upper Missouri River region, in which the Laramie was not included but its place was taken by the Judith River "group," while the post-Cretaceous was made to include this and a portion of the overlying Fort Union.

White's reasons for regarding the Laramie as post-Cretaceous were set forth in the fifth of his "Paleontological papers" [48] published in the same volume as the paper just cited. He said that all who had examined the fossils from the Dakota, Colorado, and Fox Hills deposits as they are developed in southern Wyoming and adjacent parts of Utah and Colorado, whether vertebrate or invertebrate, would not question their Cretaceous age. The fossils of the Green River and Bridger strata were said to disclose equally conclusive evidence of their Tertiary age. He went on to say that the two groups of beds between the Fox Hills below and the Green River above are the Laramie and Wasatch, and that somewhere within these vertical limits must come the line between Cretaceous and Tertiary. He then continued:

> With a few doubtful exceptions, none of the strata of the Laramie group were deposited in open-sea waters; and with equally few exceptions, none have yet furnished invertebrate fossils that indicate the Cretaceous rather than the Tertiary age of the group. * * * Again, the brackish and fresh water types of Mollusca that are afforded by the Laramie and the lower portions of the Wasatch group are in most cases remarkably similar, and some of the species of each group respectively approach each other so nearly in their characteristics that it is often difficult to say in what respect they materially differ. Moreover, they give the same uncertain indication as to their geological age that all fossils of fresh and brackish water origin are known to do.
>
> It is in view of the facts here stated, and also because I believe that a proper interpretation of them shows the strata of the Laramie group and the base of the Wasatch to be of later date than any others that have hitherto been referred to the Cretaceous, and also earlier than the Eocene epoch, that I have decided to designate those strata as post-Cretaceous, at least provisionally.

In the annual report of the Hayden Survey for 1876, published in 1878, White presented in a lengthy paper the results of his field studies in Colorado for the years 1876 and 1877. He still retained the term post-Cretaceous for the Laramie and in an instructive table (p. 22) showed that he regarded it as the equivalent of the Laramie of King, the Point of Rocks group of Powell, and the Lignitic of Hayden. He defined it as follows:

> The fact that this series passes insensibly into the Fox Hills group below and into the Wasatch group above renders it difficult to fix upon a stratigraphical plane of demarcation, either for its base or summit. I have therefore decided to regard this group as essentially a brackish-water one, referring all strata below that contain any marine Cretaceous invertebrate forms to the Fox Hills group, beginning this series with those strata that concontain brackish and fresh water forms, and ending it above with those strata in which the brackish-water forms finally cease. Thus defined, the whole series seems to form one natural paleontological group, as well as to be a sufficiently distinct stratigraphical one, for which I have adopted the name of Laramie group of King.

The term post-Cretaceous was also employed by Endlich [49] in his report on the White River area of Colorado, and by Peale [50] in his work in the Grand (now Colorado) River region.

The application of the term Laramie was carried farther and farther afield, until ultimately it was made to include a vast area in the Rocky Mountain region. When the term was first proposed by King no type locality was mentioned but it was expressly stated to include the lignite-bearing beds lying conformably above the Fox Hills along the Front Range in northern Colorado and along the west side of the range in eastern and central Wyoming. The term was immediately accepted, though with reservations as to the age represented, by the members of the Hayden

[47] Catalogue of the invertebrate fossils hitherto published from the fresh and brackish water deposits of the western portion of North America: U. S. Geol. and Geog. Survey Terr. Bull., vol. 3, pp. 607-614, May 15, 1877.

[48] Idem, pp. 625-629.

[49] U. S. Geol. and Geog. Survey Terr. Tenth Ann. Rept., for 1876, pp. 77, 109, 1878.

[50] Idem, p. 181.

Survey, who extended its application to western Colorado and adjacent areas. After the death of Meek the mantle of invertebrate paleontologic work fell largely upon the shoulders of C. A. White, and he had a large part in extending the application of the Laramie. In the seventh of his "Paleontological papers"[51] he gave the following range for Laramie as he then accepted it:

The term Laramie group is here used to include all the strata between the Fox Hills group of the Cretaceous period beneath and the Wasatch group (=Vermillion Creek group of King) of the Tertiary above. That is, it includes, as either subordinate groups or regional divisions, both the Judith River and Fort Union series of the upper Missouri River; the Lignitic series east of the Rocky Mountains in Colorado; the Bitter Creek series of southern Wyoming and the adjacent parts of Colorado; and also the "Bear River Estuary beds," together with the Evanston coal series, of the valley of Bear River and adjacent parts of Utah. Strata of this great Laramie group are known to exist in other large and widely separated districts of the western portion of the national domain.

Later the Laramie was believed by White to have been recognized as far south as the States of Chihuahua, Coahuila, and Nuevo Leon, in northern Mexico. It was also adopted by the Canadian geologists and shown by them to extend over a vast area in the British possessions. In fact, as late as 1891, after a number of important horizons had been removed from the confines of the Laramie, White[52] gave the following as the recognized distribution of the formation:

The present geographical outlines of the area within which strata of this formation occur are not yet well known, but it apparently is as great as that within which any other North American formation has been observed. Their presence has been recognized at so many and such widely separated localities that they safely may be assumed to once have formed a continuous deposit from near the twenty-sixth to near the fifty-fifth parallel of north latitude and in certain districts from near the one hundred and third to near the one hundred and fifteenth meridian. That is, it is evident that this formation originally consisted of a continuous deposit nearly or quite 2,000 miles long from north to south, and more than 500 miles across from east to west.

The structural and lithologic character of the Laramie as it was then (1891) accepted was well set forth by White,[53] who wrote as follows:

In lithological character the Laramie formation is remarkably uniform throughout both its geographical and vertical extent, and it seems everywhere to have been the result of continuous sedimentation from base to top. Its strata within the whole of the great area which they occupy are mostly composed of sandy material, but frequently they are more or less argillaceous and rarely calcareous. Sandstones of much firmness often occur among them, but a large part of the sandy strata are soft and friable. Shaly strata not infrequently occur, and these are often carbonaceous. The formation throughout its whole extent is coal-bearing.

The question concerning the Laramie which gave rise to the most extensive discussion and difference of opinion was, of course, that of its age. It may be of interest to present a brief recapitulation of the divergent views on this point that had been promulgated up to about 1890, or approximately to the time when, if it is permissible to use the expression, the reaction set in, and the pendulum began its backward swing as regards what should or should not be included within the limits of this formation—the point that subsequent investigation has shown is the cause of much of this difference of opinion.

King and the other members of the Fortieth Parallel Survey regarded the Laramie as of Cretaceous age and the equivalent of the Lignitic group of Hayden. The term was immediately accepted by Hayden and the members of the Survey under his direction, though not wholly as a substitute for the earlier "Lignitic," for they admitted undoubted Cretaceous coals. Hayden regarded the Laramie as transitional between Cretaceous and Tertiary. Endlich, from his studies in the vicinity of Trinidad, Colo., referred the coal-bearing rocks of the region (=Laramie) to post-Cretaceous or pre-Tertiary. White, Endlich, and Peale, who investigated the Laramie, especially in Utah, Wyoming, and Colorado, called it post-Cretaceous, and White in particular stated his belief that it was transitional between Cretaceous and Tertiary. Stevenson and Newberry also were familiar with the areas in southern Colorado and New Mexico and were firm in their belief that it was Cretaceous. The vertebrate paleontologists Cope, Marsh, and many others after them referred the Laramie unqualifiedly to the Cretaceous, largely on the ground that it contained remains of dinosaurian reptiles that were believed to be an unfailing mark of Cretaceous age. On the other hand, Lesquereux, from his extensive

[51] White, C. A., On the distribution of molluscan species in the Laramie group: U. S. Geol. and Geog. Survey Terr. Bull., vol. 4, No. 3, p. 721, July 29, 1878.
[52] White, C. A., Correlation papers—Cretaceous: U. S. Geol. Survey Bull. 82, p. 145, 1891.
[53] Idem, p. 146.

studies of the fossil plants, was strenuous in his claim that the "Lignitic" and later the Laramie were of Tertiary age.

In 1884–85 Lester F. Ward [54] instituted an elaborate investigation and comparison of the fossil plants, in the hope of throwing conclusive light on its age. Ward was undoubtedly influenced by the prevailing opinion, chiefly that of White, as to what should be regarded as Laramie, with the result, as is now known, of referring to it beds later proved to belong to the Montana, Laramie, Arapahoe, Denver, Lance, and Fort Union, and it is small wonder that he was unable to reach definite conclusions.

From this point on it will be inexpedient to follow the strictly chronologic method of treatment, for the reason that the literature is so very extensive and scattered, and consequently it will be taken up by regions or special horizons that have, for one reason or another, come into prominence. Each of these, particularly those of special interest as bearing on the problem, will be followed through to the present time. It is to be remembered that the area over which the Laramie was believed to be more or less continuously exposed reached its maximum extension about 1890, since when, by a process of elimination or subtraction, it has constantly been diminishing until at the present time only a comparatively small area remains to support the name.

RELATIONS BETWEEN THE LARAMIE OF THE DENVER BASIN, TAKEN AS A STANDARD, AND THE REPORTED LARAMIE IN THAT AND OTHER AREAS.

As set forth in the preceding pages, the history of the Laramie formation shows that it has had what may be called a rise and fall. From the date of the introduction of the term into geologic literature and usage, in 1875, to about 1890 its application was undergoing a process of expansion, until the formation was believed to have covered a vast area extending from northern Mexico to the Arctic Circle and many hundreds of miles in width. In part concurrent with this expansion, or from about 1888 to the present time, the application of the term has been subjected to a process of elimination or curtailment, until, as was long ago so aptly stated, the problem became not so much "To what age does the Laramie belong?" as "What belongs to the Laramie?"

As time went on, it was again and again incontestably shown that beds supposed to fulfill the requirements of the definition of the Laramie had been incorrectly so placed for one reason or another, and reasonable doubt had been cast upon the right of many other beds to be considered as typical Laramie.

It is proposed in the following pages to review the several stratigraphic units or geographic areas to which or within which the term Laramie is no longer considered applicable or at least requires a greater or less measure of qualification. So far as possible the sequence is chronologic, but naturally it has not been expedient to adhere strictly to the chronologic order, so far as that would lead to needless repetition or to the breaking up of the discussion of a natural geographic unit. Nevertheless, it has been impossible to avoid some repetition and overlapping in the treatment, owing to the fact that results obtained in one field may have a more or less important bearing on another field.

ARAPAHOE AND DENVER FORMATIONS.

The area about the city of Denver, Colo., now well known as the Denver Basin, is in a way classic ground for geology. It had been visited and studied in greater or less detail by a number of geologists and paleontologists, including J. L. LeConte, F. V. Hayden, Leo Lesquereux, A. R. Marvine, C. A. White, S. F. Emmons, Whitman Cross, G. H. Eldridge, and L. F. Ward. The coal-bearing rocks conformably above the marine Cretaceous Fox Hills formation were at first believed to be a southern extension of the "Lignitic group" of the upper Missouri River region and were held by Hayden, Lesquereux, and others to be of Tertiary age. When the Laramie "group" was established by King, this portion of the section in the Denver Basin and adjacent areas along the Front Range fell within its limits, and the beds were regarded by him and by those who accepted his views as Cretaceous. This so-called Laramie was for many years regarded as a unit, notwithstanding the fact that at certain points along the base of the mountains, notably at Golden, the lower or coal-bearing portion of the section was vertical,

[54] Ward, L. F., Synopsis of the flora of the Laramie group: U. S. Geol. Survey Sixth Ann. Rept., for 1884-85, pp. 401-557, 1886.

whereas the adjacent beds of Table Mountain were practically horizontal. Some geologists invoked the presence of a hypothetical fault to account for this obvious discordance, but it is now known to be due to a sharp fold and not to a fault. This is shown by the fact that at Green Mountain, 3 or 4 miles south of Golden, the Arapahoe and the lower part of the Denver, as well as the Laramie, are vertical. Both the lower and the upper beds are abundantly plant-bearing, and both had furnished extensive collections, but, as it later appeared, no distinction was made in the specimens or in the records concerning them, all being called simply "Laramie," with the result that when the horizons were proved to be distinct, the greatest confusion and difficulty arose in the effort to separate them.

As early as the summer of 1881, when Whitman Cross [55] began his studies in the Denver Basin, he "first observed," to use his own language, "that the Table Mountain strata possessed characteristics proving them to belong to a series distinct from the normal Laramie." No published announcement of this discovery was made at the time, and field work was continued in the region for a number of succeeding years, during which G. H. Eldridge ascertained that another distinct Tertiary formation occurred between that discovered by Cross and the normal Laramie. A preliminary statement of the most important results of this investigation was made by Eldridge and Cross in two papers read before the Colorado Scientific Society July 2, 1888. In the first of these papers [56] Eldridge named and described the Arapahoe formation,[57] which, he stated, was "the formation next succeeding the Laramie in geological order and unconformably resting on it." It was characterized as follows:

> It is composed of a basal member of conglomerate or gritty sandstone, according to its distance from the foothills, with an overlying zone of gray argillaceous or arenaceous shales, containing lenticular masses of hard, quartzose sandstone, with an occasional ironstone; when confined between under- and overlying groups it has a thickness varying between 600 and 1,200 feet.

In the succeeding paper Cross [58] named and described the Denver Tertiary formation, which he found to be unconformably overlying the Arapahoe. Lithologically it was found to be composed almost entirely of andesitic volcanic material; its thickness was given as 800 to 1,200 feet.

As already indicated, both Arapahoe and Denver were regarded originally as of Tertiary age and both were found to contain fairly abundant vertebrate remains belonging to turtles, crocodiles, dinosaurs, and, it was at first supposed, mammals. These remains were studied by O. C. Marsh, and at first the study resulted in great confusion. The dinosaurs from the Denver were pronounced to be "typical Jurassic dinosaurs of both herbivorous and carnivorous types." [59] Though found in the same beds, what was described as a bison was referred to latest Pliocene time. Later these dinosaurs and the supposed bison were found to belong to the Ceratopsidae, a group of horned dinosaurs especially abundant in Converse County, Wyo., to which consideration will be given in subsequent pages. This determination, according to the vertebrate paleontologists, fixed their age as Cretaceous. The invertebrates consisted of a few rather poorly preserved fresh-water types that did not prove of much value in fixing the age.

Fossil plants were abundant, especially in the Denver beds, but, as already stated, the specimens collected were not labeled with the names of specific localities, and all were regarded as of Laramie age. Before they could be utilized in the light of this newer information as regards their stratigraphic relations, it was necessary to separate them on the basis of the matrix. They were fortunately preserved in the United States National Museum, and a study of the matrix undertaken by Cross resulted in showing that they were abundantly distinct from those of the underlying Laramie—in fact, out of about 98 species in the Laramie and some 140 in the Arapahoe and Denver, only about 15 nominal species were found in common. Subsequent studies of the Arapahoe

[55] Cross, Whitman, The Tertiary Denver formation: Am. Jour. Sci., 3d ser., vol. 37, p. 262, 1889.

[56] Eldridge, G. H., On some stratigraphical and structural features of the country about Denver, Colo.: Colorado Sci. Soc. Proc., vol. 3, pp. 86–118, 1888.

[57] This was first named the "Willow Creek beds," but on the ground of preoccupation the name was changed in a footnote (p. 97) to Arapahoe.

[58] Cross, Whitman, The Denver Tertiary formation: Colorado Sci. Soc. Proc., vol. 3, pp. 119–133, 1888. Recast and republished under the same title in Am. Jour. Sci., 3d ser., vol. 27, pp. 261–282, 1889.

[59] Cannon, G. L., On the Tertiary Dinosauria found in Denver beds: Colorado Sci. Soc. Proc., vol. 3, p. 143, 1888.

and Denver plants have shown them to be essentially Tertiary in type.

In 1892 Cross [60] briefly reviewed the relations of the Arapahoe and Denver formations of the Denver Basin and also enumerated additional localities in the Huerfano Basin, Gunnison County, the Yampa River region, the Animas River region, Middle Park, and elsewhere, in which identical or similar stratigraphic relations had been suggested. He discussed at length the conflicting paleontologic evidence of the age of the lake-bed deposits and concluded as follows:

> The writer wishes to advocate the restriction of the term Laramie, in accordance with its original definition, to the series of conformable beds succeeding the marine Montana Cretaceous, and the grouping of the post-Laramie lake beds described, with their demonstrated equivalents, in another series to which a comprehensive name shall eventually be given. * * * The question as to whether the series shall be referred to the Cretaceous or to the Eocene can not be finally settled until the various conflicting elements of the evidence have been adjusted on a basis of further and more exact information.

Later in the same year Cross [61] published an article on the post-Laramie beds of Middle Park, as an amplification of the previous brief notice. In this article he showed that the large area referred to the "Lignite" or Laramie was occupied by a thick series of mainly andesitic rock resting unconformably on marine Cretaceous beds, with no evidence that the Laramie had ever been present. These beds, which he called the Middle Park beds, were correlated with the Denver on account of the lithologic similarity and the identity of the contained flora.

The publication of the Denver Basin monograph by Emmons, Cross, and Eldridge [62] was delayed until 1896, and in many ways the delay was perhaps of advantage, for it permitted the incorporation and discussion of many important facts that had in the meantime been made available regarding the stratigraphic and other relations of the determined or supposed correlatives of the formations here under discussion. The Laramie, Arapahoe, and Denver formations of the Denver Basin were, of course, described in detail, and the unconformable relations between the Laramie and overlying Arapahoe were especially made plain. The magnitude of the time interval represented by the unconformity was insisted upon as of major importance in Rocky Mountain geology.

The Arapahoe and Denver formations were in this monograph referred to the Cretaceous out of deference to the views of the vertebrate paleontologists, as it had been found that the vertebrates appeared to be much more nearly allied to Mesozoic than to Cenozoic types. The lithologic and stratigraphic relations of these formations, as well as a very full discussion of the several lines of paleontologic evidence, are given by Cross, who prepared this portion of the volume. In the light of subsequent development it has been found that many of his queries and adumbrations have had a wide and increasingly important application.

For ten years after the publication of the Denver Basin monograph little active work was prosecuted in this region, though investigations in adjacent or more remote areas were found to have a more or less direct bearing on the problem here involved. In 1907 A. C. Veatch,[63] from studies in Carbon County, Wyo., was led to question the validity of the current application of the term Laramie. He endeavored to prove that Carbon, Wyo., was intended by King to be the type locality for the Laramie. In this vicinity Veatch discovered that in the supposedly continuous Laramie section there is a profound unconformity similar to that found by Cross in the Denver Basin, and as the beds at Carbon studied and described by the members of the King Survey are all above this break he contended that the name should properly be applied only to these beds and not to the beds that are conformable to the Cretaceous section. Veatch further held that the delimitation of the Arapahoe and Denver constituted a virtual redefinition of the Laramie.

Replies to this paper were made by Cross [64] and Peale,[65] and it is sufficient to state that the view advocated by Veatch has not been adopted. Cross especially reviewed the facts relating to the application of the term, hold-

[60] Cross, Whitman, Post-Laramie deposits of Colorado: Am. Jour. Sci., 3d ser., vol. 44, pp. 19-42, 1892.

[61] Cross, Whitman, Colorado Sci. Soc. Proc., vol. 4, pp. 192-213, 189.2

[62] U. S. Geol. Survey Mon. 27, 1896.

[63] On the origin and definition of the geologic term Laramie: Am. Jour. Sci., 4th ser., vol. 24, p. 18, 1907; expanded under the same title in Jour. Geology, vol. 15, p. 526, 1907.

[64] Cross, Whitman, The Laramie formation as the Shoshone group: Washington Acad. Sci. Proc., vol. 11, pp. 27-45, 1909.

[65] Peale, A. C., On the application of the term Laramie: Am. Jour. Sci., 4th ser., vol. 28, pp. 45-58, 1909.

ing that the separation of the Arapahoe and Denver did not constitute redefinition, and finally, following a suggestion made by himself in 1892, proposed for the latter and their equivalents the term Shoshone group. He said:

It is proposed to apply the term Shoshone group to the deposits which unconformably succeed the Laramie and to their equivalents and which are overlain by the Fort Union or Wasatch beds when they are present.

In this paper Cross reviewed briefly the data bearing on the age of these post-Laramie beds and concluded as follows:

In the preceding discussion I have avoided the question as to the age of Shoshone beds, whether Cretaceous or Eocene. I desire now to urge their reference to the Eocene. The Denver beds were originally referred by me to the Eocene, but the great weight attached to the Mesozoic affinities of the vertebrate fauna by paleontologists led to a tentative acquiescence in the assignment of the Arapahoe and Denver formations to the Cretaceous in the Denver monograph.

RATON MESA REGION OF COLORADO AND NEW MEXICO.

In 1907 a series of observations were begun in the Raton Mesa region of southern Colorado and northern New Mexico, which were found ultimately to have an important bearing on the formations under discussion in the Denver Basin.

The Canon City field of Colorado, although slightly extralimital, is here included in the Raton Mesa region, which really begins with Walsenburg, Colo., and vicinity and extends southward to Cimarron River, N. Mex. The early history of geologic exploration and interpretation in this region has already been given in the historical review of the time which preceded the establishment of the term Laramie, and in this connection it is only necessary to mention the names of Le Conte, Lesquereux, Hayden, Newberry, and Stevenson as among those who took principal parts in the discussion. The section of coal-bearing rocks in this region was considered by one set of students as being more or less directly the equivalent of the "Lignite group" of the north and Tertiary in age. The opposing students regarded the age as Cretaceous, but when the Laramie was established by King the definition appeared to fit the Raton Mesa section, and consequently the beds in this area soon came to be accepted as of Laramie (Cretaceous) age. It should not be overlooked, however, that from his studies of the fossil plants Lesquereux was led to insist that the flora of certain localities within this area, notably Raton Pass and Fishers Peak, indicated a correlation with the so-called "Eolignitic" (=Wilcox formation) of the Gulf region and was of Tertiary age.

A critically annotated historical review of geologic and paleontologic literature on this region is given in a recent paper by Lee and Knowlton,[66] to which the reader is referred for full particulars. In the present connection it is sufficient to begin with the time—about 1900—when geologists had reached a general agreement that the coal-bearing rocks of the Raton Mesa region are of Laramie age and, moreover, that sedimentation had been continuous and uninterrupted throughout the deposition of this section. Thus, in my "Catalogue of the Cretaceous and Tertiary plants of North America,"[67] published in 1898, the plants from the Raton region were referred to the Laramie as then currently accepted. In Newberry's long delayed monograph on the later extinct floras of North America,[68] also issued in 1898, the few species from this region were referred without question to the Laramie. In the Walsenburg and Spanish Peaks geologic folios, by R. C. Hills,[69] issued in 1900 and 1901, respectively, the productive coal measures were referred to the Laramie without qualification.

In 1909, however, W. T. Lee[70] published a short paper under the title "Unconformity in the so-called Laramie of the Raton coal field, New Mexico," in which the following was given as the thesis:

The purpose of this paper is to describe an unconformity hitherto unknown that is of more than ordinary interest because it divides rocks previously referred to the Laramie into two distinct formations. * * * During the time interval represented by the unconformity the sedimentary rocks previously laid down within the Raton field were subjected to erosion for a considerable length of time, and the Rocky Mountains west of this field were elevated and eroded to a depth of several thousand feet.

Lee further pointed out that

[66] Lee, W. T., and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, pp. 17-37, 1918.

[67] Knowlton, F. H., U. S. Geol. Survey Bull. 152, 1898.

[68] Newberry, J. S., U. S. Geol. Survey Mon. 35, 1898.

[69] Hills, R. C., U. S. Geol. Survey Geol. Atlas, Walsenburg folio (No. 68), 1900; Spanish Peaks folio (No. 71), 1901.

[70] Lee, W. T., Geol. Soc. America Bull., vol. 20, pp. 357-358, 1909.

The upper formation has the stratigraphic position of the Arapahoe of the Denver Basin but contains a flora apparently more closely related to that of the Denver formation than it is to the Laramie of the Denver Basin. The lower one has the stratigraphic position of the Laramie of the Denver Basin but contains a flora that is apparently older than Laramie.

As regards the significance of this unconformity Lee added:

There are several possibilities of interpretation, as will be pointed out in the following pages, but the one considered most probable is that the uplift and erosion represented by the unconformity were contemporaneous with the post-Laramie uplift and erosion described by Cross and others from the Denver region.

Without unduly anticipating, it may be stated that subsequent work has entirely confirmed this interpretation.

In 1910 G. B. Richardson,[71] in a short report on the coal resources of the Trinidad coal field of Colorado, noted the conglomerate described by Lee in the report on the Raton coal field as marking the unconformity and said:

The significance of the conglomerate in the Trinidad field remains to be determined. Occurring intermittently in the midst of coal-bearing rocks, it may represent only a local change in conditions of deposition, or, as maintained by Lee for a conglomerate in the Raton field, presumably the same as the one just described, it may mark an unconformity contemporaneous with the post-Laramie unconformity of the Denver Basin. * * * The final word concerning the age of the rocks above and below this conglomerate in the coal measures, involving its significance as a hiatus marker, must come from the paleontologist.

As the paleobotanic data then tentatively supplied by me were more or less conflicting and inconclusive, Richardson wisely enough concluded that

Until further paleobotanical knowledge is available, the age of these rocks must remain unsettled. For the present it seems best to retain the old nomenclature and to refer the strata occurring between the Trinidad sandstone and the Poison Canyon formation to the Laramie.

In the same volume with Richardson's report is a paper by C. W. Washburne [72] on the Canon City coal field, Colo., in which he stated that

The Laramie formation, which contains all the coal beds of the Canon City field, rests conformably on the Trinidad sandstone and is unconformably overlain by the Arapahoe (?) conglomerate. The productive division of the formation is the lower 600 or 700 feet.

Although Washburne admitted that the "upper part of the coal measures contains a flora equivalent to that of the Laramie formation of the Denver Basin, while the lower part contains a flora of upper Montana age," he concluded that "there seems no good reason for separating these lower beds from the Laramie, even though they contain an upper Montana flora."

The work on the stratigraphy and paleobotany of this region was continued by Lee and Knowlton,[73] and their results were presented for publication early in 1913. These results I briefly summed up in May of that year as follows:[74]

In 1907 W. T. Lee began the study of the coal in the Raton field, and while prosecuting this work he discovered the presence of an unconformity in the midst of the section of coal-bearing, supposed Laramie rocks. This unconformity was traced throughout the entire Raton Mesa and subsequently was carried around the southern end of the mountains and well up along their western front. The rocks below the unconformity, to which the name Vermejo formation has been given, have a maximum thickness of only about 375 feet, while the rocks above the unconformity, now called the Raton formation, are about 1,600 feet in thickness. In some places the Raton formation rests on the full thickness of the Vermejo formation, while in other localities the Vermejo is greatly reduced, and in at least one place the entire Vermejo, together with the underlying Trinidad sandstone, has been removed and the Raton rests directly on Pierre.

When the unconformity had been demonstrated, it became of the greatest interest and importance that the fossil plants should be studied to ascertain their bearing, first, on the distinctness of these two formations, and, second, on the question of age. * * * The total flora of the Raton Mesa region comprises 257 forms, of which number 106 belong to the lower, or Vermejo and Trinidad formations, and 151 to the upper, or Raton formations. Only 4 species have been found to cross the line of the unconformity, which is taken as pretty conclusive evidence of the distinctness of the two formations. * * * The Vermejo formation is shown by the plants to be Cretaceous (Montana) in age, being in the approximate position of the Mesaverde.

The Raton formation is shown to be essentially of the same geologic age as the Denver formation of the Denver Basin and of the Wilcox formation of the Gulf region, the latter being indisputably of Eocene age. The conclusion is therefore reached that the Raton and Denver formations are Eocene in age.

In the meantime, as indicated above, Lee had continued the studies from Raton Mesa around the south end of the Rocky Mountains and well

[71] Richardson, G. B., The Trinidad coal field, Colo.: U. S. Geol. Survey Bull. 381, pp. 379-446, 1910.

[72] U. S. Geol. Survey Bull. 381, pp. 341-378, 1910.

[73] Lee, W. T., and Knowlton, F. H., Geology and paleontology of the Raton Mesa and other regions in Colorado and New Mexico: U. S. Geol. Survey Prof. Paper 101, 1918.

[74] Knowlton, F. H., Results of a paleobotanical study of the coal-bearing rocks of the Raton Mesa region of Colorado and New Mexico; Am. Jour. Sci., 4th ser., vol. 35, pp. 526-530, 1913.

up along the west side. His results were set forth in a paper published in 1912.[75]

COLORADO SPRINGS AREA.

Although the Colorado Springs area is in practical connection with the Denver Basin and in fact is considered a part of the basin in the present study, there are reasons that make it desirable to treat this area separately and specifically.

The first fairly comprehensive account of the geology of this area was given in 1869, by F. V. Hayden,[76] who made a reconnaissance study from Cheyenne, Wyo., through the Denver Basin, Colorado Springs, Canon City, and Raton fields. At that time he considered the coal-bearing rocks as belonging to the "Lignitic" and of Tertiary age.

In 1872 Leo Lesquereux [77] visited this region and gave a brief account of the geologic relations of the coal-bearing rocks, including a section of the rocks at the Gehrung coal mine, north of Colorado Springs, which he considered as similar to the section in the Raton Mountains. A list of the fossil plants collected is given on page 375 of his report.

In the following year A. C. Peale [78] also gave a short account of the geology of the Colorado Springs area, but it was mainly a confirmation of the work of Lesquereux, whose section at the Gehrung mine he quoted. Peale also visited the Franceville coal mines, about 12 miles east of Colorado Springs, and identified portions of the section with that at the Gehrung mine. The fossil plants he obtained at this locality are enumerated on pages 326–375 of his report.

At this point it is necessary to speak of the so-called Monument Creek group, on account of the part it played in the elucidation of the geologic history of this region. The term "Monument Creek group" was established by Hayden [79] for a series of "variegated beds of sands and arenaceous clays, nearly horizontal, resting on the upturned edges of the older rocks, * * * of various colors * * * and of various degrees of texture." This series occurs along the Front Range on the divide between the Platte and Arkansas drainage, where it covers an area "of about 40 miles in width from east to west, and 50 miles in length north and south." From its modern appearance Hayden concluded that it was of "either late Miocene or Pliocene age."

In 1873 Cope [80] referred to the "Monument Creek" as follows:

> The age of the Monument Creek formation in relation to the other Tertiaries not having been definitely determined, I sought for vertebrate fossils. The most characteristic one I procured was the hind leg and foot of an artiodactyl of the *Oreodon* type, which indicated conclusively that the formation is newer than the Eocene. From the same neighborhood and stratum, as I have every reason for believing, the fragment of the *Megaceratops* [obvious error for *Megacerops*] *coloradoensis* was obtained. This fossil is equally conclusive against the Pliocene age of the formation, so that it may be referred to the Miocene until further discoveries enable us to be more exact.

In the following year (1874) Hayden [81] again referred to the "Monument Creek group." After describing it at some length, and alluding to Cope's statement regarding the vertebrate evidence, he said: "As to the real age of this group, I am inclined to regard it as Miocene, perhaps upper Miocene."

The next publication that it is necessary to notice is the Denver Basin monograph,[82] by Emmons, Cross, and Eldridge, though in that work the discussion of these rocks was brief, as they occur in the series of beds mapped only as projecting tongues forming the divide between the Platte and Arkansas waters. Emmons gave first a brief summary (p. 38) in which, although calling the beds the "Monument Creek formation," he noted that "two divisions have been distinguished, marked by an apparent unconformity and period of erosion." The lower division was referred tentatively to the Miocene on the basis of the previous vertebrate work of Cope, while the upper division was thought probably to be referable to the Pliocene.

Eldridge devoted several pages to a general description of the stratigraphic relations, lith-

[75] Lee, W. T., Stratigraphy of the coal fields of northern central New Mexico: Geol. Soc. America Bull., vol. 23, pp. 571–686, 1912. As already indicated, the complete report on the Raton Mesa region by Lee and Knowlton was published in 1918 as U. S. Geol. Survey Prof. Paper 101; to this report the reader is referred for details of the geology and paleobotany.

[76] Preliminary field report of the United States geological survey of Colorado and New Mexico, pp. 37–46, 1869; reprint, pp. 137–146, 1873.

[77] The Lignitic formation and its fossil flora: U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, pp. 325–327, 1873.

[78] Peale, A. C., U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1873, pp. 202–203, 1874.

[79] Op. cit., p. 40.

[80] Cope, E. D., Report on the vertebrate paleontology of Colorado: U. S. Geol. and Geog. Survey Terr. Ann Rept. for 1873, p. 430, 1874.

[81] Hayden, F. V., U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1874, pp. 36, 37, 1876.

[82] Emmons, S. F., Cross, Whitman, and Eldridge, G. H., U. S. Geol. Survey Mon. 27, pp. 38, 39, 252–254, 1896.

ology, and life of the "Monument Creek formation," which was of course the basis for the general statement by Emmons. Concerning the stratigraphic relations Eldridge said:

The Monument Creek formation occurs along the southern edge of the Denver field in the steep slopes of a high mesa and also stretches from its base prairieward in thin sheets. The floor of the lake in which the Monument Creek was deposited was more or less irregular from erosion and in one part or another consisted of the clays and sandstones of the Laramie, Arapahoe, or Denver formations. In the foothill region the Monument Creek lies in contact with the Arapahoe; between Platte River and Cherry Creek a few hundred feet of Denver beds exist, which further to the east disappear. North and east of Coal Creek, on the eastern edge of the field, both Denver and Arapahoe are wanting and the Monument Creek rests directly upon the clays of the Laramie.

Although the relations between the Arapahoe and Denver and the "Monument Creek" were somewhat obscure, the interpretation naturally followed that the latter was structurally above the former, for it was then supposed that the lower division of the "Monument Creek" was of Miocene age, while the Arapahoe and Denver were referred to the Cretaceous.

In 1902 W. T. Lee [83] discussed at some length the "Monument Creek group" of Hayden. To the lower portion (of Emmons and others) he applied the name "Monument Creek formation" and described it as "composed of conglomerates, breccias, sands, and clays which alternate and intermingle and grade into each other in the most lawless manner." Continuing, Lee said:

Above the Monument Creek beds lie masses of rhyolitic tuff. This tuff has been noted by Hayden and others. It forms more or less of a sheet, or sheets in some places, while in others it occurs intermingled with sand, gravel, and clay. * * * Above the tuff occurs a sheet of glassy rhyolite about 25 feet thick which forms the protecting cap of several of the buttes near Castle Rock.

To the "youngest formation in the Castle Rock region" Lee gave the name "Castle conglomerate." This was the "Upper Monument Creek" of Hayden and the so-called upper division of Emmons and others. Concerning it Lee said:

These upper beds differ in character from those of the lower division; they are separated from it by volcanic tuffs and flows of rhyolite and by an unconformity representing a period of erosion, as shown by the presence in it of the material from the underlying rhyolite. It is therefore separate and distinct from the lower division.

Lee did not procure data bearing on the age of the divisions of the "Monument Creek" recognized by him, but three years later N. H. Darton [84] obtained additional vertebrate evidence as regards the upper division. At a number of localities he collected remains of *Titanotherium* and *Hyracodon*, concerning which he wrote as follows:

All this material appears to have been obtained from the upper beds and it correlates these beds with the Chadron formation of the White River group, or Oligocene. No evidence was obtained as to the age of the lower member. * * * The presence of the unconformity between the upper and lower members suggests that the latter may be of Wasatch or Bridger age. The nearest locality to the Monument Creek area at which Oligocene deposits occur in eastern Colorado is in the vicinity of Akron and Fremont's Butte, where *Titanotherium* remains occur in abundance.

The status of the "Monument Creek" problem remained as above indicated until 1910–11, when G. B. Richardson began a study of this region preparatory to the preparation of a report on the geology of the Castle Rock quadrangle, which is joined by the Denver Basin on the north and by the Colorado Springs quadrangle on the south. As a result of this study Richardson [85] stated that he found it necessary to separate the "Monument Creek group" into two formations on the basis of a well-marked unconformity which separates beds of Eocene and Oligocene age. The lower formation was named the Dawson arkose and the upper one the Castle Rock conglomerate. According to Richardson the stratigraphic relations indicate that the Arapahoe and Denver formations are equivalent to the lower part of the Dawson arkose, and this evidence is paleontologically supported.

The Castle Rock conglomerate may be first considered. This formation is the "Upper Monument Creek" of Hayden and others, the so-called "upper division of the Monument Creek" of Emmons, Eldridge, Darton, and others, and the Castle conglomerate of Lee.[86] It occurs in the south-central part of the Denver Basin, where it crops out in detached areas on the divides between the tributaries of South Platte River from a point near Elbert to the vicinity of Sedalia, a distance of about 40 miles.

[83] The areal geology of the Castle Rock region, Colo.: Am. Geologist, vol. 29, pp. 101-103, 1902.

[84] Age of the Monument Creek formation: Am. Jour. Sci., 4th ser., vol. 20, pp. 178-180, 1905.

[85] Richardson, G. B., The Monument Creek group: Geol. Soc. America Bull., vol. 23, pp. 267-276, 1912.

[86] Lee's name was unavailable on account of prior usage.

It is thus a remnant of a once larger formation that has been reduced by erosion. Concerning its stratigraphic relations Richardson said:

Everywhere the Castle Rock conglomerate rests on an undulating surface of the underlying Dawson arkose, and there is an abrupt change in texture of the material from the medium or fine grained arkose of the upper part of the Dawson to the coarse Castle Rock conglomerate.

Richardson procured additional vertebrate remains from the Castle Rock conglomerate, which were identified by J. W. Gidley, of the United States National Museum, as *Titanotherium*, and the correlation of these beds with the Chadron formation, the lower formation of the Oligocene White River group, was thus confirmed.

More interest attaches to the Dawson arkose—that is, the lower division of the "Monument Creek group"—for its exact age had long been in doubt. It has a maximum thickness of about 2,000 feet on the west, toward its source in the mountains, and is thinner toward the east. Its appearance was described by Richardson as follows:

The formation is a complex aggregate of varicolored and varitextured conglomerate, sandstone, shale, and clay, derived from the rocks of the Front Range and deposited under a variety of continental conditions. They are medium to coarse textured arkosic grits, composed chiefly of quartz and feldspar derived from the Pikes Peak granite and associated rocks. * * * Rhyolitic rocks * * * were extravasated on an uneven surface of arkose in the extreme upper part of the Dawson. * * * The stratigraphic relations of the Dawson arkose to the Denver and Arapahoe formations * * * are generally concealed by a cover of Quaternary deposits, so that actual conditions are obscure. It is not claimed for the recent work that final correlations have been established, but nevertheles previously unsuspected relationships are indicated.

Approaching the geologically mapped part of the Denver Basin from the south, where detailed work had not previously been done, it was found that the lower part of the Dawson arkose seems to pass along the strike into the Arapahoe and Denver formations; that the Dawson and Arapahoe can not be separated lithologically, even at the type locality of the Arapahoe, on the bluffs of Willow Creek; and that the Denver and Dawson apparently merge into each other, or interdigitate, layers of arkose typical of the Dawson being found intercalated in andesitic Denver material. These conditions indicate that the Arapahoe and Denver are equivalent to the lower part of the Dawson arkose. The marked difference in lithology between the andesitic Denver and the arkosic Dawson may be accounted for by the geographic distribution of the rocks which supplied the sediments.

The paleontologic support of the age determination of the Dawson arkose consists of a number of collections of fossil plants, which are pronounced to be of undoubted Denver age, and a single bone of a mammal, which was identified by Gidley as that of a creodont and of which he said: "From our present knowledge of the creodonts such a type could not be older than Wasatch." Although no dinosaurs were found by Richardson in the Dawson arkose, he referred to their occurrence, as reported by Marsh, in Monument Park, 8 miles north of Colorado Springs, in beds that must belong to the Dawson. Ceratopsian dinosaurs have been found in the Arapahoe and Denver formations, but not thus far in the Laramie of the Denver Basin.

In 1912, however, Lee [87] visited the locality where the creodont bone above mentioned was found (Jimmy Camp Creek, 9 miles east of Colorado Springs) and there collected the remains of turtles and of dinosaurs. The turtles were examined by O. P. Hay and the dinosaurs by C. W. Gilmore. Mr. Gilmore reported on these bones as follows:

The collection consists of fragmentary ceratopsian bones none of which is sufficiently characteristic to determine the genus to which it belongs, and one ungual phalanx is doubtfully regarded as belonging to the dinosaur *Trachodon*. Two small shell fragments show the presence of hard and soft shell turtles. Of these Dr. Hay says: "The soft shell resembles those of the Lance formation; the other resembles those of the Wasatch but is too fragmentary to be certain of its affinities."

In commenting on the above statements Lee wrote:

We have then at this locality, near Colorado Springs, in beds that lie unconformably on the Laramie, a flora that correlates these beds with undoubted Eocene on the one hand, and on the other with the Denver and Arapahoe formations; a mammal of a type not known heretofore to be older than Wasatch; a turtle whose nearest known allies are in the Wasatch fauna; another that resembles those of the Lance fauna; and dinosaurs that have been somewhat generally regarded as indicative of Cretaceous age but which occur in associations that convince some geologists that they are Tertiary. Considering this association of fossils in connection with the great unconformity, it seems wholly irrational longer to regard a formation as Cretaceous merely because it contains dinosaurs.

We may now return to the more direct consideration of the Laramie of the Colorado Springs region. In 1908 M. I. Goldman [88] spent some months in the investigation of the

[87] Lee, W. T., Recent discovery of dinosaurs in the Tertiary: Am. Jour. Sci., 4th ser., vol. 35, pp. 531-534, 1913.

[88] The Colorado Springs coal field, Colo.: U. S. Geol. Survey Bull 381, pp. 317-340, 1910.

coal resources of this area, and after describing briefly the Pierre shale and Fox Hills sandstone, he wrote as follows concerning the Laramie:

> Above the Fox Hills sandstone lie the coal-bearing rocks of Laramie age. These may be divided into two members—a lower including several massive sandstone beds and three or more of the most important coal beds of the field, and an upper composed of clay shale, sandy shale, and some sandstone with poorly developed coal beds.
>
> The best exposure of the sandy, coal-bearing member is in Popes Bluff, where the base of the formation is composed of a massive sandstone from 40 to 100 feet thick but not sharply defined from the underlying Fox Hill. The upper part of the sandstone member of the Laramie gives way gradually, toward the east, to shale with thin beds of calcareous and ferruginous sandstone about 250 feet thick. In the western part of the field the sandy member is about 200 feet thick.

Owing to the incompleteness of the paleontologic evidence, mainly that of fossil plants, Goldman did not make definite age determinations for the rocks above the Laramie, which were described under the terms "conglomerate," "andesitic material," and "arkose," in ascending order.

In some parts of the field the shaly part of the Laramie is overlain by a conglomerate, which has a maximum known thickness of about 30 feet. "The lithologic similarity of this bed to some parts of the Arapahoe formation in the Denver Basin is apparent."

At a number of localities the conglomerate is overlain by beds of andesitic material, "which in lithologic composition is similar to the Denver formation." The average thickness of the beds of andesitic material is about 125 feet.

> Beds of arkose lie unconformably upon the andesitic material and overlap the coal-bearing sandstone in the southeast corner of sec. 6, T. 13 S., R. 67 W. The arkose has two phases—(1) coarse arkose near the mountains, some sandstone, and clay containing coarse quartz grains; (2) fine-grained, very micaceous sandstone. Both phases are very irregularly bedded, and most of the lithologic units are of small horizontal extent.

The greatest thickness of arkose measured was 300 to 400 feet in Corral Bluffs, but the total thickness was believed to be still greater.

A number of collections of fossil plants made in the immediate Colorado Springs area by A. C. Peale, M. I. Goldman, and others were submitted to me for study at this time (1908). This material was not well preserved, owing to the friable nature of much of the matrix, and it was studied with difficulty. With the material available I was not then able to differentiate the three formational units—Laramie, Arapahoe, and Denver—that were theoretically inferred to be present; in fact, the Laramie elements appeared to preponderate so greatly that I was inclined to refer all the plant collections to the Laramie. On bringing together in a single list all the forms enumerated in these collections, as well as those reported originally by Lesquereux from the Gehrung mine and Franceville—both in the acknowledged Laramie—it was found that a total of 49 forms were represented. Of these 22 were not specifically determined, leaving 27 named species, most of which were known outside the Colorado Springs area. On analysis, it appeared that 19 of these forms were found in Laramie or older beds, but, as will be pointed out later, nearly all of these are found in the lots which belong to the Laramie and about which there is no question. There was one lot, however, collected high in the section of the bluffs just west of Templeton Gap that as then identified did much to influence my reference of these beds to the Laramie. As originally listed this lot contained the following forms:

- Sequoia brevifolia Heer.
- Sequoia longifolia Lesquereux.
- Dammara sp. cf. D. acicularis.
- Salix? sp., fragment.
- Ficus trinervis Knowlton, fragment.
- Rhamnus salicifolius Lesquereux.
- Cyperacites sp.
- Viburnum? sp.
- Carpites sp. (poor).

At the time these identifications were made the "Monument Creek group" was supposed to be of Oligocene age, and it was deemed absolutely impossible that these plant remains could be of this age; in fact, if they were correctly identified and stood alone, there would ordinarily be no hesitation in referring them to the Laramie, which I did. Since that time, however, I have twice visited this region and collected material from this locality, as well as from neighboring localities of similar stratigraphic position, and I have also collected material and studied several collections made some 20 miles or more to the east, out on the plains, with the result that I have acquired a better understanding of the forms represented and their stratigraphic relations.

A number of the species of plants from the Pulpit Rock area are the same as those occurring at Black Buttes, Wyo., in beds which were then supposed to be in the Laramie but which in my opinion subsequent work has shown pretty conclusively to be of post-Laramie age. This naturally makes a difference in the weight given to Laramie position. Furthermore, as already stated, much of the material from Pulpit Rock and vicinity is very fragmentary and difficult to identify satisfactorily, but in the light of the material obtained farther east it becomes clearer, and this has permitted certain revisions of earlier determinations. Below are the lists from Templeton Gap and vicinity; the first one is a revision of the one given above:

Bluffs west of Templeton Gap:
- Sequoia obovata? Knowlton ined.
- Sequoia acuminata Lesquereux.
- Dammara sp.
- Cyperacites sp.
- Salix sp.
- Ficus trinervis Knowlton.
- Rhamnus salicifolius Lesquereux.
- Carpites sp. (Palmocarpon?).

Palmer's ranch, Templeton Gap, 4 miles northeast of Colorado Springs:
- Carpites sp.
- Sequoia sp.?

Palmer's ranch, half a mile farther west:
- Rhamnus salicifolius? Lesquereux.
- Platanus? sp.
- Viburnum sp., probably new.

These lots may be considered together. Of the four named species, two (*Sequoia acuminata* and *Ficus trinervis*) were described originally from specimens obtained at Black Buttes, Wyo.; the other two are survivals from the Laramie or older. Of these the *Rhamnus* is well known as crossing the line between Cretaceous and Tertiary, but the *Sequoia* had not previously been recognized as doing this. The *Sequoia*, however, is represented only by a single rather poorly preserved branchlet and may not be correctly determined. The *Dammara* is apparently an undescribed form; it is Cretaceous in type, though the genus is still living.

The several localities above mentioned as lying out on the plains to the east and northeast of Colorado Springs may now be considered. It is a well-known fact that the Laramie, as well as certain overlying beds. stands at acute angles in many places near the mountains, but within a few miles the dips rapidly diminish and the beds become nearly horizontal. The country becomes grass covered, rock exposures are few and far between, and sections showing the contacts of the formational units are still fewer. It is especially difficult to establish satisfactorily the line between the Laramie and the overlying beds in this plains region, and recourse must be had to paleontology in the allocation of the more or less isolated localities.

A number of plant collections have been made at these uncertain points in the section. According to Richardson, by whom most of these collections were made, the plant-bearing beds are 1,000 feet or more, as determined by drill records, above the Fox Hills, and between 20 and 150 feet below a bed of conglomerate that marks the base of a thick deposit of coarse-grained light-colored arkose which is lithologically quite distinct from the underlying fine-grained drab and buff-colored plant-bearing sandstones and shales resembling the typical Laramie. It is suggested by Richardson, on stratigraphic grounds, as a possibility worth considering that these leaves come from a horizon high in the Laramie, approximately equivalent to the Scranton coal zone 15 miles east of Denver, from which few leaves have heretofore been collected.

Below are the lists of plants from the localities mentioned:

Near Mosby, Colo., 30 feet above coal:
- Flabellaria? sp., fragmentary.
- Pteris undulata Lesquereux.
- Anemia.
- Equisetum sp.
- Ficus denveriana? Cockerell.
- Laurus socialis Lesquereux.
- Laurus wardiana? Knowlton.
- Viburnum marginatum? Lesquereux.
- Sapindus sp.

One-fourth mile east of Purdon's mine, Colo.:
- Platanus haydenii Newberry.
- Nelumbo? new, fine.
- Hedera sp., new, fine.
- Populus nebrascensis Newberry.
- Ficus sp.?
- Sapindus sp.?

Red Hill, 4 miles south of Ramah, Colo.:
- Platanus raynoldsii Newberry.
- Vitis olriki Heer.
- Cissus lobato-crenata Lesquereux.
- Myrica? sp.?

NW. ¼ sec. 30, T. 9 S., R. 60 W., 50 feet below conglomerate:
- Platanus sp. cf. P. haydenii?
- Platanus rhomboidea Lesquereux.
- Populus sp.?

2½ miles southwest of Norton, Colo.:
- Platanus sp.
- Ficus denveriana Cockerell.
- Populus sp.
- Hicoria antiquora? (Newberry) Hollick.
- Palm rays, gen.?
- Salix angusta? Alex. Braun.
- Ficus denveriana Cockerell.
- Populus sp.?
- Magnolia?
- Laurus? sp., fragments.
- Fraxinus eocenica Lesquereux.

Half a mile southeast of Ramah oil prospect, Colo.:
- Lygodium kaulfusii Heer.
- Anemia lanceolata Knowlton.
- Myrica like M. torreyi, but without teeth.
- Ficus sp. cf. F. denveriana Cockerell.
- Laurus sp.
- Populus sp. cf. P. nebrascensis Newberry.

On bringing the named forms together we have the following list:

Pteris undulata.	Platanus raynoldsii.
Lygodium kaulfusii.	Platanus rhomboidea.
Anemia.	Vitis olriki.
Hicoria antiquora?	Cissus lobato-crenata.
Salix angusta?	Laurus socialis.
Populus nebrascensis.	Laurus wardiana?
Ficus planicostata.	Magnolia?
Ficus denveriana.	Fraxinus eocenica?
Platanus haydenii.	Viburnum marginatum.

As this list stands, and on the assumption that the determinations have been correctly made, no one familiar with the several floras of the Denver Basin would hesitate, I think, to pronounce this a distinctly post-Laramie flora. If we eliminate the six species of which the identification is questioned and confine attention to positively determined forms, it follows that only two species from this list—*Ficus planicostata* and *F. denveriana*—have been admitted into the Laramie flora as set forth in the present work. As may be seen by consulting the description (p. 131), *Ficus planicostata* is a wide-ranging form that occurs in the Montana, Laramie, Wilcox, and Denver formations and the beds at Black Buttes, Wyo., while *F. denveriana* (see p. 138) is essentially a Denver species, and the evidence of its presence in the Laramie consists of a single more or less imperfect leaf from Popes Bluff, near Colorado Springs, the identification of which is properly questioned.

A further analysis might be made of the forms not specifically named in the above lists; but this is not deemed necessary, as it can be confidently asserted that their affinities undoubtedly lie with post-Laramie rather than with Laramie species.

It will thus be seen that, as now understood, the plants do not lend support to the suggestion that these beds are of Laramie age, and they have not been included in the present work. If it should ultimately be shown that these horizons are really in the upper part of the Laramie and not in post-Laramie beds, such a result would help to break down the marked distinction now believed to exist between the flora of the Laramie and that of overlying beds, but this is a contingency which the writer is not now prepared to recognize.[89]

LANCE FORMATION.

The age and proper allocation of what is now very generally known as the Lance formation has been one of the most active of the storm centers about which the Laramie controversy has been waged. As viewed in retrospect, it appears that much of the discordance that arose was due to the varying weight attached to the several available kinds of paleontologic criteria, as will be made plain in the following exposition.

The most marked or conspicuous paleontologic characteristic of the Lance formation is undoubtedly the presence of the huge dinosaurian reptiles that have been found in it at so many localities, and it is beyond question that this characteristic did much to direct and stimulate investigation of the formation, which might otherwise have been long delayed.

The first collection of remains of the group of horned dinosaurs known as the Ceratopsia was made by F. V. Hayden in the vicinity of Judith River, Mont., about 1855, but the distinctive characters of the group were not discovered until more than 30 years later. The material collected by Hayden, consisting of isolated teeth, was described by Joseph Leidy, who tentatively regarded it as of Jurassic (Wealden) age. A fuller discussion of the Judith River problem will be found on page 77.

The next in order of discovery was the celebrated *Agathaumas sylvestris* Cope, found in

[89] Since the foregoing pages were written it has been demonstrated by Lee that the Scranton coal and the beds at a number of localities on Sand Creek and Coal Creek, east of Denver, are of post-Laramie age. This determination has an important bearing on the age of the beds east of Colorado Springs mentioned in this chapter. The discovery made by Lee is explained on page 103.

1872 at Black Buttes, Wyo., by F. B. Meek, and later in the same year collected by Cope himself. (See p. 8.) In the following year Cope[90] found the remains of what is now known to be a member of this group at some unidentified locality in Colorado, and in 1876 he undertook the exploration of the Judith River region, describing a number of remains that from their fragmentary nature he was not able to allocate until the group had been made better known from the studies of O. C. Marsh.

As already mentioned (p. 16), the remains of horned dinosaurs, although not at first so recognized, were found by Lakes, Cross, Eldridge, Cannon, and others in the post-Laramie beds of the Denver Basin of Colorado during the period extending from 1881 to about 1887. These were described in part by Marsh. In the summer of 1888 J. B. Hatcher, then assistant to Marsh, found the poorly preserved remains of a dinosaurian in Wyoming just north of the Seminoe Mountains, on the west side of North Platte River about 40 miles below Fort Steele.

The above brief account completes the list of discoveries of remains of the Ceratopsia that fall within the present discussion prior to the finding of the celebrated deposits in Converse County, Wyo. These deposits were made known late in the fall of 1888, when a single horn core was brought to the attention of Mr. Hatcher by a resident of the region. This discovery was considered so important by Marsh that Hatcher was directed to return to the region at the earliest moment, which was in January, 1889, and from this time until 1895 Hatcher was almost continuously employed in exploring and collecting from these rich deposits. The material he obtained, which was very extensive and varied, furnished the basis for a series of important papers by Marsh.

Before proceeding to the discussion of the Converse County area and its bearing on the question under consideration, it may be well to point out that the family Ceratopsidae, which has become so important in this connection, was established by Marsh[91] in December, 1888. The exact locality that yielded the specimen on which this family was based was not recorded by Marsh, who said it "was found in place, in Laramie deposits of the Cretaceous, in Montana," and added in the next paragraph: "Remains of the same reptile, or one nearly allied, had previously been found in Colorado, in deposits of about the same age." According to Hatcher[92] the beds of the Montana locality were near the top of the Judith River formation on Cow Creek, 10 miles above its confluence with the Missouri. The Colorado specimen referred to came from the Arapahoe formation of the Denver Basin.[93]

Marsh's first paper[94] dealing with what is now known to be the Converse County material was published in April, 1889, and describes some Jurassic forms and a single specimen from this region. This was named *Ceratops horridus*, and in August of the same year it was made the type of the genus *Triceratops*.[95] Incidentally it may be mentioned that this genus was based in part on the horn core first known from these beds as noted by Hatcher. In neither of these papers is there mention of the locality beyond the statement that the remains came from "the Laramie formation of Wyoming."

In December, 1889, a third paper by Marsh[96] was published, in which, in addition to describing the skull more in detail, he gave the following brief statement on the geologic occurrence of the Ceratopsidae:

> The geological horizon of these strange reptiles is a distinct one in the upper Cretaceous and has now been traced nearly 800 miles along the eastern flank of the Rocky Mountains. It is marked almost everywhere by remains of these reptiles, and hence the strata containing them may be called the *Ceratops* beds. They are fresh-water or brackish deposits, which form a part of the so-called Laramie but are below the uppermost beds referred to that group. In some places, at least, they rest upon marine beds which contain invertebrate fossils characteristic of the Fox Hills deposits.

In commenting on this statement a few years later, Cross[97] said:

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90 Cope, E. D., Report on the vertebrate paleontology of Colorado: U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1873, p. 429, 1874.

91 Marsh, O. C., A new family of horned Dinosauria, from the Cretaceous: Am. Jour. Sci., 3d ser., vol. 36, p. 478, 1888.

92 Hatcher, J. B., The Ceratopsia: U. S. Geol. Survey Mon. 49, p. 101, 1907.

93 Cross, Whitman, Geology of the Denver Basin of Colorado: U. S. Geol. Survey Mon. 27, p. 230, 1896.

94 Marsh, O. C., Notice of new American Dinosauria: Am. Jour. Sci., 3d ser., vol. 37, p. 331, 1889.

95 Marsh, O. C., Notice of gigantic horned Dinosauria from the Cretaceous: Am. Jour. Sci., 3d ser., vol. 38, p. 173, 1889.

96 Marsh, O. C., The skull of the gigantic Ceratopsidae: Am. Jour. Sci., 3d ser., vol. 38, pp. 501-506, 1889.

97 Cross, Whitman, Geology of the Denver Basin of Colorado: U. S. Geol. Survey Mon. 27, p. 231, 1896.

The statement that "a distinct horizon" has been "traced nearly 800 miles" and that "it is marked everywhere" by certain fossils would imply either that actual continuity had been proved or that the stratigraphic position of the fossil-bearing strata had been found to be clearly the same at numerous localities not far apart. But when Prof. Marsh made the above assertion the Denver region was the only one in which the position of the *Ceratops*-bearing beds had been established in complete sections, and here they were found to be separated from the typical Laramie below them by a great stratigraphic break. Moreover, none of the described fossils was found east of the mountains between the Denver Basin and Converse County, Wyo., a distance of 200 miles. As far, then, as the new fossils themselves are concerned, they prove either a great extension of the Arapahoe and Denver (post-Laramie of this report), or a distribution of the fossils in question beyond the limits of what may be properly termed one formation or horizon.

In the following paragraph Cross added:

In the original description by Prof. Marsh the fossils were said to have been obtained in "the Laramie of Wyoming" or "the *Ceratops* beds of Wyoming." It is important to emphasize the fact that not one of the described species came from the typical Laramie strata of southern Wyoming or from their demonstrated equivalent.

In succeeding years Marsh[98] continued to publish short papers on the Converse County material, but without a definite indication of locality, the only statement being that the fossils were "from the Laramie" or "from the *Ceratops* beds of Wyoming." In February, 1893, however, Hatcher[99] published a short paper, in which, for the first time, complete and definite information was given as to the locality at which this wonderful vertebrate fauna had been found, as well as a description of the lithologic character and stratigraphic occurrence of the beds containing it, and also the reasons for regarding the horizon as referable to the true Laramie.

The typical area for the "*Ceratops* beds," which have since become classic, was stated to be in the northeastern portion of Converse County, now included in Niobrara County, which lies on the eastern border of Wyoming. These beds were also found in adjacent portions of Weston County. In his description of the deposits Hatcher said:

The *Ceratops* beds are made up of alternating sandstones, shales, and lignites, with occasional local deposits of limestones and marls. The different strata of the series are not always continuous, a stratum of sandstone giving place to one of shales, and vice versa. This is generally true of the upper two thirds of the beds. * * * The shales are quite soft and loosely compacted, composed mostly of clay with more or less sand in places. The prevailing color is dark brown, but they are sometimes red or bluish. * * * The lignites occur in thin seams, never more than a few inches thick, of only limited extent, and with many impurities. * * * All the deposits of the "*Ceratops* beds" of this region bear evidence of having been laid down in fresh waters. Among the invertebrate fossils found in them, only fresh-water forms are known. There is no evidence that marine or brackish waters have ever had access to this region since the recession of the former at the close of the Fox Hills period.

As regards the stratigraphic position of the "*Ceratops* beds," Hatcher stated that the lowest exposed member of the section was identified by its numerous invertebrates as Pierre. Overlying this was an alternating series of sandstones and shales having an estimated thickness of 500 feet and containing, especially in the upper portion, an abundant invertebrate fauna pronounced to be typically Fox Hills. Above this series came the "*Ceratops* beds," which had an estimated thickness of 3,000 feet. He added:

All the beds of the entire section are conformable and bear evidence of a continuous deposition, from the Fort Pierre shales up through the Fox Hills sandstones and overlying fresh-water *Ceratops* beds. The Fort Pierre shales are not suddenly replaced by the Fox Hills sandstones, but the transition is a gradual one, and it is impossible to say just where the one ends and the other begins. The same is true of the beds overlying the Fox Hills. The thin seam of hard sandstone, separating the fossil-bearing Fox Hills sandstones below from the very similar nonfossiliferous sandstone above, is here regarded as the dividing line between the Fox Hills and the *Ceratops* beds. But this decision, it must be admitted, is quite arbitrary, and the evidence in its favor is negative rather than positive. The only reason for placing the overlying 400 feet of nonfossiliferous sandstones in the fresh-water series is the absence of fossils in them.

In discussing the age of the "*Ceratops* beds" Hatcher said:

Owing to the fact that very few vertebrates had previously been described from the typical Laramie, as first defined by Mr. Clarence King, and the consequent lack of vertebrate forms known to have come from the Laramie for comparison with those found in the *Ceratops* beds, it must be admitted that the vertebrate fauna of the latter is, in itself, at present not sufficient proof to establish the Laramie age of the *Ceratops* beds.

[98] Marsh, O. C., Additional characters of the Ceratopsidae, with notice of new Cretaceous dinosaurs: Am. Jour. Sci., 3d ser., vol. 39, p. 418, 1890; The gigantic Ceratopsidae, or horned dinosaurs of North America: Idem, vol. 41, p. 167, 1891.

[99] Hatcher, J. B., The *Ceratops* beds of Converse County, Wyo.: Am. Jour. Sci., 3d ser., vol. 45, pp. 135–144, 1893.

Hatcher concluded, however, that the "*Ceratops* beds" should be referred to the Laramie for the following reasons:

1. They conformably overlie the Fox Hills sandstones and contain both a reptilian and a mammal fauna, with decided Mesozoic affinities. * * *

2. They contain an invertebrate fauna comprising many forms identical with those already described from the typical Laramie, some of which are unknown except in the Laramie.

3. They immediately and conformably overlie the Fox Hills and show evidence of a continuous deposition through both series.

In 1896 Hatcher[1] published another paper dealing with the Converse County area, in which he criticized in the severest manner Marsh's statement that the "*Ceratops* beds" had been traced some 800 miles along the eastern flank of the Rocky Mountains. Hatcher showed that, with the exception of a single specimen from a doubtful locality, all the material studied by Marsh had been found in the Denver Basin, in Converse County, or in the Judith River area. He said:

These are very widely separated localities, and no attempt has ever been made to trace the continuity of the strata from one to the other, nor is it at all probable that such an attempt would meet with success.

Hatcher also questioned Marsh's statements that the "*Ceratops* beds" are below the uppermost beds referred to the Laramie and that they rest on marine beds which contain invertebrate fossils characteristic of the Fox Hills deposits. Although his comments were somewhat at variance with his former statement, Hatcher continued as follows:

At no place in the Converse County region do the true *Ceratops* beds, with the remains of horned dinosaurs, rest upon true marine Fox Hills sediments; nor are the *Ceratops* beds in this region overlain by strata which could be referred without doubt to the Laramie. The writer has, in a paper published in the American Journal of Science of February, 1893, stated that the *Ceratops* beds rest directly upon the Fox Hills series and has provisionally referred the very similar series of sandstones and shales conformably overlying the *Ceratops* beds to the upper Laramie; but it would doubtless be better to restrict the limits of the *Ceratops* beds to those strata in which horned dinosaurs occur, and to consider the underlying 400 feet of barren sandstones as the equivalent of the Judith River beds. Future investigations will doubtless show that the sandstones, shales, and lignites overlying the typical *Ceratops* beds in Converse County should be referred to the Fort Union beds and not to the Laramie, as, according to Knowlton, the limited flora sent him now indicates.

[1] Hatcher, J. B., Some localities for Laramie mammals and horned dinosaurs: Am. Naturalist., vol. 30, pp. 112-120, 1896.

In 1896 T. W. Stanton and I[2] spent several weeks in Converse County and also visited numerous localities in Colorado, Wyoming, and Utah, in a study whose object was stated as follows:

As many of the supposed typical Laramie localities had been visited and studied by the various investigators some years ago, before the recognition of the Arapahoe, Denver, and Livingston formations, it became a matter of interest and importance to revisit these places and ascertain, if possible, the bearing of the new data on the questions of their distribution, life, etc.

In the discussion of the Converse County area in this paper several sections were given showing especially the Fox Hills and overlying "*Ceratops* beds." No fossils of any kind were detected in the 400 feet of sandstones mentioned by Hatcher as occurring above the highest Fox Hills horizon, but just above these sandstones, in the basal portion of the "*Ceratops* beds," though apparently below any remains of dinosaurs, a few brackish-water invertebrates were detected. Particular attention was devoted to the "*Ceratops* beds," and numerous collections of invertebrates and plants were listed.

Regarding the interpretation of the invertebrate fauna, the following statement was made:

Of the 18 identified species in the above list just half occur at Black Buttes, Wyo., in or very near the bed that has yielded the saurian *Agathaumas sylvestris* Cope. The large proportion of identical forms and the general resemblance of the entire faunas, especially in the large number and great differentiation of species of *Unio*, makes it reasonably certain that the Converse County and Black Buttes beds are on nearly the same horizon. The evidence of the vertebrate fossils seems to trend in the same direction. It will be shown later that the Black Buttes bed should be regarded as true Laramie, and consequently the series now under consideration is placed in the same category.

The plants, of which 25 forms were listed, were compared with the floras of various localities then supposed to be of Laramie age, and the conclusion was reached that "as nearly as can be made out, the plants confirm the Laramie age of the *Ceratops* beds."

From the beds conformably overlying the highest dinosaur-bearing stratum 18 species of plants were obtained, and of the 10 named species 9 proved to be typical Fort Union

[2] Stanton, T. W., and Knowlton, F. H., Stratigraphy and paleontology of the Laramie and related formations in Wyoming: Geol. Soc. America Bull., vol. 8, pp. 127-156, 1907.

forms, and hence these beds were regarded as of Fort Union age.

For more than a decade after the studies resulting in the last-mentioned paper little or no active geologic work was done in the Converse County area, though the collecting of the remains of huge dinosaurs was continued from time to time by several persons. In the meantime, however, it had become known that the ceratopsian dinosaurs that were so abundant and characteristic in the Converse County region were by no means confined to that area. In 1907 Barnum Brown, of the American Museum of Natural History, published a short paper [3] in which he recorded their abundant presence at many localities in Montana. This discovery was made in 1901 by William T. Hornaday, director of the Bronx Zoological Garden, New York, while hunting in the badlands along Missouri River north of Miles City. Here Dr. Hornaday found a number of large bones, one of which was brought home and proved to be the tip of a horn of the large dinosaur *Triceratops*. From 1902 to 1906 Brown was engaged in exploring and collecting in Montana. The principal locality was in the vicinity of Hell Creek, a small stream entering the Missouri about 155 miles northwest of Miles City, but the same dinosaur-bearing beds were found on Yellowstone River at Castle Butte, near Forsyth, at Glendive, at Ekalaka, and at Hocket post office, from which they were thought (and have since been proved) to be continuous with similar dinosaur-bearing beds on the Little Missouri and near Grand and Moreau rivers in South Dakota.

The dinosaur-bearing beds on Hell Creek, named the "Hell Creek beds" by Brown, are described as resting unconformably on Fox Hills beds of varying thickness, while above and representing an uninterrupted continuation of them is a lignite series referred with question to the Fort Union. Above this series is the unquestioned Fort Union with a characteristic flora. In discussing the correlation and age of the "Hell Creek beds" Brown wrote as follows:

Lithologically the Hell Creek beds of Montana are similar in almost every respect to the *Ceratops* beds of Converse County, Wyo. Most genera and many species of vertebrates and invertebrates are common to both deposits, while the faunal facies may be considered a unit. * * * They are therefore considered of contemporaneous deposition.

In regard to the age of these beds he said:

Strictly following King's definition of the Laramie, neither of these deposits can be considered as such, for neither one represents a continuous sedimentation from the marine Fox Hills. They should therefore be grouped with the Livingston, Denver, and Arapahoe beds and may be considered post-Laramie.

Although Brown considered the "Hell Creek beds" as post-Laramie and thus comparable to the Arapahoe and Denver formations in position, it is evident from the title of his paper that he still regarded them as Cretaceous.

The year 1907 was also marked by the publication of the monograph on the Ceratopsia by Hatcher and Lull.[4] This comprehensive treatise was mainly the work of Hatcher and had been nearly completed at the time of his death, July 3, 1904. It was compiled and edited by Lull, who added a chapter on the phylogeny, taxonomy, distribution, habits, and environment of the Ceratopsia. From this it appears that the localities then known for the so-called Laramie Ceratopsia were Black Buttes and Converse County, Wyo., and Hell Creek, Mont. The Denver localities were considered under a separate heading, and the statement was made that these beds (Arapahoe and Denver) had been "considered to be of post-Laramie age." It was of course held that all the localities which had afforded the "Laramie Ceratopsia" belonged to the Cretaceous.

In 1905 the United States Geological Survey began an investigation that had for its object the classification of the coal lands in the public-land States of the West, and this work has been continued until the present time. The plan has been to send a party, usually a small one, to survey a definite area for the purpose of ascertaining its coal resources and incidentally of procuring such data as time and opportunity offered on the general geology of the area. In this manner a large and important body of facts has been accumulated regarding the geology of regions or localities that might otherwise have remained obscure or imperfectly known for an indefinite period.

[3] Brown, Barnum, The Hell Creek beds of the Upper Cretaceous of Montana: Am. Mus. Nat. Hist. Bull., vol. 23, p. 823, 1907.

[4] Hatcher, J. B., and Lull, R. S., The Ceratopsia: U. S. Geol. Survey Mon. 49, 1907.

One of the first of these so-called coal reports was made by A. C. Veatch [5] for a large area in southwestern Wyoming, though the coal report was expanded into a complete consideration of the geology and resources of the region covered. (See p. 67.) In 1906 this work was systematized and prosecuted in all the Rocky Mountain States, though the results were not published until 1907.

In the present connection the report by A. G. Leonard [6] on the coal fields of parts of Dawson, Rosebud, and Custer counties, Mont., is of interest. This was really hardly more than a reconnaissance report on a large area lying mainly between Missouri and Yellowstone rivers and extending from Hell Creek eastward to the State line. Four geologic formations were recognized in this field—Pierre, Fox Hills, "dinosaur-bearing beds" not otherwise named, and Fort Union. In some places, as at Glendive, the Fox Hills was supposed to be absent and the overlying dinosaur-bearing beds rested directly on the Pierre. The dinosaur-bearing beds were described by Leonard as follows:

> Heretofore all the beds above the marine Pierre shale have been regarded as belonging to a single formation which carries the lignite and subbituminous coal beds of this field. These rocks have been called at various times "Laramie" and "Fort Union," on the supposition that they compose but a single formation. The work of the last year, however, has shown that at Glendive the rocks above the Pierre shale apparently comprise two formations. * * * The beds are strikingly similar to the dinosaur-bearing beds [="Hell Creek beds" of Brown] on Hell Creek, and presumably they are identical.

The Fort Union was everywhere conformably above the "dinosaur-bearing beds" and was described as "readily distinguished by the light-gray and buff color of its beds."

The economic coal investigations, which have a more or less direct bearing on the present problem, were continued in 1907, and the results were published in 1909.[7] A. G. Leonard and Carl D. Smith reported on the Sentinel Butte lignite field, in North Dakota and Montana, where they found only the Fort Union formation. Arthur J. Collier and Carl D. Smith reported on the Miles City coal field, in Montana, where also only the Fort Union was recognized, though the lower 500 feet of beds [the equivalent of the "dinosaur-bearing beds" of the Glendive section] was described as showing a marked lithologic difference. In the main only the Fort Union was described by L. H. Woolsey in his account of the Bull Mountain coal field, in Montana, though he mentioned briefly certain beds on Dean Creek and an olive-green shale which he regarded as being beneath the Fort Union. In the report on coal near the Crazy Mountains, Mont., R. W. Stone recognized the marine Cretaceous section as defined by Stanton and Hatcher for the Judith River area (see p. 77), and above this, in ascending order, the Laramie, Livingston, and Fort Union formations. In his report on the Red Lodge coal field, Mont., E. G. Woodruff referred the whole visible section of 8,000 feet to the Fort Union, as did J. A. Taff the coal-bearing section in the Sheridan coal field, Wyo. On the southwest side of the Big Horn Basin of Wyoming Woodruff identified as Laramie (?) a series of sandstones and shales overlying the Montana group. This series was said to contain invertebrates belonging to a fauna characteristic of the "*Ceratops* beds." Woodruff said:

> As the stratigraphic position of these beds ["*Ceratops* beds"] is not definitely determined, the name Laramie is applied because the Laramie formation occupies a position in the geologic column between the Montana and Fort Union. * * * The name, however, should not be considered as indicative of a positive correlation with beds of Laramie age to the south.

The Laramie was also tentatively recognized by C. W. Washburne on the northeast side of the Big Horn Basin, though the evidence aside from position was not very clearly stated.

Up to 1909 there had been no formal, published protest against the reference of the "*Ceratops* beds" to the Cretaceous, although several writers had indicated that in certain areas the stratigraphic relations of the dinosaur-bearing beds were such that they were at variance with the original definition of the Laramie. In this year I published a paper [8] under the title "The stratigraphic relations and paleontology of the 'Hell Creek beds,' '*Ceratops* beds,' and equivalents, and their reference to the Fort Union formation," in which the following was given as the thesis:

> The present paper deals with the extensive series of fresh-water deposits of the Northwest, comprising what is

[5] Geography and geology of a portion of southwestern Wyoming, with special reference to coal and oil: U. S. Geol. Survey Prof. Paper 56, 1907.

[6] U. S. Geol. Survey Bull. 316, p. 194, 1907.

[7] U. S. Geol. Survey Bull. 341, 1909.

[8] Knowlton, F. H., Washington Acad. Sci. Proc., vol. 2, pp. 179-238, 1909.

here considered as the Fort Union formation. It is shown that the Fort Union embraces more than has been commonly assigned to it. Conformably below the beds by some geologists considered as the true Fort Union occur dark-colored sandstones, clays, and shales, which have often been incorrectly referred to the Laramie or its equivalent but which are stratigraphically and paleontologically distinct from the Laramie, and the contention is here made that these beds, which include the "Hell Creek beds" and so-called "somber beds" of Montana, the "*Ceratops* beds" or "Lance Creek beds" of Wyoming, and their stratigraphic and paleontologic equivalents elsewhere, are to be regarded as constituting the lower member of the Fort Union formation and are Eocene in age.

In this paper a brief historical summary of the Fort Union formation was followed by an account of its areal distribution and lithologic character, in which I held that it may be divided into two members. The areal distribution and paleontologic contents of the lower or dinosaur-bearing member were given as completely as available facts then warranted. The distribution included the following areas in Montana: Hell Creek, Miles City and vicinity, Forsyth, Custer, Bull Mountains, Melville, Red Lodge, Glendive, and from Glendive to Medora, N. Dak. Several areas in North Dakota were discussed, as well as a probable area (since confirmed) in northwestern South Dakota. Thence the formation was traced to Weston County, Wyo., and thence northward to connect with the area at Miles City, Mont. Other areas in Wyoming were Converse County, a great region east of the Big Horn Mountains, and the Big Horn Basin. Thus it was shown that the "*Ceratops* beds," originally supposed to occur only in Converse County, Wyo., really occupy a vast area distributed over four great States.

The essential results claimed in this paper were sufficiently set forth in the "summary and conclusions," as follows:

1. The Fort Union formation is a fresh-water Tertiary formation of wide areal extent, mainly east of the Rocky Mountains, ranging from Wyoming and western South Dakota over western North Dakota, eastern and central Montana, the central Canadian Provinces, and reaching the valley of the Mackenzie River.

2. It is shown that the Fort Union formation may be separated into two members on lithologic grounds. The present paper deals only or largely with the stratigraphy and paleontology of the lower member, which includes the "Hell Creek beds" and so-called "somber beds" of Montana and the "*Ceratops* beds" of Wyoming.

3. The areal distribution of the lower member is traced in Montana, North and South Dakota, and Wyoming, and its probable extension in other areas is indicated. Complete lists of the fossil plants are given by localities for each of the areas.

4. It is shown that the lower member rests, in some cases unconformably, in others in apparent conformity, on the Fox Hills or Pierre, and the conclusion is reached that an erosional interval is indicated during which the Laramie—if ever present—and other Cretaceous and early Tertiary sediments were removed.

5. It is shown that the beds under consideration, being above an unconformity, can no longer be considered as a part of the "conformable Cretaceous series" and hence are not Laramie.

6. It is shown that the two members of the Fort Union, although usually distinct lithologically, can not be separated structurally, sedimentation having been uninterrupted, except locally.

7. The paleontological elements of the lower members are considered at length, beginning with the plants. It is shown that of the 84 known species, 61 are common to the upper member, and only 11 species to the Laramie of Colorado, while 15 species are common to other American Eocene, and 9 species to the Miocene. The Eocene age of the Fort Union is fixed by tying its flora to that of various Old World beds of known Eocene position.

8. The invertebrate evidence is shown to be in substantial accord with that of the plants, there being only 4 of the 49 species common to the Colorado Laramie. All, with a single possible exception, are fresh-water forms.

9. It is shown that the vertebrates afford no positive evidence of Cretaceous age. That the dinosaurs exhibit Cretaceous affinities is not denied, since, being without known descendants, it is possible to compare them only with their progenitors. It has been proved beyond question that they survived the profound orogenic movement and attendant physical break at the top of the Laramie in the Denver Basin of Colorado and lived on in Arapahoe and Denver time, and it is shown that in the areas considered in this paper they passed over a similar erosional interval and are found in association with the Fort Union flora, which is of Eocene age.

10. The mammals of the lower Fort Union show very little relationship with Jurassic or Cretaceous forms but find their closest affinities with those of the Puerco and Torrejon, which are of acknowledged Eocene age.

11. The chelonians are shown to be of little value in their bearing on the age of the lower Fort Union, especially when compared with the Judith River forms, which are evidently in confusion.

12. It is held that the line between Cretaceous and Tertiary should be drawn at the top of the true Laramie.

13. The final conclusion is reached that the beds here considered ("Hell Creek beds," "somber beds," "*Ceratops* beds," "Laramie" of many writers) are stratigraphically, structurally, and paleontologically inseparable from the Fort Union and are Eocene in age.

The above-mentioned paper was followed almost immediately by a paper by T. W. Stanton,[9] entitled "The age and stratigraphic

[9] Washington Acad. Sci. Proc., vol. 2, pp. 239-293, 1909.

relations of the '*Ceratops* beds' of Wyoming and Montana." The thesis of this paper was stated as follows:

The purpose of the present paper is to show that some of the data already used in the discussion [by Knowlton, Cross, and others] are capable of a different interpretation and to call attention to some additional facts which ought to be fully considered before a final verdict is reached. All are agreed that the strata in question are near the boundary between Cretaceous and Tertiary. My opinion is that the greater weight of evidence places them on the Cretaceous side.

Under the head of "local stratigraphy and paleontology" Stanton reviewed a number of the areas in Wyoming and Montana considered in my paper and set forth his own field observations and interpretation of the stratigraphic and paleontologic conditions. In summarizing these data Stanton said:

It has been shown that, within the large area considered, the "*Ceratops* beds" with the *Triceratops* fauna are always pretty closely associated with the uppermost Cretaceous strata or are separated from them by transitional brackish-water beds. They are always overlain by a thick series of rocks containing a Fort Union flora in which no dinosaurian remains have been found, and in the Fish Creek, Mont., region this overlying series also contains primitive mammals related to those of the Puerco and Torrejon faunas. Throughout a large part of the area no evidence of an unconformity beneath the "*Ceratops* beds" has been found, while higher in the section unconformities have been demonstrated or suggested at a number of places. Unconformities have been reported below the "*Ceratops* beds" on Hell Creek, Mont., on the Little Missouri, in North Dakota, and in Weston County, Wyo., but in none of these cases has any proof been furnished that the erosion interval is important.

The conclusions reached in this paper are given as follows:

In the interior region of North America the formations between the uppermost marine Cretaceous and the Wasatch together constitute a real transition from the Cretaceous to the Teritary.

Notwithstanding the fact that there are several local unconformities at various horizons and perhaps some of more general distribution, there is no conclusive evidence that any one of these represents a very long period of erosion not represented by sediments elsewhere in the region.

The Fort Union formation, properly restricted, is of early Eocene age, the determination resting chiefly on its stratigraphic position and its primitive mammalian fauna, which is related to the earliest Eocene fauna of Europe. The very modern character of the flora tends to confirm this correlation.

The "*Ceratops* beds" are of Cretaceous age as decided by stratigraphic relations, by the pronounced Mesozoic character of the vertebrate fauna with absence of all Tertiary types, and by the close relations of the invertebrate fauna with the Cretaceous. The relation of the flora with Eocene floras is believed to be less important than this faunal and stratigraphic evidence. Taken in their whole areal extent, they probably include equivalents of the Laramie, Arapahoe, and Denver formations of the Denver Basin.

Hay [10] also published a paper in 1909 on the position and age of the "*Ceratops* beds," in which, after comparing the fauna of these beds with those of the Judith River, Puerco, Torrejon, and several European formations, he concluded as follows:

1. The answer that the writer would give to the question at the head of this paper is that the Lance Creek beds belong to the Upper Cretaceous.

2. In the Upper Cretaceous ought to be included also the Puerco and not improbably also the Torrejon and Fort Union.

3. In case of a conflict between the evidence furnished by the flora and the fauna of the Lance Creek beds and those of the Fort Union respectively, the evidence obtained from the fauna is to be preferred, as being part of a more complete and better understood history. Present knowledge regarding plants seems to indicate that they were precocious, having reached something like their present stage of development long before mammals attained anything like their present stages of differentiation. There are also indications that the floras of the western world were, during the Cretaceous, considerably in advance of those of Europe.

4. Even if it were concluded that the Fort Union belongs to the Tertiary, and that the fauna and flora of the Lance Creek epoch are more closely related to those of the Fort Union than they are to those of the Judith River, it does not follow that the Lance Creek epoch must be included in the Tertiary. A quarter before midnight on Monday is much nearer to Tuesday than it is to the previous 6 o'clock; nevertheless, it is not yet Tuesday.

The work of the United States Geological Survey in classifying the coal lands was continued in 1908, though the results of this year's investigations were not published until 1910.[11] It is noteworthy that in the areas falling within the scope of the present review the Fort Union has come to be placed unqualifiedly in the Tertiary.

In the volume cited R. W. Richards has a paper under the title "The central part of the Bull Mountain coal field, Mont.," in which the stratigraphic relations are set forth in the following table:

[10] Hay, O. P., Where do the Lance Creek ("*Ceratops*") beds belong—in the Cretaceous or in the Tertiary?: Indiana Acad. Sci. Proc., vol. 25, 1909.

[11] U. S. Geol. Survey Bull. 381, 1910.

Stratigraphy of the central part of the Bull Mountain coal field, Mont.

System.	Formation.	Thickness (feet).	Description.
Tertiary...	Fort Union.	1,650	Yellowish sandstones and shales interstratified with lignite beds.
(?)........	....	200-300	Somber-colored shale and coarse yellow sandstones with beds of carbonaceous sandstone and shale.
Cretaceous.	Laramie (?)	1,480	Alternating gray sandstones and clay shales, with thin coal beds.
	Bearpaw...	....	Gray to brown shales and clay.

The Laramie (?) was regarded as the equivalent of the "somber beds" of the Miles City field.

The Buffalo coal field, Wyo., was described in this bulletin by H. S. Gale and C. H. Wegemann. In this area the dinosaur-bearing beds were referred to the so-called Piney formation, which was said to be pre-Tertiary or Cretaceous [both terms are used in the report], though some doubt was expressed as to whether this designation would prove to be correct.

In 1910 T. W. Stanton[12] published a short paper dealing with this subject and recording new field data from areas in the Dakotas and eastern Wyoming. The term Lance formation, which has now come into such general usage, was here published for the first time and was specifically stated to be a substitute for the old terms "*Ceratops* beds," "Lance Creek beds," and equivalents. Of the three areas discussed in this paper the one first considered was the Standing Rock and Cheyenne River Indian Reservation, or the region between Grand and Cannonball rivers in North and South Dakota. In this area attention was directed principally to the Fox Hills sandstone and its contrast with overlying beds, and a number of sections were given, together with lists of the invertebrates found. Stanton said:

At the top of the Fox Hills sandstone with its purely marine fauna there is a rather thin but widely distributed brackish-water bed, which contains *Ostrea*, *Anomia*, *Corbicula*, *Melania*, etc., in great abundance. The zone in which this fauna occurs varies in thickness from 3 or 4 feet up to 40 feet and is lithologically very similar to the underlying marine beds, but its base is irregular at many places and shows channeling and other evidences of erosion. It was therefore regarded by the field geologists as the basal member of the overlying Lance formation resting unconformably on the Fox Hills. In the study of this brackish-water bed evidence was found at several localities, distributed over a considerable area, that there is a distinct transition without a break of any importance between the marine Fox Hills sandstone and the brackish-water deposit. The paleontologic evidence consists of distinctive Fox Hills species belonging to such marine genera as *Scaphites*, *Lunatia*, and *Tancredia*, found directly associated in the same bed with the brackish-water forms and occurring with them in such a way that they must have lived together or near each other and been embedded at the same time.

The second area included the valley of the Little Missouri from Marmarth to Yule, N. Dak. The point emphasized with reference to this area was the finding of an oyster bed some 500 feet above the base of the Lance formation and above all the dinosaurs that have been found in the region.

The Lance Creek area in Converse County, Wyo., which had been reexamined in company with M. R. Campbell and R. W. Stone, was the third area considered. Of this area Stanton said:

Our principal contribution to the knowledge of the stratigraphy of the area was the discovery that the marine Fox Hills deposits extend about 400 feet higher than had previously been determined, and that nonmarine coal-forming conditions were temporarily inaugurated here before the close of Fox Hills time.

In conclusion Stanton wrote:

The three areas discussed in this paper, taken together, tell a story of gradually changing conditions near the end of the Cretaceous, when the uplift of the Rocky Mountain region was draining the interior sea. The uplift was not uniform nor continuous, and the emergence above sea level could not have been simultaneous for all localities throughout the region. * * * The bearing which the facts here presented have on the Laramie problem is self-evident. If it is true that there is a transition with practically continuous sedimentation from the Fox Hills sandstone into the Lance formation in the region discussed, then the Lance formation includes or forms part of the Laramie.

The first published official statement showing that the discussion concerning the age of the Lance formation was having its effect is to be noted in a short report on the eastern part of the Bull Mountain coal field, Mont., by C. T. Lupton.[13] Here for the first time the Lance

[12] Fox Hills sandstone and Lance formation ("*Ceratops* beds") in South Dakota, North Dakota, and eastern Wyoming: Am. Jour. Sci., 4th ser., vol. 30, pp. 172-188, 1910.

[13] U. S. Geol. Survey Bull. 431, p. 163, 1911.

formation was classed as "Cretaceous or Tertiary."

In May, 1911, I published a short paper [14] entitled "Further data on the stratigraphic position of the Lance formation ('*Ceratops* beds')," which gave the results of the work of the two field seasons that had intervened since the publication of my first paper on this subject. What was then thought to be the most important result recorded was the finding in Carbon County, Wyo., of the remains of *Triceratops* in the so-called "Upper Laramie" of Veatch, above the supposed profound unconformity as described and mapped by him. After describing this occurrence I made the following statement:

Since, with the exception of their occurrence in the post-Laramie deposits of the Denver Basin, the remains of *Triceratops* have never been found outside the Lance formation, the finding of *Triceratops* at this point is of far-reaching importance. It shows that not only are the beds containing them above more than 6,000 feet of "Laramie" rocks (the basal portion of which is almost certainly of Fox Hills age), but also that they are separated from the "Laramie" ["Lower Laramie"] by an unconformity, which, according to Veatch, is profound and has involved the removal of perhaps as much as 20,000 feet of sediments. This would seem effectively to dispose of the contention that the Lance formation ["*Ceratops* beds"] is the equivalent of the Laramie.

Another part of this paper was an important contribution of several pages by W. R. Calvert, on the stratigraphic relations in the old Standing Rock and Cheyenne Indian Reservation, in South and North Dakota, as observed by him and by the parties under his charge. In this contribution particular attention was devoted to the Fox Hills and the overlying Lance formation. Calvert said: "As a result of field study by Pishel, Barnett, and the writer, it seems certain that the line between the Fox Hills sandstone and the Lance formation is marked by an unconformity." Calvert pointed out that the Fox Hills has a maximum thickness of 200 feet in this region, but it was found to vary greatly, and in some places it was entirely absent, the Lance formation resting on the Pierre. Angular as well as erosional discordances between the two were noted.

Calvert was of the opinion that the reported occurrence of Fox Hills invertebrates in the lower part of the Lance may be looked at from two divergent points of view. Because Fox Hills fossils occur in the lignitic shales at the base of the "somber beds" and mingled with the brackish-water types of the Lance formation is not necessarily proof positive that the various faunas lived at the same time, for if the deposition of the Fox Hills was followed by a definite erosion interval, what is more probable than that in the deposition of succeeding strata fossil shells would be eroded from the marine beds and carried into the channels, there to mingle with the then living brackish-water fauna of the Lance formation?

The conclusions reached in this paper were in part as follows:

It has now been demonstrated that the Lance formation is everywhere followed conformably by the acknowledged Fort Union—that is to say, sedimentation from one to the other was continuous and uninterrupted.

The unconformable relations between the Lance formation and underlying formations having been demonstrated at so many points, it could only be concluded that this unconformity is undoubtedly one of importance, and this would seem to dispose of the contention that the Lance, Arapahoe, and Denver formations may be mere "phases of Laramie." * * * This point becomes more clearly than ever the logical point at which to draw the line between Cretaceous and Tertiary.

Later in 1911 I published a short note [15] under the caption "Where are the Laramie dinosaurs?" In this note the facts regarding the relations between the Laramie and Lance formations, as recorded in previous papers, were briefly set forth, and I concluded with the following paragraph:

The vertebrate paleontologists continue to refer to the "*Ceratops* beds" as the "Laramie," the "Laramie Cretaceous," etc., as though nothing had been ascertained regarding their position since they were named 25 years ago. If there *is* valid evidence to show that the Lance formation ("*Ceratops* beds") is the equivalent to the Laramie in whole or in any part, it would be welcome. If there *is* a known locality where dinosaurs (Ceratopsidae) occur in the true Laramie, information concerning it should not longer be withheld.

The report on the work of the United States Geological Survey on mineral fuels for the year 1910, published in 1912,[16] contains many short papers and preliminary reports relating to Rocky Mountain areas, here under consideration. In these papers, by Pishel,[17] Calvert,[18]

[14] Jour. Geology, vol. 19, pp. 358-376, 1911.

[15] Science, new ser., vol. 34, p. 320, 1911.

[16] U. S. Geol. Survey Bull. 471, 1912.

[17] Pishel, M. A., Lignite in the Fort Berthold Indian Reservation, N. Dak.: Idem, p. 170.

[18] Calvert, W. R., Geology of certain lignite fields in eastern Montana: Idem, p. 187.

Bowen,[19] Herald,[20] Hance,[21] Stebinger,[22] Beekly,[23] Wegemann,[24] Winchester,[25] and others, the Lance formation was uniformly classed as "Cretaceous or Tertiary." It is not necessary to refer to these papers in detail, except to that of Calvert, in which he recorded certain facts of importance relating to a large area in eastern Montana. He divided the Lance formation of this area into two parts—a lower sandstone member, immediately overlying the Pierre and named the Colgate sandstone member, and an upper or undivided portion. As regards the line between the Lance and the overlying Fort Union he said:

In the area mapped the upper limit of the Lance formation can not be based on lithologic grounds but must instead be dependent upon the occurrence of fossil Ceratopsia bones. In the area treated in this report the highest horizon at which these bones were found is just above the lower persistent lignite bed, but there is certainly nothing in the character of the overlying strata to suggest that similar bones do not occur therein up through a stratigraphic distance of perhaps 500 feet. * * * As a result of these conditions no attempt is made on the index map or on the maps of the various areas treated in this report to differentiate the Lance formation from the overlying strata described in connection with the Fort Union formation. * * * In other words, the area bounded on one side by the contact between the Pierre shale and the Colgate sandstone member and on the other side by the outcrop of the lowest persistent lignite bed represents the distribution of the Lance formation as mapped in this field. In this connection, however, it can not be emphasized too strongly that the upper limit adopted is merely suggestive, as the finding of *Triceratops* bones higher in the section will necessitate an upward extension of the formation.

At the meeting of the Paleontological Society in Princeton, N. J., December 31, 1913, and January 1, 1914, there was held a symposium on the "Close of the Cretaceous and opening of Eocene time in North America," which was briefly introduced by Henry Fairfield Osborn, and in which Messrs. Knowlton, Stanton, Brown, Matthew, and Sinclair participated.

[19] Bowen, C. F., The Baker lignite field, Custer County, Mont.: Idem, p. 202.

[20] Herald, F. A., The Terry lignite field, Custer County, Mont.: Idem, p. 227.

[21] Hance, J. H., The Glendive lignite field, Dawson County, Mont.: Idem, p. 271.

[22] Stebinger, Eugene, The Sidney lignite field, Dawson County, Mont.: Idem, p. 284.

[23] Beekly, A. L., The Culbertson lignite field, Valley County, Mont.: Idem, p. 319.

[24] Wegemann, C. H., The Sussex coal field, Johnson, Natrona, and Converse counties, Wyo.: Idem, p. 441.

[25] Winchester, D. E., The Lost Spring coal field, Converse County, Wyo.: Idem, p. 472.

In the first paper [26] the following was given as the thesis:

It is proposed to show that the dinosaur-bearing beds known as "*Ceratops* beds," "Lance Creek beds," Lance formation, "Hell Creek beds," "somber beds," "lower Fort Union," Laramie of many writers, "Upper Laramie," Arapahoe, Denver, Dawson, and their equivalents are above a major unconformity and are Tertiary rather than Cretaceous in age.

The evidence was presented under the headings stratigraphic, paleobotanic, diastrophic, European time scale, vertebrates, and invertebrates. In the discussion of stratigraphic evidence it was held "that the dinosaur-bearing beds above mentioned are separated from underlying beds by a major unconformity which makes the logical line of separation between Cretaceous and Tertiary." The evidence bearing on the occurrence of this unconformity was traced throughout North and South Dakota, Montana, Wyoming, Colorado, and New Mexico and was demonstrated in a number of ways, including angular and erosional discordance, as well as faunal and floral differences.

The paleobotanic evidence was naturally presented in extenso. It was shown that the floras in the beds immediately below and above the line of the unconformity comprise about 350 species in the lower beds (Vermejo, Laramie, Montana, etc.) and over 700 species in the upper beds (Raton, Dawson, Arapahoe, Denver, Lance, etc.) but that they have only 21 or 22 species in common, showing "that more than 90 per cent of the Cretaceous flora was wiped out by the disturbance attending this diastrophic movement."

In the Raton Mesa region of Colorado and New Mexico the beds immediately above the unconformity have been named the Raton formation and contain a flora of 148 species, only 4 of which are common to the underlying Vermejo, which is below the line of the unconformity. The Raton flora was correlated with those of the Wilcox group of the Gulf coast and of the Dawson, Arapahoe, and Denver formations to the north. The correlation was carried from the Denver Basin of Colorado through North Park and into Carbon County, Wyo., where the "Upper Laramie" of Veatch

[26] Knowlton, F. H., Cretaceous-Tertiary boundary in the Rocky Mountain region: Geol. Soc. America Bull., vol. 25, pp. 325–340, 1914.

was held to be of the same age as the Lance formation of Converse County, Wyo., and thence throughout Montana and the Dakotas. "The Lance flora embraces about 100 named and described species. Of these 100 species, over 75 are typical Fort Union species that have never been found in older beds and most of them only in the Fort Union." The Fort Union was said to be of acknowledged Eocene age.

In discussing the European time scale it was shown that

(1) The Cretaceous and Tertiary systems were originally established on a physical basis, and the exact line of separation between them was determined by the structure; (2) after more than a century, during which the several lines of evidence have been tested, the last authoritative word on the European standard is to the effect that the structure is the determining factor in separating them, and that even dinosaurs that have been appealed to so often as proof of Cretaceous age did not end with the Cretaceous.

The vertebrate and invertebrate evidence was briefly considered. In conclusion, the thesis given at the beginning of the paper was repeated and considered as follows:

Evidence, believed to be competent, has been presented in support of this view from the side of stratigraphy, diastrophism, and paleobotany, and what is thought to be the weakness and insufficiency of the vertebrate and invertebrate evidence has been pointed out. The vertebrate paleontologist would place the Cretaceous-Tertiary line at the highest horizon at which dinosaurs have been found, notwithstanding the fact that this is a variable boundary, unattended by structural or diastrophic action. The invertebrate paleontologist would place this line at the highest point where marine invertebrates of Cannonball type occur. The paleobotanist would place the line at the lowest horizon at which Tertiary plants have been found, which corresponds with the structure. The paleontologists are not in accord. What, then, is to be the court of final appeal? There is but one answer: Structure resulting from diastrophism. The evidence from these sources supports the thesis.

The second paper of the symposium, by T. W. Stanton,[27] began with a discussion of the typical Cretaceous and Eocene of western Europe, in which it was held that the Anglo-Parisian basin "can perhaps with justice be considered the typical area of both Cretaceous and Eocene." It was shown that here there is a well-marked structural break, as well as a strong faunal break, and it is of course easy to distinguish between them, but that in other areas (Denmark, Belgium, center of Paris Basin, etc.) there are deposits,

in part marine and in part continental, which seem to belong between the highest Cretaceous and the lowest Eocene represented in England. These intermediate deposits have been called Danian, Montian, and other more local names and have been assigned by some geologists to the Cretaceous, by others to the Tertiary, and by still others part to the Cretaceous and part to the Tertiary. * * *

All will agree, I think, that when two contiguous systems as originally defined are separated by an unconformity, if there is other evidence of a break in sedimentation, it is probable that intermediate deposits will be found in some part of the world, and that when found, if they are subordinate in character, they should be assigned in each case to the system to which they are most closely related.

In discussing the contact between marine Cretaceous and marine Eocene in North America, Stanton pointed out that

In America, as in England, wherever marine Cretaceous is directly overlain by marine Eocene, there is no difficulty in recognizing the boundary between them, and there is no controversy concerning the boundary. * * * In the Interior Province, including the Great Plains and Rocky Mountain region, conditions were different. The Upper Cretaceous sea during the Colorado epoch covered a large part, if not the whole, of the province, and by the end of the Cretaceous it had entirely retreated from the area; but the Eocene sea did not return into this province at all. Instead of marine deposits great continental deposits were formed, beginning in the Cretaceous and continuing with many interruptions and with increasing restriction of areas throughout Tertiary time.

As regards the evidence of land areas in the Rocky Mountain region during the Cretaceous, Stanton wrote as follows:

The idea has sometimes been expressed that this was a period of quiet and universal submergence for the province, with no land masses within it until the end of the period, when the whole area was lifted above sea level by a single movement. There are many facts opposed to this view—so many that they form convincing evidence that at several times during the period there were differential movements which brought previously submerged local areas above sea level. The greatest submergence of the sea, and presumably the deepest submergence, seems to have been near or after the middle of the Colorado epoch; but even at that time it is probable that there were large islands. Local variations in thickness and character of sediments bespeak the nearness of land at some localities.

As examples in support of this contention were given the Datil Mountain area in western New Mexico, where a land flora was developed in the Colorado; the Mesaverde formation of Colorado, Wyoming, Utah, etc., which shows extensive coal deposits; various coal fields of

[27] Boundary between Cretaceous and Tertiary in North America, as indicated by stratigraphy and invertebrate faunas: Geol. Soc. America Bull., vol. 25, pp. 341-354, 1914.

the Colorado epoch in Utah and Wyoming; coal and fresh-water deposits in the Eagle and Judith River formations; and finally, the volcanic activity which furnished material for the Livingston formation in the area about the Crazy Mountains in Montana.

Stanton also devoted several pages to the consideration of the Lance formation, including its distribution and general character, its development in North and South Dakota, and particularly the marine member and its fauna. Regarding this fauna he said:

> In my opinion, the invertebrates from the marine member of the Lance belong to a Cretaceous fauna. This is indicated both by their close relationship with the Fox Hills fauna and by the known paleogeographic facts of the late Cretaceous and the Eocene. The fauna contains a number of species identical with Fox Hills forms, others that are closely related, a few that were ascribed to the Fox Hills but apparently were actually collected by the early explorers from beds now assigned to the marine member of the Lance, and a considerable number of new species, which, so far as known, do not occur outside of the marine member. * * * The fauna lacks a number of common Fox Hills species and contains a considerable proportion of new forms, so that it may be called a modified Fox Hills fauna.

The conclusions reached are stated as follows:

> In my opinion, therefore, the conclusion is justified that the Cretaceous period did not end in the interior province until the sea had completely retreated from the province, and that the Lance formation should be assigned to the Cretaceous.
>
> The final retreat of the Cretaceous sea from the interior province was doubtless associated more or less closely with local orogenic movements which caused active erosion to begin or to increase in various areas; but in other areas within the province the products of this erosion were laid down as terrestrial deposits, which taken together practically bridge the gap between Cretaceous and Tertiary. The boundary between the two systems in such areas is not marked by an important break caused by general diastrophism, because the breaks and discordance and erosion intervals in an area of continental deposition are not dependent on the same conditions that cause the major breaks in marine sediments. Even if it be true that there was a world-wide movement at the close of the Cretaceous which caused a break between marine Cretaceous and marine Eocene in all the areas where such sediments are now accessible, such a movement would not necessarily affect the accumulation of continental deposits of detrital material in an area already above sea level, and in this case apparently it did not affect it. On the other hand, terrestrial deposits are characteristically and necessarily irregular, and the importance of breaks and unconformities in them must therefore be tested with great care, using all kinds of available evidence.
>
> The Lance formation is believed to be Cretaceous on account of its intimate stratigraphic relation with the underlying marine Cretaceous, on account of the close relationship of its vertebrate and nonmarine invertebrate faunas with Cretaceous faunas, and on account of the occurrence in one area of a marine Cretaceous fauna within the formation. This marine Cretaceous invertebrate fauna is held to establish the Cretaceous age of the plants which occur in the beds beneath it, in spite of the fact that these plants are said to belong to Eocene species. In other areas where the Lance formation does not include a marine member but has a thicker development of strata, with a large vertebrate fauna of Mesozoic types, it is a fair inference that the whole formation, with its contained flora, is also of Cretaceous age. If, then, the Lance flora is in fact a Cretaceous flora, notwithstanding its close relationship with Eocene floras, it is obvious that the correlation of other formations with known Eocene formations on the evidence of fossil plants alone is open to serious question. In the case of the Denver and Arapahoe formations such a correlation is directly opposed by the evidence of the vertebrate fauna, which allies them closely with the Lance formation.

In the contribution of Barnum Brown [28] to this symposium he stated that he had been "continuously engaged since June, 1900, in the exploration of the geology, flora, and fauna of three great formations which in their animal and plant life bridge over the passage from Cretaceous to Eocene time, as determined by the comparison with the life of the same epochs in Europe." These formations are "Hell Creek formation of northern Montana; series embracing in descending order Paskapoo, Edmonton, Fort Pierre (upper), Belly River (intercalation), Fort Pierre (lower) of Red Deer River, Alberta; Ojo Alamo formation of northern New Mexico; Lance Creek formation of Converse County, Wyo."

In a former paper Brown had described his "Hell Creek beds" as resting unconformably on the underlying Fox Hills, but this statement he now desired to modify. He described a number of localities in which "these marine beds [Fox Hills] have been eroded in places, sometimes to a depth of 10 feet, before the succeeding massive sandstone of the fresh-water 'Lance' was deposited." This break, he concluded, "is evidently of local erosional character," as "the strata are, however, in all cases parallel to the bedding planes of the succeeding sandstones."

The Paskapoo and Edmonton formations as exposed along Red Deer River, Alberta, were described at some length. The conclusion was reached that the Paskapoo has a mammal fauna in which "the multituberculates

[28] Cretaceous Eocene correlation in New Mexico, Wyoming, Montana, Alberta: Geol. Soc. America Bull., vol. 25, pp. 335-380, 1914.

and trituberculates are unmistakably those of the Lance, but the placental mammals have not been found in the Lance and appear to belong to the Paleocene groups of mammals," while the invertebrates "are suggestive of Fort Union rather than earlier forms." The Edmonton formation, although containing a flora, at least in the upper part, that is undoubtedly indicative of Fort Union age, was concluded to be Cretaceous and older than Lance on account of the presence of a plesiosaur (*Leurospondylus*), a marine reptile "clearly of Mesozoic age," above the plants. Brown concluded as follows:

From the vertebrate and invertebrate remains it seems very clear that these rocks are not of Fort Union age, but as shown by the plants the climatic conditions of Fort Union time were long foreshadowed toward the close of the Cretaceous.

The dinosaur-bearing beds beneath the Puerco formation of northern New Mexico were briefly described under the name Ojo Alamo beds.

The final conclusion of the paper was as follows:

There is no doubt that the Hell Creek beds were synchronous with the Lance, and little doubt that the Belly River and Ojo Alamo beds should be correlated with the Judith River. The Edmonton is intermediate in age between the Judith River and the Lance.

W. D. Matthew[29] stated that the term "Paleocene" as he used it "denotes what we have been calling basal Eocene, comprising the Fort Union, Puerco and Torrejon, and other equivalent formations older than Wasatch or typical lower Eocene." Matthew gave lists of the vertebrate faunas of the Puerco, Torrejon, Paskapoo, and Fort Union and made comparisons between them and those of the Lance and Belly River and with the Wasatch. In an interpretation of the faunas he stated: "The evidence of fossil vertebrates in correlation is very valuable, provided it is interpreted correctly." The difference between two faunas may be due, he said, to "lapse of time; difference of local environment; migration movements representing a change in environment somewhere else, not necessarily in the region concerned." With these precautions in mind Matthew presented the table reproduced in figure 1.

[29] Evidence of the Paleocene vertebrate fauna on the Cretaceous-Tertiary problem: Geol. Soc. America Bull., vol. 25, pp. 381-402, 1914.

The correlation of the faunas here involved with the European succession is of special interest. It was shown that the Thanetian (Cernaysian) has furnished a "small fauna of mammals and reptiles, comparable in facies to our Torrejon and apparently of equal age." The Sparnacian and Ypresian, which include the London clay, the Argiles plastique of the Paris Basin, and equivalents in Belgium and elsewhere, are equivalent to our Wasatch. According to Matthew, the Puerco, arbitrarily correlated by Osborn with the Montian, "has no certain equivalent in Europe," and he stated that the "Lance is equally difficult to correlate," as "there are no European formations of corresponding facies in the late Cretaceous."

As regards faunal migrations and diastrophism the following statements were made:

As I read the evidence from the vertebrates it is to this effect:

1. From the Belly River to the Lance there is a considerable lapse in time, but they represent the same faunal facies and they indicate that there was no great migration movement intervening, and hence no great upheaval, either continental or universal. There was undoubtedly a considerable local uplift along the Rocky Mountain ridges and extensive recession of the sea from the plains to eastward of them.

2. Between the Lance and the Paleocene there is a somewhat smaller lapse in time but a very marked change in fauna; but they do not represent the same facies, and while a great migration movement is probably indicated by the extinction of the dinosaur phyla and incoming of certain groups of placental mammals (Creodonta, Condylarthra, etc.), its extent remains a little uncertain.

3. Between the Paleocene and Eocene a great migration movement intervenes, the progressive orders of placental mammals, of turtles, and perhaps other groups appearing simultaneously in Europe and North America. The lapse of time between the uppermost Paleocene and lowest Eocene is slight.

If, therefore, we are to use diastrophic criteria as the basis of our geologic classification, the dividing line between Cretaceous and Tertiary should be drawn either between the Lance and the Paleocene or between the Paleocene and Eocene. It should not be drawn between Belly River and Lance.

The following is Matthew's conclusion:

The question to my mind shapes itself thus: Does the evidence conclusively support the present classification; and, if not, is it sufficiently conclusive to warrant our changing it? I have indicated what I regard as the weight and trend of the vertebrate evidence. Without entering into any detailed criticism of the stratigraphic and paleobotanic evidence, a task for which others are far more competent, I may say that to me it appears to be inconclusive because it does not allow for the characteristics of epicontinental formations nor for the varying facies of faunas and floras; that the asserted magnitude of the break between Laramie and Lance rests not on evidence but on a definition of the Laramie; and that no really adequate evidence has been adduced of its relations to the Cretaceous-Tertiary break in Europe. The paleobotanic argument for placing the Lance in the Tertiary is the resemblance of its flora to that of the Paleocene and its great difference from that of the true Laramie. But there is no evidence that the Lance flora was absent from Europe in the late Cretaceous, and the Laramie clearly represents a different facies from the Lance. Dr. Knowlton has insisted strongly on the entire absence of dinosaurs in the true Laramie, apparently with the idea that it showed it to be much older than the Lance. But as the same phyla of dinosaurs are present in the older Belly River and in the newer Lance, their absence from the Laramie is obviously due to a difference in environmental conditions. The facies of the fauna is different, and much, if not all, of the difference in flora should be ascribed to this cause.

For these and many other reasons the evidence in favor of transferring the Lance and associated formations to the Tertiary appears to me inconclusive and is directly in conflict with the evidence from fossil vertebrates, so far as I am able to understand it.

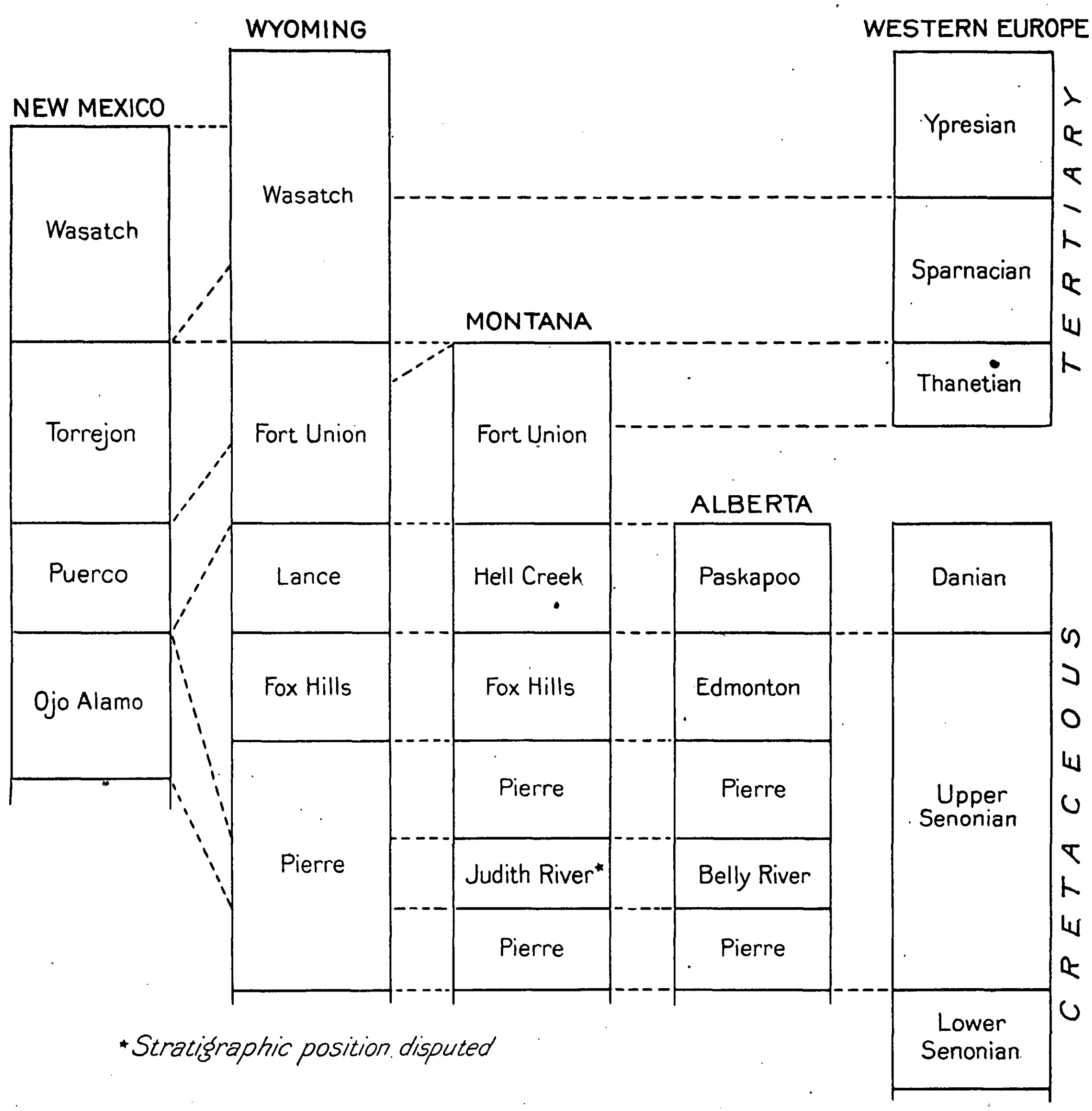

FIGURE 1.—Approximate correlations of typical formations of late Cretaceous and early Tertiary in Europe and western America, based on their vertebrate faunas. After W. D. Matthew, Geol. Soc. America Bull., vol. 25, p. 393, 1914.

The final paper of the symposium was presented by W. J. Sinclair [30] and later published under joint authorship with Walter Granger.

[30] Sinclair, W. J., and Granger, Walter, Paleocene deposits of the San Juan Basin, N. Mex.: Am. Mus. Nat. Hist. Bull., vol. 33, pp. 297-316, 1914.

As the title indicates, the authors were concerned principally with the lower Eocene mammal-bearing formations and only incidentally with the underlying dinosaur-bearing beds. As this phase of the paper is treated at length under the discussion of the San Juan Basin (pp. 69-76) it need not be further considered here.

In May, 1914, after a prolonged discussion of all the lines of evidence then available, it was decided by the United States Geological Survey that, so far at least as its official publications are concerned, the Lance formation is to be classed as "Tertiary (?)" instead of "Cretaceous or Tertiary," as previously, and that the Arapahoe, Denver, Dawson arkose, and Raton formations, with which I believe the Lance formation to be in part synchronous, are to be classed as Eocene instead of Cretaceous.

One of the first places in which this newer interpretation of the position of the Lance formation appears was a paper by Bauer,[31] published in 1914. This paper presented the results of an examination of an area in northeastern Montana along the north border of the Fort Peck Indian Reservation. The only sedimentary formations present are the Lance and Fort Union. Concerning the line between them Bauer said:

> Owing to the absence of a sharp lithologic boundary between the formations and to the lack of exposures near the critical horizon in this field and also in the northern part of the reservation, the accurate mapping of the Lance-Fort Union boundary is impossible. In drawing the line shown on the map the known outcrops of somber-colored beds are considered to belong to the Lance, and those of yellow beds to the Fort Union. * * * Its [the Lance's] separation from the overlying Fort Union formation is thus based on its stratigraphic position and lithologic character. In these particulars it agrees with the Lance formation as recognized in other areas in eastern Montana and in North Dakota, where it is further characterized by a dinosaur fauna which has not been found in the Fort Union. Formerly the Survey considered the evidence of the age of the Lance so conflicting that it was ascribed to the Cretaceous or Tertiary, but recently the close correlation of the Lance flora with that of well-determined Tertiary formations of the Gulf coast, considered together with the mountain-making movements that are supposed to have immediately preceded the deposition of the strata, has led the Survey to assign the formation to the Tertiary (?) system.

A small coal area on the west side of Big Horn River, Mont., in the angle formed by its junction with the Yellowstone, was described by Rogers.[32] The strata examined are mainly referable to the Lance formation, concerning which Rogers said:

> The Lance formation in this area may be divided into two parts, namely, a coal-bearing member, which comprises the upper 250 feet, and a lower portion about 900 feet thick. This distinction is made partly on lithologic grounds and partly because of the slight difference in the fossils found in the two divisions.

In the same volume with the two papers just mentioned was one by Lloyd[33] on the lignite field of the Cannonball River region, N. Dak. The four principal sedimentary formations recognized were the Fox Hills sandstone, Lance, Fort Union, and White River (Oligocene). Concerning the Fort Union and Lance formations he said:

> The Fort Union formation, of the lower part of the Tertiary system (Eocene), which contains the greater part of the valuable lignite in the Dakotas and eastern Montana, embraces the surface rocks in the western and northwestern parts of the Cannonball River field. Underneath the Fort Union is a series of beds which are now tentatively classified as probably of early Tertiary age and which have been referred to the Lance formation. The upper 250 or 300 feet of this formation is in the field markedly different in lithologic character from the underlying more typical Lance and has been found at numerous places to contain the remains of a marine fauna which has not previously been known in this part of the stratigraphic section. These beds have been mapped separately and are herein designated the Cannonball marine member of the Lance formation. The underlying lower part of the Lance is of fresh-water origin and is composed of alternating beds of shale and sandstone which on erosion give rise to the badlands described above. Its thickness is approximately 400 feet.

The fauna of the Cannonball member was alluded to as follows: "In the Cannonball River field several collections of marine invertebrate fossils made from the Cannonball member * * * have been identified by T. W. Stanton as belonging to a modified Fox Hills fauna."

In 1915 Lloyd and Hares[34] described in considerable detail the areal distribution, lithologic character, and stratigraphic relations

[31] Bauer, C. M., Lignite in the vicinity of Plentywood and Scobey, Sheridan County, Mont.: U. S. Geol. Survey Bull. 541, pp. 293, 315, 1914.

[32] Rogers, G. S., Geology and coal resources of the area southwest of Custer, Yellowstone and Big Horn counties, Mont.: U. S. Geol. Survey Bull. 541, pp. 316-328, 1914.

[33] Lloyd, E. R., The Cannonball River lignite field, Morton, Adams, and Hettinger counties, N. Dak.: U. S. Geol. Survey Bull. 541, pp. 243-292, 1914.

[34] Lloyd, E. R., and Hares, C. J., The Cannonball marine member of the Lance formation of North and South Dakota and its bearing on the Lance-Laramie problem: Jour. Geology, vol. 23, pp. 523-547, 1915.

of the Cannonball member and argued for its probable Cretaceous age. They wrote:

Field examinations by the writers and the paleontological determinations by Drs. Stanton and Knowlton during the years 1912 and 1913 show that in a large area west of Missouri River in North and South Dakota the Lance formation consists of two distinct parts—a lower nonmarine part containing a flora very similar to if not identical with that of the Fort Union, and an upper marine member containing a fauna closely resembling but not identical with that of the Fox Hills sandstone. This upper part, on account of its peculiar fauna, has been mapped separately and named the Cannonball marine member of the Lance formation. Farther west nonmarine beds bearing lignite and occupying a similar stratigraphic position have been named the Ludlow lignitic member of the Lance.

After describing the areal distribution and giving a number of sections of the strata, they proceeded to a discussion of interrelationships. The fauna of the Cannonball was studied by T. W. Stanton, who wrote concerning it as follows:

The fauna of the Cannonball member of the Lance may now be characterized as a modified Fox Hills fauna. It contains a considerable proportion of undescribed species of Cretaceous affinities, and it is noteworthy that a number of the most common Fox Hills species have not been discovered in this fauna. * * * In this list of about 40 forms there are 21 named species and varieties, of which 15 occur in the Fox Hills, 4 occur in the Pierre, and 5 were originally described from rocks now known to belong to the marine member of the Lance. One species, *Corbicula cytheriformis*, was described from the Judith River formation and is known in the Mesaverde formation and the Lance of other areas.

After presenting and weighing the several lines of evidence that may be used in fixing the age of the Cannonball, these authors concluded as follows:

A recent detailed consideration of all the evidence has led to a decision by the United States Geological Survey that the Denver and Arapahoe, Dawson, and Raton formations in Colorado and New Mexico all be placed in the Tertiary system. This decision was based primarily on the correlation of these formations with the Wilcox formation of the Gulf region on the evidence of their fossil floras and also on the consequent correlation of the unconformities in the two regions. Although the Lance formation is believed to be of the same age as the Denver, Raton, and "Upper Laramie," it is classified by the United States Geological Survey as Tertiary (?), the doubt being thus expressed on account of the Cretaceous character of the Cannonball marine fauna. The writers believe that greater weight should be given to the evidence of the marine faunas and the dinosaurs, and that, in view of the strong evidence presented by these faunas, the correlations made on the basis of fossil floras should not be considered as conclusive.

In a final footnote they added that "further studies on the Lance problem have strengthened the conviction of the writers that the Lance is Cretaceous."

FORT UNION FORMATION.

The early history of the Fort Union formation, or "Great Lignitic," as it was at first called, has been sufficiently set forth in the preceding pages. In fact, it was not until the Laramie was established that the element of discord was introduced which gave rise to so much subsequent discussion and difference of opinion. Most of the geologists and paleontologists who had studied the Fort Union contended for its Tertiary age, and Newberry, who investigated the flora, was at first inclined to refer it to the Miocene. It appears that Hayden was in the end more or less responsible for promulgating what has since been accepted as an erroneous view regarding the relation of the Fort Union to the Laramie. When the Laramie was adopted by Hayden, he made it include or at least be equivalent to the Fort Union, as the following statement shows:[35]

If objection is made to the use of the term "Lignitic" group, I would say that in this work it is restricted to a series of coal-bearing strata lying above the Fox Hills group, or Upper Cretaceous, and these are embraced in the divisions Laramie and Fort Union.

On the same page Hayden continued:

As far back as 1859 it was my belief, founded on what appeared sufficient evidence, that the sequence between the well-characterized Cretaceous strata and those of the Lignite group, as defined at that time, was continuous, and that the chasm that was supposed to exist between the Cretaceous and the Tertiary epoch would be found to be bridged over.

He then proceeeded to quote Dr. C. A. White, who, he said,

had made a critical examination of these formations during the past season, and he says that his investigations have freely confirmed the views expressed by me some years ago and indicated by the paleontological studies of Mr. Meek, that the Fort Union beds of the upper Missouri River are the equivalent of the Lignitic formation as it exists along the base of the Rocky Mountains in Colorado.

Inasmuch as the Fort Union was regarded as equivalent to the lignite-bearing beds east of the mountains in Colorado, which fell within the typical areas included by King in the Laramie, it of course followed that the

[35] Hayden, F. V., letter of transmittal for Lesquereux's "Tertiary flora": U. S. Geol. Survey Terr. Rept., vol. 7, p. iv, 1878.

Fort Union was regarded by Hayden as of the same age as the Laramie, if not, indeed, included in it.

As is well known, Hayden originally considered all of his Laramie (Laramie and Fort Union) as of Tertiary age, but his latest conclusion was that the whole mass was of a transitional character—that is, it formed beds of passage between the Cretaceous and Tertiary. Newberry [36] in commenting on this conclusion said: "It is easy to see that this result was inevitable, after he had united an Upper Cretaceous with a Tertiary formation under one name."

Clarence King, however, did not accept Hayden's reference of the Fort Union to the Laramie. When preparing the final volume on the systematic geology of the vicinity of the fortieth parallel, he had before him Lesquereux's "Tertiary flora," above quoted, and after admitting that he had never visited the locality and could not therefore "speak with any definiteness," he added (p. 353):

> I consider it worth while to point out here a noticeable ambiguity in its evidence. Cope, in his introduction to his volume on the Cretaceous, cites dinosaurs as coming from the Fort Union, from which he refers the fauna to the Mesozoic series. On the other hand, the characteristic plant life of the country differs entirely from that described by Lesquereux in Volume II, Tertiary flora. It is noticeable that he nowhere describes in that volume any of the plants from the classic Fort Union locality, a series which has been studied by Newberry and which contains not only a general resemblance but some actual species identical with the Miocene of Greenland and northern Europe. * * * Until fresh evidences of the stratigraphical relations, and a full discussion of the fauna of the whole series of rocks at Fort Union is fully made, a definite correlation is impossible, and at present writing the entire difference between the plants at Fort Union and anything in Colorado or Wyoming that is of value at all suggests that they can not be related to any of the southern groups. I apprehend that the plant horizon at Fort Union will be found to be nothing but a northward extension of the White River Miocene.

King's reference of the Fort Union to the White River has not of course been sustained, but otherwise his suggestions have proved to be wonderfully near the truth.

C. A. White did much to merge the Fort Union in the Laramie. In fact, in what was perhaps his last utterance [37] on the subject he said:

> The localities at which Laramie strata were first studied by geologists were often distant from one another, and they were not then recognized as constituting one great formation. * * * These deposits consequently received a different name in each district. They thus have received such names as Fort Union group, Judith River group, Lignitic group, and Bitter Creek series. The term Lignitic soon came to be applied to the strata of several districts which are now included in the Laramie.

It was not possible, according to White, to distinguish between Fort Union and Laramie by the invertebrates, and this view was generally entertained by paleontologists for many years thereafter.

The influence of what are now known to have been the erroneous views of Hayden, White, and others is well shown in Ward's elaborate paper "Synopsis of the flora of the Laramie group," [38] in which he included in the Laramie not only the Fort Union but also beds now known to belong to the Montana, Arapahoe, Denver, Lance, and other formations. It should not be presumed, however, that he failed to note that there were striking differences between the typical Laramie flora and that of the Fort Union, but he was misled by the opinion of the time that all the formations he included formed an unbroken sedimentary sequence. His investigation was undertaken primarily to ascertain the bearing of the plants on the question of the age of the Laramie, but naturally it failed in reaching definite results. In this paper Ward described many new forms from a great many localities and horizons, though so many were from the Fort Union that Newberry,[39] in commenting on it, said: "But his monograph as a whole is simply an important contribution to what was before known of the Fort Union flora."

It is undoubtedly to J. S. Newberry that most credit is due for keeping alive and insisting upon the distinctness of the Fort Union from the Laramie. From the beginning of his studies of the material collected by Hayden in

[36] Newberry, J. S., The Laramie group: New York Acad. Sci. Trans., vol. 9, p. 3, 1889 (reprint).

[37] White, C. A., Correlation papers—Cretaceous: U. S. Geol. Survey Bull. 82, p. 147, 1891.

[38] Ward, L. F., U. S. Geol. Survey Sixth Ann. Rept., pp. 399-557, pls. 31-65, 1886.

[39] Newberry, J. S., The Laramie group: New York Acad. Sci. Trans., vol. 9, p. 4, 1889 (reprint).

the fifties until his death he maintained its Tertiary age. In the paper above quoted he said:

Whether the Laramie is Cretaceous and the Fort Union Tertiary are other questions, but they are certainly distinct from each other—distinct in the general botanical facies of their floras as well as in the absence of common species. That the Fort Union is Tertiary there can be no reasonable doubt; it has many species in common with the recognized Tertiary in the Canadian provinces of North America, in Greenland, and in the British islands, and it contains some plants which are living at the present day, such as *Onoclea sensibilis*, *Taxodium distichum*, *Corylus americana*, *C. rostrata*, etc. Moreover, the grouping of the plants composing it gives it a facies which enables one to recognize it at a glance. The abundance of species and specimens of *Populus*, *Viburnum*, and *Corylus* imparts to it an aspect as different from that of the flora of the Laramie as are the recent floras of Europe and America from each other.

In his last published utterance on this subject Newberry [40] made the following emphatic statement:

The floras of the Laramie and Fort Union groups are totally distinct, and these formations should be referred to different geological systems—the Fort Union to the Tertiary and the Laramie to the Cretaceous.

In 1896 W. H. Weed [41] published a short paper entitled "The Fort Union formation," in which, after briefly reviewing the early history of the Fort Union and Newberry's contention that it should be referred to the Tertiary, he described the geologic section in the vicinity of the Crazy Mountains, in Montana, where, he said, the Fox Hills, Laramie, Livingston, and Fort Union formations are superimposed. This view I hold to be in the main correct, although, as will be shown later in the discussion of the Livingston formation, there are many who do not accept it. In any event, it was made plain that the Fort Union formation of this region was above beds that should properly be referred to the Laramie or were in its position.

More than 25 years ago I became convinced of the correctness of Newberry's conclusion as to the Tertiary age of the Fort Union formation, and in many papers and reports published since that time I have consistently adhered to this view. It is perhaps not necessary further to allude to these papers, nor is it possible to fix an exact date on which the Fort Union became generally accepted as a Tertiary unit. The term with the present accepted application has been in current use for a dozen years or more and apparently is no longer seriously questioned.

As an example of the completeness of this change mention may be made of the treatment of the Fort Union in the reports of the Geological Survey of North Dakota. Thus, in the third biennial report of the State geologist, published in 1904, the term Fort Union does not occur, all beds under consideration being referred to the Laramie, but in the fifth biennial report, issued in 1908, the conditions were reversed and the Laramie was no longer accepted as present, all the beds being referred to the Fort Union or Lance. In a geologic map of North Dakota, published by A. G. Leonard [42] in 1913, the Laramie was not recognized, but nearly half of the State was shown to be covered by the Fort Union formation. In the text accompanying this map Leonard said:

The Fort Union is one of the best-known formations of the Northwest. It covers a vast area east of the Rocky Mountains, stretching from Wyoming to the Arctic Ocean in the valley of the Mackenzie River and including part of several Canadian provinces, much of western North Dakota, eastern Montana, northwestern South Dakota, and central and eastern Wyoming.

"LARAMIE" IN THE CANADIAN PROVINCES.

It appears that as early as 1873 George M. Dawson, while acting as geologist to the British North American Boundary Commission, noted the presence at certain points along the international boundary of lignite-bearing beds that he identified with the "Great Lignitic or Fort Union group" of Hayden, as exposed along Missouri River. This view was affirmed the following year in an article on the "Lignite formations of the West," [43] in which this statement was made:

In view of the evidence of the preponderant animal and vegetable forms, it seems reasonable to take the well-marked base of the Lignite series as that of the lowest Tertiary, at least at present. The formations described belong to this lowest Tertiary, being in fact an extension of Hayden's Fort Union group, and from analogy may be called Eocene.

So far as I have been able to ascertain, the term Laramie was first applied in the Canadian provinces also by Dawson [44] in his "Report on

[40] Newberry, J. S., The Laramie group: Geol. Soc. America Bull., vol. 1, p. 525, 1890.

[41] Am. Geologist, vol. 12, pp. 201-211, 1896.

[42] The geological map of North Dakota: North Dakota Univ. Quart. Jour., vol. 4, No. 1, October, 1913.

[43] Dawson, G. M., Canadian Naturalist, new ser., vol. 7, p. 252, 1874.

[44] Dawson, G. M., Canada Geol. Survey Rept. Progress for 1879-80, pp. 127-134B.

an exploration from Fort Simpson, on the Pacific coast, to Edmonton, on the Saskatchewan, embracing the northern part of British Columbia and the Peace River country." In discussing the Peace River section he several times alluded to the Laramie as following the Fox Hills conformably, but whether he intended to refer it to the Cretaceous or the Tertiary is not quite clear, though in a "comparative table of Cretaceous rocks" he made the so-called Laramie equivalent to the Fort Union and Judith River beds of Nebraska and Missouri rivers and also to the "Lignite Tertiary" of the forty-ninth parallel.

A year or two later, in his preliminary paper on the "Geology of the Bow and Belly River region," Dawson [45] took occasion to define the use of Laramie as follows:

The term Laramie is used in a general sense for the Upper Cretaceous or lower Eocene beds which overlie the Fox Hills series (Cretaceous No. 4). It is not intended by its use to differentiate the beds so named from those of the Judith River and Fort Union series, with which they may be found to blend as the intervening district is more completely explored.

In describing the general arrangement of the beds in the Belly River region, Dawson gave the following section:

Laramie.	Beds of the Porcupine Hills, chiefly thick-bedded sandstones and some shales.
	Willow Creek series. Reddish and purplish clays with gray and yellow sandstones.
	St. Mary River series. Sandstones, shales, and clays of general grayish or grayish-green colors.
	Yellowish sandstones and shaly beds, with a mingling of fresh-water and brackish or marine mollusks.
Fox Hills.	Yellowish sandstones, with some shales, irregular in thickness and character. Mollusks all marine.
Pierre.	Blackish and lead-colored shales, etc.
Niobrara (?).	Belly River series.

The complete report on the "country in the vicinity of Bow and Belly rivers, Northwest Territory," was published by Dawson [46] in 1885. In this report the descriptions of the "Laramie" are amplified and the thickness given. Thus the Porcupine Hills beds are given a thickness of 2,500 feet, the Willow Creek beds 450 feet, and the St. Mary River beds 2,800 feet.

Dawson [47] continued his explorations in the Canadian Rocky Mountains, his report published in 1886 including that portion from the international boundary northward to the headwaters of Red Deer River. In this report he alluded many times to the presence of the "Laramie" but always with the signification already given to it.

In the same volume R. G. McConnell [48] published a "Report on the Cypress Hills, Wood Mountain, and adjacent country in Assiniboia," in which he referred to the current uncertainty regarding the position of the "Laramie" and adopted the view that it is probably transitional between Cretaceous and Tertiary. In the Cypress Hills and vicinity, according to McConnell, it is apparently conformable to the Fox Hills sandstone and of small thickness, but in the Wood Mountain region it was found to be better represented and in some places capable of being divided into three "somewhat dissimilar groups." He quoted extensively from Dawson's report of 1875.

In the following year (1887) J. B. Tyrrell [49] presented an important paper on northern Alberta and adjacent districts in Assiniboia and Saskatchewan, in which he made a complete realinement of the "Laramie," although still using it as a group term. He established the Edmonton and Paskapoo series in substitution for the names proposed by Dawson. As these terms have now come into wide usage the formations may be described at some length.

The Edmonton series, which comprises the lower 700 or 800 feet of Dawson's St. Mary River series, was described as follows:

This is perhaps, on the whole, the most characteristic series of the entire region, for though its thickness, wherever determinable, was never found to exceed 700 feet, the horizontal position of the strata causes it to underlie a very large extent of country.

[45] Dawson, G. M., Canada Geol. Survey Rept. Progress for 1880–1882, p. 2B, 1883.

[46] Dawson, G. M., Canada Geol. Survey Rept. Progress for 1882–1884, pp. 1–159C, 1885.

[47] Dawson, G. M., Canada Geol. and Nat. Hist. Survey Ann. Rept., new ser., vol. 1, for 1885, pp. 1–169B, 1886.

[48] Idem, pp. 1–85C.

[49] Canada Geol. and Nat. Hist. Survey Ann. Rept., new ser., vol. 2, for 1886, pp. 1–176E, 1887.

It consists generally of whitish or light-gray clay and soft clayey sandstone, weathering very rapidly, with more or less rounded outlines. In some places, as on Red Deer River and in the Hand Hills, it is seamed with a great number of beds of ironstone, which with thin beds of lignite and lignitic shale give a definite banded character to all the escarpments. It also contains a great number of nodules of compact ironstone, which are often perched on little pinnacles cut out of the soft sandstone. In the northern portion, especially along the North Saskatchewan, the banded appearance is seldom seen, though with the exception of a smaller quantity of ironstone, the rock has very much the same character as further south.

This is essentially the coal-bearing horizon within the district, all the coal found east of the foothills, except probably the seams on the upper North Saskatchewan and at Egg Creek, being of this age. The top of the formation is marked by an extensive coal deposit seen first in the Wintering Hills as a thin bed of carbonaceous shale, but on being traced northward is found to thicken very greatly, till on the North Saskatchewan, near Goose Encampment, it has a thickness of 25 feet. The bottom of the series lies conformably on the Pierre shales, without any sharp line of demarcation between the two. In fact, the shales gradually lose their massive character and change almost insensibly into thin beds, which are of decidedly brackish-water origin. In the Pierre remains of land plants and animals are very rare, while here traces of land plants become fairly plentiful, and on Red Deer River dinosaurian bones are met with in great abundance, showing, with the presence of estuarine shells, the partly land-locked character of the area within which the beds were deposited.

Toward the west the Edmonton gradually disappears beneath the overlying beds of the Paskapoo, and, Tyrrell added,

In many places the junction of the Pierre and Laramie was plainly seen, the sandstones of the Paskapoo series appearing to rest conformably on the shales of the Pierre, so that the Edmonton series seems to thin out and disappear between its western outcrop and the eastern edge of the foothills.

The Edmonton was identified with the lower division of the Laramie in the Cypress Hills region, described by McConnell, and with the Wapiti River group of Dawson in the Peace River region.

The Paskapoo series was said to include "all the Laramie rocks lying above those of the Edmonton series" and to embrace Dawson's "Porcupine Hills and Willow Creek series and all but the lowest 700–900 feet of his St. Mary River series." The maximum thickness noted was 5,700 feet. The beds, according to Tyrrell,

consist of more or less hard light-gray or yellowish, brownish-weathering sandstone, usually thick bedded but often showing false bedding; also of light bluish-gray and olive sandy shales often interstratified with bands of hard lamellar ferruginous sandstone and sometimes with bands of concretionary blue limestone, which burns into excellent lime. * * * The whole series, as shown by its invertebrate fauna, is of fresh-water origin.

The lists of fossils given by Tyrrell show clearly that the Paskapoo is to be correlated with the Fort Union of the Missouri River region.

As regards the age of the "Laramie," Tyrrell concluded, after briefly reviewing the evidence, that

it seems reasonable to place the close of the Cretaceous epoch at the time of the deposition of the topmost beds of the Edmonton series, and that the Tertiary epoch began with the commencement of the Paskapoo period, during which a great thickness of sandstones and sandy shales was laid down without any apparent break or unconformity.

In the same volume as that containing Tyrrell's report George M. Dawson [50] presented certain "Notes to accompany a geological map of the northern portion of the Dominion of Canada, east of the Rocky Mountains," in which he stated that in the valley of Mackenzie River near the mouth of Bear Lake River Richardson found rocks which he referred to the "Lignite formation" but which "with little doubt represent the series now known as the Laramie."

In the subsequent annual reports of the Canada Geological Survey the "Laramie" continued to receive occasional mention, but no extensive papers in which it was involved were published, and the usage of the term continued about as established by Tyrrell for central Alberta. A number of papers were published from time to time by Sir William Dawson, J. F. Whiteaves, E. D. Cope, L. M. Lambe, and others on different phases of the paleontology of the Canadian "Laramie." Thus, as early as 1885 Whiteaves [51] published a "Report on the Invertebrata of the Laramie and Cretaceous rocks of the vicinity of the Bow and Belly rivers and adjacent localities in the Northwest Territory," in which he described some 35 species from the so-called Laramie of Alberta and the Souris River district, this being a paleontologic supplement to Dawson's paper on the same region already noted. He also described many species from the Belly River series, of which he said:

[50] Canada Geol. and Nat. Hist. Survey Ann. Rept., new ser., vol. 2, for 1886, pp. 18, 19R, 1887.

[51] Whiteaves, J. F., Contr. Canadian Paleontology, vol. 1, pt. 1, 1885.

Judging from their respective invertebrate faunae, it would seem impracticable to separate the "Belly River series" from the Laramie and more especially from the "Judith River group" on purely paleontological evidence.

Dawson published several papers on the flora of the "Laramie." In a paper on the Cretaceous and Tertiary floras of British Columbia and the Northwest Territory[52] he gave lists of "Laramie" plants from several localities. He considered the so-called Laramie as equivalent to the Fort Union, and the plants mentioned undoubtedly bear this out. In 1885, in his paper on the Mesozoic floras of the Rocky Mountain region of Canada,[53] he discussed the Belly River and so-called Laramie series, which he then failed to differentiate. He divided the "Laramie" into three "groups"—the "Lower Laramie," which embraced the St. Mary River series of George M. Dawson; the "Middle Laramie," or Willow Creek series of Dawson; and the "Upper Laramie," or Porcupine Hill series of Dawson. To judge from the lists of plants given, it would seem that there had been some mixture of horizons when the collections were made.

Dawson's third paper, on the fossil plants of the Laramie formation of Canada,[54] introduced still another set of terms. He stated that the "Laramie" of Canada occurs in two large areas west of the 100th meridian and separated from each other by a tract of older Cretaceous rocks. The eastern of these areas extends for some distance along the United States boundary between the 102d and 109th meridians and northward nearly to the parallel of 51°. Here, he said, the lowest beds of the "Laramie" rest on Fox Hills and are overlain by Miocene. He continued:

They are undoubtedly continuous with the Fort Union group of the United States geologists on the other side of the international boundary, and they contain similar fossil plants. They are divisible into two groups—a lower, mostly argillaceous, and to which the name of "Bad Lands beds," may be given from the "badlands" of Wood Mountain, where they are well exposed, and an upper, partly arenaceous member, which may be named the Souris River or Porcupine Creek division. In the lower division are found reptilian remains of Upper Cretaceous type, with some fish remains more nearly akin to those of the Eocene.

The western area is of still larger dimensions and extends along the eastern base of the Rocky Mountains from the United States boundary to about the 58th parallel of latitude and thence eastward to the 111th meridian. In this area three divisions of the beds are made:

(1) The Lower Laramie, or St. Mary River series, corresponding in its character and fossils to the Lower or Bad Lands division of the other area; (2) a middle division, the Willow Creek beds, not recognized in the other area; (3) the Upper Laramie or Porcupine Hills division, corresponding in fossils and to some extent in mineral character to the Souris River beds of the eastern area.

The paper enumerated 51 forms of plants, of which 10 were found in the "Lower Laramie" and the remainder in the "Upper Laramie," with about 8 in common. It is essentially a Fort Union flora.

Several years later Dawson[55] published another short paper dealing mainly with plants from Mackenzie River, which he showed are to be identified with the Fort Union.

In 1893 Whiteaves[56] delivered a presidential address before the Royal Society of Canada, on "The Cretaceous system of Canada," which was mainly an enumeration of the fossil forms that had been recorded from the several members of the Cretaceous. Although he did not specifically so state, it is evident that he included in the "Laramie" both the "Lower Laramie" and "Upper Laramie" of previous writers, and of course it was all regarded as Cretaceous.

In 1908 D. P. Penhallow[57] presented an elaborate "Report on Tertiary plants of British Columbia," which was based primarily on collections made by L. M. Lambe in 1906 but which was made to include all previous work by Dawson and others within this area. If Penhallow had taken occasion to revise the earlier work, this could have been made a very valuable contribution, but unfortunately he made no attempt at revision and the lists were compiled without change. The "Laramie" here was said to include only the "Upper Laramie" (Paskapoo of Tyrrell), which was made synonymous with Fort Union, lower Eocene, and "Lignite Tertiary." The conclusion of Sir William Dawson that the "Upper Laramie" is undoubtedly of Tertiary age was confirmed.

[52] Roy. Soc. Canada Trans., vol. 1, sec. 4, pp. 15–34, 1883.

[53] Idem, vol. 3, sec. 4, pp. 1–22, 1885.

[54] Idem, vol. 4, sec. 4, pp. 19–34, 1887.

[55] Dawson, William, On fossil plants from the Mackenzie and Bow rivers: Roy. Soc. Canada Trans., vol. 7, sec. 4, pp. 69–74, 1889.

[56] Whiteaves, J. F., Roy. Soc. Canada Trans., vol. 9, sec. 4, pp. 1–19, 1893.

[57] Canada Geol. Survey Mem. 1013, pp. 1–167, 1908.

For a decade or more after the publication of the papers above mentioned very little investigation appears to have been prosecuted in the areas covered by the so-called "Laramie," and the subject remained practically as left by the earlier writers. Then, in a valuable paper published in 1909, by D. B. Dowling,[58] on the "Coal fields of Manitoba, Saskatchewan, Alberta, and eastern British Columbia," the "Laramie" was said to embrace the Edmonton and Paskapoo with the significance attached by Tyrrell, from whom extensive quotations were taken.

Dowling's report was summarized in the report of the Director of the Canadian Geological Survey,[59] who gave a full-page table of correlations of the formations involved, in which the "Laramie" was assigned the interpretation adopted by Dowling.

In the following year Dowling[60] published a short bulletin on the Edmonton coal field, Alberta, which was devoted mainly to the wonderfully rich coal deposits of the Edmonton formation. The term "Laramie" was not mentioned in this bulletin, but the Edmonton was "classed with the undoubted Cretaceous beds below and represents the upper member of this series." The plants listed, if correctly identified, indicate a mixture of Cretaceous and Tertiary (Fort Union) types.

In 1913 Malcolm[61] published a paper on the "Oil and gas prospects of the Northwest Provinces of Canada," in which the Edmonton and Paskapoo were grouped under the "Laramie" with the following qualification:

> In placing under this heading the formations to be described, it is not the intention of the author to indicate in this way the precise age of the formations or to indicate the dividing line between the great geological systems. The grouping is for convenience in description and for the purpose of showing the stratigraphic relations of the formations.

There seems, however, to have been no general understanding or usage, and in the Summary Report of the Canada Survey for 1913, published in 1914, D. B. Dowling[62] had a short paper on the Sheep River gas and oil field of Alberta, in which the Paskapoo was put into the Tertiary and the Edmonton into the Cretaceous, but the term "Laramie" was not used.

In the same volume Bruce Rose[63] had a short paper on the Willowbunch coal area, Saskatchewan, in which he stated that the only rocks exposed in this area are to be referred to the Fort Union formation, which is essentially the same as the Paskapoo formation of Alberta and is practically continuous with the Fort Union of the United States.

Barnum Brown[64] published a paper in 1914, already mentioned in another connection, which presented the results of his studies for a number of years of the Edmonton formation of the Red Deer River region of Alberta. The splendid section exposed for a distance of 300 miles along this river cuts successively through the Paskapoo and Edmonton and well down into the Pierre. The classification adopted was "the latest determination of these formations by the Canadian Geological Survey" and grouped the Paskapoo and Edmonton under the "Laramie." According to Brown, the Edmonton wherever observed was found resting in apparent conformity on the Pierre. The relations between the Edmonton and the overlying Paskapoo were described by Brown as follows:

> Near the mountains these beds (Paskapoo), according to Tyrrell, appear to rest conformably on the Pierre shales. On the Red Deer River and elsewhere they are separated from the underlying brackish-water Edmonton beds by a widely distributed coal seam of varying thickness. No other sign of unconformity has been recognized, but a considerable time elapsed between the close of the Edmonton and the beginning of the Paskapoo—a time interval represented by all or the greater part of the Lance. No dinosaurs are found in these beds, and the abundant and varied dinosaurs of the underlying Edmonton formation are an older facies than those of the Lance.

The several lines of paleontologic evidence were discussed somewhat at length, especially the vertebrate evidence, in which Brown is a specialist. Concerning the dinosaur fauna he said:

> The vertebrate fauna is distinct from that of the Lance, and few species are common to the two formations. Most of the Edmonton genera are structurally more primitive than those of the Lance, and several genera not found in the Lance are common to the Judith River. The faunal facies, as a whole, is intermediate but closer to that of the Judith River formation than to the Lance. * * * The

[58] Canada Geol. Survey Pub. 1035, pp. 38-43, 1909.
[59] Canada Geol. Survey Summary Rept. for 1909, p. 38, 1910.
[60] Dowling, D. B., Canada Geol. Survey Mem. 8E (Pub. 1115), 1910.
[61] Malcolm, Wyatt, Canada Geol. Survey Mem. 29E, 1913.
[62] Canada Geol. Survey Summary Rept. for 1913, p. 142, 1914.
[63] Idem, p. 153.
[64] Cretaceous Eocene correlation in New Mexico, Wyoming, Montana Alberta: Geol. Soc. America Bull., vol. 25, pp. 355-380, 1914.

dinosaur fauna forms a series of successive genera, the phyletic relationship of which is determined by the evolutionary development of skeletal parts, and there is no break in this series from its first appearance low down in the Cretaceous to the final disappearance of the entire group in what we propose to call the close of the Cretaceous.

The invertebrates were submitted to T. W. Stanton, who commented as follows:

I have recently examined your invertebrates from the Edmonton and Paskapoo formations of Alberta. Those which you have already sent from the Edmonton beds include several lots of brackish-water shells, with a slighter mixture of marine forms (*Lunatia*), and several lots of purely fresh-water shells. The brackish-water collections are certainly Cretaceous and consist of species which all occur either in identical or very closely related forms in both the Judith River and in the brackish-water bed which occurs at the top of the Fox Hills and the base of the Lance.

The fresh-water collections contain no species characteristic of either the Judith River or the Lance, and while some of them, like *Goniobasis tenuicarinata*, occur in the Lance, the general aspect of the fossils is somewhat more suggestive of [Fort Union than of anything earlier. It should be remembered, however, that Whiteaves has reported a number of] Fort Union species as occurring in the Belly River beds of Alberta, and it may be that more of these types than we have supposed range down as low as the Judith River.[65]

The fossil plants were studied by Arthur Hollick and me and pronounced to be of Fort Union age, though a small collection from the lower part of the Edmonton submitted to me at a later date appeared to be of Cretaceous affinity.[66]

As regards the age of the Edmonton, Brown said:

The Edmonton formation differs greatly in lithologic character from the Fox Hills, which occupies the same relative position in the United States, where it is a sandstone formation, but I believe it to have been, in part at least, synchronous with the Fox Hills. It may possibly be correlated with the Laramie, according to its original definition.

In a later paragraph he added:

The strata (Edmonton) are of marine and brackish-water origin and everywhere conformably overlie the marine beds below. The shale series shows an interrupted successive sedimentation from purely marine conditions at the base, through brackish water during most of the period, with a gradual freshening toward the top. This formation fulfills the original definition of the term Laramie.[67]

[65] The words in brackets, which were omitted from Brown's paper through an error in transcription or in printing, were supplied by Mr. Stanton in a personal communication to me.

[66] Knowlton, F. H., Cretaceous-Tertiary boundary in the Rocky Mountain region: Geol. Soc. America Bull., vol. 25, p. 337, 1914.

[67] Brown was in error on this point, for, according to King's original definition, the Laramie is the "uppermost member of the conformable Cretaceous series above the Fox Hills."

According to Brown, the Paskapoo formation, as already mentioned, was conformable on the Edmonton, though he thought there was a time interval between them, as shown by the absence of all or nearly all of the Lance formation. The Paskapoo, although containing no dinosaurs, has a small mammal fauna, which, he said, "is more varied than that of the Lance and is comparable to it."

A late word on the correlation of the Edmonton with beds in the United States is spoken by Eugene Stebinger[68] in his paper on "The Montana group of northwestern Montana." The uppermost member of the Montana group recognized was here called the Horsethief sandstone, which is the equivalent of the Fox Hills as identified by G. M. Dawson in Alberta. Stebinger's conclusion was as follows:

Above the Horsethief sandstone in the section on Two Medicine River there are light-colored soft clayey and sandy strata, already referred to as of continental origin, that are identical in appearance with the Belly River and Judith River strata. Although these rocks are younger than Montana in age, they deserve mention here because they seem to complete for a third time a cycle of sedimentation proceeding from purely marine to fresh-water or continental conditions. The first of these cycles is from the marine Colorado shale, through Virgelle sandstone, to the strata of continental origin in the lower part of the Two Medicine formation; the second is from the marine shale of the Claggett, through the sandstone in its upper part, to strata, also of continental origin, comprising the Judith River formation; and the third is from the marine Bearpaw, through the Horsethief sandstone, to the continental deposits above that sandstone. The relations in each cycle between the continental deposits and the underlying sandstone seem to be identical. The strata are apparently perfectly conformable, and the impression is very strong that the same conditions ruled in each transition from marine to land conditions, or, in other words, the strata above the Horsethief sandstone are physically as closely related to the Bearpaw shale as the Judith River formation is to the Claggett or the Two Medicine formation to the Colorado shale. Now, these strata of continental origin above the Horsethief sandstone constitute the St. Mary River beds of Dawson, which occupy the same position in the geologic column as the Edmonton formation of central Alberta and approximately that of the Lance formation of Wyoming.

"LARAMIE" AND LIVINGSTON FORMATIONS IN MONTANA.

The area in the vicinity of Livingston, Mont., and extending thence southward to the northern border of the Yellowstone National Park and northward around the Crazy

[68] U. S. Geol. Survey Prof. Paper 90, p. 68, 1914.

Mountains has proved to be of much geologic interest. A number of short reports and newspaper and magazine articles regarding this area had appeared prior to 1871, but they were devoted mainly to descriptions of scenic features and contained little or no geologic information. In 1871 F. V. Hayden [69] began his investigations in the Yellowstone National Park and incidentally described the geology of the area between Fort Ellis and what is now the north line of the park. He noted the presence of both Cretaceous and Tertiary rocks in the area. In the same report [70] Lesquereux described the fossil plants obtained by the Hayden parties, referring those found 6 miles above Spring Canyon; on High Ridge, about 10 miles west of Hot Springs; and at Yellowstone Lake, among basaltic rocks, to the Eocene, while those from the mouth of Spring Canyon were not definitely placed.

In the following year the exploration of the Yellowstone National Park was continued by the Hayden Survey, and A. C. Peale [71] reported on the geology of the area between Fort Ellis and the Yellowstone Valley and thence up the Yellowstone to the park. He also noted the presence of Cretaceous and Eocene, the latter on the basis of the determinations of the fossil plants by Lesquereux.

In 1878 Lesquereux [72] published his "Tertiary flora," in which he brought together all the species of plants—329 in number—which he then considered as belonging to the flora of the "Lignitic." The beds at the localities near Fort Ellis, above Spring Canyon, and at Yellowstone Lake he referred to his so-called "first group," which he considered as of Eocene age. The species from the locality at the mouth of Spring Canyon were not alluded to, as they were, at least by inference, considered as Cretaceous.

In 1886 the final report of the Tenth Census of the United States relating to the mineral resources, exclusive of the precious metals, was published under the general direction of Raphael Pumpelly. It embraced reports by Waldemar Lindgren [73] and George H. Eldridge [74] on the geology and coal resources of Montana, and each contained data bearing more or less directly on the present problem. Lindgren reported especially upon the section from the Bull Mountains to Musselshell River and referred the immense thickness of nearly 10,000 feet of beds above the Fox Hills to the Laramie, which he divided into a "Lower Laramie" and an "Upper Laramie," the latter being recognized as the Fort Union.

The so-called Bozeman coal field was described by Eldridge. He presented a section of the rocks (LVI, fig. 2) through this field, beginning with the Jurassic and including the Dakota, Benton, and Niobrara and of course the coal-bearing rocks. The coal-bearing rocks were not definitely referred to the Laramie, though they were obviously considered as belonging in it. As regards the stratigraphic relations of the coal measures, Eldridge wrote as follows:

> There is another most important peculiarity in the behavior of the principal coal seams, noticed in the eastern portion of the field. The surface of the ground on which the coal bed was originally laid down is most irregular. For a length of 2 miles at least, and for an undetermined width, but presumably covering quite an area altogether, the surface was covered by gentle undulations in the form of knolls, of varying and irregular dimensions, oftentimes extensive, oftentimes a few feet only either way, with no definite arrangement of the axes. In the hollows of these, overlapping some and only coming up on the sides of others, the material subsequently to be converted into coal was laid down, and finally came the roof of sandstone, capping the whole. These irregularities have furthermore been increased by disturbances in certain parts, which have caused both rock and coal to be slickensided and rendered it extremely friable.

In the same year (1886) Lester F. Ward [75] briefly alluded to the plants from the Hayden locality known as "6 miles above Spring Canyon, near Fort Ellis, Mont.," and from several places in the Yellowstone Park. He said:

> These plants are all classed by Mr. Lesquereux in his first or lowest group as true Laramie, but upon careful investigation I am tolerably well satisfied that they belong to the Fort Union deposits.

In 1891 Walter H. Weed [76] published a short paper on "The Cinnabar and Bozeman coal fields of Montana," in which he described in

[69] U. S. Geol. Survey Terr. Fifth Ann. Rept., for 1871, pp. 1-165, 1872.
[70] Idem, pp. 296-300.
[71] U. S. Geol. Survey Terr. Sixth Ann. Rept., for 1872, pp. 108 et seq., 1873.
[72] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7, 1878.
[73] U. S. Tenth Census, vol. 15, pp. 743-746, 1886.
[74] Idem, pp. 739-743.
[75] Synopsis of the flora of the Laramie group: U. S. Geol. Survey Sixth Ann. Rept., p. 741, 1886.
[76] Geol. Soc. America Bull., vol. 2, pp. 349-364, 1891.

some detail the coal measures of these areas. His conclusions concerning their age were set forth as follows:

While the evidence presented in this paper is not considered conclusive, and while the work upon the district is not far enough advanced to warrant a final statement, yet it is believed that the facts show that the coal measures of the Cinnabar and Bozeman coal fields are probably of Laramie age, occurring at the very base of the Laramie series, and that they are conformably overlain by a totally different series of rocks, composed entirely of volcanic material and containing an abundant fossil flora of recognized Laramie types, in turn overlain by beds of fresh-water clays and sandstones of undetermined age but belonging to what has heretofore been considered as undoubtedly Laramie strata.

The Livingston formation was named by Weed[77] in 1893 from its typical development near the town of Livingston, Mont. For the decade or more preceding the publication of this paper the great thickness of rocks in this region above the supposed Montana Cretaceous had been very generally regarded as Laramie. Weed said:[78]

Measured sections of the strata about the Crazy Mountains show a thickness of 12,000 feet of fresh-water sandstones and clays referred to the Laramie. It is now possible to subdivide this great thickness of beds into Laramie, a higher horizon herein named the Livingston, and the still higher beds of the Crazy Mountains, which have not as yet been differentiated into horizons but probably represent the Fort Union beds of eastern Montana.

It was thought by Weed and later by others that "these beds present proof of a series of events following the epoch of the coal-making Laramie similar to those described by Whitman Cross, in Colorado, of which the Arapahoe and the Denver beds are the evidence."

Weed's description of the Mesozoic section began with the Jurassic, above which is what he, following previous workers in the field, called the Dakota, which, he said, "forms the most persistent and readily recognizable horizon of the Rocky Mountain Mesozoic." Above the beds identified as the Dakota are over 3,000 feet of shales, in many places carbonaceous, and interbedded sandstones, that he divided about equally between the Colorado and the Montana, though he stated that "a satisfactory discrimination between the beds of the Colorado and those forming this group (Montana) can not be made on paleontologic grounds, as few fossils have been collected in the beds assigned to the Montana." The Fox Hills was not definitely recognized, though Weed said: "In the eastern part of the field the dark-gray sandy shales [of the Montana] are directly overlain by a heavy ledge of yellow, rather dark, and very massive sandstone, which is thought to be the equivalent of the Fox Hills sandstone." Conformably above this is the Laramie as then recognized. It is about 1,000 feet in thickness and is composed of massive light-colored sandstones with intercalated shale beds and coal seams. "The upper limit of the Laramie in the region studied is marked by an abrupt change in the composition of the beds and closely resembles in general characteristics that change which has been found so prominently developed in Colorado."

The Livingston was described by Weed as follows:

Overlying the coal-bearing Laramie strata there is a series of beds constituting a newly recognized formation, for which the name Livingston is proposed, as it is typically developed in the vicinity of Livingston. This formation consists of a series of beds, in places aggregating 7,000 feet in thickness, composed of sandstones, grits, conglomerates, and clays, made up very largely of the débris of andesitic lavas and other volcanic rocks and including local intercalations of volcanic agglomerates.

The Livingston formation was believed by Weed to rest unconformably on the Laramie, and the basis for this belief was set forth at length in the paper under consideration. The upper part of the Livingston was said to pass without observed stratigraphic break into the overlying beds then presumed and since proved to belong to the Fort Union formation.

The fossil plants of the Bozeman coal field and adjacent areas were considered by me in Weed's report above cited,[79] in a more formal presentation of the facts published the preceding year.[80] The fossil flora, as then known, embraced 44 species, and the conclusion was reached that the plants from the coal-bearing beds belong "to what is generally known as the Laramie," while "the flora of the Livingston formation finds its nearest relationship with the flora of the Denver beds of Colorado."

[77] Weed, W. H., The Laramie and the overlying Livingston formation in Montana, with report on flora, by F. H. Knowlton: U. S. Geol. Survey Bull. 105, pp. 1-68, 1893.

[78] Idem, p. 11.

[79] Knowlton, F. H., Annotated list of the fossil plants of the Bozeman, Mont., coal field, with table of distribution and description of new species: U. S. Geol. Survey Bull. 105, pp. 43-66, pls. 5, 6, 1893.

[80] Knowlton, F. H., The fossil flora of the Bozeman coal field: Washington Biol. Soc., vol. 7, pp. 153, 154, 1892.

In 1894, in the Livingston folio, Weed[81] described and mapped the several formations under discussion with the signification and limits given to them in the bulletin above cited. In 1896 the Three Forks quadrangle, which adjoins the Livingston quadrangle on the west, was described in a folio by A. C. Peale.[82] He accepted the Dakota, Colorado, Montana, Laramie, and Livingston formations as defined by Weed and wrote of the Laramie as follows:

The formation consists essentially of light-gray or whitish sandstones, with interlaminated argillaceous beds, some of which are locally much indurated. The two areas in which the strata are best exposed are in the Nixon basin, north of the Gallatin Valley, and in the Gallatin basin, lying between the Gallatin and Madison ranges. The total thickness of the formation is from 800 to 1,000 feet. In the Nixon basin Unios and other fresh-water shells are found in connection with the coal.

Concerning the Livingston formation he said:

The Livingston formation occupies at the present time comparatively little area within the limits of the Three Forks sheet, and nowhere is it likely that the entire thickness of the formation is shown. The largest area is probably that in the vicinity of the Sphinx Mountain, where the Sphinx conglomerate rests unconformably upon it. This area is about 15 to 20 square miles in extent, and the deposits are made up of a mass of volcanic materials indistinctly bedded, mostly andesitic in nature, and of a somber hue. At one or two places conglomerates made up of all sorts of volcanic pebbles are seen near the base. This generally black mass rests unconformably upon the eroded surfaces of the previously deposited Cretaceous formations, contrasting strongly in color with the Laramie sandstones and the Dakota conglomerates, with both of which it is in contact at different points.

The unconformable relation near Sphinx Mountain described by Peale, which was known to Weed, was one of the factors upon which Weed based his contention of an unconformity between so-called Laramie and Livingston.

Weed[83] published in 1896 a short paper which was devoted mainly to the Fort Union, with only incidental mention of the Laramie and Livingston formations. The immense section of strata forming the eastern foot slopes of the Crazy Mountains on Lebo Creek, Mont., was divided as follows: Laramie, 1,080 feet; Livingston, 7,136 feet; Fort Union, 4,649 feet.

[81] Weed, W. H., U. S. Geol. Survey Geol. Atlas, Livingston folio (No. 1), 1894.
[82] U. S. Geol. Survey Geol. Atlas, Three Forks folio (No. 27), 1896.
[83] Weed, W. H., Am. Geologist, vol. 18, pp. 201-211, 1896.

The Little Belt Mountains quadrangle, immediately north of the Livingston quadrangle, was described by Weed[84] in 1899. The Dakota, Colorado, and Montana were grouped together in the Yellowstone formation, which was said to be followed conformably by the Laramie formation. The Laramie was described in much the same terms and assigned the same thickness as in the Livingston and Three Forks folios. The Livingston, believed to rest unconformably on the Laramie, was described at considerable length and was given a maximum thickness of 7,000 feet. In the text of the folio the Livingston was placed under the heading "Rocks of the Cretaceous period," and in the generalized section of the sedimentary rocks of the Crazy Mountains it was given as "Cretaceous?" Although included with the Livingston formation in mapping, the upper 4,000 feet of beds were in the columnar sections differentiated as the Fort Union.

The next paper in chronologic order is one by Earl Douglass,[85] published in 1902, entitled "A Cretaceous and lower Tertiary section in south-central Montana," in which the interpretation was radically different from that given by Weed. The area covered by this paper lies east of the Crazy Mountains and south of the Big Snowy Mountains, in the basin of Musselshell River. The section, according to Douglass, comprises the following units:

Tertiary	Fort Union.
Cretaceous	Laramie. Fox Hills. Pierre. Fish Creek beds. Niobrara. Benton.

The Livingston formation was not recognized in this section, although the locality is only a few miles from the Lebo Creek section recorded by Weed, in which it was given a thickness of over 7,000 feet. Douglass apparently included the Livingston in whole or in major part within the so-called Laramie, concerning which he wrote as follows:

What is supposed to be Laramie in the present section is very thick, probably approximately that of Lindgren's measurements [7,000 feet]. But here, as everywhere else, the boundaries of the Laramie are uncertain. Here,

[84] Weed, W. H., U. S. Geol. Survey Geol. Atlas, Little Belt Mountains folio (No. 56), 1899.
[85] Am. Philos. Soc. Proc., vol. 41, pp. 207-224, 1902.

however, we have it confined between certain limits. We have it above a characteristic Fort Pierre fauna and below a characteristic Fort Union flora. Just how much of that which intervenes is Laramie is not known.

On another page he added:

We found here no traces of the volcanic material of the Livingston formation, which only 30 or 40 miles to the southwest is so well developed.

Part of the same area was examined in 1903 by Stanton and Hatcher,[86] whose report was published in 1905. They were, however, more concerned in the elucidation of the Montana group, the classification of which, as will be subsequently shown, has played an important part in the Laramie-Livingston controversy, and they made only incidental mention of the higher beds. Concerning these they said:

South and west of Fish Creek these shales [Bearpaw] are overlain by marine Cretaceous sandstones and by a thick series of beds that have been referred to the Laramie, Livingston, and Fort Union formations.

The generalized section for central and northern Montana as worked out by Stanton and Hatcher is as follows:

	Laramie (?).
Montana group.	Fox Hills (?).
	Bearpaw. Judith River. Claggett. Eagle.
Colorado group.	Benton.
	Dakota (?).

In 1906 R. W. Stone[87] studied the stratigraphy and coal resources of an area of approximately 1,000 square miles in central Montana, extending from Shawmut westward to the head of Musselshell River and southward in the Shields River valley to the town of Clyde Park. A large part of this belt is included in the area covered by the Little Belt Mountains folio, already mentioned, but whereas Weed recognized only four formational units in the Cretaceous system, Stone was able to differentiate and map seven such units. These were set forth by Stone as follows:

Tertiary	Fort Union formation. Livingston formation.
Cretaceous	Laramie formation. Montana group: Bearpaw shale. Judith River formation. Claggett formation. Eagle sandstone. Colorado shale. Kootenai formation.

The rocks referred to the Laramie were divided roughly into two parts. The lower division, resting on the Bearpaw shale and ranging in thickness from 200 to 460 feet, was said to be composed of red and greenish sandstones. "Its age has not been determined, but lithologically it belongs to the overlying formation and hence it will be provisionally regarded as a part of the Laramie." Concerning the upper portion, Stone said:

Taken as a whole, the upper part of the Laramie formation is distinguished from the formations above and below by its light-gray color in comparison with their somber hues. It is composed largely of soft gray sandstone and variegated shale. The gray beds, from 1,000 to 2,400 feet thick, make a conspicuous valley. * * * The gray beds of the Laramie formation are overlain, possibly with unconformity, by somber-colored sandstone and shale which may represent the Livingston formation. Sufficient paleontologic evidence has not been obtained, however, to determine the limits of these stratigraphic units. A section measured by C. A. Fisher and T. W. Stanton on a fork of Big Elk Creek gives a thickness of 5,592 feet from the base of the Laramie to the base of the sandstone and grit probably of Fort Union age, and of 10,324 feet for the beds above the Bearpaw shale.

Douglass[88] revisited the Fish Creek area in 1909 and published additional notes on the geology, revising his previous views to some extent. He accepted the classification of the Upper Cretaceous by Stanton and Hatcher but was still more or less confused concerning the Fox Hills and the limits and extent of the so-called Laramie.

In 1909 also I published a note[89] on the geologic section of the Fish Creek area, giving it the following interpretation:

Above the Bearpaw is a series of shaly sandstones, at least several hundred feet in thickness, that unmistakably

[86] Stanton, T. W., and Hatcher, J. B., Geology and paleontology of the Judith River beds: U. S. Geol. Survey Bull. 257, p. 59, 1905.

[87] Coal near the Crazy Mountains, Mont.: U. S. Geol. Survey Bull. 341, pp. 78–91, 1909.

[88] Douglass, Earl, A geological reconnaissance in North Dakota, Montana, and Idaho, with notes on Mesozoic and Cenozoic geology: Carnegie Mus. Annals, vol. 5, pp. 272–280, 1909.

[89] Knowlton, F. H., The stratigraphic relations and paleontology of the "Hell Creek beds," "*Ceratops* beds," and equivalents and their reference to the Fort Union formation: Washington Acad. Sci. Proc., vol. 11, pp. 192–194, 1909.

belong to the Livingston, as plants identical with those found near the base of this formation southeast of Bozeman, Mont., have now been located, and moreover the matrix is characteristically that of the Livingston. Between this point and the base of the upper member of the Fort Union formation, according to Stanton, is a thickness of 3,000 to 5,000 feet of beds, a portion of the lower part of which belongs with little doubt to the Livingston, but the top of the Livingston has not been definitely placed, though its maximum thickness apparently exceeds 2,000 feet. The dinosaurs occur in this thick series of beds above the Livingston, and the beds are probably referable to the lower member of the Fort Union, though no plants have been found until within approximately 1,000 feet of the top.

Later in the same year (1909) T. W. Stanton [90] published still another interpretation of the Fish Creek section. After discussing briefly the units of the Montana group and their thicknesses as worked out by Stone, he continued:

Another important fact brought out by Stone's work is that the "Laramie" of Weed's mapping east and north of the Crazy Mountains in the Little Belt Mountains folio is really Eagle sandstone, and the "Livingston" of the same area includes in its lower part the Claggett, Judith River, and Bearpaw formations. The Livingston formation was described as resting unconformably on the Laramie and older rocks and as composed largely of andesitic material, both of which features played a prominent part in correlating the Livingston with the Denver formation. It became necessary, therefore, to study the lithologic character of the various formations of the Montana group in this area. * * * The specimens from the Eagle and a few of those from the Claggett and Judith River proved to be sandstone without admixture of igneous material, but many others from both Claggett and Judith River and some from the Bearpaw are identified as tuffaceous rock and contain much andesite.

After discussing a number of collections of invertebrates from beds originally supposed to be Laramie but here shown to be from the Claggett, Stanton said:

With the facts above recited in mind, the whole question of the age and relations of the Livingston formation is reopened. * * * Whatever may be true of the Livingston in the type area near the town of that name, the rocks assigned to it by Weed east of the Crazy Mountains, notably in the Lebo Creek section, certainly belong to several distinct formations ranging in age from well down in the Cretaceous to the lower Eocene.

The thick series of beds referred provisionally to the Laramie by Stone and including in part at least the Fox Hills? and Laramie of Douglass were next considered. The paleontologic evidence included dinosaurs (*Triceratops* and others), fresh-water invertebrates, which "indicate close relationship with the fauna of the *Ceratops* beds of Hell Creek and Converse County," mammals, and plants.

From what has preceded it is of course evident that the previously accepted status of the Laramie and Livingston formations in the region under discussion had been brought seriously in question. The newer data bearing on the problems involved were presented in an important paper by Stone and Calvert [91] under the title "Stratigraphic relations of the Livingston formation of Montana," in which the following was given as the thesis:

It is the purpose of this paper to show (1) that the coal-bearing formation of the Livingston section is not Laramie but is Eagle or at least lower Montana in age; (2) that the andesitic beds above, known as the Livingston formation, are not separated from the underlying formation by an unconformity anywhere within the area discussed; and (3) that their peculiar lithologic character is not a criterion of specific age but is a shore phase of many formations ranging from Colorado to Fort Union, inclusive.

Some of the main points advanced in this paper may be briefly enumerated. First, in regard to the Laramie as identified by Weed, Peale, and others, Calvert, in studying the area between Red Lodge and Livingston, observed an especially well exposed Mesozoic section on Boulder River in T. 2 S., R. 13 E., where he found invertebrates that were pronounced by Stanton to be of Colorado age at a horizon 300 feet below the lowest coal. Several similar collections were obtained on Trail Creek, near Electric, and elsewhere, from a horizon "very near the top of beds previously considered Montana," all being considered as Colorado. As this determination does not leave room for the thick Montana section between the Colorado and the "Laramie" coal measures, and moreover, as no time interval has been noted between them, the conclusion follows, according to Calvert, that the coal measures must be well down in the Montana. "At Livingston the section shows about 800 feet of coal measures, underlain by about 3,700 feet of Colorado shale, as measured below Yellowstone Canyon." This thickness of 3,700 feet accounts for the thickness assigned by Weed to both Colorado and Montana.

[90] The age and stratigraphic relations of the "*Ceratops* beds" of Wyoming and Montana: Washington Acad. Sci. Proc., vol. 11, pp. 255-265, 1909.

[91] Stone, R. W., and Calvert, W. R., Econ. Geology, vol. 6, pp. 551-557, 652-669, 741-764, 1910.

On the east side of the Crazy Mountains Stone, starting with the Upper Cretaceous section as established on Fish Creek by Stanton and Hatcher, held that he was able to trace the heavy whitish Eagle sandstone around the north end of the mountains and thence along the eastern base of the Bridger Range to a point above Clyde Park, which was subsequently connected by Calvert, except for a number of covered areas believed by him to be unimportant, with the coal measures near Livingston. The other units of the Montana group (Claggett, Judith River, and Bearpaw) were differentiated with more or less certainty to the vicinity of Lennep, just east of the Crazy Mountains, but they disappear at the north end of the mountains and southward along the Bridger Range, the southernmost point at which either has been identified being about 10 miles north of Myersburg, or 40 miles north of Livingston, where the upper part of the Bearpaw was seen. It was argued by Stone and Calvert that south of Myersburg the Montana section interdigitates with and loses its identity in the thick Livingston beds near the type locality. Their conclusion was as follows:

A great thickness of sedimentary deposits occurring at Livingston, Mont., composed largely of tuffaceous material, has been called the Livingston formation. It is described as lying unconformably on coal-bearing sandstone of Laramie age.

The evidence, both from stratigraphy and invertebrate paleontology, submitted in these pages shows that the coal-bearing sandstone is Eagle or at least lower Montana in age. It is admitted by paleobotanists that the flora of the upper part of the coal-bearing beds is similar to the Livingston flora, the greater part of which comes from within 600 feet above the coal-bearing sandstone. The coal-bearing beds are transitional into the tuffaceous beds above. Therefore, the evidence of both stratigraphy and paleobotany indicates that the Livingston beds are conformable on the underlying coal-bearing beds.

The Livingston formation was originally described as a lithologic unit of tuffaceous material derived from volcanic activity, the material of which the beds are composed and not the fossils determining the extent of the formation. Beds of this character are most abundant in the Livingston region, but they have been traced north and east around the Crazy Mountains, where beds of similar lithology are found in all the formations from Colorado to Fort Union and where they feather out into and merge with fresh and brackish water and marine deposits.

Stratigraphic relations, marine invertebrates, and fossil plants prove the Montana age of the lower part of the tuffaceous beds on the west side of the Crazy Mountains originally mapped by Weed as Livingston. Northeast of the mountains some of the tuffaceous beds are younger than Bearpaw and older than Lance, while the youngest of the andesitic deposits are Fort Union. From this evidence it is concluded that the lithologic unit of tuffaceous deposits originally described as the Livingston formation has no definite age and no formational value except in the immediate vicinity of the type locality.

I dissent from the above conclusions and still hold that the Livingston, at least in the type area, is of post-Montana age.

In 1912 Calvert [92] published two short reports on the southern portion of the area including the Livingston, Trail Creek, and Electric coal fields. His conclusions are sufficiently set forth in the following generalized section:

[92] Calvert, W. R., The Livingston and Trail Creek coal fields, Park, Gallatin, and Sweetgrass counties, Mont.: U. S. Geol. Survey Bull. 471, pp. 384-405, 1912; The Electric coal field, Park County, Mont.: Idem, pp. 406-422.

Geologic formations in the Livingston district.

Previous interpretation.		Present interpretation.		
		Eocene.		
Post-Laramie.	Livingston, 7,000 feet.	Upper Cretaceous.	Montana.	Livingston formation, 5,000+ feet.
....	Unconformity			Conformable ....
	Laramie, 1,000± feet.			Undifferentiated Montana, 750+ feet.
Upper Cretaceous.	Montana, 1,800 feet.			Colorado shale, 3,700 feet.
	Colorado, 1,800 feet.			
	Dakota, 500 feet.	Lower Cretaceous.		Kootenai formation, 500 feet.

UINTA AND GREEN RIVER BASINS.

The Uinta and Green River basins are broad structural basins or depressions of rock strata in northwestern Colorado, southern Wyoming, and the adjacent part of Utah. The Uinta Basin, which lies south of the Uinta Mountains, extends on the east to the foothills of the Rocky Mountains and on the west to the Wasatch Mountains in Utah and is terminated on the south by the La Sal Mountains and the San Rafael Swell. It is separated from the Green River Basin by the anticlinal axis of the Uinta Mountains, which reaches eastward through Axial Basin, Colo., to the White River Plateau and the western spurs of the Rocky Mountains.

The Green River Basin was defined by Emmons [93] as follows:

> The Green River Basin proper is a rudely triangular area embraced between the systems of elevation of the Rocky Mountains on the east and the Wasatch Range on the west and extending from the sources of the Green River, in the Wind River Mountains, on the north, to the base of the Uinta Range, on the south. * * * From the western flanks of the Park Range to the outlying ridges of the Wasatch, a distance of about 150 miles, [it] extends a practically desert region.

The area as thus defined may be considered as the broader conception of the Green River Basin. It is capable of division into a number of more or less well-defined subordinate basins, such as the Red Desert Basin, the Great Divide Basin, and the Green River Basin proper.

H. S. Gale [94] in writing of these basins said:

> These two basins outline the dominant geologic structure of nearly the whole of northwestern Colorado. They are in the form of broad synclinal folds or troughs, narrowing to an apex toward the southeast. Within this State their longer axes are approximately parallel, extending from southeast to northwest. The coal-bearing rocks outcrop in practically continuous rims around the borders of the basins where they have not been buried by later formations, and the strata dip toward the interior of the basins.

These basins have been the scene of prolonged geologic research, especially in view of the bearing they have or have been supposed to have on the problems under consideration. The several fields will be taken up in sequence, so far as possible.

[93] Emmons, S. F., U. S. Geol. Expl. 40th Par. Rept., vol. 2, p. 191, 1877.
[94] U. S. Geol. Survey Bull. 316, p. 270, 1907.

UINTA BASIN.

BOOK CLIFFS FIELD, UTAH AND COLORADO.

The Book Cliffs coal field forms a part of the southern rim of the Uinta Basin and extends from the vicinity of Mount Hilgard, in central Utah, northward to Castlegate and thence southward to Colorado (formerly Grand) River, in Colorado, beyond which it forms the southern face of Grand Mesa. The geology of the Book Cliffs was first studied by A. C. Peale,[95] of the Hayden Survey, who in 1876 examined the eastern part of the field. In his report the rocks now referred to the Mesaverde were separated into "Fox Hills" and "Laramie," though it was recognized that there is no lithologic break between the two, and this nomenclature was an attempt to conform to the subdivisions used in other fields.

The western part of the field was embraced in a map of the Uinta Basin by George H. Eldridge [96] published in 1901 in his report on asphalt and bituminous-rock deposits. On this map, which is of small scale, the Book Cliffs are simply denominated Cretaceous, but in the description of the formations in the Uinta Basin [97] the uppermost member of the Cretaceous, which contains the workable coals of the region, is referred to the Laramie.

The above-mentioned reports have, until recently, been practically the only source of information concerning the geology of this region, though several short papers dealing with the coal deposits were published by Hills, Storrs, Lakes, and others.

In 1905 Joseph A. Taff [98] made a careful study of the western part of the Book Cliffs field from the vicinity of Sunnyside to Castlegate, Utah, and its southern continuation along the escarpment of the Wasatch Plateau. In his report comparatively small space was devoted to the geology, which he summed up as follows:

> The rocks are naturally arranged in thick groups of strata. In each group either sandstone or shale greatly

[95] Geological report on the Grand River district: U. S. Geol. and Geog. Survey Terr. Tenth Ann. Rept., for 1876, pp. 170-185, 1878.
[96] The asphalt and bituminous-rock deposits of the United States: U. S. Geol. Survey Twenty second Ann. Rept., pt. 1, p. 332, 1901.
[97] Idem, p. 334.
[98] Book Cliffs coal field, Utah, west of Green River: U. S. Geol. Survey Bull. 285, p. 289, 1906.

predominates. They contain scant fossil remains, and sufficient information regarding their age has not been obtained to correlate them with similar well-known beds in other parts of the country. The entire section is without doubt Cretaceous, and the principal coal-bearing strata are within the Laramie formation.

The following year (1906) the eastern part of the Book Cliffs field was studied by G. B. Richardson, and a preliminary report was issued in 1907.[99] In this report was recorded a complete change of front regarding the age of the coal-bearing rocks. Richardson said:

Fossils have been found at several horizons between 200 feet from the base and 250 feet from the top of the formation. They consist of land plants and fresh- and brackish-water invertebrates. The evidence of the fossils and the general stratigraphic and areal relations of the beds together indicate that the coal-bearing formation should be referred to the Mesaverde rather than to the Laramie. The transition from the Mancos to the Mesaverde is marked lithologically by the increasing prevalence of sand and paleontologically by the change from marine to brackish- and fresh-water conditions. On lithologic grounds all the coal beds would be classed with the sandstone-shale formation, the greater part of which at least is considered to be Mesaverde.

Two years later (1909) Richardson's full report on this field[1] was published, and in this report the reasons for referring the coal-bearing rocks to the Mesaverde were more fully set forth:

There has been much misapprehension concerning the age of the coal-bearing rocks of the Uinta Basin. In the Book Cliffs field, as already stated, Peale mapped the rocks here referred to the Mesaverde as two formations and correlated them respectively with the "Fox Hills" and the "Laramie." Later writers have considered the entire formation to be Laramie, because it overlies marine Cretaceous beds and in turn is overlain by Wasatch strata, and the fauna and flora were believed to belong to the Laramie.

The reason for assigning the coal-bearing formation of the Book Cliffs to the Mesaverde is explained in the following extract from a letter of T. W. Stanton to the writer:

"In northwestern Colorado, southern Wyoming, and elsewhere many of the coal-bearing rocks previously called Laramie are really older and are overlain by marine Cretaceous formations, thus corresponding with the Mesaverde formation first described in southwestern Colorado. * * * The invertebrate fossils that have been collected from the coal-bearing rocks of the Book Cliffs all occur in the Mesaverde of northwestern Colorado, and Dr. Knowlton finds that this is essentially true of the plants also. It is admitted that most of the fossils in question from the Book Cliffs would not seem out of place in the Laramie, yet their close agreement with those known to occur in the Mesaverde of a neighboring area and the general stratigraphic and areal relations of the rocks in which they are found make this reference to the Mesaverde most reasonable. The unconformable relations that doubtless exist between these rocks and the overlying Wasatch will explain the absence of the later Cretaceous rocks from the area."

[99] Richardson, G. B., The Book Cliffs coal field, between Grand River, Colo., and Sunnyside, Utah: U. S. Geol. Survey Bull. 316, pp. 302–320, 1907.

[1] Richardson, G. B., Reconnaissance of the Book Cliffs coal field between Grand River, Colo., and Sunnyside, Utah: U. S. Geol. Survey Bull. 371, 1909.

GRAND MESA AND WEST ELK MOUNTAINS, COLORADO.

The Grand Mesa and West Elk Mountains include a very considerable area on the southern rim of the Uinta Basin, lying partly in west-central Colorado and partly in eastern Utah. The Grand Mesa field extends westward into the Book Cliffs field and eastward into the Anthracite-Crested Butte region and thence westward along the Grand Hogback, which in turn connects in part with the field in Carbon County, Wyo.

The eastern portion of this field was studied in 1874 by A. C. Peale,[2] of the Hayden Survey, before the Laramie had been established. Peale gave many sections of the rocks, especially along Grand and Gunnison rivers, and stated that in some places he had difficulty in distinguishing between Cretaceous Nos. 4 and 5, or between Pierre and Fox Hills. He said:

The upper portion of these beds may possibly have to be referred to the Lignitic group, but for the present I refer them to the Upper Cretaceous.

On the publication of the Geological Atlas of the Hayden Survey, in 1881, the coal-bearing rocks of this region were referred to the Laramie, which had then become very generally accepted, and this reference was followed in the main by geologists who had occasion to discuss the area. Thus in 1894 George H. Eldridge, in the Anthracite-Crested Butte folio,[3] gave a section which, at least from the base of the Fox Hills, corresponds in part with that of the Hayden Survey Atlas. The coal-bearing beds were referred to as the "Laramie coal measures" and were said to have a maximum thickness of 2,000 feet; they were described as being overlain unconformably by the Tertiary Ohio formation.

In 1907 W. T. Lee[4] investigated the Grand Mesa coal field and obtained information which

[2] U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1874, pp. 73–179, 1876.

[3] U. S. Geol. Survey Geol. Atlas, Folio 9, 1894.

[4] Lee, W. T., The Grand Mesa coal field, Colo.: U. S. Geol. Survey Bull. 341, p. 306, 1909.

made it necessary to modify greatly the determination of the age relations of the principal coal-bearing portion of the section, until then accepted as Laramie. It was referred to the Mesaverde formation and was described by Lee as follows:

The lower part of it [Mesaverde] was called "Fox Hills" and the upper part "Laramie" by the geologists of the Hayden Survey, and other geologists have followed them in referring the coal to the Laramie. However, a study of the fossils, in connection with the stratigraphy of western Colorado, proves that it is much older than the Laramie, and the entire series of coal bearing rocks in this field is now referred to the Mesaverde formation, originally named by Holmes in southwestern Colorado. Where the full section is exposed the Mesaverde is separated from the Laramie by a marine formation known as the Lewis shale, but in the Grand Mesa field there is no representative of the Lewis or Laramie beds. The sedimentary rocks of Tertiary age rest unconformably upon the Mesaverde.

Lee[5] continued and extended the work in this field in 1909. On further and more critical study it was found possible to separate the Mesaverde into several members, as follows: The Rollins sandstone member, at the base, is a white cliff-making sandstone containing fucoids and marine invertebrates. Above this is the Bowie shale member, with a maximum thickness of about 425 feet, composed of dark-colored shale and gray sandstone. It contains marine and brackish-water invertebrates and important coal deposits; it is not present in all parts of the field. Unconformably above this is the Paonia shale member, 400 feet thick, made up of sandstone and shale, in places carbonaceous, with plant remains, mainly fresh-water invertebrates and coal deposits. Above the Paonia is what is called the undifferentiated part of the Mesaverde, a series of gray quartzose sandstones and shales some 2,000 feet thick, containing plants and fresh-water invertebrates.

The Paonia shale member and the overlying undifferentiated Mesaverde constitute the beds which had previously been called Laramie and which, according to Lee, "may prove to be Laramie or younger." The age significance of the invertebrates from these beds was interpreted by Stanton as follows:

Although this nonmarine fauna contains many Laramie elements, on the whole it agrees better with the fauna of the Mesaverde as we are now beginning to know it, and the stratigraphic and structural evidence of the entire region, including the Durango, Grand Hogback, and Yampa fields, is strongly in favor of referring all the upper coal-bearing beds of the Grand Mesa field to the Mesaverde.

The plants were critically reviewed by me as follows:

In conclusion I feel justified in stating that in my opinion the beds containing the plants here under discussion are of post-Montana age. The facts upon which this conclusion is based are (1) the apparently satisfactory demonstration of an unconformity between the upper and lower coal-bearing rocks, (2) the fact that the marine invertebrates are confined to the beds below the unconformity, (3) the fact that the plants are confined to the beds above the unconformity, (4) the marked difference in the quality of the coals in the lower and upper beds—that is, below and above the unconformity, (5) the marked resemblance between the plants of the Grand Mesa field and those of Black Buttes, Wyo., which is only a short distance north, and (6) when the first report was given, comparisons of the plants were made with areas then tentatively regarded as Montana but which subsequent investigation has shown beyond much question to be of post-Montana age.

From the above exposition it appears that the upper coal-bearing beds in the Grand Mesa region that were formerly regarded as of Laramie age are now tentatively classed as Mesaverde, with the possibility that subsequent study may prove that they are Laramie or younger. In any event, their reference to the Laramie is not now accepted.

GLENWOOD SPRINGS AREA, COLORADO.

The Glenwood Springs area is directly north of the Grand Mesa area and is in stratigraphic connection with it. It has been studied by A. L. Beekly, of the United States Geological Survey, but the report is not yet published. A brief description of this field was given by Gale,[6] who showed that it also merges with the Grand Hogback field and has the same structural relations. The section of coal-bearing rocks is essentially the same as that of Grand Mesa and like it was referred to the Mesaverde, and both Lewis and Laramie were believed to be absent. In considering the paleobotanic evidence for the possible "Laramie or later" age of the beds in the Grand Mesa area above the Paonia shale, I wrote as follows[7] concerning similar evidence in the Glenwood Springs field:

If the discussions and comparisons made above had included the adjacent Glenwood Springs area, with which

[5] Lee, W. T., Coal fields of Grand Mesa and the West Elk Mountains, Colo.: U. S. Geol. Survey Bull. 510, 1912.

[6] Gale, H. S., Coal fields of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 415, pp. 128-136, 1910.

[7] Knowlton, F. H., in Lee, W. T., Coal fields of Grand Mesa and the West Elk Mountains, Colo.: U. S. Geol. Survey Bull. 510, p. 47, 1912.

there is stratigraphic connection, the post-Montana facies would be even more apparent. In the latter area are found such distinctively post-Montana forms as *Zizyphus fibrillosus*, *Cinnamomum affine*, *Populus meekii?*, *Populus monodon*, *Viburnum contortum*, etc., which have not been noted in the Grand Mesa field. This but emphasizes the fact that the collections of plants are too meager and obviously incomplete to enable us to reach thoroughly conclusive results, though when fuller collections are obtained, as in the Glenwood Springs area, the resemblance to higher beds is accentuated.

GRAND HOGBACK AND DANFORTH HILLS AREA, COLORADO.

The important coal area of the Grand Hogback and Danforth Hills lies along the eastern rim of the Uinta Basin and is in direct stratigraphic connection with the Glenwood Springs area, on the southeast, while to the west it passes with some interruptions into the less important coal field of Uinta County, Utah. This general region was visited in 1872 by S. F. Emmons,[8] of the Fortieth Parallel Survey, and in 1876 and 1877 by C. A. White,[9] of the Hayden Survey. White referred the coal-bearing rocks of this region to the Fox Hills and Laramie. The Fox Hills, in accordance with what he called the "modified classification of the Cretaceous strata adopted in this report," included both the Pierre and Fox Hills of the Missouri River section and was regarded as of Cretaceous age, while the Laramie was classed as post-Cretaceous and was supposed to be transitional between Cretaceous and Tertiary.

A number of other reports on the coal resources of the region by Chisholm, Hills, Storrs, Hewett, and others do not need special mention in this connection.

This field was studied by H. S. Gale[10] in 1906, and the final results in this and other related areas in northwestern Colorado and northeastern Utah were published in 1910.[11] The section as worked out by Gale is essentially the same as that in the Book Cliffs, Grand Mesa, and Glenwood Springs fields—that is, the Mesaverde formation was regarded as the uppermost or youngest formation of the Upper Cretaceous section in this part of the basin. The divisions established by Lee in the Grand Mesa region were not recognized by Gale, though he divided the Mesaverde into lower and upper members, the line of separation being in many parts of the field a conspicuous white sandstone. The character of the two members was described as follows:

> Fossil invertebrates have been found in almost all parts of the Mesaverde formation. They indicate that the lower part is largely of marine origin, up to and probably including the "white rock." Above the "white rock" fresh and brackish water invertebrates and plants indicate a change of character in the body of water in which the succeeding beds were formed. The fresh or brackish water conditions, however, were not permanent and gave way to true marine conditions again near the top of the formation.

The absence of the Lewis shale and the "Laramie," both of which are present in the adjacent Yampa field, may of course be explained in either of two ways—that is, they may never have been deposited in this basin, or, if deposited, they may have been removed by erosion. The fossil plants, so far as they have been discussed in published reports, appear to be of Mesaverde types, but there is some evidence not yet published that suggests the possibility that the Laramie also may be represented here. Be this as it may, however, the Laramie is not now recognized as present in the Grand Hogback and Danforth Hills fields, or, indeed, in the Uinta Basin.

The conditions just described may be traced westward from the Danforth Hills, except that the unconformity separating the Mesaverde from the overlying Tertiary appears to cut deeper and deeper. Thus at Vernal, Utah, the Mesaverde is only about 1,500 feet thick, and the upper coal-bearing portion is thought to be absent, and in the Deep Creek district in Uinta County, Utah, the whole of the Mesaverde has apparently been removed. Reports on several of these fields have been made by Gale,[12] Lupton,[13] and others, but as the Laramie is not involved, they may be passed over.

GREEN RIVER BASIN.

YAMPA COAL FIELD, COLORADO.

The Yampa field, which occupies a considerable area in Routt County, Colo., lies along

[8] U. S. Geol. Expl. 40th Par. Rept., vol. 2, pp. 167–189, 1877.

[9] U. S. Geol. and Geog. Survey Terr. Tenth Ann. Rept., for 1876, pp. 5–60, 1878.

[10] Coal fields of the Danforth Hills and Grand Hogback, in northwestern Colorado: U. S. Geol. Survey Bull. 316, 1906, p. 264, 1907.

[11] Coal fields of northwestern Colorado and northeastern Utah: U. S. Survey Bull. 415, 1910.

[12] Gale, H. S., Coal fields of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 415, pp. 179–219, 1910; Geology of the Rangely oil district, Rio Blanco County, Colo.: U. S. Geol. Survey Bull. 350, 1908.

[13] Lupton, C. T., The Deep Creek district of the Vernal coal field, Uinta County, Utah: U. S. Geol. Survey Bull. 471, p. 579, 1912; The Blacktail (Tabby) Mountain coal field, Wasatch County, Utah: Idem, p. 595.

the southern border of the Green River Basin and is separated from the Uinta Basin by an anticlinal axis that extends from the Uinta Mountains eastward to the Rocky Mountains. At one point in Axial Basin only about 4 miles intervenes between the Yampa and Danforth Hills fields, yet the sections of coal-bearing rocks in the two areas, as published, are considerably different.

The Yampa field was studied by members of both the King and Hayden surveys, and the coal-bearing rocks were in large part referred to the Laramie, a reference that became more and more firmly fixed as time went on; in fact, the whole coal-bearing section was accepted as of this age until about 1905. In that year this field was investigated by Fenneman and Gale,[14] who were able to divide the Cretaceous portion of the coal-bearing rocks into three formations—the Mesaverde, which was believed to correspond in whole or in part to the beds so named in southwestern Colorado; the Lewis shale, a marine formation of soft shales and sandstones overlying the Mesaverde; and the Laramie. This field, together with the others to the south, was more fully considered by Gale[15] in 1910.

The "Laramie" in the Yampa field was described as being about 1,200 feet thick and composed of relatively soft sandstones and shales. It was said to be limited at the top by an unconformity that separates it from overlying Tertiary beds, also coal-bearing, which are probably to be regarded as Fort Union or its equivalent. The base of the "Laramie"—that is, the line separating it from the Lewis—was apparently established with difficulty; in fact, it appears to have been drawn arbitrarily in this field. On this point Gale said:

> As mapped, the formation is intended to represent a group that is distinguished from those adjacent by a difference of rock composition and that may be recognized by this distinction in the field. In the case of the Laramie the feature that distinguishes it from the underlying Lewis shale is the presence of sandstone beds that form prominent ridges or ledges in the topography. Unfortunately the horizon of its lowest sandstone does not appear to be constant in different parts of the field, so that if it were possible to fix on a single definite plane as marking the basal member of that formation and trace it throughout the field, it would not everywhere lie in the same relation to the lowest of the principal group of sandstones overlying. Furthermore, though the formation as a whole is considered to mark the transition from marine to brackish and fresh water deposits, the fossils found in the lowest part of the sandstones included in the Laramie, including those in the massive sandstone beds, are distinctly marine and include a fauna apparently not distinguishable from that of the Lewis beneath.

North of Craig the relations at the base of the "Laramie" appear to be particularly uncertain. Gale stated:

> The base of the Laramie formation has been assumed to be at the base of the ledge that forms the prominent cliff or rock wall just north of the town. The outcrop of this stratum may be traced almost continuously for about 6 miles west of Craig, but beyond that it is concealed by the overlapping deposits of the Browns Park formation. Similar beds are again revealed farther west. * * * In that region the identity of the horizon already adopted as marking the base of the Laramie is, however, much in doubt.

LITTLE SNAKE RIVER AREA, WYOMING AND COLORADO

The area drained by Little Snake River extends from the Sierra Madre westward to the Red Desert, and from the summit of the Elkhead Mountains in Colorado northward to the divide separating this area from the Great Divide Basin, which is just south of the Union Pacific Railroad. It is separated by the Elkhead Mountains from the Yampa field, considered above.

The western part of this field was studied by M. W. Ball[16] in 1907, and the eastern part by Ball and Stebinger[17] in 1908. The section is essentially the same as that of the Yampa field and also of the field studied by A. C. Veatch in east-central Carbon County. As these areas will be considered in detail in discussing the relations between the Laramie of the Denver Basin and the so-called "Lower Laramie" of Veatch, no further mention at this point is necessary.

CARBON COUNTY, WYOMING, AND ADJACENT AREAS.

An extensive area lying mainly in east-central Carbon County, Wyo., just east of the Green River Basin and forming the western part of what has sometimes been designated the Laramie Plains, is a structural and geologic basin lying in the angle where

[14] Fenneman, N. M., and Gale, H. S., The Yampa coal field, Routt County, Colo.: U. S. Geol. Survey Bull. 297, 1906.

[15] Gale, H. S., Coal fields of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 415, 1910.

[16] Ball, M. W., The western part of the Little Snake River coal field, Wyo.: U. S. Geol. Survey Bull. 341, p. 243, 1909.

[17] Ball, M. W., and Stebinger, Eugene, The eastern part of the Little Snake River coal field, Wyo.: U. S. Geol. Survey Bull. 381, p. 186, 1910.

the Rocky Mountains, from their west of south course through Colorado, turn northwestward through Wyoming toward the Yellowstone National Park. With this area is also considered a long, narrow area extending southward from the vicinity of Rawlins, Wyo., into Routt County, Colo., and connecting through the Elkhead Mountains with the Yampa coal field, which is separated only by the Axial Basin from the coal-bearing rocks that more or less completely surround the Uinta Basin.

East-central Carbon County has been the scene of more or less critical geologic study for nearly 50 years. The historical account of this work is presented in detail on pages 61–65 and need not be repeated here, except in so far as is necessary to keep the problem well in mind. The following is the section of the rocks of the region as worked out by Veatch:[18]

	Feet.
North Park Tertiary	4,500
Unconformity.	
Fort Union	800–2,000
"Upper Laramie"	6,000
Unconformity.	
"Lower Laramie"	6,500
Montana:	
Lewis } Fox Hills of the early surveys.	3,000
Mesaverde } Fox Hills of the early surveys.	3,200
"Pierre shale"	3,500
Colorado:	
Niobrara	800
Benton	1,500
Dakota	150
Morrison	200
Marine Jurassic	75
Red beds	1,650
Carboniferous	1,800
Pre-Cambrian crystallines.	

The section of coal-bearing rocks, given a thickness of 12,500 feet by Veatch, was supposed, prior to his work in 1906, to be a unit and all referable to the Laramie. Veatch's discovery of a profound unconformity, then thought to be similar in position and magnitude to that detected by Cross in the Denver Basin, naturally made a readjustment necessary, and consequently the beds above the unconformity were called the "Upper Laramie" and those below it the "Lower Laramie." The latter therefore corresponds in position to the Laramie of the Denver Basin, and the present comparison is instituted to ascertain the bearing of the floras on this correlation.

Fossil plants occur in greater or less abundance in connection with the coal, especially in the vicinity of Carbon, where some of the earliest mines were situated, but it now appears that the work of the Hayden and King surveys was all along or south of the Union Pacific Railroad, where the lower division is usually absent, hence the plants studied by Lesquereux were from the "Upper Laramie," and it is now plain why the "Laramie" of this region appeared to be so distinctively Tertiary in facies. Since the importance of having collections from the "Lower Laramie" has become realized plants have been procured from many localities, as is shown by the lists on page 100, where further data on the geologic occurrence are given.

It was evident that much more field work would be necessary in this region before several more or less discordant views could be harmonized. This was finally accomplished by Bowen, and his results were published in 1918 in a paper entitled "Stratigraphy of the Hanna Basin, Wyo."[19] In this paper Bowen made a number of important changes in the interpretation of the Carbon County section as given by Veatch. The two sections are given below:

Section in Carbon County, Wyo.

	Bowen, 1918.	Veatch, 1912.
Tertiary.	North Park formation, 0–400 feet.	North Park Tertiary, 4,500 feet.
	—Unconformity—	—Unconformity—
	Hanna formation, 7,000± feet.	Fort Union formation, 800–2,000 feet.
	—Unconformity—	
Tertiary (?).	Ferris formation, 6,500± feet.	"Upper Laramie," 6,000 feet.
		—Unconformity—
Cretaceous.	Medicine Bow formation, 6,200± feet.	"Lower Laramie," 6,500 feet.
	Lewis shale.	Lewis shale.

[18] Veatch, A. C., On the origin and definition of the geologic term "Laramie": Jour. Geology, vol. 15, p. 527, 1907.

[19] Bowen, C. F., U. S. Geol. Survey Prof. Paper 108, pp. 227–235, 1918.

Bowen wrote as follows concerning this section:

Above the highest marine formation—the Lewis shale—is a mass of continental deposits, divisible into four formations having a maximum thickness of more than 20,000 feet. For the lowest of these formations the name Medicine Bow is here proposed, because the formation is best exposed and most easily studied along both sides of North Platte River at the mouth of the Medicine Bow. The Medicine Bow formation is the equivalent of the "Lower Laramie" as defined by Veatch. The latter term is not applicable, for the "Upper Laramie," in the sense in which that term was originally used, is not of Laramie age. As the relation of the Medicine Bow formation to the Laramie of the Denver Basin can not be determined by field relations, and as paleontologists are not agreed as to the relation of the fossil remains found in the two formations, the use of the unqualified term "Laramie" is not advisable, and it is thought that confusion may be avoided by the use of an entirely new name for the formation hitherto called "Lower Laramie."

The Medicine Bow formation rests conformably on the Lewis shale and consists of an alternating succession of shale and massive to thin-bedded, ripple-marked, and cross-bedded sandstones, with several beds of coal in the lower third of the formation. * * *

The Medicine Bow formation is terminated above by a conglomeratic zone taken as the base of the Ferris formation, so named because it is best exposed at the old Ferris ranch, on North Platte River. * * * As defined the Ferris formation is approximately equivalent to the lower half of the "Upper Laramie" of Veatch. The conglomerate at the base of the Ferris formation ranges through an interval of about 1,000 feet, in which massive sandstone, more or less conglomeratic, alternates with nonconglomeratic sandstone and shale. * * * For the upper part of the "Upper Laramie" as defined by Veatch the name Hanna formation is proposed, because the formation is well exposed to the west and north of the town of Hanna and yields all the coal mined at that place.

According to Bowen, perhaps the most interesting structural problem in the field relates to the occurrence and magnitude of the unconformities. He said:

There are certainly two and possibly three unconformities present. The highest of these is at the base of the North Park formation, which overlaps all other formations in the field.

The next lower unconformity is that at the base of the Hanna formation, formerly assigned to the base of the Ferris formation. It represents the removal of more rather than less than the 20,000 feet assigned by Veatch.

This was thought by Bowen to be the unconformity assigned by Veatch to the base of his "Upper Laramie." Veatch's mistake was perhaps natural, as it resulted from rapid reconnaissance work.

The possibility of a third unconformity—namely, at the base of the Ferris formation—was discussed at length by Bowen, who showed that there is a well-marked conglomerate at the base of the Ferris formation and in seeking to interpret its significance commented as follows:

The field relations of the Ferris conglomerate and the underlying formation show (1) that the two have been equally deformed; (2) that there is no angular discordance between them either in the Hanna Basin or in other areas where both are present; (3) that the Ferris formation is nowhere known to transgress the Medicine Bow formation and overlap older rocks; (4) that, as previously indicated, the conglomerate seems to have been derived from the same source as the Medicine Bow; (5) that there appears to be a gradual transition from the Medicine Bow formation to the Ferris formation.

Bowen therefore concluded

that the weight of evidence so far as it can now be interpreted is opposed to the existence of a great unconformity at the base of the Ferris formation, but it is freely admitted that more detailed field work over wider areas is necessary to decide this question.

As regards the paleontologic evidence afforded by what is now called the Medicine Bow formation Bowen wrote as follows:

The plants are regarded by F. H. Knowlton as of the same age as the plants of the Laramie of the Denver Basin. The invertebrates are considered by T. W. Stanton as belonging to the fauna of the Lance formation. The bones belong in part to the ceratopsians, but no specimens have been found that are sufficiently diagnostic for even generic determination.

BLACK BUTTES, WYOMING.

Hardly any other locality that is involved in the Laramie problem has given rise to more extended discussions than Black Buttes, Wyo. Being on the line of the first completed transcontinental railway, it was early made easily accessible and, moreover, it happened to fall within the areas studied by three of the geological survey organizations that worked in the West 40 years or more ago, with the result that it has been discussed and described more frequently and by a greater number of students than any other similar area that has been referred to the Laramie. The first dinosaur (*Agathaumas sylvestris*) accredited to the Laramie, which was supposed to fix the Cretaceous age of everything associated with it, was found at Black Buttes. This locality has also afforded large collections of fossil plants and "a greater number of the described invertebrate species of the Laramie than any other single locality."

As much of the early history of opinion regarding Black Buttes has been given on pages 8–9, it is only necessary to refer to it in the briefest manner at this point. As is well known, Lesquereux from his studies of the fossil plants argued strenuously for the Tertiary age of the coal and plant bearing beds at Black Buttes. Hayden also regarded these beds as Tertiary, or, after the establishment of the Laramie, as in a measure transitional between Cretaceous and Tertiary. In 1872 Meek and Bannister visited this region and discovered the remains of the dinosaur which has played so prominent a part in the discussion of the age of these beds. These dinosaurian remains were described the same year by Cope, who of course referred the beds containing them without hesitation to the Cretaceous, as he and other vertebrate paleontologists considered the mere presence of dinosaurs as proof positive of Cretaceous age. Meek, in discussing the age of the deposits at Black Buttes ("Bitter Creek beds" of Powell), was extremely cautious, his statement being as follows:

As we discovered in these rocks between three and four times as many species of fossils as had been previously known from the same, it becomes a matter of some interest to consider the whole with regard to their bearing on the question as to the age of the group. The reptilian remains found at Black Butte, near the top of the series, have, as elsewhere stated, been investigated by Prof. Cope and by him pronounced to be decidedly dinosaurian and therefore indicative of Cretaceous age; on the other hand, the fossil plants from the same beds have been studied by Prof. Lesquereux, who informs me that they are unquestionable Tertiary types. My own investigations having been confined to the invertebrates, it is of these chiefly that I will speak here. In the first place, it will be seen that all of these yet known belong to a few genera of mollusks, represented by some twelve or fourteen species. And just here it may be stated that, although partly committed in favor of the opinion that this formation belongs to the Cretaceous and still provisionally viewing it as most probably such, I do not wish to disguise or conceal the fact that the evidence favoring this conclusion, to be derived from the mollusks alone, as now known, is by no means strong or convincing. The genera are probably all common both to the Cretaceous and Tertiary as well as to the present epoch.

Meek finally concluded that "aside from the dinosaurian, the organic remains favor the conclusion that it is Tertiary." Later, however (1876), he recorded his impression that the "Bitter Creek series" and the underlying "Point of Rocks series" should probably be considered a unit and hence were presumably Cretaceous, though again he was far from positive in his opinion.

In 1876 J. W. Powell published his "Report on the geology of the eastern portion of the Uinta Mountains," which contains also a chapter on the paleontology by C. A. White. In this report the "Bitter Creek group" was placed unqualifiedly in the Tertiary and was described as resting with marked angular unconformity on the underlying "Point of Rocks group." In commenting on this King [20] wrote as follows:

Powell and White draw the line below the Hallville and Black Butte coals, leaving these upper beds, including the dinosaurian and leaf beds of Black Butte, in the Tertiary. They describe a slight "nonconformity of erosion," producing little irregularities in the upper surface of the bed directly above the horizon of the *Anomia* and *Odontobasis* in the lower strata near Point of Rocks. This, however, draws an arbitrary line between the groups of fossils of close relationship, some of the identical forms occurring in their upper Cretaceous appearing in their lower Tertiary at Black Butte. Moreover, they disregard entirely the evidence of the dinosaurian, which would seem to be conclusive proof of Cretaceous age. We prefer to draw the line at the top of Black Butte, including the dinosaurian and plant beds in the Cretaceous, believing also that in tracing the contact between the beds next over the dinosaurian series and the ashy beds which overlie them we detect a slight unconformity, which, when traced north, seems both more persistent and more observable than the unconformity of erosion noted by Powell, which we fail to follow north.

Later (1877) White placed the beds at Black Buttes in the Laramie, which he then regarded as of post-Cretaceous age, though ultimately he of course came to consider it as Cretaceous. In 1886 Lester F. Ward published his "Synopsis of the flora of the Laramie group," in which the plant beds at Black Buttes were discussed and a few plants were described. He was not able to decide from the data he employed whether the Laramie is Cretaceous or Tertiary, though he inclined to the then prevailing opinion that it is Cretaceous.

In 1896 T. W. Stanton and I [21] spent several days in studying the section at Black Buttes and in collecting plants and invertebrates. We

[20] King, Clarence, Systematic geology: U. S. Geol. Expl. 40th Par. Rept., vol. 1, p. 338, 1878.

[21] Stanton, T. W., and Knowlton, F. H., Stratigraphy and paleontology of the Laramie and related formations in Wyoming: Geol. Soc. America Bull., vol. 8, pp. 127–156, 1907.

did not succeed in finding any trace of vertebrate remains, though the horizon that had afforded the celebrated *Agathaumas* was at least approximately placed and the beds carefully searched. The conclusion was reached that the beds here under consideration rest conformably on the underlying Cretaceous and pass upward without observed discordance into beds then identified as Fort Union and Wasatch. They seemed to fill all the requirements demanded by the definition of the Laramie and were so referred.

For a number of years after the publication of the above-mentioned paper there was little activity in the study of the Black Buttes region. In 1907 A. R. Schultz [22] and party made an investigation of the coal resources of the northern part of the Rock Springs coal field and reached important conclusions concerning the geology of this and adjacent areas. The oldest rocks exposed in the region were identified as of Montana age, and names were applied to them that had been established in southern Colorado. The lowest, called the Mesaverde formation, is made up of four members and aggregates 5,000 feet in thickness. Conformably above the Mesaverde is the Lewis shale, composed of soft gray, drab, and black gypsiferous shale and soft shaly sandstones and forming a region of low relief. The lower part of the Mesaverde was said to include in the main the "Point of Rocks series" of Powell, and the upper part of the Mesaverde and the Lewis shale Schultz assigned to the "Bitter Creek." Above the Lewis shale and apparently conformable with it is the so-called Black Buttes coal group, which was described by Schultz, as follows:

> Along the east side of the [Rock Springs] dome the Black Buttes coal group lies conformably upon marine Lewis shale, which weathers readily and produces regions of low relief. The basal member of the Black Buttes coal group consists of a massive bed of yellowish-white sandstone, in places over 100 feet thick and not known to be coal bearing. This member, resting upon the soft, friable Lewis shale, forms steep hills and cliffs along the contact. The rocks above the sandstone consist of a series of variable sandstones, clay, and coal beds that lie exposed in the low hills and ridges east of the main scarp. On the west side of the dome this group is absent.

In the tabular statement the Black Buttes coal group was referred to as Laramie (?). Its maximum thickness in this field was given as 2,371 feet. Resting unconformably on the Black Buttes coal group is the Black Rock coal group, which in the table was classed as Wasatch, although in the discussion Schultz stated that it "is thought to belong to the Fort Union formation." In thickness it ranges from 1,200 to over 2,600 feet. The Black Rock coal group was briefly described by Schultz as follows:

> At the base is a thin band of conglomerate, ranging in thickness from 2 to 6 feet. The pebbles are very fine, consisting mostly of quartz, although in many places other pebbles are present. This conglomerate marks an uncomformable contact between this coal group and the Black Buttes. Lithologically this group resembles the upper part of the Black Buttes coal group. The sandstone and shale, however, are more highly colored and more poorly cemented and contain a large number of spherical and irregular concretions. The formation is prolifically coal bearing.

In the following season (1908) Schultz [23] investigated the southern part of the Rock Springs coal field, which included the Black Buttes area, though Black Buttes is really on the line between the two areas. The section up to and including the Black Buttes coal group was found to be the same as that just described for the northern part of the Rock Springs dome, but above this point in the general section of the whole region a number of differences were discovered. Although not then known to be anywhere exposed in the Rock Springs dome, it appeared from studies in the Rawlins area, to the east, that there is an immense series of soft sandstones and shales, called the Knobs-Cherokee coal group, with a thickness of 6,000 to 9,400 feet, which is to be intercalated between the Black Buttes and Black Rock coal groups. If these thicknesses are even approximately correct, as they are believed to be, the unconformity between these two series of beds is of course one of tremendous magnitude. As regards the age determinations, the Knobs-Cherokee coal group was referred by Schultz to the "Upper Laramie" of Veatch as defined in Carbon County, Wyo., while the Black Rock coal group was still referred to the Wasatch, although containing a Fort Union flora.

The general geologic relations of the Black Buttes area having been discussed, a more detailed description of the beds in question may now be given. The following is quoted from

[22] U. S. Geol. Survey Bull, 341, pp. 256–282, 1909.

[23] U. S. Geol. Survey Bull. 381, p. 214, 1910.

the paper by Stanto and Knowlton already mentioned:

The most prominent feature of the section at Black Buttes is the massive bed of sandstone, somewhat over 100 feet thick at the base of the exposure, forming steep hills and cliffs northeast of the railroad opposite the station and passing beneath the surface by its dip of 9° or 10° near the coal mine. The upper portion of it is also exposed on the south side of Bitter Creek valley, about a mile from the station. All of the Laramie fossils, whether plants, invertebrates, or vertebrates, that have hitherto been described or listed as coming from Black Buttes were obtained from the overlying beds within about 100 feet of the top of this massive sandstone. The original specimen of *Agathaumas sylvestris* was found about 20 feet above it, and the plants that have been described came from the same horizon and from several higher bands up to the bed overlying the principal coal, some 60 or 75 feet higher. The invertebrates from this locality have about the same range. Most of the beds vary considerably in character and thickness within short distances; but the fossiliferous and overlying portions of the section may be described in general terms as a series of variable sandstones, clays, and coal beds exposed in low hills and ridges with a dip of 9° or 10° eastward at the base, but decreasing in the upper portions to 5° or 6°, which is about the same as the overlying Wasatch beds.

The character of the mollusks shows that the lower beds were mostly deposited in brackish waters, but that there were alternations of fresh waters in which the genus *Unio* thrived with an abundance of individuals and great variety of species, and several fresh-water gastropods were common. Between the top of the massive sandstone and the dinosaur horizon there is a band filled with brackish-water fossils, including *Ostrea glabra* var. *arcuatilis* Meek, *Anomia micronema* Meek, *Corbula undifera* Meek, and *Modiola* sp. The greater number of the Black Buttes invertebrates, however, have been obtained from strata some 40 or 50 feet higher and consequently a little above the dinosaur bed. Here there is a band which in some places is about 4 feet thick, almost wholly made up of shells. By far the most abundant species is *Corbicula fracta* Meek, and immediately associated with it are *Corbicula occidentalis* Meek and Hayden, *Neritina baptista* White, *N. valvilineata* White, and *Melania wyomingensis* Meek, all of which probably lived in slightly brackish water, for this species of *Melania* has almost invariably been found associated with brackish-water or marine forms, although it belongs to a fresh-water genus. At the base of this shell bed and immediately above a coal seam *Unio* shells are abundant. These purely fresh-water forms are found on the slope mingled with the *Corbicula* shells, but all that were found in situ were either at the base of or a few feet above the *Corbicula* bed.

We may now consider the delimitation of the base of the beds at Black Buttes (=Laramie of White and many subsequent writers, Black Buttes coal group of Schultz, etc.) in the light of certain recently acquired but hitherto unpublished data. Powell described the "Bitter Creek series" as resting with marked unconformity on the underlying "Point of Rocks series." Meek was inclined to draw the line at the point—if it could be determined—where the fresh-water deposits begin and the estuarine or brackish-water deposits cease, "considering the brackish-water deposits most probably Cretaceous, and those above them Tertiary." Bannister described an apparent unconformity beneath 130 feet of "thin sandstone alternating with grayish shaly clays," which underlie the massive sandstone that forms bluffs

on the northern edge of the bottom lands of Bitter Creek for a distance of 2 or 3 miles northwest of Black Buttes station, where there appears below them, and apparently dipping unconformably beneath them, a massive bluish-white soft sandstone. * * * The dip of the underlying beds is nearly southeast about 18°, while that of the overlying rocks is only from 5° to 7° and nearly due east.

King detected "a slight unconformity between the beds next over the dinosaurian series and the ashy beds which overlie them," which had the effect of placing the *Agathaumas* in the Cretaceous. None of these supposed unconformities, however, appear to have been definitely detected and accepted by subsequent students.

In later years it came to be the prevailing custom to make the massive sandstone so conspicuous at the base of the exposure the basal portion of the so-called "Laramie" section at Black Buttes, because sedimentation was supposed to be uninterrupted between this massive sandstone and the overlying beds, and, moreover, because the sandstone is very sharply delimited from the underlying soft Lewis shale.

In 1909 A. C. Peale and I spent several weeks in the study of the section at Black Buttes and vicinity. In the massive sandstones a few hundred yards northeast of the station we found numerous specimens of *Halymenites major* Lesquereux, an alga, which wide experience has shown is present only in marine beds. In addition to this, we found a number of invertebrates which, although fragmentary, were, in the opinion of T. W. Stanton, sufficient to prove that the beds are marine and probably of Fox Hills age. We also observed what we interpreted as an unconformity between this massive sandstone and the overlying soft shales containing the fauna and flora under consideration. In the vicinity of the station at Black

Buttes and for many miles southwest of the railroad the uppermost layer of this basal sandstone is a soft white sandstone which can be easily traced. It has a maximum thickness of 20 feet, but the thickness varies from point to point, in some place being reduced to a foot or less, and in one locality about 2 miles south of the railroad the white sandstone has entirely disappeared and the soft shales rest on the yellowish sandstone. At another point about 8 miles southeast of the railroad we observed an irregular trench at least 10 feet deep in this white sandstone, which was filled almost solid with the shells of *Corbicula fracta*, a well-known species of the upper beds.

It is but fair to state, however, that the above interpretation of observed conditions has not been accepted by Schultz and other observers, who argue that although the upper white sandstone may vary in thickness from place to place the variation is due to a lateral change in color from white to brown, and vice versa, rather than to erosion. Peale and I failed to observe any locality where there was a lateral change in the color of this sandstone, and the conditions as we saw them appeared to indicate a slight unconformity. Moreover, the inherent probability that this may be correctly interpreted as an unconformity is indicated by the fact that the massive sandstone marked the close of marine conditions in this region, and further by the fact, as will be shown in a future publication, that the abundant flora gives evidence of being younger than Laramie.

POINT OF ROCKS, WYOMING, AND VICINITY.

With the possible exception of Black Buttes, no locality in this region has given rise to more extended discussion than Point of Rocks. The section is well exposed in the bluff just north of the station and consists of massive white sandstones and soft clay shales and coal beds. The plants have been found mainly in proximity to the coal. These beds constituted the "Point of Rocks series" of Powell and were described by him as strongly unconformable beneath the "Bitter Creek series." Powell, Meek, and White agreed in regarding these beds as of Cretaceous age, but Lesquereux from his studies of the plants considered them as Tertiary. After the Laramie formation was established the beds at Point of Rocks were referred by White and others to this formation, or group, as it was then called, and this disposition remained undisputed for many years.

In 1897 Stanton and I [24] pointed out that the coal and plant bearing beds at Point of Rocks are below marine Cretaceous beds containing a Fox Hills fauna and hence could not be of Laramie age. The statement was as follows:

> At Point of Rocks, 11 miles northwest of Black Buttes, a lower series of coal-bearing beds is well exposed in cliffs and high hills north and east of the station. Here, as at Black Buttes, the base of the exposure is formed by a massive light-colored sandstone about 100 feet thick, and this fact, together with evidence of local faulting along the railroad between the two places, has led several geologists to regard the two exposures as representing about the same horizon. Our observations confirm those of Meek and Bannister in putting the Point of Rocks coal beds several hundred feet lower than those at Black Buttes, and we discovered the additional fact that a considerable portion of the intervening strata consists of marine beds and contains a Fox Hills fauna. The uneven upper surface of heavy sandstone at Point of Rocks was regarded by Powell as evidence of an erosion interval which separated the Point of Rocks group below from the Bitter Creek group above. The larger number of fossil plants described from this locality were obtained in argillaceous lenticular masses in the upper part of the sandstone. Others are associated with the coal beds, of which there are several in the series of soft sandstones, sandy shales, and clays exposed in the bluffs north of Point of Rocks station to a thickness of about 260 feet above the massive sandstone. Above the middle of the coal-bearing part of the section two fossiliferous bands have yielded a few species of invertebrates, consisting of one marine shell, four brackish-water forms, and one fresh-water form. * * *
>
> In the neighborhood of Point of Rocks the dip of the beds is about 6° a little north of east, almost parallel with a valley that joins that of Bitter Creek just east of the station, so that the heavy sandstone soon disappears beneath the surface and the beds above it successively come down to the valley level in the hills on its north side. * * * The beds on the top of the bluffs north of the station thus come down to the valley a little over a mile east of that place, and immediately above them, in a brown ferruginous sandstone, marine Cretaceous species indicating a Fox Hills horizon were found. * * *
>
> Above this horizon there are few exposures seen on going eastward until a line of cliffs is reached nearly 4 miles east of Point of Rocks. These cliffs show at their base about 150 feet of clay shales with bands of sandstone, and a concretion in the clay yielded *Baculites ovatus* Say, *Lunatia occidentalis* Meek and Hayden, and *Mactra* sp., showing that this horizon, some 700 feet above the last one mentioned, is still in the Fox Hills. The shales are overlain by massive sandstone somewhat over 100 feet thick, yellowish brown below and nearly white above, and this is succeeded by a series of shales, sandstones, and coal

[24] Stanton, T. W., and Knowlton, F. H., Stratigraphy and paleontology of the Laramie and related formations in Wyoming: Geol. Soc. America Bull., vol. 8, p. 146, 1897.

beds like that at Black Buttes and containing many of the same characteristic species of fossils in the sane stratigraphic order.

As already pointed out, the coal and plant bearing section at Point of Rocks had for many years been regarded as belonging in the Laramie, and the flora especially had come to be known as a "true Laramie flora," although it had long been recognized that it was "somewhat different from that of any other locality in the West." In accordance with the discovery above set forth, that the coal and plant-bearing rocks were some hundreds of feet below well-defined marine Cretaceous, a readjustment became necessary. These facts are set forth at some length in my paper on the "Flora of the Montana formation,"[25] published in 1900.

In the summer of 1907 A. R. Schultz[26] and party investigated the resources of the northern portion of the Rock Springs field and gave a brief account of the geologic relations. The Point of Rocks coal and plant bearing beds, as well as the upper coal measures at Rock Springs, were called the Almond coal group, which was referred to the Mesaverde formation. It is separated by the marine Lewis shale (750± feet) from the overlying Black Buttes coal group, which was classed as Laramie (?). Schultz's results thus confirmed the observations of Meek and Bannister regarding the placing of the Black Buttes coal beds well above the Point of Rocks coals and those of Stanton and Knowlton in recognizing a marine Cretaceous formation between the two groups of coals.

In 1908 Schultz[27] continued this study to include the southern part of the Rock Springs field. No change was made in the stratigraphic assignment of the coal and plant bearing beds under consideration.

SOUTHWESTERN WYOMING.

Within an area about 40 miles wide and 175 miles long, in Uinta and Lincoln counties, in the extreme southwest corner of Wyoming, there are numerous economically important deposits of coal, and the area has been often visited and more or less critically studied by geologists. The geologic relations in the vicinity of Evanston have been frequently alluded to in the first portion of this discussion, and hence it is only necessary in this connection to call attention to a few of the more salient points before reviewing the present accepted status.[28]

In connection with the coal at Evanston fossil plants were discovered at an early day, and the locality has been studied by Hayden, Peale, Lesquereux, Newberry, Ward, and many others. Lesquereux[29] always regarded the plants as indicating a Tertiary age, and in his final report he placed the Evanston locality in his so-called "second group," which included also Mount Bross and Troublesome Creek, in Middle Park, Colo., and Bridger Pass, Wyo. Newberry[30] expressed the opinion that these plant beds, as well as practically all lignite-bearing beds in Wyoming and Utah, were Cretaceous, and hence when the Laramie was established they were naturally referred to this time division. In 1878 C. A. White[31] included the "Evanston coal series" in the Laramie and gave a list of four species of invertebrates common with the Judith River beds.

In his "Synopsis of the flora of the Laramie group" Ward[32] described a number of plants from Evanston and Hodges Pass; the latter locality, he stated, "may be regarded as forming a northern member of the Evanston coal field." Evanston and Carbon were placed together in the table showing the extent and range of the Laramie flora as he accepted it, and both were regarded as belonging in its upper portion.

Two years later White[33] went a step further and referred the coal-bearing series at Evanston to the Wasatch on the ground that sedimentation was continuous from the undoubted Cretaceous through the Laramie and into the Wasatch, and, moreover, the invertebrates, before supposed to be characteristic of the

[25] Knowlton, F. H., U. S. Geol. Survey Bull. 163, 1900.

[26] The northern part of the Rock Springs coal field, Sweetwater County, Wyo.: U. S. Geol. Survey Bull. 341, pp. 256-282, 1909.

[27] The southern part of the Rock Springs coal field, Sweetwater County, Wyo.: U. S. Geol. Survey Bull. 381, pp. 214-281, 1910.

[28] A complete bibliography of works relating to the geography and geology of this region is given by A. C. Veatch (Geography and geology of a portion of southwestern Wyoming: U. S. Geol. Survey Prof. Paper 56, pp. 17-32, 1907).

[29] Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, 1878.

[30] Newberry, J. S., On the lignites and plant beds of western America: Am. Jour. Sci., 3d ser., vol. 7, p. 400, 1874.

[31] On the distribution of molluscan species in the Laramie: U. S. Geol. and Geog. Survey Terr. Bull., vol. 4, p. 722, 1878.

[32] Ward, L. F., U. S. Geol. Survey Sixth Ann. Rept., for 1884-85, pp. 541 et seq., 1886.

[33] White, C. A., On the relation of the Laramie molluscan and fresh-water Eocene fauna to that of the succeeding fresh-water Eocene and other groups: U. S. Geol. Survey Bull. 34, pp. 9-16, 1886.

Laramie, were then found to be more closely related to those of the Wasatch or later beds.

In 1895 Wilbur C. Knight [34] published a paper on the "Coal and coal measures of Wyoming," in which he stated that coal-bearing beds" are found at "Henrys Fork, Almy, Twin Creek, Hams Fork, and Coalville [Cokeville]. The last four localities are probably in the same coal field, which belongs to the Lower Cretaceous and has been known as the Bear River group." This view was widely at variance with the facts even as then understood and has not been followed.

The following year (1896) Stanton and I [35] spent a few days at Evanston and Hodges Pass and concluded that the Wasatch was probably unconformable on the coal-bearing beds, which were presumed to be in the upper part of the Laramie.

In the summer of 1905 A. C. Veatch [36] and party began an investigation of the coal and oil resources of this region and presented a short preliminary statement of results, which was published the next year. The several formations observed and mapped, with their geologic time values, were set forth in the form of a table. The uppermost Cretaceous formation, with a thickness of over 5,000 feet, was referred to the Laramie. It was said to include the Adaville-Lazeart coal, 10 to 84 feet thick, and to be terminated at the top by a marked unconformity. To the beds above the unconformity, which included the coal at Evanston—that is, the bed worked at the Almy and Red Canyon mines—the name Evanston formation was given, but the exact age determination was left questionable.

Veatch's complete report on this area [37] was published a year or more later, and in this the geologic and paleontologic data were reviewed in full. The uppermost member of the Cretaceous section, called Laramie in the preliminary report, was here called the Adaville formation, which included also a white basal sandstone denominated the Lazeart sandstone member. A few hundred feet of the basal part of the Adaville formation was thought to be of Montana age, and the remainder of the 5,000 feet was called "Lower Laramie." Fossils were found only in the lower part of this formation, and both plants and invertebrates appeared to indicate an age older than Laramie, and these furnished the basis for placing the lower portion in the Montana.

The unconformity at the top of the Adaville formation ("Lower Laramie"), according to Veatch, involved a long period of folding, faulting, and erosion, inferred on stratigraphic grounds and indicating the removal of over 20,000 feet of strata.

In the geologic column given by Veatch [38] the overlying Evanston formation was referred without qualification to the "Upper Laramie" and made the basal member of the Eocene, but in the discussion of this formation [39] this reference was not quite so positively stated. On this point Veatch wrote as follows:

> The Evanston formation was considered by the geologists of the early Government expeditions as Laramie. Later Dr. White, after studying in detail its invertebrate fauna and comparing it with that found at Wales, Utah, concluded that these beds were undoubtedly Wasatch. Ward and Knowlton, because of its flora, have regarded it as essentially the same as the Carbon beds, but as the stratigraphic position of the Carbon beds has never been determined this correlation does not lead very far. Knowlton reported that the leaves collected in 1905 are "Upper Laramie." As early as 1893 he suggested the possibility of their representing the Denver beds, and again, in 1898, doubtfully referred this locality to the Denver. Dr. T. W. Stanton regards the invertebrates as Laramie or Fort Union, and the question thus becomes involved in the larger one of the true age of the Fort Union, which has been regarded both as Upper Cretaceous and Eocene. The paleontologic collections made at this locality do not prove conclusively that the beds are Upper Cretaceous or, on the other hand, show that they are basal Eocene. * * * The stratigraphic evidence strongly suggests that the line between the Eocene and the Cretaceous should be drawn at the base of the Evanston and certainly shows no reason for drawing it between the Evanston and the Almy [the formation conformably above the Evanston]. On the whole, the Evanston formation may be tentatively regarded as Eocene.

The reference of the Adaville and Evanston formations to the "Lower Laramie" and "Upper Laramie," respectively, was in accord with the section as worked out in Carbon County, Wyo., even including the great unconformity separating them.

[34] U. S. Geol. Survey Sixteenth Ann. Rept., pt. 4, pp. 208–212, 1895.

[35] Stanton, T. W., and Knowlton, F. H., Stratigraphy and paleontology of the Laramie and related formations in Wyoming: Geol. Soc. America Bull., vol. 8, p. 148, 1897.

[36] Coal and oil in southern Uinta County, Wyo.: U. S. Geol. Survey Bull. 285, p. 331, 1906.

[37] Veatch, A. C., Geography and geology of a portion of southwestern Wyoming: U. S. Geol. Survey Prof. Paper 56, 1907 [1908].

[38] Idem, facing p. 50.

[39] Idem, pp. 76–87.

In 1906 A. R. Schultz [40] continued the field work directly north of the area covered by Veatch in the report just considered, but his report was not published until 1914. When the field study was made the area covered by Schultz was in the northern part of Uinta County, but subsequently (1912) this area was included in Lincoln County. In the main the geologic formations present in the southern area were carried northward into Lincoln County, though with some notable changes in the thickness of the beds. The Adaville formation showed a decrease in thickness from a maximum of 4,000 to 2,800 feet, and the Evanston an increase from 1,600 to over 9,500 feet. Both these formations were described in much the same terms as were used by Veatch; in fact, full quotations were made from his report. No stratigraphic or paleontologic evidence was procured or recorded concerning them that would tend to change their age assignments as recorded by Veatch, yet in the stratigraphic column given on page 29 of Schultz's report striking modifications appeared. Thus the Adaville was placed entirely in the Montana, and the designation "Lower Laramie" had disappeared, while the Evanston, before called "Upper Laramie" and made the basal member of the Eocene, was here placed under the designation "Cretaceous or Tertiary," and the Almy formation became the lowest accepted Eocene.

COALVILLE, UTAH, AND VICINITY.

The geology in the vicinity of Coalville, Utah, is somewhat complicated, and extensive differences of opinion on it have prevailed among geologists. The following brief historical account of it is given by T. W. Stanton:[41]

The coal-bearing Cretaceous beds exposed at Coalville, Utah, and on Bear River, near the mouth of Sulphur Creek, Wyo., have been the subject of considerable discussion, and various opinions concerning their precise age have been published by several geologists and paleontologists who have visited the localities or examined collections from them. They were referred to the Cretaceous by Messrs. Meek and Engelmann in 1860 and were compared with certain Cretaceous beds at the mouth of Judith River, then regarded as belonging to No. 1 (Dakota) but afterward proved to be of Fox Hills age. When Capt. Simpson's report was published in 1876 Mr. Engelmann again expressed the opinion that these beds are probably "Lower Cretaceous" [Dakota].

They were at first regarded as Tertiary by Messrs. Hayden and Lesquereux. In 1870 Messrs. Meek and Hayden adopted the view that the Coalville beds are Cretaceous but that they "occupy a higher horizon in the Cretaceous than even the Fox Hills beds of the Upper Missouri Cretaceous series."

Mr. Meek visited Coalville in 1872, and after making larger collections and studying the stratigraphy he decided that the entire upper Missouri Cretaceous section, with perhaps some older beds, is represented here. The detailed section that he published shows correctly the essential features of the stratigraphy. The opinions that he then expressed concerning the correlation of these beds were repeated in subsequent publications.

Messrs. King and Emmons assigned the Cretaceous strata at Coalville to the Colorado, Fox Hills, and Laramie formations and so mapped them in the atlas accompanying their report. The principal (lower) coal bed is included in the Colorado formation and the upper one in the Fox Hills, the line between these two formations being drawn in the second ridge above the lower coal bed. It should be remembered that the Colorado formation was then made to include the Fort Pierre division.

Dr. C. A. White studied the section in 1877, and after discussing the fossils collected in it, he states that it is impracticable to refer the strata to any one or more of the established Cretaceous groups with certainty, but he thinks there is no reason to doubt that the greater part of the series at least is referable to the Fox Hills.

Stanton presented a detailed section, which shows the presence of about 6,000 feet of strata below the recognized Tertiary. Of this column about 1,700 feet was assigned to the Colorado, about 2,800 feet tentatively to the Montana, and approximately 1,500 feet of unfossiliferous strata were said to include the Laramie if it is present.

None of the investigators prior to Stanton had noticed the presence of plants, but he found a fairly rich deposit nearly 1,000 feet above the base of the Montana, overlain by fully 1,800 feet of richly fossiliferous marine Cretaceous, representing the upper portion of the Montana.

These plants were studied by me, and a brief report on them is printed on page 42 of Stanton's bulletin. In this report it was stated that the most important of the species "belong clearly to the Laramie group," but it should be remembered that this statement was in accord with the current conception of the Laramie when the flora from Point of Rocks was regarded as typical. The subject was reviewed and the plants from Coalville properly re-

[40] Schultz, A. R., Geology and geography of a portion of Lincoln County, Wyo.: U. S. Geol. Survey Bull. 543, 1914.

[41] The Colorado formation and its invertebrate fauna: U. S. Geol. Survey Bull. 106, pp. 37, 38, 1893 [1894].

ferred to the Montana in my "Flora of the Montana formation." [42]

The economic resources of this region were briefly examined by J. A. Taff [43] in 1906; but he made only incidental mention of the geologic relations, taken mainly from the results of the earlier students.

The Coalville section was also briefly summarized by A. C. Veatch [44] in his paper on the "Geography and geology of a portion of southwester Wyoming," published in 1908, for the purpose of comparing it with the Wyoming section, of which it doubtless represents a part. He suggested that the Colorado group may extend higher in the section so as to include the plant-bearing beds. Veatch also gave a very complete bibliography relating to the exploration and geology of this general region. The latest report on this field is that by Carroll H. Wegemann,[45] published in 1915. In this report the Coalville section, with a thickness of about 9,000 feet, was described as a slightly overturned anticline. Folding and faulting here further complicated matters until in the absence of adequate paleontologic data, it is difficult to draw satisfactory formational boundaries; in fact, Wegemann stated that "although the area has been studied by several geologists, the formation boundaries are by no means definitely determined."

According to Wegemann, the workable coal of the region is of Colorado age, but the thickness that is to be assigned to the Colorado part of the section is indefinite. Its thickness is at least 1,000 feet, and there is a tendency to extend the Colorado upward to include an additional 1,000 feet, but the evidence for this was not regarded as conclusive. It would then include the plant horizon already mentioned, which contains a flora correlated with the Montana (Mesaverde) at Point of Rocks, Wyo.

The Laramie is not known to be present in this section, but in this connection Wegemann pointed out that there are over 4,000 feet of beds between those last mentioned and the unconformity at the base of the Tertiary (Wasatch formation) that are still unplaced. This great thickness of beds was divided into two parts, the lower of which (No. 3 of Wegemann's section on p. 163), 1,650 feet thick, is marine, while the upper (No. 2), 2,500 feet thick, contains leaves and fresh-water shells, though they are not sufficiently abundant or sufficiently well preserved to admit of definite stratigraphic determination.

[42] Knowlton, F. H., U. S. Geol. Survey Bull. 163, pp. 8-9, 1900.

[43] Notes on the Weber River coal field, Utah: U. S. Geol. Survey Bull. 285, pp. 285-288, 1906.

[44] U. S. Geol. Survey Prof. Paper 56, p. 103, 1907 [1908].

[45] The Coalville coal field, Utah: U. S. Geol. Survey Bull. 581, pp. 161-184, 1915.

SAN JUAN BASIN AND ADJACENT AREAS IN COLORADO AND NEW MEXICO.

The area included in the San Juan Basin and vicinity extends from the vicinity of Durango, Colo., on the north, beyond Gallup and Mount Taylor, N. Mex., on the south, and from a point near the Arizona-New Mexico line on the west to Chama, Elvado, and the Sierra Nacimiento, near the longitude of Albuquerque on the east, or nearly 150 miles from north to south and 100 miles from east to west. The coal-bearing rocks form a more or less continuous rim around this basin and dip toward the center, where, however, they are deeply buried.

The San Juan district was studied by W. H. Holmes,[46] of the Hayden Survey, in 1875. In Plate XXXV of his report he gave a general section of the rocks in the valley of San Juan River. The uppermost member was referred to the Wasatch, which he divided into two parts, the lower being the Puerco marl of Cope. Immediately below this is the so-called "upper coal group," made up of 800 feet of soft sandstones and marls, which was referred to as Laramie?. This in turn rests on the Pictured Cliff sandstone, which with the underlying 1,500 to 2,000 feet of rocks Holmes referred to the Fox Hills.

Except for a number of economic reports on the coal of the region, little systematic work was done in this area until 1899, when Whitman Cross,[47] in the La Plata folio, established the units of the Upper Cretaceous section of the region, which have subsequently been so widely identified in Colorado, Wyoming, and Montana. These units in ascending order are Mancos shale, Mesaverde formation, and Lewis shale. Concerning the Lewis Cross wrote as follows:

> Above the Mesaverde formation occurs another formation of clay shale, reaching an observed thickness of nearly 2,000 feet, which is very much like the Mancos shale but contains fewer fossils. The only identifiable form thus far found in this shale occurs also in the Mancos shale, so

[46] Geological report on the San Juan district: U. S. Geol. and Geog. Survey Terr. Ninth Ann. Rept., p. 241, 1877.

[47] U. S. Geol. Survey Geol. Atlas, La Plata folio (No. 60), p. 4, 1899.

that this division is still apparently below the true Fox Hills. This formation is called the Lewis shale.

Continuing, Cross said:

> Still above the Lewis shale is a second series of sandstones, shales, and coals, bearing some resemblance to the Mesaverde formation but differing in detail. The lowest member of this complex is the "Pictured Cliff sandstone" of Holmes's San Juan section, which he placed in the Fox Hills upon the evidence of invertebrate remains. The remainder was referred to the Laramie, but without fossil evidence. The present survey has also failed to bring to light valid ground for assigning any of the beds in question to the Laramie, while there is some reason to believe that more than the lower sandstone belongs to the Montana group.

In 1905 F. C. Schrader [48] made a preliminary or reconnaissance examination of the Durango-Gallup coal field, in which he adopted the stratigraphic classification established by Cross, the uppermost coal-bearing sandstone being classed as Laramie?, though no fossil evidence was presented.

In 1906 more detailed examinations were made in the region by Joseph A. Taff and M. K. Shaler. Taff [49] considered the Durango coal district, which lies just off the southern foothills of the San Juan and La Plata mountains. In this report the upper coal-bearing rocks here under consideration were referred without question to the Laramie, though no details were given as to the reasons for this reference. Shaler's report [50] deals with that part of the Durango-Gallup field lying west of longitude 107° 30′. The beds here in question were also referred to the Laramie without qualification, on the basis, as he stated, of fossils studied by T. W. Stanton and me, though the evidence was not presented in detail. Examination of the original reports on the plants collected by Shaler and others in this region shows that the collections were few and fragmentary and the tendency was to regard them as older than Laramie.

The status of the "Laramie" in the region under consideration is so succinctly summed up by W. T. Lee [51] in his paper on the "Stratigraphy of the coal fields of northern New Mexico" that his remarks are quoted entire as follows:

> The "Laramie" formation occurs within the area described in this paper only in the San Juan Basin. It is more than 1,000 feet thick in the southern rim of the basin but is thinner in the eastern rim, probably due to post-Cretaceous erosion. At Dulce it is only 225 feet thick. The formation lies conformably on Lewis shale and probably for this reason more than for any other has been called Laramie, although Dr. Cross several years ago called attention to the fact that investigation had "failed to bring to light valid ground for assigning any of the beds in question to the Laramie, while there is some reason to believe that more than the lower sandstone belongs to the Montana group." Since that time a considerable number of fossils, both of invertebrates and of plants, have been collected from these beds in the Durango region. The base of the formation—the Pictured Cliff sandstone—contains marine invertebrates, and the lower part of the coal-bearing rocks above this sandstone contains brackish-water invertebrates, several of which occur in the Mesaverde of other fields. But higher in the formation the rocks contain fresh-water invertebrates which Dr. Stanton regards as Laramie and fossil plants which Dr. Knowlton regards as older than Laramie. The fossil plants have been given in the table previously given, and from this table, as well as from the accompanying statement by Dr. Knowlton,[52] it will be seen that the flora differs but little from that of the Mesaverde farther to the south.
>
> The name "Laramie" is here used for this formation not because the writer wishes to argue for the Laramie age of the rocks, but because the name is in use and because in this paper the writer is intentionally avoiding the introduction of new names for rock formations. It must be noted, however, that while the formation is called "Laramie" it contains a flora which denotes Montana age, having nothing in common with the Laramie flora of the Denver Basin.
>
> Whether the formation will eventually be called "Laramie" or be designated in some other way depends largely on the final use of that somewhat migratory name. But in view of the facts that many of the species of marine and brackish-water invertebrates from the lower part of the formation occur in the Mesaverde of other localities, that the invertebrates from the upper part are of fresh-

[48] The Durango-Gallup coal field of Colorado and New Mexico: U. S Geol. Survey Bull. 285, pp. 241–258, 1906.

[49] The Durango coal district, Colo.: U. S. Geol. Survey Bull. 316, pp. 321–337, 1907.

[50] A reconnaissance survey of the western part of the Durango-Gallup coal field of Colorado: Idem, pp. 376–426.

[51] Geol. Soc. America Bull., vol. 23, pp. 607–608, 1912.

[52] The statement here alluded to is as follows: "Near Dulce, N. Mex., and near Durango, Colo., there have been obtained two collections of plants from above the Lewis shale in coal-bearing rocks that have been referred to the so-called 'Laramie' of this region. These collections are very full and embrace a number of easily recognized species, hence their identification is satisfactory and complete. These collections prove clearly that these beds do not belong to the Laramie, since, so far as known to the writer, not a single species there present has been found in beds of this age. On the other hand, the plants indicate beyond question that they belong to the Montana, there being, for instance, ***Ficus speciosissima***, ***Ficus*** sp. (narrow, 3-nerved type), ***Ficus*** sp., type of *F. lanceolata*, a palm, etc., which link them with the Mesaverde floras to the south and the beds already discussed in the Raton Mesa region. Associated with these, however, and tending to give them a slightly higher position, though still within the Montana, are such forms as *Brachyphyllum*, *Cunninghamites*, *Geinitzia*, *Sequoia*, etc., all of which are beyond doubt Montana types not found in the Laramie.

A number of collections were made by J. H. Gardner in the Ignacio quadrangle, east of Durango, Colo., from beds regarded as the Laramie of that area. The plants in these collections, almost species by species, are identical with the forms from Dulce and near Durango, and I have no hesitation in saying that they occupy the same stratigraphic position and are the same in age, viz, Montana."

water origin and admittedly unreliable for purposes of correlation, and that the plants are of Montana types, serious doubt is cast on the Laramie age of the formation.

It now remains to consider certain dinosaur-bearing beds near Ojo Alamo, N. Mex., 12 miles south of Farmington, which may have a bearing on the "Laramie" of the San Juan Basin. In 1908 James H. Gardner, then of the United States Geological Survey, found vertebrate remains near the head of Coal Creek, 1 mile southeast of Ojo Alamo, "in variegated sands, shales, and conglomerates, indisputably above the unconformity at the top of the Laramie."[53] These remains were studied by C. W. Gilmore, who reported the presence of *Triceratops*, *Trachodon*, *Tyrannosaurus*, *Aspidiretes*, and crocodiles, which, he said, "appears to represent a typical fauna of the so-called Laramie, or better, *Ceratops* beds." At the time this was written it was thought possible that these dinosaur-bearing beds might be a part of the Puerco formation, but subsequent investigation has shown that this is not so.

In the same year (1909) Stanton[54] listed several collections of invertebrates from the so-called Laramie "coal measures immediately above the Lewis shale," on the line between La Plata and Archuleta counties, Colo., which he considered as belonging to the same fauna and "at about the same horizon" as the fauna in the beds at Black Buttes, Wyo.

It appears that dinosaurs had been known at the Ojo Alamo locality as early as 1902, but it was not until 1904 that a systematic attempt was made to collect them. In that year Barnum Brown, of the American Museum of Natural History, made a reconnaissance trip to the locality and procured "a small but interesting collection of fossils." His report on these fossils, however, was not published until 1910.[55] He said:

> This collection is of special interest, as it represents a fauna that is distinctly older than that of the "Lance Creek beds or *Ceratops* zone" and "Hell Creek beds" of the Laramie Cretaceous. I am unable definitely to correlate the horizon in which these bones occur, but the faunal facies appears to be even older than that of Black Buttes, Wyo., and probably represents a period synchronous with the lower part of the Edmonton series of Alberta, Canada. * * *
>
> Less than a mile south of the store at Ojo Alamo the Puerco formation rests unconformably on a conglomerate that is composed of red, gray, yellow, and white pebbles. The position of these beds is below what may be called the type of the Puerco or basal Eocene, and their unconformable relation is highly significant. * * * Below the conglomerate there is a series of shales and sandstones, evenly stratified and usually horizontal, in which there is much less cross-bedding than commonly occurs in the Laramie of the northern United States.
>
> The shales below the conglomerate that contain numerous dinosaur and turtle remains I shall designate as the Ojo Alamo beds. They are estimated to be about 200 feet thick, but owing to lack of time I was unable to determine their relation to the underlying formations. The vertebrate remains were numerous in several places from 30 to 100 feet below the conglomerate.

The new dinosaurian was described as *Kritosaurus navajovicus*.

During the summer of 1909 James H. Gardner, in company with James W. Gidley, of the United States National Museum, spent two days in the vicinity of Ojo Alamo and obtained a number of remains of turtles from Brown's Ojo Alamo beds. These were described by O. P. Hay[56] the following year. Concerning the stratigraphic relations Hay said:

> In this region they found two distinct formations. In the lower, composed of sandstones, clays, and a bed of conglomerate, there were found fragmentary remains of dinosaurs and the turtles below described. * * * These beds are probably the equivalent of the Lance Creek beds.

Also in 1910 Gardner[57] published a paper on "The Puerco and Torrejon formations of the Nacimiento group," which involved, incidentally, the beds under discussion. He recorded the Puerco as resting unconformably on the "Laramie" of the region, as Brown had reported, and he stated that at Ojo Alamo he "obtained dinosaurs from beds unconformably above the 'Laramie' and below the Wasatch." These beds are, of course, the Ojo Alamo beds of Brown, and Gardner's discovery tended to establish the fact that these dinosaur-bearing beds rest unconformably on the "Laramie" and are unconformably overlain by the Puerco.

An expedition from the American Museum of Natural History, under the charge of W. J.

[53] Knowlton, F. H., The stratigraphic relations and paleontology of the "Hell Creek beds," "*Ceratops* beds," and equivalents: Washington Acad. Sci. Proc., vol. 11, p. 233, 1909.

[54] Stanton, T. W., The age and stratigraphic relations of the "*Ceratops* beds" of Wyoming and Montana: Washington Acad. Sci. Proc., vol. 11, p. 274, 1909.

[55] Brown, Barnum, The Cretaceous Ojo Alamo beds of New Mexico, with description of the new dinosaur genus *Kritosaurus*: Am. Mus. Nat. Hist. Bull., vol. 28, pp. 267-274, 1910.

[56] Descriptions of eight new species of fossil turtles from west of the one hundredth meridian: U. S. Nat. Mus. Proc., vol. 38, pp. 307-326, 1910.

[57] Gardner, J. H., Jour. Geology, vol. 18, pp. 702-741, 1910.

Sinclair and Walter Granger,[58] spent the season of 1913 in collecting fossils from the Puerco and Torrejon formations of New Mexico. Although these authors were concerned mainly in procuring mammal remains from the formations mentioned, they recorded certain important observations on the underlying dinosaur-bearing or Ojo Alamo beds. They agreed with Brown and Gardner in finding the Puerco resting with marked erosional discordance on the underlying beds. The reptilian and other vertebrate material procured by Sinclair and Granger from the Ojo Alamo beds was studied by Brown, whose report they quoted. From this it appears that Brown's *Kritosaurus* was regarded as generically identical with *Gryposaurus,* described later by Lambe [59] from the Belly River formation of Canada. Continuing, Brown said:

> The fauna of the Ojo Alamo beds is certainly older than that of the Lance, and I have expressed the opinion that it is probably synchronous with the Edmonton. *Kritosaurus* is now known from the Belly River beds and has not yet appeared in extensive collections from the Edmonton, and as other reptilian remains are of primitive facies the Ojo Alamo beds may well be of Judith River age.

Sinclair and Granger did not attempt to reach any decision concerning the age of the Ojo Alamo beds, though they gave an alternative hypothesis, as follows:

> Willis T. Lee favors a correlation of the dinosaur beds and associated conglomerate members with the Animas formation. If the Animas is in turn to be correlated with the Lance, * * * then the line between Cretaceous and Tertiary in the Ojo Alamo region would have to be drawn * * * not at the unconformity below the Puerco, where the vertebrate paleontologist would incline to put it, but at some level not yet discovered.

The probable correlation of the Ojo Alamo beds was suggested by me [60] as follows:

> The Puerco formation rests unconformably on dinosaur-bearing beds, beneath which is the "Laramie" of the region. I have shown elsewhere, however, that these later beds are undoubtedly much older than Laramie. The "*Ceratops* beds," immediately beneath those containing the Puerco fauna, have been practically traced into the Animas formation, which Cross holds is of Denver age. The Animas formation is now known to extend eastward to the eastern border of the San Juan Basin, near Dulce, N. Mex., where it is conglomeratic at the base and consists of an andesitic matrix, in which are pebbles of many kinds of older rocks; above this conglomerate are Eocene leaves.

The last published contribution to the geology and paleontology of the San Juan Basin was made in 1916, when four short papers by C. M. Bauer, C. W. Gilmore, T. W. Stanton, and me were issued under the general caption "Contributions to the geology and paleontology of San Juan County, N. Mex." [61] The first paper of the series, by Bauer, was entitled "Stratigraphy of a part of the Chaco River valley" and was based on field work and collections made in 1915. The thesis of Bauer's paper he gave as "an attempt to set forth the principal features of the stratigraphy in a part of the San Juan Basin—to describe the succession of strata irrespective of possible correlations and thereby to establish a type section for the formations exposed and to bring out their relations to the strata immediately above and below."

In the complex generally designated by previous writers as Laramie Bauer was able to differentiate two additional formational units. The lower of these, called the Fruitland formation, rests conformably on the Pictured Cliffs sandstone, has a thickness of 49 to 275 feet, and contains the coal of the region. Conformably above this formation is the Kirtland shale, with a maximum thickness of 1,180 feet and including what is called the Farmington sandstone member, which reaches a thickness of 455 feet. Above the Kirtland is the Ojo Alamo sandstone of Brown. The relation between the newer and older interpretations was shown in the following table:

[58] Paleocene deposits of the San Juan Basin, N. Mex.: Am. Mus. Nat. Hist. Bull., vol. 33, pp. 297-316, 1914.

[59] Lambe, L. M., Ottawa Naturalist, vol. 27, p. 145, 1914.

[60] Knowlton, F.H., Cretaceous-Tertiary boundary in the Rocky Mountain region: Geol. Soc. America Bull., vol. 25, p. 338, 1914.

[61] U. S. Geol. Survey Prof. Paper 98, pp. 271-353, 1916.

Older interpretations.	Bauer, 1916.
Wasatch.	Wasatch.
Torrejon.	Torrejon and Puerco.
Puerco.	
Laramie.	Ojo Alamo sandstone.
	Kirtland shale and Farmington sandstone member.
	Fruitland formation.
	Pictured Cliffs sandstone.
Lewis.	Lewis shale.
Mesaverde.	Mesaverde.

The second paper, by Gilmore, was entitled "Vertebrate faunas of the Ojo Alamo, Kirtland, and Fruitland formations." The vertebrates include dinosaurs, turtles, crocodiles, and fishes, and according to Gilmore they "are found throughout these deposits, though they appear to occur most abundantly in the Ojo Alamo and the upper part of the Kirtland, sparsely in and below the Farmington sandstone member of the Kirtland, and more abundantly in the Fruitland." His conclusion regarding their age was as follows:

After a study of the material in the United States National Museum collections from this area, and after reviewing the literature in which specimens from these formations have been described, I conclude that the vertebrate remains from the Ojo Alamo, Kirtland, and Fruitland formations show beyond all question that they pertain to a fauna or faunas distinctly older than that of the Lance, and that such evidence as there is contributes to the support of Brown's contention that the Ojo Alamo sandstone is synchronous with the Judith River and Belly River formations as found in areas to the north.

The third paper, by Stanton, was entitled "Nonmarine Cretaceous invertebrates of the San Juan Basin" and dealt mainly with brackish and fresh water species from the Fruitland formation, only 2 of the 27 recorded species coming from the Kirtland shale and none from the Ojo Alamo sandstone. A table giving the stratigraphic range of these forms was presented and was discussed by Stanton as follows:

The distribution of the species as exhibited in the table may seem at first glance to indicate that the Fruitland fauna is about as closely related to the Mesaverde and Judith River faunas (which are approximately contemporaneous with each other) as it is to the Lance and Laramie faunas. A closer analysis of the table, however, will show that most of the species occurring or represented by related forms in the Mesaverde and Judith River are long-lived brackish-water species which range at least as high as the Laramie. *Melania insculpta* belongs to this class, for like all the other American Cretaceous species referred to *Melania* it is invariably associated with brackish-water forms. The only two Fruitland species with an outside distribution which do not elsewhere range into the higher formations are *Modiola laticostata*, from the Mesaverde, and *Goniobasis? subtortuosa*, from the Judith River. With fresh-water species, especially those belonging to the genus *Unio*, the case is different. The majority of the identical and closely related species are found in the Laramie, the so-called "Lower Laramie" of southern Wyoming, and the Lance and do not range below these formations. It is my opinion, therefore, that the invertebrate evidence as a whole favors the assignment of the Fruitland formation to an epoch considerably later than Mesaverde and Judith River and possibly somewhat earlier than Lance. If due weight is given to the known stratigraphic relations and to the faunal evidence from the underlying formations, the Fruitland can hardly be older than Fox Hills, and the sequence from the base of the Fruitland up to the top of the Ojo Alamo, which is conformable, according to Mr. Bauer, may include the equivalents of everything from the Fox Hills to the Lance inclusive.

In my paper, on the "Flora of the Fruitland and Kirtland formations," the flora was discussed as follows:

Of the 40 forms making up the known flora of the Fruitland and Kirtland formations, 16 have been found in other areas, and the list brings out the fact that no less than 15 of these forms are known to occur in the Montana. A further analysis of the list shows that 12 of the 15 forms occur in the Vermejo formation of Colorado and New Mexico, 10 occur in the Mesaverde, or rocks of about this age, in Wyoming and elsewhere, and 6 species are common to both these areas. On the basis of this showing the conclusion seems justified, therefore, that the Fruitland and Kirtland formations are of Montana age.

The material in a single small collection from the Ojo Alamo beds was so fragmentary that it could not be identified with satisfaction. Concerning it I said:

It includes portions of a large leaf of unknown affinity, a small willow-like leaf, and a large leaf that appears to be an *Aralia* of the type of *Aralia notata* Lesquereux, a species very abundant and widely distributed in the Fort Union formation. Nothing like this has been noted in the underlying beds, and to a certain extent it argues for the Tertiary age of the Ojo Alamo beds, though obviously the evidence is not strong. For the present, therefore, the dictum based on the evidence of the fossil vertebrates that these beds can not be separated from the underlying beds must be accepted, though the writer can not escape the impression that they may ultimately be shown to be of Tertiary age.

From the above exposition it appears that the plants and vertebrates are in substantial agreement in indicating a Montana age (Mesaverde or Judith River position) for the beds previously considered referable to the Laramie, whereas the invertebrates are interpreted as "indicating an epoch considerably later than Mesaverde and Judith River and possibly somewhat earlier than Lance."

"LARAMIE" IN WESTERN TEXAS AND NORTHERN MEXICO.

WESTERN TEXAS.

The extreme desirability of establishing a connection between the late Cretaceous and early Tertiary section of the great interior region and the well-authenticated marine section of the Gulf coast region has long been recognized. The Laramie in particular was one of the stratigraphic units characteristic of the Rocky Mountain region that it was hoped might sometime be brought into harmony with the marine succession of the Coastal Plain. C. A. White, who had taken so large a part in the exploitation of the Laramie and who was more or less familiar with both these areas, was especially desirous of establishing such a relation. In an article published in 1888 [62] he says:

> During the 12 years preceding the autumn of 1887, in which I had made extensive studies and observations concerning the Laramie group, I was never able to obtain any personal knowledge of the actual stratigraphic relation of that group to any of the marine Tertiary groups which border various portions of North America.

He then wrote of having studied the Laramie from the State of Nuevo Leon, Mexico, on the south, to northern Montana on the north, and added that within this vast region

> wherever any strata were found resting upon the Laramie they were always those of the great fresh-water Tertiary series; but I had not then traced the Laramie into a district within which marine Tertiary strata were known to exist. That is, in tracing the Laramie into Mexico I had followed the trend of that formation from the north and thus passed to the westward of the outcrops of the Gulf Tertiaries.
>
> In 1884 Prof. E. D. Cope [63] announced that he had found "the Claiborne beds resting immediately upon the Laramie at Laredo," Tex., but he then mentioned no correlated facts in support of this important announcement, and, so far as I am aware, none have since been published. The known southeastward trend of the Laramie and the circling and therefore converging trend of the Gulf series of formations made it evident that the district traversed by the lower Rio Grande would be found to be the most promising field in which to search for the stratigraphical relation between the Laramie and the Eocene Tertiary. With this object in view, I last autumn visited that region and had the satisfaction of confirming the observation previously made by Prof. Cope.
>
> Starting at Eagle Pass, Tex., I proceeded down upon the Texan side of the valley of the Rio Grande to Laredo, making observations by the way. The strata representing the Fox Hills group of the western section and the Ripley group of the eastern were found to dip gradually in the direction of the course of the river and to receive those of the Laramie group upon them, the older strata passing finally from view in that direction.
>
> The strata which are exposed in the bluffs along the left bank of the Rio Grande from 25 to 30 miles above Laredo and which bear one or more workable beds of coal there are referred confidently to the Laramie, although they afforded me only a few imperfect fossils. These strata dip gradually to the southeastward, or approximately in the direction of the river's course, and disappear beneath the sandy strata of the Eocene Tertiary some 10 or 12 miles above Laredo. Below this and all around Laredo the strata which I found exposed are of Eocene age, and in many places they bear an abundance of characteristic fossils.
>
> While I have no doubt as to the Laramie age of the strata referred to, which I observed on both sides of the Rio Grande, and none as to the Eocene age of the strata which I found overlying them, I am by no means certain that the lowermost strata which I found resting upon the Laramie near Laredo represent the lowermost strata of the Eocene division of the Gulf series. Indeed, so far as I could discover, no equivalent of the "Northern Lignite," the lowermost member of the Eocene of Hilgard's Mississippi section, exists in the region round about Laredo, unless the coal-bearing strata of the upper portion of the Laramie are really its equivalent. I am disposed to accept this view of the case and to regard the Northern Lignite of the Mississippi section and its equivalent elsewhere, including the uppermost strata of the Laramie, as really of Eocene age.

The view above expressed was entertained by White when he published his correlation paper on the Cretaceous in 1891.[64] He said:

> The Laramie formation prevails over a large part of the Great Interior area, but within the Texas region it has been recognized only in western Texas, and it has hitherto

[62] White, C. A., On the relation of the Laramie group to earlier and later formations: Am. Jour. Sci., 3d ser., vol. 35, pp. 432-438, 1888.

[63] Cope, E. D., Am. Philos. Soc. Proc., vol. 3, p. 615, 1884.

[64] White, C. A., U. S. Geol. Survey Bull. 82, p. 117, 1891.

been observed there only in the valley of the Rio Grande and in that of the Nueces River, but there seems to be little room for doubt that the lignite beds of eastern Texas, as well as those of the State of Mississippi, which are usually regarded as of early Eocene age, are really equivalent to the upper part of the Laramie.

The presence of the Laramie formation in western Texas, so confidently proclaimed by White, has not been confirmed by subsequent workers in this field; in fact, in the year following the publication of his paper above mentioned, Penrose[65] in a way laid the foundation for a quite different interpretation of the section. In speaking of the Cretaceous along the Rio Grande he said:

It may be said, however, that Cretaceous fossils have been found at Eagle Pass, and from there down the river to the Webb County line are found great quantities of ammonites and other fauna of that epoch. In fact, it is not until we reach a point 3 miles below the northwest corner of Webb County that true Tertiary (or Laramie) forms are found.

In 1892 Dumble[66] studied this same section, concerning which he wrote as follows:

From this point [10 miles below Eagle Pass] to the falls of the Rio Grande, just above the Webb County line, the exposures are but repetitions one of another—brown, buff, blue, or green clays, with sandstones, sometimes friable and sometimes so indurated as to be semiquartzites. Abundant fossils, consiting of ammonites (*Placenticeras*), oysters, and gastropods, are found. The rapids (or falls of the Rio Grande), which continue almost to the line between the two counties, are formed by the edges of some of these ammonite-bearing beds as they pass below water level. From this point to the Webb Bluff, a distance of 3 miles, no fossils were found; but there was no change in the lithologic character of the rock materials, nor could the clays at the base of the Webb Bluff section be distinguished in any way from those observed at the rapids above. * * * We have, therefore, only 3 miles in which there can be any room for deposits intermediate between strata containing fossils of recognized and decisively Cretaceous forms and those containing marine Eocene forms. The average dip does not exceed 100 feet per mile, and we saw nothing in any of the exposures on either bank of the river in this space to indicate a change until we reached Webb Bluff itself.

In 1900 Vaughan,[67] in a paper entitled "Reconnaissance in the Rio Grande coal fields of Texas," discussed the Cretaceous-Eocene contact along the Rio Grande. He agreed with White, Penrose, and Dumble that there is no sharp lithologic line between the Cretaceous and Eocene; in fact, no actual contact had been discovered up to that time. Vaughan added:

The principal result of the writer's work on the Rio Grande was in proving the existence of Eocene fossils some 3 or 4 miles above the Webb-Maverick county line, 6 or 7 miles above where Penrose and Dumble first found such fossils. The fossils obtained here are typical lower Eocene.

In 1911 Dumble[68] published additional remarks on the Cretaceous-Eocene contact along the Rio Grande, in which he stated that the contact is "well shown below Toro Colorado, just above the falls of the Rio Grande and on Caballero Creek."

In the fall of 1912 L. W. Stephenson[69] made investigations in Maverick County, Tex., which, he said, "resulted in the exact determination of the Cretaceous-Eocene contact along the river [Rio Grande] and the approximate determination of the outcrop of the contact northward through the county." He found the contact at a point on the Rio Grande below White Bluff, about 5 miles above the Webb County line. At this point the undoubted Upper Cretaceous beds, known as the Escondido formation, are overlain unconformably by undoubted marine Eocene, the contact between them being sharp and slightly undulating.

The results above set forth appear to settle conclusively the fate of the Laramie of western Texas as advocated by White. The highest Cretaceous beds of the region are known as the Escondido formation and correspond approximately to the Fox Hills of the Rocky Mountain area and the Ripley formation of the Gulf coast. Above the Escondido formation are the beds referred by White to the Laramie, but all recent workers in the field agree that they are undoubtedly Eocene. The lowest is the Midway formation, above which is the Wilcox formation, which in turn is overlain, at least in certain areas, by the Claiborne or upper Eocene.

NORTHERN MEXICO.

So far as I know C. A. White was the first to announce that the Laramie is present in northern Mexico, a conclusion which of course followed from his supposed identification of this

[65] Penrose, R. A. F., jr., Texas Geol. Survey First Ann. Rept., pp. 38-41, 1889.

[66] Dumble, E. T., Geol. Soc. America Bull., vol. 3, pp. 228, 229, 1892.

[67] Vaughan, T. W., U. S. Geol. Survey Bull. 160, pp. 35 et seq., 1900.

[68] Dumble, E. T., Rediscovery of some Conrad forms: Science, new ser., vol. 33, p. 971, 1911.

[69] Stephenson, L. W., The Cretaceous-Eocene contact in the Atlantic and Gulf Coastal Plain: U. S. Geol. Survey Prof. Paper 90, pp. 155-182, 1915.

horizon along the Rio Grande in adjacent Texas. In a paper published in 1883 [70] he mentioned a small collection of invertebrates obtained at a point about 7½ miles northwest of Lampazos, in the State of Nuevo Leon. He enumerated seven species, as follows:

Ostrea wyomingensis Meek.
Anomia micronema Meek.
Modiola regularis White?
Corbula subundifera White.
Corbicula cytheriformis Meek and Hayden?
Odontobasis buccinoides White.
Melania wyomingensis Meek.

Concerning these invertebrates White said:

This Mexican collection, so far as it goes, is an almost exact duplication of the Laramie molluscan fauna of the Bitter Creek series as found at Rock Springs, Point of Rocks, and Black Buttes, in southern Wyoming, points which are more than a thousand miles north of the Mexican locality.

The collection of invertebrates above listed is not now known to be in existence, but other similar material, collected later at or near the same locality by White, is preserved in the United States National Museum. I am informed by T. W. Stanton, in whose custody this material now is, that he does not accept all these identifications as being correct, and further, certain of the species have so great a known vertical range as to render them of slight stratigraphic value. The comparisons that White made between the Mexican specimens and the fauna of the "Bitter Creek series" shows that at least two horizons were then confused as Laramie.

In 1888, in an article already mentioned, White [71] again referred to this Mexican locality, writing as follows:

Going westward from Laredo to Lampazos in Mexico I was able to recognize the Eocene strata for a distance of about 20 miles, beyond which the underlying rocks are so fully obscured by the débris of the plain that no exposures were observed until the neighborhood of Lampazos was reached. The known presence of Laramie strata a few miles to the northward of Lampazos, which bear characteristic molluscan fossils of that formation, however, leaves no room for doubt that the Laramie is overlaid by the Eocene upon the Mexican side of the Rio Grande, just as it is upon the Texan side.

This view was still entertained by White [72] when he published his correlation essay in 1891, for we find him saying:

The Laramie, which is such an important formation in the two interior regions, is also an important one in the north Mexican region, especially in the States of Chihuahua, Coahuila, and Nuevo Leon. Its presence in the first-named State has just been mentioned, and it is also well developed in the Sabinas Valley, in Coahuila, where it is an important coal-bearing formation.

It has also been recognized by its characteristic fossils as far south as the vicinity of Lampazos, in the State of Nuevo Leon. In this State, near to the Rio Grande, as well as on the Texan side of that river, it has been found to rest upon the equivalent of the Eagle Pass beds and in turn to pass by a gentle southerly dip beneath the marine Eocene beds which occur there.

The stratigraphic relation of the Laramie to the immediately underlying Cretaceous formation is quite as intimate in the north Mexican region as it is elsewhere. The two formations appear to have been the result of continuous sedimentation, their interdelimitation being marked only by a material change in the paleontologic character of the strata.

For a decade or more after the above-recorded investigations by White comparatively little work bearing on the question under consideration was done in northern Mexico. As late as 1905, however, the Mexican geologists appear to have followed White in recognizing the presence of Laramie. Thus Aguilera,[73] in discussing the stratigraphy and structure of the State of Coahuila, accepted the Laramie and described it as consisting of glauconitic sandstones with impressions of plants and silicified wood. He placed it as equivalent to the upper part of his Esperanzas beds and above what has been called Eagle Pass formation in the Texan section.

E. T. Dumble has published several papers on the geology of northern Mexico, though relating mainly to the Tertiary part of the section. In one [74] he wrote of having traced the Cretaceous-Tertiary contact from Caballero, on the Rio Grande, to Rainones, 40 miles east of Monterey. The uppermost Cretaceous strata he referred to the Escondido formation.

The conclusions reached concerning the present disposition of the beds in western Texas

[70] White, C. A., Late observations concerning the molluscan fauna and the geographical extent of the Laramie: Am. Jour. Sci., 3d ser., vol. 25, pp. 207-209, 1883.

[71] White, C. A., On the relation of the Laramie group to earlier and later formations: Am. Jour. Sci., 3d ser., vol. 35, p. 433, 1888.

[72] White, C. A., Correlation papers—Cretaceous: U. S. Geol. Survey Bull. 82, pp. 138 et seq., 1891.

[73] Aguilera, J. G., Les gisements carbonifères de Coahuila: Cong. géol. internat., 10e sess., Guide des excursions, Mexico, No. 27, pp. 1-17, 1906 [1907].

[74] Dumblé, E. T., Tertiary deposits of northeastern Mexico: Science, new ser., vol. 33, pp. 232-238, 1911.

that were formerly referred to the Laramie apparently apply with equal force to the similar beds in adjacent Mexico. That is to say, there is every reason to believe that the Eocene beds immediately above the Cretaceous line, which on the Texas side of the Rio Grande are referred to the Midway, continue without much if any change to the Lampazos region, in the the State of Nuevo Leon. Similarly, the beds in the coal-bearing area of northern Coahuila, south of Eagle Pass, are presumably the same as or similar to the coal-bearing series in the Eagle Pass region along the Rio Grande. According to my knowledge and belief the Laramie is not present in Mexico, or if there its presence must be demonstrated according to modern standards established for the recognition of this formation.

JUDITH RIVER FORMATION.

The Judith River beds, in the vicinity of the mouth of Judith River, Mont., have been the subject of prolonged discussion and difference of opinion, and even at the present time there are some geologists who do not consider the question of age conclusively settled. As this question comes only incidentally into the present discussion, it is not necessary to go freely into the early history of opinion, especially as this has been so thoroughly covered up to 1905 by Stanton and Hatcher.[75]

At first Leidy's studies of the vertebrates inclined him to refer these beds to the Jurassic (Wealden). The invertebrates then known (1856) proved very puzzling. At one time they were considered by Meek and Hayden as possibly lowest Cretaceous, though they were described as Tertiary, and ultimately Meek considered it highly probable that they are Cretaceous. Marine beds immediately below the Judith River beds were identified as Fox Hills, and the beds immediately above as Fort Union. Cope, in 1875, from his extensive studies of the vertebrates, referred the beds to the uppermost Cretaceous but stated that the fauna has "some Tertiary affinities." By the time the Laramie was established by King, it had come to be generally accepted that the Judith River beds were stratigraphically and paleontologically in the proper position demanded by the definition of the Laramie, and hence we find C. A. White[76] referring to them as one of the subordinate groups or regional divisions of this group, as it was then called. He said (p. 865):

> The proof of the identity of these widely separated portions of the Laramie group consists in the recognition of various species of fossil mollusks in all of them that are found in some one or more of the others, thus connecting the whole by faunal continuity.

So far as the Judith River is concerned the above disposition was consistently held by White in all his subsequent publications, and the subject continued practically without essential change until 1905, when Stanton and Hatcher published the paper above mentioned. As the result of their studies in the original Judith River area, as well as in adjacent areas in northern Montana and along Milk River in Canada, they reached the conclusion that the Judith River formation is of Montana age and the equivalent of the Belly River beds of Canada. Their stratigraphic results and correlations are displayed graphically in the following section:

South Dakota.	Central and northern Montana.
Laramie.	Laramie (?).
Fox Hills.	Fox Hills (?).
Pierre.	Bearpaw. Judith River. Claggett. Eagle.

The Fox Hills and Laramie formations were not definitely identified by them in Montana.

The above interpretation regarding the Judith River was brought in question by A. C. Peale[77] in a long article published in 1912, in which he contended that there are two formations lithologically similar that have been confused, one being in the position of the Belly River and preferably to be called by that name, and the other—the real Judith River—being later than Fox Hills and probably to be re-

[75] Stanton, T. W., and Hatcher, J. B., Geology and paleontology of the Judith River beds: U. S. Geol. Survey Bull. 257, 1905.

[76] U. S. Geol. and Geog. Survey Terr. Bull., vol. 4, p. 721, 1878.

[77] On the stratigraphic position and age of the Judith River formation: Jour. Geology, vol. 20, pp. 530-549, 640-652, 738-757, 1912.

garded as equivalent to the lower part of the Lance formation.

Peale's view was essentially sustained by Charles H. Sternberg, in a short paper published in Science for July 25, 1914, based on the recollection of 30 years before, when he had assisted Cope in collecting the vertebrate forms that later came into prominence in connection with this problem. In 1914, however, Sternberg again visited the region about the mouth of Judith River and completely reversed his conclusions as to the Tertiary age of the beds in question.[78]

The latest and most authoritative statement is that published by C. F. Bowen [79] in 1915, which presented the result of several seasons' work in this and adjacent areas. In general Bowen agreed with the statements of Stanton and Hatcher, namely, that the Judith River is the equivalent of the Belly River of Canada and is of Montana age. He recognized, however, that there was possibly some mixing of horizons in the earlier collections of vertebrate remains, as I pointed out [80] in regard to the turtles, and said that to this may be due the confusion that has resulted. Bowen wrote as follows:

> The extensive faulting that has disturbed the strata along Missouri River renders it possible, though it is not extremely probable, that blocks of the Lance formation may be faulted down among the beds of Judith River age and that some of the vertebrates collected by Hayden and others "from the badlands of the Judith" may have been obtained from the Lance formation instead of the Judith River formation, as they supposed.

The results obtained by Bowen, as set forth above, were essentially duplicated by Stebinger [81] in his work farther west in Montana, though he did not find it possible to recognize all the units present at the mouth of Judith River.

It therefore seems settled that the Judith River formation is not to be regarded as of Laramie age.

[78] Science, new ser., vol. 42, p. 131, 1915.

[79] Bowen, C. F., The stratigraphy of the Montana group, with special reference to the position and age of the Judith River formation in north-central Montana: U. S. Geol. Survey Prof. Paper 90, pp. 95–153, 1915.

[80] Knowlton, F. H., Remarks on the fossil turtles accredited to the Judith River formation: Washington Acad. Sci. Proc., vol. 13, pp. 51–65, 1911.

[81] Stebinger, Eugene, The Montana group of northwestern Montana: U. S. Geol. Survey Prof. Paper 90, pp. 61–68, 1914.

BEAR RIVER FORMATION.

The Bear River formation, as it is now called, has given rise to almost as much discussion and difference of opinion as the Judith River formation, just mentioned. It comprises a series of purely fresh-water strata of considerable areal extent, mainly in the valley of Bear River in southeastern Wyoming and adjacent Idaho. With the exception of a few unidentifiable fragments of dicotyledonous leaves and a single species of *Chara*—a fresh-water alga—its only paleontologic contents known are numerous invertebrates of fresh-water types and a few brackish-water forms. On account of the supposed affinities of these invertebrates the beds containing them were at first, in 1860, and for many years thereafter referred with little hesitation to the Tertiary. Then, as certain differences came to be detected, it was hinted by Meek and others that the age might possibly be latest Upper Cretaceous instead of Tertiary, and when the Laramie was promulgated the Bear River beds were immediately mapped by King and others—in this convenient catchall. They came later to be known as the "Bear River Laramie."

In 1891 T. W. Stanton [82] was able to show that this formation, previously considered to be of Laramie or later age, is in reality intermediate between the Jurassic and the Colorado Cretaceous. Of its thirty or more species of invertebrates none have been found in the true Laramie. Thus another supposed Laramie area has been eliminated. The complete historical summary of opinion regarding the Bear River formation may be found in two papers by C. A. White,[83] published in 1892 and 1895, to which the reader desiring further details is referred.

PRESENT USAGE OF THE TERM LARAMIE.

The term Laramie, as originally established by King, seemed to have a very definite signification and delimitation, but during the 40 years after it was first defined it had come,

[82] The stratigraphic position of the Bear River formation: Am. Jour. Sci., 3d ser., vol. 43, p. 98, 1892.

[83] On the Bear River formation, a series of strata hitherto known as the Bear River Laramie: Am. Jour. Sci., 3d ser., vol. 43, pp. 91–97, 1892; The Bear River formation and its characteristic fauna: U. S. Geol. Survey Bull. 128, 1895.

through faulty interpretation, mistaken stratigraphic identification, and general looseness of application, to have a somewhat varying and vicarious usage. It was undoubtedly established by King as a formational term, although, owing to lack of definiteness in stratigraphic nomenclature current then and later, it was sometimes alluded to as the "Laramie group," the "Laramie series," etc. As an instance of this latitude in the usage of the term, mention may be made of a recent textbook of geology, in which "Laramie series" is applied to all the beds between the Montana and the Fort Union, while "Upper Laramie" and "Lower Laramie" or "Laramie proper" are applied, respectively, to the beds above and below the unconformity first shown by Cross to exist in the Denver Basin. It has been and indeed to some extent still is the custom among vertebrate paleontologists to employ Laramie as a group term, applying it collectively to the beds containing the well-known ceratopsian fauna, such as the Arapahoe, Denver, and Lance. In the Canadian provinces Laramie is used practically as it was established by Dawson, Tyrrell, and others, namely, as a group term including the Edmonton (lower) and Paskapoo formations. The Edmonton is sometimes called "Lower Laramie," and the Paskapoo "Upper Laramie."

In the present work the usage established in the United States Geological Survey is followed. Laramie is considered as a formational term, and the Laramie formation is defined in accordance with the original definition of King, namely, as the uppermost member of the conformable Cretaceous series above the Fox Hills. This usage not only brings the term into harmony with the original application but places it in accord with most recent interpretation and obviates the confusion and looseness that must inevitably result from using it as a group term. If, as has been recently suggested, Laramie were to be employed as a group term it would involve the anomalous condition of embracing portions of two geologic systems which are separated by an unconformity that is believed by many to be one of the most important in the whole Rocky Mountain section. If a group term is needed for the several recognized formations containing the *Triceratops* fauna, it has already been supplied by Cross,[84] who has proposed for them the term Shoshone group, which is "defined as embracing the lacustrine, fluviatile, or terrestrial deposits, composed of detritus from the rising land area of the Rocky Mountain province, formed between the Laramie and Fort Union epochs."

IS THERE A TYPE SECTION FOR THE LARAMIE?

In the refinement of modern geologic methods it is considered essential that a type section be designated when a new formational or other stratigraphic unit is proposed, though it not infrequently happens that subsequent study discloses the fact that what was described as "typical" is a more or less incomplete expression of what the unit under consideration is found ultimately to represent. Concerning this point Ulrich [85] said:

> No local section contains within itself the data required for anything approaching a final classification of its component parts. This becomes possible only when exhaustive comparisons with many other near and far sections have been made. * * * The divisions are seldom drawn with due regard to the organic and diastrophic histories of the several beds.

At the time of the early work in the Rocky Mountain region, which resulted in the establishment of many of the stratigraphic units that have since become so widely known, appreciation was not so keen as to the necessity of tying such units to a definite type section, though even then the practice varied among the several geologists who were prominent in this field. The naming of the Laramie offers a case in point. It appears that it was the usual custom of King, who named and established the Laramie, to designate more or less definitely a type section or locality for each stratigraphic unit that he established. For the Laramie, however, he failed to do this specifically, though there was not then nor is there believed to be now any valid doubt as to just what he had in mind.

This state of affairs led Veatch [86] some years ago to make a critical historical study of

[84] Cross, Whitman, The Laramie formation and the Shoshone group: Washington Acad. Sci. Proc., vol. 11, pp. 27-45, 1909.

[85] Ulrich, E. O., Revision of the Paleozoic systems: Geol. Soc. America Bull., vol. 22, p. 387, 1911.

[86] Veatch, A. C., On the origin and definition of the geologic term "Laramie": Jour. Geology, vol. 15, pp. 526-549, 1907; abstract under same title in Am. Jour. Sci., 4th ser., vol. 24, pp. 18-22, 1907.

various direct and collateral data which might be expected to afford some conclusion regarding what the term can and can not properly be used to designate. This study led Veatch to the conclusion that the Laramie Plains, and more specifically the vicinity of the town of Carbon, Wyo., should be considered as the type locality for the Laramie. He said:

The name "Laramie" is derived from the Laramie Plains, in eastern Wyoming. As commonly used in the early seventies, this included the plains region extending from the Front Range to and slightly beyond the North Platte River.

The most important locality on the Laramie Plains at this time was Carbon. * * * It was the only locality on the Laramie Plains where the King Survey critically examined and distinctly delimited the Laramie beds.

It was the practice of the King and Hayden surveys to name formations and groups from localities where the beds were regarded as typically exposed. While King and Hayden did not always definitely state that a name was derived from a certain locality, the source of the name can in all cases be completely inferred from the context.

Veatch then proceeded to argue that if the name was derived from the Laramie Plains, and if Carbon as the place best known at that time is taken as the type locality, it then follows that the term Laramie has been incorrectly applied for all these years, as it is now disclosed that only the beds above the great unconformity are exposed in that vicinity.

This question has been so thoroughly reviewed by Whitman Cross [87] in his paper on "The Laramie formation and the Shoshone group" that the following extended quotation is made:

As to the origin of the term Laramie Mr. Veatch points out that Clarence King, who proposed the name and defined its application, was very careful in the choice of appropriate geographic formations. That is undoubtedly true in a general way; still King was not working under any such rule as that now prevailing in the United States Geological Survey. Much space is given to establishing by citations the exact application of the name Laramie Plains in the seventies, and to showing that sections of "Laramie" beds examined by the Hayden and King geologists were probably all above the unconformity seen at Carbon. * * * If the term Laramie had been in fact proposed especially for strata of the Laramie Plains, or even for a formation known by King and Hayden only in the zone traversed by the Union Pacific Railroad or the fortieth parallel in Wyoming, it is probable that many stratigraphers would agree with the sweeping conclusion that "strictly considered, the term Laramie, therefore, can appropriately be applied only to the beds above the great unconformity." * * * But the name was not so proposed. It was introduced into literature and defined by King as a compromise term for beds known to be widely distributed from Montana to New Mexico. The statement made by King is very clear as to the desire of Hayden and himself to have a name which each could use for a great series of supposedly conformable beds, without prejudice as to age. Laramie was practically proposed as a synonym for "Lignitic," but not as an exact one, for the term had been very broadly used by Hayden and others.

There is not the slightest doubt as to the fundamental stratigraphic relations which King and Hayden thought characteristic of the Laramie. In all statements quoted and in others which might be cited the relation most strongly emphasized in regard to the Laramie is its conformity with the underlying Cretaceous beds. King believed the Laramie to be Cretaceous; Hayden thought it transitional between Cretaceous and Tertiary. King believed that Mesozoic sedimentation ended by reason of a great Rocky Mountain revolution and that the Laramie was separated from the lowest Eocene beds, erroneously supposed by him to be the Wasatch, by a marked unconformity. * * *

The Laramie of King's conception was a natural stratigraphic unit with a well-defined base to be found in many places, but with an upper theoretical limit which might nowhere be represented, owing to the assumed pre-Tertiary erosion. It was to embrace the upper group of conformable Cretaceous sediments, deposited in brackish or fresh waters during gradual continental uplift.

The same ground was taken by A. C. Peale [88] in a paper published a few months after that by Cross. As Peale was a member of the Hayden Survey at the time the Laramie was established and was of course familiar with all the details connected with it, his testimony is especially valuable. Concerning a type locality for Laramie he said:

There was no type locality so far as we [members of the Hayden Survey] were concerned, nor was there any such idea in the mind of Hayden. He proposed the name partly because it was a euphonious name and a broad one as he conceived it, the beds outcropping not only in the Laramie Plains but also on both sides of what was then sometimes known as the Laramie Range and also in the vicinity of the Laramie River. It was also proposed by him partly out of compliment to Clarence King, who was then working in what Hayden termed the Laramie Plains, he using the term in its very broadest sense as reaching from the Laramie Range to the Wasatch Range.[89] * * * It was intended that the name should cover all localities in which the beds occurred. If any localities should be considered as typical localities they would be those mapped by us along the Front Range in eastern Colorado and by King along the range in Wyoming. That Clarence King

[87] Washington Acad. Sci. Proc., vol. 11, p. 29, 1909.

[88] On the application of the term Laramie: Am. Jour. Sci., 4th ser., vol. 28, pp. 45-58, 1909.

[89] Cf. Hayden, F. V., U. S. Geol. Survey Wyoming Rept., 1870, p. 121, 1871.

had no type localities of the Laramie Plains in his mind is also evident from the fact that immediately following his definition of the Laramie he gives as localities of its occurrence the following in eastern Colorado, just north of the area in which the Hayden Survey was at work:

Parks Station, Colo.
6 or 7 miles west of Carr's Station, Colo.
West of Greeley, Colo.
Crow Creek, Colo.
Platteville, Colo.

These were followed by references to "good exposures of Laramie" east of Separation and at other localities along the line of the Union Pacific Railroad in northwestern Colorado. It is interesting to note that Carbon, Wyo., does not appear in the list, and that Carr's Station is only about 24 miles east of the lower end of the Laramie Hills, while the other localities are within short distances of the east and southeast of the mountains.

Further quotations might be made from the writings of King and others in support of the contention above made by Cross and Peale, but they are hardly necessary, as it would seem to be established beyond reasonable question that no type section was named or intended for the Laramie, and it is still clearer that it was not intended to make Carbon and the Laramie Plains such a locality. It has been contended by some geologists that the original delimitation of the Arapahoe and Denver formations from the supposedly continuous Laramie section constituted a virtual redefinition of the Laramie, but this ground does not seem well taken, for the essential part of King's definition—namely, that it is the uppermost member of the conformable Cretaceous series above the Fox Hills—is maintained. This view was further emphasized by Cross,[90] who said:

Although the Laramie was simple in its essential definition and conception, the strata referred to it included local deposits as well as those of wide distribution, and knowledge concerning some of these beds was very meager and untrustworthy when the group was established. It is a most natural result of detailed studies during the last 30 years that several formations at the top of the group assumed to have the relations embodied in King's definition have been found to possess other relations. But there is still a large formation answering to the fundamental part of King's definition, and to such beds it seems to me both natural and most expedient to apply the term Laramie in future. In the Laramie Plains there are, according to Veatch, 6,500 feet of conformable Cretaceous beds above the Montana strata and below the break at the base of the Carbon beds. The geographic term is thus still appropriate, even if the Carbon section be excluded from the Laramie. The term has now been so widely applied and for such a long time that it appears unwise to drop it, even if there should be proved to be no true Laramie beds on the Laramie Plains.

[90] Cross, Whitman, The Laramie formation and the Shoshone group: Washington Acad. Sci. Proc., vol. 11, p. 31, 1909.

PART II. GEOLOGIC RELATIONS AND FLORA OF THE LARAMIE OF THE DENVER BASIN.

LITHOLOGIC AND STRATIGRAPHIC RELATIONS.

It is not my intention in the present connection to attempt a complete exposition of the lithology and stratigraphic relations of the Laramie in this area but simply to give enough of this history to serve as a setting for the paleobotanic data. One wishing to go thoroughly into this phase of the subject should consult the monograph on the geology of the Denver Basin,[91] from which much of the following brief account is condensed.

With the exception of a narrow belt along the foothills which is occupied by older formations, practically the entire Denver Basin is presumably underlain by the Laramie. As a surface formation it is confined chiefly to the northern portion of the basin and to a very narrow strip parallel with the foothills and at a distance from them of 1 or 2 miles. In this narrow belt the formation crops out in detached areas separated by overlapping deposits and extends from a point a few miles north of Denver to the vicinity of Colorado Springs. The beds are steeply tilted eastward along the foothills, but the dip becomes less toward the east, and in the central part of the basin, where the beds lie almost flat, the Laramie is covered by the Arapahoe, Denver, and Dawson formations.

The Laramie is the youngest Cretaceous formation in the Colorado Front Range region. It rests conformably on the Fox Hills sandstone, from which it is distinguished where in continuous outcrop by its lighter color and the presence in the topmost layer of the Fox Hills of numerous marine invertebrates.[92] In this area the Laramie was reported by the authors of the Denver Basin monograph to range in thickness between 600 and 1,200 feet, and Richardson, in the Castle Rock folio, reports a thickness of 1,200 feet in the foothill region to the south of Denver. Near Colorado Springs, the southernmost point at which the Laramie is recognized, the thickness is reduced to less than 400 feet.

According to Eldridge the Laramie is "divisible into two parts, a lower of sandstone and an upper composed of clay. The former has a uniform thickness of about 200 feet; the latter varies."[93]

In the lower division there are three persistent beds of sandstone, two of which occur at the base and have a thickness of approximately 60 feet, while the upper one has a thickness of 8 or 10 feet.

> The intervening ones not only disappear but vary in the horizon at which they occur. The coal beds also vary, one of several seams being workable at one locality and another in another.
>
> The sandstones are white and are composed almost exclusively of quartz, clear and opaque white. The material is somewhat loosely held together by cement, usually white but occasionally tinged brown by iron oxide.

In the upper division the thickness,

> owing to uneven denudation from the top, varies between 400 and 1,000 feet. The strata are chiefly clays, through which are distributed small lenticular bodies of sandstone, innumerable concretionary ironstones from 2 to 4 feet in diameter, and narrow local seams of impure lignitic material. One or two beds of lignite are also present in its upper portion east of Denver.

The interpretation embodied in this quotation was generally accepted prior to 1915, and the coal formerly mined at Scranton, Colo., was believed to be in the upper division of the Laramie. In recent years certain fossil plants were collected near beds of coal which are supposed to be the same as the Scranton coals. These plants indicate Tertiary rather than Cretaceous age.

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[91] Emmons, S. F., Cross, Whitman, and Eldridge, G. H., U. S. Geol. Survey Mon. 27, 1896.

[92] It was stated by Eldridge that none of these invertebrates were known to pass into the Laramie, but according to Henderson (p. 87) at least two brackish-water species (*Ostrea glabra* and *Melania wyomingensis*) are now found to be common to the contiguous portions of both formations.

[93] This division into a lower and upper part has been interpreted by some as comparable to the use of "Lower Laramie" and "Upper Laramie" by Veatch in describing the section in Carbon County Wyo., but a careful reading of Eldridge's context shows clearly that no such separation was implied or intended. I am informed by Mr. Cross, the only surviving author of the Denver monograph, that these divisions were made simply to show that the lower part is made up prevailingly of sandstones and the upper part of clays. There is not the slightest known evidence of an unconformity between them, and no stratigraphic or formational importance is to be attached to this use of "lower" and "upper."

During the summer of 1915 W. T. Lee obtained evidence that the Scranton coal beds are in the Denver formation rather than in an upper division of the Laramie. He obtained the record of a well put down near Sable station, on the Union Pacific Railroad east of Denver and a few miles west of Scranton. This well is more than 3,000 feet deep and penetrated the Scranton coal beds, the Arapahoe conglomerate, the Laramie formation, the Fox Hills sandstone, and nearly 1,500 feet of the underlying shale. The record seems to establish the following relations:[94]

1. The coal beds of the so-called upper division of the Laramie occur in the Denver formation 200 to 450 feet above the top of the Laramie.
2. At this point the Arapahoe conglomerate is 50 feet thick.
3. The Laramie formation is here 700 feet thick with one thick bed of coal at the base.
4. The sandstone which underlies the Laramie coal and which presumably represents the so-called basal sandstone of the Laramie and the sandstone at the top of the Fox Hills is here only 160 feet thick.
5. Below this Fox Hills sandstone the upper part of the sandy fossiliferous shale may be of Fox Hills age, but there seems to be no way of distinguishing this part from the Pierre shale.

ANIMAL LIFE OF LARAMIE TIME IN THE DENVER BASIN.

VERTEBRATES.

If we are to judge from the remains that have thus far been brought to light, animal life of all kinds was exceedingly rare in the Denver Basin during Laramie time. So far as I know only a single fragment of a vertebrate has been reported from beds supposed to be of Laramie age within this area. The occurrence of this specimen was described as follows by G. H. Eldridge:[95]

> The vertebrate, according to Prof. Marsh, belongs to the order Ornithopoda of the subclass Dinosauria. The genus is undetermined. The specimen was found by a ranchman about 30 feet below the surface, in a well sunk through the upper Laramie strata, on the slopes of Dry Creek, about 8 miles southwest of the town of Brighton.

This locality is apparently about 10 miles due north of Denver and according to the geologic map accompanying the Denver Basin monograph should fall within an area indicated as Laramie. The beds were thought by Eldridge to represent the upper part of the Laramie, but in the light of the results obtained by Lee (p. 103) only a few miles east of this Dry Creek locality, it seems more than probable that this supposed upper Laramie belongs to the Denver formation, in which case the bone came either from the Denver or the Arapahoe. A depth of only 30 feet below the surface would certainly not reach the Laramie and would probably place it in the Arapahoe, which is well known to contain vertebrate remains. Thus, to the uncertainty of the biologic interpretation of this fragment is added the indefiniteness of its stratigraphic position, and it can be dismissed as absolutely without value.

INVERTEBRATES.

The only remains of invertebrates recorded from the Laramie of the Denver Basin by Eldridge[96] are *Ostrea glabra* and *Unio* sp.?, determined by C. A. White. Eldridge said: "The occurrence of *Ostrea glabra* is general for the field and always at the same horizon, a short distance above the basal sandstones of the formation."

Beds held to be of true Laramie age have been found in the valley of Crow Creek, which is about 25 miles east of Greeley and between 40 and 50 miles north a little east of Denver, outside the strict limits of the Denver Basin as accepted in the Denver monograph. This region was visited by C. A. White[97] in 1877, while he was attached to the Hayden Survey.

[94] In a personal communication Lee states that the written log of the upper part of this well to a depth of 1,300 feet could not be obtained, but that the record of the beds below this depth is copied from the driller's notes. The upper part of the record is based on the independently procured statements of the driller and two other men who were sufficiently interested to keep themselves constantly informed of the progress of the well. The testimony of these three men agreed in all essential points. They were questioned particularly in reference to the Scranton coals and the conglomerate. The position of the beds of coal can not be reasonably doubted, as they crop out east of the well and are reported from numerous water wells in the vicinity of Sable. The conglomerate was described as consisting of pebbles of "quartz, flint, black diamonds," etc., the largest an inch or more in diameter. Some of the pebbles described as "black diamonds" had been preserved and appear to consist of black chert. In response to a query as to the number of the pebbles the statement was made that "bushels of them came out." Lee afterward visited the locality near Morrison where these beds crop out and found that the driller's description corresponded very closely with the beds as they are exposed at the surface. All things considered, the log seems to be as well authenticated as the average driller's record.

[95] U. S. Geol. Survey Mon. 27, p. 77, 1896.

[96] Op. cit., p. 78.

[97] Report on paleontological field work for the season of 1877: U. S. Geol. and Geog. Survey Terr. Eleventh Ann. Rept., pp. 163-175, 1879.

He wrote as follows concerning the stratigraphy and paleontology:

In this valley, as in all the plains region round about, the exposures of strata are not only few, but none of them are extensive. The most southerly exposure is about 10 miles from the mouth of the creek, and here I again recognized the oyster horizon, which has been mentioned twice before. The species mentioned before were found abundantly here, and many other molluscan species besides, in associated layers. I traced this fossiliferous horizon northward for a distance of 5 or 6 miles above the point where I first discovered it and found it to occupy nearly a uniform height above the level of the creek. The exposures are in the face of the low sloping hills that border the east side of the valley and are distant from the creek only from a few hundred feet to half a mile.

The full section of the strata constituting the valley side here was quite clearly ascertained, although the débris which prevails upon the plains has so obscured them in most places, even on the slope, that they were not all observable at any one point. The following is a record of the section as ascertained by measurements at several different points within the few miles that they were found exposed, as before stated:

Crow Creek section.

	Feet.
1. Sandy soil or débris of the plains	10
2. Grayish siliceous marl	5
3. Sandy and calcareous layers; with *Corbula*, etc	3
4. Soft sandy and argillaceous material; with *Ostrea* and *Anomia*	5
5. Arenaceous rock, somewhat concretionary; with numerous fresh-water forms	2
6. Arenaceous marly strata	20
7. Carbonaceous shale	6
8. Gray siliceous marl	6
9. Carbonaceous shale	3
10. Gray siliceous marl	25
11. Unexposed to the surface of the creek	5

No. 1 is the prevailing débris of the plains, which at top constitutes the sandy soil.

No fossils were found in No. 2, but it is evidently a part of a continuous deposit with those beneath. * * *

The following is a list of the fossils obtained from the different members of this section:

List of fossils from the valley of Crow Creek, Colo.

1. Anomia micronema Meek.
2. Anomia gryphorhynchus Meek.
3. Ostrea glabra Meek and Hayden.
4. Volsella (Brachydontes) regularis White.
5. Anodonta parallela White.
6. Unio ———?
7. Corbicula cleburni White.
8. Corbicula obesa White.
9. Corbicula cardiniaeformis White.
10. Corbicula (Leptesthes) subelliptica Meek and Hayden.
11. Corbicula (Leptesthes) fracta Meek.
12. Corbicula (Leptesthes) macropistha White.

List of fossils from the valley of Crow Creek, Colo.—Contd.

13. Corbicula (Leptesthes) planumbona Meek
14. Corbula subtrigonalis Meek and Hayden.
15. Bulinus disjunctus White.
16. Bulinus subelongatus Meek and Hayden.
17. Physa felix White.
18. Goniobasis gracilienta Meek and Hayden.
19. Goniobasis nebrascensis Meek and Hayden.
20. Melania wyomingensis Meek.
21. Viviparus prudentia White.
22. Tulotoma thompsoni White.
23. Campeloma multistriata Meek and Hayden.
24. Corydalites fecundum Scudder.

* * * * * * *

At a point about 18 miles east of Greeley I found the uppermost strata of the Fox Hills group in the south valley side of South Platte River, and from that point to about 6 miles farther eastward I continued to see small exposures of the same, most of which were obscure. I however recognized about 20 feet in thickness of strata, and the fossils, which were few and imperfect, were quite sufficient to indicate an exact equivalency of the strata containing them with those of the upper part of the section at the mouth of the St. Vrains. Besides these few characteristic invertebrate fossils, I also found fragments of the fucoid *Halymenites major* in one of the upper layers. The known general dip of the strata of all that region makes it practically certain that the Cretaceous strata pass beneath the level of the streams along a northward and southward line which may be drawn a couple of miles west of Greeley; that they receive a greater or less thickness of Laramie strata upon them beneath the débris of the plains. Then a gentle rise brings them up again to view in the valley of South Platte River, from 18 to 25 miles east of Greeley, as already mentioned. They seem then to pass again by a gentle easterly dip beneath the surface of the river, but I did not trace them farther, as my journey led up the valley of Bijou Creek. It is probable, however, that the exposures of these uppermost of the Fox Hills strata continue at the surface farther down the South Platte, in its immediate valley. Between Greeley and the point where these Cretaceous strata are exposed the space is no doubt occupied by at least a small portion of the strata of the Laramie group, which are covered with the débris of the plains, but I found no exposures of Laramie strata until I reached the valley of Bijou Creek, about 12 miles above its mouth. * * *

From the valley of Bijou Creek my investigations led me southwestward to Cherry Creek Plateau, during which I passed over the higher strata of the Laramie group, which come in the series between those that I found exposed near Bijou Station and the sandstones of the Monument Creek group that constitute the plateau. I found no fossils of any kind in these higher Laramie strata except silicified wood, which in some places was quite plentiful. It is possible that certain layers in this portion of the Laramie group contain invertebrate fossils, but the whole series in this region above the horizon of the fossiliferous layers of the Crow Creek and Bijou Creek sections is apparently destitute of invertebrate remains.

The whole thickness of Laramie strata which I thus passed over, from the uppermost layers of the Fox Hills group in the valley of South Platte River to the base of the Monument Creek group on Cherry Creek Plateau, is estimated at about 1,800 feet. So far as I could discover, only about the lower 200 or 250 feet of this series is known to contain invertebrate fossils; and the lower 700 or 800 feet appears also to contain all the coal of the Laramie group in this region.

This area was visited by T. W. Stanton and me in 1896,[98] and the thickest section found showed the invertebrates and plants through a distance of only 40 or 50 feet. The beds underlying the Laramie were at no place disclosed.

In this connection inquiry was made of Prof. Junius Henderson, of the University of Colorado, who is known to have an extensive knowledge of the geology of northeastern Colorado. In a letter to me Prof. Henderson states that after a very thorough exploration of this region he has not been able to fix the thickness of the Laramie section in this area with any degree of positiveness. He says: "On the whole I have no evidence that would show more than 100 feet of Laramie around Crow Creek, but my impression is that it is a little more."

It appears to have been thought by those who had previously visited this area that there was probably a considerable thickness of Laramie beds both beneath and above the Crow Creek exposures and, further, that these exposures should hold a position relatively high in the full Laramie section, as would naturally be inferred from their location far out on the plains and away from the mountains against which the Laramie is so steeply upturned. This view also finds some confirmation in the fact that only one of the species of invertebrates (*Ostrea glabra*) common on Crow Creek is known to occur in the Laramie of the Denver Basin. This was the view at first entertained by Prof. Henderson, but he states that his faith in the high position of the deposits on Crow Creek was shaken by the "finding of Fox Hills strata in geographically high positions on the divides and in the ravines far out from the mountains and in some instances unquestionably not far below fossiliferous beds of the Laramie."

Continuing, he says:

In the irregular cross-bedded sandstone on top of Wildcat Mound northwest of Platteville, within 40 feet of the Fox Hills sandstone, I found a thick bed containing great quantities of *Ostrea glabra*, with a few specimens which I have identified as *Corbicula cleburni* White, *C. fracta* Meek, *C. micropistha* White, and *Anomia micronema*. They were not very well preserved, but certainly they are correctly determined generically and I believe also specifically. The shales intervening between this stratum and the topmost sandstone of the Fox Hills is doubtless the same as that found between the Fox Hills and the coal beds at Windsor and elsewhere, but I have never been able to find any determinative fossils or ascertain whether or not it is marine. At Wildcat Mound *Halymenites major* occurs in both the marine and the *Corbicula* beds.

Going northward from Wildcat Mound to Milliken the upper Fox Hills sandstone thins out very much and is overlain by shales. From 100 to 150 feet up in the shale is a coal vein, but no fossils were found in this shale.

I also failed to find the *Ostrea-Corbicula* sandstone at Windsor, where the exposure of the strata overlying the uppermost sandstone of the Fox Hills is almost complete for a long distance, or at Indian Spring mine, north of Wellington, where such a sandstone if present would show in the slope between this sandstone and the coal.

Throughout the Crow Creek district, eastward to Wildcat Creek and Cottonwood Spring, I always found Corbiculas, etc., in contact with or beneath the lowest coal. On the divide some miles east of Crow Creek, near Greasewood Lake, southeast of Osgood post office, I found Fox Hills strata yielding *Lunatia*, *Tellina*, *Cardium*, *Dentalium*, *Mactra*, *Nucula*, *Baroda*, and *Halymenites*. Almost anywhere to the east, west, northeast, and north of Osgood *Ostrea glabra* and various species of *Corbicula* may be found, with coal seams, some of the fossiliferous beds being surely not many feet above the marine Fox Hills strata just mentioned.

At Cottonwood Springs, some 15 miles northeast of Orchard, I found a 4-foot bed of shale containing *Ostrea glabra*, *Anomia micronema*, *Corbicula cleburni*, *C. fracta*, *Corbula subtrigonalis*, and *Melania wyomingensis*. Thirty feet of shales immediately underlying this bed yielded *Nucula*, *Baroda*, *Cardium speciosum*, and *Turritella?*

I found Fox Hills strata again well up the west valley slope of Wildcat Creek, north of Fort Morgan. There I found *Vaniella humilis* and *Pholadomya subventricosa*, which usually are found at the base of and below the uppermost Fox Hills sandstone, together with *Tellina scitula* and *Lucina* sp. I found Fox Hills marine fossils in the bluffs and slopes of the South Platte Valley as far out as Canton, Weldon, and Messex.

From all the evidence now at hand I can not see how the lowest fossil horizon at Crow Creek can be, at most, more than 50 to 100 feet above the Fox Hills marine strata.

A critical analysis of the geographic and stratigraphic range of these Crow Creek invertebrates would be of considerable interest, but this is outside of my knowledge or the scope of the present report. I may simply note in passing that it appears to have been demonstrated that certain of the species present at Crow Creek have a very considerable vertical range,

[98] Stanton, T. W., and Knowlton, F. H., Stratigraphy and paleontology of the Laramie and related formations in Wyoming: Geol. Soc. America Bull., vol. 8, p. 151, 1897.

occurring in the Claggett and Judith River formations of Montana, the Belly River of Canada, the "Lower Laramie" of Carbon County, Wyo., the "Laramie" of Black Buttes, Wyo., the Mesaverde of Routt County, Colo., and of the Grand Mesa of northwestern Colorado, the Montana of the San Juan Basin, and other formations. Prof. Henderson, in the letter above mentioned, has the following to say regarding two of the species:

> One of the most abundant fossils on the east side of Crow Creek valley and thence well out on the divide to the east for miles is *Ostrea glabra*, which is also abundant in the Boulder district and in many places occurs in the Fox Hills beds as well as low in the Laramie. *Melania wyomingensis* also occurs 4 miles east of Boulder, in marine Fox Hills strata, though smaller than the exceedingly large specimens on the east side of Crow Creek.

AMBER IN THE LARAMIE OF THE DENVER BASIN.

Amber in minute quantities has long been known to be rather widely distributed in certain Upper Cretaceous strata of the eastern United States,[99] but so far as known to me it appears to be of extremely rare occurrence in other parts of North America. A small quantity from the Laramie at Marshall, Boulder County, Colo., has recently been reported by T. D. A. Cockerell.[1] Concerning it he wrote as follows:

> This locality produces much of the coal used in Boulder and has long been known to paleobotanists, having furnished important materials to Lesquereux many years ago. Perhaps the most interesting thing found was a small piece of amber embedded in the solid rock. It measures about 8 millimeters by 5.5 millimeters and is translucent orange-brown, darker than Baltic amber. It is practically insoluble in alcohol; a small fragment left in it over night was scarcely if at all diminished. In ether it eventually becomes opaque and friable.

In a footnote Cockerell states that "since the above was written we have found quantities of amber in the coal at Marshall. None of the pieces is of large size." The amber was searched for included insects, but so far without success.

The well-known Baltic or typical amber is the product of a coniferous tree, but coniferous remains are of extremely rare occurrence in the plant beds at Marshall, and it is quite impossible with the data at present available to ascertain the plant that produced the amber found there. As Cockrell stated, "Judging from the accompanying foliage, it is very probably not even the product of a conifer."

[99] Hollick, Arthur, The occurrence and origin of amber in the eastern United States: Am. Naturalist, vol. 39, p. 137, 1905. Berry, E. W., Coastal Plain amber: Torreya, vol. 7, p. 4, 1907. Knowlton, F. H., An American amber-producing tree: Science, new ser., vol. 3, p. 582, 1896.

[1] Amber in the Laramie Cretaceous: Torreya, vol. 9, p. 140, 1909.

Part III. THE LARAMIE FLORA.

BIBLIOGRAPHY OF PAPERS RELATING TO THE LARAMIE FLORA IN THE DENVER BASIN.

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Lesquereux, Leo, in Le Conte, J. L., Notes on the geology of the survey for the extension of the Union Pacific Railway, E. D., from the Smoky Hill River, Kansas, to the Rio Grande, pp. 47–53, Philadelphia, 1868.

Lesquereux, Leo, [Notes on fossil plants from lignite deposits of the West]: Am. Jour. Sci., 2d ser., vol. 45, pp. 198–204, 1868; copied without change in Hayden, F. V., U. S. Geol. and Geog. Survey Terr. [Third] Ann. Rept., p. 96, 1869; reprint, p. 196, 1873.

1873.

Lesquereux, Leo, Lignitic formation and fossil flora: U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, pp. 317–427, 1873. [See pp. 382–384 for description of plants from Marshall and Erie.]

1878.

Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, pp. 1–366, pls. 1–45, 1878.

Lesquereux, Leo, Catalogue of the Cretaceous and Tertiary plants of North America, with references to their descriptions: U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1876, pp. 487–520, 1878.

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1909.

Cockerell, T. D. A., Amber in the Laramie Cretaceous: Torreya, vol. 9, pp. 140–143, 1909.

1915.

Knowlton, F. H., in Richardson, G. B., U. S. Geol. Survey Geol. Atlas, Castle Rock folio (No. 198), p.7, 1915.

1919.

Knowlton, F. H., A catalogue of the Mesozoic and Cenozoic plants of North America: U. S. Geol. Survey Bull. 696, 815 pp., 1919.

LOCAL DISTRIBUTION OF THE FLORA.

Before proceeding to the discussion of the geologic, biologic, and ecologic relations of the Laramie flora comprised in the present work, it may be of some interest to enumerate the several localities together with the forms found at each place. The first Laramie plants made known to science were named and described by Leo Lesquereux.[2] They are given in the first of the following lists.

Marshall's mine, Marshall, Boulder County, Colo.:

- Lygodium compactum Lesquereux.
- Juglans rugosa Lesquereux.
- Quercus chlorophylla Unger.
- Quercus lyelli Heer.
- Cinnamomum affine Lesquereux.
- Acer, fruit of.
- Acer, leaves of.
- Rhamnus salicifolius Lesquereux.
- Cornus incompletus Lesquereux.
- Echitonium sophiae.
- Phyllites sulcatum Lesquereux.

Marshall's mine, Marshall, Colo.; collected by N. L. Britton for J. S. Newberry, about 1884:

- Sequoia acuminata? Lesquereux.
- Carpites marshallensis Knowlton, n. sp.
- Juglans praerugosa Knowlton, n. sp.
- Ficus coloradensis Cockerell.
- Ficus navicularis Cockerell.
- Ficus planicostata Lesquereux.
- Cinnamomum affine Lesquereux.
- Aristolochia brittoni Knowlton, n. sp.
- Dombeyopsis ovata Knowlton, n. sp.
- Phyllites marshallensis Knowlton, n. sp.

Railway cut between old and new stations, Marshall, Colo.; collected by A. C. Peale, 1908:

- Hicoria angulata Knowlton, n. sp.
- Hicoria minutula Knowlton, n. sp.
- Ficus impressa Knowlton, n. sp.
- Rhamnus salicifolius Lesquereux.
- Zizyphus minimus Knowlton, n. sp.
- Mimosites marshallensis Knowlton, n. sp.
- Dombeyopsis obtusa Lesquereux.

Dump of old Marshall mine, Marshall, Colo.; collected by A. C. Peale, 1908:

- Ficus impressa? Knowlton.

[2] [Notes on fossil plants from Rock Creek, etc.]: Am. Jour. Sci., 2d ser., vol. 46, p. 208, 1868; copied in Hayden, F. V., U. S. Geol. Survey Terr. [Third] Ann. Rept., p. 96, 1869 [reprint, p. 196, 1873.]

Dump of mine at west end of wooded bluff just south of Marshall, Colo.; collected by A. C. Peale, 1908:

Ficus arenacea Lesquereux.
Ficus impressa? Knowlton.
Dombeyopsis obtusa Lesquereux.

Marshall, Colo., railway cut at junction of Eldorado Springs branch of Colorado Southern Railroad:

Cyperacites, fragment.
Rhamnus salicifolius Lesquereux.

Marshall, Colo., west of wooded bluff just south of the town and above coal in an old opening; collected by A. C. Peale, 1908:

Ficus cockerelli Knowlton, n. sp.
Ficus coloradensis? Cockerell.
Cinnamomum affine Lesquereux.
Palm, gen. and sp.?

Marshall, Colo., half a mile south of railway station and in first draw north of white sandstone bluff, just above highest coal of the region; collected by F. H. Knowlton, 1908:

Sequoia longifolia Lesquereux.
Ficus coloradensis? Cockerell.
Ficus planicostata magnifolia n. var.
Ficus? impressa Knowlton, n. sp.
Artocarpus lessigii (Lesquereux) Knowlton.
Cassia laramiensis Knowlton, n. sp.

Marshall, Colo., wooded bluff just south of the town; collected by A. C. Peale, 1908:

Pteris? sp.
Dammara sp.
Cyperacites sp.
Salix wyomingensis Knowlton and Cockerell.
Ficus navicularis Cockerell.
Cinnamomum affine Lesquereux.
Malapoenna louisvillensis Knowlton, n. sp.
Rhamnus salicifolius Lesquereux.
Rhamnus marshallensis Knowlton, n. sp.
Rhamnus goldianus? Lesquereux.
Leguminosites? coloradensis Knowlton, n. sp.

Dump of mine at Erie, Colo.; collected by N. L. Britton for J. S. Newberry about 1884. This mine has long been abandoned, and when I visited it in 1908, I could not obtain even a scrap of a plant:

Anemia.
Ficus sp.?
Juglans newberryi Knowlton, n. sp.
Quercus eriensis Knowlton, n. sp.
Nelumbo tenuifolia (Lesquereux) Knowlton, n. comb.
Dombeyopsis? sinuata Knowlton, n. sp.
Dombeyopsis ovata Knowlton n. sp.
Dombeyopsis obtusa Lesquereux.
Ceanothus eriensis Knowlton, n. sp.
Rhamnus brittoni Knowlton, n. sp.
Rhamnus minutus Knowlton, n. sp.
Rhamnus salicifolius Lesquereux.
Celastrinites alatus Knowlton, n. sp.
Celastrinites eriensis Knowlton, n. sp.
Pistacia eriensis Knowlton, n. sp.
Pistacia hollicki Knowlton, n. sp.
Ilex laramiense Knowlton, n. sp.
Leguminosites columbianus Knowlton, n. sp.
Hedera lucens Knowlton, n. sp.

1¾ miles northeast of Erie, Colo.; collected by F. H. Knowlton and G. C. Martin, 1908:

Asplenium martini Knowlton, n. sp.

Railway cut near Superior, Colo.; collected by A. C. Peale, 1908:

Rhamnus salicifolius Lesquereux.

Dump of Rex mine No. 11, Louisville, Colo.; collected by A. C. Peale, 1908:

Sequoia longifolia Lesquereux.
Cyperacites sp.
Cinnamomum affine Lesquereux.
Malapoenna louisvillensis Knowlton, n. sp.
Ficus sp.
Zizyphus or Ceanothus sp., fragment of base.

Dump of Simpson mine, Lafayette, Colo.; collected by A. C. Peale, 1908:

Phanerophlebites pealei Knowlton, n. sp.
Sapindus-like fragment.

Coal Creek, Boulder County, Colo.; collected by N. L. Britton for J. S. Newberry about 1884:

Salix brittoniana Knowlton, n. sp.
Salix wyomingensis Knowlton and Cockerell.
Juglans laramiensis Knowlton, n. sp.
Ficus arenacea Lesquereux.
Ficus planicostata Lesquereux.
Ficus praeplanicostata Knowlton, n. sp.
Artocarpus liriodendroides Knowlton, n. sp.
Dombeyopsis obtusa Lesquereux.
Aristolochia brittoni Knowlton, n. sp.
Phyllites trinervis Knowlton, n. sp.

Murphy coal mine, on Ralston Creek, 5½ miles north of Golden, Colo.; collected by A. C. Peale, 1908:

Palm, gen. and sp.?
Ficus cockerelli Knowlton, n. sp.
Ficus navicularis? Cockerell.

Murphy coal bank, Ralston Creek, north of Golden, Colo.; collected by Arthur Lakes, 1890:

Carpites lakesii Knowlton, n. sp.
Palaeoaster similis Knowlton, n. sp.

Hoyt's coal mine, 1 mile south of Golden, Colo.; collected by Arthur Lakes, 1890:

Sabal montana Knowlton.
Phragmites sp.
Ficus arenacea Lesquereux.
Ficus cockerelli Knowlton, n. sp.
Ficus navicularis Cockerell.
Dombeyopsis obtusa Lesquereux.

Leyden Gulch, east of road to Boulder and 6½ miles north of Golden, Colo.; collected by A. C. Peale, 1908:

Cyperacites sp.
Cyperacites? sp.
Sabal montana Knowlton.
Juglans leydenianus Knowlton, n. sp.
Ficus cockerelli Knowlton, n. name.
Ficus navicularis Cockerell.
Ficus? leyden Knowlton, n. sp.
Cinnamomum affine Lesquereux.
Dombeyopsis sp. cf. D. trivialis Lesquereux.
Apeibopsis? laramiensis Knowlton, n. sp.
Phyllites leydenianus Knowlton, n. sp.
Apocynophyllum taenifolium Knowlton, n. sp.

Cut on Moffat railroad (Denver & Salt Lake) at crossing of road to Boulder, about 8 miles north of Golden, Colo.; collected by A. C. Peale, 1908:

Sequoia acuminata? Lesquereux.
Cyperacites sp.
Palm, gen. and sp.?
Juglans praerugosa Knowlton, n. sp.
Salix myricoides Knowlton, n. sp.
Ficus arenacea Lesquereux.
Ficus cockerelli? Knowlton, n. name.
Ficus neodalmatica Knowlton, n. sp.
Ficus navicularis Cockerell.
Ficus planicostata Lesquereux.
Cinnamomum affine Lesquereux.
Rhamnus? pealei Knowlton, n. sp.
Rhamnus salicifolius Lesquereux.
Phyllites sp.

1¼ miles west of Golden, Colo.; collected in 1881 by Lester F. Ward. A hard white sandstone showing the following forms:

Sabal montana? Knowlton.
Ficus crossii Ward.
Ficus arenacea Lesquereux.
Ficus cockerelli Knowlton, n. name.
Ficus navicularis Lesquereux.
Ficus planicostata Lesquereux.
Salix wyomingensis Knowlton and Cockerell.
Platanus platanoides (Lesquereux) Knowlton.

Half a mile west of Golden, Colo.; collected by Lester F. Ward, 1881:

Sabal montana? Knowlton, fragment only.

About 2 miles south of Golden, Colo,; collected by A. C. Peale, 1908:

Juglans praerugosa Knowlton, n. sp.
Platanus platanoides (Lesquereux) Knowlton.
Rhamnus salicifolius Lesquereux.

About 3 miles south of Golden, Colo.; collected by A. C. Peale, 1908:

Ficus navicularis Cockerell.

1½ miles south of Golden, Colo.; collected by A. C. Peale, 1908:

Ficus cockerelli Knowlton, n. name.
Ficus sp.
Zizyphus hendersoni Knowlton, n. sp.

Mount Carbon, Morrison, Colo.; collected by Arthur Lakes, 1890:

Dryopteris carbonensis Knowlton, n. sp.
Sequoia acuminata Lesquereux.
Phragmites sp.
Salix wyomingensis Knowlton and Cockerell.
Hicoria angulata Knowlton, n. sp.
Artocarpus lessigiana (Lesquereux) Knowlton.
Ficus? smithsoniana (Lesquereux) Lesquereux.
Ficus navicularis Cockerell.
Cinnamomum laramiense Knowlton, n. sp.
Rhamnus salicifolius Lesquereux.
Ceanothus ovatifolius Knowlton, n. sp.

Mount Carbon, Morrison, Colo.; collected by Arthur Lakes, 1890:

Phragmites sp.
Sequoia acuminata Lesquereux.

Cowan Station, south of Denver, Colo.; collected by F. H. Knowlton and A. C. Peale, 1908:

Ficus cowanensis Knowlton, n. sp.
Dombeyopsis obtusa Lesquereux.
Cornus praeimpressa Knowlton, n. sp.
Celastrinites sp.
Salix wyomingensis Knowlton and Cockerell.
Cinnamomum affine Lesquereux.
Populus? distorta Knowlton, n. sp.
Phyllites.
Zizyphus regularis Knowlton, n. sp.
Artocarpus lessigiana (Lesquereux) Knowlton.
Ficus pealei Knowlton, n. sp.
Anona coloradensis Knowlton, n. sp.
Cinnamomum laramiense Knowlton, n. sp.
Cornus sp.
Cyperacites sp.
Ficus apiculatus Knowlton, n. sp.
Rhamnus salicifolius Lesquereux.
Ficus praetenuinervis? Knowlton.
Palm, Sabalites sp.?

Old Franceville mine, 12 miles southeast of Colorado Springs, Colo.; obtained by A. C. Peale,[3] 1873, and identified by Lesquereux:

Sabal campbelli? Newberry=Sabal montana Knowlton?
Smilax grandifolia? Unger=Smilax? inquirenda?
Quercus sp.=?
Ficus spectabilis Lesquereux=Ficus denveriana?
Rhamnus cleburni Lesquereux=Rhamnus sp.
Paliurus sp.=Zizyphus coloradensis?

Near Old Franceville mine, 12 miles southeast of Colorado Springs, Colo., from sandstone overlying the main (lowest) coal, in south bank of creek 200 feet north of high-road bridge, near west line of sec. 19, T. 14 S., R. 64 W.; collected by A. C. Peale and M. I. Goldman, 1908 [No. 19]:

Cyperacites sp., fragments.
Myrica torreyi Lesquereux.
Ficus arenacea Lesquereux.
Ficus navicularis Cockerell.

Old Franceville mine, 12 miles southeast of Colorado Springs, Colo. [NW. ¼ sec. 24, T. 14 S., R. 65 W.]; collected by A. C. Peale and M. I. Goldman, 1908 [No. 18]. This is the same locality as that at which Peale made his collection in 1873, but as the mine has long been abandoned, only the following fragments could be identified:

Cinnamomum affine Lesquereux.
Ficus sp.?
Cissus? sp. (base only preserved).

Gehrung's coal mine, Popes Bluff, west of Pikeview, Colo.; collected by Leo Lesquereux,[4] 1872:

Sabal campbelli? Newberry=Sabal montana? Knowlton.
Platanus haydenii Newberry.
Ficus tiliaefolia (Al. Braun)=Ficus cockerelli?
Dombeyopsis obtusa Lesquereux=Dombeyopsis obtusa.

[3] South Park division [Colo.]: U. S. Geol. and Geog. Survey Terr. Rept. for 1873, pp. 203, 393, 1874.

[4] Lignitic formation and fossil flora: U. S. Geol. and Geog. Survey Terr. Rept. for 1872, pp. 326, 375, 1873.

Popes Bluff, west of Pikeview, Colo.; collected by A. C. Peale and M. I. Goldman, 1908:

- Pteris goldmani Knowlton, n. sp.
- Cyperacites? tessellata Knowlton, n. sp.
- Sabal sp. cf. S. montana Knowlton?
- Smilax? inquirenda Knowlton, n. sp.
- Juglans praerugosa Knowlton, n. sp.
- Juglans laramiensis Knowlton, n. sp.
- Myrica dubia Knowlton, n.sp.
- Ficus arenacea Lesquereux.
- Ficus denveriana? Cockerell.
- Ficus cockerelli Knowlton, n. name.
- Ficus navicularis Cockerell.
- Ficus planicostata Lesquereux.
- Cinnamomum affine Lesquereux.
- Rhamnus salicifolius Lesquereux.
- Rhamnus sp.
- Zizyphus coloradensis Knowlton, n. sp.
- Dombeyopsis obtusa Lesquereux.

Opposite sand-lime brick works, Pikeview, 4 miles north of Colorado Springs, Colo.; collected by A. C. Peale, 1908 [No. 24]:

- Anemia sp.
- Ficus arenacea? Lesquereux.
- Ficus navicularis Lesquereux.
- Ficus sp.
- Cinnamomum affine? Lesquereux.
- Rhamus salicifolius Lesquereux.
- Dombeyopsis trivialis? Lesquereux.
- Leguminosites laramiensis Knowlton, n. sp.

Crow Creek, about 25 miles northeast of Greeley, Colo.; collected by F. H. Knowlton and T. W. Stanton, 1896:

- Sequoia acuminata Lesquereux.
- Myrica torreyi Lesquereux.
- Platanus platanoides? (Lesquereux) Knowlton.
- Dombeyopsis obtusa Lesquereux.

DIFFICULTIES IN THE STUDY OF THE EARLIER COLLECTIONS.

Much difficulty has been experienced in studying the older collections from this region. For many years it was not supposed to be necessary to give more than a very general locality label—such as "Golden, Colo.," "near Denver, Colo.," as it was presumed that all the plant-bearing beds were of the same age. At first the age was given as "Lignitic" or "Colorado Lignitic," and later all the specimens were referred to the Laramie without distinction. However, when it was later demonstrated that two or even three distinct plant-bearing formational units may be present in the same section, confusion became confounded. It was the fusion of horizons, here and elsewhere, that for so long a time obscured and negatived any results that could be obtained by a study of the flora. Consequently, after the segregation of the Arapahoe and Denver formations from the Laramie, it naturally became of the greatest interest and importance to ascertain the extent to which the fossil flora confirmed this differentiation of horizons.

In the absence of original labels or other data by which the plants can be connected with a definite locality or horizon, there appear to be only two methods by which their position can be arrived at—(1) by a study of the lithologic characteristics of the matrix containing the fossils, or (2) by the collection of additional specimens from beds of known position. When Whitman Cross [5] established the Denver formation he recognized at once the necessity for making an examination of this kind, and consequently he made a careful study of the matrix of such of the Golden plants as were then available. Fortunately, nearly 90 per cent of the specimens on which Lesquereux based his work are preserved in the collections of the United States National Museum, and by studying the matrix of each species Cross was able to arrive at valuable results. As is now known, it is comparatively easy to distinguish between the quartzose sandstone of the Laramie and the peculiar yellowish-brown andesitic material of the Denver.

This study by Cross was confined to the plants from Golden enumerated by Lesquereux in his "Tertiary flora" and "Cretaceous and Tertiary floras." These works together describe just 100 species from this locality, hence numbers express percentages. Cross was then able to find 79 species, of which he says:

> Eighteen occur in what is judged to be Laramie sandstone or shale, and 59 in distinct Denver beds of Table Mountain, while 7 occur in both rocks, and 9 cases are in doubt. Lesquereux gives horizons for 6 species that were not found. By combining these two sources of information we get probable indications for 76 per cent of the Golden fossil plants; 22 per cent came from true Laramie strata and 63 per cent from Table Mountain beds; 9 per cent occur in both formations.

A few years later Lesquereux [6] published a short paper entitled "Fossil plants collected at Golden, Colo.," in which he added 60 species to this flora. There is no mention in this paper of a definite horizon or of an exact

[5] The Denver Tertiary formation: Am. Jour. Sci., 3d ser., vol. 37, pp. 272–275, 1889.

[6] Lesquereux, Leo, Harvard Coll. Mus. Comp. Zoology Bull., vol. 16, pp. 43–59, 1888.

locality for a single species beyond the statement that they were collected at Golden and came from the Laramie. It was ascertained later from Arthur Lakes, who collected this material, that so far as he could recall all came from Table Mountain or Green Mountain, and that "none of them came from the proximity of the lower coal measures." This material is the property of Harvard University and has not been reviewed in the present connection, but I saw it casually some years ago and do not recall any specimens not preserved on the matrix characteristic of the Denver formation at Golden.

The difficulty, not to say danger, of relying implicitly on the matrix to separate collections of questioned stratigraphic position is well illustrated in the attempts made to locate the early collections from Coal Creek, east of Denver. (See p. 90.) This material is preserved on a very soft carbonaceous sandstone and was supposed to have come either from the extreme upper part of the Laramie or from the Arapahoe formation. Recent information derived from a study of the log of a deep well makes it probable that these Coal Creek plants did not come from either the Laramie or the Arapahoe, but from the Denver formation. The study of the matrix of these plants did not and could not settle the horizon with certainty.

Another source of difficulty in dealing with the older collections has arisen in the following manner: It was Lesquereux's custom to publish preliminary accounts, in the annual reports of the Hayden Survey and elsewhere, of the flora of various localities and formations. These included new species more or less adequately described and previously known species, some of them European, but when the formal presentation of the floras was made, as in "The Tertiary flora," or "The Cretaceous and Tertiary floras," certain of these species were merged with other forms and no synonymic record was made of such combinations. It is thus practically impossible now to determine the disposition that was made in such cases, and this explains why forms once reported as present in a flora are no longer accepted, or if admitted are so carefully qualified. A case in point is offered by *Cercis eocenica* Lesquereux. In 1873 this species was named and imperfectly described from "Erie mines, Boulder Valley,"[7] but so far as known it was not afterward alluded to by Lesquereux. It was never figured nor adequately characterized, nor is there known to be a specimen representing it. It was probably united with some other species, but if so there is no record of such transfer.

Another example is furnished by *Quercus lyelli* Heer, a European Tertiary form listed by Lesquereux[8] in his first account of the plants from Marshall, Colo. It was not mentioned again in this connection and has not been since identified from that locality.

Still another series of errors has come from the obvious mislabeling of localities. Under the system at present employed a locality number is placed on each specimen, and it is practically impossible to give a wrong locality, but in the earlier days a single detached label was all that accompanied a whole collection, which might comprise dozens or even hundreds of specimens. When such collections became mixed, as there is undoubted evidence to show that they sometimes did, the only possible way in which the forms can be allocated is by the matrix. If this is sufficiently distinct to be characteristic, the specimens can be separated with a fair degree of certainty, as, for example, when a specimen labeled "Table Mountain, Golden"—which should be in the Denver formation—is found preserved on the whitish arkosic sandstone known to belong to the Laramie of the region, or when a specimen preserved on the andesitic matrix characteristic of the Denver formation is labeled "Black Buttes, Wyo.," where there is a somewhat similar appearing yellowish sandstone, the error can be detected. When the matrix is the same or practically the same, the case is hopeless, and this is undoubtedly the cause for much erroneous distribution of species, both areal and vertical.

I have taken the trouble to explain at length certain of the difficulties encountered in evaluating the original collections. Many toilsome hours have been spent in trying to secure a rational treatment of this material, but even so, it is probably too much to assume that the

[7] U. S. Geol. and Geog. Survey Terr. Rept. for 1872, p. 384, 1873.

[8] Lesquereux, Leo, [Notes on fossil plants from Rock Creek, etc.]: Am. Jour. Sci., 2d ser., vol. 45, p. 208, 1868.

result is yet or ever will be entirely free from errors of the kind detailed above. This should not be interpreted, however, as meaning that all the older work was uniformly of poor quality, for it was not, but it was pioneer work, with all the handicaps incident to such work, and as such it is to be judged. Whether good or bad, it is the foundation upon which all subsequent effort must be built.

SYNONYMS AND CHANGES OF INTERPRETATION.

During the half century that the flora of the Laramie formation has been under consideration by geologists and paleontologists it has naturally happened that there have been many changes in nomenclature and in interpretation. As the literature is more or less widely scattered and difficult of consultation, I have thought it might be of use to have all these changes brought together. The users of this literature will have no difficulty in noting and collating the changes that have taken place by consulting the following alphabetically arranged list:

Acer, fruit and leaves of, Lesquereux, Am. Jour. Sci., 2d ser., vol. 45, p. 208, 1868; Hayden, U. S. Geol. and Geog. Survey Terr. [Third] Ann. Rept., p. 96, 1869 [reprint, p. 196, 1873]. Not subsequently recognized.

Anemia haydenii (Lesquereux) Cockerell=*Anemia elongata* (Newberry) Knowlton, n. comb.

Araucarites reichenbachi Geinitz=*Sequoia reichenbachi* (Geinitz) Heer.

Aspidium goldianum Lesquereux=*Dryopteris lesquereuxii* Knowlton, n. name.

Aspidium fischeri? Lesquereux, 1870=*Dryopteris laramiensis* Knowlton, n. name.

Aspidium (*Lastrea*) *pulchellum?* Heer, Lesquereux, 1870=*Dryopteris laramiensis* Knowlton, n. name.

Caulinites fecundus Lesquereux=*Onoclea fecunda* (Lesquereux) Knowlton.

Clathropodium mirabile (Lesquereux) Ward=*Cycadeoidea mirabilis* (Lesquereux) Ward.

Cornus incompletus Lesquereux, Am. Jour. Sci., 2d ser., vol. 45, p. 208, 1868; Hayden, U. S. Geol. and Geog. Survey Terr. [Third Ann. Rept.], p. 96, 1869 [reprint, p. 196, 1873]. Not described, figured, or subsequently referred to by Lesquereux.

Cornus orbifera Heer, Lesquereux=*Cornus suborbifera* Lesquereux.

Cunninghamites? sp. Knowlton, U. S. Geol. Survey Bull. 163, p. 29, pl. 5, fig. 3, 1900=*Sequoia longifolia* Lesquereux.

Cycadeoidea zamiostrobus Solms=*Cycadeoidea mirabilis* (Lesquereux) Ward.

Echitonium sophiae O. Weber. Lesquereux, Am. Jour. Sci., 2d ser., vol. 45, p. 208, 1868; Hayden, U. S. Geol. and Geog. Survey Terr. [Third] Ann. Rept., p. 96, 1869 [reprint, p. 196, 1873]. Not subsequently recognized from this locality [Marshall, Colo.].

Equisetum laevigatum Lesquereux=*Equisetum perlaevigatum* Cockerell.

Ficus irregularis (Lesquereux) Lesquereux=*Ficus coloradensis* Cockerell.

Ficus lanceolata Heer=*Ficus navicularis* Cockerell.

Ficus lanceolata Heer, U. S. Geol. Survey Bull. 152, p. 102, 1898=*Ficus arenacea* Lesquereux.

Ficus planicostata latifolia Lesquereux=*Ficus cockerelli* Knowlton, n. sp.

Ficus spectabilis Lesquereux=*Ficus denveriana* Cockerell.

Ficus spectabilis Lesquereux, in Peale, U. S. Geol. and Geog. Survey Terr. Rept. for 1873, pp. 203, 393, 1874 =*Ficus denveriana?* Cockerell.

Ficus tiliaefolia Al. Braun. Lesquereux, U. S. Geol. and Geog. Survey Terr. Rept. for 1872, pp. 326, 275, 1873 =*Ficus cockerelli?* Knowlton, n. sp.

Ficus uncata Lesquereux, Knowlton, U. S. Geol. Survey Bull. 152, p. 105, 1898=*Ficus crossii* Ward.

Goniopteris polypodioides Ettingshausen=*Dryopteris* (*Lastrea*) *polypodioides* (Ettingshausen) Knowlton.

Gymnogramma haydenii Lesquereux=*Anemia elongata* (Newberry) Knowlton, n. comb.

Juglans rugosa Lesquereux (in part)=*Juglans praerugosa* Knowlton, n. sp.

Juglans smithsoniana Lesquereux=*Ficus? smithsoniana* (Lesquereux) Lesquereux.

Lastrea (*Goniopteris*) *goldiana* Lesquereux=*Dryopteris lesquereuxii* Knowlton, n. name.

Lastrea (*Goniopteris*) *intermedia* Lesquereux=*Dryopteris laramiensis* Knowlton, n. name.

Lastrea (*Goniopteris*) *polypodioides* (Ettingshausen) Lesquereux, Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 57, pl. 4, figs. 11, 12, 1878=*Dryopteris* (*Lastrea*) *polypodioides* (Ettingshausen) Knowlton.

?Lastrea arguta Lesquereux, Am. Jour. Sci., 2d ser., vol. 45, p. 207, 1868=*Anemia supercretacea* Hollick.

Laurus ocoteoides Lesquereux=*Laurus wardiana* Knowlton.

Myrica? lessigiana Lesquereux=*Artocarpus lessigiana* (Lesquereux) Knowlton.

Myrica? lessigii Lesquereux=*Artocarpus lessigiana* (Lesquereux) Knowlton.

Nelumbium James=*Cycadeoidea mirabilis* (Lesquereux) Ward.

Nelumbium tenuifolium Lesquereux=*Nelumbo tenuifolia* (Lesquereux) Knowlton, n. comb.

Paliurus sp. Lesquereux, in Peale, U. S. Geol. and Geog. Survey Terr. Rept. for 1873, pp. 203, 393, 1874= *Zizyphus coloradensis?* Knowlton, n. sp.

Phragmites oeningensis Al. Braun. Lesquereux=*Phragmites laramianus* Cockerell.

Phyllites sulcatum Lesquereux, Am. Jour. Sci., 2d ser., vol. 45, p. 208, 1868; Hayden, U. S. Geol. and Geog. Survey Terr. [Third] Ann. Rept., p. 96, 1869 [reprint, p. 196, 1873]=nomen nudum. Neither described, figured, nor subsequently referred to by Lesquereux.

Platanus haydenii Newberry. Lesquereux, U. S. Geol. and Geog. Survey Terr. Rept. for 1872, pp. 326, 375, 1873. Not subsequently recognized.

Pteris gardneri Lesquereux=*Gymnogramma gardneri* (Lesquereux) Lesquereux.

Quercus angustiloba Al. Braun. Lesquereux=*Quercus praeangustiloba* Knowlton, n. sp.

Quercus chlorophylla Unger. Lesquereux, Am. Jour. Sci., 2d ser., vol. 45, p. 208, 1868; Hayden, U. S. Geol. and Geog. Survey Terr. [Third] Ann. Rept., p. 96, 1869 [reprint, p. 196, 1873]. Rejected.

Quercus lyelli Heer. Lesquereux, Am. Jour. Sci., 2d ser., vol. 45, p. 208, 1868; Hayden, U. S. Geol. and Geog. Survey Terr. [Third] Ann. Rept., p. 96, 1869 [reprint, p. 196, 1873]. Rejected.

Rhamnus cleburni Lesquereux, in Peale, U. S. Geol. and Geog. Survey Terr. Rept. for 1873, pp. 203, 393, 1874=*Rhamnus* sp.

Rhamnus elegans Newberry = *Rhamnus belmontensis* Knowlton and Cockerell.

Sabal campbelli? Newberry. Lesquereux, U. S. Geol. and Geog. Survey Terr. Rept. for 1872, pp. 326, 375, 1873=*Sabal montana?* Knowlton.

Sabal campbelli? Newberry. Peale, U. S. Geol. and Geog. Survey Terr. Rept. for 1873, pp. 203, 393, 1874= *Sabal montana?* Knowlton.

Sabalites grayanus (Lesquereux) Lesquereux=*Sabal montana* Knowlton.

Salix integra Göppert=*Salix wyomingensis* Knowlton and Cockerell.

Smilax grandifolia? Unger. Lesquereux, in Peale, U. S. Geol. and Geog. Survey Terr. Rept. for 1873, pp. 203, 393, 1874=*Smilax? inquirenda?* Knowlton, n. sp.

Sphenopteris (Asplenium) elongatum Newberry=*Anemia elongata* (Newberry) Knowlton, n. comb.

Ulmus? irregularis Lesquereux=*Ficus coloradensis* Cockerell.

Viburnum platanoides Lesquereux=*Platanus platanoides* (Lesquereux) Knowlton.

Zamiostrobus mirabilis Lesquereux=*Cycadeoidea mirabilis* (Lesquereux) Ward.

LARAMIE PLANTS IN THE DENVER BASIN.

The following is a complete list of the plants found in the Laramie formation in the Denver Basin:

Delesseria fulva Lesquereux.
Onoclea fecunda (Lesquereux) Knowlton.
Dryopteris georgei Knowlton, n. sp.
Dryopteris laramiensis Knowlton n. name.
Dryopteris lesquereuxii Knowlton, n. name.
Dryopteris? carbonensis Knowlton, n. sp.
Phanerophlebites pealei Knowlton, n. gen. and sp.
Asplenium martini Knowlton, n. sp.
Pteris goldmani Knowlton, n. sp.
Pteris? sp.
Anemia elongata (Newberry) Knowlton, n. comb.
Anemia supercretacea Hollick.
Anemia sp.
Lygodium? compactum Lesquereux.
Equisetum perlaevigatum Cockerell.
Dammara sp.
Sequoia acuminata? Lesquereux.
Sequoia reichenbachi (Geinitz) Heer.
Sequoia longifolia Lesquereux.
Cycadeoidea mirabilis (Lesquereux) Ward.
Cyperacites? hillsii Knowlton, n. sp.
Cyperacites? tessellatus Knowlton, n. sp.
Cyperacites? sp.
Phragmites laramianus Cockerell.
Smilax? inquirenda Knowlton, n. sp.
Sabal montana Knowlton, n. sp.
Juglans leydenianus Knowlton, n. sp.
Juglans newberryi Knowlton, n. sp.
Juglans laramiensis Knowlton, n. sp.
Juglans leconteana Lesquereux.
Juglans praerugosa Knowlton, n. sp.
Hicoria angulata Knowlton, n. sp.
Hicoria minutula Knowlton, n. sp.
Myrica torreyi Lesquereux.
Myrica dubia Knowlton, n. sp.
Myrica oblongifolia Knowlton, n. sp.
Salix myricoides Knowlton, n. sp.
Salix wyomingensis Knowlton and Cockerell.
Salix brittoneana Knowlton, n. sp.
Populus? distorta Knowlton, n. sp.
Quercus praeangustiloba Knowlton, n. sp.
Quercus stramineus Lesquereux.
Quercus eximia Knowlton, n. sp.
Quercus viburnifolia? Lesquereux.
Artocarpus lessigiana (Lesquereux) Knowlton.
Artocarpus liriodendroides Knowlton, n. sp.
Ficus? smithsoniana? (Lesquereux) Lesquereux.
Ficus pealei Knowlton, n. sp.
Ficus planicostata Lesquereux.
Ficus cockerelli Knowlton, n. name.
Ficus planicostata magnifolia Knowlton, n. var.
Ficus praeplanicostata Knowlton, n. sp.
Ficus impressa Knowlton, n. sp.
Ficus coloradensis Cockerell.
Ficus dalmatica Ettingshausen.
Ficus neodalmatica Knowlton, n. sp.
Ficus? leyden Knowlton, n. sp.
Ficus posttrinervis Knowlton, n. sp.
Ficus cannoni Knowlton, n. sp.
Ficus navicularis Cockerell.
Ficus multinervis? Heer.
Ficus denveriana? Cockerell.
Ficus crossii Ward.
Ficus cowanensis Knowlton, n. sp.
Ficus berryana Knowlton, n. sp.
Ficus arenacea Lesquereux.
Ficus? apiculatus Knowlton, n. sp.
Aristolochia brittoni Knowlton, n. sp.
Nelumbo tenuifolia (Lesquereux) Knowlton, n. comb.
Magnolia marshalli Knowlton, n. sp.
Magnolia lakesii Knowlton, n. sp.
Anona coloradensis Knowlton, n. sp.
Anona robusta Lesquereux.
Laurus lanceolata Knowlton, n. sp.
Laurus lakesii Knowlton, n. sp.
Laurus wardiana Knowlton.
Malapoenna louisvillensis Knowlton, n. sp.
Cinnamomum affine Lesquereux.
Cinnamomum laramiense Knowlton, n. sp.
Platanus platanoides (Lesquereux) Knowlton.
Leguminosites? coloradensis Knowlton, n. sp.
Leguminosites columbianus Knowlton, n. sp.
Leguminosites? laramiensis Knowlton, n. sp.
Mimosites marshallensis Knowlton, n. sp.
Cassia? laramiensis Knowlton, n. sp.

Cercis eocenica Lesquereux.
Celastrinites alatus Knowlton, n. sp.
Celastrinites eriensis Knowlton, n. sp.
Celastrinites cowanensis Knowlton, n. sp.
Negundo brittoni Knowlton, n. sp.
Pistacia eriensis Knowlton, n. sp.
Pistacia hollicki Knowlton, n. sp.
Ilex laramiensis Knowlton, n. sp.
Ceanothus eriensis Knowlton, n. sp.
Ceanothus ovatifolius Knowlton, n. sp.
Rhamnus goldianus? Lesquereux.
Rhamnus salicifolius Lesquereux.
Rhamnus minutus Knowlton, n. sp.
Rhamnus marshallensis Knowlton, n. sp.
Rhamnus belmontensis Knowlton and Cockerell.
Rhamnus brittoni Knowlton, n. sp.
Rhamnus? pealei Knowlton, n. sp.
Rhamnus sp.
?Paliurus zizyphoides Lesquereux.
Zizyphus coloradensis Knowlton, n. sp.
Zizyphus hendersoni Knowlton, n. sp.
Zizyphus corrugatus Knowlton, n. sp.
Zizyphus minutus Knowlton, n. sp.
Apeibopsis? laramiensis Knowlton, n. sp.
Cornus suborbifera Lesquereux.
Cornus praeimpressa Knowlton, n. sp.
Cornus sp.
Hedera lucens Knowlton, n. sp.
Diospyros berryana Knowlton, n. sp.
Fraxinus? princetoniana Knowlton, n. sp.
Apocynophyllum taenifolium Knowlton, n. sp.
Dombeyopsis obtusa Lesquereux.
Dombeyopsis trivialis Lesquereux.
Dombeyopsis? sinuata Knowlton, n. sp.
Dombeyopsis ovata Knowlton, n. sp.
Carpites lakesii Knowlton, n. sp.
Carpites lesquereuxiana Knowlton, n. sp.
Carpites rhomboidalis Lesquereux.
Phyllites leydenianus Knowlton, n. sp.
Phyllites marshallensis Knowlton, n. sp.
Phyllites trinervis Knowlton, n. sp.
Phyllites dombeyopsoides Knowlton, n. sp.
Phyllites sp.
Phyllites sp.
Phyllites sp.
Palaeoaster? similis Knowlton, n. sp.

BIOLOGIC RELATIONS OF THE FLORA.

The Laramie flora as herein set forth is not an especially rich one as regards specific forms, types of vegetation represented, or individual specimens. Most of the plants have been found in more or less direct connection with the coal. A few of them were found in a fine-grained sandstone or shale, and so far as they are retained in this matrix they are fairly well preserved and admit of satisfactory study. In some places the sandstone matrix, although fine grained, is so hard as to render it difficult to procure perfect specimens, though in perhaps the most fossiliferous localities the matrix is a rather coarse-grained, soft sandstone that crushes or breaks so readily that good material is the exception. As much of the rock disintegrates rapidly on exposure, it is almost impossible to procure identifiable material unless it happens to be collected very soon after it is brought out. All these conditions help to explain why so many of the plants appear fragmentary.

The great group of the algae is represented by a single more or less doubtful specimen that has been referred to the genus *Delesseria*. This is, of course, a very inadequate expression of the algal life that must have existed in the abundant coal swamps and streams of the time. None of the other groups of lower plants below the ferns—that is, fungi, simple algae, mosses, hepatics, etc.—are represented in the collections.

The ferns, although not very abundant as individuals, are diversified in type, being represented by 8 genera and 14 forms. One of the most interesting, but unfortunately also one of the most fragmentary, is represented by the form for which the genus *Phanerophlebites* is created. Its nervation is very similar to that of the living *Phanerophlebia nobilis* (*Aspidium nobile* Chamisso and Schlechtendahl) and *Phanerophlebia juglandifolia* (Willdenow) J. Smith, both from Mexico. What is believed to be the fruiting stage of an *Onoclea* is represented by *Onoclea fecunda*, a form originally described as *Caulinites*. The sterile leaves of this form have not been detected. The largest representation is found in forms referred to *Dryopteris*, of which there are five species. Perhaps the finest of these is the form here named *Dryopteris georgei*, which must have been of rather imposing size and appearance, as the pinnae must have been 15 or 20 centimeters long and 6 to 8 centimeters wide. A small, rather coriaceous form is described as *Dryopteris? carbonensis*. The only form referred to *Asplenium* is fragmentary, but to judge from the portion found it was of striking appearance; it appears to be rather closely allied to a species in the Vermejo formation of the Raton Mesa region. *Pteris* is represented by two forms, neither of which, however, is very well preserved. The Schizaeaceae are represented by a single, rather doubtful species of *Lygodium* and three forms of *Anemia*. A single species of *Equisetum* represents the Equisetaceae.

The conifers appear to have been an unimportant element, as regards both forms and individuals, in this flora, being represented by only two genera and four forms. Of these *Dammara* is represented by a single fragmentary scale and, of course, is of little importance. The species of *Sequoia* are represented by several leafy branchlets.

The only example belonging to the Cycadaceae is a beautifully preserved small trunk now referred to *Cycadeoidea*, but unfortunately its exact horizon is open to question.

The monocotyledons were apparently not an abundant element during the Cretaceous period, and the Laramie flora is no exception, though the number and variety present are rather greater than might have been expected. There are, for example, three forms of sedgelike plants described under the name *Cyperacites*, and a single grass with strong, reedlike stems, designated *Phragmites*, that must have been a striking denizen of the swamps. The flora contains also a fairly well-marked leaf of a *Smilax*, and two species of palms, one of which at least had leaves of large size and imposing appearance.

The dicotyledons were, of course, the most abundant and diversified elements of this flora. Beginning with the lower or apetalous groups, we have five species of *Juglans* known from the leaves, and two of *Hicoria* known from the fruits. The waxberries were represented by three or four forms of *Myrica*, and the willows by the species of *Salix*, some of which were individually abundant. One species of *Populus* is described, though it is neither abundant nor very well marked. The oaks are represented by four forms of *Quercus*, one of which (*Q. praeangustiloba*) was a deeply lobed leaf of modern appearance.

The large, mainly tropical family Moraceae was apparently an abundant and diversified element, embracing two species of *Artocarpus* or breadfruit that possessed very strongly marked leaves and 21 species of *Ficus*. The figs were not only more abundant in species but also in individuals, as there is hardly a collection that does not contain from one to several species. A number of the species have leaves of large size.

Aristolochia was represented by a single species with leaves of much the same shape as two well-known European forms. In both form and nervation it approaches an American species (*A. sipho*). To the Nymphaeaceae is referred a fine species of *Nelumbo* with large peltate leaves.

The Magnoliaceae, although represented by two species of *Magnolia*, were neither abundant nor of especially striking aspect, as the small leaves indicate.

The Lauraceae embrace three genera and five species—*Laurus* with two, *Malapoenna* with one, and *Cinnamomum* with two. *Cinnamomum affine* was abundant and widely distributed.

The Platanaceae were very poorly represented, there being only one small-leaved form and a doubtful fragment not specifically named. The named species (*Platanus platanoides*) was first referred to *Viburnum*, and its reference to *Platanus* is not positively authenticated.

The Leguminosae are supposed to be represented by three forms of *Leguminosites*, one of *Mimosites*, and a very doubtful *Cercis*. The two forms of *Celastrinites* and one of *Negundo* show little of special biologic interest. There are three forms of *Cornus*, two each of *Anona* and *Pistacia*, four of *Dombeyopsis*, and one each of *Fraxinus*, *Apocynophyllum*, *Hedera*, and *Ilex*. Of the more or less indefinite *Carpites* there are four, and of *Phyllites* about seven forms.

ECOLOGIC RELATIONS OF THE FLORA.

After having briefly reviewed the Laramie flora, we are in position to draw at least tentative conclusions regarding the ecologic conditions which appear to have existed during Laramie time. As I have had occasion to remark in another similar connection:

> In estimating the value of individual organisms in an inquiry of this kind, dependence must of course be placed on our knowledge of present-day requirements, and in this there is always the possibility of error from two sources, namely, (1) the organism may not have been correctly placed biologically, and (2) the requirements in past geologic time may not have been the same as those which now dominate the life activities of its supposed analogue. However, when all of the elements of a flora appear with apparent unanimity to point in the same direction, the liability to serious error is minimized if not eliminated.

The presence of very considerable veins of coal, which occur mainly in the lower portion of the formation, undoubtedly calls for widespread and long-continued swamp or marsh conditions. David White,[9] in speaking of the physiographic conditions attending the formation of coal, said:

The enormous horizontal extent of many of the coal groups as indicated by the remnants now found in basins detached as the result of folding and erosion, the demonstrated continuity of some of the individual coal beds over areas of amazing size, the high degree of parallelism of the beds, and the recognition that the coal beds were laid down beneath a water cover join in predicating the existence, at the time the coal was being formed, of vast swamps and broad but shallow lagoonal areas subject to subsidence at a generally slow rate.

The above is known as the autocthonous (formed in place) hypothesis of the origin of coal. It is but fair to state, however, that the allocthonous (transported) hypothesis, which argues that much of the coal may have been formed by floating and sedimentation at the bottom of open lakes or lagoons, has still an occasional advocate. In a recent article on "The mode of origin of coal" E. C. Jeffrey [10] set forth the results of the microscopic examination of great numbers of coals from all parts of the world and from horizons ranging from Devonian to Tertiary. He held that he is able to distinguish the relatively few types that appear to have been formed under peat-swamp conditions and asserted that the vast majority give evidence of deposition in open water. "Coal is not a compost heap but a sedimentary deposit," he concluded. Be this as it may, it is not within the scope of the present paper further to discuss the origin of coal.

Concerning the interpretation of the climates of the coal-forming periods, White said:

It will be seen that during the times of deposition of most of the principal coal groups the climate has been characterized by (1) general mildness of temperature, approaching in most cases tropical or subtropical conditions; (2) conspicuous equability or approximation to uniformity of climatic conditions, which, with few exceptions, appear to have lacked cold winters or severe frosts; (3) a generally high humidity, the rainfall being from moderately heavy to very heavy and fairly well distributed during the year, though in many cases there is evidence of the occurrence of dry periods, which, however, seem ordinarily to have been comparatively short and not severe; (4) an amazingly wide geographical distribution of these genial and equable climates.

To repeat, then—the abundant presence of coal in the Laramie of the Denver Basin offers in itself sufficient proof of the existence of long-continued, relatively uniform swamp or marsh conditions. According to currently accepted theories a larger percentage of all coals were formed by accumulations of vegetable matter under conditions similar to those existing in a modern peat swamp. The types of vegetation that contributed to the formation of the coals depend of course upon the geologic period during which they were laid down; but whatever the age, the process is believed to have been essentially identical throughout.

We may now examine the plants found in the flora under discussion to ascertain if possible which of its members appear to demand a habitat that would make it a potential contribution to or at home in such a peat-producing environment. The sedgelike plants described as *Cyperacites* might very well have found a home in such a swamp, and the tall, canelike grass *Phragmites* is notably such a swamp-loving plant. *Smilax*—or at least the form to which the Laramie species seems to be related—is essentially a denizen of swamps and low places, where it often forms dense tangles. Equally at home in or about a swamp, or along adjacent watercourses, would be found the waxberries (*Myrica*), willows, and poplars, while the shallow, quiet waters furnished a congenial surrounding for the floating leaves of *Nelumbo*. Among the ferns there are several, such as *Onoclea*, *Lygodium*, and *Anemia*, that might well have found a home in or near swampy or low ground, while the others, including *Asplenium*, *Dryopteris*, etc., demand shade and moisture such as is afforded in or adjacent to low ground.

If the data have been correctly interpreted, the Moraceae formed the most conspicuous group in this flora, comprising two genera and nearly 25 species. Of these *Artocarpus* is represented by two very well-marked forms. The members of this genus at the present time demand a warm, moist habitat such as might be afforded by the swamp we are predicating. In the same way the several species of *Ficus* call for like conditions. This great swamp may well have harbored also the

[9] White, David, and Thiessen, Reinhardt, The origin of coal: Bur. Mines Bull. 38, p. 53, 1913.

[10] Jour. Geology, vol. 23, pp. 218-230, 1915.

two *Magnolias*, the *Fraxinus*, and possibly the *Zizyphus*, and about its border the two palms may have had their home.

The conifers do not offer very definite evidence and, moreover, are so rare in individuals that they could hardly have been a conspicuous element. It is probable that they grew on adjacent higher ground and found their way into the deposits through the agency of streams. Growing with them on higher ground may well have been the *Cornus*, *Quercus*, *Juglans*, *Hicoria*, *Rhamnus*, *Hedera*, *Ilex*, etc., which complete the picture.

We may now proceed to draw some perhaps tentative conclusions as to the climatic conditions under which the Laramie flora may be presumed to have existed. From the abundant presence of coal and the apparent requirements of the majority of the plants enumerated, it is beyond question that there must have been an abundance of moisture. It also appears naturally to follow from the presumed requirements of the flora that the climate was warm; at least warm temperate.

GEOLOGIC RELATIONS OF THE FLORA.

Naturally one of the most interesting and important phases of this study of the Laramie flora is the bearing it may have on the interpretation of the age and stratigraphic relations of the beds in which it occurs. As has been so abundantly shown in the section on the historical treatment of the term Laramie, this term has been so bandied about that at one time its significance as a stratigraphic designation had been practically lost or at least greatly obscured. Much of the earlier paleobotanic work on the flora was rendered unavailable for the reason that practically every student had a different concept of the Laramie, and this could only lead to irreconcilable confusion. The present study was undertaken in the hope that by taking a comparatively small area and thoroughly working up its flora, data might be obtained that would serve as a basis for comparison elsewhere. It remains to be seen how far this desire has been realized.

The flora of the Laramie in the Denver Basin comprises 129 forms, of which 74 are here described as new to science, 8 forms have been regarded as too fragmentary or obscure to warrant being named specifically, and 47 forms have been previously named and described. It is to be noted, however, that although the proportion of new forms may seem to be large, many of them have been known to the writer for years; in fact, the descriptions of perhaps more than half of them have been in manuscript since about 1895 and have been utilized in discussions of this and related floras.

RELATIONS TO THE MONTANA FORMATIONS.

The Laramie flora, as might perhaps be expected, is on the whole most closely related, either by identical or obviously related species, to the Montana flora, yet with adequate collections there should be no difficulty in separating them. As the unconformity which separates the Laramie from the Arapahoe and Denver formations is believed to be the same as that which separates the Vermejo from the overlying Raton formation in the Raton Mesa region, it might be presumed that there should be a close correspondence between the Laramie and the Vermejo, but a critical study of the floras does not bear out this presumption. At first it was thought that only a single species (*Rhamnus salicifolius*) was common to the two formations, but later study discloses the fact that there are five or six species that occur in both. Inasmuch as there are 106 species in the Vermejo and 129 in the Laramie, however, the relationship obviously is not very strong. The species in common are as follows:

Sequoia reichenbachi (Geinitz) Heer.
Sabal montana Knowlton.
Myrica torreyi Lesquereux.
Ficus dalmatica Ettingshausen.
Ficus trinervis Knowlton.
Rhamnus salicifolius Lesquereux.

Of these species, *Sequoia reichenbachi* has an almost worldwide distribution and ranges in age from Jurassic to Upper Cretaceous, and it is therefore of no importance as a close horizon marker. The known presence of this species in the Laramie rests on a few more or less doubtful fragments, though if correctly identified its rarity has, of course, no bearing in the present consideration. *Sabal montana* is a very large leaved species, perhaps the largest-leaved Rocky Mountain form, and as a consequence it is rather rarely found in perfect condition. There is little doubt, however, that it occurs in both Vermejo and Laramie. *Myrica torreyi*, though occurring mainly in the Montana, is a widely ranging form and has even been found in beds above the unconformity. *Rhamnus saliciformis* was described originally from specimens obtained in the Laramie and has subsequently been found in the Montana at a number of horizons. The two species of *Ficus* are well-marked forms and probably have been correctly identified in both areas.

In addition to the flora of the Vermejo, which is of course of Montana age, it may be of interest to compare the Laramie flora with the Montana flora as a whole. The following species are common to the two:

Anemia elongata (Newberry).
?Anemia supercretacea Hollick.
Sequoia reichenbachi (Geinitz) Heer.
Sequoia longifolia (Lesquereux) Knowlton.
Sabal montana Knowlton.
Myrica torreyi Lesquereux.
Ficus dalmatica Ettingshausen.
Ficus praetrinervis Knowlton.
Ficus planicostata Lesquereux.
Rhamnus salicifolius Lesquereux.

In addition to the species that are regarded as actually identical in the Laramie and Montana floras, there are two that are obviously related to Montana species, as follows:

Palaeoaster? similis, aff. P. inquirenda.
Artocarpus liriodendroides, aff. A. dissecta.

RELATIONS TO THE "LOWER LARAMIE" OF CARBON COUNTY, WYO.

One of the most interesting results brought out by this study is the close relation that is shown to exist between the flora of the Laramie in the Denver Basin and the flora of the so-called "Lower Laramie" (now the Medicine Bow formation) of Carbon County, Wyo., and adjacent areas. The flora of the "Lower Laramie" at present known is confined in the main to the lower 300 or 400 feet of beds, and though it has not yet been fully exploited, the following forms at least are known to occur:

Apeibopsis discolor Lesquereux.
Aristolochia sp.
*Artocarpus lessigii (Lesquereux) Knowlton.
Carpites sp.
*Cassia marshallensis Knowlton.
Ceanothus? sp.
*Cinnamomum affine Lesquereux.
*Cyperacites sp.?
Daphnogene elegans Watelet.
Diospyros? ficoidea Lesquereux.
*Dombeyopsis obtusa Lesquereux.
*Dombeyopsis trivialis Lesquereux.
Dryophyllum cf. D. aquamarum Ward.
Dryophyllum bruneri Ward.
*Dryopteris carbonensis Knowlton.
Equisetum, tubers of.
*Ficus arenacea Lesquereux.
*Ficus impressa.
*Ficus cockerelli Knowlton.
*Ficus navicularis Cockerell.
*Ficus planicostata? Lesquereux.
*Ficus praetrinervis Knowlton.
Ficus sp., new.
Ficus? sp.
*Sequoia longifolia Lesquereux.
Geonomites cf. G. ungeri Lesquereux.
Ilex? sp.
*Juglans praerugosa.
*Laurus wardiana Knowlton.
Mimosites? sp.
Mimosa sp.?
*Myrica torreyi Lesquereux.
Paliurus zizyphoides?
Palmoxylon sp., new?
*Pecopteris sepulta Newberry cf. Hollick.
*Phyllites sp.
Pistia corrugata? Lesquereux.
Platanus marginata (Lesquereux) Heer.
*Platanus platanoides (Lesquereux) Knowlton.
*Rhamnus elegans Newberry.
*Rhamnus saliciformis Lesquereux.
*Sabal montana Knowlton.
*Salix elongata? Al. Braun.
Salix sp.
*Sequoia reichenbachi (Geinitz) Heer.
Sequoia sp.
Woodwardia, new, nearest to W. crenata Knowlton.
*Zizyphus minimus Knowlton.

An analysis of the above list shows that it contains 48 forms, of which 26, marked with an asterisk in the list, are named species having a distribution outside this area. Of these 26 species no less than 25 are found also in the Laramie of the Denver Basin, and it therefore seems legitimate to conclude that the age of the beds is the same in the two areas. As set forth at length on page 60, the section of "Lower Laramie" rocks has a thickness of about 6,000 feet. According to Veatch, this thick section is separated from the overlying beds (now called the Ferris formation) by an unconformity which he regarded as profound, because it was believed to have involved the removal of more than 20,000 feet of sediments. This unconformity was presumed to be the same as that which separates the Laramie from the overlying Arapahoe and Denver formations in the Denver Basin, but as a result of later work Bowen would place this unconformity at the top of the Ferris formation and not at its base, though not denying the possibility of an unconformity at the base of the Ferris. That this may be the correct interpretation finds physiographic support in a paper read by W. T. Lee[11] before the Geological Society of Washington, entitled "Relation of the Cretaceous formations to the Rocky Mountains." In this paper data were presented to show that the entire marine Upper Cretaceous section was laid down uninterruptedly over the area now occupied by the Rocky Mountains. Lee held

that the Cretaceous sediments of the Rocky Mountain region came mainly from the continental land mass that lay west of the interior sea during Cretaceous time. * * * Comparisons of published sections viewed in the light of personal observation in the field indicate that the Cretaceous formations on opposite sides of the mountains and in the intermontane basins are comparable in thickness, character, and stratigraphic succession. * * * It seems probable that the interior Cretaceous basin, which includes the present Rocky Mountain areas, was a great geosyncline in which, until near the close of the Cretaceous, the main movement was downward, with minor warpings. It also seems probable that there was no effective barrier in the relatively small area now occupied by the mountains to prevent the uniform spread of sediments derived from the continental mass west of the Cretaceous sea.

If, as Lee contended, the entire marine Upper Cretaceous section was laid down over the Rocky Mountain area, there is every reason to suppose that the Laramie was also, for it is everywhere conformable with the marine beds on which it rests; indeed, the definition of the Laramie—as the uppermost member of the conformable Cretaceous section above the Fox Hills—demands that it be considered with the marine portion of the section. With the uplifting of the Rocky Mountains came erosion and unconformity. In the Denver Basin the Laramie has a maximum thickness of approximately 1,200 feet, but 90 miles to the south, in the Colorado Springs area, it is reduced to less than 400 feet, and in the Raton Mesa region the Laramie has entirely disappeared and the Eocene (Raton formation) there rests on the Montana (Vermejo formation). In North Park, Colo., the Laramie is not known to be present, but in Carbon County, Wyo., the "Lower Laramie" occupies the same stratigraphic position as the Laramie of the Denver Basin and has a thickness of several thousand feet. The strong similarity of the floras of the Medicine Bow and the Laramie of the Denver Basin is interpreted as evidence of identity in age.

[11] Washington Acad. Sci. Jour., vol. 5, pp. 29-30, 1915; U. S. Geol. Survey Prof. Paper 95, pp. 27-58, 1915.

For an account of the latest interpretation of the stratigraphic relation in Carbon County as worked out by Bowen, the reader is referred to page 60.

It remains to be pointed out that the fossil plants support the contention of Veatch, perhaps as modified by Bowen, namely, that there are some 5,000 or 6,000 feet of beds in the "Lower Laramie," and that this portion, at least, is of the same age as the true Laramie of the Denver Basin. In my opinion the "Lower Laramie" is not Lance. On the other hand I believe that the Lance is to be correlated with a part of the "Upper Laramie" of this region, a view supported by the plants and in the main by the vertebrates also.

RELATIONS TO THE DENVER FORMATION.

The following species are common to the Laramie and Denver formations:

Sequoia acuminata Lesquereux.
Quercus viburnifolia Lesquereux.
Ficus coloradensis Cockerell.
Ficus denveriana? Cockerell.
Nelumbo tenuifolia (Lesquereux) Knowlton.
Dombeyopsis obtusa Lesquereux.
Laurus wardiana? Knowlton.
Paliurus zizyphoides? Lesquereux.
Rhamnus salicifolius Lesquereux.

The flora of the Denver formation numbers about 98 named and described species, but in addition to these there are a number of others in manuscript or otherwise recognized, which will bring the total number up to about 225. Nine species in common is really a very small number.

The status of the several species in this list may be briefly considered. *Sequoia acuminata* was described originally from specimens obtained at Black Buttes, Wyo. Its presence in the Laramie of the Denver Basin rests on a single, rather doubtful fragment found at Cowan station, near Denver, and its presence in the Dawson arkose rests on a specimen found near Templeton Gap, 4 miles northeast of Colorado Springs. *Ficus coloradensis* is one of the most satisfactorily identified of the species occurring in both Laramie and Denver in the Denver Basin. The types are preserved in the characteristic andesitic material from Golden, Colo., and it has been found in subsequent collections from the same horizons. It occurs in the Laramie at Marshall and 1½ miles south of Golden. A discussion of its reported presence at Point of Rocks and Black Buttes, Wyo., will be found in the systematic treatment of the species (p. 134). *Ficus denveriana* (*F. spectabilis* Lesquereux) is essentially a Denver species, and its occurrence in the Laramie depends on a doubtfully determined leaf from Popes Bluff, near Colorado Springs. *Dombeyopsis obtusa* was first obtained from the Laramie at Popes Bluff and has since been noted in the Laramie at Coal Creek, Marshall, Hoyt's mine, south of Golden, and Crow Creek, northeast of Greeley; in the Dawson arkose at Pulpit Rock; and in the Denver at the Douglas coal mine, Sedalia. Though it is more abundant in the Laramie it is undoubtedly present in the post-Laramie beds as above indicated. *Laurus wardiana* is a rare species, known positively only from a single leaf from Golden and questionably in the supposed Dawson near Mosby, Colo. *Paliurus zizyphoides* was established on material from Black Buttes, Wyo., and was reported by Lesquereux to have been found also in the Laramie at Erie and the supposed Laramie at Sand Creek, Colo., but no specimens from these localities are known to exist. *Rhamnus salicifolius* was described from material obtained in the Laramie at Marshall and has since been found at Cowan station, near Denver. Its presence in the Dawson arkose depends on specimens from Templeton Gap, near Colorado Springs. It also occurs in the Vermejo formation, the Montana group of Wyoming, and elsewhere.

RELATIONS TO THE ARAPAHOE FORMATION.

Before it will be possible to consider any relation between the flora of the Laramie and that of the Arapahoe, it will be necessary to review with some care the present status of knowledge concerning the Arapahoe flora. According to Eldridge, on whom largely devolved the task of studying the Arapahoe formation for the Denver Basin monograph, the formation was found to contain poorly preserved fossil leaves at a number of localities within the Denver region, but no determinable species were collected. Only two localities were known from which determinable plants supposed to be of Arapahoe age have been reported—Sand Creek, east of Denver, and the vicinity of the Douglas coal mine, Sedalia, about 20 miles south of Denver.

Some 9 or 10 species of plants are recorded as having come from the Sand Creek locality, all of which were obtained by the earlier workers in this field—that is, probably about 1873. Considerable uncertainty has existed as to the exact locality whence these plants came, but apparently important light is thrown on this point by a chance statement made by A. R. Marvine [12] in his paper on "The geology of Middle Park," which on account of its importance is quoted entire below.

> East of Denver, in T. 4 S., and probably between Rs. 65 and 66 W., a shaft has been sunk for some depth in a high bank on the south side of Sand Creek but is now abandoned. The coal also outcrops on the bank and there appears as of very poor quality. Fossil leaves are abundant.
>
> It was near here that the first discoveries of coal were made in Colorado, and the stream at this point is often known as Coal Creek, though called Sand Creek further down. The latter name should be retained, to prevent confusion between this and the better-known Coal Creek on the west side of the Platte.
>
> About 4 miles to the north, near Box Elder, on the Kansas Pacific Railroad, in R. 65 W., T. 3 S., sec. 28 (?), and probably at the same horizon as the last, are two shafts which reach coal and on which work has been done now and then for some years. It is probably in one of these three shafts that the following section was made by Mr. E. B. Mally (quoted by Lesquereux in Hayden's report for 1872, p. 327), and which seems to give an idea of the strata near here. * * *
>
> The work was abandoned on account of the poor quality of the coal.

That the above-indicated plant-bearing horizon is probably the important one in the present consideration was still further indicated by Marvine, who, after mentioning a number of coal openings in another direction from Denver, said: "The only others I have heard of lie from 15 to 17 miles east of Denver City and near the Box Elder station on the Kansas Pacific Railroad." The assumption seems to be justified, therefore, that the plants labeled "Sand Creek" probably came from this area.

In Lesquereux's "Tertiary flora" the following data are recorded concerning six of the species reported to have come from Sand Creek:

Lastrea (G.) polypodiodes. Sand Creek (W. H. Holmes).
Gymnogramma gardneri. Roof of a coal mine, Sand Creek (A. Gardner).
Equisetum laevigatum. Sand Creek, 8 feet above coal (W. H. Holmes).
Eriocaulon? porosum. Sand Creek (W. H. Holmes) with leaves of Nelumbium.

[12] U. S. Geol. and Geog. Survey Terr. Rept. for 1873, pp. 120, 121, 1874.

Nelumbium tenuifolium. Sand Creek, Colorado (Prof. A. Gardner).

Quercus viburnifolia. Sand Creek (A. R. Marvine).

These species are similarly recorded in the catalogue of fossil plants in the United States National Museum, in Lesquereux's own handwriting, so it may be presumed that the statements are correct, at least so far as his information went. The species obtained by Marvine was doubtless collected on the occasion of his visit there in 1873, but no data are available as to the date on which the two species accredited to Prof. Gardner were collected. W. H. Holmes assisted Marvine in his geologic work in 1873, and the plants recorded as having been collected by him were probably obtained at that time, but on consultation with Prof. Holmes I find that he has now no recollection of having collected the plants, or, indeed, of having visited any coal mines east of Denver. This injects another element of uncertainty into the already sufficiently complicated matter, but we shall probably never come any nearer to a complete explanation. To sum up, it appears in its final analysis that we do not know the precise locality for a single one of these Sand Creek plants, though in all reasonable probability they apparently came from the vicinity of the coal openings on Coal or Sand Creek about 15 miles east of Denver; but as the locality is in doubt, it naturally follows that the horizon is also uncertain. It was apparently assumed by Cross that they came from the Arapahoe, for he stated that along Sand Creek this formation rests on the Laramie, but according to the map showing the areal geology in the Denver Basin monograph, the Laramie occurs on the north bank of the creek, and the Denver on the south bank, no Arapahoe being indicated. Cross,[13] in discussing the Sand Creek locality, said: "The specimens preserved in the National Museum do not satisfactorily indicate the horizon from which they came. It seems probable that a part of them came from the Arapahoe beds and a part from the Laramie."

Up to this point, from the data available, it appeared to me that if any of the Sand Creek plants came from the Laramie they probably all did, and on this basis it was my original intention to include them provisionally in the present work. However, important observations made by W. T. Lee during the field season of 1915 put an entirely different light on the matter and have led me to exclude all the Sand Creek species from both Arapahoe and Laramie, and to refer them with little or no question to the Denver. The evidence is as follows: Lee examined the log of a deep well that has been drilled about 2½ miles northeast of Coal Creek (or Sand Creek). This well starts at the surface in sandy coal-bearing beds that are lithologically and stratigraphically identical with the beds in question along Sand Creek, and are also the same as the coal-bearing beds at Scranton, which from the presence of coal are supposed to be in the upper part of the Laramie. Lee's description of the well is as follows:

Section of oil well east of Denver, Colo., in sec. 24, T. 3 S., R. 67 W.

		Feet.
Denver:		
Clay, sand, and gravel		200
Coal	Scranton coal.	2
Clay, sand, and arkose	Scranton coal.	248
Coal	Scranton coal.	4
Sand, gravel, and clay		346
Arapahoe:		
Conglomerate		50
Laramie:		
Soft blue shale		175
Sandstone and shale alternating		275
Shale, light colored		140
Shale, dark colored		35
Brown shale		65
Coal		10
Fox Hills:		
Massive sandstone containing artesian water		130
Shale		10
Sandstone		20
Pierre:		
Shale and limestone (shells)		1,500+

The facts brought out by this well record are of far-reaching significance. It shows that the Scranton coal, heretofore thought to be in the upper part of the Laramie, is about 350 feet above what is believed to be the Arapahoe conglomerate. This conglomerate is about 50 feet thick. It also appears that the Scranton coal is more than 400 feet above beds that can with reasonableness be referred to the Laramie, and more than 1,000 feet above the main Laramie coal. The thickness of beds between the Scranton coal and the main Laramie coal is not of particular significance in view of the fact that the maximum thickness previously as-

[13] Cross, Whitman, U. S. Geol. Survey Mon. 27, p. 225, 1896.

signed to the Laramie in this area was about 1,600 feet. The crucial point is the disclosure of the Arapahoe conglomerate between the two coal horizons, which naturally tends to decrease the observed thickness of the Laramie strata.

The other supposed locality for Arapahoe plants—namely, that near the Douglas coal mine, west of Sedalia—may now be considered. As this is at or near the type locality for the Arapahoe there should apparently be no question as to its relation, but it appears from the work of G. B. Richardson, who critically studied this area in 1910–11, that the Arapahoe occupies the stratigraphic position of the Dawson arkose and in fact interdigitates with the lower part of it. Concerning this point Richardson [14] wrote as follows: "It was found that the lower part of the Dawson arkose seems to pass along the strike into the Arapahoe and Denver formations; that the Dawson and Arapahoe can not be separated lithologically, even at the type locality of Arapahoe, on the bluffs of Willow Creek." This conclusion does not, of course, affect the stratigraphic relations of the plant-bearing beds, and it is unimportant whether the beds are to be called Arapahoe or Dawson, as they are separated from the underlying Laramie by an unconformity marking a considerable time interval.

Below is a tentative list of the plants from the Douglas mine locality as worked up about 12 years ago. Additional material not yet studied may necessitate slight changes, though it is not presumed that these will greatly affect the result.

Acer trilobatum productum.
Asplenium erosum.
Berchemia multinervis.
Cissus laevigata.
Cissus lobato-crenata.
Dicksonia, new.
Diospyros brachysepala?
Dombeyopsis obtusa.
Dombeyopsis, new.
Dryopteris lakesii.
Dryopteris lesquereuxii?
Ficus planicostata.
Ficus, new.
Hicoria? sp.
Laurus primigenia.
Nelumbo lakesii.
Nelumbo, new.
Phyllites, new.
Quercus, new.
Viburnum, new.
Woodwardia latiloba.

[14] Richardson, G. B., The Monument Creek group: Geol. Soc. America Bull., vol. 23, p. 274, 1912.

It will be seen at once that this is essentially a Denver flora, with only two species that occur in the Laramie—*Dombeyopsis obtusa* and *Ficus planicostata*. Both of these species have already been several times mentioned as passing from Laramie into post-Laramie beds.

RELATIONS TO THE LANCE FORMATION.

It is difficult at present to make an accurate and wholly satisfactory comparison between the flora of the Laramie in the Denver Basin and the flora of the Lance formation. This difficulty arises from the fact that the Lance flora has not yet been thoroughly worked up and described. It is known that the Lance flora comprises approximately 125 forms. It is possible that when this flora has been fully described, the number of species found to be in common with the Laramie may be slightly increased over the number given below, but it is improbable that they will be increased to as many as twice that number. Another difficulty in the way of making an accurate comparison between these two floras is the uncertainty that still attaches to certain of the localities that have afforded some of the supposed Lance plants. It is perhaps unnecessary to state that there has been—and indeed still is—more or less uncertainty in fixing the limits of the Lance formation, though the difficulty is much greater in fixing the upper limit than it is in fixing the lower limit. Be this as it may, the species mentioned below are the only ones that are at present recognized as passing from the Laramie into the Lance.

Equisetum perlaevigatum.
Myrica torreyi.
Ficus planicostata.
Cinnamomum affine??
Rhamnus salicifolius.
Platanus platanoides.
Quercus viburnifolia?

A discussion of these species may be of interest. Thus, *Equisetum laevigatum* (now *perlaevigatum*) was reported by Hollick from the so-called "Hell Creek beds" (Lance) in the vicinity of Hell Creek, Mont. In the descriptive part of this paper (p. 113) it is stated that this species was founded on two specimens, one of which (from Sand Creek, Colo., in beds now believed to be of Denver age) is probably only a piece of bark, and the other (from the true Laramie at Golden, Colo.) is based on a portion of an underground stem of an *Equisetum* with characters so poorly defined that the advisability of retaining it is open to question. It is not to be doubted that there are *Equisetum* stems in the "Hell Creek beds," but the propriety of identifying them with *Equisetum perlaevigatum* may well be questioned. *Rhamnus salicifolius* is another of the forms identified by Hollick in the "Hell Creek beds." This, together with *Myrica torreyi*, is well known as a species enjoying a wide vertical range. *Ficus planicostata* is also a species of considerable vertical range. It is extremely rare in the Lance formation, and its identification is not beyond question. The identification of *Cinnamomum affine* rests on its doubtful presence in the Kingsbury conglomerate, east of the Big Horn Mountains, Wyo., and *Quercus viburnifolia* was identified with question at Forsyth, Mont.

In a paper published in 1909[15] I listed 11 species that were at that time believed to be common to the Laramie and Lance formations. The species additional to those in the above list are *Ficus trinervis*, *Flabellaria eocenica*, *Sabalites grayanus*, and *Juglans rugosa*. According to present understanding neither *Ficus trinervis* nor *Juglans rugosa* is known in the Laramie of the Denver Basin. The two palms may be the same as the Montana and Laramie form known as *Sabal montana*, but there is usually difficulty in certainly identifying remains of palms.

From this brief account it appears that there are not now known to be more than four or five species of plants that are common to the Laramie and Lance, and when it is recalled that there is about the same number of species in the two floras, it is seen that the relationship between these floras is not a strong one.

RELATIONS TO THE UPPERMOST CRETACEOUS OF THE ATLANTIC COASTAL PLAIN.

In the major portion of the Atlantic Coastal Plain the uppermost Cretaceous is believed to be either lower in position than the Laramie, or where the section is more nearly complete—as in the northern portion—it is a marine deposit and not plant-bearing.

RELATIONS TO THE PATOOT SERIES OF GREENLAND.

The Cretaceous system is very considerably developed in Greenland, reaching a thickness of approximately 4,000 feet. The area of exposure includes Disco Island and the Nugsuak Peninsula and is a belt about 75 miles wide along the deeply indented coast line from latitude 69° 15′ to 72° 15′ N. The beds at many places are very fossiliferous and have yielded altogether more than 350 species of plants, which were, in the main, elaborated by Oswald Heer in his well-known "Flora fossilis arctica," comprising seven quarto volumes, published in 1868 to 1883. On the basis of the plants, Heer divided the Cretaceous into three series. A lower division, called the Kome series, with a flora of 88 species, was correlated with the Urgonian of Europe; a middle division, the Atane series, with 177 species of plants, was correlated with the Cenomanian; and an upper division, the Patoot series, with a flora of 123 species, was correlated with the European Senonian and the Fox Hills of the United States. Above this in other parts of the Arctic region is a considerable thickness of Tertiary beds, also with an abundant flora, which constitute the so-called Arctic Miocene, now very generally referred to the Eocene.

The Atane and Patoot series have a combined thickness of at least 1,300 feet, and probably considerably more. There is no sharp line of demarcation between them, the boundary having been drawn by Heer purely on paleontologic grounds.

Although Heer definitely correlated the Patoot series with the Senonian, White and Schuchert,[16] who visited the region in 1897, expressed the view that there was a transition without sedimentary break into the overlying Tertiary. These writers also stated that the Patoot series contains "many plants common to the upper part of the Amboy clays, with others allied more closely to the higher Cretaceous flora, such as that of the Laramie."

[15] Knowlton, F. H., Stratigraphic relations and paleontology of the "Hell Creek beds," "*Ceratops* beds," and equivalents, and their reference to the Fort Union formation: Washington Acad. Sci. Proc., vol. 11, p. 222, 1909.

[16] White, David, and Schuchert, Charles, Cretaceous series of the west coast of Greenland: Geol. Soc. America Bull., vol. 9, p. 367, 1898.

Subsequent study of the Laramie flora, however, does not bear out this suggestion, for so far as now known the two floras contain no species in common. This is also the view reached by Berry,[17] who pointed out that of the 123 Patoot species 20 occur in the Dakota sandstone, 22 in the Raritan, 19 in the Magothy, 8 in the Tuscaloosa, and 4 in the Black Creek formation. He says: "The large number of Atane species present (34), as well as the numerous Dakota, Raritan, and Magothy species, precludes considering the flora as young as, for example, the Laramie."

It may be accepted, then, that the Laramie flora is younger than that of the Patoot series and there is little or no relation between them.

RELATIONS TO THE UPPER CRETACEOUS OF EUROPE.

As a preliminary to the consideration of the possible relations between the flora of the Laramie and such floras as are available in the European Upper Cretaceous, it may be of interest to give a brief tabular view of the Upper Cretaceous section that is now quite generally accepted. It is taken in the main from the fifth edition of De Lapparent's Geology:

Danian.
Aturian {Maestrichtian, Campanian} Upper Senonian.
Emscherian {Santonian, Coniacian} Lower Senonian.
Turonian {Angoumian., Ligerian.}
Cenomanian.

The Campanian, the lower division of the Aturian (Upper Senonian), is thought to correspond approximately to the Pierre shale and the Fox Hills sandstone of the United States. The Maestrichtian, which constitutes the upper division of the Aturian (Upper Senonian), together with the Danian, corresponds to the Laramie, at least in position. The Maestrichtian is abundantly plant-bearing at a number of localities, especially in the Münster Basin of Westphalia. The plants from these localities—Sendenhorst, Haldene, Lunfüde, etc.—were studied and described specially by Hosius[18] and by Hosius and Von der Marck.[19]

E. W. Berry,[20] in a chapter on the Upper Cretaceous floras of the world, has compiled a complete list of the Maestrichtian flora of the Münster Basin, which is as follows:

Apocynophyllum cuneatum Hosius and Von der Marck.
Apocynophyllum subrepandum Von der Marck.
Aralia denticulata Hosius and Von der Marck.
Cf. Ceanothus sp.
Chondrites furcilentus latior Von der Marck.
Chondrites intricatus Sternberg.
Chondrites jungiformis Debey and Ettingshausen.
Chondrites polymorphus Hosius and Von der Marck.
Chondrites subcurvatus Hosius and Von der Marck.
Comptonia tenera Hosius and Von der Marck.
Cunninghamites elegans (Corda) Endlicher.
Cunninghamites squamosus Heer.
Dewalquea gelindensis Saporta and Marion.
Dewalquea haldemiana Saporta and Marion.
Dewalquea haldemiana angustifolia Hosius and Von der Marck.
Dewalquea haldemiana latifolia Hosius and Von der Marck.
Dewalquea insignis Hosius and Von der Marck.
Dryandroides haldemiana Hosius and Von der Marck.
Dryandroides macrophylla Hosius and Von der Marck.
Eolirion? nervosum Hosius and Von der Marck.
Eolirion primigenum Schenck?
Eolirion? subfalcatum Hosius and Von der Marck.
Eucalyptus haldemiana Debey.
Eucalyptus inaequilatera Von der Marck.
Ficus angulata Hosius and Von der Marck.
Ficus densinervis Hosius and Von der Marck.
Ficus laurifolia Hosius and Von der Marck.
Frenelopsis königii Hosius and Von der Marck.
Haliserites contortuplicatus Von der Marck.
Laurus affinis Hosius and Von der Marck.
Myrica leiophylla Hosius and Von der Marck.
Myrica primaeva Hosius and Von der Marck.
Cf. Myrtophyllum cryptoneuron Saporta and Marion.
Nerium röhlii Von der Marck.
Cf. Oreodaphne apicifolia Saporta and Marion.
Osmunda haldemiana Hosius and Von der Marck.
Pinus monasteriensis Hosius and Von der Marck.
Populus tremulaeformis Hosius and Von der Marck.
Pisidonia cretacea Hosius and Von der Marck.
Quercus asymetia Hosius and Von der Marck.

[17] Berry, E. W., Maryland Geol. Survey, Upper Cretaceous, p. 196, 1916.

[18] Hosius, A., Die in der Westfälischen Kreideformation vorkommen den Pflanzenreste Münster, pp. 1-34, 1869; Ueber einige Dicotyledonen der Westfälischen Kreideformation: Palaeontographica, vol. 17, pp. 89-104, pls. 12-17, 1869.

[19] Hosius, A., and Von der Marck, Die flora der Westfälischen Kreideformation: Palaeontographica, vol. 26, pp. 125-256, pls. 24-44, 1880.

[20] Maryland Geol. Survey, Upper Cretaceous, p. 283, 1916.

Quercus castanoides Hosius and Von der Marck.
Quercus dryandraefolia Von der Marck.
Quercus euryphylla Hosius and Von der Marck.
Quercus formosa Hosius and Von der Marck.
Quercus heiracifolia Hosius and Von der Marck.
Quercus iliciformis Hosius and Von der Marck.
Quercus rhomboidalis Hosius and Von der Marck.
Quercus sphenobasis Hosius and Von der Marck.
Quercus westfalica latior Hosius and Von der Marck.
Quercus westfalica oblongata Hosius and Von der Marck.
Quercus westfalica obtusata Hosius and Von der Marck.
Cf. Rhamnus sp.
Sequoia reichenbachi (Geinitz) Heer.
Taenidium alysoides Hosius and Von der Marck.
Tetraphyllum dubium Hosius and Von der Marck.
Thalassocharis westfalica Hosius and Von der Marck.

This flora comprises 56 forms, only one of which, *Sequoia reichenbachi,* is found in the Laramie. This is without special significance, for this species enjoys a world-wide distribution and ranges in age from Jurassic to uppermost Cretaceous. A number of genera, such as *Ficus, Laurus, Myrica, Populus,* and *Quercus,* are common to the two, but the species are all perfectly distinct and apparently unrelated. It appears to the writer that the Maestrichtian flora is much more closely related to the Montana flora. This is especially shown by the common presence of certain conifers, such as *Cunninghamites, Frenelopsis,* and *Sequoia reichenbachi.* Be this as it may, the Maestrichtian certainly has no particular relationship with the flora of the Laramie.

THE FLORA.

Phylum THALLOPHYTA.

Delesseria fulva Lesquereux.

Plate I, figure 4 (type).

Delesseria fulva Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 376, 1873; idem for 1873, p. 379, 1874; idem for 1876, p. 496, 1878; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 39, pl. 1, fig. 10, 1878. [Lesquereux's original figure of the type is here reproduced.]

The type of this species is No. 9 of the United States National Museum collection of fossil plants and appears to be the only example ever obtained. It is preserved on a fine-grained hard white sandstone, on which it stands out in bold relief, being itself of a reddish-brown color.

Occurrence: Laramie formation, Golden, Colo., under or between coal beds.

Phylum PTERIDOPHYTA.

Order FILICALES.

Family POLYPODIACEÆ.

Onoclea fecunda (Lesquereux) Knowlton.

Plate I, figures 2, 3.

Caulinites fecundus Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 384, 1873; idem for 1873, p. 380, 1874; idem for 1876, p. 501, 1878; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 101, pl. 14, figs. 1–3, 1878. [Lesquereux's original figures are here reproduced.]
Onoclea fecunda (Lesquereux) Knowlton, U. S. Geol. Survey Bull. 152, p. 153, 1898.

Fertile frond contracted, closely pinnate; main rachis broad (2 millimeters), smooth, divided into opposite erect branches which bear on each side thickly set short-pediceled simple spherical "capsules" (sporangia); sterile portion not known.

The type specimens of this plant are preserved in the United States National Museum (Nos. 120, 121). Their original reference to the genus *Caulinites* was a matter of uncertainty, for Lesquereux in his first mention says,[21] "This relation to species of our time is unknown," and later [22] adds:

> It is very questionable if these fine fruiting branches may be referred to this genus. They have this in common only—a monospermous (?) nucula with a cellulose envelope. As I have been unable to find either in the fossil species described until now or in the collection of living plants which I was able to consult anything to which they had apparent relation, I have left them in this as yet vaguely defined genus.

No additional material has been obtained since that described by Lesquereux, and it is perhaps hazardous to transfer these specimens to another genus, but all things being taken into account, the suggestion of the late Joseph F. James [23] that they closely resemble the fruiting frond of the living *Onoclea sensibilis* seems to justify the change. When the fossil and living plants are placed side by side it is seen that the resemblance is striking and suggestive. The fossil has the same pinnate branching and opposite, contiguous, short-

[21] U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 384, 1873.
[22] The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 101, 1878.
[23] Science, vol. 3, p. 433, fig. 1a, 1884.

pediceled "capsules" as the living species. The living form, as is well known, has the fertile pinnules rolled up into berry-like bodies, on the outside of which thick veins are very prominent. In the fossil this feature is apparently absent. Considering the fact that this fruiting portion has been found only once, it is not strange that the sterile portion remains unknown.

A species that has a somewhat similar history has been found in the Raritan and Magothy formations of southern New York and the islands south of the New England mainland. It was first described as *Caulinites inquirendus* Hollick [24] and later transferred to *Onoclea* [25] on the ground of its resemblance to the species under consideration. Like our form, it has pinnately arranged branches with the spheroidal "capsules" in a single row on each side, and associated sterile fronds have not been found with it.

One of the most abundant and widely distributed plants of the Fort Union formation is a fern that can not be distinguished from the living sensitive fern, *Onoclea sensibilis*. It occurs at some localities by hundreds, but in only one known place in all the vast area covered by the Fort Union formation has it been found fruiting. In a small collection obtained near Porcupine Butte, Sweetgrass County, Mont., there were many of the usual sterile fragments, and associated with them a few fertile fronds.[26] A comparison of these fertile fronds with the Laramie specimens under consideration shows a close, at least generic similarity.

Thus, as at present provisionally marked out, our knowledge of the geologic history of the living sensitive fern may stand as follows:

Onoclea inquirenda Hollick	Raritan.
Onoclea neo-mexicana Knowlton.	Montana.
Onoclea fecunda (Lesquereux) Knowlton.	Laramie.
Onoclea sensibilis fossilis Newberry.	Fort Union.
Onoclea sensibilis Linné	Living.

[24] Hollick, Arthur, New York Bot. Gard. Bull., vol. 3, p. 403, pl. 20, fig. 3, 1904.

[25] Hollick, Arthur, U. S. Geol. Survey Mon. 50, p. 32, pl. 1, figs. 1-7, 1906.

[26] Knowlton, F. H., Torrey Bot. Club Bull., vol. 29, p. 705, p. 26, figs. 1-4, 1902.

Occurrence: Laramie formation, Erie, Boulder County, Colo., collected by Leo Lesquereux about 1872.

Dryopteris georgei Knowlton, n. sp.

Plate I, figures 6, 7.

Fronds probably of large size but the complete outline unknown, though apparently it was at least thrice pinnatified; main rachis not sure; secondary rachis strong, straight, grooved; pinnae apparently lanceolate; pinnules numerous, very close, alternate or subopposite, narrowly linear-lanceolate, sessile, narrowly acuminate at apex, cut into numerous small, oblong, rather obtuse lobes, the cutting being made less toward the apex; nervation fairly strong, consisting of a stout midvein and five or six pairs of once-forked veins; fruit not seen.

This fine species, which I am able to include by the courtesy of Prof. R. D. George, of the University of Colorado, is all that has been found, and although a considerable portion of the frond is preserved it was evidently of much larger size when perfect. Two of the pinnae are parallel and lie in such a position as to suggest that they were attached to a common rachis, in which case the whole frond must have been of imposing appearance. The pinnae appear to have been 15 or 20 centimeters in length and 7 or 8 centimeters in width. The pinnules, as already noted, are narrowly linear-lanceolate, their length being 4 or 5 centimeters and their width about 1 centimeter at base; they begin to narrow near the middle and become narrowly acuminate at the apex.

The coriaceous appearance of the frond and its rather strict aspect suggest the probability that it was of xerophytic habit.

The photograph showing the whole frond somewhat less than natural size was sent by Prof. George, who also kindly donated the two fragments of the counterpart shown in figures 6 and 7.

Occurrence: Laramie formation, shaft of Columbia mine, 150 feet from the surface, near Louisville Junction, Boulder County, Colo., submitted by R. D. George. Type specimen in the Museum of the University of Colorado. Boulder, Colo.; pieces of counterpart in United States National Museum.

Dryopteris laramiensis Knowlton.

Plate I, figure 5 (type).

Dryopteris laramiensis Knowlton, U. S. Geol. Survey Bull. 696, p. 248, 1919.

Lastrea (Goniopteris) intermedia Lesquereux, Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 56, pl. 4, fig. 14, 1878. [Lesquereux's original figure is here reproduced.]

Aspidium (Lastrea) pulchellum? Heer, or *A. fischeri?* Heer. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1870, p. 384, 1872.

This species is evidently very closely related to *Dryopteris lesquereuxii,* from which it appears to differ in having the pinnae closer, at a more acute angle of insertion on the rachis, and with the pinnules or lobes somewhat longer. Neither of these differences is of much importance, and it is quite possible that a series of specimens, if they were available, would show the two forms as merging, but so far as known the specimen figured by Lesquereux is the only specimen extant, and if it were not for some phases of the earlier history of the present "species," it would perhaps do no great harm to combine them. The specimens on which Lesquereux founded *Lastrea intermedia* are involved in some complications. In the first mention [27] (under the designation *Aspidium pulchellum* Heer, or *A. fischeri* Heer) they are said by Lesquereux to have come from "Muddy Creek," without mention of the State or other more exact location. From Hayden's itinerary, which precedes the report on the fossil plants, it appears reasonably certain that they must have come from the Muddy Creek that rises in Bridgers Pass, in the mountains south of Rawlins, in Carbon County, Wyo., and flows into Little Snake River. At a point in the valley of this stream near Barrel Springs Hayden [28] found, in addition to shells, remains of turtles, fish, etc., "a few obscure plants, like blades of grass, stems of rushes, etc., in the clays; still higher up on the tops of the hills that border the stream are some thin, chalky clays crowded full of plants, as ferns, rushes, grasses, palms, etc., finely preserved." It is doubtful if any of this material is present in the collections of the United States National Museum, at least under this designation.

In the next mention of *Lastrea intermedia* by Lesquereux [29] it is said to have come from "Henrys Fork, a mixed lot." It is easy to see how this mistake arose, for in the Annual Report for 1870, page 384, the designation "Henrys Fork" occurs at the top of the page, while that of "Muddy Creek" is in the middle of the page without indention or other display and so is easily overlooked. But this error is apparently responsible for Lesquereux's reference of *Lastrea intermedia* to the Green River formation,[30] which would doubtless be correct if it had actually come from Henrys Fork. There seems, therefore, absolutely no warrant for Henrys Fork as a locality or Green River formation as a horizon for this species.

Golden, Colo., is also given by Lesquereux [31] as a locality for "*Lastrea intermedia,*" and the only specimen figured is preserved in the United States National Museum. It is preserved on the hard white sandstone characteristic of the Laramie at this locality and is apparently correctly recorded.

Owing to the absence of all specimens, except the one from the Laramie at Golden, the occurrence of this form in Wyoming will have to be ignored, at least until more material has been procured.

Occurrence: Laramie formation, Golden, Colo.

Dryopteris lesquereuxii Knowlton.

Aspidium goldianum Lesquereux,[32] U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1873, p. 393, 1874.

Lastrea (Goniopteris) goldiana Lesquereux, Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 56, pl. 4, fig. 13, 1878.

Dryopteris lesquereuxii Knowlton, U. S. Geol. Survey Bull. 696, p. 248, 1919.

Frond bipinnate (tripinnate?), broadly deltoid in outline; pinnae linear, alternate, parallel, at an obtuse or rarely somewhat acute angle of divergence (40°–50°), alternately and equally pinnately lobed; lobes cut or separated by two-thirds or three-fourths of their length, oblong-lanceolate, obtusely pointed, inclined outside; middle nerve strong, distinct, lateral veins five to seven pairs, curving slightly upward, simple, parallel.

The ferns first described by Lesquereux under the name *Aspidium goldianum* appear

[27] U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1870, p. 384, 1872.

[28] Idem, p. 73.

[29] The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 56, 1878

[30] The Cretaceous and Tertiary floras: U. S. Geol. Survey Terr. Rept., vol. 8, p. 138, 1883.

[31] Op. cit. (Tertiary flora), p. 57, pl. 4, fig. 14.

[32] This name was preoccupied by the living *Aspidium goldianum* Hooker, 1824, now *Dryopteris goldiana* (Hooker) A. Gray, 1848. I have therefore given the fossil orm a new name in honor of its describer.

to be very well characterized, being bipinnate, or perhaps it would be better to say bipinnatified, with the pinnae alternate, at a low angle of divergence with the main rachis, and lanceolate in general outline. They are cut nearly to the secondary rachis, with numerous linear-lanceolate, rather obtuse segments. In the type species figured in the "Tertiary flora" (pl. 4, fig. 13) the segments of the pinnae are short, being from 7 to 9 millimeters in length, and have from five to seven pairs of simple nerves.

The type of *Aspidium goldianum* Lesquereux (now *Dryopteris lesquereuxii*) is said to have come from Golden, Colo., and an examination of the specimen (No. 26, U. S. Nat. Mus.) appears to confirm this statement; in any event there is no tangible evidence to the contrary. The species has not been noted in any of the recent collections from Golden.

Occurrence: Laramie formation, Golden, Colo.

Dryopteris? carbonensis Knowlton, n. sp.

Plate XX, figures 3–5.

Dryopteris? carbonensis Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 249, 1919.

Fronds once pinnate (?); pinnae probably lanceolate, deeply pinnatified, the divisions nearly opposite, narrowly deltoid or broadly lanceolate in outline, with obtusely acuminate apex and perfectly entire margins; secondary rachis strong; midnerve of segments thin, practically straight; nerves obscure, apparently remote and simple; fruit unknown.

This species is based on the three fragments figured and is apparently quite distinct from anything from the true Laramie heretofore described. Whether it belongs to the genus *Dryopteris* is not by any means certain, for without fruit that point can not be positively ascertained, but from its general resemblance to certain species of this genus I have decided so to refer it. It is, for example, quite like some of the larger pinnae of *Dryopteris goldiana* (Hooker), a living species of eastern North America.

From its general resemblance to the above-mentioned living species, I have assumed that it had once-pinnate fronds with numerous lanceolate pinnae, but this, of course, is largely conjecture. The divisions of the pinnae are cut a little more than half the distance to the midvein. They are slightly scythe-shaped and have rather acute apices. The secondary nerves of the divisions appear to be simple, but the specimens are preserved on a rather coarse grained matrix which is not well suited to preserve the finer nervation, and it is impossible to say whether they were forked or not. No trace of the fructification is preserved.

A single fragment of this species is found also in the collections from Marshall, Colo.; it is without nervation and is on the same piece of rock with *Ficus arenacea*.

Occurrence: Laramie formation, Mount Carbon, Morrison, Colo.; sandstone near coal seam, Marshall, Colo.; collected by A. Lakes, 1890.

Genus PHANEROPHLEBITES Knowlton, n. gen.

Of the general type of the living *Phanerophlebia*, but with thick, fleshy midrib, and few free veins.

Phanerophlebites pealei Knowlton, n. sp.

Plate III, figure 5.

Phanerophlebites pealei Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 439, 1919.

Outline of whole frond not known but presumably pinnate, pinnae large, strap-shaped, with apparently entire margins; midrib extremely thick and fleshy; nerves numerous, rather fine, usually forking near the midrib and once or twice before reaching the margin, sometimes free but usually anastomosing; fruit not preserved.

This form is represented only by the example here figured, and this is more or less fragmentary, neither base nor apex being retained. It is now about 12 centimeters long but was obviously very much longer when perfect. The width was 4.5 or 5 centimeters. The small portion of the margin preserved shows it to be entire or perhaps slightly undulate. This pinna was evidently of thick substance, as indicated by the very strong midrib and the immersed appearance of the veins. The veins are fine and very close and are more or less conspicuously anastomosed. All the veins fork, and some of them appear to be free, but this feature, owing to the small amount of material, is difficult to make out.

It is with some hesitation that this fragmentary specimen is described as establishing a new genus. It is aspidioid in general appearance and seems to approach most closely the living genus *Phanerophlebia*. This genus embraces about a dozen rather closely related species extending from the southern border of the United States through Mexico and Central America to Brazil. In some ways the specimen approaches most closely *Phanerophlebia nobilis* (Schlechtendal and Chamisso) Presl, a native of Mexico, especially in type of nervation.

Occurrence: Laramie formation, Lafayette, Colo., dump of Simpson mine, collected by A. C. Peale, for whom the species is named.

Asplenium martini Knowlton, n. sp.

Plate II, figure 6.

Asplenium martini Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 105, 1919.

Outline of whole frond unknown but at least thrice-pinnatified, apparently thick or coriaceous in texture; pinnae long-lanceolate, with an exceedingly strong rachis, cut with numerous opposite or subopposite, short, ovate or ovate-oblong, obtuse pinnules; nervation of pinnules strong, consisting of a very strong midvein and 8 or 10 pairs of strong veins, which are once-forked, usually near the base; fruit not seen.

This form is so fragmentary as hardly to be worthy of characterization, yet even these small pieces show clearly that it must have been a plant of striking appearance. The fragment is about 8 centimeters in length, and to judge from the very thick rachis it must have been when perfect at least twice this length and was probably even larger. The rachis is fully 2 millimeters thick. Only one pinnule is anywhere near perfect. This is nearly 2 centimeters in length and is about 12 millimeters broad. The pinnules, so far as can be ascertained, were opposite or subopposite and cut by a sharp sinus within 4 or 5 millimeters of the rachis. The nervation of the pinnules, as already indicated, is very deeply impressed, showing that the texture was thick and probably coriaceous. The strong midvein is slightly irregular, and the nerves, also very strong, are once-forked, usually near the midvein.

In the absence of fruit it is impossible to be certain of the generic reference, but the form is so distinct, even in the fragments available, that it must constitute a good horizon marker. Among fossil species it is suggestive of *Asplenium magnum* Knowlton,[33] from the Fort Union of the Yellowstone National Park, but it differs in a number of important particulars. It is much larger than *Asplenium magnum,* being in fact nearly as large as the enlargement of that species shown in figure 8a of the plate above cited. Its pinnules are more deeply cut, and the nervation is very much stronger, though of the same type.

In some respects it is closer to *Asplenium coloradense* Knowlton,[34] from the Vermejo formation of the Raton Mesa region, which was at first identified by Hollick [35] with *Asplenium magnum.* The form under consideration seems to differ from *Asplenium coloradense* in its larger size, more obtuse pinnules, and much stronger nervation. A series of specimens showing the variation in size might bring them together, but for the present they are best kept apart, though obviously closely related.

This species is named in honor of George C. Martin, of the United States Geological Survey, who assisted in making the collection of which it is a part.

Occurrence: Laramie formation, dump of Reliance mine, 1¾ miles northeast of Erie, Colo., collected by F. H. Knowlton and G. C. Martin.

Pteris goldmani Knowlton, n. sp.

Plate II, figure 3.

Pteris goldmani Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 518, 1919.

Outline of frond unknown; pinnae lanceolate, margin entire; rachis thin, grooved; nerves numerous, at an angle of 50° or 60°, slightly curved, forking a short distance above the base and again below the margin, often anastomosing.

Although this is a mere fragment 3 centimeters long and the same in width, it is so well characterized by the nervation that it seems worthy of full specific rank. It is of the type of what has been called *Pteris subsimplex* Lesquereux,[36] *Pteris erosa* Lesquereux,[37] *Pteris undulata* Lesquereux, etc., but differs essen-

[33] U. S. Geol. Survey Mon. 32, pt. 2, pl. 79, figs. 5–8, 1899.
[34] U. S. Geol. Survey Prof. Paper 101, pl. 1, figs. 1, 2, 1918.
[35] Hollick, Arthur, Torreya, vol. 2, p. 146, pl. 4, figs. 1, 2, 1902.
[36] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7, pl. 4, figs. 5–7, 1878.
[37] Idem, fig. 8.

tially in having the nerves at a more acute angle and regularly twice-forked. The nerves are also frequently anastomosed, especially near the margin.

This species is named in honor of Marcus I. Goldman, of the United States Geological Survey, who assisted in making the collection at this locality.

Occurrence: Laramie formation, Popes Bluff, west of Pikeview, Colo. (sec. 14, T. 13 S., R. 67 W.), collected by A. C. Peale and M. I. Goldman, 1908.

Pteris? sp.

Plate II, figure 5.

Pteris? sp. Knowlton [nomen], U. S. Geol. Survey Bull. 696, p. 513, 1919.

The specimen here figured is so small a fragment that were it not for the fact that it is very different from anything heretofore found in the Laramie, it would hardly be worthy of mention. It is the wedge-shaped basal portion of what was apparently a large lanceolate frond or pinnule. The midrib was exceedingly thick, and the blade appears also to have been thick or coriaceous. The nerves are very fine, close, parallel, and at a low angle of emergence. It is difficult to ascertain whether the veins fork at the extreme base or are simple, though presumably they are forked just above their point of origin. Occasionally a vein may be observed to fork near the middle, but beyond this little can be made out.

This fragment is so small and obscure that comparisons with other forms are hardly warranted, though in passing it may be said that the specimen somewhat resembles what Lesquereux described as *Gymnogramma gardneri*,[38] especially in the shape of the base and the thick midrib, but it differs strongly in the more numerous finer veins, which do not anastomose.

Occurrence: Laramie formation, Marshall, Colo., wooded bluff just south of station, at the highest plant-bearing point in the section, collected by A. C. Peale.

Family SCHIZAEACEAE.

Anemia elongata (Newberry) Knowlton.

Plate II, figure 2.

Anemia elongata (Newberry) Knowlton, U. S. Geol. Survey Bull. 696, p. 74, 1919.

Sphenopteris (*Asplenium*) *elongatum* Newberry, Boston Soc. Nat. Hist. Jour., vol. 7, p. 511, 1863.

Anemia subcretacea? (Saporta) Gardner and Ettingshausen, British Eocene flora, vol. 1, Filices, pt. 2, p. 45, pls. 8, 9, 1880.

Knowlton, U. S. Geol. Survey Bull. 152, p. 34, 1898; Mon. 32, pt. 2, p. 657, 1899; Bull. 163, p. 20, 1900.

Anemia perplexa Hollick, in Newberry, U. S. Geol. Survey Mon. 35, p. 3, pl. 15, figs. 1, 1a, 1898.

Gymnogramma haydenii Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 295, 1873; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 59, pl. 4, figs. 1–3, 1878.

Anemia haydenii (Lesquereux) Cockerell, Torreya, vol. 9, p. 142, 1909.

My understanding of the status of the American material usually referred to *Anemia subcretacea* is set forth at length in my "Flora of of the Montana formation,"[39] and I have little or nothing to add to that account. One difficulty in the study of ferns of this group is lack of sufficient material, for somehow it happens that although *Anemia* is fairly well distributed both geologically and geographically, it is rarely found abundant or well preserved. The type specimens of Lesquereux's *Gymnogramma haydenii*, for instance, are mere fragments that can give only a partial idea of its size and appearance. The example here figured, although exceptionally well preserved, is the only one present in the collections from Erie. It is almost entire in the upper portion and sparingly toothed below, but otherwise it is very much like the figures of *Gymnogramma haydenii*. It is rather more robust than the figures of the English species shown by Gardner and Ettingshausen would imply, though it approaches that species most closely. I have questioned the reference of the Erie specimen to *Anemia subcretacea* rather than make a new species. If additional material can be procured it may serve to settle the status of this form.

Occurrence: Laramie formation, ?Erie, Colo.; Mesaverde, ?Point of Rocks, Wyo.; Puget group, ?Washington.

Anemia supercretacea Hollick.

Anemia supercretacea Hollick, Torreya, vol. 2, p. 145, pl. 3, figs. 6, 7, 1902.

Cockerell, Torreya, vol. 9, p.142, 1909.

This species was described by Hollick from material collected in the well-known reddish sandstone at Florence, Colo., from beds then supposed to be of Laramie age but subse-

[38] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7, pl. 4, fig. 2, 1878.

[39] Knowlton, F. H., U. S. Geol. Survey Bull. 163, pp. 20–22, 1900.

quently determined to belong to the Vermejo formation of the Montana group. It is recorded from the Laramie at Marshall, Colo., by Cockerell, who says:

> Found first at Marshall by Paul Haworth. Our specimens run a little larger than Hollick's but appear to be otherwise quite identical; the pinnules are entire. The plant may possibly be a variety of *Anemia haydenii* (*Gymnogramma haydenii* Lesquereux, 1872), which appears to be distinctly different from *A. subcretacea* (Saporta) Gardner and Ettingshausen as originally figured by Saporta.

I have not seen the material mentioned by Cockerell, nor has *Anemia* been noted in any of the collections from Marshall and vicinity that have passed through my hands, though I have no reason to doubt the above determination.

Occurrence: Vermejo formation, Florence, Colo. (type); Laramie formation, Marshall, Colo., reported by Prof. T. D. A. Cockerell.

Anemia sp.

Plate II, figure 1.

Anemia sp. Knowlton [nomen], U. S. Geol. Survey Bull. 696, p. 75, 1919.

In the material from a locality a few miles north of Colorado Springs there is a single fragment of the pinnule of an *Anemia*. The matrix on which it is preserved is so coarse grained that only the outline can be made out with certainty. The nervation appears to consist of slender veins at a rather acute angle, but their manner of forking can not be seen.

This fragment is very readily comparable with various species of *Anemia*, especially *Anemia subcretacea*, but it is so poorly preserved and so small that it is best left without speculation as to its specific identification.

Occurrence: Laramie formation, opposite sand-lime brick works about 4 miles north of Colorado Springs, Colo., collected by A. C. Peale and G. I. Finlay, 1908.

Lygodium? compactum Lesquereux.

Plate I, figure 1 (type).

Lygodium compactum Lesquereux, Am. Jour. Sci., 2d ser., vol. 16, p. 206, 1868; U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1869, p. 196 [reprint, 1875]; idem for 1873, p. 380, 1874; idem for 1876, p. 498, 1878; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 64, pl. 5, fig. 9, 1878. [Lesquereux's figure of the type is here reproduced.]

The type and so far as known the only specimen ever obtained of this species is No. 118 of the fossil-plant collections of the United States National Museum. It is a small fragment preserved on a piece of hard, rather coarse-grained sandstone, and is very obscure.

There is much uncertainty as to the proper disposition of this specimen. It is so fragmentary and its nervation is so poorly preserved that a satisfactory characterization of it is impossible. There is even some doubt as to whether it is a fern. But in the absence of additional specimens or further information concerning the type, it is retained as left by its author, in the hope that future exploration may clear up its position, though at present it is not of much value.

Occurrence: Laramie formation, Marshall mine, Marshall, Colo., original collection of F. V. Hayden.

Order EQUISETALES.

Family EQUISETACEAE.

Equisetum perlaevigatum Cockerell.

Plate I, figures 8, 9.

Equisetum perlaevigatum Cockerell, West Am. Scientist, vol. 6, p. 154, 1889.

Equisetum laevigatum Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1873, p. 395, 1874; idem for 1876, p. 498, 1878; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 68, pl. 6, figs. 6, 7, 1878. [Lesquereux's original figures are here reproduced.] [Homonym, Al. Braun, 1867.]

This so-called species is a very unsatisfactory one indeed. The material upon which it is founded is preserved in the United States National Museum (Nos. 42, 43) and represents, so far as known, all that has ever been found. The larger specimen (original of Lesquereux's fig. 7), from Sand Creek, Colo., is very obscure and has more the appearance of a piece of dicotyledonous bark, or the impression of a stem. Its surface is wrinkled irregularly rather than striately, and the so-called tubercles can hardly be made out. As a factor in the distribution of the species this specimen can safely be ignored.

The smaller specimen (original of Lesquereux's fig. 6), from the hard white sandstone at Golden, Colo., is without doubt a portion of the underground stem of an *Equisetum*, but it could probably not be distinguished from certain other described species, and the advisability of retaining it is open to question. It is permitted to stand simply for the purpose of showing that the horsetails were present in these beds, though it may be but poorly characterized.

Occurrence: Laramie formation, Golden, Colo., original Museum collections.

Phylum **SPERMATOPHYTA.**

Class **GYMNOSPERMAE.**

Order **CONIFERALES.**

Family **ARAUCARIACEAE.**

Dammara sp.

Plate II, figure 4.

Dammara sp. Knowlton [nomen], U. S. Geol. Survey Bull. 696, p. 228, 1919.

In the collection from the wooded bluff south of Marshall, Colo., there is a single fragmentary scale that appears to be a *Dammara*. It is about 13 millimeters long and some 8 millimeters wide at the broadest point; it is strongly ribbed. The apical portion is broken away, so it is impossible to observe the spine of the scale, if there was one. The specimen is so fragmentary that it is hardly worth while to institute any comparisons with published forms. It was found in the association with *Rhamnus salicifolius*, *Rhamnus goldianus?*, and the fragment of a fern described as *Pteris?* sp.

Occurrence: Laramie formation, Marshall, Colo., wooded bluff just south of station, highest point in section, collected by A. C. Peale.

Family **TAXODIACEAE.**

Sequoia acuminata? Lesquereux.

Plate II, figures 7, 8.

Sequoia acuminata Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1874, p. 310, 1875; idem for 1876, p. 500, 1878; idem, Bull., vol. 1, No. 5, 2d ser., p. 384, 1876; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 80, pl. 7, figs. 15–16a, 1878.

The type specimens of this species are supposed to be preserved in the United States National Museum (No. 62), but they can not now be found. So far as can be made out from the figures it seems to be very close to *Sequoia longifolia* Lesquereux, a fact which Lesquereux recognized, as he says:

This species differs from the former by the proportionally narrower leaves, with a very distinct middle nerve, and smooth surfaces; also by the stem, which is striate when decorticated. * * * The average size of the leaves is about the same in both forms, the leaves varying from 3 to 6 centimeters long and from 2 to 5 millimeters broad.

In the collection from Cowan station there is a single fragment that may belong to this species, but it is so fragmentary that the essential characters can not be made out with certainty.

The two examples figured, though fragmentary and not well preserved, appear to agree in all essential features with the specimens figured by Lesquereux.

Occurrence: Post-Laramie, Black Buttes, Wyo. (types). Laramie formation,? Cowan station, 10 miles south of Denver, Colo., collected by F. H. Knowlton; cut on Moffat railroad (Denver & Salt Lake) near Leyden Gulch, Colo., collected by A. C. Peale. Dawson arkose, Templeton Gap, 4 miles northeast of Colorado Springs, Colo., collected by A. C. Peale, 1908.

Sequoia reichenbachi (Geinitz) Heer.

Plate XX, figures 1, 2.

Araucarites reichenbachi Geinitz, Charakteristik der Schichten und Petrefacten des sächsisch-böhmischen Kreidegebirges, pt. 3, p. 98, pl. 24, fig. 4, 1842.

Sequoia reichenbachi (Geinitz) Heer, Flora fossilis arctica, vol. 1, p. 83, pl. 43, figs. 1d, 2b, 5a, 1868.

Lesquereux, U. S. Geol. Survey Terr. Rept., vol. 6, p. 51, pl. 1, figs. 10–10b, 1874; U. S. Geol. Survey Mon. 17, p. 35, pl. 2, fig. 4, 1892.

Hollick, New York Acad. Sci. Trans., vol. 12, p. 30, pl. 1, fig. 18, 1892.

Fontaine, U. S. Geol. Survey Mon. 15, p. 243, pl. 118, figs. 1, 4; pl. 119, figs. 1–5; pl. 120, figs. 7, 8; pl. 122, fig. 2; pl. 167, fig. 5, 1889.

Dawson, Roy. Soc. Canada Trans., vol. 3, p. 21, 1882.

Newberry, U. S. Geol. Survey Mon. 26, p. 49, pl. 9, fig. 19, 1896.

Knowlton, U. S. Geol. Survey Mon. 32, pt. 2, p. 657, 1898.

In the collection from Coal Creek, Boulder County, Colo., there is a single specimen which I am unable to separate from many of the figures referred to *Sequoia reichenbachi*, and I have so regarded it. As may be noted in the figure (Pl. XX, fig. 1), it is a fairly well preserved specimen with a large main branch and several smaller branchlets bearing rather closely appressed, sharp-pointed leaves. It is, for example, hardly to be distinguished from figures of this species given by Velenovsky [40] from the Cretaceous of Bohemia. I also find in the old United States National Museum collections a single specimen, recorded under No. 865, which was collected at Coal Creek by George Hadden. It was not figured by Lesquereux and represents the impression of a fragment from a large branch. It is indistinguishable from figure 23 of Plate VII in Lesquereux's "Tertiary flora." [41]

Among the specimens collected by Arthur Lakes at Mount Carbon, Morrison, Colo., from the sandstone near the coal seam, are a number of rather poorly preserved but evidently large branches of a conifer that I am unable to distinguish from this species. By taking an impression in clay the original form of the branches is restored in a fairly satisfactory manner. The leaves are seen to be rather long, sharp pointed, and spreading, but with incurved tips.

The small collection made on Crow Creek, Colo., contains three rather poorly preserved specimens of conifers that appear to be referable to this species. They are long, slender twigs covered with short, appressed scalelike leaves and apparently additional more slender leaves. They are not well enough preserved to warrant a positive reference to this or any other species.

Occurrence: Laramie formation, Coal Creek, Boulder County, Colo., collected by N. L. Britton about 1884; Mount Carbon, Morrison Colo., collected by A. Lakes in 1890; Crow Creek about 25 miles northeast of Greeley, Colo., collected by F. H. Knowlton and T. W. Stanton, 1896. The last is questionable.

Sequoia longifolia Lesquereux.

Plate III, figure 3; Plate IV, figure 2.

Sequoia longifolia Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1874, p. 298, 1876; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 79, pl. 61, figs. 28, 29 [not pl. 7, figs. 14, 14a, which = *Sequoia magnifolia* Knowlton].

Geinitzia longifolia (Lesquereux) Knowlton, U. S. Geol. Survey Bull. 63, p. 28, 1900.

Cunninghamites? sp.? Knowlton, U. S. Geol. Survey Bull. 163, p. 29, pl. 5, fig. 3, 1900.

There appears to be some confusion regarding Lesquereux's *Sequoia longifolia*. So far as can be made out, Lesquereux had specimens of a long-leaved conifer from Black Buttes, Wyo., to which it is inferred he gave the manuscript name "*Sequoia longifolia*." Before this species was published, however, specimens thought to represent the same species were obtained from Point of Rocks, Wyo., and the name was first published in the Hayden Annual Report for 1874 (1876), page 298, under the designation "*Sequoia longifolia* Lesq., MSS." In explanation he adds: "This species was already described from Black Buttes specimens." I can not find that it was ever published in connection with the Black Buttes specimens, and it seems that when Lesquereux actually came to publishing a report on the Black Buttes material he changed the name of the long-leaved conifer common at that place to *Sequoia acuminata*.[42] It is certain that he nowhere definitely recorded *Sequoia longifolia* as coming from Black Buttes, nor has it since been found there.

If the above interpretation is correct, as it is believed to be, it establishes Point of Rocks, Wyo., as the type locality for *Sequoia longifolia* and excludes the species from Black Buttes. The type specimens are the originals of figures 28 and 29 of Plate LXI of the "Tertiary flora" and are Nos. 73 and 74, respectively, of the United States National Museum collections. This leaves the specimen figured under this name in Plate VII, figures 14, 14a, of the "Tertiary flora" still to be accounted for. It is said [43] to have come from the "Haley coal mine, 10 miles northeast of Greeley, Colo. (A. C. Peale)"; it is No. 61 of the United States National Museum collections. I was informed by Dr. Peale that this statement was in error, as he did not collect it and was never at this locality. Inasmuch as Lesquereux pointed out certain marked differences between the Point of Rocks and Greeley specimens and added, "It may be, therefore, that these specimens represent two different species," and in further consideration of the uncertainty regarding the so-called Greeley specimen, it is apparently justifiable to consider only the Point of

[40] Velenovsky, Josef, Die Gymnospermen der böhmischen Kreideformation, pl. 9, figs. 12, 14, etc., 1885.

[41] U. S. Geol. Survey Terr. Rept., vol. 7, 1878.

[42] U. S. Geol. Survey Terr. Bull., vol. 1, No. 5, 2d ser., p. 384, 1876; U. S. Geol. Survey Terr. Rept., vol. 7, p. 80, 1878.

[43] Lesquereux, Leo, op. cit., p. 80.

Rocks specimens in the present comparisons and discussions. Additional specimens from Point of Rocks were procured by L. F. Ward in 1883,[44] but none have been found in or about the supposed Greeley locality.

In the light of material recently studied it now seems probable that the specimen from the North Fork of Dutton Creek, Laramie Plains, Wyo., which I figured and described under the name *Cunninghamites?* sp., [45] should be referred to the present form. Although the full characters can not be made out, owing to poor preservation, the general appearance is the same as in many specimens that undoubtedly belong to *Sequoia longifolia*.

It was suggested by Schenk [46] a number of years ago that Lesquereux's *Sequoia longifolia* should be referred to the genus *Geinitzia*, and as cones had not been found at that time, I adopted the suggestion and in my "Flora of the Montana formation"[47] transferred it to this genus. Although cones have not been found in connection with these specimens, they have been found attached to specimens that are now described under the name *Sequoia magnifolia* Knowlton,[48] and as these two forms are undoubtedly congeneric it is best to refer them all to *Sequoia*.

The material from Marshall, Colo., includes several specimens of coniferous branches that are not to be distinguished from *Sequoia longifolia* as described and figured by Lesquereux from Point of Rocks, Wyo. One of the best of these branches is here figured. It is a thick branch 1 centimeter in diameter and about 15 centimeters long. The scars on the branch and the insertion of the long, slender, acuminate leaves are the same as shown in figure 29 of Plate LXI in the "Tertiary flora." The manner in which the leaves are matted together is also the same, and there can be no reasonable doubt of their identity with Lesquereux's species.

A single poorly preserved branchlet (shown in Pl. IV, fig. 2) from Cowan station, south of Denver, appears to belong to this species.

[44] Knowlton, F. H., U. S. Geol. Survey Bull. 163, p. 28, 1900.

[45] Idem, p. 29, pl. 5, fig. 3.

[46] Schenk, A., in Zittel, K. A., Handbuch der Palaeontologie, Abt. 2, pp. 301, 302, 1880.

[47] Knowlton, F. H., U. S. Geol. Survey Bull. 163, p. 28, 1900.

[48] Knowlton, F. H., The flora of the Fox Hills sandstone: U. S. Geol. Survey Prof. Paper 98, p. 88, pl. 15, figs. 1-3, 1916.

Occurrence: Mesaverde formation, Point of Rocks, Wyo. (type locality). Laramie formation, Marshall, Colo., railroad cut between old and new stations, collected by A. C. Peale, 1908; Cowan station, 10 miles south of Denver, Colo., collected by F. H. Knowlton, 1908.

Order CYCADALES.

Family CYCADACEAE.

Cycadeoidea mirabilis (Lesquereux) Ward.

Cycadeoidea mirabilis (Lesquereux) Ward, Biol. Soc. Washington Proc., vol. 11, p. 86, 1894.

Zamiostrobus mirabilis Lesquereux, U. S. Geol. and Geog. Survey Terr. Bull., vol. 1, No. 5, 2d ser., p. 383, 1876; idem, Ann. Rept. for 1874, p. 309, 1876; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 70, pl. 63, figs. 1-1d, 1878.

Nelumbium James, Science, vol. 3, p. 434, 1884.

Clathropodium mirabile (Lesquereux) Ward, Science, vol. 3, p. 532, 1884.

Cycadeoidea zamiostrobus Solms, Real. accad. sci. Ist. Bologna Mem., 5th ser., vol. 2, p. 210, 1892.

It is extremely doubtful whether this species should properly be included in this work, but I have given it the benefit of the doubt. It was found by F. V. Hayden lying on the surface of the ground near Golden, Colo., within the Laramie area, but it probably belonged to a more ancient formation, from which it had been transported. The microscopic appearance of this interesting species was well described and fairly well figured by Lesquereux, and the internal structure has been admirably worked out by Count Solms, to whom the cutting and study of the specimen was submitted. It is mentioned further by G. R. Wieland in his work on American fossil cycads.[49]

Occurrence: Laramie formation (?), near Golden, Colo.

Class ANGIOSPERMAE.

Subclass MONOCOTYLEDONAE.

Order GRAMINALES.

Family CYPERACEAE?

Cyperacites? hillsii Knowlton, n. sp.

Plate XX, figure 6.

Cyperacites? hillsii Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 222, 1919.

Leaves flat, without keel; nerves numerous, parallel, 5 millimeters apart, with a single more

[49] Carnegie Inst. Washington Pub. 34, vol. 2, p. 169, pl. 1, figs. 1, 2, 1916.

delicate intermediate nerve between the principal ones.

The material upon which this form is based is in reality hardly sufficient for the proper characterization of a new species, but as it appears to differ from all other Laramie species already described it must receive a name. It is based on fragments of leaves 7 or 8 centimeters long and from 1 to 1.5 centimeters wide. They are marked by numerous parallel veins about 5 millimeters apart, with slender intermediate veins, one between every two of the stronger ones. It is named in honor of Mr. R. C. Hills, of Denver, Colo.

Occurrence: Laramie formation, Erie and Coal Creek, Colo.

Cyperacites? tessellatus Knowlton, n. sp.

Plate III, figures 1, 2.

Cyperacites? tessellatus Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 222, 1919.

In the material from Popes Bluff, the locality earlier known as the Healey coal mine, there are several fragments of a large monocotyledonous leaf that is very strongly marked. Neither the length nor the width can be ascertained, though there are fragments 8 centimeters long and 5 or 6 centimeters wide. It is provided with strong, deeply impressed longitudinal veins which are a little less than 1 millimeter apart and without intermediate veins. It is, however, also provided with cross veins, which are nearly as deeply impressed as the others and cut the space between the veins into very regular rectangular areas about 1 millimeter long. This was evidently a thick, firm leaf, as the veins and cross veins are so deeply impressed.

The proper generic reference for this form is uncertain. Superficially it resembles *Zingiberites dubius* Lesquereux,[50] from the Denver formation, but it is excluded at once by the fact that the latter species has six or seven very thin veins between the strong veins. It also resembles certain leaves that have been referred to *Typha*, such as *Typha latissima* Heer,[51] but it is twice the width of even the largest leaves of that species and has three or four intermediate veins between the larger ones. The cross veins in *Typha* are very much like those in the present specimens, but none of the nervation is deeply impressed.

Occurrence: Laramie formation, Popes Bluff, west of Pikeview, Colo. (sec. 14, T. 13 S., R. 67 W.), collected by A. C. Peale and M. I. Goldman, 1908.

Cyperacites? sp.

Plate IV, figure 1.

Cyperacites? sp. Knowlton [nomen], U. S. Geol. Survey Bull. 696, p. 223, 1919.

The collections from Leyden Gulch contain a number of specimens that are somewhat difficult of interpretation, though obviously they are of monocotyledonous type. They appear to represent the stems and leaves of some plant resembling a sedge or possibly a grass. They are from 8 to 10 millimeters wide and nearly 1 millimeter in thickness as now compressed; what appear to be leaves of the same plant are 1.5 centimeters wide. They are provided with numerous very fine, close, parallel nerves, about 8 or 10 to each millimeter. There is a little evidence to show that some of the nerves are slightly heavier than the others, but the difference is not marked. There is also some evidence of the presence of cross veins, but this is very obscure.

This form is of no particular importance biologically and is described simply for the purpose of showing that certain plants of this general type were present at this time.

Occurrence: Laramie formation, Leyden Gulch, 6½ miles north of Golden, Colo., collected by A. C. Peale, 1908.

Family GRAMINEAE.

Phragmites laramianus Cockerell.

Phragmites laramianus Cockerell, Torreya, vol. 9, p. 141, 1909.

Phragmites oeningensis Al. Braun. Lesquereux, Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 88, pl. 8, figs. 1, 2, 1878.

The specimens figured by Lesquereux in the "Tertiary flora" under the name *Phragmites oeningensis* are preserved in the collections of the United States National Museum (Nos. 93, 94). They came from Golden, Colo., the matrix on which they occur being the hard white sandstone characteristic of the Laramie at that locality. These specimens are before me and appear to have been fairly well figured and described. They are mere fragments,

[50] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7, p. 95, pl. 16, fig. 1, 1878.

[51] Heer, Oswald, Flora tertiaria Helvetiae, vol. 1, pls. 43, 44, 1855.

however, and fail to show any very marked characters. The specimen shown in Lesquereux's figure 2 is a ribbed, intranodal portion of a stem about 4.5 centimeters long and 2 centimeters broad; it does not exhibit any of the characters of the node or joint. The small fragment just below it is without markings except for the deep scar at one end. It is wholly unconnected with the other fragments, and there is no certainty that they were organically in union. The specimen of Lesquereux's figure 1 appears to represent roots or underground portions with scattered scars which may indicate the origin of the rootlets, but this point is obscure. Its connection with the ribbed portion of the stem is purely conjectural.

The material from Hoyt's mine, near Golden, contains a single fragment of a ribbed stem like that shown in Lesquereux's figure 2, but it is even shorter than the one figured and shows none of the nodal characters. A small stem evidently referable to this form was contained in the material from Mount Carbon, near Morrison, but it adds nothing to our knowledge of this plant.

The question has arisen as to the propriety of identifying these American plants with the European *Phragmites oeningensis*. A comparison with the figures of the Old World form, such as those of specimens from the Swiss Miocene given by Heer,[52] discloses a strong generic resemblance, and possibly there would also be specific resemblance if the essential characters of our specimens could be fully made out. As already pointed out, no specimen appears to have been found which shows the full node with its markings. The strong ribs on the European specimens have usually about six intermediate, much slenderer veins between them. The Golden specimens are preserved on a rather coarse grained rock which obscures the intermediate veins, but so far as can be made out there are not more than three between the strong ribs. In view of the stratigraphic difference between these American and the European specimens, it seems best not to identify the Laramie forms with *Phragmites oeningensis*.

Cockerell in 1909 separated the American specimens under the name *Phragmites laramianus*.

[52] Heer, Oswald, Flora tertiaria Helvetiae, vol. 1, pl. 24, 1855.

Occurrence: Laramie formation, Golden, Colo. [original Lesquereux specimens figured in the "Tertiary flora" as *P. oeningensis*]; Hoyt's coal mine, 1 mile south of Golden, Colo., collected by Arthur Lakes, 1890; Mount Carbon, Morrison, Colo., sandstone near coal seam, collected by Arthur Lakes, 1890.

Order LILIALES.

Family SMILACEAE?

Smilax? inquirenda Knowlton, n. sp.

Plate IV, figure 5.

Smilax? inquirenda Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 602, 1919.

Leaf of medium size, apparently firm in texture, ovate, abruptly rounded to the slightly heart-shaped base; apex destroyed; nervation palmate, five-ribbed from the base of the blade, midrib and next pair of ribs about equally strong, the ribs passing up apparently to the apex of the leaf; lower pair of ribs slenderer, much curved upward, ending near or below the middle of the leaf, secondary branches few, thin, camptodrome.

This leaf was probably about 7 centimeters long when perfect and is 4.5 centimeters wide. It may be known by its ovate-elliptical outline, rounded, slightly heart-shaped base, and five ribs, the three inner ones being of nearly equal strength; these ribs pass up nearly or probably quite to the apex of the blade. The secondary and finer nervation is obscure.

Smilax grandifolia Unger, or *S. carbonensis*, as it has recently been named by Cockerell,[53] was reported by Lesquereux[54] from the Laramie at the Franceville mines, near Colorado Springs, but the material on which this determination was based is not now available, nor is the species contained in the recent collections from that locality. The present leaf differs from *S. grandifolia* in being narrower, less heart-shaped at the base, and five instead of seven ribbed; in fact, it is not certain that this leaf is properly referable to the genus *Smilax*.

Occurrence: Laramie formation, Popes Bluff, west of Pikeview, Colo. (sec. 14, T. 13 S., R. 67 W.).

[53] Cockerell, T. D. A., Two now plants from the Tertiary of the West: Torreya, vol. 14, p. 135, 1914.

[54] Lesquereux, Leo, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1873, p. 393, 1875.

Order ARECALES.

Family PALMACEAE.

Sabal montana Knowlton.

Plate III, figure 4.

Sabal montana Knowlton, U. S. Geol. Survey Prof. Paper 101, p. 253, pl. 32, fig. 3, 1918.
Sabalites grayanus (Lesquereux) Lesquereux, Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 112, pl. 12, fig. 1 [not pl. 12, fig. 2], 1878.
Knowlton, U. S. Geol. Survey Bull. 163, p. 32, pl. 6, fig. 5, 1900.

Leaves of large size, perhaps the largest of all species found in the Rocky Mountain area, palmate, with approximately 90 rays or folds; petiole unarmed, apparently rounded on both surfaces, 4 to 6 centimeters broad, prolonged at apex with a relatively short triangular point that is usually not more than 10 or 15 centimeters long, and often only 8 centimeters.

Notwithstanding the fact that this species has been reported—mainly under the name of *Sabal* or *Sabalites grayanus*—from a number of localities, it is still imperfectly known. It is so large that usually specimens that are anywhere near perfect can not be obtained.

The type locality for *Sabalites grayanus* is the Wilcox group of the Gulf region, where, according to the recent work of E. W. Berry, it is not uncommon in several localities. It is a relatively small-leaved species with a rather slender petiole and fewer rays than in *S. montana*. What is believed to be the same species has been found in the Raton formation of southeastern Colorado and northern New Mexico.

Sabal montana was based on material from the Vermejo formation of the Raton Mesa region of Colorado and New Mexico, together with the very large leaf from the Mesaverde formation at Point of Rocks, Wyo., described by Lesquereux [55] under the name *Sabalites grayanus*. The original of this specimen is No. 108 of the fossil-plant collections in the United States National Museum, and I obtained an additional example at Point of Rocks in 1896.

The other specimen figured in the "Tertiary flora" (Pl. XII, fig. 2) is No. 109 of the United States National Museum collections. It is said to have come from the "hard sandstone between coal banks" at Golden, Colo., but an examination of the matrix shows that it is not from the sandstone but from the andesitic material and hence must have come from the Denver formation. It is the one specimen on which the presence of this species in the Denver depends, for no leaves have been found that could with certainty be referred to that formation. That this specimen is the petiole of a palm is clear, but beyond that it is impossible to go. It might as well belong to any of the other large palms, and as a factor in revealing the distribution of this species it must be dismissed.

Occurrence: Laramie formation, dump of Reliance mine, 1¾ miles northeast of Erie, Colo., collected by F. H. Knowlton; Hoyt's coal mine, 1 mile south of Golden, Colo., collected by Arthur Lakes, 1890.

Order JUGLANDALES.

Family JUGLANDACEAE.

Juglans leydenianus Knowlton, n. sp.

Plate V, figure 1.

Juglans leydenianus Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 334, 1919.

Leaflet evidently membranaceous, apparently ovate-lanceolate, strongly unequal sided; margin perfectly entire; midrib fairly strong, straight; secondaries rather remote, alternate, thin, those on the narrow side of the leaflet at an angle of approximately 40°, then much curved upward and camptodrome, those on the broad side of the leaflet emerging nearly at a right angle, then curved upward and running for a considerable distance just inside the margin; nervilles few, thin, oblique to the secondaries.

The fragment figured, which is apparently near the middle of the leaflet, is all that has been found of this form, and but for the fact that the nervation is so strongly marked, it would hardly be worthy of treatment. The length can not be made out, though it probably exceeded 12 centimeters; the width is nearly 7 centimeters.

Occurrence: Laramie formation, Leyden Gulch, 6½ miles north of Golden, Colo., collected by F. H. Knowlton, 1908.

[55] Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, pl. 12, fig. 1, 1878.

Juglans newberryi Knowlton, n. sp.

Plate XX, figures 8-10.

Juglans newberryi Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 335, 1919.

Leaves or leaflets large, about 15 centimeters long and 4.5 or 5 centimeters wide, with entire margins; blade long, narrow, wedge-shaped and strongly inequilateral at base, rather long-acuminate at apex; midrib thick, strong; secondaries alternate, numerous (about 20 pairs), at an open angle, camptodrome, arching and joining just inside the borders, sometimes festooned outside the arches; intermediate secondaries numerous, often extending nearly to the margin; nervilles strong, mainly percurrent and oblique to the secondaries; reticulation obsolete.

This fine species is represented by four specimens, none of which, however, is preserved entire. Two of them have the bases preserved, one the apex, and the other represents a segment near the middle of the blade. They are rather long, narrow leaflets, strikingly inequilateral at the base and acuminate at the apex.

This species calls to mind a number of fossil forms, yet when carefully compared with them it is found to differ from all. It has, for example, much the shape and size of *Juglans denticulata* Heer, or *J. crossii* Knowlton, as it is now called,[56] which differs in having numerous sharp teeth. It also suggests certain of the narrower leaflets of *J. rugosa* Lesquereux,[57] which differs in general in being more or less heart-shaped at the base and in having fewer secondaries.

Juglans acuminata Al. Braun,[58] of the Swiss Miocene, which, by the way, it is almost impossible to distinguish from *J. rugosa*, has much the same nervation and size as *J. newberryi* but differs in shape. *Juglans californica* Lesquereux,[59] from the auriferous gravels of California, is not greatly unlike the form under discussion, differing in being obtuse at the apex and less unequal-sided at the base.

I have named this species in honor of the late Dr. J. S. Newberry, who did so much to develop the paleobotany of the Rocky Mountain region.

Occurrence: Laramie formation, Erie, Colo., collected by N. L. Britton about 1880.

Juglans laramiensis Knowlton, n. sp.

Plate XX, figure 12.

Juglans laramiensis Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 334, 1919.

Leaflets coriaceous, long and narrowly ovate-lanceolate, often slightly unequal-sided at the base, rather gradually narrowed from the widest point, which is about one-fourth the length of the blade, to the base and upward to the long, narrow acuminate apex; margin entire; nervation strongly and plainly marked, consisting of a rather strong, straight midrib and some 9 or 10 pairs of alternate or sub-opposite secondaries which arise at an angle, curve considerably upward, and disappear close to the margin or, especially in the upper part, join the secondary next above; nervilles numerous, strong, both percurrent and broken, inclining to be at right angles to the midrib on one side of the blade and to the secondaries on the other side; finer nervation not retained.

This strongly marked species is represented by several specimens, one of the best of which is figured. They are lanceolate or very narrowly ovate-lanceolate, with an obtusely wedge-shaped base and a long, gradually narrowed, sharp-pointed apex. The larger of these two examples is 9.5 centimeters in length and about 3 centimeters in width; the smaller is about 8 centimeters in length and 2.25 centimeters in width. The petiole is not preserved in either.

This species is very suggestive of *Juglans schimperi* Lesquereux,[60] from the Green River formation at Green River, Wyo. It is of practically the same shape and size but differs in having only 9 or 10 instead of some 18 pairs of secondaries, which are at a more acute angle and rather more arched upward, while the nervilles are stronger, more commonly percurrent, and at right angles to the midrib on one side.

In his treatment of *Juglans schimperi* in the "Tertiary flora" Lesquereux states[61] that the original of his Plate LVI, figure 9, came from Golden, Colo. This particular specimen is fortunately preserved in the United States

[56] U. S. Geol. Survey Bull. 152, p. 122, 1898.

[57] U. S. Geol. Survey Terr. Rept., vol. 7, p. 286, pl. 55, figs. 1-9, 1878.

[58] Flora tertiaria Helvetiae, vol. 3, pl. 128, figs. 1-10.

[59] Harvard Coll. Mus. Comp. Zoology Mem., vol. 6, pl. 9, fig. 14, 1878.

[60] The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, pl. 56, figs. 5-10, 1878.

[61] Idem, p. 288.

National Museum (No. 468), and in the catalogue of fossil plants it is recorded in Lesquereux's handwriting as having come from Green River, Wyo. The matrix is not that of Golden but agrees perfectly with the abundant material found above the fish beds at Green River, and there is consequently no reason for supposing that this species has ever been found in the Denver beds at Golden.

Occurrence: Laramie formation, Coal Creek, Boulder County, Colo., collected by N. L. Britton about 1880.

Juglans leconteana Lesquereux.

Plate VIII, figures 1–3 [types].

Juglans leconteana Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1870, p. 382, 1872; idem for 1876, p. 517, 1878; U. S. Geol. Survey Terr. Rept., vol. 7, p. 285, pl. 54, figs. 10–13. 1878 [figs. 10–12 here reproduced].

Friederich, Beiträge zur Kentniss der Tertiärflora von Sachsen, p. 150, pl. 19, fig. 7, 1883

This species is in much confusion. Three of the specimens figured in the "Tertiary flora" (figs. 10–12) are not now and have apparently never been in the collections of the United States National Museum. They came, according to Lesquereux, from the Marshall coal mine, in Boulder County, Colo., and are probably lost. The original of Lesquereux's figure 13 is the only one in the United States National Museum (No. 453). It is stated in the "Tertiary flora" to have come from Evanston, Wyo., but in the Museum catalogue it is recorded from Black Buttes, Wyo., in Lesquereux's handwriting. This last statement is probably correct, for the fossil is preserved in a fragment of the "red baked shale" so characteristic of the upper beds at this place.

In the annual report of the Hayden Survey for 1870, page 382, this species is recorded in a list of species found at Raton Pass, N. Mex., but the specimen or specimens upon which this statement is based has never been in the United States National Museum, and the reference may safely be dismissed as an error.

Lesquereux has also reported this species from Cherry Creek, Wasco County, Oreg., but there was only a single example, which I excluded from my flora of these beds [62] on the ground that it was so poorly preserved as to be impossible of determination.

[62] U. S. Geol. Survey Bull. 204, p. 88, 1902.

Friederich has identified this species with a leaf from the lower Oligocene of Bornstedt, in Saxony, remarking at the same time that he was unable to draw any line between Lesquereux's *Juglans rugosa*, *J. rhamnoides*, and *J. leconteana*. He also adds that they might better be referred to *Diospyros*, a view which can hardly be accepted, for *J. rugosa* at least. Lesquereux himself acknowledges that it is hardly possible to distinguish this species from *J. rugosa*, yet he says:

> It differs by comparatively shorter, broader leaves, which are first rounded, then abruptly curved or narrowed to the short petiole; by the lateral nerves at a more acute angle of divergence (40°), passing nearly straight toward the borders, with thin simple bows nearer to them.

Although the differences are not great and might possibly break down with a larger series of specimens for comparison, I have decided to maintain this species as left by its author, especially as the types are nearly all lost, and no additional material is forthcoming.

Occurrence: Laramie formation, Marshall mine, Marshall, Boulder County, Colo. Post-Laramie (in my opinion), ?Black Buttes, Wyo. Evanston formation ?, ?Evanston, Wyo.

Juglans praerugosa Knowlton, n. sp.

Plate V, figure 2; Plate XXI, figure 5.

Juglans praerugosa Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 396, 1916.

Juglans rugosa Lesquereux, Am. Jour. Sci., 2d ser. vol. 45, 1868; U. S. Geol. Survey Terr. Third Ann. Rept., p. 96, 1869 [reprint, p. 196, 1873].

Leaflets evidently rather thin in texture, ovate or ovate-elliptical, abruptly rounded to the truncate base (apex destroyed); margin entire; midrib slender, straight; secondaries apparently six or seven pairs, alternate, at a low angle, camptodrome.

The specimens upon which this form is of necessity founded are fragmentary, and complete characterization is difficult. It appears to be broadly ovate or perhaps elliptical-ovate. It may also possibly be slightly unequal-sided. The length was apparently about 9 or 10 centimeters, and the width between 4 and 4.5 centimeters.

Juglans rugosa Lesquereux was named in 1868 from material obtained from the Marshall mine, Marshall, Colo., but it was neither described nor figured at that time. The only note of explanation then given is as follows:[63] "Very nearly related to *J. acuminata* Al. Braun, a species extensively distributed in the European Miocene." This note was copied without change by Hayden [64] in 1869, and the species was alluded to in several other Hayden reports, but not until 1878 [65] was it really described and figured. Now, another complication is introduced with the describing and figuring of this species. The original locality of Marshall for *Juglans rugosa* is nowhere mentioned in the "Tertiary flora," and, so far as known, none of the original specimens are extant. The diagnosis and figures in the "Tertiary flora" are based in the main on material from Evanston, Wyo., obtained "above the coal." Of the 13 figured specimens of *Juglans rugosa*, 11 are now in the collection of the United States National Museum, the missing ones being the originals of Lesquereux's Plate LIV, figure 5, and Plate LVI, figure 1. Both these specimens are said to have come from Golden, Colo., though whether from Laramie or Denver beds can not be ascertained.

In order that there may be less trouble in future in identifying these type specimens, the following list is given of their illustrations in the "Tertiary flora" and the corresponding numbers in the United States National Museum catalogue:

	Catalogue No.
Plate LIV, figure 14	454
Plate LV, figure 1	851
figure 2	455
figure 3	455a
figure 4	456
figure 5	457
figure 6	458
figure 7	460
figure 9	459
Plate LVI, figure 2	463

Of these specimens Nos. 455, 455a, 457, 458, 459, 461, and 851 are from Evanston, Wyo., and are so recorded in the Museum catalogue. No. 460 is recorded as being from Golden, Colo., but attached to the specimen is a small, obscure original label which states that it also is from Evanston, and as it agrees perfectly with the matrix of the other specimens this label is probably correct. No. 456 is said to be from Point of Rocks, Wyo., but the matrix is also like that of the Evanston specimens and unlike that ordinarily found at Point of Rocks, though we are confronted by the fact that it bears an original label recording it from the latter locality. This species was not recognized in my "Flora of the Montana formation,"[66] and it is probably safe to exclude it from Point of Rocks. It has, however, been found subsequently at many localities, such as Golden, Colo., in beds of Denver age; Carbon, Wyo., in the "Upper Laramie" of Veatch; many points in southern Colorado and northern New Mexico, in the Raton formation; the Bozeman coal field of Montana; and Black Buttes, Wyo., in beds believed by me to be of post-Laramie age.

From the above account it appears that, although named from material of Laramie age at Marshall, *Juglans rugosa* as it has come to be known is based on described and figured material from higher or post-Laramie horizons. There is no means of knowing just what the original Marshall leaves were like, beyond the fact already mentioned that they are said to resemble *Juglans acuminata*. It is for these reasons that *Juglans rugosa* is excluded from the Laramie flora. It appears to be essentially a Tertiary species, and its occurrence in Cretaceous beds must be left open to subsequent discoveries.

There is, of course, no certainty that the leaflets here described as *Juglans praerugosa* are the same as the form to which Lesquereux gave the name of *J. rugosa*, and in fact they do not differ from it very markedly. The leaves of *J. praerugosa* seem to have been thinner and do not appear particularly rugose. As a matter of fact, better material is needed before it can be completely diagnosed.

Occurrence: Laramie formation, Marshall mine, Marshall, Colo., collected by Arthur Lakes, 1890.

Hicoria angulata Knowlton, n. sp.

Plate V, figure 4.

Hicoria angulata Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 319, 1919.

Fruit ovoid, truncate at base, obtusely pointed at apex, strongly several-angled (probably four) or ridged.

This beautifully preserved fruit is well shown in the figure. It is 22 millimeters long

[63] Am. Jour. Sci., 2d ser., vol. 45, p. 206, 1868.
[64] U. S. Geol. Survey Terr. Third Ann. Rept. [reprint, 1873], p. 195.
[65] Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 286, pl. 54, figs. 5, 14; pl. 55, figs. 1–9; pl. 56, figs. 1, 2, 1878.
[66] U. S. Geol. Survey Bull. 163, 1900.

and about 14 millimeters in broadest diameter. If correctly interpreted, it should belong to that section of the living genus in which the husk or exocarp adheres closely to the shell and splits away only at maturity, and even then not to the extreme base.

In the material from Mount Carbon, near Morrison, there is another specimen of this species. It is of about the same shape as the one figured but is a little larger.

Occurrence: Laramie formation, Marshall, Colo., railroad cut between old and new stations, collected by A. C. Peale; Mount Carbon, near Morrison, Colo., collected by Arthur Lakes.

Hicoria minutula Knowlton, n. sp.

Plate V, figure 5.

Hicoria minutula Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 320, 1919.

Similar to the last but very much smaller. The length is 14 millimeters and the diameter about 9 millimeters. The husk, less than 1 millimeter thick, is apparently present, and in the apical portion it may be noted becoming fibrous or slightly frayed.

It is not certain that this should be held as distinct from *H. angulata*, as it hardly differs except in size and may be only an immature specimen of that species. However, it can do no harm to consider them separately until further data can be procured.

Occurrence: Laramie formation, wooded bluff south of Marshall, Colo., collected by A. C. Peale, 1908.

Order MYRICALES.

Family MYRICACEAE.

Myrica torreyi Lesquereux.

Myrica torreyi Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 392, 1873; idem for 1876, p. 503, 1878; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 129, pl. 14, figs. 3–10, 1878.

Ward, U. S. Geol. Survey Sixth Ann. Rept., p. 551, pl. 40, fig. 4, 1886; idem, Bull. 37, p. 32, pl. 14, fig. 5, 1887.

Knowlton, U. S. Geol. Survey Bull. 163, p. 34, pl. 6, figs. 1–3, 1900.

Cockerell, Colorado Univ. Studies, vol. 7, p. 150, 1910.

The type locality of this species is Black Buttes, Wyo., and all but two of the figured types are preserved in the United States National Museum (Nos. 138–142, inclusive), the others having been lost or misplaced. The species was well described and illustrated by Lesquereux, and none of the material since obtained adds materially to our knowledge of it.

Since the original finding at Black Buttes this species has been reported, on evidence of more or less value, as occurring at so many additional localities that it has largely been robbed of its value as a stratigraphic marker. Thus, Ward found it at Point of Rocks, Wyo., in beds now referred to the Mesaverde formation. These specimens are illustrated in my "Flora of the Montana formation,"[67] and although the leaves shown in figures 1 and 2 of that bulletin are probably correctly identified, that of figure 3 is more doubtful.

What was presumed to be this species was found at Dunn's ranch, 30 miles north of Laramie, Wyo., and also at Harper station, on the Union Pacific Railroad about 6 miles west of Dunn's ranch. All these localities are now referred to the Mesaverde formation. The species has also been reported from the Mesaverde formation near Meeker, Colo., and the Vermejo formation at Rockvale, near Canon City, at La Veta, near Trinidad, and at Walsenburg, Colo. It has likewise been reported from the Lance formation of Converse County, Wyo., although the specimens found there are narrower than is usual.

Occurrence: Laramie formation, Crow Creek, 25 miles southeast of Greeley, Colo. Post-Laramie (in my opinion), Black Buttes, Wyo. (types). ?Lance formation, Converse County, Wyo. Mesaverde formation, Point of Rocks, Wyo. Vermejo formation, Rockvale, La Veta, and Walsenburg, Colo.

Myrica dubia Knowlton, n. sp.

Plate V, figure 3.

Myrica dubia Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 394, 1919.

Leaves small, lanceolate, obtusely wedge-shaped at base (apex destroyed); margin entire; midrib relatively thick; intramarginal vein well marked, other nervation consisting of thin, irregular veins connecting the midrib and intramarginal vein.

This species is most closely related to *Myrica torreyi* Lesquereux[68] but differs in its smaller size, more obtuse base, and above all the perfectly entire margin.

[67] U. S. Geol. Survey Bull. 163, p. 34, pl. 6, figs. 1–3, 1900.

[68] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7, pl. 16, figs. 3–10, 1878.

Occurrence: Laramie formation, Popes Bluff, just west of Pikeview, Colo. (sec. 14, T. 13 S., R. 67 W.), collected by A. C. Peale and M. I. Goldman, 1908.

Myrica oblongifolia Knowlton, n. sp.

Plate XXI, figure 1.

Myrica oblongifolia Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 396, 1919.

Leaves membranaceous, long-elliptical, rounded to a slightly wedge-shaped base and to an obtuse apex; margin with numerous small, sharp teeth for the lower two-thirds, thence undulate and nearly entire to the apex; nervation paryphodrome, with a slender marginal nerve around the leaf 1 millimeter from the border; slender nerves from the outside of this intramarginal nerve appear to enter the teeth; nerves very numerous, yet at an acute angle, irregular and broken, often joining, ending when they reach the border, in the intramarginal vein; nervilles usually percurrent.

This species is based upon the single fine specimen figured. It is about 8.5 centimeters long and 4 centimeters broad, with a petiole 0.5 centimeter long. It is a broad, long-elliptical leaf which is about equally rounded to both base and apex. The teeth begin within 1 centimeter of the base, and are fine, sharp-pointed, and directed toward the apex. In the upper portion of the blade the teeth are reduced to mere undulations, and at the apex the margin is nearly entire.

The most pronounced characteristic of this leaf is the strongly marked paryphodrome nervation—that is, a thin intramarginal nerve extending all around the leaf about 1 millimeter distant from the margin. The other nerves, or secondaries, if they may be so called, are very numerous, at a low angle of divergence, and much broken and irregularly joined.

It is difficult to determine the genus to which this leaf should be referred. There are a number of living genera that have this peculiar paryphodrome nervation, as, for example, *Tristania* of the family Myrtaceae, *Ardisia* of the Myrsinaceae, and *Dodonaea* of the Sapindaceae, as well as many others less likely to be represented in a fossil state. On the whole it appears best to refer it to *Myrica* because it agrees in this character with many living species of the genus—for example, *M. terebiuttacea* Göppert, from tropical America, and *Myrica* sp. from Brazil—and also because it is evidently allied to *Myrica torreyi* Lesquereux, a fossil species of wide vertical range which is also found in the Laramie. *Myrica torreyi* is undoubtedly the nearest relative of *M. oblongifolia* that has not been described from material collected in this area. It differs, however, in being narrowly lanceolate instead of broadly oblong and in being linear-acuminate instead of obtuse. The teeth in *M. torreyi* are larger and more distant.

This new species does not appear to be closely related to any of the other fossil American species of *Myrica*. It has much the shape and marginal dentation of *Celastrophyllum decurrens* Lesquereux, from the Dakota sandstone, but that species differs absolutely in the nervation. *Myrica oblongifolia* is also in outline and serration like the figures of *Quercus haidingeri* Ettingshausen given by Lesquereux,[69] but that species also differs in nervation.

Occurrence: Laramie formation, Marshall mine, Marshall, Boulder County, Colo.

Order SALICALES.

Family SALICACEAE.

Salix myricoides Knowlton, n. sp.

Plate IV, figure 7.

Salix myricoides Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 569, 1919.

Leaf linear-lanceolate, with a very long, slenderly acuminate apex and an apparently rather obtusely wedge-shaped base; margin entire; midrib relatively very thick; secondaries very numerous, probably about 20 pairs, approximately at right angles to the midrib, each joining the one next above by a broad loop just inside the margin; finer nervation obsolete.

The only example of this characteristic species observed is the one here figured. It is about 8 centimeters in length and 1 centimeter in maximum width; this width holds for more than half the length of the leaf. The leaf appears to have been rather thick, and as it is the upper side that is exposed, the nervation is obscured, all that can be made out being the very thick midrib and the numerous close, parallel secondaries nearly at right angles to it.

[69] Lesquereux, Leo, U. S. Geol. Survey Terr. Rept., vol. 7, p. 156, pl. 20, figs. 9, 10, 1878.

Occurrence: Laramie formation, cut on Moffat railroad (Denver & Salt Lake) about 6 or 8 miles north of Golden, Colo., collected by A. C. Peale, 1908.

Salix wyomingensis Knowlton and Cockerell.

Plate IV, figures 3, 4, 8.

Salix wyomingensis Knowlton and Cockerell, U. S. Geol. Survey Bull. 696, p. 572, 1919.

Salix integra Göppert, Deutsch. geol. Gesell. Zeitschr., vol. 4, p. 493, 1852.

Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1873, p. 397, 1874; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 167, pl. 7, figs. 1, 2, 1878.

The American specimens on which is based the determination that this form occurs in the United States are included in the collections of the United States National Museum (No. 197) and are preserved on the red baked shale characteristic of a certain horizon at Black Buttes, Wyo. They agree fairly well with the European figures of this species, and the species may be considered as probably present in this country.

In the "Tertiary flora" Lesquereux mentions a single example from Golden, Colo. This specimen is No. 837 of the United States National Museum collection and is preserved on a hard fine-grained whitish sandstone characteristic of the Laramie at Golden. This species is also represented by specimens from Coal Creek, Boulder County, Colo., one of the best preserved of which is shown in Plate IV, figure 8.

In a collection made at Marshall by Peale there are a number of willow leaves, the most perfect of which are here figured (Pl. IV, figs. 3, 4). They are evidently fairly thick, but the nervation is obscure. So far as can be made out, however, they are the same as the form figured by Lesquereux under the name *Salix integra*. It is to be noted that the leaves of *Salix* are often lacking in diagnostic characters, and they are described with difficulty.

Occurrence: Laramie formation, Golden, Colo., original collections studied by Lesquereux; Coal Creek, Boulder County, Colo., collected by N. L. Britton about 1884; Marshall, Colo., collected by A. C. Peale, 1908. Post-Laramie (in my opinion), Black Buttes, Wyo.

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Salix brittoniana Knowlton, n. sp.

Plate XXI, figure 8.

Salix brittoniana Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 565, 1919.

Leaf of firm texture, narrowly lanceolate, tapering below to a long, narrowly wedge-shaped base; apex not preserved; margin perfectly entire; nervation strong, pinnate, consisting of a relatively strong midrib and probably 8 or 10 pairs of alternate, remote secondaries, each of which arises at an acute angle, passes upward for a long distance, and disappears near the margin or unites by a slender apex to the secondary next above; nervilles none; finer nervation obscure but apparently consisting of a minute quadrangular areolation.

The type of this species, and unfortunately the only one observed, lacks the upper portion of the leaf and would not be described as new except for the marked difference between it and anything else thus far noted in these beds. The portion observed, which includes the base, is 5.5 centimeters long and was possibly twice this length when perfect; the width does not exceed 1 centimeter. Its principal feature is the secondary nervation, described above.

As regards size, shape, and margin this leaf is very much like many leaves that have been referred to *Salix angusta* Al. Braun,[70] but it differs distinctly in the nervation; so also it agrees with *S. amygdalaefolia* Lesquereux as regards the type of secondary nervation but differs in shape and margin. It is believed to be hardly worth while to follow resemblances further, as willow leaves are in general so variable, yet it is thought that this species, fragmentary as the type is, is sufficiently well marked to be readily recognized in the future. It has been named in honor of N. L. Britton, director of the New York Botanical Garden, who collected it.

Occurrence: Laramie formation, Coal Creek, Boulder County, Colo. (Laramie), collected by N. L. Britton about 1880.

[70] Cf. Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, pl. 22, fig. 4, 1878.

Populus? distorta Knowlton, n. sp.

Plate IV, figure 6.

Populus? distorta Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 488, 1919.

Leaf of small size, unequal sided, probably more or less distorted or malformed, outline now broadly ovate, possibly nearly circular when perfect, base abruptly rounded and truncate, apex obtusely acuminate; three-ribbed from the extreme base of the blade, midrib with about two pairs of thin secondary branches high up above the middle, lateral much arched outward, each with several thin branches on the outside.

This form is represented by the single example figured, and this seems not to be normal in that it was probably nearly circular in outline when perfect, though now it is distinctly narrowed on one side. The length is 4.5 centimeters and the width about 3 centimeters, though if the supposition of its abnormality is correct it should have been a little over 4 centimeters in width.

This appears to be a poplar of the type of *Populus arctica* Heer [71]—that is, on the supposition that one side has become reduced, probably by injury or pressure—but as it may be normal the reference to *Populus* has been questioned.

Occurrence: Laramie formation, Cowan station, 10 miles south of Denver, Colo., collected by F. H. Knowlton.

Order FAGALES.

Family FAGACEAE.

Quercus praeangustiloba Knowlton,

Plate V, figures 6, 7 (types).

Quercus praeangustiloba Knowlton, U. S. Geol. Survey Bull. 696, p. 535, 1919.

Quercus angustiloba Al. Braun. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 378, 1873; idem for 1873, p. 381, 1874; idem for 1876, p. 506, 1878; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 161, pl. 21, figs. 4, 5, 1878. [Lesquereux's original figures of these types are here reproduced.]

The two specimens upon which this species is based, and apparently the only ones ever obtained, are in the collections of the United States National Museum (Nos. 191, 192). They are preserved on the white fine-grained sandstone characteristic of the Laramie at Golden, Colo., and are rather obscure, though the figures given by Lesquereux and here reproduced show them very well.

These leaves have until now been referred to the European *Quercus angustiloba* Al. Braun,[72] but as that species occurs in the Oligocene it seems inherently improbable that it should be common also to the American Upper Cretaceous, though of course this is not in itself proof that they are not the same. In the matter of outline they are certainly very similar, but the nervation is obscurely retained in the European specimens, and until material is obtained showing them to be identical it seems best to treat them as distinct.

These American leaves have a rather strong resemblance to certain leaves of *Artocarpus*. In both the leaves under consideration, the strong secondaries next above the ones going to the lower lobes pass directly toward the sinuses, but it is impossible to see whether they enter the margin or pass around the sinus as intramarginal veins. In one of the larger lobes there seems to be an intramarginal vein, as in *Artocarpus*, but it is too indistinct to be made the basis for transferring them to that genus.

The specimen from Campbell's quarry, Cross Lakes, La., referred by Lesquereux [73] to *Quercus angustiloba*, is also in the United States National Museum (No. 2551). It proves to be a minute fragment without base, apex, or perfect sides and is absolutely worthless in determining the presence of this or any other species.

Occurrence: Laramie formation, Golden, Colo.

Quercus straminea Lesquereux.

Quercus straminea Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 373, 1873; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 151, pl. 19, figs 6, 7, 1878.

The type specimens of this species are preserved in the United States National Museum (fig. 6 = No. 173, fig. 7 = No. 174) and are on the hard sandstone matrix of the Laramie. These two specimens are so unlike that it was at one time thought best to separate them; in fact, Lesquereux himself has called attention to this difference. On this point he says:

[71] Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, pl. 23, figs. 1–5, 1878.

[72] Braun, Al., in Ludwig, Rudolph, Paleontographica, vol. 8, p. 103, pl. 36, fig. 3, 1860.

[73] U. S. Nat. Mus. Proc., vol. 11, p. 25, 1888.

These leaves seem to represent two different species. They have, however, a common character—that of the yellowish, shining secondary veins, which I have not seen on any other species of fossil plant of this locality. The leaf in figure 6 is smaller, with the secondary veins at a more acute angle of divergence; it has, however, the same character of nervation, shorter intermediate tertiary veins, and more or less distinct veinlets, oblique to the secondary veins. In both leaves, also, the basilar veins are marginal and ascend to the branches of the secondary nerves above.

In a subsequent paper describing plants from the Denver formation Lesquereux [74] identified this species with question, saying:

The leaf which I refer to this species is oval, apparently denticulate near the apex, and narrower than those figured in Plate XIX, figures 6, 7. It may, therefore, belong to a different species.

I have not seen these forms, but to judge from the remarks quoted it would seem that they are properly excluded from *Q. straminea.*

Occurrence: Laramie formation, Golden, Colo.

Quercus eximia Knowlton, n. sp.

Plate XXI, figure 2.

Quercus eximia Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 527, 1919.

Leaf oblong-lanceolate, gradually or evenly narrowed from what appears to be about the middle of the blade to a long acuminate apex; margin provided with few distant upward-pointing teeth; midrib very strong, running directly to the apex; secondaries alternate, 10 or more pairs in the upper half of the leaf, emerging at an angle of approximately 30°–40°, some apparently entering the teeth but most of them arching to join the one next above, thence forming a practically continuous line just inside the margin; finer nervation entirely obsolete.

This species, which unfortunately is represented only by the fragmentary example figured, must have been 18 or 20 centimeters long, for the portion preserved, which appears to be only about half of the leaf, is 11 centimeters long. It is about 4 centimeters in greatest width and tapers gradually to an acuminate apex. One side of the leaf is provided with several rather prominent upward-pointing teeth; the other side is merely undulate with but faint indications of teeth. The secondaries are distinctly alternate, each usually—so far as can be made out—arching just inside the border to join the one next above by a sort of bifurcation in the upper portion, thus producing a nearly continuous intramarginal line, a character observed in certain living leaves of this genus.

Among described forms this has a decided resemblance to *Quercus lyelli* Heer,[75] from the Atanekerdluk beds of Greenland. It is, for example, very close to the forms shown in Heer's figures 7b of Plate LXX, 9 and 10 of Plate LXXII, and 1, 2, and 4 of Plate LXXIII, differing in the thicker midrib and stronger secondaries, which are more continuous and, so far as can be made out, less branched. The teeth in the two forms are very similar. There can be almost no question as to their generic identity, and but for a number of quite differently appearing forms included by Heer in his species there would be little question of their specific similarity. Without more and better material I have thought it best to keep them apart.

Occurrence: Laramie formation, Coal Creek, Boulder County, Colo.

Quercus viburnifolia? Lesquereux.

Quercus viburnifolia Lesquereux, Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 159, pl. 20, figs. 11, 12, 1878; U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1876, p. 505, 1878; Harvard Coll. Mus. Comp. Zoology Bull., vol. 16, p. 46, 1888.
Ettingshausen, Roy. Soc. London Proc., vol. 30, p. 232, 1880.

Quercus triangularis Göppert [in part]. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 377, 1873.

Quercus attenuata? Göppert. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1873, p. 389, 1874.

One of the figured types of this species (the original of fig. 11 in the "Tertiary flora") is preserved in the United States National Museum (No. 186), together with the others that were the basis for Lesquereux's remarks concerning this form. None of them are very perfect, yet a careful study brings out well the characters upon which the species is founded. This original specimen is from Sand Creek, Colo., and others were reported from Golden, Colo., and Black Buttes, Wyo., the latter preserved on red baked shale. The matrix of the

[74] Lesquereux, Léo, Fossil plants collected at Golden, Colo.: Harvard Coll. Mus. Comp. Zoology Bull., vol. 16, p. 46, 1888.

[75] Flora fossilis arctica, vol. 7, pt. 1, p. 87, pl. 66, figs. 4, 5a; pl. 70, fig. 7b; pl. 72, figs. 1-10; pl. 73, figs. 1-6, 1883.

Golden specimen shows it to have come from the andesitic beds, probably on South Table Mountain, and no less than 11 additional examples were found by Lesquereux in the collection from these beds determined for the Museum of Comparative Zoology. This species has also been reported by Ettingshausen in the flora from Alum Bay, England.

A number of well-preserved leaves apparently belonging to this species have been found in the material from Converse County, Wyo. They do not differ essentially from the type specimen shown in Lesquereux's figure 11.

The basal portion of what appears to be a small leaf of this species has been found in material from Mount Bross, Middle Park, Colo., and a rather narrow but otherwise nearly normal leaf is contained in the small collection made in the Laramie at Crow Creek, Colo.

Occurrence: Laramie formation, Canfield ranch on Crow Creek, about 25 miles northeast of Greeley, Colo., collected by F. H. Knowlton and T. W. Stanton, June, 1896. Post-Laramie (in my opinion), Black Buttes, Wyo. Denver formation, Sand Creek, 18 miles east of Denver, Colo. (type); Golden, Colo. Lance formation, gulch south of Lightning Creek, opposite mouth of Box Elder Creek, Converse County, Wyo., collected by T. W. Stanton, July, 1896.

Order URTICALES.

Family MORACEAE.

Artocarpus lessigiana (Lesquereux) Knowlton.

Plate XII, figure 1; Plate XXII, figure 4.

Artocarpus lessigiana (Lesquereux) Knowlton, Science, vol. 21, p. 24, 1893; U. S. Geol. Survey Bull. 152, p. 42, 1898.

Myrica? lessigiana Lesquereux, U. S. Geol. and Geog. Survey Terr. Bull., vol. 1, p. 386, 1876; idem, Ann. Rept. for 1874, p. 312, 1876.

Myrica? lessigii Lesquereux, Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 138, pl. 64, fig. 1, 1878; U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1876, p. 503, 1878.

Leaf very large, coriaceous, oblong, deeply pinnately lobed, the lobes opposite, oblong-lanceolate, pointed, at an open angle of divergence, separated usually to a point near the midrib, where they are joined by broad, rounded sinuses; midrib very thick; secondaries of two orders, the first strong, ascending to the points of the lobes and branched on either side, the second smaller, emerging from the midrib between the others, passing up to the sinus, where they divide into two branches that arch around the sinus just inside the margin and then follow the lobes in festoons, anastomosing with the tertiaries; tertiaries numerous, alternate, curved more or less in passing to the margin, along which they form long festoons just inside the border; ultimate areolation in the main quadrangular, formed by divisions at right angles to the tertiaries.

These magnificent leaves were from 20 to 30 centimeters or more long and from 12 or 15 to 18 centimeters wide. They are thick, probably coriaceous, and broadly oblong, and the lobes are connected by broad, rounded sinuses.

This species was first described by Lesquereux under the name *Myrica? lessigiana* from material collected on Coal Creek, Boulder County, Colo., where it was found just above the coal. It was obtained, according to Lesquereux, by Gen. W. H. Lessig, for whom it was named. For many years the location of the type specimen was unknown, but recently it came to light among the collections donated to the United States National Museum by R. D. Lacoe, of Pittston, Pa., and is now No. 7172 of the Museum collection. It was with great doubt that this specimen was referred to *Myrica* by Lesquereux,[76] who says:

> It is doubtful if this leaf represents * * * a species of the section of the *Comptonia*. It resembles *Comptonia grandifolia* Unger, which till now has been considered as the giant representative of this section but whose leaf is scarcely half as large as this.

The reference of these leaves to the genus *Artocarpus* was first suggested by Nathorst[77] in his paper describing a new species of the genus from the Cenomanian of Greenland. After discussing a number of poorly defined fossil species and describing the new form (*A. dicksoni*), which he was fortunate enough to find associated with undoubted fruits, he calls attention to its resemblance to and possible identity with the *Aralia pungens* and *Myrica? lessigii* of Lesquereux. A comparison of these leaves with leaves of living species of *Artocarpus*, particularly of the common breadfruit (*A. incisa*), proves beyond reason-

[76] Lesquereux, Leo, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1874, p. 312, 1876.

[77] Nathorst, A. G., Ueber die Reste eines Brotfruchtbaums: K. svenska Vet.-Akad. Handl., vol. 24, p. 7, 1890.

able doubt that Nathorst's supposition is correct, and they are consequently referred to this genus. In leaves of *Artocarpus incisa* before me the base is broadly wedge-shaped, and the distance to which the lobation extends decreases toward the apex, or just the reverse of what occurs in *A. lessigiana*. The nervation in the lobes is exactly the same as in the living leaf, including the arching of the tertiaries, the intramarginal nerve, and the secondary emerging from the midrib, dividing and passing around on either side of the sinus. The Greenland species (*A. dicksoni*) seems to approach more closely in outline to the living *A. incisa* than the leaves under consideration. No fruits or flowers have been found in the American deposits that can be referred to this genus.

After the discovery of a well-authenticated species of *Artocarpus* in the Cenomanian of Greenland it was logical to expect to find representatives in later formations on the American continent, and such has been shown to be the case. The genus is now confined in its native state to tropical Asia and the Malay Archipelago, though once extending as far north as latitude 70° in Greenland. In America it has been found in the Laramie and Denver formations of the Denver Basin, in the Vermejo and Raton formations of southern Colorado and northern New Mexico, in the Wilcox group of the Gulf region, and in the Miocene (auriferous gravels) of California.

The form most closely related to *Artocarpus lessigiana* is undoubtedly *A. dissecta* Knowlton,[78] from the Vermejo formation at Walsenburg, Colo. This form is a leaf of large size, deeply cut into at least three pairs of opposite lobes, the lower pair remote from the ones next above and connected with them by an exceedingly narrow wing that is hardly more than the petiole. The lower pair of lobes are also curiously cut into almost to the midrib on the lower side, but the upper side is attached by the whole base. Otherwise the general outline, number, and shape of the lobes, as well as the type of nervation of the lobes, are practically the same in both, and, as I have pointed out in my paper on the flora of the Raton Mesa region, it is entirely possible that a series of leaves would show them to be identical. As the facts now stand, however, it seems best to consider them as distinct.

[78] Knowlton, F. H., U. S. Geol. Survey Prof. Paper 101, p. 267, pl. 42, fig. 6, 1918.

Occurrence: Laramie formation, Coal Creek, Boulder County, Colo. (type), collected by W. H. Lessig, now in United States National Museum; Marshall, Colo., half a mile south of railway station, in first draw north of white sandstone bluff, just above the highest coal of the vicinity, collected by F. H. Knowlton and G. C. Martin, 1908; Cowan station, 10 miles south of Denver, Colo., collected by F. H. Knowlton.

Artocarpus liriodendroides Knowlton, n. sp.

Plate XXI, figure 3.

Artocarpus liriodendroides Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 100, 1919.

Leaf of medium size and probably membranaceous in texture, deeply cut into at least three pairs of large, opposite, distant lobes, which are, with the exception of the lowest, attached by the whole, evenly expanded base, which continues along the petiole between the lobes as a narrow web or wing and also persists below the lowest pair of lobes nearly or quite to the base of the petiole; lowest segment ovate, rather obtuse, attached by about one-third of its width; primary midrib strong, straight, margined between and below the lobes by the narrow wing; nervation of lowest segment consisting of a plainly marked secondary that forms a "midrib" very near the center and four or five pairs of thin, alternate branches that form broad loops just inside the margin; nervilles anastomosing in all directions.

This interesting specimen is, so far as known, the only one found in these beds. Unfortunately it is so fragmentary that its complete size and appearance can not be determined. The portion retained is about 10 centimeters long, of which some 4 centimeters is taken up with the petiole below the lower pair of lobes; but, to judge from the undiminished thickness of the midrib above, it must have been considerably larger. The lower, nearly perfect lobe, which is attached by a narrowed base only 5 millimeters wide, is 3.5 centimeters long and 1.5 centimeters broad in the middle. The segment next above is 2.5 centimeters broad at the base and is preserved for a length of only 3 centimeters. None of the other lobes is as well preserved, though all appear to be opposite. The nervation, marginal wing to the petiole, and other features are well shown in the figure.

This species is undoubtedly most closely related to *Artocarpus dissecta* Knowlton,[79] from the Vermejo formation near Walsenburg, Colo., with which it agrees in general type, though differing in a number of important particulars. In the first place, although, of course, this difference is not of cardinal importance, it may be mentioned that *Artocarpus dissecta* is nearly twice the size of the present species. In *A. dissecta* the lower lobes are attached by the whole width of the segment, and the main secondary or "midrib" is very close to the lower margin, which gives the segment the appearance of being cut away on the lower side. In *A. liriodendroides*, on the other hand, the lower segment is attached by a much contracted base, and the "midrib" is practically central. In shape and major nervation the upper segments appear to be much the same in both forms. The petiolar wing connecting the segments is much more pronounced in *A. liriodendroides* and extends down the petiole below the lower segment for a greater distance than in *A. dissecta*. It is quite possible that if a series of specimens from both localities were available the two forms might be shown to approach more closely or even to combine, but with only a single example from each locality, the forms seem sufficiently distinct to warrant different names.

The leaf here described has an undoubted resemblance to what has been called *Liriodendron* from the Dakota sandstone of Kansas, being in a way intermediate between *L. pinnatifidum* Lesquereux[80] and *L. snowii* Lesquereux.[81] The former is described by its author as "pinnately, alternately lobed; lobes short, obtuse truncate or angular, abruptly narrowed into an obtusely lobate or subtruncate apex, separated by broad, unequal sinuses," and the latter is described as "pinnately, horizontally divided into linear, obtuse lobes, distant and distinct for their whole length, attached by their whole base to the thick median nerve (petiole) like pinnules of a compound leaf." The specimens upon which *L. pinnatifidum* is based are imperfect, so that it is not possible to make out the whole leaf with satisfaction, but it appears to have had at least three pairs of large, obtuse, irregularly quadrangular, alternate lobes, which are separated by broad, rounded sinuses. The portion of the blade between the lobes is sufficiently broad to support a considerable nervation, whereas in the Laramie species the interlobular margin or wing is too narrow to be provided with nervation. Superficially the leaf of *Artocarpus liriodendroides* appears to be most like *L. snowii*, for unless examination is careful enough to disclose the narrow wing between the lobes it seems essentially identical with that species.

Occurrence: Laramie formation, Coal Creek, Boulder County, Colo., collected by N. L. Britton about 1884.

[79] Knowlton, F. H., U. S. Geol. Survey Prof. Paper 101, p. 267, pl. 42, fig. 6, 1918.

[80] Lesquereux, Leo, The flora of the Dakota group: U. S. Geol. Survey Mon. 17, pl. 27, figs. 4, 5, 1892.

[81] Idem, pl. 29, figs. 1, 2.

Ficus? smithsoniana? (Lesquereux) Lesquereux.

Plate XXI, figure 4.

Ficus smithsoniana (Lesquereux) Lesquereux, Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 200, pl. 32, fig. 5, 1878.

Knowlton, U. S. Geol. Survey Prof. Paper 101, p. 305, 1918.

Juglans smithsoniana Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, Supplement, p. 16, 1873.

The type of this species is preserved in the collections of the United States National Museum (No. 106a) and is said to have come from "Fishers Peak, Raton Mountains, N. Mex." It is preserved on the same piece of matrix as the type of *Geonomites ungeri* Lesquereux, and there is thus every reason to suppose that the locality is correctly stated. However, no additional specimens of this species were found in the very extensive collections from the Raton Mesa region recently studied.

In the collections from Mount Carbon, Morrison, Colo., there is a single example that may be this species. The matrix on which it is preserved is the coarse-grained sandstone so characteristic of many of the Laramie deposits and hence is not well fitted to retain the details of nervation. The primary nervation is similar to that of the type, but the shape of the blade differs somewhat in being a little broader and more tapering both at base and apex. At least this identification must be considered as open to some question.

Occurrence: Raton formation (type), Fishers Peak, Raton Mountains, Colo. Laramie formation, Mount Carbon, Morrison, Colo., collected by Arthur Lakes, 1890.

Ficus pealei Knowlton, n. sp.

Plate XI, figure 6.

Ficus pealei Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 284, 1919.

Leaf ovate, apparently abruptly rounded below to the truncate base, and more gradually rounded above to the obtusely acuminate apex; margin perfectly entire; nervation pinnate, midrib comparatively thick; secondaries four pairs, alternate, thin, remote, at an angle of approximately 40°, slightly curved upward, apparently camptodrome.

The example figured is the most nearly complete of those observed. It is about 8.5 centimeters in length and 4.5 centimeters in width. It is not a very marked leaf, its strongest characters being the regular ovate shape, very thick midrib, and few, thin, alternate secondaries. The finer nervation is not retained.

In shape this leaf resembles certain of the leaves referred to *Ficus arenacea* Lesquereux,[82] and the nervation is more of the type of *Ficus pseudo-populus* Lesquereux,[83] but it differs essentially from either.

Occurrence: Laramie formation, Cowan station, 10 miles south of Denver, Colo., collected by A. C. Peale, for whom it is named.

Ficus planicostata Lesquereux.

Ficus planicostata Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 393, 1873; idem for 1874, p. 304, 1875; idem for 1876, pp. 181, 508, 1878; U. S. Geol. and Geog. Survey Terr. Bull., vol. 1, p. 379, 1876; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 201, pl. 31, figs. 1-8, 10-12, 1878.

Ettingshausen, Roy. Soc. London Proc., vol. 30, p. 232, 1880.

Hollick, Louisiana Geol. Survey Ann. Rept. for 1899, pt. 5, pp. 276, 282, 1890.

Newberry, The later extinct floras of North America: U. S. Geol. Survey Mon. 35, pp. 88, 146, pl. 46, fig. 1, 1898.

Knowlton, U. S. Geol. Survey Bull. 163, p. 52, pl. 10, fig. 4, pl. 12, figs. 2-4, 1900; U. S. Geol. Survey Bull. 204, p. 56, 1902.

Leaves of medium size, subcoriaceous, entire, elliptical or broadly oval, slightly acuminate or obtuse, rounded to a short thick petiole, palmately three-nerved from the top of the petiole, rarely from a short distance above the base; primary and secondary nerves broad, flat, all camptodrome, as well as their divisions.—Lesquereux.

This species appears to have been first described from specimens collected at Black Buttes, Wyo., and subsequent events prove that this is the principal locality for it. All the types figured in the "Tertiary flora" are from this place, and these, together with numerous duplicates, are preserved in the United States National Museum (Nos. 271–280). There is also a single example in the Museum (No. 895) said to have come from Coal Creek, Boulder County, Colo., a statement made probable by the finding of at least two fairly perfect examples in the material from this locality, one belonging to Columbia University (Nos. 119, 120) and now deposited in the New York Botanical Garden and the other belonging to the United States National Museum (No. 3611). This species is a very fine and characteristic one and was well described and figured by Lesquereux. It does not appear to have been obtained by Ward, who collected extensively at Black Buttes in 1881, but it has been reported from other localities with more or less certainty by various writers. It is, for instance, reported by Ettingshausen[84] from the Eocene of Alum Bay, England, which appears to be its only Old World occurrence. Hollick[85] reports it from the Wilcox of Louisiana, but, as he says, the specimen so referred is very much larger than even the largest specimens of *F. planicostata* figured by Lesquereux. The strong lateral secondaries arise at some distance above the apex of the petiole, whereas in the typical *F. planicostata* they usually take their origin at the very base of the blade. The general appearance of the leaf, however, aside from the particulars mentioned above, is very like that of *F. planicostata*, and Hollick's reference may perhaps be permitted to stand. In my "Flora of the Montana formation."[86] I referred to this species with some question a single leaf from Coalville, Utah, and a number from Dunn's ranch, on the Laramie Plains, Wyo. Newberry[87] mentions and figures a single leaf from the upper part of the Clarno formation at Bridge Creek, Oreg. The leaves from the Montana group may be correctly determined, though there

[82] Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, pl. 29, fig. 1, 1878.

[83] Idem, pl. 34, figs. 1, 12.

[84] Roy. Soc. London Proc., vol. 30, p. 232, 1888.

[85] Hollick, Arthur, Louisiana Geol. Survey Ann. Rept. for 1899, pt. 5, p. 282, pl. 36, 1900.

[86] U. S. Geol. Survey Bull. 163, p. 52, pl. 10, fig. 4; pl. 12, figs. 2-4, 1900.

[87] U. S. Geol. Survey Mon. 35, p. 88, pl. 46, fig. 1, 1898.

are differences, but the leaf from Bridge Creek should probably be referred to another species.

A single broken leaf from Green Mountain, Golden, Colo., I am unable to distinguish from this species, but as it is only the basal portion I may be in error.

In the material from the vicinity of the Douglas mine, Sedalia, Colo., I find a single small leaf that is referred with some hesitation to this species. It is smaller than the ordinary leaves of *F. planicostata*, being only about 4 centimeters in length and 3 centimeters in width, and is obtusely wedge-shaped instead of rounded or subcordate at the base, and, further, the lateral ribs, which arise at the very base of the blade, have a greater number of secondary branches than is usual in this species. However, the thick texture of the leaf, the palmately three-ribbed nervation, and the strong nervilles are all suggestive of *F. planicostata*. If numerous other leaves agreeing with this one are found, it should be removed, either as a new variety or possibly as a full species.

The recently collected material from the Denver beds also contains at least one example that apparently must be referred to *F. planicostata*. It is about the size of the largest example figured by Lesquereux [88] and has the short petiole preserved. It is slightly less rounded at the base than is usual with this species, but otherwise I am unable to see any mark of difference.

The material from Rock Springs also embraces a single fairly well preserved leaf that, although not quite normal, must be referred to this species. It is a rather small leaf with a long petiole and is slightly less full and rounded at the base than is usual in *F. planicostata*, but in shape (other than as just noted), as well as in the primary and secondary nervation, it is indistinguishable.

Occurrence: Laramie formation, Coal Creek, Boulder County, Colo.; Hoyt coal mine, 1 mile south of Golden, Colo. Post-Laramie (in my opinion), Black Buttes, Wyo. (types). Denver formation, Golden and Sedalia, Colo. Wilcox formation, Shreveport, La. Mesaverde formation, Rock Springs, Wyo.

[88] Op. cit. (Tertiary flora), pl. 31, fig. 1.

Ficus cockerelli Knowlton.

Plate XII, figure 2; Plate XXIII, figures 1, 2.

Ficus cockerelli Knowlton, U. S. Geol Survey Bull. 696, p. 273, 1919.

Ficus latifolia (Lesquereux) Knowlton, U. S. Geol. Survey Bull. 152, p. 102, 1898. [Homonym, Kunth, 1846.]

Ficus planicostata latifolia Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 393, 1873; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 202, pl. 31, fig. 9, 1878. [Lesquereux's original figure is here reproduced as Pl. XII, fig. 2.]

Leaves thick, very large, 9 to 15 centimeters long, 10 to 14 centimeters broad, from nearly circular to short oblong, a little longer than broad, heart-shaped at base, evenly rounded at apex; margin perfectly entire; petiole short, thick; leaf strongly palmately three-ribbed from the apex to the petiole; the two lateral ribs form an angle of about 40° with the central or midrib and thence proceed nearly straight to the margin high above the middle, sending off from their outer side from 8 to 10 well-developed, often somewhat irregular secondaries, the lowest of which supports 6 to 8 tertiaries; midrib naked for some distance above the insertion of the lateral primaries, then giving rise to three or four strong, alternate, distant nerves on each side, which branch in the same manner as the lateral nerves; secondary and tertiary nerves arching near the margin by rounded loops; nervilles very prominent, usually simple, and curved or several times subdivided so as to form small quadrangular meshes.

When this form was first described by Lesquereux he was in doubt as to whether it should be ranked as a large, broad-leaved variety of *F. planicostata* or regarded as specifically distinct. In the "Tertiary flora," page 202, he reiterates this expression of doubt, but as he had found only two leaves of this character, he was inclined to regard it as only a variety of *F. planicostata*. He remarks, however, that among very numerous examples of *F. planicostata* there appeared to be no marked variation from the normal size and shape, whereas the species under consideration is twice as large and has a heart-shaped base. The nervation is of precisely the same character in both.

The fortunate discovery of a number of well preserved leaves of this species in the coarse sandstones at Hoyt's coal mine, near Golden, Colo., and also at Marshall's coal mine, in Boulder County, Colo., makes it possible to arrive at a better understanding of this form, which it now seems best to raise to full specific rank. It turns out that the smallest leaf that has been found is the original type from Black Buttes,[89] while the largest is fully 15 centimeters long and 14 centimeters broad. They are undoubtedly very closely allied to *F. planicostata* but differ from it in being uniformly at least twice the size and without intermediate forms and in being heart-shaped at the base. This species is also closely allied to *F. speciosissima* Ward,[90] from Point of Rocks, Wyo., which differs merely in being more markedly heart-shaped at the base and in having the nervilles joining the arches of the secondary and tertiary nervation to the margin, either character being of special importance. *Ficus speciosissima* is also slightly inequilateral, thus approaching certain forms of *F. tiliaefolia*.

The figured type of *F. latifolia* (U. S. Nat. Mus. No. 278) is from Black Buttes, Wyo. The other type specimen is said to have come from Golden, Colo., but as it can not be found in the Museum collections I can not state whether it came from the true Laramie or the Denver formation, but inasmuch as all the recent collections from Golden containing it are in the true Laramie, it is probably a lower or true Laramie species.

As the specific name *latifolia* proved to be a homonym of a living species (Kunth, 1846), it has been necessary to give this form a new name. It is named in honor of Prof. T. D. A. Cockerell, of Boulder, Colo., a well-known student of the Colorado fauna and flora.

Occurrence: Post-Laramie (in my opinion), Black Buttes, Wyo. Laramie formation, Hoyt's coal mine, near Golden, and Marshall's coal mine, both in Boulder County, Colo.

Ficus planicostata magnifolia Knowlton, n. var.

Plate X, figure 3.

Ficus planicostata magnifolia Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 285, 1919.

Similar to the type but much larger, reaching 14 centimeters in length and 9 centimeters in width, slightly more pointed above and less evidently truncate below, but otherwise much the same.

This form is described as new with some hesitation. It clearly belongs to that group of species which includes *Ficus planicostata*, *F. cockerelli*, *F. speciosissima*, *F. leei*, and others. *Ficus cockerelli* differs from it in being very much larger and in having a deeply cordate base, which produces marked differences in the nervation; *F. leei* differs in size and shape, being smaller and more elongate, and in a number of minor particulars of nervation.

It is of course quite true that difference in size is an unreliable criterion on which to base specific or even varietal distinction, provided there is agreement in other particulars, but in the present case it is thought that the differences are sufficient to warrant keeping these leaves from identification with the typical *F. planicostata*.

Occurrence: Laramie formation, Marshall, Colo., half a mile south of railroad station, in first draw north of white sandstone bluff, just above the highest coal of the region, collected by F. H. Knowlton and G. C. Martin, 1908.

Ficus praeplanicostata Knowlton, n. sp.

Plate XXII, figure 2.

Ficus praeplanicostata Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 285, 1919.

Leaf coriaceous, elliptical-obovate, apparently rounded below to a more or less distinctly wedge-shaped base and narrowed above in like degree to an obtusely acuminate apex; margin perfectly entire; midrib rather slender, perfectly straight; apparently three-ribbed from or near the base, the lateral ribs slender, at an acute angle, somewhat curving upward, ascending nearly to the top of the blade, and joining the lowest secondary just within the margin; lateral ribs with seven or eight secondary branches on the outside, each of which arises at an acute angle, curves slightly upward and joins the one next above just at the margin; secondaries on the midrib four or five pairs, scattered, strongly alternate, each passing upward practically parallel to the lateral ribs and joining the one next above, the upper pair arching completely around and joining the midrib near the apex of the blade; nervilles very numerous and conspicuous, mainly percurrent but also broken, approximately at right angles to the midrib.

[89] Lesquereux, Leo, op. cit. (Tertiary flora), pl. 31, fig. 9.

[90] Ward, L. F., Types of the Laramie flora: U. S. Geol. Survey Bull. 37, p. 39, pl. 21, fig. 3, 1887.

This species, of which a very good figure is given, appears to be represented only by this example. It lacks the basal portion and most of the margin on one side, but as nearly as can be made out it is about 10 or 12 centimeters in length and about 6 centimeters in width at the broadest point, which seems to be a little above the middle. The nervation is very distinct and regular, as described above.

This species is undoubtedly most closely related to *Ficus planicostata* Lesquereux,[91] from which it differs in its apparently wedge-shaped base, more pointed apex, and more erect, relatively slenderer nervation, for it is in a way intermediate between this and Lesquereux's variety *clintoni*, but it appears sufficiently distinct from *F. planicostata* by the characters mentioned, and it is clearly distinct from the variety *clintoni*. Additional material may give evidence of variation in the direction of the typical form, but until that is forthcoming this may stand as a distinct though obviously closely related variety.

Occurrence: Laramie formation, Coal Creek, Boulder County, Colo.

Ficus impressa Knowlton, n. sp.

Plate VII, figures 1–3; Plate XVI, figure 3.

Ficus impressa Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 278, 1919.

Leaves of thick texture, uniform size, and ovate or elliptical outline, rounded and truncate or very obtusely wedge-shaped at the base, obtusely pointed at the apex; margin entire; nervation deeply impressed, three-ribbed from the base of the blade, the midrib slightly the strongest, with about three pairs of strong camptodrome secondaries above the middle; lateral ribs at an angle of 50° or 60°, each with five to seven secondary branches on the outside, these camptodrome and arching just inside the margin; nervilles very numerous, strong, often broken.

This species is represented by a considerable number of examples, one of which is nearly perfect. They are about 7 centimeters in length and vary in width from 3.5 to 6 centimeters.

This species is also the type of *Ficus planicostata* Lesquereux, from which it differs in being narrower, more elliptical, and less truncate at the base. The lateral ribs are at a slightly more acute angle, and both these and the secondary branches are less regular; the nervilles are the same in both.

Occurrence: Laramie formation, Marshall, Colo., collected by Arthur Lakes, 1890.

[91] Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, pl. 31, 1878.

Ficus coloradensis Cockerell.

Plate XXII, figure 1.

Ficus coloradensis Cockerell, Torreya, vol. 10, p. 223, 1910.
Ficus irregularis (Lesquereux) Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1874, p. 304, 1876; idem, Bull., vol. 1, p. 368, 1876; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 196, pl. 34, figs. 4–7, 1878; Harvard Coll. Mus. Comp. Zoology Bull., vol. 16, p. 50, 1888. [Homonym, Miquel, 1867.]
Ward, U. S. Geol. Survey Sixth Ann. Rept., p. 552, pl. 44, fig. 4, 1886 [not fig. 5, which=*Rhamnus goldianus*]; U. S. Geol. Survey Bull. 37, p. 38 pl. 20, fig. 4, 1887 [not fig. 5, which=*Rhamnus goldianus*].
Knowlton, U. S. Geol. Survey Bull. 163, p. 51, 1900.
Ulmus? irregularis Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 378, 1873.

A good deal of confusion seems to be current regarding the distribution of this species. It was originally described under the name *Ulmus? irregularis* from specimens found in the Denver beds at Golden, Colo., and subsequently was reported by Lesquereux from Point of Rocks, Black Buttes, and Carbon, Wyo. The type specimens figured by Lesquereux in the "Tertiary flora" (Pl. XXXIV, figs. 4–7) are preserved in the United States National Museum and are before me. The originals of Lesquereux's figures 5, 6, and 7 (Museum Nos. 296, 297, 831) are all in the andesitic material characteristic of the Denver beds, and additional examples are to be found in subsequent collections from this area. The original of his figure 4 (Museum No. 295) is recorded as coming from Carbon, Wyo., but later collections from this locality do not seem to contain it.

The material upon which Lesquereux based his statement of the abundant presence of *F. irregularis* at Black Buttes is not to be found in the Museum collections, and as this species has not been found there by any of the subsequent collectors, Lequereux's statement may be set down as extremely doubtful and not entitled to any consideration.

The status of *F. irregularis* at Point of Rocks, Wyo., is hardly more satisfactory. The single specimen figured by Lesquereux[92] as from this locality is No. 295a of the United States National Museum collection and represents only the petiole and extreme basal portion of a leaf. I admitted this species in my "Flora of the Montana formation" on the basis of this example alone, for none other seems to have been found, but I doubt the wisdom of so doing without further reservation. So far as can be made out from so small a portion it might have belonged to *F. irregularis*, and on the other hand it would be equally hard to exclude it from a number of other species of similar size. In any event, if admitted as a member of the Montana flora, its status as above outlined should be distinctly recalled and weighed accordingly.

As noted in the synonymy, one of the two leaves figured by Ward is with little doubt *Rhamnus goldianus*. It has a slightly but distinctly heart-shaped base with a number of short tertiaries going out from the lower side of the lowest pair of secondaries, exactly as Lesquereux described for *R. goldianus* and quite unlike typical *Ficus irregularis*. The latter has a wedge-shaped base, with no tertiaries on the lower side of the lowest pair of secondaries.

In the material collected by Ward in 1883 and figured but not described is one specimen obtained in white sandstone at a point 1¼ miles southeast of Golden and therefore probably in the true Laramie; and a leaf which can hardly be distinguished has been found at Marshall, Colo.

Occurrence: Laramie formation, Marshall and 1¼ miles south of Golden, Colo. Denver formation, Golden, Colo. (types). "Upper Laramie," Carbon, Wyo. (doubtful). Mesaverde formation, Point of Rocks, Wyo. (doubtful).

Ficus dalmatica Ettingshausen.

Plate XXI, figure 9; Plate XXII, figure 5.

Ficus dalmatica Ettingshausen, Eocene flora of Mount Promina, p. 29, pl. 7, fig. 11, 1855.

Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1874, p. 303, 1875; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 199, pl. 63, figs. 3–5, 1878.

Knowlton, U. S. Geol. Survey Bull. 163, p. 51, pl. 8, fig. 4, 1900.

[92] Op. cit. (Tertiary flora), pl. 63, fig. 9.

This European species was identified by Lesquereux with specimens from Point of Rocks, Wyo. One of these specimens (No. 294, U. S. Nat. Mus., original of Lesquereux's Pl. LXIII, fig. 4) is in the United States National Museum and agrees very closely with the figures of this species in Ettingshausen's paper above cited, though it is perhaps to be doubted if they are really identical.

In the collections from Coal Creek there is a single leaf—the one here figured—that is almost the exact counterpart of figure 4 of Lesquereux's Plate LXIII. Another leaf shown in Plate XXII, figure 5, also from Coal Creek, is referred here with some question. It is not well preserved, and its characters are made out with difficulty.

Occurrence: Laramie formation, Coal Creek, Boulder County, Colo. Mesaverde formation, Point of Rocks, Wyo.

Ficus neodalmatica Knowlton, n. sp.

Plate VII, figure 6.

Ficus neodalmatica Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 283, 1919.

Leaf of small size and firm texture, ovate-cuneate, broadest at or near the middle, from which it narrows regularly to the base and above to the obtusely acuminate apex; midrib very thick, especially below; lower pair of secondaries arising at the base of the blade, at a much more acute angle than the ones above, passing up to or above the middle of the leaf and there joining by a broad loop with the pair next above; upper secondaries about four pairs, alternate, at irregular distances, camptodrome, each joining the one above by a broad loop well inside the margin and with a series of loops outside; nervilles sparse, mainly broken.

The leaf figured is nearly perfect. It is slightly unequal sided, being ovate-cuneate, with a wedge-shaped base and an obtusely acuminate apex. It is 6.5 centimeters in length and 3.5 centimeters in width at a point a little above the middle of the blade. This species is undoubtedly most closely related to what Lesquereux has figured from Point of Rocks, Wyo., as *Ficus dalmatica* Ettingshausen.[93] It differs from that form in its

[93] Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, pl. 63, figs. 3–5, 1878.

larger size and broader outline, but in the nervation they are of the same type, as may be seen on comparing especially Lesquereux's figure 4 with the present species.

Occurrence: Laramie formation, cut on Moffat railroad (Denver & Salt Lake) about 6 or 8 miles north of Golden, Colo., collected by A. C. Peale, 1908.

Ficus? leyden Knowlton, n. sp.

Plate XIV, figure 1.

Ficus? leyden Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 283, 1919.

Size and complete outline not known, but apparently very unequal sided; base truncate; margin entire; nervation palmate from the extreme base of the blade, the ribs five, very unequally distributed; the first rib on the narrow side of the blade is nearly straight and has four or five slender branches on the outside; the next rib, which may be called the midrib, is slightly larger than either of the others, with several pairs of thin secondary branches in the upper part; the other ribs supply the full side of the blade and have several branches on the outside which are probably camptodrome, but as the margin is missing at this point it is impossible to be positive; finer nervation obsolete.

This leaf has the appearance of having been sessile, and the narrow side was naturally the upper side. It is so well shown in the figure that no other description is necessary.

It is perhaps doubtful if this leaf should be referred to *Ficus*, but the generic affinity is believed to be with what Newberry called *Ficus? alaskana*,[94] from the Kenai formation of the Cook Inlet region of Alaska, especially the one shown in the figure cited. This has the five ribs in the somewhat unequal sided leaf, but the form under consideration differs in being truncate instead of heart-shaped at the base and in being very unequal sided, and this affects the direction of the ribs. It is possible that this is only an individual variation or abnormal form of *Ficus cockerelli*, though the texture of the leaf and the absence of finer nervation mark it as distinct.

Occurrence: Laramie formation, Leyden Gulch, about 6½ miles north of Golden, Colo., collected by A. C. Peale.

[94] Newberry, J. S., U. S. Geol. Survey Mon. 35, pl. 55, fig. 2, 1898.

Ficus post-trinervis Knowlton, n. sp.

Plate VI, figures 1, 2.

Ficus post-trinervis Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 285, 1919.

Leaves of firm texture, ovate or ovate-elliptical, about equally narrowed to both base and apex, three-ribbed from the very base to the blade, all the ribs of equal size, the lateral ones passing up for two-thirds or three-fourths the length of the blade, curving in in the upper portion; secondaries few, alternate, above the middle of the leaf, camptodrome; finer nervation not retained.

The two leaves figured illustrate this species very well, though neither is quite perfect. They are 6 or 7 centimeters in length and about 3 centimeters in width. One has the petiole preserved for a length of 1 centimeter, but it is obviously broken. Where the petiole merges into the blade it splits into three equal ribs which divide the blade into four approximately equal areas.

This species is undoubtedly most closely related to *Ficus praetrinervis* Knowlton, from the Vermejo formation of southern Colorado. The leaves are much smaller than is usual in that species, are more nearly elliptical, and are not known to have secondary branches on the outside of the lateral ribs. The secondaries on the midrib start at a higher point than in *F. praetrinervis*, but this is perhaps a variable character. This species is also related to *F. cannoni*, described below, which, however, differs in its much smaller size and thinner lateral ribs or secondaries, which join the secondaries on the midrib near the middle of the blade.

Occurrence: Laramie formation, Cowan station, 10 miles southeast of Denver, Colo., collected by F. H. Knowlton, 1908.

Ficus cannoni Knowlton, n. sp.

Plate VI, figure 3; Plate X, figure 1.

Ficus cannoni Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 272, 1919.

Leaves small, of firm texture, obovate-lanceolate, rather obtuse above, narrowly wedge-shaped below, perfectly entire; midrib very slender; secondaries about four or five pairs, the lower ones arising at the very base of the blade and running up for nearly or quite half the length of the leaf and joining the next pair of secondaries, which arise high above the base; other secondaries thin, at an angle of about 45°, considerably curved upward, camptodrome, each joining the one next above; finer nervation not retained.

This species is represented by several examples, two of which have been figured. The larger one is about 5 centimeters long and nearly 2 centimeters broad; the other is about 4 centimeters long and 1.5 centimeters wide. It may be distinguished at once by its obovate shape, narrowly wedge-shaped base, and thin lower secondaries, which run up and join the next pair of secondaries, the latter originating near the middle of the blade.

This species is of the type of *Ficus trinervis* (Ward) Knowlton, *F. praetrinervis* Knowlton, from the Vermejo formation, and *F. post-trinervis* of this report. From all these it differs in its smaller size and more markedly obovate outline. It was at one time thought that these specimens might be very small, narrow leaves of *F. praetrinervis*, but as that species is usually very abundant where it occurs at all, intermediate forms connecting the two should be found, but they have not, and so *F. cannoni* is considered as undoubtedly distinct.

This species is named in honor of George L. Cannon, of Denver, who has long been identified with the study of the geology of the Denver Basin.

Occurrence: Laramie formation, Cowan station, 10 miles southeast of Denver, Colo. (Pl. VI, fig. 3), collected by F. H. Knowlton, 1908; Popes Bluff, just north of Pikeview, Colo. (sec. 14, T. 13 S., R. 67 W.), collected by A. C. Peale and M. I. Goldman, 1908.

Ficus navicularis Cockerell.

Plate VI, figures 4, 5; Plate XI, figures 3-5.

Ficus navicularis Cockerell, Am. Mus. Nat. Hist. Bull., vol. 24, p. 89, 1908; Torreya, vol. 9, p. 141, figs. A, C (in text), 1909.

Ficus lanceolata Heer, Flora tertiaria Helvetiae, vol. 2, p. 62, pl. 81, figs. 2-5, 1856. [Homonym, Buchenau-Hamilton, 1814.]

Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, p. 300, 1872; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 191, pl. 28, figs. 1-5, 1878. [Figures 1-5 reproduced on Pl. XI, figs. 3-5.]

The first American specimens referred to *Ficus lanceolata* Heer were mentioned by Lesquereux in 1871 [1872], having probably been collected the previous year. He wrote as follows of the collection of which they form a part:

> Hard, shaly, fine-grained whitish sandstone. About the same consistence and color as the specimens from Carbon station. The precise locality is unknown, the labels having been lost or forgotten.

Most of this collection is still preserved in the United States National Museum, and, although it was originally stated to be from an unknown locality, the next time—and in fact at all subsequent times—it was mentioned it was said by Lesquereux to have come from the Green River formation. The nature of the matrix entirely precludes the probability of this being true, a view further confirmed by the other species in the collection, as well as by the geologic distribution subsequently shown for the various species.

Other specimens from Willow Creek, in Middle Park, and from Florissant, Colo., have been referred to this species, but most of these specimens can not now be found. The only one that I have been able to see is a very fragmentary leaf from Florissant that may or may not belong to this species, and in any event it should have little weight in any scheme of geologic distribution, unless other clearly identical material can be obtained. In the very extensive collections from Florissant studied by Cockerell and me it has not been observed with certainty.

Ficus lanceolata was described by Heer from material obtained in the Swiss Miocene in 1856, but, as set forth in the synonymy above, this name is preoccupied by a living oriental species named in 1814, and consequently the species was renamed by Cockerell *Ficus navicularis*. This name, however, should be applied only to the American specimens that had been referred to *Ficus lanceolata* Heer, for a comparison of the figures given by Heer and Lesquereux leads to the conclusion that they are not conspecific. The American leaves are long, narrowly lanceolate, with many close, parallel secondaries, whereas the leaves from the Swiss Miocene are not only larger but incline to the obovate-lanceolate and have fewer secondaries, which are scattered, much curved upward, and very markedly camptodrome. It is probable that the European leaves should be given a new name, for they can not be called *F. lanceolata* and they appear to differ from the American *F. navicularis*.

I was at one time inclined to refer a part of *Ficus arenacea* Lesquereux [95] to what was then called *F. lanceolata*, but, as Cockerell [96] has pointed out, it may be distinguished by its broader and strongly inequilateral base. It was a part of the same collection from an unknown locality and is certainly very close to *F. navicularis*.

Ficus navicularis belongs to that type of nondescript, narrow leaves that are difficult to identify with certainty unless they are exceptionally well preserved, a condition unfortunately far from being usual in the Laramie material. It is on this account that the species (usually under the name *F. lanceolata*) has been reported from a number of localities, and as the material is often fragmentary or the nervation poorly preserved, some of these identifications are probably open to more or less question. Thus, a narrow lanceolate form from the Vermejo formation of the Starkville mine at Starkville, Colo., has been described under the name *Ficus? starkvillensis* Knowlton.[97] *Ficus navicularis* has also been reported from beds described as of Mesaverde age in the vicinity of Lay, Colo.

The material from Marshall embraces a number of lanceolate leaves that are referred to *F. navicularis* with little hesitation. The one shown in Plate VI, figure 4, is of approximately the same size and shape as that shown in figure 4 of Plate XXVIII of the "Tertiary flora" and differs only slightly in the secondaries. The fragmentary leaf shown in Plate VI, figure 5, is of the same type as Lesquereux's figure 3 but is a little larger.

Occurrence: Laramie formation, types from an unknown locality, subsequently collected from the Marshall coal mine, Marshall, Colo., by Arthur Lakes, 1890.

Ficus multinervis? Heer.

Plate XII, figures 3, 3a, 4.

Ficus multinervis Heer. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, p. 300, 1872; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 194, pl. 28, figs. 7, 8. [Lesquereux's figures are here reproduced.]

This species was described by Heer [98] in 1856 from specimens obtained in the Miocene of Switzerland. The American specimens referred by Lesquereux to this species have the same history as *Ficus lanceolata* (now *F. navicularis*)—that is, the source of the original specimens is not known. They have likewise usually been referred to the Green River formation up to the present time.

The collection from the coal mine on Coal Creek, Boulder County, Colo., made by Arthur Lakes in 1890 contains a number of fragments that seem to belong to this form. They are similar in shape to *Ficus navicularis* but have the more numerous secondaries at a more acute angle of divergence.

Occurrence: Laramie formation, Coal Creek, Boulder County, Colo., collected by Arthur Lakes, June, 1890.

Ficus denveriana? Cockerell.

Plate XII, figure 5.

Ficus denveriana Cockerell, Torreya, vol. 10, p. 224, 1910. Knowlton, U. S. Geol. Survey Prof. Paper 101, p. 302, pl. 76, figs. 1, 2, 1918.

Ficus spectabilis Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 379, 1873; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 199, pl. 33, figs. 4–6, 1878; Harvard Coll. Mus. Comp. Zoölogy Bull., vol. 16, p. 50, 1888; U. S. Nat. Mus. Proc., vol. 11, p. 25, 1888. [Homonym, Kunth and Bouché, Annales sci. nat., 3d ser., vol. 7, p. 235, 1847.]

This species is essentially a Tertiary form, having been first described from material found in the Denver formation at Golden, Colo. It is abundant in the Denver formation in the Denver Basin and was subsequently found in beds supposed to be of the same age in Middle Park and was also shown to be abundant in the Raton formation of the Raton Mesa region.

It is very rare, if indeed it is present at all, in the Laramie formation. It was first noted by Lesquereux [99] in a small collection from the old Franceville coal mine, a few miles southeast of Colorado Springs, Colo., though it is not contained in collections made at the same locality in 1908. The single, somewhat fragmentary leaf here figured was obtained by Peale and Goldman near the coal in Popes

[95] Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, pl. 29, figs. 1, 4, 1878 (not figs. 2, 3).

[96] Cockerell, T. D. A., Am. Mus. Nat. Hist. Bull., vol. 24, p. 89, 1908.

[97] Lee, W. T., and Knowlton, F. H., U. S. Geol. Survey Prof. Paper 101, p. 262, pl. 38, fig. 9, 1918.

[98] Heer, Oswald, Flora tertiaria Helvetiae, vol. 2, p. 63, pl. 81, figs. 6–10, 1856.

[99] Lesquereux, Leo, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1873, p. 203, 1874.

Bluff, west of Pikeview, Colo., in sec. 14, T. 13 S., R. 67 W. It is of about the same size as the largest of the types of this species figured by Lesquereux,[1] but it is more obtuse at the apex and apparently has fewer secondaries and these at a slightly more acute angle. The basal portion can not be compared with the types. Possibly this leaf should not be referred to *Ficus denveriana*, though it undoubtedly approaches that species most closely.

Occurrence: Laramie formation, Popes Bluff, west of Pikeview, Colo. (sec. 14, T. 13 S., R. 67 W.), collected by A. C. Peale and M. I. Goldman, 1908. Denver formation (types), Golden, Colo. Raton formation, Raton Mesa region of Colorado and New Mexico.

Ficus crossii Ward.

Plate XI, figure 2.

Ficus crossii Ward, U. S. Geol. Survey Sixth Ann. Rept., p. 552, pl. 44, fig. 7, 1886; U. S. Geol. Survey Bull. 37, p. 39, pl. 21, fig. 2, 1887.

Ficus uncata Lesquereux. Knowlton, U. S. Geol. Survey Bull. 152, p. 105, 1898.

The type specimen of this species (U. S. Nat. Mus. No. 4106) is before me. Although it is described by Ward as being "preserved with considerable fidelity," a careful study discloses the fact that Ward's figure of it is somewhat in error. None of the basal portion and indeed very little of the margin is preserved. The blade alone was probably over 8 centimeters in length, and it may have been longer. The midrib has the appearance of being unusually thick for a leaf of this size, and it was largely on this account that I was at one time inclined to refer this leaf to *Ficus uncata*, which has an especially strong midrib.

The later collections from Golden included the specimen here figured, which is believed to be the same as *Ficus crossii*. It is a longer leaf than Ward's figure of *F. crossii* would imply, but they were probably really of the same dimensions. The present leaf, which is also ovate-oblong in outline, was about 9 centimeters long and nearly 6 centimeters wide. The midrib is very thick below but becomes thinner above. There are 10 or 11 pairs of secondaries, which arise at an angle of about 70° and are abruptly camptodrome near the margin. The lower secondary has a few very short camptodrome branches on the outside. The nervilles are seen to be numerous, strong, and oblique to the secondaries, as in *F. crossi*. They seem best removed from *Ficus uncata*.

These leaves suggest *Rhamnus goldianus* Lesquereux,[2] but they are more wedge-shaped at the base and, moreover, the secondaries curve near the margins in a very different manner.

Occurrence: Laramie formation (type), Golden, Colo., collected by Whitman Cross, for whom it is named. The specimen figured was collected by L. F. Ward 1¼ miles southwest of Golden, Colo.

Ficus cowanensis Knowlton, n. sp.

Plate VIII, figure 6; Plate IX, figures 2, 3.

Ficus cowanensis Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 273, 1919.

Leaves of large size and thick texture; ovate-lanceolate, or perhaps narrowly obovate-lanceolate, with long, wedge-shaped base and rather obtuse apex; margin perfectly entire; midrib extremely thick, especially below; secondaries few—about six or seven pairs—far apart, relatively very thin, at an angle of approximately 30° or 40°, apparently camptodrome; nervilles numerous, very thin, at nearly right angles to the secondaries.

This species is represented by several examples, all of which are fragmentary or more or less distorted. The length, so far as can be made out, is about 15 centimeters and the width 7 or 8 centimeters. The secondaries are exceptionally slender for a leaf of this size.

Occurrence: Laramie formation, Cowan station, 10 miles south of Denver, Colo., collected by F. H. Knowlton.

Ficus berryana Knowlton, n. sp.

Plate XI, figure 1.

Ficus berryana Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 272, 1919.

Leaf thin in texture, broadly ovate, very abruptly rounded and truncate at the base, deltoid-acuminate at the apex; margin entire; nervation very light, triple-nerved from the base of the blade; midrib straight, with about two pairs of alternate, apparently campto-

[1] The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, pl. 33, fig. 5, 1878.

[2] Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, pl. 53, figs. 4-8, 1878.

drome secondaries; lateral ribs at an angle of approximately 45°, thin, passing up about half the length of the leaf; finer nervation obsolete.

The single example figured is all that was observed of this species. It is 5.5 centimeters long and a little over 4.5 centimeters wide. It appears to be closely related to *Ficus ovatifolia* Berry,[3] from the Eutaw formation of McBrides Ford, Ga. It is, however, more truncate at the base and more obtuse at the apex, and the lateral ribs do not ascend as high as in the Eutaw form.

This species is named in honor of Edward Wilber Berry, of Johns Hopkins University.

Occurrence: Laramie formation, Marshall, Colo., railroad cut between old and new stations, collected by A. C. Peale, 1908.

Ficus arenacea Lesquereux.

Plate X, figures 2, 4; Plate XXI, figure 6.

Ficus arenacea Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1871, p. 300, 1872; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 195, pl. 29, figs. 1, 4, 5, 1878.

Ficus lanceolata Heer. Knowlton, U. S. Geol. Survey Bull. 152, p. 102, 1898.

The early history of this species is the same as that of *Ficus lanceolata* (now *F. navicularis*, q. v.)—that is, it is a part of the collection from an unknown locality, the original labels, according to Lesquereux, "having been lost or forgotten." The matrix is a hard, shaly, fine-grained whitish sandstone, and although it was subsequently supposed to have come from the Green River formation it probably came from the Laramie. In any event, the two fragmentary leaves from the Laramie at Marshall here figured are not to be distinguished from figure 4 of Plate XXIX of Lesquereux's "Tertiary flora," and the species may now take definite place in the Laramie flora.

Occurrence: Laramie formation, Marshall, Colo., collected by Arthur Lakes, 1890.

Ficus? apiculatus Knowlton, n. sp.

Plate XI, figure 6.

Ficus? apiculatus Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 270, 1919.

Leaf membranaceous, ovate-lanceolate, being abruptly rounded below and prolonged above into a long, slender acuminate apex; margin entire; nervation consisting of a rather strong midrib and four or five pairs of thin, remote secondaries, which curve upward and follow the margin for a considerable distance; finer nervation very obscure.

This leaf, the only one observed, is nearly perfect, as it lacks only the basal portion. It is about 12 centimeters long and 3.5 centimeters wide and may be known by its ovate-lanceolate outline with long, slender tip and the few curving secondaries.

This species has the same shape of leaf and type of nervation as *Ficus populina* Heer,[4] from the Swiss Miocene, but it differs absolutely in the margin, which is entire in the present species and crenate in the European form. It is perhaps doubtful whether this leaf should be referred to *Ficus*.

Occurrence: Laramie formation, Cowan station, south of Denver, Colo., collected by F. H. Knowlton, 1908.

Order ARISTOLOCHIALES.

Family ARISTOLOCHIACEAE.

Aristolochia brittoni Knowlton, n. sp.

Plate XXIII, figures 3-5.

Aristolochia brittoni Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 96, 1919.

Leaves of medium size, broadly reniform, with rounded lobes, a deep rounded sinus, entire margin, and abruptly acuminate or obtuse apex; petiole very thick; nervation palmately three-ribbed from the very base of the blade; midrib thick, especially below, becoming flexuose in the upper portion, three or four pairs of alternate secondaries above the middle, arising at an angle of approximately 35°, forking well below the margin, and each joining the one next above by a broad loop and with one or two series of loops outside; lateral ribs strong, arising at an angle of about 45°, passing upward, and joining the lowest secondary on the midrib by a broad loop, each with about four secondary branches on the outside, which arch and join similarly to the upper secondaries; the lowest pair of secondaries with about four tertiary anastomosing branches on the lower side, supplying the rounded lobes of the blade; nervilles strong, percurrent, forming large rectangular areas; ultimate nervation not preserved.

[3] Berry, E. W., U. S. Geol. Survey Prof. Paper 84, pl. 19, figs. 5-7. 1914.

[4] Flora tertiaria Helvetiae, vol. 2, pl. 85, figs. 4, 5, 1856.

This fine species, which appears to be quite unlike anything before reported from the Laramie, is represented by the nearly perfect example figured and by another, much poorer specimen which has little but the margin preserved. The form is broadly reniform, entire leaf about 6.5 centimeters wide and about 5.5 centimeters long, exclusive of the petiole, which is 17 millimeters along and 2 millimeters in diameter. The leaf is characterized by the three strong palmate ribs, the central with three or four camptodrome secondaries, and the lateral with an equal number of tertiary branches, all the ultimate branches of secondaries and tertiaries anastomosing, and with one or two series of broad loops outside.

After a somewhat careful comparison of this species with both living and fossil leaves referred to the genus *Aristolochia*, there can be little doubt as to the correctness of this determination. Among the living species, for example, it has very much the same shape as *A. clematis* Linné and *A. hirta* Linné, both of the Old World, and in both form and nervation, it approaches the American *A. tomentosa* Sims.

Among the fossil species described, the one under discussion somewhat resembles *A. aesculapi* Heer,[5] but is a little larger. It is also considerably like *A. cordifolia* Newberry,[6] from the Fort Union formation of Montana, which differs in being longer than broad and in having five ribs springing from the top of the petiole.

Among the specimens from Marshall's mine is a fragment of the upper portion of a leaf that is referred with some hesitation to this species. It was a somewhat larger leaf, with a slightly more obtuse apex and a relatively thicker midrib. It bears about four pairs of alternate or subopposite, remote secondaries, which arch by a broad curve far within the margin and are provided with two or three distinct series of large loops outside. There are also intermediate secondaries which anastomose with the main secondaries by irregular rectangular areas. This is certainly a leaf of the same type as that first described and hardly differs except as regards the intermediate secondaries and the more irregular nervilles. It may be a different but closely related species, but it seems best, in the light of our present knowledge, to regard them as identical.

This species is named in honor of Dr. N. L. Britton, director of the New York Botanical Garden, by whom the specimens were collected.

Occurrence: Laramie formation, Coal Creek and Marshall's mine, Boulder County, Colo., collected by N. L. Britton about 1880.

[5] Heer, Oswald, Flora tertiaria Helvetiae, vol. 2, p. 104, pl. C, fig. 11, 1856.

[6] Newberry, J. S., U. S. Geol. Survey Mon. 35, pl. 40, fig. 7, 1898.

Order RANALES.

Family NYMPHAEACEAE.

Nelumbo tenuifolia (Lesquereux) Knowlton.

Plate XXVI, figure 7.

Nelumbo tenuifolia (Lesquereux) Knowlton, U. S. Geol. Survey Bull. 696, p. 407, 1919.

Nelumbium tenuifolium Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1873, pp. 382, 402, 1874; idem for 1876, p. 514, 1878; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 253, pl. 46, fig. 3, 1878.

The type specimen of this species is preserved in the United States National Museum (No. 372, by error in the catalogue, 472). It is very indistinct, and the figure of it in the "Tertiary flora" is far from accurate. The only part of the true margin preserved is a fragment hardly 3 centimeters in extent shown in the upper left-hand portion of the figure. A careful examination of the specimen fails to show the margin in the lower portion, as given in the figure. This proves that the leaf was larger than appears from the drawing. It has thin ribs, as described by Lesquereux, and the whole leaf appears to have been of thin texture. In the original description Lesquereux states that the leaf is "exactly round, peltate from the middle, and 8 or 9 centimeters in diameter." As noted above, the type specimen is larger than the description calls for, being fully 10 centimeters in diameter. The ribs are 13 in number, but this feature is of little or no specific significance.

This species is most closely related to *Nelumbo lakesiana* (Lesquereux) Knowlton,[7] a well-known Denver species, from which it differs in its obviously thin texture, thin ribs, and smooth surface.

[7] Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 252, pl. 46, figs. 1, 2, 1878.

In the collection from Erie, Colo., there is a single example (here figured) which appears to belong with *N. tenufolia*. It is folded around on both sides of a thin piece of matrix and appears to have been a thin, delicate leaf. Its diameter is about 10 centimeters; it has the same number of ribs as the type specimen. The margin is gently undulate, and the ribs are forked or branched some distance below the margin. The finer nervation is obscure.

Occurrence: Laramie formation, Erie, Colo., collected by N. L. Britton about 1885. Denver formation, Sand Creek, 15 miles east of Denver, Colo., collected by A. Gardner.

Family MAGNOLIACEAE.

Magnolia marshalli Knowlton, n. sp.

Plate XXI, figure 10.

Magnolia marshalli Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 374, 1919.

Leaf oblong-lanceolate, with an obtuse apex and an obtusely wedge-shaped base; midrib straight, thick; secondaries about 15 pairs, alternate or a few subopposite, emerging at an angle of 40° or 45°, running with a slight upward curve to a point within one-fifth of their length from the margin, where each arches around and joins the one next above by an even, regular loop, from the outside of which smaller tertiaries are sent toward the margin; nervilles strong, percurrent, at right angles to the secondaries; finer nervation obsolete.

This fine leaf is 10.5 centimeters long and 3.5 centimeters wide at the broadest point, which is perhaps a little above the middle of the leaf. From the broadest point it tapers gradually to a rather obtuse apex and in about the same manner to the base. The petiole is not preserved. The midrib is very thick and prominent.

This leaf is referred to *Magnolia* with little hesitation. In outline it is very similar to a number of living species, as, for example, some of the cultivated forms of *M. grandiflora* Linné, young leaves of *M. umbrella* Linné, and particularly *M. pealii* King, a large tree found in Upper Assam, India. Its relation with *M. pealii* is very close, indeed, for it has the exact outline—except the taper-pointed apex—and much the same nervation. In nervation *M. marshalli* has clearly the characters of *Magnolia*, as shown by the figure.

Among fossil species of the Laramie and post-Laramie formations the present species approaches most closely *M. attenuata* Lesquereux,[8] differing by being much smaller and narrower. It also somewhat resembles *M. dayana* (Lesquereux) Cockerell, from the auriferous gravels of California,[9] from which it differs in being only half the size and relatively broader and less wedge-shaped at base.

Occurrence: Laramie formation, Marshall's mine, Boulder County, Colo., collected by Arthur Lakes, 1890.

Magnolia lakesii Knowlton, n. sp.

Plate XIII, figure 2.

Magnolia lakesii Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 373, 1919.

Leaf of firm texture, broadly elliptical, almost oval, abruptly rounded in about the same degree to base and apex; margin perfectly entire; midrib strong below, becoming much thinner above, straight; secondaries four or five pairs, very thin, opposite or subopposite, at a very low angle, much curved upward, each joining the one next above and far inside the margin by a broad loop; nervilles few, mostly unbroken, oblique to the secondaries; finer nervation obsolete.

The leaf figured, which is one of several of its form, was about 7 centimeters long and 5.5 centimeters wide. It is nearly elliptical, with an abruptly rounded and truncate base. It is well marked by the thick midrib and few, thin secondaries arising at a very low angle and joining the ones above far from the margin of the blade.

Among the living American species of the genus *Magnolia* the leaf under consideration seems to be most closely related to *Magnolia acuminata* Linné, or more especially its variety *cordata*, which has been somewhat modified, apparently by long cultivation. The fossil leaf differs in being more nearly elliptical and in having fewer secondaries, but its general appearance is much like that of the species mentioned.

This species has some resemblance to what was called *Ficus haguei* Knowlton,[10] from the

[8] The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 250, pl. 45, fig. 6, 1878.

[9] Harvard Coll. Mus. Comp. Zoology Mem., vol. 6, pl. 6, fig. 4, 1878.

[10] Knowlton, F. H., Fossil flora of the Yellowstone National Park: U. S. Geol. Survey Mon. 32, pt. 2, pl. 90, fig. 3, 1899.

Miocene of the Yellowstone National Park, but it differs slightly in shape and more markedly in nervation. It is rather doubtful if *F. haguei* was correctly referred to the genus *Ficus*.

Occurrence: Laramie formation, Marshall, Boulder County, Colo., collected by Arthur Lakes, 1890.

Family ANONACEAE.

Anona coloradensis Knowlton, n. sp.

Plate XVIII, figure 4.

Anona coloradensis Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 78, 1919.

Leaves evidently thin and membranaceous, narrowly ovate-lanceolate, very obtusely wedge-shaped at the base, long acuminate at the apex; margin perfectly entire; midrib strong, straight; secondaries about seven pairs, alternate, thin, at an angle of about 50°, much curved upward just along the borders; finer nervation obsolete.

The specimen figured is about 8 centimeters long and 2.75 centimeters wide and is perfect except for small areas at the extreme base and apex.

This species appears to be closely related to *Anona palmeri* Safford,[11] a recently described living species from the vicinity of Acapulco, Mexico, being especially like the larger uppermost leaves of that form. They are of the same size and shape and have the same character of nervation, about the only apparent difference being the fewer secondaries in *A. coloradensis*.

Three species of *Anona* from this country have thus far been described—*A. cretacea* Lesquereux,[12] from the Dakota sandstone; *A. robusta* Lesquereux,[12a] from the Laramie at Golden, Colo.; and *A. spoliata* Cockerell,[13] from the Miocene at Florissant, Colo. The Dakota species has never been figured. The original figure of *A. robusta*, the Laramie species, is reproduced in Plate XVII, figure 7. The Florissant species is smaller and very different in shape, being similar to the living *A. glabra* Linné, of Florida. The present species, if referable to this genus, belongs to quite another section than those above mentioned.

[11] Safford, W. E., Contr. U. S. Nat. Herb., vol. 18, pl. 24, 1914.
[12] Lesquereux, Leo, The Cretaceous and Tertiary floras: U. S. Geol. Survey Terr. Rept., vol. 8, p. 77, 1883.
[12a] Idem, p. 124, pl. 20, fig. 4.
[13] Cockerell, T. D. A., Descriptions of Tertiary plants, II: Am. Jour. Sci., 4th ser., vol. 26, p. 542, fig. 7, 1908.

Occurrence: Laramie formation, Cowan station, 10 miles south of Denver, Colo., collected by F. H. Knowlton.

Anona robusta Lesquereux.

Plate XVII, figure 7.

Anona robusta Lesquereux, Cretaceous and Tertiary floras: U. S. Geol. Survey Terr. Rept., vol. 8, p. 124, pl. 20, fig. 4, 1883.

Leaf large, about 13 centimeters long, 6 centimeters broad below the middle, coriaceous, ovate-lanceolate, gradually narrowed to the pointed apex, abruptly rounded and truncate at the base, margin slightly undulate; median nerve very thick, especially below, straight; secondaries 12 or 13 pairs, strong, mainly alternate, close, parallel, very open or nearly at right angles toward the base, then gradually at a more acute angle, slightly curved upward, camptodrome; nervilles prominent, oblique to the secondaries, simple and continuous or anastomosing in the middle.

The type and so far as known the only specimen of this fine species is in the collection of the Museum of Princeton University (No. La. 74). It is preserved on the coarse white sandstone characteristic of the true Laramie in the vicinity of Golden, Colo. There is nothing to add to the description and well-executed figure given by Lesquereux.

Occurrence: Laramie formation, Golden, Colo., first sandstone hogback west of Tarr Hall.

Family LAURACEAE.

Laurus lanceolata Knowlton, n. sp.

Plate XXI, figure 7.

Laurus lanceolata Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 346, 1919.

Leaf coriaceous, narrowly lanceolate or possibly oblanceolate, long and narrowly wedge-shaped at the base, somewhat unequal sided (apex destroyed); midrib relatively strong, especially below, perfectly straight; secondaries few (only four pairs showing in the specimen), opposite or subopposite, at an acute angle, passing up for long distances and but slightly curved, disappearing just at the margin; nervilles few and obscure, apparently unbroken and at right angles to the secondaries.

This species is represented by the single example figured, which unfortunately lacks the upper portion for an unknown length. The absence of the apical portion makes it impossible to determine the shape satisfactorily; it appears to be simply narrowly lanceolate, though it may be larger above, which would make it oblanceolate. The portion preserved is a little over 7 centimeters in length and a little under 1.5 centimeters in greatest width.

This species is quite distinct from anything previously noted in the Laramie and appears to find its closest relative in *Laurus oregoniana* Knowlton,[14] from the Mascall formation (Miocene) of the John Day Valley, Oreg. That species is very much larger than the leaf under discussion, being some 18 centimeters in length and 3.5 or 4.5 centimeters wide, but it has the same shape and general appearance. It differs slightly, however, in having the secondaries markedly alternate and the nervilles much broken.

Occurrence: Laramie formation, Coal Creek, Boulder County, Colo., mine on road near McNamara's, collected by Arthur Lakes, June, 1890.

Laurus lakesii Knowlton, n. sp.

Plate XXII, figure 6.

Laurus lakesii Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 346, 1919.

Leaf of firm texture, lanceolate; about equally narrowed to both base and apex; midrib slender, straight; secondaries about six or seven pairs, alternate, at a low angle, camptodrome, arching close to the border; finer nervation forming quadrangular areolae.

This little leaf is about 6 centimeters long and 1.2 centimeters wide. The nervation is not very well preserved.

This species is of the same type as and pretty closely related to what Lesquereux [15] described and figured under the name *Laurus primigenia* Unger, mainly from Evanston, Wyo., but it is rather smaller and has fewer secondaries at a more acute angle of divergence.

Lesquereux mentions specimens from Black Buttes, Wyo., and Spring Canyon, Mont., which he at first considered identical with those subsequently described under the name *Laurus primigenia* Unger, but they were so fragmentary that he hesitated to place them together. It is possible that they may prove to be the same as the leaf here described.

The leaf described above as *Laurus lanceolata* is of about the same size and shape as the present one but differs markedly in its primary nervation.

Occurrence: Laramie formation, Coal Creek, Boulder County, Colo., collected by Arthur Lakes, 1890.

Laurus wardiana Knowlton.

Plate XVI, figure 1 (type).

Laurus wardiana Knowlton, U. S. Geol. Survey Bull. 152, p. 129, 1898.

Laurus ocoteoides Lesquereux, Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 215, pl. 36, fig. 10, 1878; U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1876, p. 510, 1878. [Lesquereux's original figure of the type is here reproduced.] [Homonym, *Laurus ocoteaeoides* Massalongo, Synopsis florae fossilis senogalliensis, p. 57, pl. 24, fig. 3; pl. 40, fig. 1, 1858.]

The type of this fine species is preserved in the United States National Museum (No. 905) and is the only specimen ever obtained from the Laramie. It comes from the hard white sandstone at Golden, Colo., and therefore belongs in the Laramie.

Occurrence: Laramie formation, Golden, Colo. ?Dawson arkose, near Mosby, Colo., 30 feet above the coal.

Malapoenna louisvillensis Knowlton, n. sp.

Plate VII, figure 5.

Malapoenna louisvillensis Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 379, 1919.

Leaf of medium size, narrowly ovate-lanceolate, apparently wedge-shaped at the base, narrowly acuminate at the apex; margin perfectly entire; midrib strong, straight; secondaries about three pairs, opposite or subopposite, at an angle of nearly 80°, the lower pair ascending far above the middle of the blade, with few outside branches, camptodrome; nervilles numerous, mainly broken or irregular; finer nervation forming a complete irregular network.

This species is represented by two fragmentary specimens, of which the larger and better is figured. As this specimen lacks both base and apex it is impossible to ascertain the length, though it must have been about 8 centimeters; the width is a little less than 3 centimeters.

[14] U. S. Geol. Survey Bull. 204, p. 58, pl. 9, figs. 2, 3, 1902.

[15] Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 214, pl. 36, figs. 5, 6, 8, 1878.

The smaller leaf could hardly have been over 6 centimeters in length.

In shape and size this species is near *Malapoenna cuneata* Knowlton,[16] from the Yellowstone National Park, but it differs essentially in the fewer, more acute-angled secondaries.

Occurrence: Laramie formation, dump of Rex mine No. 1, Louisville, Colo., collected by A. C. Peale, 1908.

Cinnamomum affine Lesquereux.

Plate VIII, figure 4; Plate XVII, figure 6.

Cinnamomum affine Lesquereux, Am. Jour. Sci., 2d ser., vol. 45, p. 206, 1868; U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1869 [reprint, 1873], p. 169; idem for 1872, p. 383, 1873; idem for 1873, p. 401, 1874; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 219, pl. 37, figs. 1–4, 7 [not fig. 5, which = *Ficus trinervis* Knowlton].

Knowlton, U. S. Geol. Survey Bull. 163, p. 59, pl. 14, fig. 2, 1900.

Cockerell, Torreya, vol. 9, p. 142, 1909.

For many years there has been much confusion concerning this species, but it is believed that there are now sufficient data at hand to clear up most of this uncertainty. *Cinnamomum affine* was named by Lesquereux[17] in 1868 and based on material from "Marshall's mine, near Denver," Colo., but it was neither described nor figured at that time. It was next mentioned the following year, when Hayden reproduced Lesquereux's article without change in his Third Annual Report of the United States Geological Survey of the Territories.[18] It was briefly alluded to but not described by Lesquereux[19] in discussing material from Marshall collected by himself in 1872. He was then undecided as to whether it was really distinct from his *Cinnamomum mississippiense*, from what is now known as the Wilcox group of the Gulf region. The following year Lesquereux[20] wrote of it as follows:

> From the comparison of a large number of specimens representing various forms of this species, it proves to be, as I had supposed, a mere variety of *C. mississippiense*. The species is common at Golden and found in the whole thickness of the North American lignitic measures.

Cinnamomum affine was first figured and properly described in the "Tertiary flora," published in 1878, or 10 years after it had been named. In discussing it Lesquereux says:

> I have been for a long time undecided in regard to the possible identity of this northern species with the beautiful *C. mississippiense* Lesquereux, communicated by Prof. E. W. Hilgard. From the larger size of the Mississippi leaf, more enlarged below the middle, its more rugose nervation, and the greater distance of the lateral nerves from the borders, I came to the conclusion that the leaves from Golden did represent a new species, or at least a diminutive variety of *C. mississippiense*.

In any event it was kept distinct from the Gulf species, and subsequent study of larger and better collections has confirmed this view.

Lesquereux expressed some doubt as to whether the specimen illustrated in figure 7 of Plate XXXVII in the "Tertiary flora" was conspecific with the others but added that as it was "found upon the same piece of shaly hard sandstone as the leaves of figures 1–3," it could not be separated from them. He further stated that the leaf depicted in his figure 4 was the specimen first obtained from Marshall's mine, Colo., and this is undoubtedly the type of the species. Unfortunately, neither this specimen nor the originals of Lesquereux's figures 1–3 can now be found in the United States National Museum, where they should be, and their location is unknown. However, the originals of figures 5 and 7 of Plate XXXVII of the "Tertiary flora" are in the Museum (No. 312) and came from Golden, Colo. They are preserved in hard whitish sandstone and hence are referable to the Laramie. So far as known this species has not subsequently been found at Golden.

Although a considerable collection from Marshall, the type locality, has been studied in the present connection, no examples of *Cinnamomum affine* were found, but Cockerell[21] reports finding it there in connection with what he has identified as *Juglans leconteana*. He states that it comes from a relatively high level.

The leaf shown in Plate VIII, figure 4, came from Cowan station, about 10 miles south of Denver, Colo.; it is indistinguishable from figures 1, 3, and 4 of Plate XXXVII of the "Tertiary flora."

In this connection it may be well to correct a number of erroneous references that have long been current regarding *Cinnamomum affine*. Thus, it was said to be very common in the

[16] U. S. Geol. Survey Mon. 32, pt. 2, p. 726, pl. 92, figs. 2–4, 1899.
[17] Am. Jour. Sci., 2d ser., vol. 45, p. 206, 1868.
[18] Reprint, 1873, p. 196.
[19] U. S. Geol. and Geog. Survey Terr. Sixth Ann. Rept., p. 383, 1873.
[20] U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1873, p. 401, 1874.
[21] Cockerell, T. D. A., Torreya, vol. 9, p. 142, 1909.

Canon City field, but here it was confused with what has been described as *Ficus praetrinervis* Knowlton,[22] an exceedingly abundant form in the Vermejo formation. Lesquereux also stated that he had specimens of it from the Raton region of Colorado, but so far as now known it is not present there, the leaves mistaken for it being the larger *C. mississippiense*, which is confined to the Raton formation.[23]

The specimens from beds of post-Laramie age at Carbon, Wyo., are probably to be referred to *Populus* sp. undet., and the specimens obtained by Ward [24] at Black Buttes, Wyo., have been referred to *Ficus trinervis* Knowlton,[25] a species now known to be of wide distribution.

The final conclusion is reached that in no authenticated instance has *Cinnamomum affine* been found at a horizon younger than the true Laramie.

Occurrence: Laramie formation, Marshall, Colo. (types); Marshall, Colo., half a mile south of railway station, collected by F. H. Knowlton, 1908; Rex mine, Louisville, Colo., collected by A. C. Peale, 1908; Leyden Gulch, 6½ miles west of Golden, Colo., collected by A. C. Peale, 1908; Cowan station, 10 miles south of Denver, Colo., collected by F. H. Knowlton.

Cinnamomum laramiense Knowlton, n. sp.

Plate XXII, figure 3.

Cinnamomum laramiense Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 170, 1919.

Leaf apparently rather thin in texture, very narrowly obovate-lanceolate, being broadest at a point somewhat above the middle, from which it tapers or rounds rather abruptly to a rounded apex and narrows downward to a wedge-shaped base; triple-nerved, the midrib slender, straight; lateral nerves or ribs of same size as midrib, opposite, arising high above the base and running nearly to the apex of the leaf, with very few branches on the outside; upper secondaries apparently only one pair, less than one-fourth the length of the blade from the apex, running to or near the margin.

This leaf, of which only a single one seems to have been found, is about 9 centimeters long and a little less than 3 centimeters wide.

It is perhaps unwise to attempt the characterization of a species of *Cinnamomum* on a single specimen, but the one in hand seems to differ from others sufficiently to be worthy of independent rank, at least until further material can be obtained.

Among living species it is perhaps nearest to *C. cassia* Blume, except that it is relatively rather narrower below. Among fossil forms it approaches a number of species, especially *C. lanceolatum* as usually depicted from European sources. From that species, however, it appears to differ in having a more obtuse apex and only two pairs of secondaries on the midrib.

Occurrence: Laramie formation, Morrison, Colo., white sandstone near coal seam, collected by Arthur Lakes, 1890; Cowan station, 10 miles south of Denver, Colo., collected by F. H. Knowlton, 1908.

Order ROSALES.

Family PLATANACEAE.

Platanus platanoides (Lesquereux) Knowlton?

Plate XIII, figure 1.

Platanus platanoides (Lesquereux) Knowlton, U. S. Geol. Survey Bull. 152, p. 171, 1899.

Viburnum platanoides Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1874, p. 314, 1876; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 224, pl. 38, figs. 8, 9, 1878.

One of the original types of this species, illustrated in the "Tertiary flora," Plate XXXVIII, figure 8, is preserved in the United States National Museum collection (No. 327). It came, according to Lesquereux, from Black Buttes, Wyo. As indicated above, it was described under the name *Viburnum platanoides* and was regarded as being rather closely related to *Viburnum marginatum* (now *Platanus marginata*), from which it differs in having "less numerous, more open, lateral veins, whose branches are more curved in passing up to the borders, and especially by the enlarged truncate or subtruncate base of the leaves." The type specimen is rather fragmentary, but so far as known it has been accurately diagnosed by Lesquereux.

Platanus platanoides has since been found in beds of "Lower Laramie" (Medicine Bow) age in Carbon County, Wyo., and has been

[22] U. S. Geol. Survey Prof. Paper 101, p. 263, pl. 41, figs. 1–4; pl. 42, fig. 1, 1918.

[23] Idem, p. 320, pl. 89, fig. 2.

[24] U. S. Geol. Survey Sixth Ann. Rept., p. 558, 1886; U. S. Geol. Survey Bull. 37, p. 43, 1887.

[25] U. S. Geol. Survey Bull. 163, p. 42, 1900.

reported as doubtfully present in the Raton formation of southern Colorado.

The probable presence of this species in the Laramie near Erie, Colo., is attested by the single example here figured. It is very fragmentary, lacking nearly all of the basal portion, and the secondaries and ribs are at a more acute angle in the type specimen, but otherwise it appears to be referable to this species.

Occurrence: Laramie formation, Reliance mine, 1¾ miles northeast of Erie, Colo., collected by F. H. Knowlton and G. C. Martin, 1908.

Family LEGUMINOSAE.

Leguminosites? coloradensis Knowlton, n. sp.

Plate XIX, figure 9.

Leguminosites? coloradensis Knowlton [nomen nudum]. U. S. Geol. Survey Bull. 696, p. 352, 1919.

Fruit of large size, flattened obovoid, point of attachment small (apex not seen), thickened or ridged along one side, body provided with numerous fine transverse lines.

This specimen, the only one observed, lacks the apical (?) end but otherwise is apparently perfect. Its present length is 2.5 centimeters, but when perfect it was probably not less than 3 centimeters in length. The width is 1.5 centimeters, and the thickness in its present flattened condition is about 5 millimeters. The transverse lines are obscure, and there is no indication of lines in the other direction.

The generic reference of this specimen is somewhat uncertain, from the fact that it is not perfect and also because it does not lie in the matrix so as to be displayed to the best advantage. In its shape and the transverse lines it somewhat resembles what has been called *Nyssa? racemosa* Knowlton, from the Denver beds at Golden, but it differs greatly in size and in the absence of longitudinal lines or ribs. It may possibly belong to the genus *Podogonium*, so many species of which from the Swiss Miocene are described by Heer,[26] but it is not clear that it is a pod of this character, and, moreover, there are no transverse striae in the forms shown by Heer. In general shape and in size it suggests *Leguminosites? arachioides* Lesquereux,[27] though it differs markedly in the striations and their direction.

[26] Heer, Oswald, Flora tertiaria Helvetiae, vol. 3, pl. 136, 1859.
[27] Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, pl. 59, fig. 14, 1878.

Occurrence: Laramie formation, wooded bluff south of Marshall, Colo., collected by A. C. Peale, 1908.

Leguminosites columbianus Knowlton, n. sp.

Plate XIX, figures 4, 5.

Leguminosites columbianus Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 352, 1919.

As interpreted this appears to have been a small turgid pod which was a little longer than broad, acuminate at the apex, and short-pediceled.

This remarkable form is represented by three specimens, all of which are figured. The two more nearly perfect examples appear to be small pods that have been split along one of the sutures and are now open on the stone. The larger one has a length of 9 millimeters exclusive of the pedicel, which is 2 millimeters long, and a width of 6 millimeters as it is spread open, or 3 millimeters to each "valve." The smaller specimen is 5.5 millimeters long and 6 millimeters wide and is without a pedicel. The third specimen is somewhat crushed and distorted. It is 11 millimeters long and appears to have been 6 or 7 millimeters wide; it also is without a pedicel.

Just at the point of the more crushed specimen there are two small round or oblong, pealike seeds, each 3 millimeters in diameter. Very close to the large perfect specimen is the impression of what appears to have been a similar "seed." There is of course no proof that either of the "seeds" came from these pods, but their proximity renders it possible, if not probable, although none of the pods appear to show traces or imprints of the seeds, as it would seem they should.

It is with hesitation that this fossil is given so definite a name as *Leguminosites*. This genus was instituted for the reception of certain miscellaneous plant remains which appear to belong to the Leguminosae but about which knowledge is too indefinite to permit a satisfactory generic reference. The fossils under consideration appear to belong to the Leguminosae—that is, they appear to be pods from which small round, pealike "seeds" may have escaped. They have a form very like that of certain living species of *Astragalus*, as *A. canadensis* Linné and *A. confertifolius* Gray, or rather, as these would appear when opened and lying in a rock. The identification is to be regarded as tentative, but whatever their nature, they are very definite organisms and undoubtedly may be easily recognized in future.

Occurrence: Laramie formation, Erie, Colo.

Leguminosites? laramiensis Knowlton, n. sp.

Plate XVII, figure 4.

Leguminosites? laramiensis Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 353, 1919.

Leaflet narrowly obovate-lanceolate, broadest well above the middle, whence it narrows evenly in wedge-shaped form to the base and more abruptly to the more obtusely acuminate apex; margin entire; midrib relatively very thick; secondaries thin, obscure, apparently about eight pairs.

This is a small leaf or leaflet 3 centimeters long and about 1 centimeter wide. It is preserved on a rather coarse grained sandstone, which has retained but little trace of the nervation. It is so poorly characterized that the generic reference is very uncertain, hence it is not worth while to institute comparisons with described species, as they might be very misleading.

Occurrence: Laramie formation, opposite sand-lime brick works about 4 miles north of Colorado Springs, Colo., collected by A. C. Peale and G. I. Finlay, 1908, on same stone with *Dombeyopsis trivialis*.

Mimosites marshallanus Knowlton, n. sp.

Plate XVI, figure 4.

Mimosites marshallanus Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 387, 1919.

Leaflet small, narrowly obovate, very obtusely pointed at the apex and wedge-shaped at the base, 2.75 centimeters long, 14 millimeters wide; margin perfectly entire; nervation faint, consisting of a slender midrib and apparently two or three pairs of secondary branches.

This little leaflet is the only one observed. It is perfect so far as outline goes, but the nervation is obscure. It appears to have been sessile, as the base is slightly enlarged.

Occurrence: Laramie formation, Marshall, Colo., railroad cut between old and new stations, collected by A. C. Peale, 1908.

Cassia? laramiensis Knowlton, n. sp.

Plate XIX, figure 3.

Cassia? laramiensis Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 146, 1919.

Leaflet small, about 3 centimeters long and 1.3 centimeters wide, ovate or elliptical-lanceolate, rather abruptly rounded at the base, obtusely pointed at the apex; margin apparently entire; nervation rather obscure, consisting of a rather strong midrib and seven or eight pairs of thin, alternate or subopposite camptodrome secondaries.

This little leaf or leaflet is so obscurely preserved that it is hardly worth a name and description. It lacks most of the margin, and this fact of course obscures its affinity. It is referred provisionally to the genus *Cassia*.

Occurrence: Laramie formation, Marshall, Colo., collected by A. C. Peale, 1908.

Cercis eocenica Lesquereux.

Cercis eocenica Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 384, 1873.

Lesquereux's description and remarks concerning this species are as follows:

Leaf nearly round, entire, of a thin texture, smooth surface, deeply cordate at base, nervation of *Cercis canadensis*.

The leaf has its point destroyed; it is apparently obtuse or rounded. Except that it is more deeply cordate than the average leaves of our *Cercis canadensis*, there is no difference whatever between the fossil leaves and those of the living species.

So far as known this species was not again referred to by Lesquereux, and it should probably be omitted from further consideration, yet it is described so definitely that apparently it could be recognized if it should be found, and for this reason it is retained.

Occurrence: Laramie formation, Erie, Colo.

Order SAPINDALES.

Family CELASTRACEAE.

Celastrinites alatus Knowlton, n. sp.

Plate XXV, figures 4, 5; Plate XXVI, figure 1.

Celastrinites alatus Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 152, 1919.

Leaves thin, membranaceous, ovate or broadly ovate, extended above into a short, sharp acumen and below into a rounded or slightly wedge-shaped base, which is extended down the petiole, producing a decided wing;

margin from or a little below the middle provided with numerous fine, sharp upward-pointing teeth; midrib strong, straight; secondaries about five pairs, opposite or sometimes alternate, emerging at an angle of about 45°, curving a little upward and joining below the margin, thence giving rise to a series of loops which appear to have branches entering the teeth; nervilles strong, at right angles to the secondaries, percurrent.

This species appears to be one of the best-characterized forms belonging to the Laramie. The matrix is a rather coarse sandstone upon which the finer nervation is not well preserved, yet the outline and more characteristic nervation are well shown. It is represented by four specimens, of which the two figured ones are the best. The larger (Pl. XXV, fig. 4) is 5.5 centimeters long and 4 centimeters broad, and the smaller (Pl. XXV, fig. 5) is 6 centimeters long and about 3 centimeters broad. The species is especially characterized by the winged petiole, unequal base, fine teeth above the middle of the blade, and brachidiodrome nervation.

In nervation this species is very similar to *Celastrus cassinefolius* Unger,[28] but the size and shape are very different.

Occurrence: Laramie formation, Murphy's coal bank, Ralston County, north of Golden, Colo.; Erie, Colo., collected by N. L. Britton, 1885.

Celastrinites eriensis Knowlton, n. sp.

Plate XXVI, figure 2.

Celastrinites eriensis Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 152, 1919.

Leaves small, membranaceous, broadly oval, tapering from the broadest point at the middle regularly to an acute apex and to a similar base which extends as a narrow wing to the petiole; margin finely and sharply serrate; nervation consisting of a thin midrib and four or five pairs of camptodrome secondaries; remaining nervation obsolete.

This species is founded on the example figured, which is 3.5 centimeters long and 1.7 centimeters broad, with the petiole about 1 centimeter long. The nervation is obscure, about the only thing that can be made out being the midrib and the four or five pairs of alternate, thin secondaries which emerge at an acute angle and arch just inside the borders.

This species is found associated with and may possibly belong to *C. alatus*, described above. They both have the same serrate margin and winged petiole and approximately the same nervation, but they differ markedly in shape and size, the leaves of *C. alatus* being several times the size of those of *C. eriensis* and broadly oblong instead of broadly lanceolate.

Occurrence: Laramie formation, Erie, Colo., collected by N. L. Britton about 1884.

Celastrinites cowanensis Knowlton, n. sp.

Plate XVI, figure 6.

Celastrinites cowanensis Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 152, 1919.

Leaf apparently of rather thin texture, elliptical, probably about 10 centimeters in length and a little less than 5 centimeters in width; upper portion rather abruptly rounded to a short, obtuse point (basal portion destroyed); margin strongly toothed, the teeth rather sharp; midrib very slender; secondaries about seven pairs, alternate, thin, at an angle of 30° to 40°, not much curved upward, disappearing before they reach the margin; none of the finer nervation preserved.

Occurrence: Laramie formation, Cowan station, 10 miles south of Denver, Colo., collected by F. H. Knowlton.

Family ACERACEAE.

Negundo brittoni Knowlton, n. sp.

Plate XXVI, figures 8–10.

Negundo brittoni Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 405, 1919.

Leaves compound, trifoliate; terminal leaflet largest, long-petioled, broadly ovate, rounded at the base, obscurely three-lobed, the lateral lobes very short, obtuse, apex apparently obtusely acuminate; lateral leaflets short-petioled, oblong, entire, slightly inequilateral; terminal leaflet three-nerved from a point a little above the base, other nerves remote, opposite, effaced at the borders; lateral leaflets with about five pairs of alternate secondaries, which are effaced at their extremities; finer nervation obsolete.

This well-marked species, which I take pleasure in naming in honor of its collector, Dr. N. L. Britton, of the New York Botanical

[28] Flora tertiaria Helvetiae, vol. 3, p. 67, pl. 121, figs. 25, 26.

Garden, is based upon the several examples figured. In the larger specimen (fig. 10) the whole leaf is about 12 centimeters long, including the petiole, which is 3.5 centimeters long. The terminal leaflet appears to have had a petiole fully 2 centimeters long, and the blade is about 6 centimeters long and 5 centimeters broad. The lateral leaflets have petioles only about 4 millimeters long. The one wholly preserved is 5 centimeters long and 3 centimeters broad. The nervation is obscure, and it is possible to make out only a few of the secondaries.

The genus *Negundo* [29]—if it is to be maintained as distinct from *Acer*—is represented by three living species, with a number of more or less well-marked varieties, and is entirely North American in distribution.

Up to the present time about eight fossil species of *Negundo* have been described, of which three are European and the remainder American. Of these the oldest is *Negundo* (or *Negundoides*) *acutifolia* (Lesquereux) Pax,[30] from the Dakota sandstone of Kansas and Nebraska, which differs in having thin lanceolate leaflets, obscure as to their point of attachment. The next younger species is *N. decurrens* Lesquereux,[31] from the Denver formation at Golden, Colo. This species rests upon a single specimen which has not been figured, but it is regarded by Lesquereux as being closely allied to *N. triloba* Newberry,[32] a species found only in the Fort Union near the mouth of Yellowstone River in Montana. *Negundo triloba* is evidently closely related to the living box elder (*N. aceroides*) and differs from *N. brittoni*, the one here described, in having the terminal leaflet smallest and in all being coarsely toothed.

[29] There has been much discussion as to the propriety of maintaining *Negundo* as a separate genus, and it is probable that the grounds for so doing are inadequate from the botanist's point of view. The box elders appear to be most closely related to the red maples, with which they agree in having the flowers appearing before the leaves, and these two types are separated from other maples by having compound instead of lobed leaves. If the possession of compound leaves was confined to this group (*Negundo*) it might be best to consider them generically separate from *Acer*, but there is another, otherwise unrelated group of Chinese and Japanese species with ternate leaves. For paleontologic purposes it has been thought best to retain the box elders under *Negundo*, though recognizing full well the fact that the basis for this action is not very secure.

[30] Pax, F., in Engler's Bot. Jahrb., vol. 6, p. 356, 1885. Lesquereux, Leo, The Cretaceous flora; U. S. Geol. Survey Terr. Rept., vol. 6, p. 97, pl. 21, fig. 5, 1874.

[31] Lesquereux, Leo, Harvard Coll. Mus. Comp. Zoology Bull., vol. 16, p. 54, 1888.

[32] Newberry, J. S., U. S. Geol. Survey Mon. 35, p. 115, pl. 31, fig. 5, 1898.

The only other American species, from the Mascall formation of the John Day Basin, Oreg., was described under the name *Rulac crataegifolium* Knowlton [33] when it was thought that *Rulac* was the tenable name for replacing *Negundo*. This species also rests on a single rather fragmentary specimen and, if correctly interpreted, has the terminal leaflet much smaller than the lateral ones; both are sharply toothed.

The European forms are *N. bohemicum* Menzel,[34] from the Oligocene of Sulloditz, Bohemia, and *N. europaeum* Heer [35] and *N. trifoliata* (Al. Braun) Al. Braun,[36] from the Miocene of Oeningen, neither of which approaches closely our species.

In North America we have the following species, which, when arranged in ascending geologic order, exhibit what we now know of the development of the genus:

Negundo acutifolia (Lesquereux) Pax	Dakota sandstone.
Negundo brittoni Knowlton, n. sp.	Laramie formation.
Negundo decurrens Lesquereux	Denver formation.
Negundo triloba Newberry	Fort Union formation.
Negundo crataegifolia (Knowlton) Knowlton, n. comb.	Miocene.
Negundo aceroides Moench	Living.

Occurrence: Laramie formation, Marshall, Colo.

Family SAPINDACEAE.

Pistacia eriensis Knowlton, n. sp.

Plate XXVIII, figures 1–4.

Pistacia eriensis Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 460, 1919.

Leaf compound, imparipinnate, tri(?)-foliolate; rachis slender; leaflets arising from the same point, the terminal one short-petioled, the lateral ones sessile; leaflets oblong-lanceolate, acuminate at the apex, the terminal one with a wedge-shaped base, the lateral ones inequilateral in the upper side, all entire; midrib of leaflets rather strong; secondaries numerous, 14 to 20 pairs, mainly opposite or subopposite,

[33] Knowlton, F. H., U. S. Geol. Survey Bull. 204, p. 77, pl. 16, fig. 7, 1902.

[34] Naturw. Gesell. Isis, Bautzen, Sitzungsb. und Abh., 1896–97, p. 52, pl. 2, figs. 8–9.

[35] Heer, Oswald, Flora tertiaria Helvetiae, vol. 3, p. 60, pl. 118, figs. 20–22, 1869.

[36] Bruckmann, Dr., Ver. vaterl. Naturkunde Württemberg Jahresb., VI. Jahrg., p. 235, 1850.

emerging at a low angle, camptodrome, often forking at about one-third their length from the margin, curving just inside the margin and each joining the one next above; additional shorter secondaries frequently interspersed between the principal ones, thence running one-third or sometimes more than half the distance to the margin, becoming obsolete or curving downward and each uniting with the secondary next below; nervilles strong, percurrent, sometimes crossing at right angles to the secondaries, but oftener oblique to them; finer nervation mostly obsolete.

This species is represented by the examples showing the compound nature of the leaves and by ten or more detached leaflets. The largest specimen with the leaflets attached has a rachis 3.5 centimeters long, and the terminal leaflet has a petiole about 6 millimeters long. All the leaflets in this specimen are broken, but they must have been at least 5 centimeters long and about 2.5 centimeters wide. In the smaller specimen in which the leaflets are attached only about 5 millimeters of the rachis is preserved, and the petiole of the terminal leaflet is only about 2 millimeters long. These leaflets are much narrower than those in the other specimen, the terminal one being long, narrowly wedge-shaped at the base, and the lateral ones very much narrowed on the upper side. They must, however, belong to the same species as the larger one.

The numerous detached leaflets all appear to have been lateral ones, as they are strongly inequilateral. Several of them are hardly to be distinguished from the lateral leaflets in the larger specimen mentioned above.

Pistacia eriense is obviously related to and possibly identical with *P. hollicki*, described below. They come from the same locality and have many points in common, the principal difference being that the leaves of *P. eriense* are odd-pinnate and those of *P. hollicki* abruptly pinnate. This character, however, does not hold in the living species, as pointed out in the description of *P. hollicki*, but I have decided to keep them separate, provisionally, even on the slight grounds mentioned. There are also minor differences in size and nervation.

Occurrence: Laramie formation, Erie, Colo.

Pistacia hollicki Knowlton, n. sp.

Plate XXVIII, figures 5, 6.

Pistacia hollicki Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 460, 1919.

Leaves compound, abruptly pinnate; rachis slender; leaflets nearly sessile, oblong-lanceolate, entire, inequilateral on the upper side, slightly rounded or wedge-shaped at the base, abruptly acuminate at the apex; midrib of leaflets strong, secondaries numerous, 10 to 12 pairs, alternate, emerging at a low angle, craspedodrome, frequently forking near the margin, which they enter; tertiaries usually midway between the secondaries, slender, running halfway to the margin and disappearing or bending downward and each joining the secondary next below; nervilles rather strong, percurrent, running obliquely between the secondaries; finer nervation not retained.

This beautiful species is represented by three specimens and seven or eight leaflets, all well preserved. The larger example has the rachis preserved for 2.5 centimeters. The terminal leaflets are sessile and exactly opposite. They are very inequilateral, the upper side near the base being reduced quite to the midrib. They appear to have been about 3.5 centimeters long and are about 1.5 centimeters wide in the broadest part, which is above the middle. The lateral leaflet is 7 millimeters below the terminal ones and has a petiole scarcely 1 millimeter long. It is more nearly oblong-lanceolate and is 3.5 centimeters long and 13 millimeters wide. Like the terminal ones, it is inequilateral, but not to the same extent.

The other example figured has three leaflets preserved, but the point of their attachment can not be made out. They are shorter than those of other specimens, being only 3 centimeters long. They have the same nervation as the others.

It is with considerable certainty that these leaves are referred to the genus *Pistacia*, for in the manner of arrangement and shape of leaflets and nervation they approach closely certain living species of the genus. In the abruptly pinnate character of the leaves, as well as in the shape of the leaflets, they are similar to *P. lentiscus* Linné, a species of southern Europe. They approach more closely, however, some of the abruptly pinnate leaves of *P. mutica* Frick and Meyer, also from southern Europe. Most of the leaves of *P. mutica* are odd-pinnate, at least on the specimen preserved in the herbarium of the United States National Museum, yet now and then one is found which is abruptly pinnate. They have the same shape and arrangement as observed in the fossil. The nervation is also strikingly like that of the fossil species.

I have not been able to see the only American species of the genus—*P. mexicana* Humboldt, Bonpland, and Kunth, of Mexico and possibly southern Texas, but it is described as having a winged petiole and must differ considerably from the fossil under consideration.

A number of fossil species of *Pistacia* have been described, all of which differ more or less from *P. hollicki*. Thus, *P. bohemica* Ettingshausen,[37] from Bilin, has much the same shape but is twice as large and differs in nervation. Certain of the detached leaflets of *P. miocenica* Saporta,[38] from the "Bassin de Marseille," are very much like the lateral leaflets of *P. hollicki*, though broader and somewhat less inequilateral. The other described fossil species approach the living *P. lentiscus* Linné or *P. terebinthinus* Linné.

I have ventured to name this species in honor of Dr. Arthur Hollick, in partial recognition of his kindness in placing this material at my disposal.

Occurrence: Laramie formation, Erie, Colo., collected by N. L. Britton about 1885.

Family ILICACEAE.

Ilex laramiensis Knowlton, n. sp.

Plate XXIV, figures 4–7.

Ilex laramiensis Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 326, 1919.

Leaves coriaceous, oval, rounded at the base, acute at the apex, the margin provided with scattered, upward-pointing, spiny teeth; midrib rather slender; secondaries four or five pairs, alternate, open, camptodrome, arching some distance inside the margin and each joining the one next above, with branches from the outside entering the teeth; nervilles obscure but apparently percurrent.

These well-characterized leaves are broadly oval, 3.5 centimeters long and about 2 to 2.5 centimeters wide. The margin is remotely spiny-toothed above the lower third of the blade, the teeth pointing upward and separated by rounded sinuses. The camptodrome secondaries have outside branches entering the teeth, a well-known character of the genus *Ilex*.

There can be little or no question of the correctness of referring these leaves to *Ilex*. Among the several living species they undoubtedly approach most closely *I. opaca* Aiton, the well-known holly of the eastern United States. This living species differs in having the spiny teeth outward-pointing and in having more numerous secondaries. The camptodrome arrangement of the secondaries with the branches entering the teeth is very like the arrangement in the fossil under consideration.

Among fossil forms the present one has some resemblance to *Ilex quercifolia* Lesquereux,[39] from Florissant, Colo., which, however, differs in being obovate, with irregular teeth and more numerous secondaries, which enter the teeth directly.

Occurrence: Laramie formation, Erie, Colo., collected by N. L. Britton about 1885.

Order RHAMNALES.

Family RHAMNACEAE.

Ceanothus eriensis Knowlton, n. sp.

Plate XXVI, figures 3–6.

Ceanothus eriensis Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 151, 1919.

Leaves evidently thick and coriaceous, elliptical or broadly oval, rather abruptly rounded to the base and in about equal degree to the obtuse or abruptly acuminate apex; margin entire for lower third, then finely serrate; nervation craspedodrome, consisting of a strong, straight midrib and three or four pairs of strong, opposite or subopposite secondaries, the lower pair nearly as strong as the midrib and arising at or very near the base of the blade, each of the lower secondaries with three or four rather remote, occasionally forking branches on the lower side; the lower pair of secondaries, which arise at an angle of about 45°, pass upward for a little more than

[37] Die fossile Flora des Tertiärbeckens von Bilin: K. Akad. Wiss. Wien Denkschr., vol. 29, p. 49, pl. 50, fig. 25, 1869.

[38] Annales sci. nat., 5th ser., Botanique, vol. 9, p. 184, pl. 6, figs. 4–6, 1868.

[39] Lesquereux, Leo, The Cretaceous and Tertiary floras: U. S. Geol. Survey Terr. Rept., vol. 8, p. 186, pl. 38, figs. 2–5, 1883.

half the length of the blade and end in the margin, as do all the branches; upper pairs of secondaries dividing the blade into two or three approximately equal divisions, arising at a slightly more acute angle than the lower pair and terminating in the margin, the lower pair with one or two branches on the lower side; nervilles rather faint, percurrent, and at right angles to the midrib.

This species is represented by eight or ten more or less perfect examples, four of which have been figured. They range, so far as can be made out, from 4.5 to about 5.5 centimeters in length and from 3 to 4 centimeters in width. They are elliptical or broadly oval, with a rounded base and an apex which is similarly rounded to an abruptly acuminate point. Each specimen has three or four pairs of secondaries, the lowest of nearly the same size as the midrib and emerging at the top of the petiole and bearing three or four branches on the lower side, while the other secondaries are remote and simple or once or twice branched. The margin is finely serrate from a point one-third or more above the base.

There is considerable uncertainty as to the proper generic reference for these little leaves. They have, for example, the same size, shape, and superficial appearance as *Ficus planicostata* Lesquereux,[40] but they differ at once in the serrate margin and craspedodrome instead of camptodrome nervation. The broader forms have also some resemblance to *Cissus lobato-crenata* Lesquereux,[41] but that species differs in having an irregularly toothed margin and a different, looser nervation. *Morus italica* Massalongo,[42] from the Italian Tertiary, is very suggestive of this species but differs in being five instead of three ribbed from the base and in minor details of nervation. At one time it was thought that these specimens should be referred to *Viburnum,* as certain of the more rounded forms have the shape and much the nervation of *V. dichotomum* Lesquereux,[43] but that species differs in having more prominent teeth and a markedly flexuose midrib. Several of the broader forms approach *V. lakesii* Lesquereux [44] in the configuration of the base, but that species differs in being three-lobed and in having a different branching of the lower secondaries. Among living species of *Viburnum* this much resembles *V. dilatatum* Thunberg, from Japan, which has the shape and dentition but differs in having eight or more pairs of secondaries. From *V. dentatum* Linné it is also distinguished by much the same characters.

But, all things considered, it seems best to refer this form to *Ceanothus*, as it is, for instance, very similar to certain of the rounder-leaved forms of the living *C. americanus* Linné, and more especially to a form presumed to be a hybrid of this, known as *C. azureus*, cultivated in the parks at Washington, D. C. All the fossil leaves, however, appear to be more nearly elliptical than either of the above-mentioned forms. The marginal teeth are similar to those in the living species except that they do not occur on the lower third of the blade. This species differs from *C. azureus* in its larger size, more rounded form, serrate margin, and craspedodrome nervation.

Occurrence: Laramie formation, Erie, Colo., collected by N. L. Britton about 1885.

Ceanothus ovatifolius Knowlton, n. sp.

Plate XXV, figure 3.

Ceanothus ovatifolius Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 151, 1919.

Leaf cuneate-ovate, 3 centimeters long, 1.5 centimeters wide, long wedge-shaped at the base, rather abruptly acuminate at the apex; margin entire; nervation camptodrome, of about five pairs of opposite or subopposite secondaries, the lower pair arising from the very base just at the margin of the blade, thence running up for nearly two-thirds the length of the leaf and there joining the third pair of secondaries, which in turn arch to the pair next above, the whole forming a line just inside the border; finer nervation not preserved.

This leaf, which is the only one found in the collection, is referred with considerable certainty to the genus *Ceanothus*, being in shape quite like the living *C. ovatus* Desfontaines or *C. velutinus* Hooker and in nervation strik-

[40] Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, pl. 31, figs. 3, 4, 5, etc., 1878.
[41] Idem, pl. 41, fig. 3.
[42] Synopsis florae fossilis senogalliensis, pls. 10–11, fig. 10, 1859.
[43] Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, pl. 88, fig. 6, 1878.
[44] Idem, pl. 87, fig. 13, 1878.

ingly like certain of the leaves of *C. americana* Linné. In *C. americana* the lowest pair of secondaries arises at the extreme lower limit of the blade outside the parenchyma, and as they are of the same strength as the midrib the leaf appears triple-nerved. In the fossil leaf the lowest pair of secondaries arises in the same manner, but they are not quite so strong as the midrib, thus producing less of the triple-nerved appearance. This lower pair does not seem to be branched on the outside, as in the living *C. americana*, but the leaf is preserved on a coarse-grained sandstone; none of the finer nervation can be made out. The first pair of prominent secondaries above the base is about in the middle of the leaf.

Occurrence: Laramie formation, Mount Carbon, Morrison, Colo., sandstone near coal seam, collected by Arthur Lakes, June, 1890.

Rhamnus goldianus? Lesquereux.

Plate XVIII, figure 3.

Rhamnus goldianus Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 381, 1873; idem for 1873, p. 405, 1874; idem for 1876, p. 517, 1878; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 281, pl. 53, figs. 4–8, 1878.

The collection from the wooded bluff just south of the station at Marshall, Colo., contains the single fragmentary specimen here figured. It seems to be identical with some of the smaller leaves referred to *Rhamnus goldianus*, but the base and all the sides, except a minute portion, are lacking, and the identification can not be positive. It is a Denver species and has not before been reported from the Laramie.

Occurrence: Laramie formation, Marshall, Colo., wooded bluff just south of station and the highest point in the section, collected by A. C. Peale. Denver formation, Golden, Colo.

Rhamnus salicifolius Lesquereux.

Plate XV, figure 4; Plate XIX, figure 2b.

Rhamnus salicifolius Lesquereux, Am. Jour. Sci., 2d ser., vol. 46, p. 206, 1868; U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1869 [reprint, 1873], p. 196; idem for 1872, p. 400, 1873; idem for 1873, p. 382, 1874; idem for 1876, p. 517, 1878; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 282, pl. 53, figs. 9, 10, 1878.

Knowlton, U. S. Geol. Survey Bull. 163, p. 70, 1900.

This species was first named from specimens obtained in the Marshall coal mine, Boulder County, Colo. The type specimen is the original of figure 9, Plate LIII, of the "Tertiary flora" and is No. 446 of the United States National Museum collection, though unfortunately it can not be found at present. There is in its place another specimen with the same number which may have been the counterpart of the one figured, although, as it is very fragmentary, it is impossible to be certain of this. It is exactly like Lesquereux's figure 9 in its characters, at least so far as can be made out, and is preserved in the whitish sandstone characteristic of the locality.

The other figured type ("Tertiary flora," Pl. LIII, fig. 10) is said by Lesquereux to have come from Black Buttes, Wyo., where it was obtained by Meek,[45] but as the United States National Museum catalogue of fossil plants made up by Lesquereux does not record the species from Black Buttes, this is probably an error. As the original type of this figure can not be found among specimens of this species from any other locality, it must be ignored until it is found or is again collected from the locality mentioned.

The United States National Museum catalogue records a specimen from Golden, Colo., which is evidently the one referred to by Lesquereux in the Hayden report for 1872, page 382. It is No. 837a and is preserved on the same stone with *Salix integra* Göppert (No. 837). The matrix is a hard, fine-grained whitish sandstone, not unlike that from Marshall, and undoubtedly belongs to the true Laramie.

A specimen of *Rhammus salicifolius* is also recorded from the roof of a coal mine on Sand Creek, Colo. This example (No. 935) bears the imprint of two leaves which are much larger than the figured specimens, being 11 or 12 centimeters long and 4 or 5 centimeters wide, whereas the largest type as figured is 9.5 centimeters long and only 2 centimeters wide. It is possible that this should be referred to a new species.

The material from Cowan station contains several specimens that appear to belong to this species, especially the one shown in figure 4, Plate XV. This is indistinguishable from the type specimen (Lesquereux's fig. 9), from Marshall.

[45] U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 400, 1873.

There are several other leaves that have the same shape and nervation as those described above but are considerably larger. They are referred to *R. salicifolius*, though they may represent a closely related form.

Occurrence: Laramie formation, Marshall, Boulder County, Colo. (type); Cowan station, 10 miles south of Denver, Colo., collected by F. H. Knowlton; cut on Moffat railroad (Denver & Salt Lake), collected by A. C. Peale, 1908. Dawson arkose, Templeton Gap, 4 miles northeast of Colorado Springs, Colo., collected by A. C. Peale; 1908. Vermejo formation, Canon City field (Rockvale), Colo., collected by George Hadden; 2 miles west of Trinidad, Colo., collected by G. B. Richardson. Mesaverde formation, near Harper Station, Wyo.; near the Van Dyke coal, Rock Springs, Wyo., collected by F. H. Knowlton and T. W. Stanton, 1896.

Rhamnus minutus Knowlton, n. sp.

Plate XVII, figure 2.

Rhamnus minutus Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 548, 1919.

Leaf very small (2 centimeters long, 6 millimeters wide) but of firm, perhaps coriaceous texture, lanceolate, rather wedge-shaped at the base, and obtusely acuminate at the apex; margin entire but slightly undulate; nervation strong, consisting of a very thick midrib and six pairs of alternate secondaries, which are considerably curved upward and apparently enter the margin; nervilles fairly numerous, unbroken, and approximately at right angles to the secondaries.

The nearly perfect little leaf figured is the only one observed. It appears to be most closely related to *Rhamnus salicifolius* Lesquereux and may, indeed, be only a small leaf of that species. The slightly undulate margin and the nervilles at right angles instead of oblique to the secondaries are apparent differences.

Occurrence: Laramie formation, Erie, Colo.

Rhamnus marshallensis Knowlton, n. sp.

Plate XV, figure 3.

Rhamnus marshallensis Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 547, 1919.

Leaf small, linear-lanceolate, rounded and obtuse at the base (apex not seen); margin entire; midrib very strong, straight; secondaries numerous, probably about 12 pairs, close, parallel, little curved upward, just reaching the border; nervilles numerous, mainly unbroken, approximately at right angles to the midrib.

The little leaf figured is all that was observed of this form. It was probably about 5 centimeters long and is evenly 1 centimeter wide nearly throughout.

This species appears to be most closely related to *Rhamnus salicifolius* Lesquereux, from which it differs in its smaller size, rounded instead of wedge-shaped base, and more numerous secondaries.

Occurrence: Laramie formation, wooded bluff south of Marshall, Colo., collected by A. C. Peale, 1908.

Rhamnus belmontensis Knowlton and Cockerell.

Rhamnus belmontensis Knowlton and Cockerell, U. S. Geol. Survey Bull. 696, p. 544, 1919.

Rhamnus elegans Newberry, New York Lyc. Nat. Hist. Annals, vol. 9, p. 49, 1868; U. S. Geol. Survey Mon. 35, p. 117, pl. 50, fig. 2, 1989.

This fine species has been well described and figured by Newberry. At the time it was named (1868) it was said to have come from "Miocene sandstone, Belmont, Colo.," a statement which reflects the opinion current at the time that all the coal of the West was of Tertiary age. When it was figured in 1898, however, it was said to be from the "Cretaceous (Laramie group), Belmont, Colo.," a statement which again reflects the opinion of the time. A question arose as to the exact location of "Belmont, Colo." No town of this name could be located on any available map of the State, and it was suggested by Prof. Junius Henderson, of Boulder, Colo., to whom an appeal was made, that it might possibly be a corruption of "Valmont," where the Laramie is present. Quite by accident it was discovered that Belmont was the older name for Marshall, as shown by the following quotation from Hayden's discussion of the region:[46] "In the Boulder Valley the Tertiary coal beds are enormously developed. The Belmont or Marshall's coal and iron mines, on South Boulder Creek * * *." This species has not been detected in any of the recent collections from Marshall or elsewhere in the

[46] U. S. Geol. and Geog. Survey Terr. Third Ann. Rept. (reprint, 1873), p. 129.

Laramie. It rather closely resembles *Rhamnus? williardi* Knowlton,[47] from the Fox Hills sandstone of the Greeley quadrangle, Colo. That species is a little smaller and not quite so truncate at the base, but in nervation there appears comparatively little difference. The type specimen of *R. belmontensis*, however, which is preserved in the United States National Museum (No. 10958), presents an entirely different aspect. The nervation is very thin and delicate, and the nervilles are made out with much difficulty. Notwithstanding the agreement between the leaves in outline, disposition of nervation, etc., it is impossible to believe that the two could belong to the same species.

Occurrence: Laramie formation, Marshall (formerly Belmont), Colo.

Rhamnus brittoni Knowlton, n. sp.

Plate XV, figure 6; Plate XXIV, figure 8.

Rhamnus brittoni Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 544, 1919.

Leaves rather stiff and evidently coriaceous, lanceolate, 8 or 10 centimeters long, 3 or 4 centimeters wide, apparently obtusely wedge-shaped at the base, long-pointed and sharply acuminate at the apex, broadest about one-third the length of the blade above the base; margin entire; midrib moderately strong, perfectly straight; secondaries relatively strong, numerous (about 14 pairs), close, parallel, at an angle of about 50°, very little curved upward, ending in the margin; nervilles very numerous, close, parallel, mainly unbroken, oblique to the secondaries.

The nearest relative of this species appears to be *Rhamnus elegans* Newberry[48] (now *R. belmontensis*), from the Laramie at Belmont, now Marshall, Colo., with which it agrees closely in size and shape but differs in the more numerous close, parallel secondaries, which are but little curved upward. The nervilles are much the same in both.

This species is also related to *Rhamnus salicifolius* Lesquereux[49] but is much broader and has more numerous secondaries, which are at a lower angle of divergence with the midrib; the nervilles are about the same in both.

[47] Knowlton, F. H., The flora of the Fox Hills sandstone: U. S. Geol. Survey Prof. Paper 98, p. 91, pl. 16, figs. 1, 2, pl. 17, figs. 1-4, 1916.

[48] Newberry, J. S., U. S. Geol. Survey Mon. 35, p. 117, pl. 50, fig. 2, 1898.

[49] Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 282, pl. 53, figs. 9, 10, 1878.

Occurrence: Laramie formation, Erie, Colo., collected by N. L. Britton, in whose honor the species is named.

Rhamnus? pealei Knowlton, n. sp.

Plate XV, figure 7.

Rhamnus? pealei Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 548, 1919.

Leaf evidently rather thick, ovate-elliptical, unequal sided, base truncate on one side, wedge-shaped on the other, apex obtusely acuminate; margin apparently entire; midrib relatively very thick; secondaries 10 or 12 pairs, alternate, strong, nearly at right angles near the base on one side, others gradually at a more acute angle, camptodrome; nervilles numerous and prominent, mainly broken and oblique to the secondaries.

In the specimen figured nearly all of the margin is lacking, but so far as can be made out it was perfectly entire. This leaf is 7 centimeters long and a little over 3 centimeters broad; it is very regular in size from the unequal-sided base to about the upper fourth of its length, where it narrows to the rather obtusely pointed apex.

Occurrence: Laramie formation, cut on Moffat railroad (Denver & Salt Lake) about 6 or 8 miles north of Golden, Colo., collected by A. C. Peale, for whom it is named.

Rhamnus sp.

Plate XVII, figure 1.

In the material from Popes Bluffs, near Pikeview, Colo., was found the single fragmentary leaf here figured. It was apparently about 4 centimeters long and 2 centimeters wide, with entire margin and a rather abruptly rounded and obtuse apex; the base is destroyed. It has a very thick midrib and at least 10 pairs of light camptodrome secondaries. The most marked feature of this little leaf consists of the nervilles, which are very numerous, mainly forked or broken, and oblique to the secondaries.

This leaf is at once suggestive of either *Rhamnus cleburni* Lesquereux or *Rhamnus goldianus* Lesquereux, both well-known Denver species, but it is smaller than either, though approaching *R. goldianus* most closely. In the nervation, except for size, it is not different from either of these species.

Rhamnus cleburni was reported by Lesquereux [50] from the Laramie at the old Franceville mine, near Colorado Springs, but it is not found in the recent collections from that place. The present leaf from Popes Bluffs is hardly one-fourth the size of the ordinary leaves of this species and, moreover, differs in shape, being narrower. The absence of the basal portion makes it impossible to decide whether to assign this leaf to *Rhamnus cleburni* or to *Rhamnus goldianus*, and the most that can be said is that the present specimen is of the same type as these species. Its smaller size and narrower outline suggest that it probably is neither of these species, though obviously allied.

Occurrence: Laramie formation, Popes Bluffs, west of Pikeview, Colo. (sec. 14, T. 13 S., R. 67 W.), collected by A. C. Peale and M. I. Goldman, 1908.

Paliurus zizyphoides Lesquereux?

Paliurus zizyphoides Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 397, 1873; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 274, pl. 51, figs. 1–6, 1878.

This form was established on material from Black Buttes, Wyo., a part of which, at least, is still in the collections of the United States National Museum (cf. No. 416a). In the same connection Lesquereux wrote as follows: "The same species, represented by a smaller leaf, has been found at Erie." The Museum collection does not contain a specimen from Erie, nor has this form been noted in any of the recent collections from that place, and it is consequently questioned as a Laramie species.

Occurrence: Post-Laramie (in my opinion), Black Buttes, Wyo. (types). Laramie formation(?), Erie, Colo.

Zizyphus coloradensis Knowlton, n. sp.

Plate XV, figure 5.

Zizyphus coloradensis Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 660, 1919.

Leaf apparently rather thin in texture, elliptical or slightly ovate-elliptical, obtusely wedge-shaped at the base, apparently about the same shape at the apex; margin entire below, possibly slightly toothed above; five-ribbed, the central or midrib stronger than the others, apparently with two or three secondaries high in the upper part; inner pair of ribs nearly as strong as the midrib, passing up well toward the apex of the blade; lower or outside ribs slender, possibly arising from the basal portion of the inner ribs, not reaching for more than half the length of the blade; all finer nervation effaced.

Only a single specimen of this form has been found, and this has lost much of the apical portion. It was presumably about 6 centimeters long and 2.5 centimeters wide. It is preserved on a very soft sandstone, and not many of the details of nervation can be made out except the ribs.

This species may be only a small, narrow leaf of *Zizyphus hendersoni*, but it appears to be a thinner leaf and is possibly toothed in the upper portion. It has also some resemblance to *Zizyphus cinnamomoides* Lesquereux,[51] from the Green River formation, but the latter is smaller, strongly toothed nearly to the base, and only three-ribbed.

Occurrence: Laramie formation, Popes Bluffs, west of Pikeview, Colo. (sec. 14, T. 13 S., R. 67 W.,) collected by A. C. Peale and M. I. Goldman, 1908.

Zizyphus hendersoni Knowlton, n. sp.

Plate XV, figures 1, 2.

Zizyphus hendersoni Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 660, 1919.

Leaf evidently firm in texture, ovate or ovate-elliptical, rather abruptly rounded to the slightly wedge-shaped base; apex not well preserved but apparently rather obtuse; margin perfectly entire; petiole stout, at least 1 centimeter long; three-ribbed, or in effect five-ribbed, the petiole splitting into approximately three branches or ribs, and just as they leave the wedge-shaped basal portion of the blade each of the lateral ones gives rise to a strong secondary branch which simulates a rib, the five about equally dividing the area of the blade; middle rib straight, with several secondary branches in the upper part; next pair of ribs about as strong as the midrib, ascending well toward the apex of the blade, each with

[50] Lesquereux, Leo, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1873, p. 203, 1874.

[51] Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 277, pl. 52, figs. 7, 8, 1878.

several secondary branches on the outside; lower or outer pair of ribs slightly more slender than the others, passing up for nearly or quite half the length of the blade, each with five or six secondary branches on the outside which arch forward and disappear just inside the margin; nervilles numerous, strong, mainly unbroken, and at right angles to the ribs or secondaries.

This form is represented by a number of examples, of which the two best preserved are here figured. The specimen that is most nearly perfect in outline is shown in figure 2. It is about 9 centimeters long and 5.5 centimeters wide. The nervation shows only the ribs and some of the secondaries, the nervilles being obscure or effaced. The other specimen (fig. 1) comprises only the base of a leaf of about the same size as the one seen in figure 2, but the nervation is much better preserved. The origin of the outer pair of ribs is very well shown in this specimen—that is, they are seen to arise as branches from the inner pair of ribs, thus being virtually secondaries. Each gives rise to some five or six branches on the outside. The nervilles and their disposition are well shown in the figure.

This fine species most closely resembles *Zizyphus fibrillosus* (Lesquereux) Lesquereux,[52] a species well known in the Denver and Raton formations. From this it differs essentially in having the base distinctly wedge-shaped instead of truncate or heart-shaped. The manner in which the principal ribs arise is the same in both species—that is, they are essentially three-ribbed with the lateral and basal secondaries arising just above the base and by their strength simulating ribs. The nervilles in the present species are similar to those in *Zizyphus fibrillosus* except that they are neither so numerous nor so regular.

I take pleasure in naming this species in honor of Judge Junius Henderson, curator of the museum of the University of Colorado, Boulder, Colo.

Occurrence: Laramie formation, in cut in clay beds about 1½ miles south of Golden, Colo., collected by A. C. Peale, 1908; Cowan station, 10 miles south of Denver, Colo., collected by F. H. Knowlton.

[52] Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 276, pl. 52, figs. 1-6, 1878.

Zizyphus corrugatus Knowlton, n. sp.

Plate XVII, figure 3.

Zizyphus corrugatus Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 660, 1919.

Leaf apparently rather thick in texture, ovate, with abruptly rounded, truncate or slightly cordate base and obtusely pointed apex; seven-ribbed from the top of the petiole, the midrib strong, straight, with two pairs of alternate secondary branches in the upper part; next pair of ribs at an angle of about 80°, passing to the upper margin, each with three or four secondary branches on the outside; next outer pair of ribs at an angle of about 60°, reaching the margin below the middle of the blade, each with two or three secondary branches on the outside; lower pair of ribs at an angle of about 30°, apparently without secondary branches; nervilles thin, few, usually unbroken.

The leaf figured, which is nearly perfect, is about 8.5 centimeters long and about 5 centimeters wide and is very well characterized. This form is in some ways more closely related to *Zizyphus fibrillosus* Lesquereux [53] than *Zizyphus hendersoni*, the form just described. It differs, however, in being more broadly ovate, in having the ribs nearly or quite straight instead of curved, and above all in the character of the nervilles which is much the same in both and is wholly unlike that of *Zizyphus bfirillosus*.

Occurrence: Laramie formation, Cowan station, 10 miles south of Denver, Colo., collected by F. H. Knowlton.

Zizyphus minutus Knowlton, n. sp.

Plate XVIII, figure 1.

Zizyphus minutus Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 661, 1919.

Leaf of small size, probably about 3.5 centimeters in length and 8 millimeters in width, apparently coriaceous, linear-lanceolate, narrowly wedge-shaped at the base (apex destroyed); three-ribbed from the extreme base of the blade, the ribs nearly equal in strength, the lateral ones passing well up to the apex; all finer nervation obscure or effaced.

Although this species is based on a single specimen, which lacks all of the apical portion,

[53] Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 276, pl. 52, figs. 1-6, 1878.

it is obviously so distinct from anything else in these collections that it merits description. It is very unlike either of the other Laramie forms referred to *Zizyphus*—in fact, it belongs to quite a different section of the genus. It is, however, so well characterized, though it is fragmentary, that there should be no trouble in its subsequent recognition.

Occurrence: Laramie formation, railroad cut between old and new stations, Marshall, Colo., collected by A. C. Peale, 1908.

Order MALVALES.

Family TILIACEAE?

Apeibopsis? laramiensis Knowlton, n. sp.

Plate VII, figure 4.

Apeibopsis? laramiensis Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 80, 1919.

Leaf evidently membranaceous, broadly ovate, at least 8 centimeters in length and 5.5 centimeters in width, abruptly rounded and truncate at the base, apex destroyed but apparently obtusely pointed; margin perfectly entire; petiole 3.5 centimeters long, slender; midrib straight, rather strong; secondaries about 15 pairs, mostly opposite or subopposite, thin, at an angle of 20° or 30°, close, parallel, very little curved upward, disappearing just before reaching the margin; finer nervation obsolete.

This species appears to be most closely related to *Apeibopsis? discolor* (Lesquereux) Lesquereux,[54] from Black Buttes, Wyo., but it differs in its more truncate base, thinner nervation, and more numerous secondaries.

The generic reference of both these species is more or less questionable, as Lesquereux pointed out when discussing his species, but they are apparently congeneric and may remain for the present with the question mark to indicate this doubt.

Occurrence: Laramie formation, Leyden Gulch, about 6½ miles north of Golden, Colo., collected by A. C. Peale.

Order UMBELLALES.

Family CORNACEÆ.

Cornus suborbifera Lesquereux.

Plate XIV, figures 2, 2a (type).

Cornus suborbifera Lesquereux, Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 243, pl. 42, figs. 2, 2a, 1878; U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1876, p. 512, 1878. [Lesquereux's figure of the type is here reproduced.]

Cornus orbifera Heer. Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1873, p. 402, 1874; idem for 1876, p. 512, 1878.

The type specimen of this species was found in the United States National Museum collections (No. 353) under the name *Cornus orbifera* Heer, with which it was at first identified. Lesquereux explains, however, in the "Tertiary flora," page 243, that on the advice of Saporta he decided to give it a new name, although he found difficulty in distinguishing it from the European species. The type of *Cornus suborbifera* is very imperfect and hardly admits of close comparison.

This species is apparently related to *Cornus impressa* Lesquereux, from the Denver formation of Golden, Colo., but appears to differ essentially in the secondaries emerging at a much more open angle.

Occurrence: Laramie formation, Golden, Colo., in the white sandstone.

Cornus praeimpressa Knowlton, n. sp.

Plate XIV, figure 5; Plate XIX, figure 2a.

Cornus praeimpressa Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 195, 1919.

Leaf evidently firm in texture, elliptical, apparently rounded or perhaps truncate at the base and abruptly rounded at the apex to a short obtuse point; length about 8 centimeters and width 5 centimeters; midrib very thick, especially below, perfectly straight; secondaries about 10 pairs, mainly alternate, at an angle of about 50°, slightly curved upward, camptodrome, arching just inside the margin; nervilles numerous, strong, mainly unbroken, at nearly right angles with the secondaries; finer nervation obsolete.

This form is based on the single example from Cowan station here figured. It is very well characterized by its regular elliptical outline, very thick midrib, relatively thin secondaries, and nervilles at nearly right angles to the secondaries.

This species, as its name implies, is most closely related to *Cornus impressa* Lesquereux,[55] the type of which came from Mount Bross, Middle Park, Colo., where it was found in beds believed to be of Denver age. So far as known

[54] Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 259, pl. 46, figs. 4-7, 1878.

[55] Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 343, pl. 43, fig. 3, 1878.

only two additional examples of *Cornus impressa* have been collected. These are a broken individual from the andesitic beds at Golden, Colo., and the leaf from the ravine opposite St. Luke's Hospital in Denver, which was described by Ward [56] as *Cornus emmonsii.*

The other leaf described and figured by Ward [57] under the name *Cornus emmonsii* came from beds known to be of Montana age at Point of Rocks, Wyo. In my "Flora of the Montana formation" [58] this specimen was also referred to *Cornus impressa* on the basis of the figure of it given by Ward, but the specimen itself was not then available. This figure will be seen to agree very closely with that of *Cornus impressa*, though much of the essential part of it has been entirely misinterpreted and incorrectly drawn. The margin throughout and the distal terminations of the secondaries are exceedingly obscure. Several of the secondaries seem to enter the margin, but in one place it is possible to demonstrate with considerable certainty that they are camptodrome and arch just within the margin; hence it is probable that all do this. But the apex is entirely wrong in the figure. The point at which it is there made to curve inward is clearly a break, and it was undoubtedly prolonged for a distance of probably 3 or 4 centimeters beyond the point where it is now made to terminate. This is shown by the undiminished thickness of the midrib at the broken upper margin of the blade, as well as by the upper pairs of secondaries, which do not arch but clearly pass beyond the broken margin. This leaf was undoubtedly ovate-acuminate, instead of elliptical-oblong, and is in all probability a small leaf of what has with some hesitation been called *Cornus studeri.* In any event it can not possibly be the same as *Cornus impressa,* and I doubt whether it should be given specific rank.

Among the specimens from the cut on the Moffat railroad (Denver & Salt Lake) near the Leyden mine is a piece of matrix bearing a small leaf of this species and a broken leaf of *Rhamnus salicifolius.* It is only about 5 centimeters long and 2.5 centimeters wide but does not otherwise differ essentially from the larger example figured.

[56] U. S. Geol. Survey Sixth Ann. Rept., p. 553, pl. 48, fig. 2, 1886; U. S. Geol. Survey Bull. 37, p. 55, pl. 26, fig. 2, 1887

[57] Op. cit. (Sixth Ann. Rept.), pl. 48, fig. 3.

[58] U. S. Geol. Survey Bull. 163, p. 68, 1900.

Occurrence: Laramie formation, Cowan station, 10 miles south of Denver, Colo., collected by F. H. Knowlton; cut on Moffat railroad (Denver & Salt Lake), collected by A. C. Peale, 1908.

Cornus sp.

Plate XIV, figure 4.

Leaf of firm texture, elliptical or perhaps elliptical-obovate; margin entire; nervation pinnate, the midrib strong, straight; secondaries about six or seven pairs, at an angle of about 45°, alternate below, subopposite above, camptodrome, arching just inside the border, the upper ones much curved inward and probably reaching the midrib.

The specimen here figured is the only one obtained, and this is fragmentary, lacking all of the base and one side and the extreme tip. It was about 8 centimeters long and a little over 5 centimeters wide. It is very obtuse and rounded above and was probably abruptly rounded below.

This form is of the same type as *Cornus suborbifera* Lesquereux and *Cornus praeimpressa* Knowlton, just described, but differs in its fewer secondaries at a more acute angle.

Occurrence: Laramie formation, Cowan station, 10 miles south of Denver, Colo., collected by F. H. Knowlton.

Family ARALIACEAE.

Hedera lucens Knowlton, n. sp.

Plate IX, figure 1.

Hedera lucens Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 315, 1919.

Leaves small, thick, evidently smooth and polished on the upper surface, deltoid-ovate, truncate and square-cut across the base, obtusely acuminate at the apex; margin entire; petiole thin, evidently short; midrib thin, straight; secondaries about five or six pairs, very thin and delicate, camptodrome; finer nervation obsolete.

This fine little species is represented by two leaves preserved side by side on the same piece of matrix. One is absolutely perfect; the other is somewhat fragmentary but shows well the nervation. The perfect example is 3 centimeters long and 2.3 centimeters wide, and, so far as can be made out, the other was of similar dimensions.

Occurrence: Laramie formation, Erie, Colo.

Order EBENALES.

Family EBENACEAE.

Diospyros berryana Knowlton, n. sp.

Plate XVII, figure 5.

Diospyros berryana Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 237, 1919.

Leaf apparently of medium thickness, broadly lanceolate, broadest near or just below the middle, whence it tapers gradually to the wedge-shaped base and presumably to an acuminate apex, but this portion of the leaf is destroyed; margin entire; petiole apparently rather slender; midrib slender; secondaries about 10 pairs, mainly alternate, thin, arising at angles of 30° to 45° with the midrib arching and joining well below the margin and with a series of large loops outside; nervilles numerous, relatively strong, very irregular and broken, the finer nervation forming irregular quadrangular areas.

The leaf figured was certainly not less than 10 centimeters and may have been as much as 11 centimeters long. It is a little less than 5 centimeters wide. The petiole, which appears to be rather slender, was at least 1 centimeter long.

In size and shape of leaf, as well as in the essentials of nervation, this form is apparently congeneric with the common persimmon (*Diospyros virginiana*) but differs in specific details. It is also congeneric with a species described as *Diospyros copeana* Lesquereux,[59] from Elko, Nev., but differs in its larger size, more pointed apex, and fewer secondaries.

Occurrence: Laramie formation, 2 miles east of Lafayette, Colo., collected by F. H. Knowlton, 1908.

Order GENTIANALES.

Family OLEACEAE?

Fraxinus? princetoniana Knowlton, n. sp.

Plate XXII, figure 7.

Leaf long, lanceolate, acuminate at the apex (base destroyed); margin entire or slightly undulate in the middle portion, sparsely toothed above; midrib slender, straight; secondaries 10 or 11 pairs, opposite or occasionally subopposite, emerging at an angle of 40° or 45°, curving slightly upward in passing to the border, along which they appear to curve; nervilles percurrent, close, parallel, mainly at right angles to the secondaries; finer nervation obsolete.

This form is represented by the single example figured, which unfortunately is very fragmentary, lacking the base and both margins for half the distance above the base. The apex is also split and more or less distorted, and altogether its status is unsatisfactory. I have looked carefully for some known species to which this can be referred, but as none has been found it is necessarily regarded as new. It by no means certainly belongs to the genus *Fraxinus*, but as it appears to resemble certain forms placed in this genus, it has been provisionally so referred.

This specimen was furnished by Prof. William Libbey, jr., of Princeton University.

Occurrence: Laramie formation(?), Sandstone Ridge, east of South Table Mountain, Golden, Colo.

Family APOCYNACEAE.

Apocynophyllum? taenifolium Knowlton, n. sp.

Plate XVI, figure 2.

Apocynophyllum? taenifolium Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 81, 1919.

Leaf of firm texture, linear-lanceolate, being about 13 centimeters in length and 2 centimeters in width; it is abruptly rounded to the obtuse base (apex destroyed); petiole very thick, apparently short; margin entire; midrib very thick below but thin above, straight; secondaries few, eight or nine pairs, alternate, thin, regular, emerging at an angle of about 45°, considerably curved upward, camptodrome; finer nervation not retained.

This form, represented only by the fragment shown in the figure, is too imperfect to be regarded as adequately characterized, and consequently the generic reference has been questioned. It was a long, narrow leaf that was rather abruptly rounded at the base and presumably acuminate at the apex. It is not closely similar to any other form found in these beds.

Among the several species of *Apocynophyllum* described from this country may be mentioned *Apocynophyllum sordidum* Lesquereux,[60] from the Dakota sandstone of Kansas. That species,

[59] Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 232, pl. 40, fig. 11, 1878.

[60] Lesquereux, Leo, Flora of the Dakota group: U. S. Geol. Survey Mon. 17, p. 109, pl. 64, fig. 11, 1892.

however, is a smaller leaf, is distinctly ovate-lanceolate, and has numerous secondaries. The form here described is of about the same size and shape as *Apocynophyllum wilcoxensis* Berry,[61] from the Raton formation of southern Colorado, but differs in having fewer and more curved secondaries.

Occurrence: Laramie formation, Leyden Gulch, 6 or 8 miles north of Golden, Colo., collected by A. C. Peale, 1908.

Order POLEMONIALES.

Family BIGNONIACEAE.

Dombeyopsis obtusa Lesquereux.

Plate XIII, figure 4; Plate XX, figure 11; Plate XXVII, figures 1–4.

Dombeyopsis obtusa Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 375, 1873; idem for 1873, p. 382, 1874; idem for 1876, p. 514, 1878; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 255, pl. 47, figs. 4, 5, 1878.

Leaves subcoriaceous, entire, round oval, obtuse, cordate; nervation three-palmate.—Lesquereux.

This species was first described from a specimen found in Gehrung's coal bed, near Colorado Springs, Colo., but the specimen does not appear to belong to the United States National Museum unless, to judge from the description, it is the specimen figured as one of the types,[62] which is recorded in the Museum catalogue as coming from Golden, Colo. It is probable, however, that the original is not now preserved, for the specimen above mentioned agrees in character with others known to be from Golden.

The two figured types are preserved in the United States National Museum (Nos. 380, 381) and if they are correctly labeled, both came from the lower or true Laramie at Golden. The collection also contains another example from the same locality.

There is a single very fine example of this species (No. 281d) from the upper or Denver beds at Golden. It was only partly exposed, but by removal of the matrix the whole of a large and very perfect leaf was revealed. This agrees in shape with *Dombeyopsis obtusa* and in nervation rather more closely with *Dombeyopsis platanoides*, all of which goes to show that these species are very closely allied.

In the material from Coal Creek, Boulder County, Colo., I find three specimens which clearly belong to this species. All are more nearly perfect than Lesquereux's types, and two, shown in Plate XXVII, figures 1, 2, are preserved nearly entire. The smaller of these two specimens lacks only a small portion of the base, and the larger a portion of the side and apex. In figure — the two lateral thick ribs are parallel with the midrib for at least two-thirds of the upper portion, as in Lesquereux's figure 5. The other specimen figured has the base as in his figure 5, while the ribs are slightly more divergent than in his figure 4. The unfigured example is almost the exact counterpart of Lesquereux's figure 4, thus connecting them all with his species.

As stated above, the type of *Dombeyopsis obtusa* appears to have come from the true Laramie near Colorado Springs, Colo., and the finding of these specimens is a satisfactory confirmation of the horizon of which they are characteristic.

The collections made by Lakes at the Douglas coal mine, Sedalia, Colo., embrace three or four rather fragmentary specimens that appear to belong also to this species. They represent only basal portions of the leaves, for it seems to be the unfortunate circumstance that leaves of this type are as a rule poorly preserved. So far as I am able to determine there is no distinction to be drawn between them and the types of *Dombeyopsis obtusa*, and they are so referred.

In figures 3 and 4 of Plate XXVII are shown specimens from Marshall's coal mine, near Golden, Colo., that appear indistinguishable from the leaves from Coal Creek shown in figures 1 and 2, the only difference being the further splitting of the petiole, or rather the origin of the three ribs at a lower point than in the other. As a result of this lower origin of the ribs the basal portion of the lamina is slightly more decurrent, but otherwise in shape and nervation these leaves are certainly identical.

Several fragmentary examples, which are indistinguishable from Lesquereux's figured types are present in the small collection from Crow Creek, Colo.

[61] Berry, E. W., U. S. Geol. Survey Prof. Paper 91, p. 342, pl. 103, figs. 2, 3; pl. 108, fig. 4, 1916. Knowlton, F. H., U. S. Geol. Survey Prof. Paper 101, p. 345, pl. 103, fig. 3; pl. 105, figs. 1, 2; pl. 106, fig. 1, 1918.

[62] Lesquereux, Leo, op. cit. (Tertiary flora), pl. 47, fig. 4.

Occurrence: Laramie formation, Gehrung's coal mine, near Colorado Springs, Colo. (type); Coal Creek, Colo.; Marshall's coal mine, at Marshall, Colo.; Hoyt's coal mine, 1 mile south of Golden, Colo.; and Crow Creek, 25 miles northeast of Greeley, Colo. Denver formation, 3,000 feet east of Douglas coal mine, Sedalia, Colo. Dawson arkose, Pulpit Rock, near Colorado Springs, Colo.

Dombeyopsis trivialis Lesquereux.

Plate XIII, figure 3; Plate XIV, figure 3.

Dombeyopsis trivialis Lesquereux, U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1872, p. 380, 1873; idem for 1873, pp. 382, 404, 1874; idem for 1876, p. 514, 1878; Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 255, pl. 47, fig. 3, 1878. [Lesquereux's original figure is here reproduced as Pl. XIII, fig. 3.]

The type specimen of this species is preserved in the collections of the United States National Museum (No. 379) and is found on the hard white sandstone characteristic of the Laramie at Golden, Colo. The species has not been detected in any of the subsequent collections from this locality, but in the material from a locality north of Colorado Springs there occurs the fragment shown in Plate XIV, figure 3, which appears referable to this species. Although only a fragment of the basal portion of one side, it appears to agree with the type in essential details. It is, for instance, deeply heart-shaped at the base, with several large lobes on the margin. The nervation consists of three principal ribs, with a lighter basal pair which makes it in effect five-ribbed. Branches from lateral strong ribs pass to the marginal lobes, and probably the basal pair of ribs also terminated in more or less pronounced lobes.

Dombeyopsis trivialis is undoubtedly closely related to *D. platanoides* Lesquereux,[63] from which it differs, according to Lesquereux, in being smaller, in having the nervation less deeply marked, with all the nerves thinner and with the secondaries placed in the upper part of the leaf at a great distance above the base. The two lower veinlets coming from the top of the petiole indicate a tendency for the leaf to become five-ribbed. Whether these are characters of sufficient weight to separate these two forms must remain for more complete material to settle.

The present species is also like *Dombeyopsis obtusa* Lesquereux [64] in general shape and nervation but differs in having the margin lobed instead of entire. It is possible that when a sufficient amount of material can be obtained it may show that all three forms are referable to a single species, but for the present they must be kept apart.

Occurrence: Laramie formation; Golden, Colo. (type), collector not known but probably F. V. Hayden; opposite sand-lime brick works about 4 miles north of Colorado Springs, Colo., collected by A. C. Peale and G. I. Finlay, 1908.

Dombeyopsis? sinuata Knowlton, n. sp.

Plate XXV, figures 1, 2.

Dombeyopsis? sinuata Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 243, 1919.

Leaf evidently thin and membranaceous, apparently broadly ovate, well rounded to a slightly cordate base and probably a rather obtuse apex; margin undulate-sinuate; midrib very thick, especially below, provided above with several pairs of thin, alternate, remote secondaries that fork and send branches to the marginal undulations; just above the base of the blade there is a pair of opposite, strong ribs that arise at an angle of about 45° and pass up for more than half the length of the blade, each with five or six rather strong secondary branches that are at right angles to the midrib and apparently end in the marginal teeth; below the large ribs is a pair of thin ribs that bear thin secondary branches on the lower side; finer nervation can not be satisfactorily made out.

The example shown in figure 1 is in a poor state of preservation, being folded around the rock on which it is imprinted and more or less effaced by rubbing. As nearly as can be made out it is broadly ovate, about 15 centimeters long and nearly 12 centimeters wide. It is in effect five-ribbed; the midrib is very thick and strong, as are a pair of ribs which arise at an angle of 45° some distance above the base and pass up for apparently more than half the length of the blade. Below this pair of strong ribs is a second pair of much more slender ribs which arise at nearly a right

63 Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, pl. 47, figs. 1, 2, 1878.

64 Idem, pl. 47, figs. 5, 6.

angle and are provided with secondary branches on the lower side. The margin of the blade seems to be entire for a short distance above the base, then strongly undulate-sinuate. The nervation all appears to be craspedodrome, ending in the large marginal teeth.

The poor state of preservation makes it difficult properly to place this leaf, but on the whole it appears to be most like the several species of *Dombeyopsis* figured by Lesquereux, and I have provisionally referred it to that genus. It is larger than even the largest leaf figured by Lesquereux and differs in being quasi five-ribbed and in having a looser, more forked nervation. It is perhaps closest to *Dombeyopsis platanoides* Lesquereux,[65] from the Bozeman coal field, Mont., but has a much more sinuate-toothed margin and a different nervation.

A specimen has been found among the Coal Creek material which seems to belong with this species. This specimen is much broken but was evidently a leaf of large size. It is more deeply heart-shaped than the first and has an enormously thick midrib and lateral ribs. Except as regards size it has exactly the same character of nervation as the type, including the secondary ribs at right angles to the midrib and below the strong lateral ribs; the nervilles are also the same.

I am in doubt as to the correctness of referring these leaves to *Dombeyopsis*, but they may perhaps remain here until more nearly perfect examples are forthcoming.

Occurrence: Laramie formation, Coal Creek, Boulder County, Colo. (type).

Dombeyopsis ovata Knowlton, n. sp.

Plate XXIV, figures 1–3, 9.

Dombeyopsis ovata Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 243, 1919.

Leaves rather membranaceous, ovate in general outline, rounded and truncate or very slightly heart-shaped at the base, rounded above into a very small acuminate point; margin entire below, then undulate or provided with two or three low, rounded lobes which are separated by shallow rounded sinuses; triple-nerved from the base of the blade, the central or midrib slightly the stronger, nearly straight, provided above with about six or seven pairs of strong, very irregular, remote, and alternate secondaries, of which the lower one is often forked; the secondaries curving very near the margin and each joining the one next above or running along just inside the margin and fading out; lateral ribs arising at the base of the blade at an angle of about 50°, running nearly straight to the margin, just inside which they apparently curve inward and join the lower pair of secondaries, each with six or eight secondary branches on the lower side which are approximately at right angles to the midrib, somewhat curved upward, often forked, each curving near the margin and forming by union with the next higher one a series of large bows; nervilles thin, percurrent, and broken.

This form is represented in the collection by several well-preserved leaves, four of which are figured. There is considerable range in size, the smallest (fig. 3) being about 6.5 centimeters long and 4 centimeters wide and the largest (fig. 1) about 10 centimeters long and 7 centimeters wide. The leaf shown in figure 9 is 9.5 centimeters long and 6 centimeters wide. The configuration of the base is shown in figures 1 and 2 and is found to be truncate or very slightly heart-shaped.

This species seems to be related to *Dombeyopsis platanoides* Lesquereux,[66] from the Bozeman coal field of Montana. It is, however, much longer and narrower, being ovate instead of nearly circular, and, further, is truncate instead of very deeply heart-shaped at the base. The nervation is similar in character in the two species, except that in *D. ovata* the lateral ribs are at a slightly more acute angle.

Occurrence: Laramie formation, Erie, Colo.

SYSTEMATIC POSITION UNCERTAIN OR UNKNOWN.

Carpites lakesii Knowlton, n. sp.

Plate XIX, figures 6–8.

Carpites lakesii Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 135, 1919.

Fruit evidently hard-shelled, ovoid, rounded at the base, apparently acuminate at the apex, surface not obviously striate or otherwise marked.

[65] Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, pl. 47, fig. 2, 1878.

[66] Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, pl. 47, figs. 1, 2, 1878.

The material from the Murphy coal mine, near Golden, Colo., contains several obscure fruits, the best of which are here figured. Fruits of this kind are all unsatisfactory, and I have hesitated to name them, but they undoubtedly represent a type of vegetation present in these beds and should perhaps legitimately be designated for the benefit of future workers, though their affinities are and probably must remain uncertain.

These fruits appear to occur in pairs, though there is no evidence of organic connection, and it may be that this association is merely accidental. The shape and apparent consistence suggest the hard, stony putamen of certain species of *Prunus*, but this is mere conjecture. They are perhaps sufficiently well figured to permit subsequent identification.

Occurrence: Laramie formation, Murphy coal bank, Ralston County, Colo., west of Golden, collected by Arthur Lakes, June, 1890.

Carpites lesquereuxiana Knowlton, n. sp.

Carpites lesquereuxiana Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 135, 1919.

Fruit large, about 18 millimeters long, about 17 millimeters in greatest diameter and 13 millimeters in least diameter, slightly obovoid, with a broad, flat base and an obtuse apex; provided with about twelve well-defined ridges or ribs at the base and up the sides which by their union are reduced just below the apex to about five.

This specimen is recorded in the fossil-plant catalogue of the United States National Museum (No. 951) as *Carpites rostellatus* Lesquereux—that is, the small piece of matrix on which it occurs is so recorded. The smaller of the two fruits on this matrix obviously belongs to *Carpites rostellatus*, but the one above described is quite different and undoubtedly represents a new species.

Occurrence: Laramie formation, Coal Creek, Boulder County, Colo.

Carpites rhomboidalis Lesquereux.

Carpites rhomboidalis Lesquereux, Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, p. 306, pl. 60, figs. 28, 29, 1878; U. S. Geol. and Geog. Survey Terr. Ann. Rept. for 1876, p. 520, 1878.

The two types of this species are on one piece of matrix, which is No. 507 of the United States National Museum collections. They represent so far as known the only specimens obtained.

In the "Tertiary flora," page 306, this species is said to have come from South Table Mountain, near Golden, Colo., but as the matrix is the coarse white sandstone so characteristic of the true Laramie, it is practically certain that the specimen did not come from that locality, where the rock is of Denver age, but from a locality south or west of Golden, where the Laramie is known to be exposed.

Occurrence: Laramie formation, Golden, Colo.

Phyllites leydenianus Knowlton, n. sp.

Plate XVIII, figure 5.

Phyllites leydenianus Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 446, 1919.

Leaves of thick texture, ovate, somewhat unequal at the base, margin and apex practically destroyed; midrib very strong; secondaries only two or three pairs, the lowest pair arising a short distance above the base and producing a pseudo three-ribbed appearance, each with a few tertiary branches on the outside; next pair of secondaries near the middle of the blade, opposite, strong, apparently craspedodrome, but this can not be made out with certainty.

This form is represented by several leaves, all of which are so fragmentary that the whole character can not be made out. It appears to have been ovate and entire, being about 9 centimeters long and 5 centimeters wide. The only portion of the margin preserved is at the base. The peculiarity of this form lies in the nervation, the two pairs of especially strong secondaries being opposite and probably craspedodrome. The affinities of this leaf are not recognizable, though it can probably be recognized for stratigraphic purposes.

Occurrence: Laramie formation, Leyden Gulch, 6½ miles north of Golden, Colo., collected by A. C. Peale, 1908.

Phyllites marshallensis Knowlton, n. sp.

Plate XXVIII, figure 7.

Phyllites marshallensis Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 446, 1919.

Leaf large, coriaceous, lanceolate, apparently rounded at the base, narrowly acuminate at the apex; margin prominently undulate, the lobes and sinuses broadly rounded; midrib exceedingly strong below, becoming very thin above; secondaries about 12 pairs, alternate, thin, arising at a low angle, much curved upward, camptodrome, arching near the margin, along which they pass in a series of loops; nervilles numerous, both percurrent and broken; finer nervation forming an intricate network of large and small irregularly quadrangular areolae.

This remarkable leaf is the only one observed in the collections. It is rather broadly lanceolate, about 16 centimeters long, and was undoubtedly several centimeters longer when perfect; the width at the broadest point is about 5.5 centimeters. The margin is deeply undulate, and both lobes and sinuses are broadly rounded. The midrib, as may be seen from the figure, is extremely thick below, where it exceeds a thickness of 3 millimeters, but in the upper portion of the blade it is reduced almost to the vanishing point.

I am entirely at a loss to suggest the proper generic reference for this leaf. The very thick midrib and arching, camptodrome secondaries suggest certain species of *Ficus*, but I do not regard this resemblance as sufficient warrant for placing it under this caption. For the present it may remain as designated.

Occurrence: Laramie formation, Marshall's mine, Boulder County, Colo., collected by N. L. Britton about 1885.

Phyllites trinervis Knowlton, n. sp.

Plate XXIV, figure 12.

Phyllites trinervis Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 449, 1919.

Leaf evidently thick and leathery, ovate, broadly rounded below to an apparently decurrent base, very obtuse and rounded above; margin perfectly entire; triple-ribbed from the extreme base of the blade, the ribs of equal size, the middle one with about three pairs of alternate, thin, much curved secondaries, the lateral ones with several secondary branches on the outside; all secondaries seemingly camptodrome; finer nervation not retained.

The little leaf here figured is broadly and very obtusely ovate, the length being 5 centimeters and the width about 4 centimeters. The base is broadly rounded, with a slightly decurrent portion through which pass the three ribs, their origin evidently being the top of the petiole. Little of the other nervation is preserved, and this is well shown in the figure.

The real affinities of this leaf are hard to make out. It has, for example, exactly the same type of base, as regards shape, size, and nervation, as *Ficus trinervis*, a part of which was formerly called *Cinnamomum affine* Lesquereux, but the upper portion of the leaf is wholly different.

The basal portion of this leaf is also similar to a form from Marshall that has been described as *Populus distorta* (p. 126), but it differs in having the apex rounded instead of acuminate. In general shape it suggests *Populus arctica* Heer, as figured by Lesquereux,[67] but it differs in details of primary nervation. It also suggests one of the leaves from the Bozeman coal field described under the name *Populus* cf. *P. arctica* Heer,[68] but the Bozeman leaf differs markedly in the primary nervation.

Occurrence: Laramie formation, Coal Creek, Boulder County, Colo.

Phyllites dombeyopsoides Knowlton, n. sp.

Plate XVIII, figure 2.

Phyllites dombeyopsoides Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 445, 1919.

Leaf ovate, truncate or possibly slightly heart-shaped at the base, regularly and obtusely acuminate at the apex; margin slightly undulate, especially about the middle of the blade; apparently triple ribbed from or near the base of the blade, the central or midrib very much the strongest, especially below, with two pairs of strong, remote secondary branches in the upper part; lateral ribs slender, at an angle of about 60°, with a large lateral branch in the lower portion, this with several tertiary branches on the outside which arch just inside the margin; lateral ribs forked above, the branches passing to or near the margin, the rib itself arching in a broad bow and joining the lower secondary on the midrib; intermediate secondaries and nervilles strong, unbroken.

This form is represented by the leaf figured and several rather poor fragments. The example figured, which lacks both base and apex,

[67] Lesquereux, Leo, The Tertiary flora: U. S. Geol. Survey Terr. Rept., vol. 7, pl. 23, fig. 5, 1878.

[68] Knowlton, F. H., U. S. Geol. Survey Bull. 105, pl. 6, fig. 7, 1892.

is about 14 or 15 centimeters in length and 10 centimeters in width, and the widest point is at about one-third the length of the blade above the base. It is rather broadly ovate and has a distinctly undulate margin. The nervation is remarkable for the very thick midrib, with only two pairs of secondaries in the upper part.

This species appears to be closely related to *Dombeyopsis ovata,* from which, however, it differs in its larger size, more distinctly undulate margin, and fewer secondary branches on the midrib, as well as by the joining of the upper secondaries before they reach the margin. It also resembles certain species of *Ficus* of the *Ficus planicostata* group, yet it apparently differs in essential ways.

Occurrence: Laramie formation, Cowan station, 10 miles south of Denver, Colo., collected by F. H. Knowlton.

Phyllites sp.

Plate XIX, figure 1.

Phyllites sp. Knowlton [nomen], U. S. Geol. Survey Bull. 696, p. 450, 1919.

In the material obtained by Peale in the cut on the Moffat railroad (Denver & Salt Lake) some 6 or 8 miles north of Golden, Colo., is the fragment here figured. It is only the basal portion of what was apparently a large leaf and shows the very thick midrib and the pair of nearly as strong lateral ribs, each of which is branched on the outside. It is doubtful if any portion of the margin is preserved.

This specimen is so fragmentary that there is little use in speculating as to its probable affinity, though it is not unlike certain species of *Platanus,* such as *Platanus raynoldsii,* figured by Lesquereux in the "Tertiary flora," Plate XXVII, figure 1, but obviously it can have little value beyond calling attention to the fact of the presence of a large, perhaps platanoid leaf in these beds.

Occurrence: Laramie formation, cut on Moffat railroad (Denver & Salt Lake) 6 or 8 miles north of Golden, Colo., collected by A. C. Peale, 1908.

Phyllites sp.

Plate XVI, figure 5.

Phyllites sp. Knowlton [nomen], U. S. Geol. Survey Bull. 696, p. 450, 1919.

The fragment of the tip of the small toothed leaf here figured is all that was observed of this form and is hardly worthy of mention except to call attention to the presence of this type of leaf. Its affinity is obviously uncertain. It might be the apical portion of the leaf of a maple (*Acer*) or a sycamore (*Platanus*), but it is quite impossible to decide further.

Occurrence: Laramie formation, Marshall, Colo., collected by A. C. Peale, 1908.

Phyllites sp.

Plate VIII, figure 5.

Phyllites sp. Knowlton [nomen], U. S. Geol. Survey Bull. 696, p. 451, 1919.

In the material from Cowan station, near Denver, is the fragmentary leaf here figured. It was a lanceolate leaf with a wedge-shaped base and presumably an entire margin and was evidently of firm texture. It was 10 centimeters or more long and 3.5 centimeters wide. The nervation is strongly marked, consisting of a strong midrib and probably about six pairs of strong alternate secondaries at an acute angle of divergence. None of the finer nervation is preserved.

This leaf has some resemblance to what has been described as *Ficus cowanensis,* especially to the leaf shown in Plate IX, figure 3, and it is to be noted that they come from the same locality. The latter is a larger leaf and has the secondaries more numerous and at a less acute angle. The fragment under discussion has some suggestion of certain narrow leaves of *Quercus,* but it is too fragmentary to be certain of the reference to that genus. On the whole it seems best to refrain from giving it a definite designation.

Occurrence: Laramie formation, Cowan station, south of Denver, Colo., collected by F. H. Knowlton, 1908.

Palaeoaster? similis Knowlton, n. sp.

Plate XXIV, figures 10, 11.

Palaeoaster? similis Knowlton [nomen nudum], U. S. Geol. Survey Bull. 696, p. 427, 1919.

Organism consisting of a whorl or rosette apparently of about six thick, linear-lanceolate, acuminate, erect, one-nerved "leaves" or segments which are sessile or nearly sessile on a short, stout stem or axis.

This form is represented by the nearly perfect example figured and a number of detached segments. So far as can be made out this species consists of about six "leaves" or segments which are disposed in a whorl at the top of a short, stout branch or axis. The individual "leaves" are narrowed to a long wedge-shaped basal portion and apparently are not in contact with one another. The only nervation that can be observed is a thick midrib.

This species appears to be related to a curious organism from the extreme upper part of the Vermejo formation and the lowermost part of the Raton formation of southern Colorado, described under the name *Palaeoaster inquirenda* Knowlton,[69] as follows:

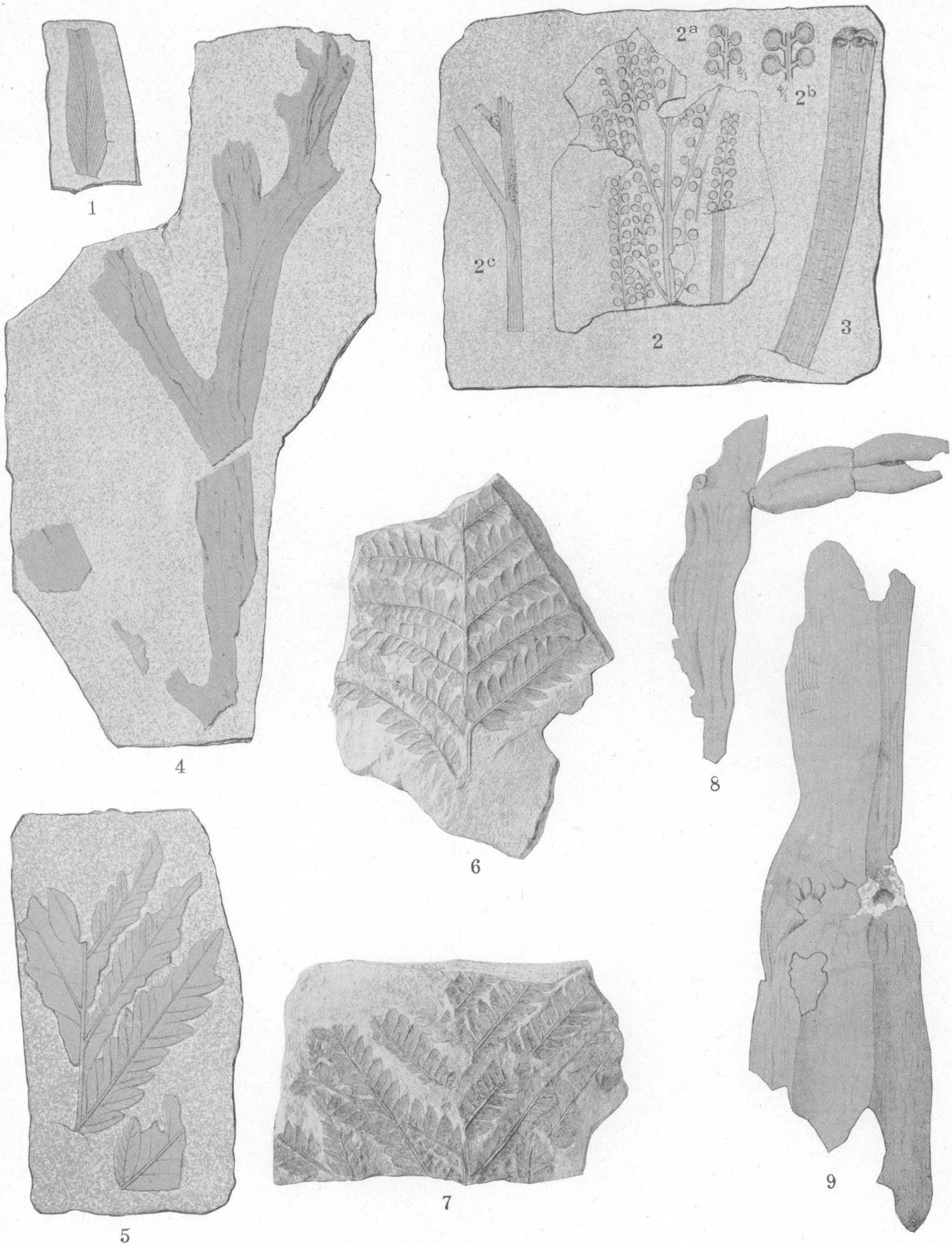
> It consists of usually about 9 (the number ranges from 8 to 12) narrow, erect "leaves" or members which are 3.5 to about 4.5 centimeters long and 6 to 10 millimeters wide in the middle. They are slightly narrowed to the sessile base, where they are in contact, though evidently perfectly free at the point of attachment. Above they are narrowed to a quite slender acuminate apex, which is usually somewhat incurved. The segments are thick and leathery, if not indeed woody, and are traversed diversely by a deep median furrow. * * * It seems probable that these organisms were terminal, for there is some evidence of the presence of a scar or point of attachment at the base, but there has never been noted any axis on which they might have stood. They are certainly not leaves whorled around a stem, for had they been, some trace of the stem should have been detected in some of the numerous specimens that have passed in review. It appears more likely that they were capsular in nature, for if the now spreading segments were brought together they would apparently make a tightly closed "capsule." The incurved tips of the segments lend support to this view, though no evidence of seeds or any interior structure has been observed.

The specimen under consideration appears to differ in several particulars from those above described. Thus, instead of eight to twelve "leaves" there are apparently only five or six; instead of being in contact at their bases they are slightly separated and have much more the appearance of a whorl of leaves; and finally, instead of being sessile they appear to stand on a short stem or axis. The individual "leaves" or segments are practically indistinguishable in the two forms, and the question naturally arises whether they are slightly different phases of the same or similar organisms, or whether they should be considered wholly distinct. In the absence of sufficient material it is deemed best to describe them as separate species, and I have even questioned the generic reference of the present form.

Occurrence: Laramie formation, Murphy's coal mine, Ralston County, west of Golden, Colo.

[69] Knowlton, F. H., U. S. Geol. Survey Prof. Paper 101, p. 278, pl. 49, figs. 5, 6, 1918.

PLATES.



LARAMIE FLORA.

1. *Lygodium? compactum* Lesquereux (reproduced from Lesquereux, Leo, Tertiary flora, pl. 5, fig. 9, 1878); p. 113.

2, 3. *Onoclea fecunda* (Lesquereux) Knowlton (reproduced from Lesquereux, Leo, op, cit., pl. 14, figs. 1-3); p. 107.

4. *Delesseria fulva* Lesquereux (reproduced from Lesquereux, Leo, op. cit., pl. 1, fig. 10); p. 107.

5. *Dryopteris laramiensis* Knowlton, n. name (reproduced from Lesquereux, Leo, op. cit., pl. 4, fig. 14); p. 109.

6, 7. *Dryopteris georgei* Knowlton, n. sp.; p. 108.

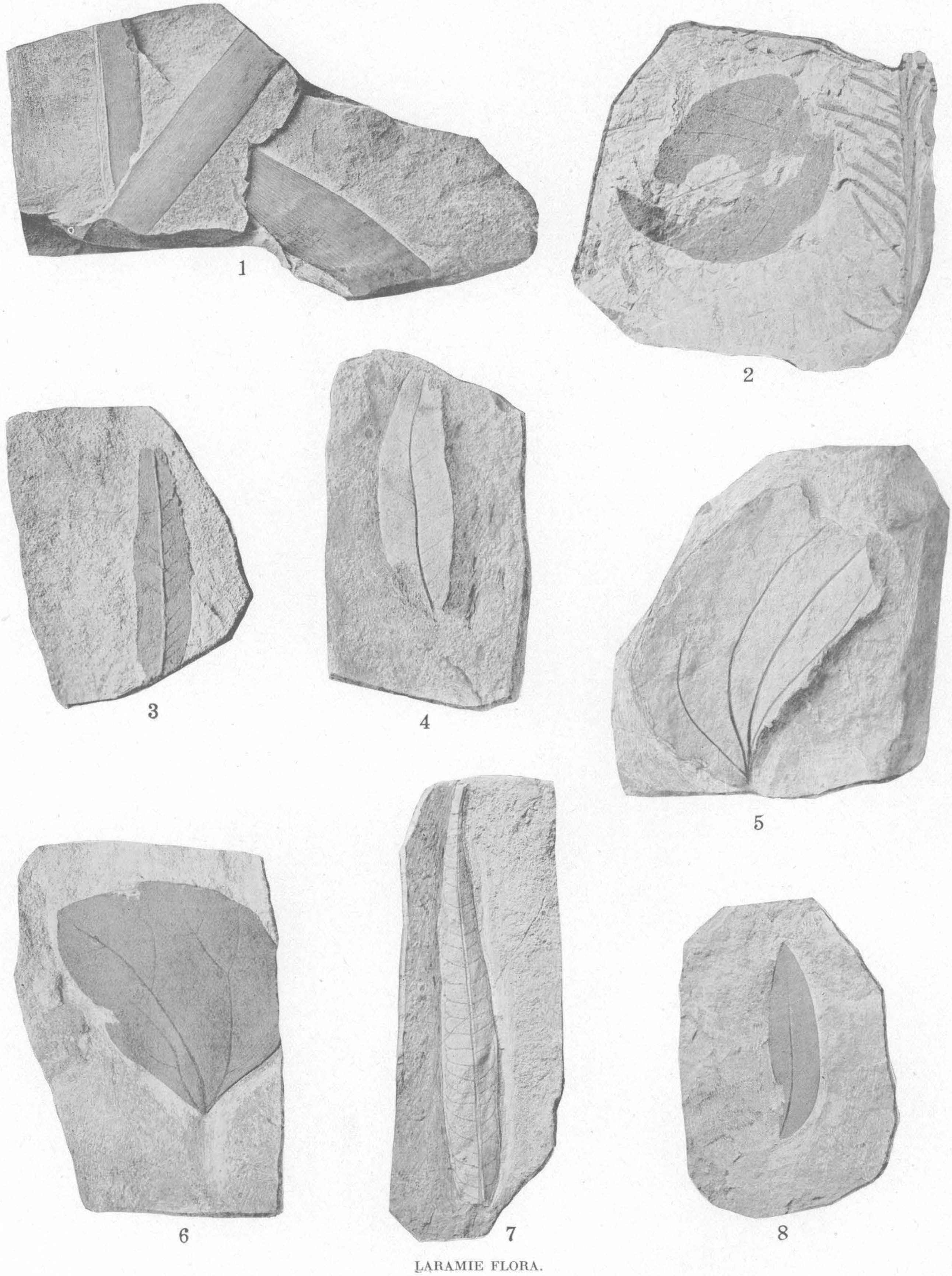
8, 9. *Equisetum perlaevigatum* Cockerell (reproduced from Lesquereux, Leo, op. cit., pl. 6, figs. 6, 7); p. 113.

LARAMIE FLORA.

1. *Anemia* sp.; p. 113.
2. *Anemia elongata* (Newberry) Knowlton, n. comb.; p. 112.
3. *Pteris goldmani* Knowlton, n. sp.; p. 111.
4. *Dammara* sp.; p. 114.
5. *Pteris?* sp.; p. 112.
6. *Asplenium martini* Knowlton, n. sp.; p. 111.
7, 8. *Sequoia acuminata?* Lesquereux; p. 114.

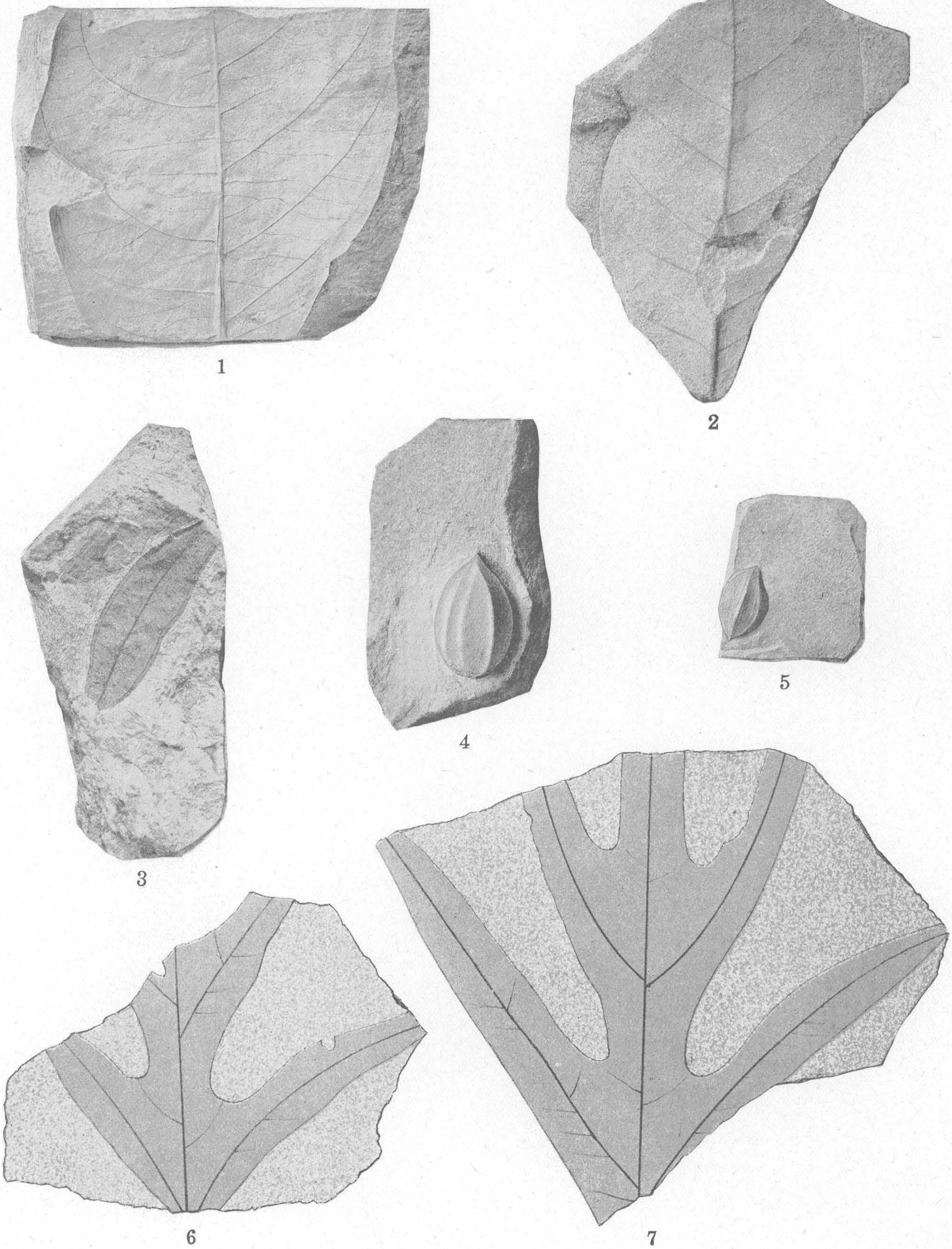
LARAMIE FLORA.

1, 2. *Cyperacites? tessellatus* Knowlton, n. sp.; p. 117.
3. *Sequoia longifolia* Lesquereux; p. 115.
4. *Sabal montana* Knowlton; p. 119.
5. *Phanerophlebites pealei* Knowlton, n. gen., n. sp.; p. 110.



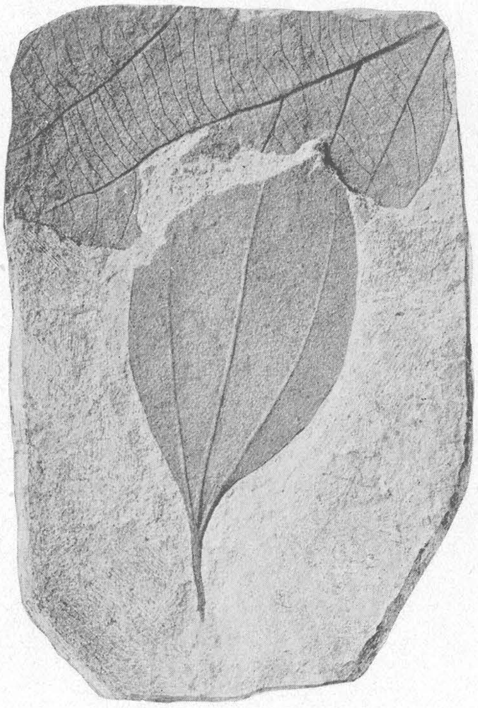
LARAMIE FLORA.

1. *Cyperacites* sp.; p. 117.
2. *Sequoia longifolia?* Lesquereux; p. 115.
3, 4. *Salix wyomingensis* Knowlton and Cockerell; p. 125.
5. *Smilax inquirenda* Knowlton, n. sp.; p. 118.
6. *Populus? distorta* Knowlton, n. sp.; p. 126.
7. *Salix myricoides* Knowlton, n. sp.; p. 124.
8. *Salix wyomingensis?* Knowlton and Cockerell; p. 125.



LARAMIE FLORA.

1. *Juglans leydenianus* Knowlton, n. sp.; p. 119.
2. *Juglans praerugosa* Knowlton, n. sp.; p. 121.
3. *Myrica dubia* Knowlton, n. sp.; p. 123.
4. *Hicoria angulata* Knowlton, n. sp.; p. 122.
5. *Hicoria minutula* Knowlton, n. sp.; p. 123.
6, 7. *Quercus praeangustiloba* Knowlton, n. sp. (reproduced from Lesquereux, Leo, Tertiary flora, pl. 21, figs. 4, 5, 1878); p. 126.



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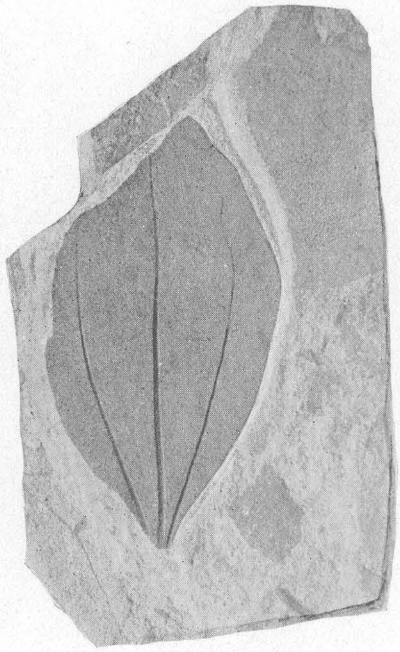

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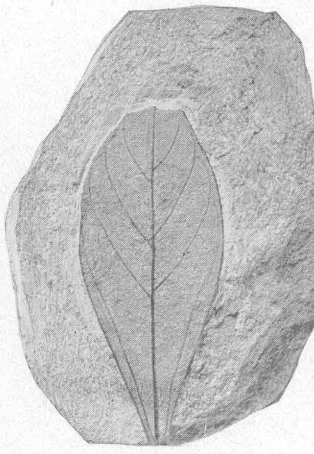

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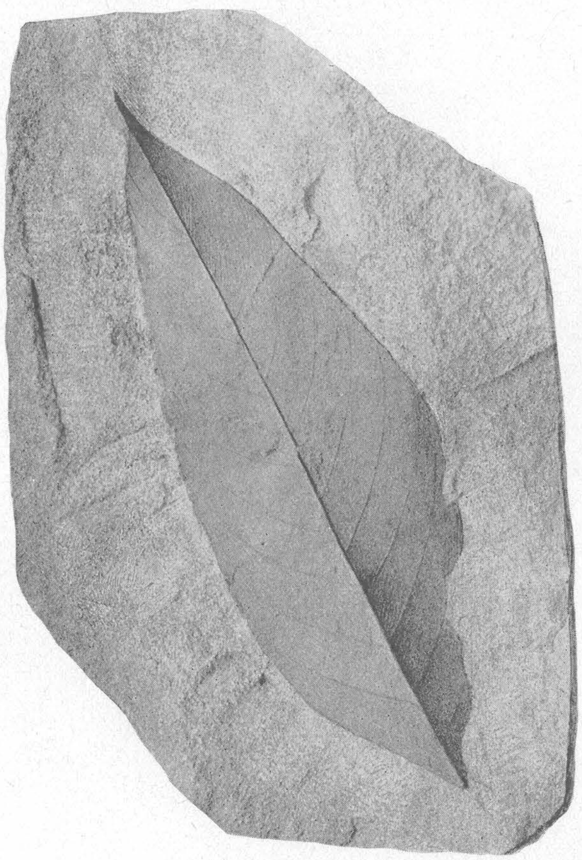

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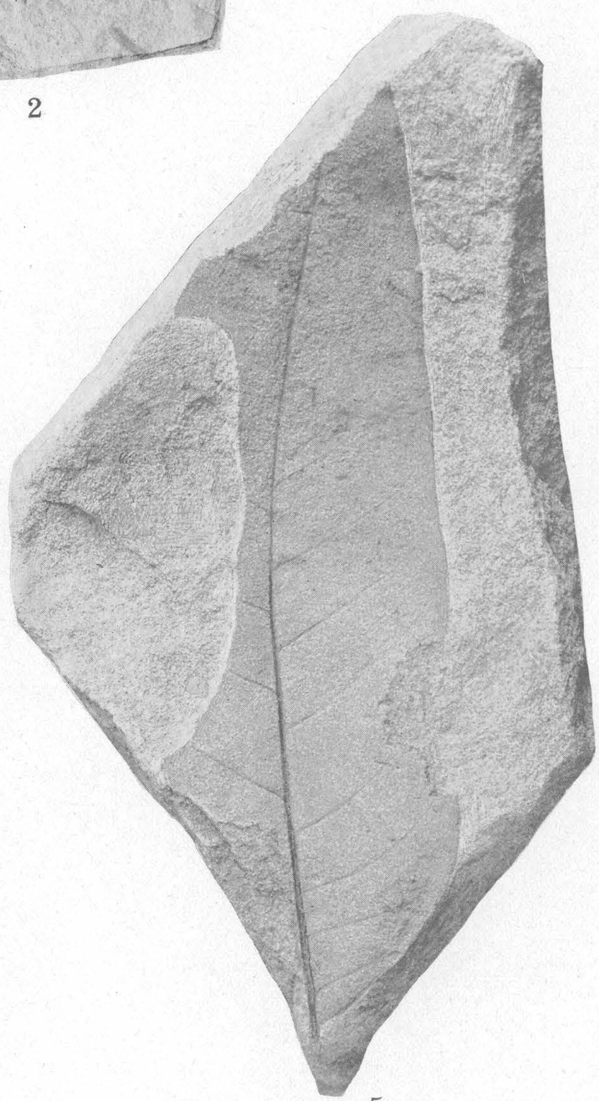

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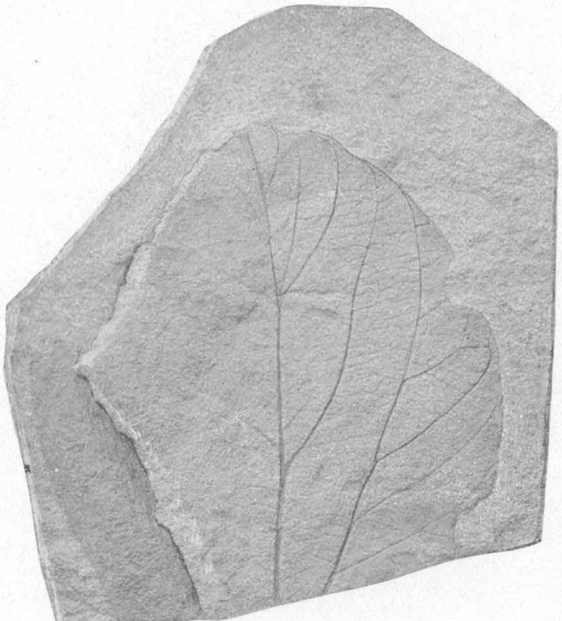
LARAMIE FLORA.

1, 2. *Ficus post-trinervis* Knowlton, n. sp.; p. 136.
3. *Ficus cannoni* Knowlton, n. sp.; p. 136.
4, 5. *Ficus navicularis* Cockerell; p. 137.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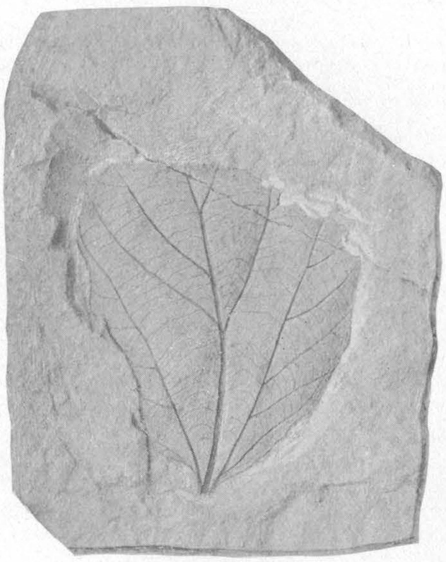
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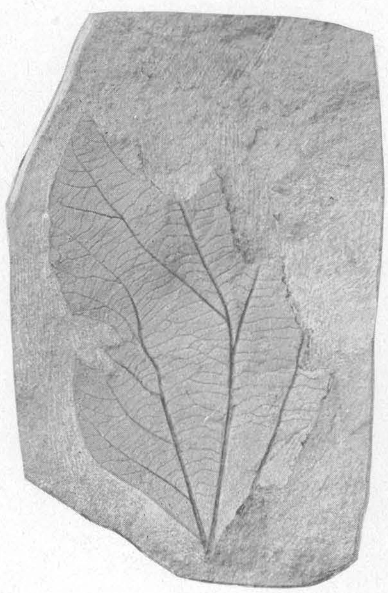
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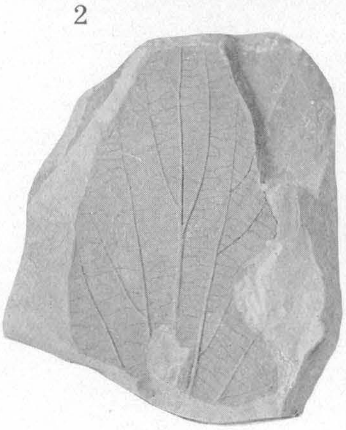
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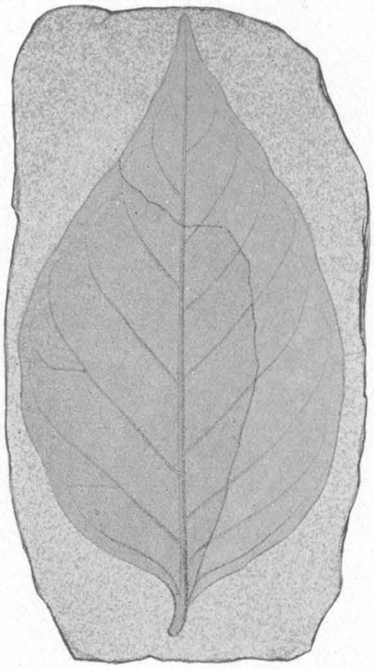
LARAMIE FLORA.

1-3. *Ficus impressa* Knowlton, n. sp.; p. 134.
4. *Apeibopsis laramiensis* Knowlton, n. sp.; p. 159.
5. *Malapoenna louisvillensis* Knowlton, n. sp.; p. 144.
6. *Ficus neodalmatica* Knowlton, n. sp.; p. 135.



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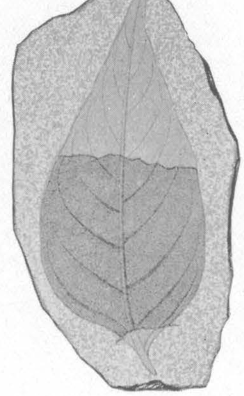

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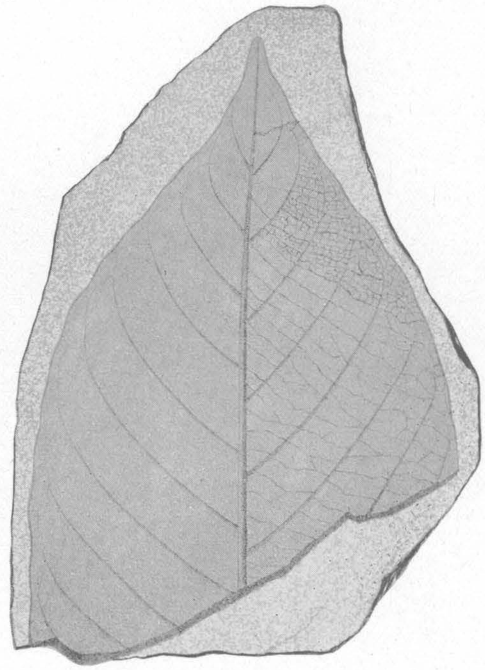

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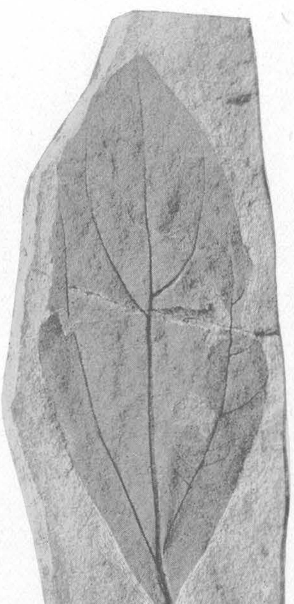

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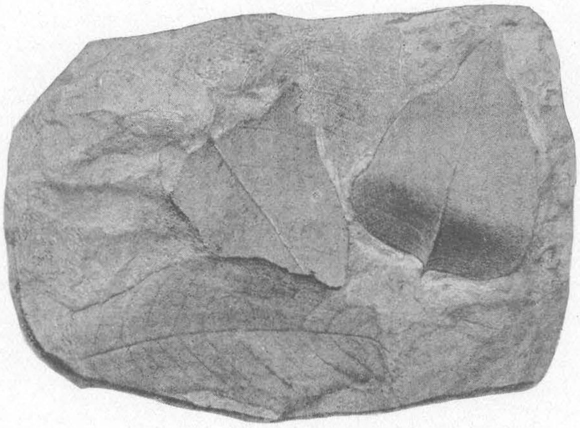
LARAMIE FLORA.

1-3. *Juglans leconteana* Lesquereux (types; reproduced from Lesquereux, Leo, Tertiary flora, pl. 54, figs. 10-12, 1878); p. 121.
2.
4. *Cinnamomum affine* Lesquereux; p. 145.
5. *Phyllites* sp.; p. 167.
6. *Ficus cowanensis* Knowlton, n. sp.; p. 139.



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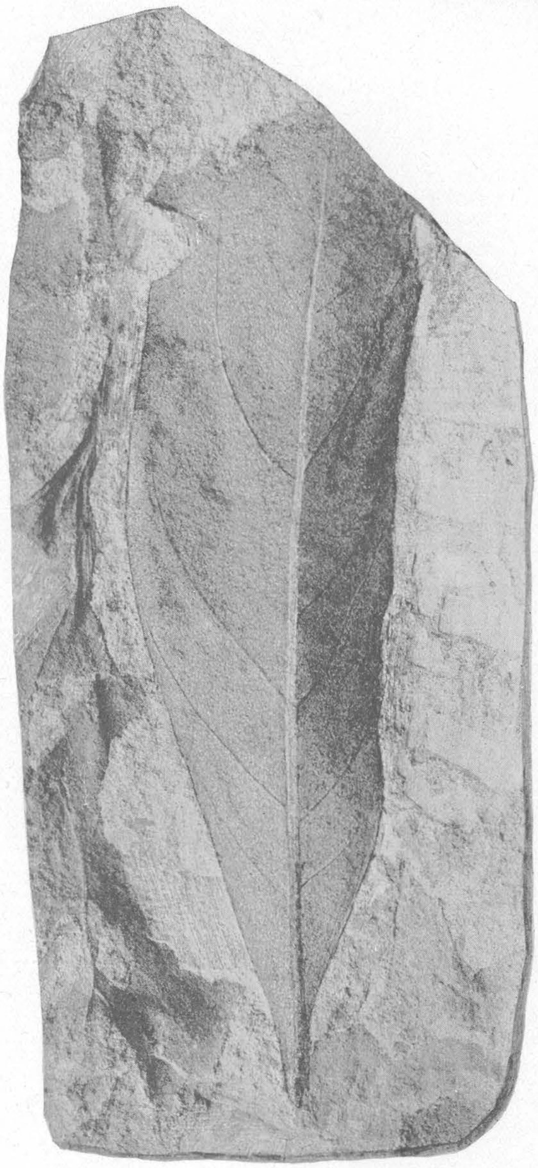

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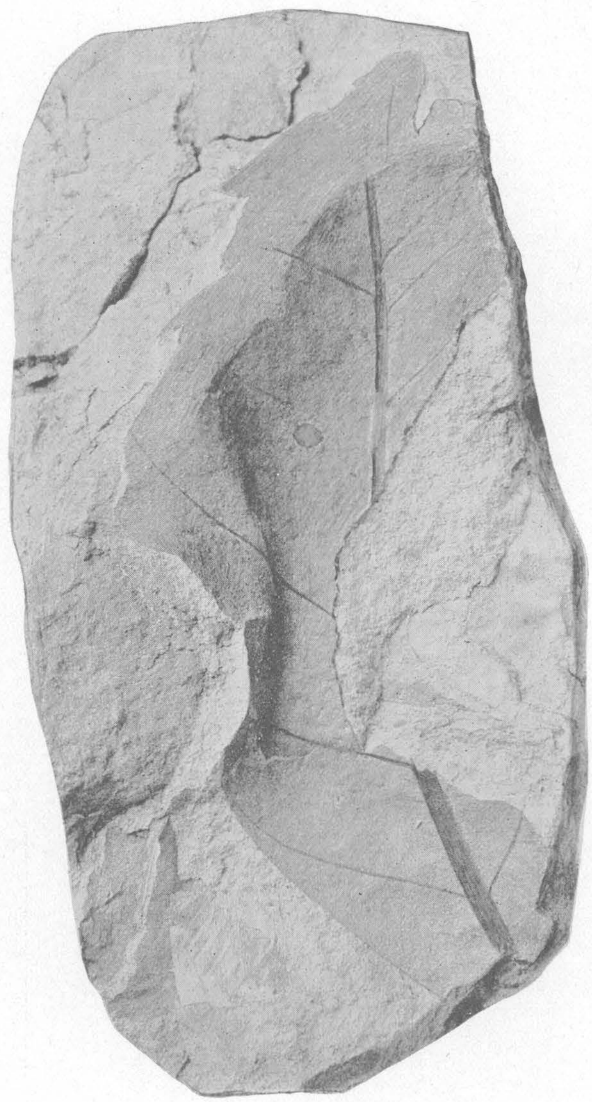

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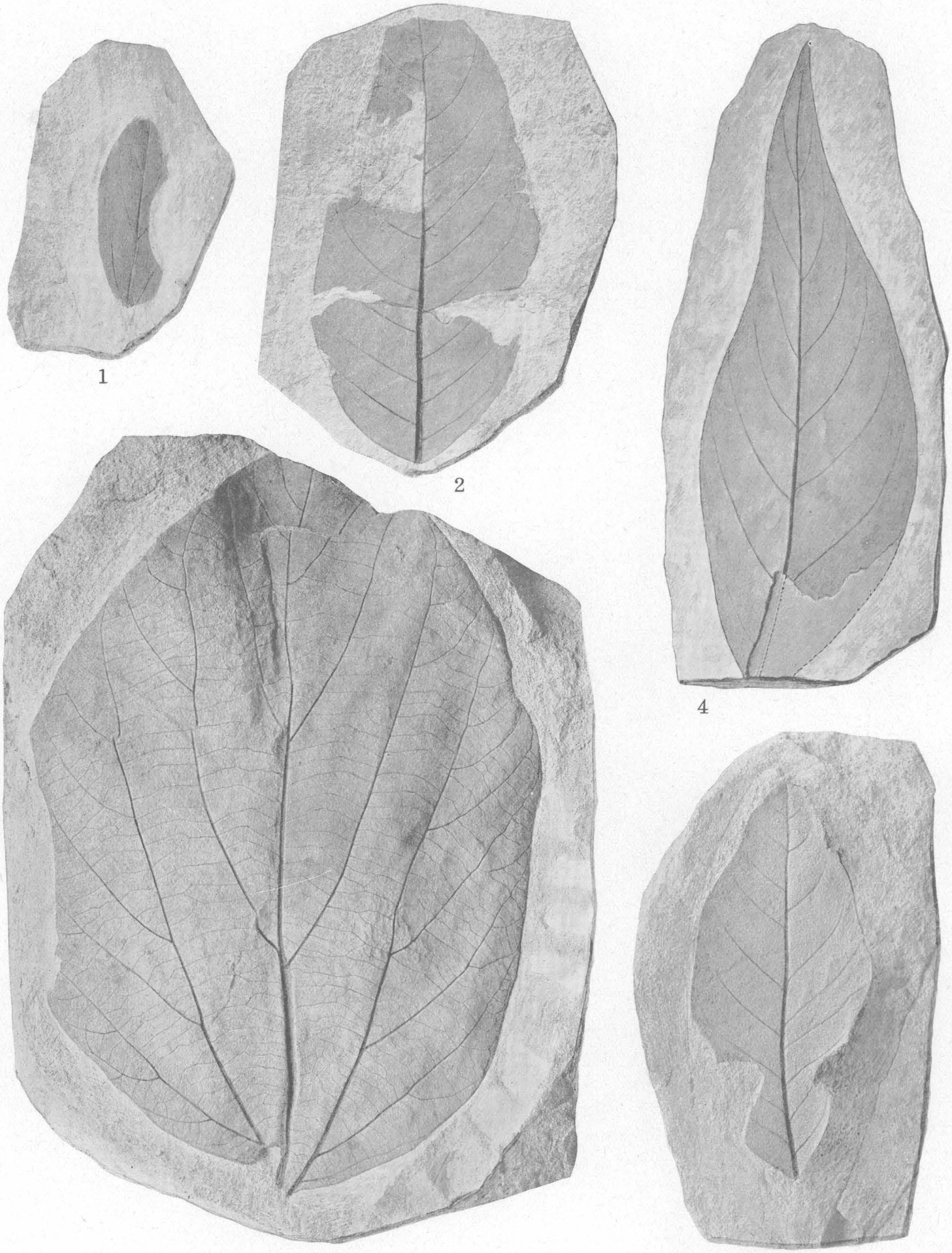
LARAMIE FLORA.

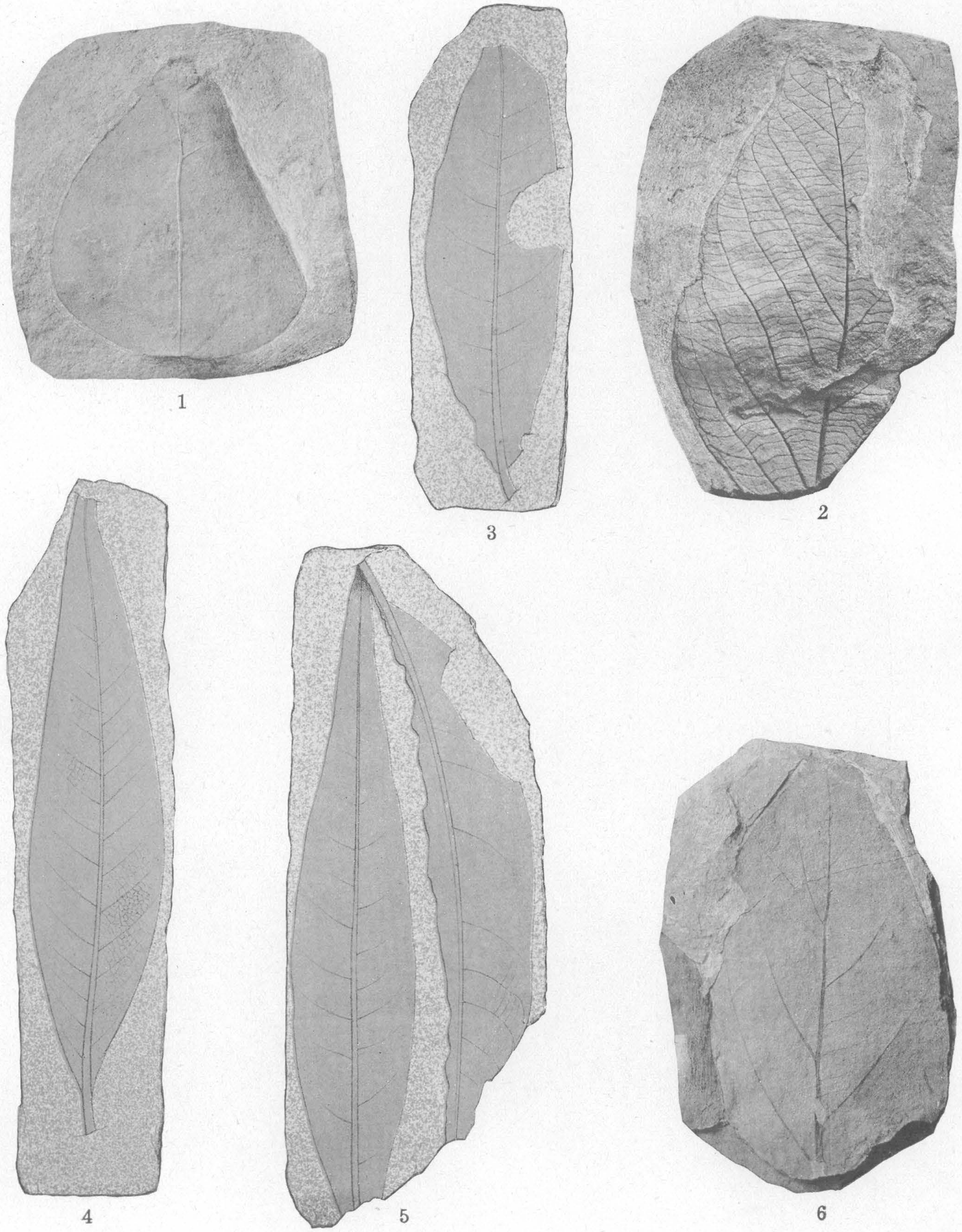
1. *Hedera lucens* Knowlton, n. sp.; p. 160.

2, 3. *Ficus cowanensis* Knowlton, n. sp.; p. 139.



LARAMIE FLORA.

1. *Ficus cannoni* Knowlton, n. sp.; p. 136.
2. *Ficus arenacea* Lesquereux; p. 140.
3. *Ficus planicostata magnifolia* Knowlton, n. var.; p. 133.
4, 5. *Ficus arenacea* Lesquereux; p. 140.

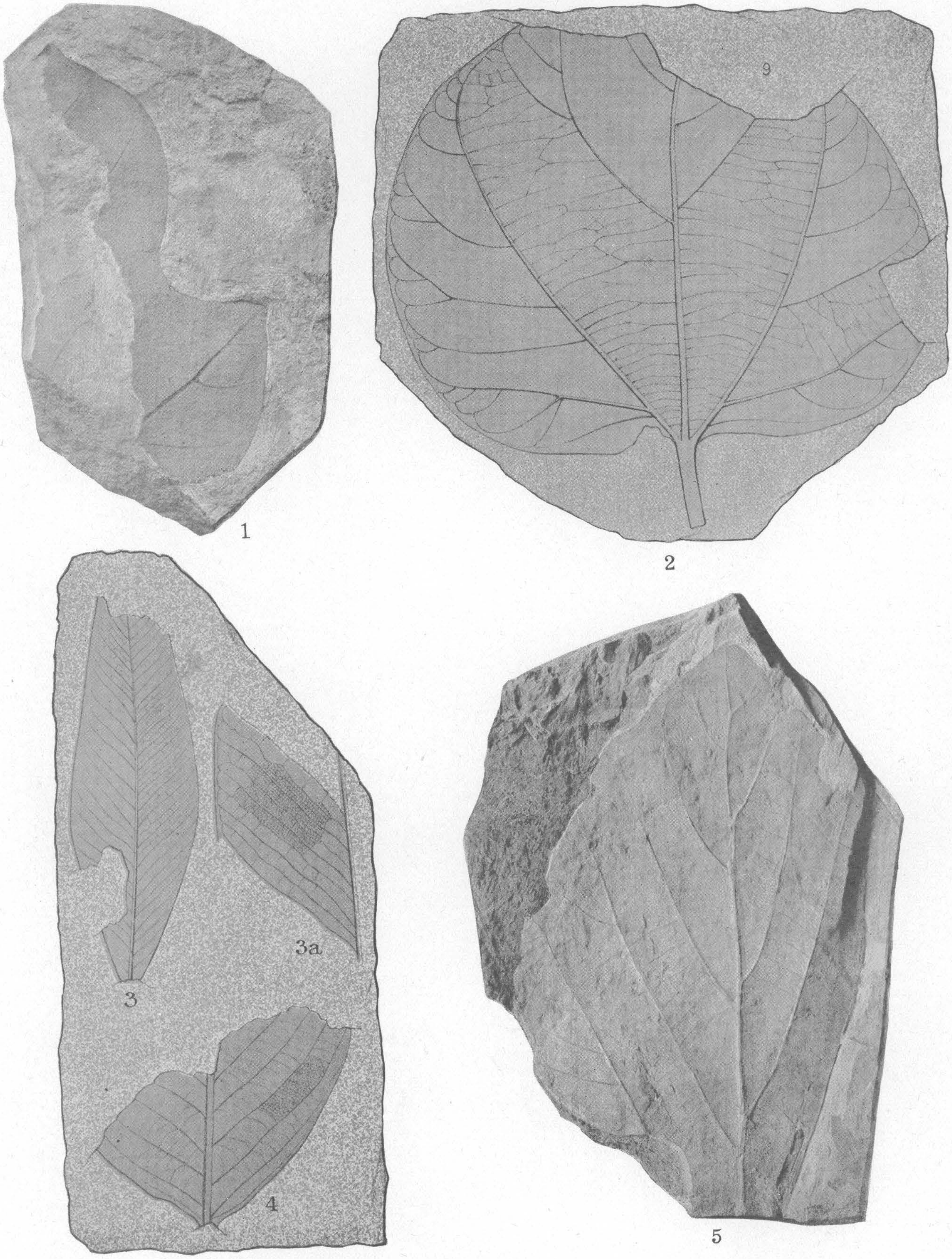


LARAMIE FLORA.

1. *Ficus berryana* Knowlton, n. sp.; p. 139.
2. *Ficus crossii* Ward; p. 139.

3–5. *Ficus navicularis* Cockerell (reproductions of figures by Lesquereux under *Ficus lanceolata:* Tertiary flora, pl. 28, figs. 1–3, 1878); p. 137.

6. *Ficus pealei* Knowlton, n. sp.; p. 131.



LARAMIE FLORA.

1. *Artocarpus lessigiana* (Lesquereux) Knowlton; p. 128.
2. *Ficus cockerelli* Knowlton, n. name (reproduced from Lesquereux, Leo, Tertiary flora, pl. 31, fig. 9, 1878); p. 132.
3, 3a, 4. *Ficus multinervis?* Heer (reproduced from Lesquereux, Leo, op. cit., pl. 28, figs. 7, 8, 1878); p. 138.
5. *Ficus denveriana?* Cockerell; p. 138.

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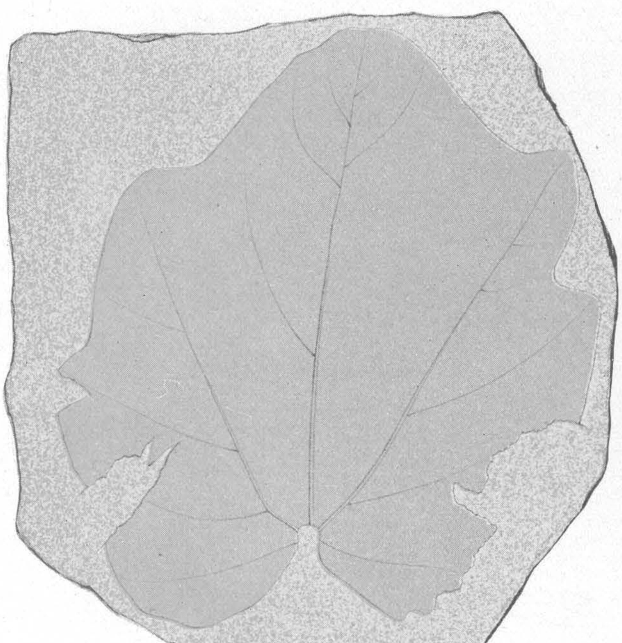

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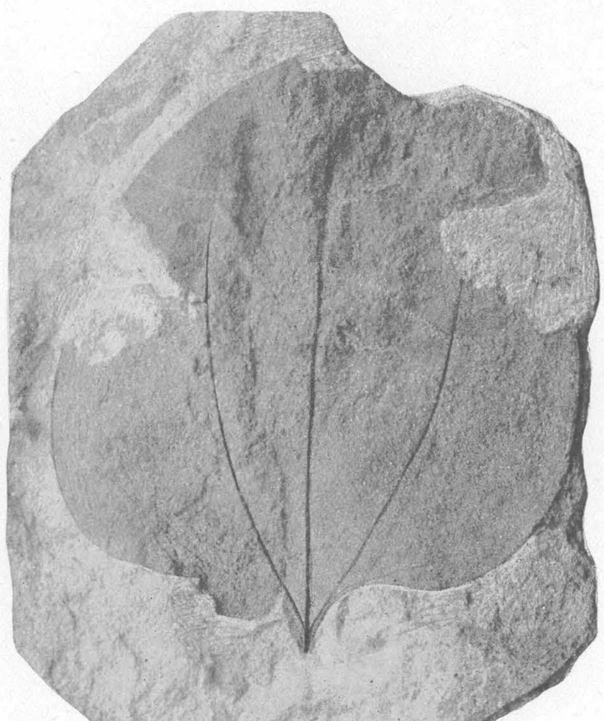

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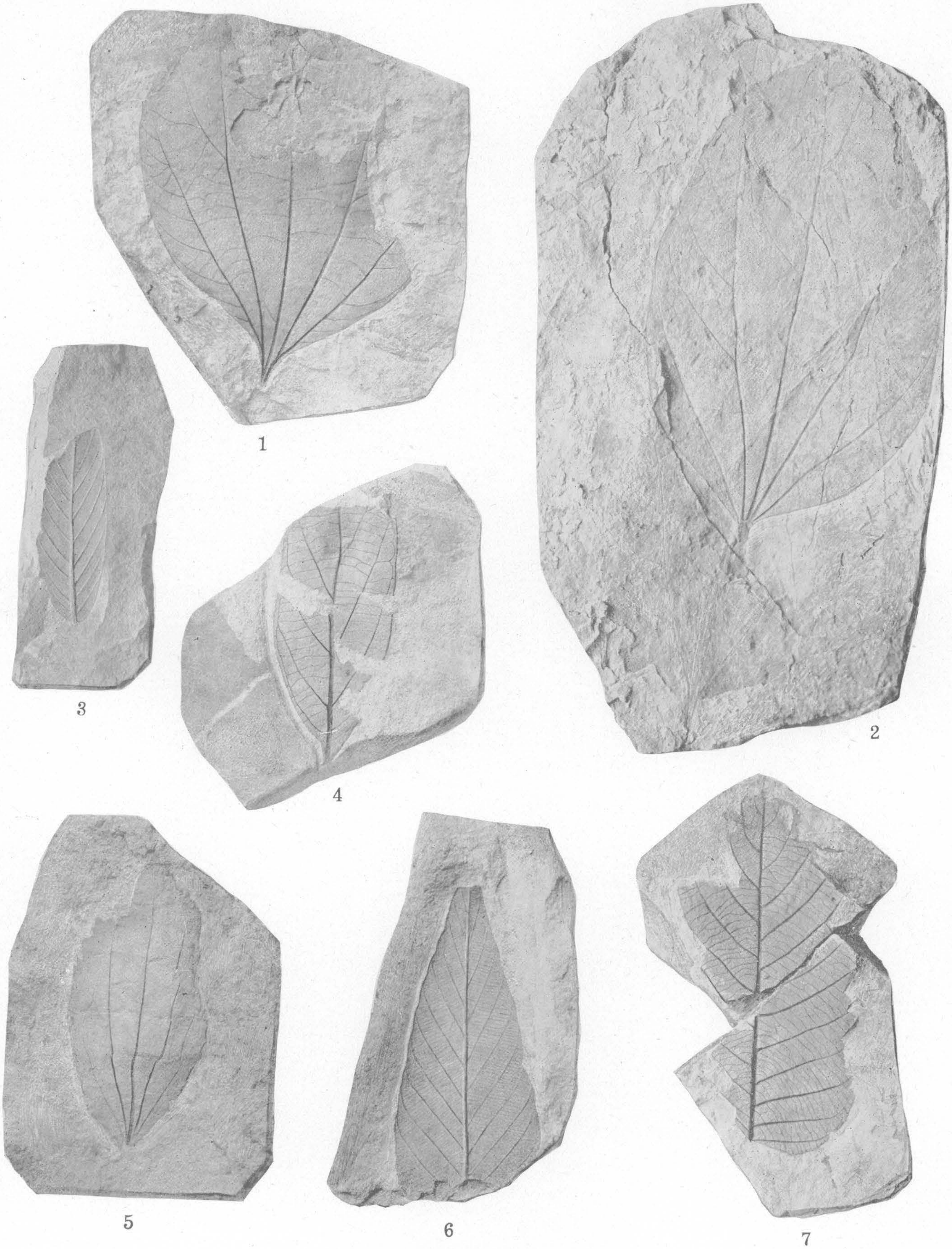
LARAMIE FLORA.

1. *Platanus platanoides* (Lesquereux) Knowlton; p. 146.
2. *Magnolia lakesii* Knowlton, n. sp.; p. 142.
3. *Dombeyopsis trivialis* Lesquereux (reproduced from Lesquereux, Leo, Tertiary flora, pl. 47, fig. 3, 1878); p. 163.
4. *Dombeyopsis obtusa* Lesquereux; p. 162.

LARAMIE FLORA.

1. *Ficus leyden* Knowlton, n. sp.; p. 136.
2. *Cornus suborbifera* Lesquereux (reproduced from Lesquereux, Leo, Tertiary flora, p. 42, fig. 2, 1878); pl. 159.
3. *Dombeyopsis trivialis?* Lesquereux; p. 163.
4. *Cornus* sp.; p. 160.
5. *Cornus praeimpressa* Knowlton, n. sp.; p. 159.



LARAMIE FLORA.

1, 2. *Zizyphus hendersoni* Knowlton, n. sp.; p. 157.
3. *Rhamnus marshallensis* Knowlton, n. sp.; p. 155.
4. *Rhamnus salicifolius* Lesquereux; p. 154.
5. *Zizyphus coloradensis* Knowlton, n. sp.; p. 157.
6. *Rhamnus brittoni* Knowlton, n. sp.; p. 156.
7. *Rhamnus pealei* Knowlton, n. sp.; p. 156.

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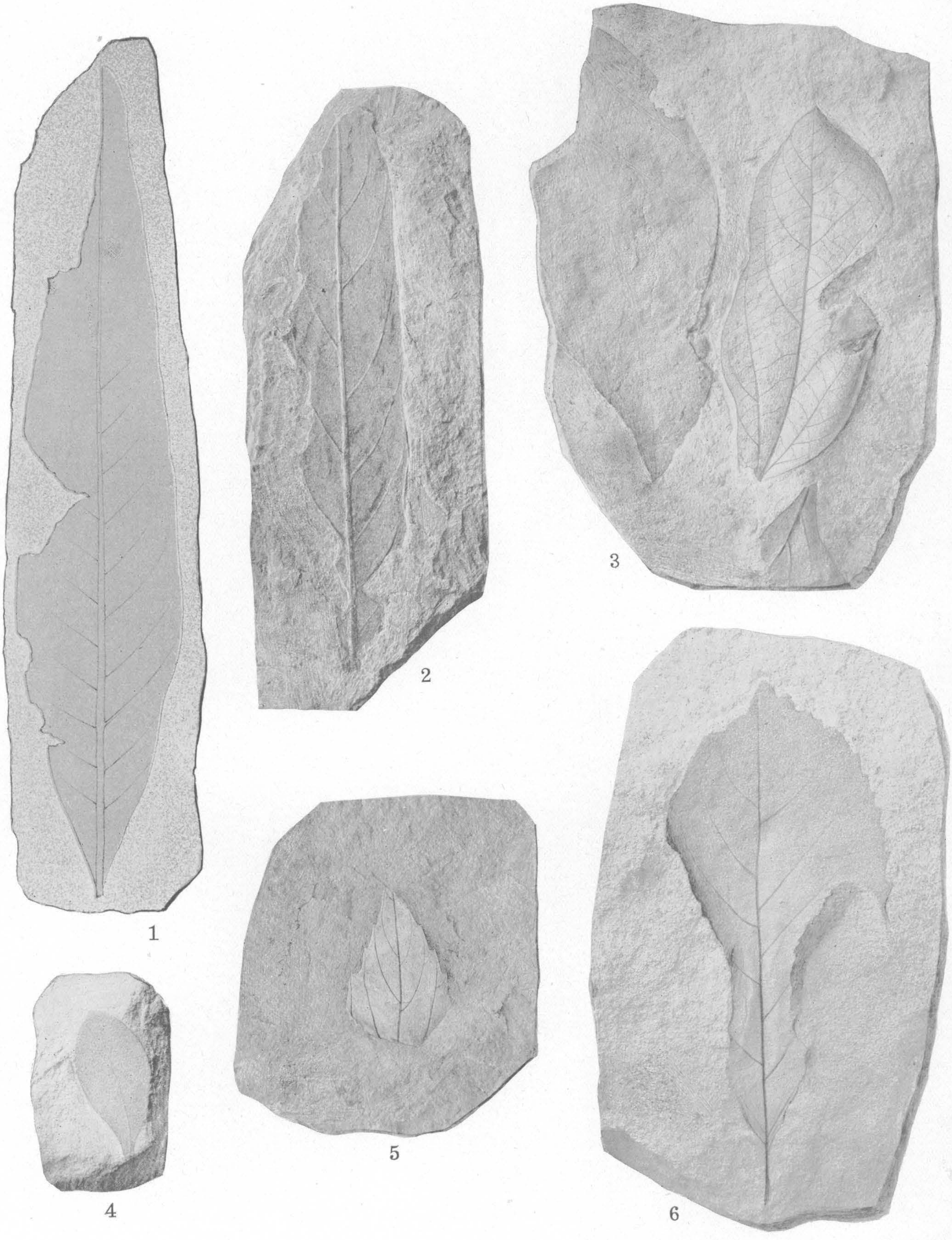
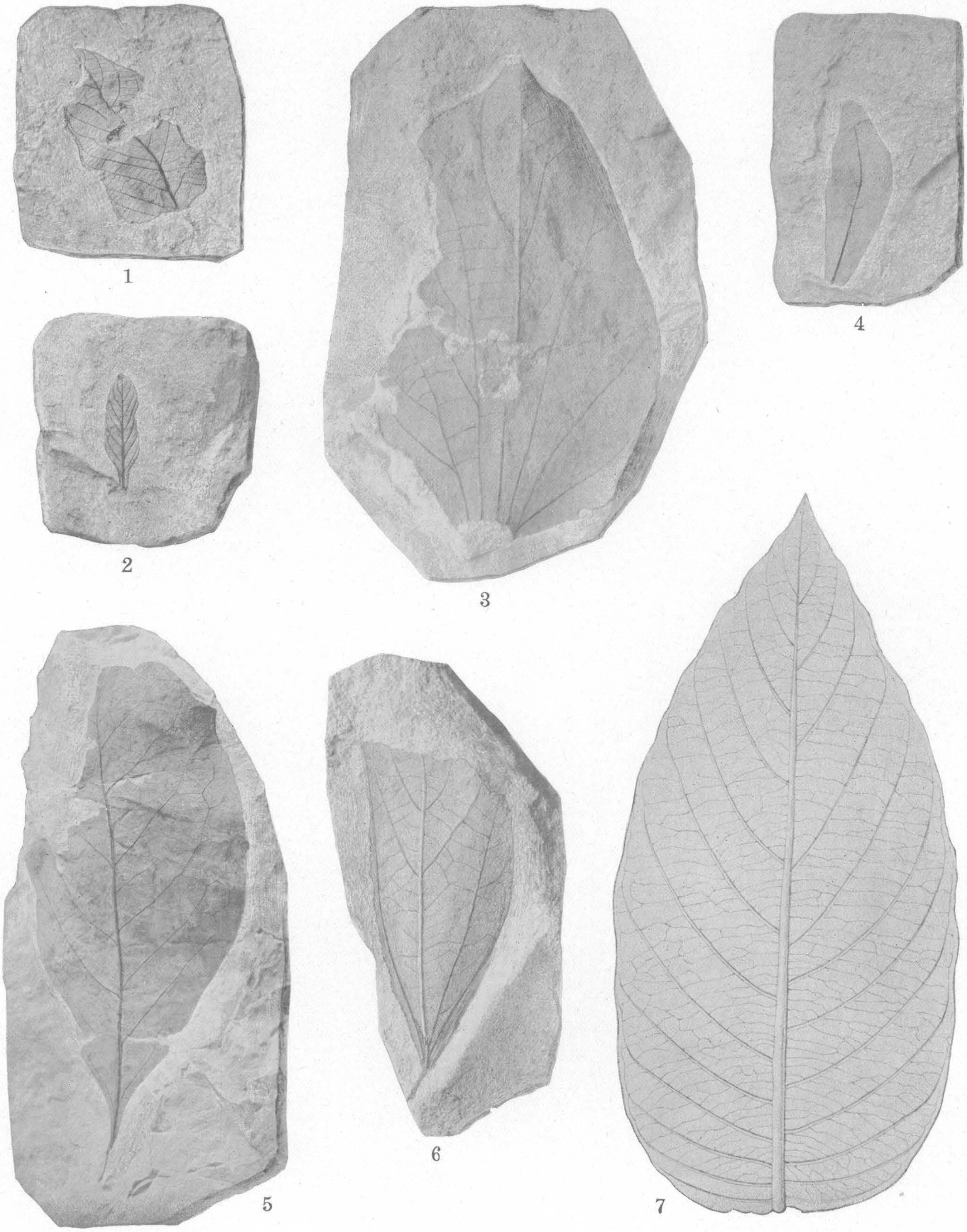


LARAMIE FLORA.

1. *Laurus wardiana* Knowlton (reproduced from Lesquereux, Leo, Tertiary flora, pl. 36, fig. 10, 1878); p. 144.
2. *Apocynophyllum? taenifolium* Knowlton, n. sp.; p. 161.
3. *Ficus impressa* Knowlton, n. sp.; p. 134.
4. *Mimosites marshallanus* Knowlton, n. sp.; p. 148.
5. *Phyllites* sp.; p. 167.
6. *Celastrinites cowanensis* Knowlton, n. sp.; p. 149.



LARAMIE FLORA.

1. *Rhamnus* sp.; p. 156.
2. *Rhamnus minutus* Knowlton, n. sp.; p. 155.
3. *Zizyphus corrugatus* Knowlton, n. sp.; p. 158.
4. *Leguminosites? laramiensis* Knowlton, n. sp.; p. 148.
5. *Diospyros berryana* Knowlton, n. sp.; p. 161.
6. *Cinnamomum affine* Lesquereux; p. 145.
7. *Anona robusta* Lesquereux (reproduced from Lesquereux, Leo, Cretaceous and Tertiary floras, pl. 20, fig. 4, 1883); p. 143.

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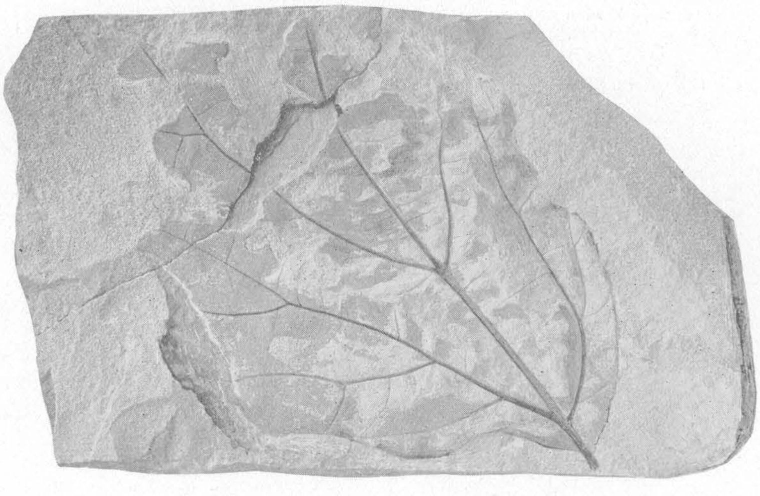

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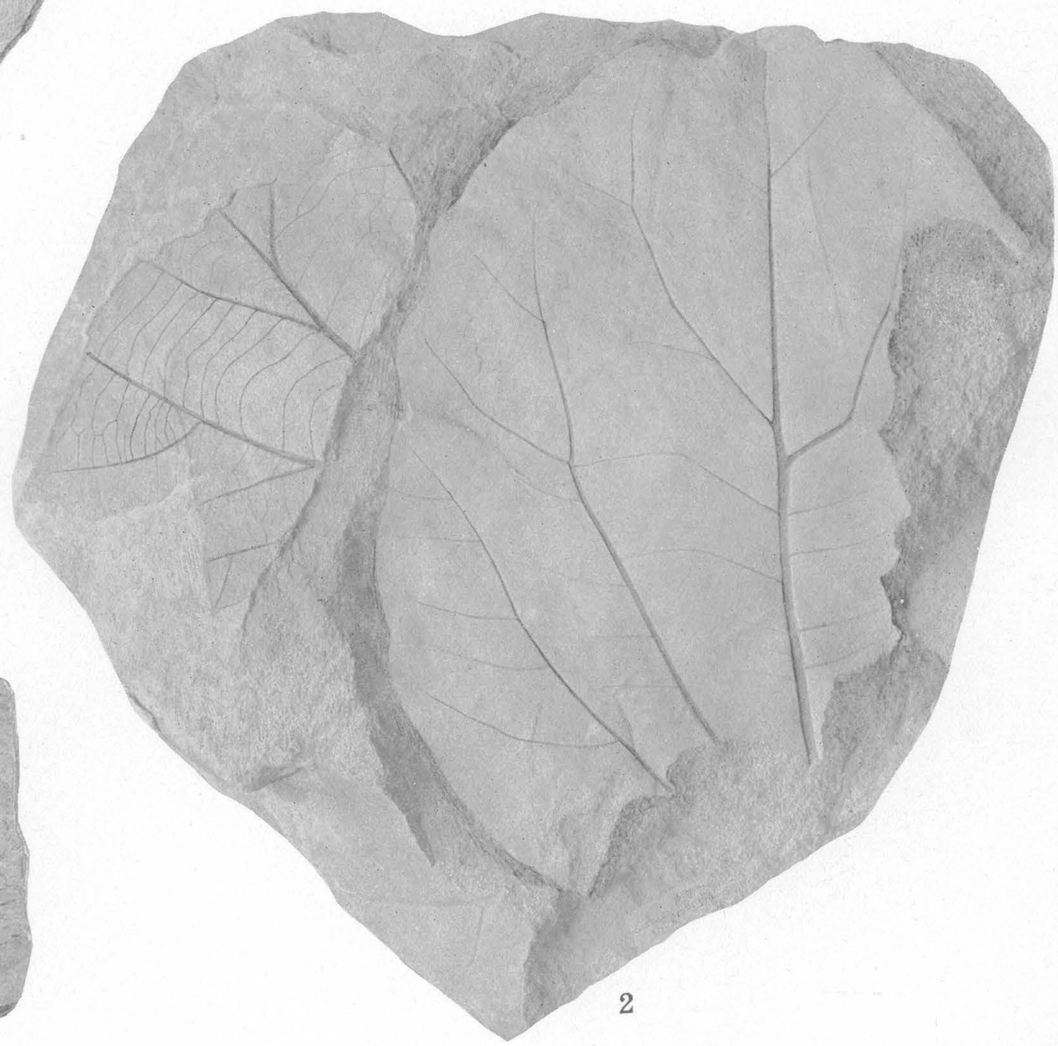

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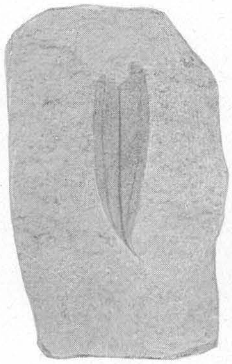

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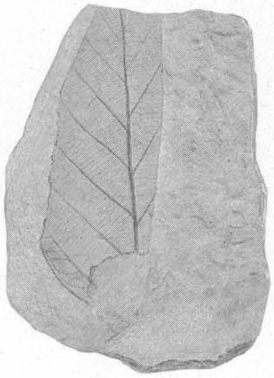

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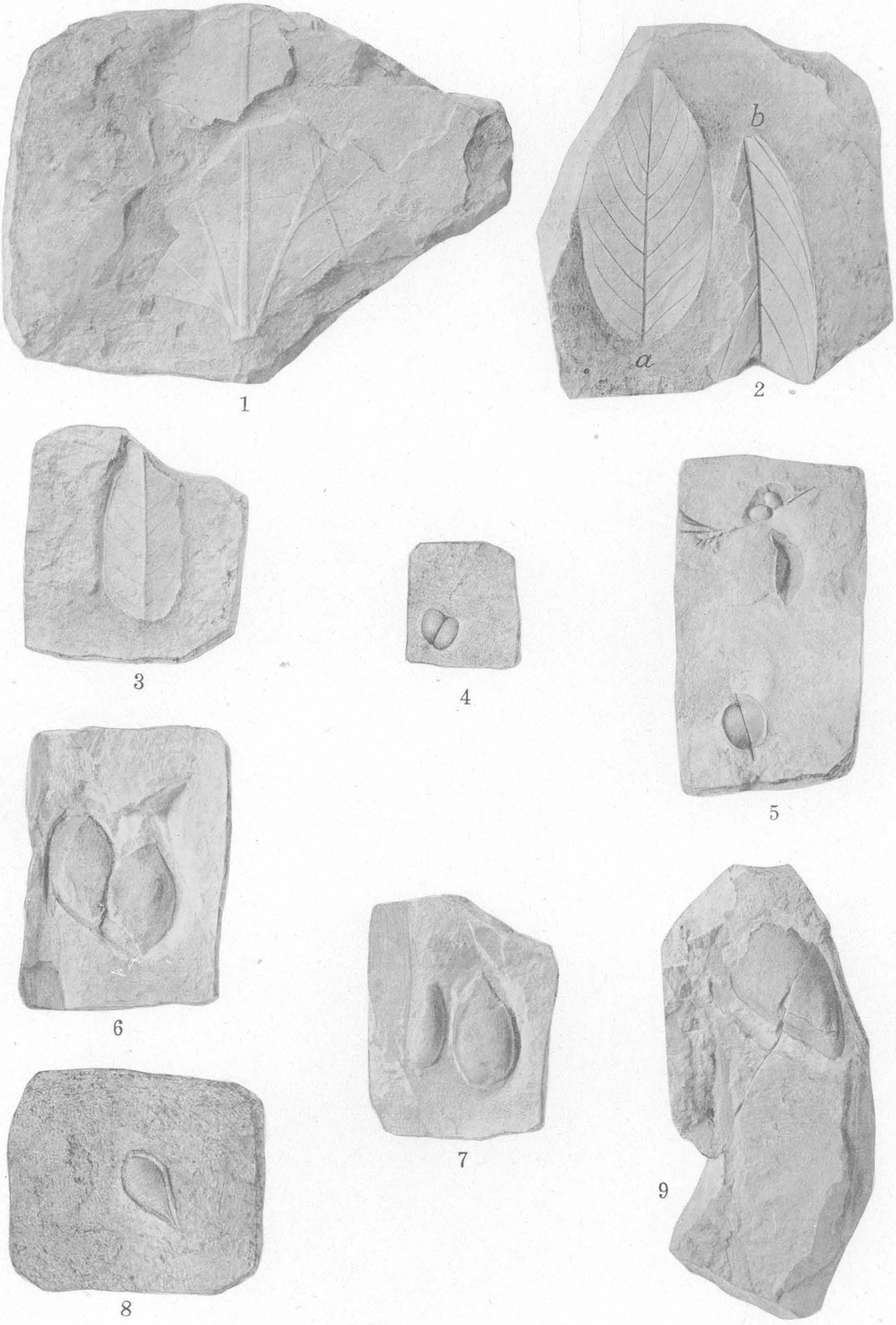
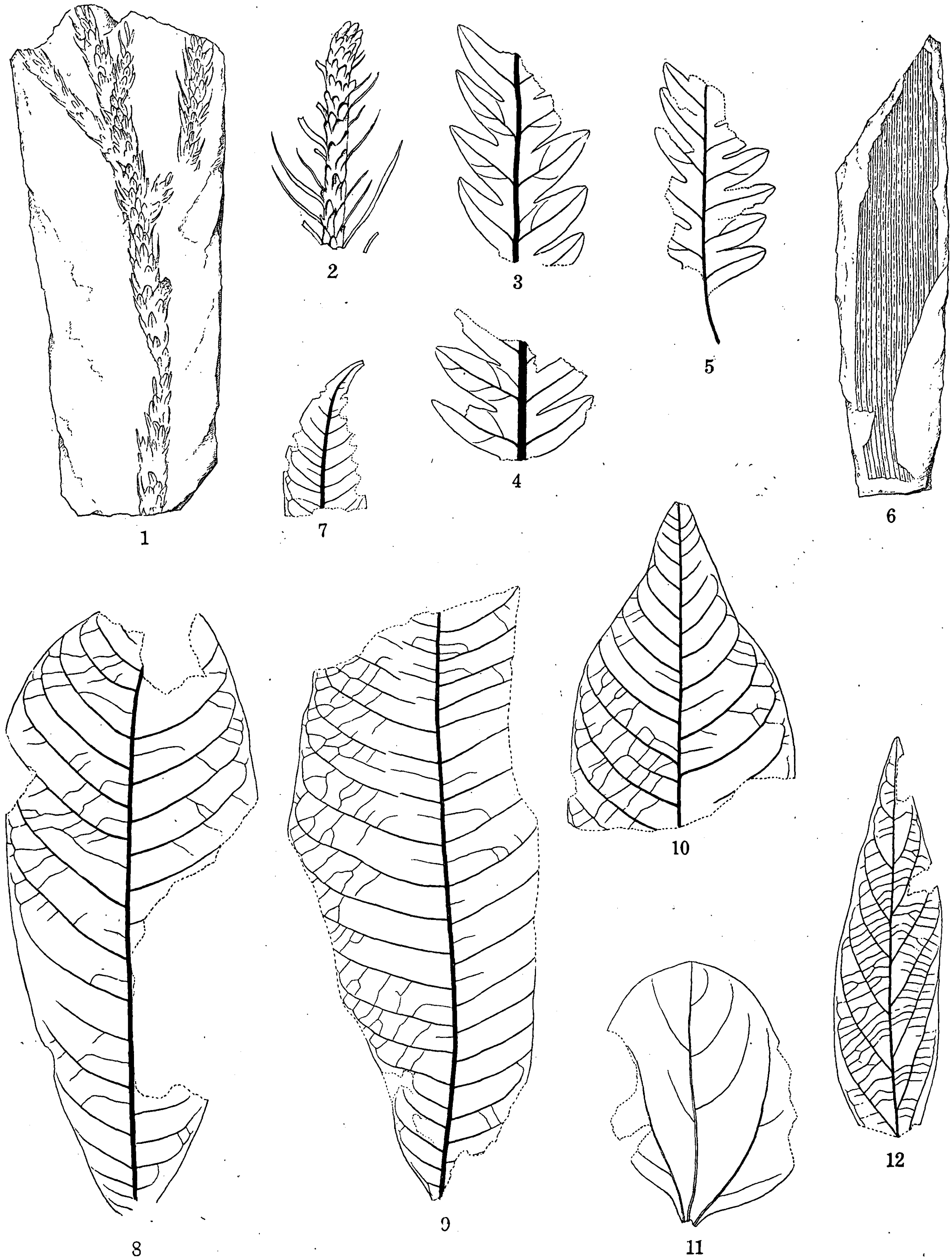
LARAMIE FLORA.

1. *Zizyphus minutus* Knowlton, n. sp.; p. 158.
2. *Phyllites dombeyopsoides* Knowlton, n. sp.; p. 166.
3. *Rhamnus goldianus?* Lesquereux; p. 154.
4. *Anona coloradensis* Knowlton, n. sp.; p. 143.
5. *Phyllites leydenianus* Knowlton, n. sp.; p. 165.



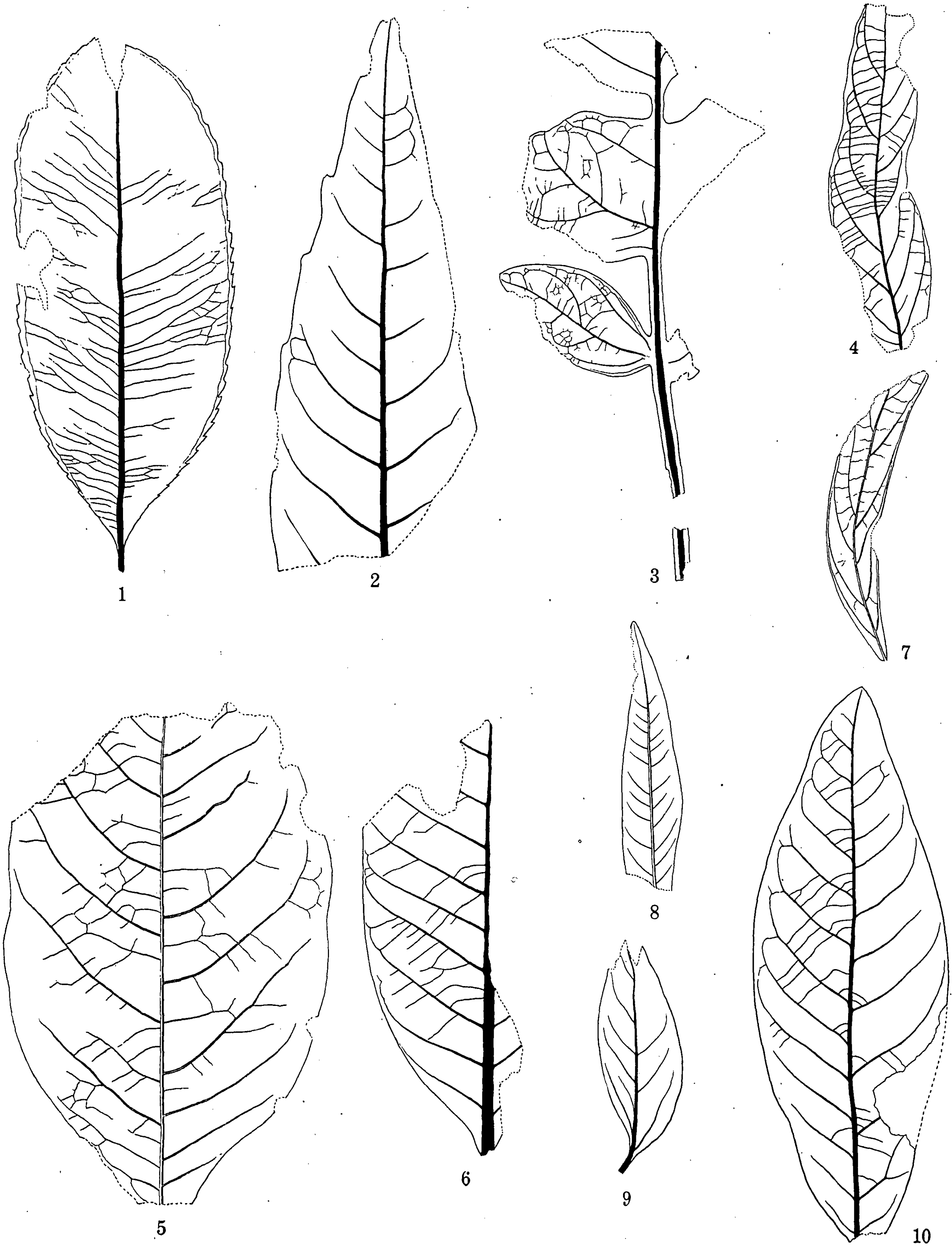
LARAMIE FLORA.

1. *Phyllites* sp.; p. 167.
2a. *Cornus praeimpressa* Knowlton, n. sp.; p. 159.
2a. *Rhamnus salicifolius* Lesquereux; p. 154.
3. *Cassia? laramiensis* Knowlton, n. sp.; p. 148.
4, 5. *Leguminosites columbianus* Knowlton, n. sp.; p. 147.
6-8. *Carpites lakesii* Knowlton, n. sp.; p. 164.
9. *Leguminosites? coloradensis* Knowlton, n. sp.; p. 147.



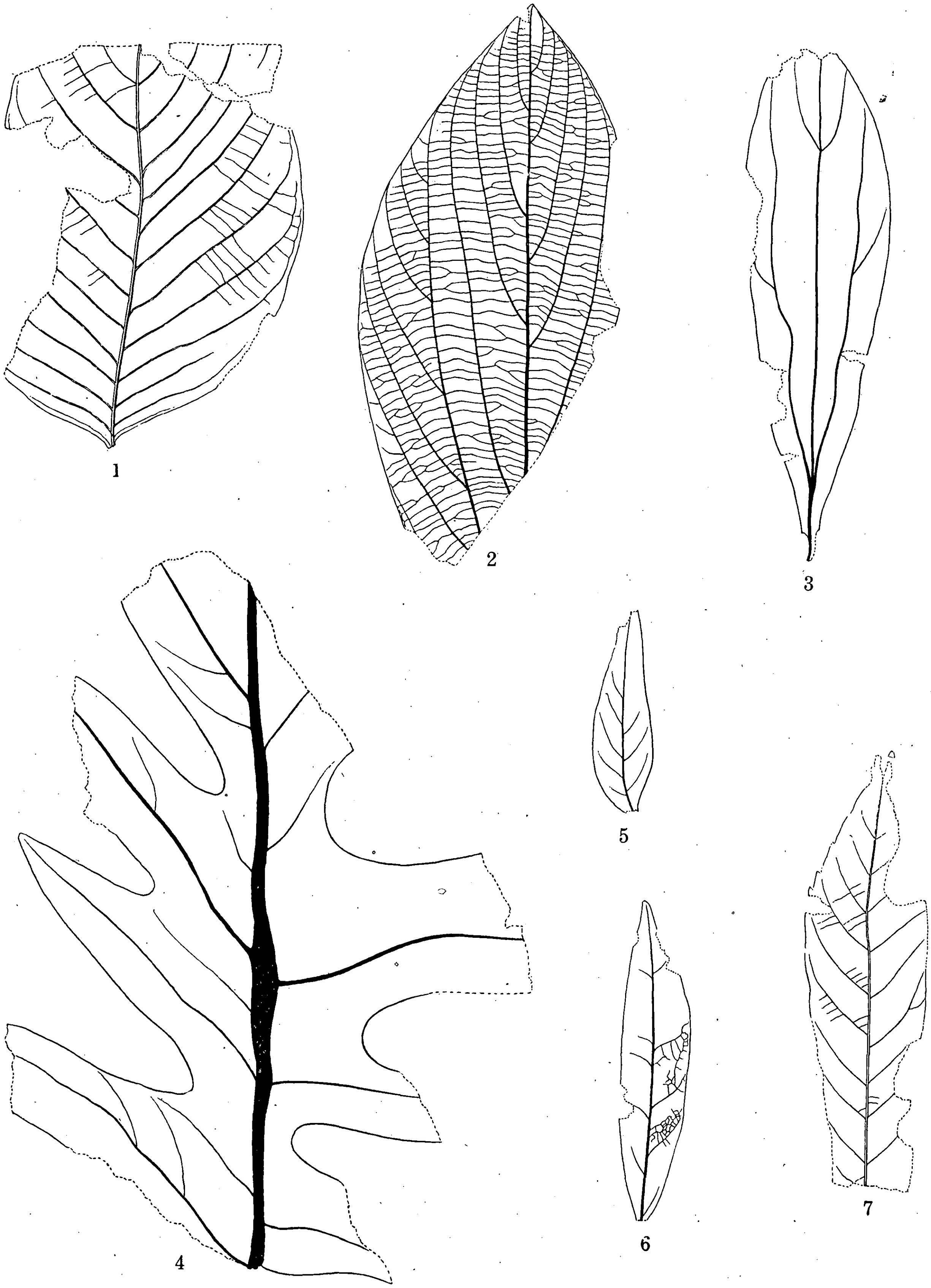
LARAMIE FLORA.

1, 2. *Sequoia reichenbachi* (Geinitz) Heer; p. 114.
3-5. *Dryopteris? carbonensis* Knowlton, n. sp.; p. 110.
6. *Cyperacites? hillsii* Knowlton, n. sp.; p. 116.
7. *Phyllites* sp. (Not described in text.)
8-10. *Juglans newberryi* Knowlton, n. sp.; p. 120.
11. *Dombeyopsis obtusa* Lesquereux; p. 162.
12. *Juglans laramiensis* Knowlton, n. sp.; p. 120.



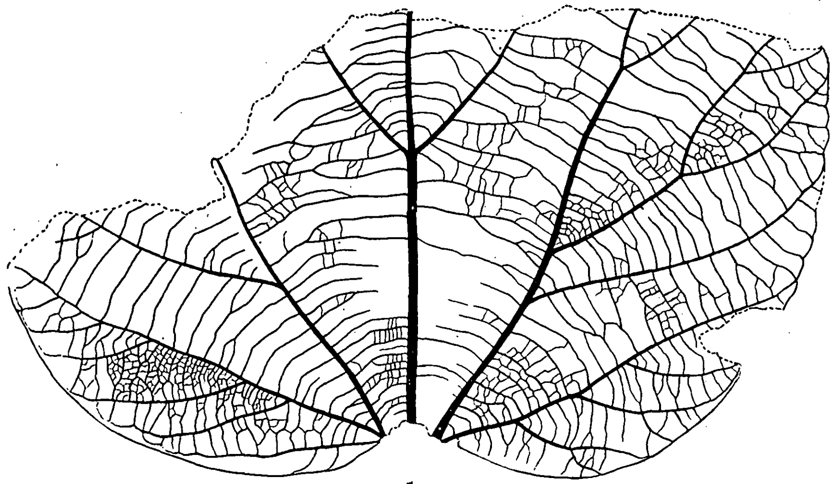
LARAMIE FLORA.

1. *Myrica oblongifolia* Knowlton, n. sp.; p. 124.
2. *Quercus eximia* Knowlton, n. sp.; p. 127.
3. *Artocarpus liriodendroides* Knowlton, n. sp.; p. 129.
4. *Ficus? smithsoniana?* (Lesquereux) Lesquereux; p. 130.
5. *Juglans praerugosa* Knowlton, n. sp.; p. 121.
6. *Ficus arenacea* Lesquereux; p. 140.
7. *Laurus lanceolata* Knowlton, n. sp.; p. 143.
8. *Salix brittoniana* Knowlton, n. sp.; p. 125.
9. *Ficus dalmatica* Ettingshausen; p. 135.
10. *Magnolia marshalli* Knowlton, n. sp.; p. 142.



LARAMIE FLORA.

1. *Ficus coloradensis* Cockerell; p. 134.
2. *Ficus praeplanicostata* Knowlton, n. sp.; p. 133.
3. *Cinnamomum laramiense* Knowlton, n. sp.; p. 146.
4. *Artocarpus lessigiana* (Lesquereux) Knowlton; p. 128.
5. *Ficus dalmatica?* Ettingshausen; p. 135.
6. *Laurus lakesii* Knowlton, n. sp.; p. 144.
7. *Fraxinus? princetoniana* Knowlton, n. sp.; p. 161



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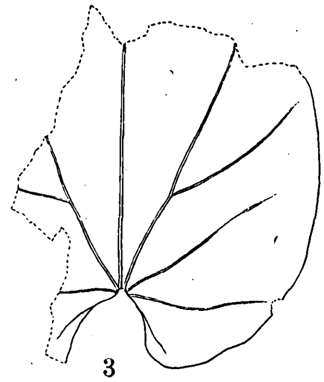

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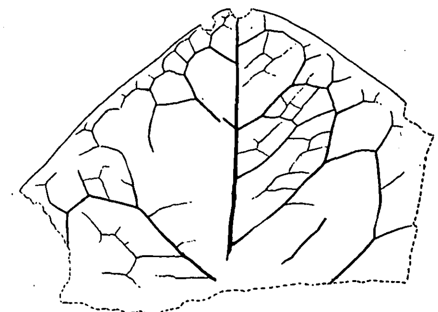

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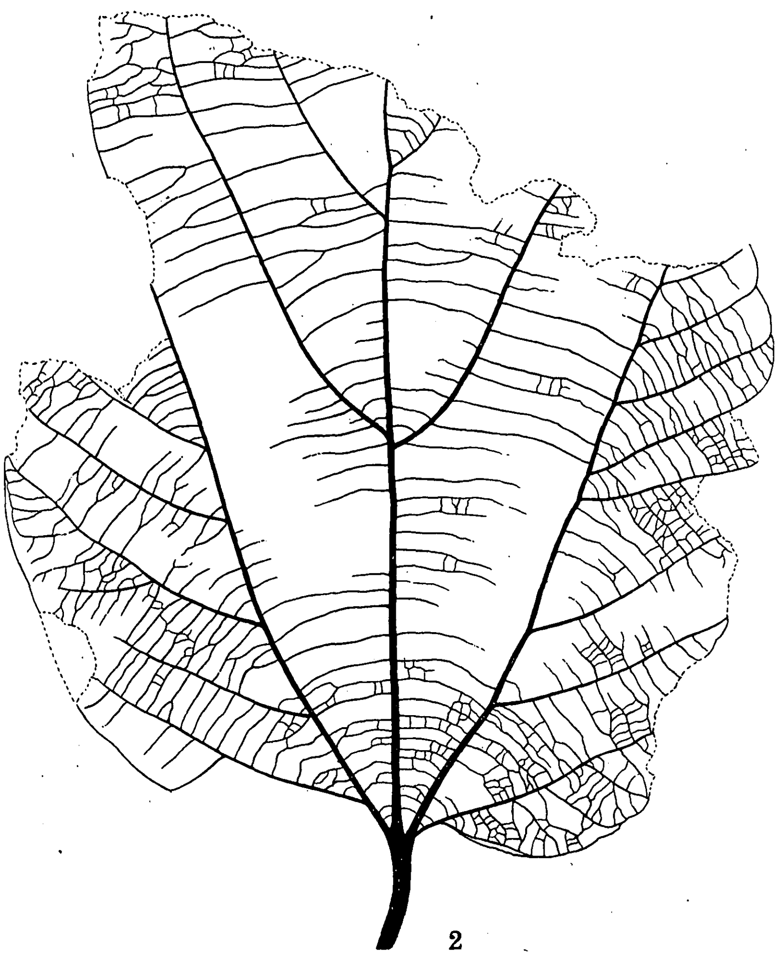

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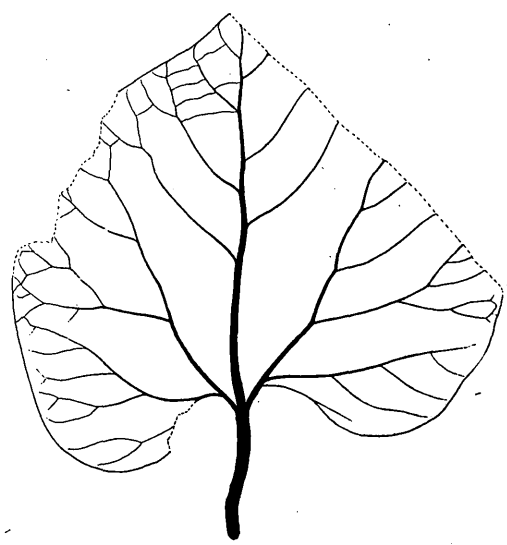

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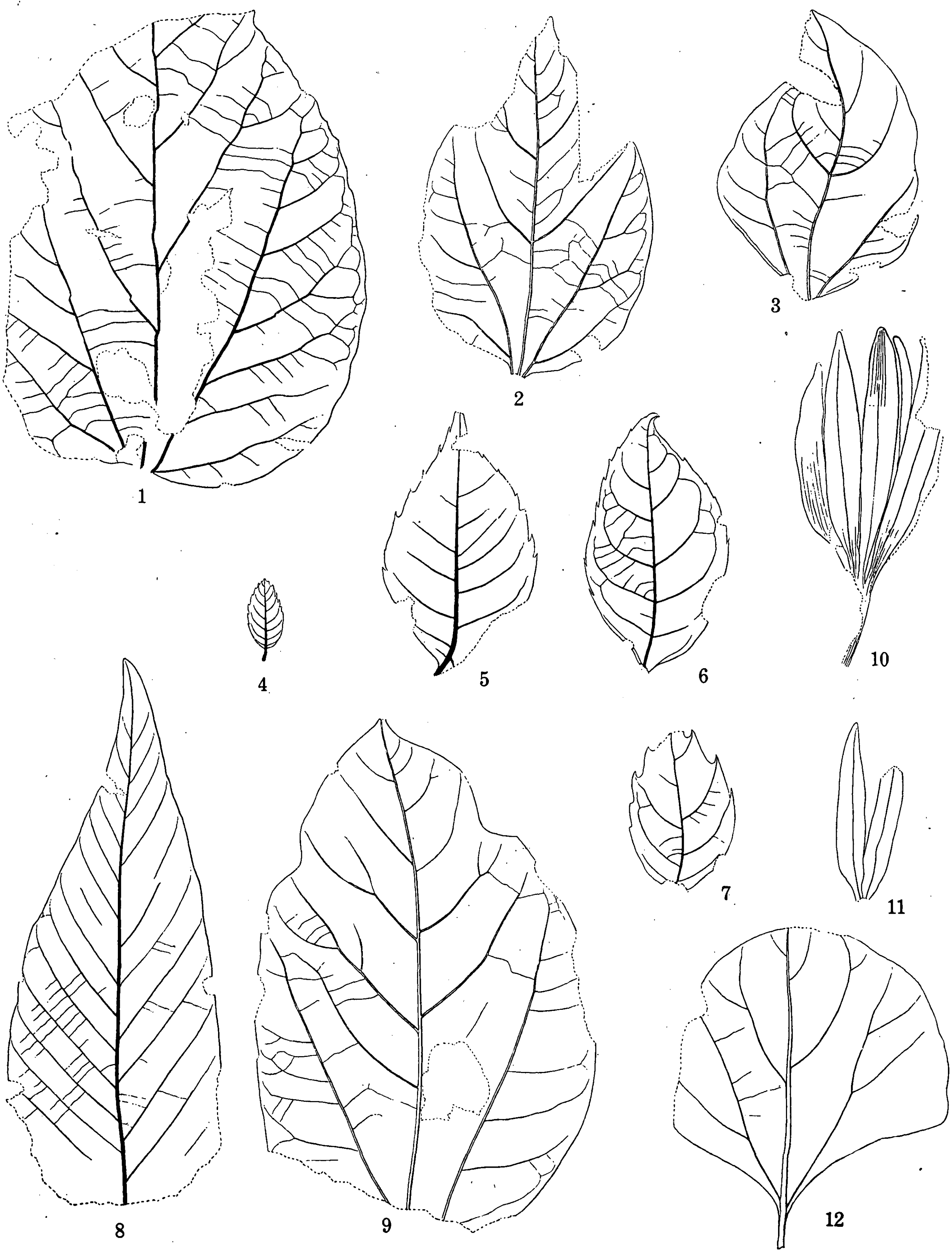
LARAMIE FLORA.

1, 2. *Ficus cockerelli* Knowlton, n. name; p. 132.

3-5. *Aristolochia brittoni* Knowlton, n. sp.; p. 140.



LARAMIE FLORA.

1-3. *Dombeyopsis ovata* Knowlton, n. sp.; p. 164.
4-7. *Ilex laramiensis* Knowlton, n. sp.; p. 152.
8. *Rhamnus brittoni* Knowlton, n. sp.; p. 156.
9. *Dombeyopsis ovata* Knowlton, n. sp.; p. 164.
10, 11. *Palaeoaster? similis* Knowlton, n. sp.; p. 167.
12. *Phyllites trinervis* Knowlton, n. sp.; p. 166.

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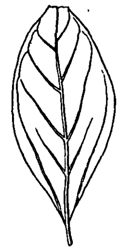

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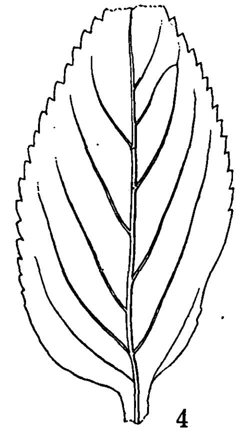

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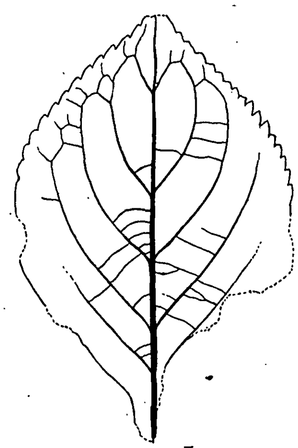

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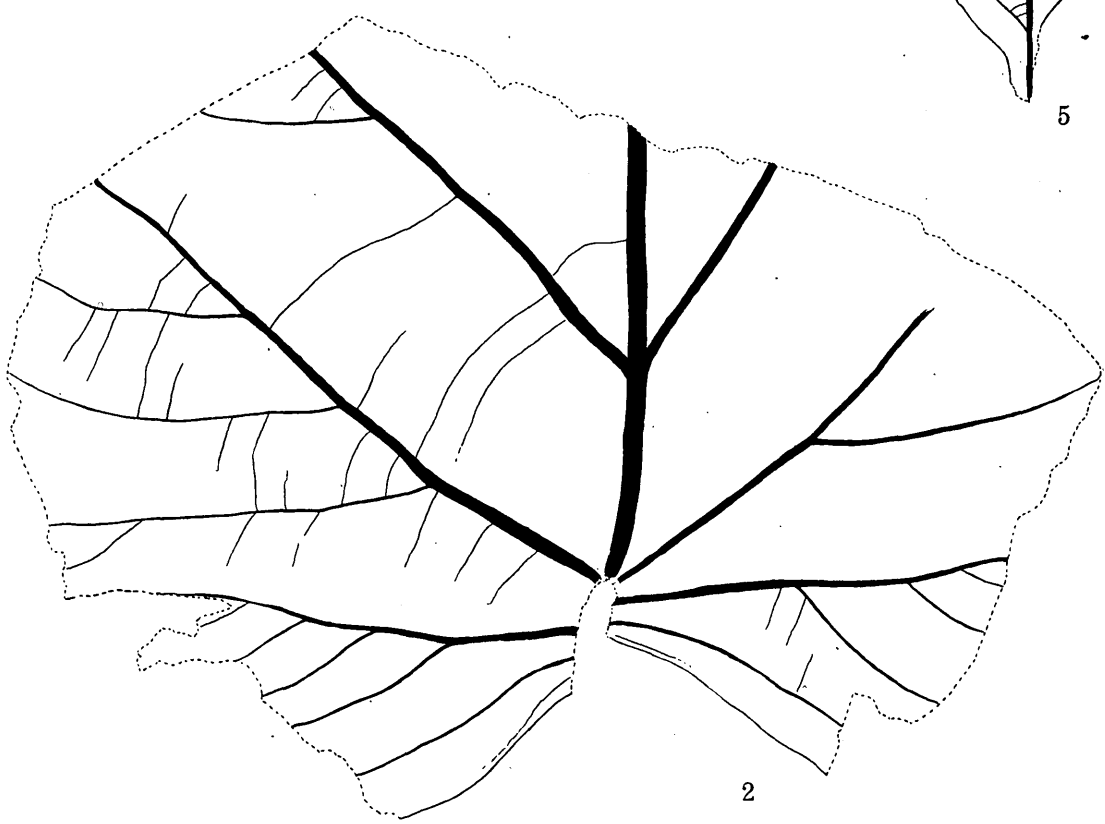

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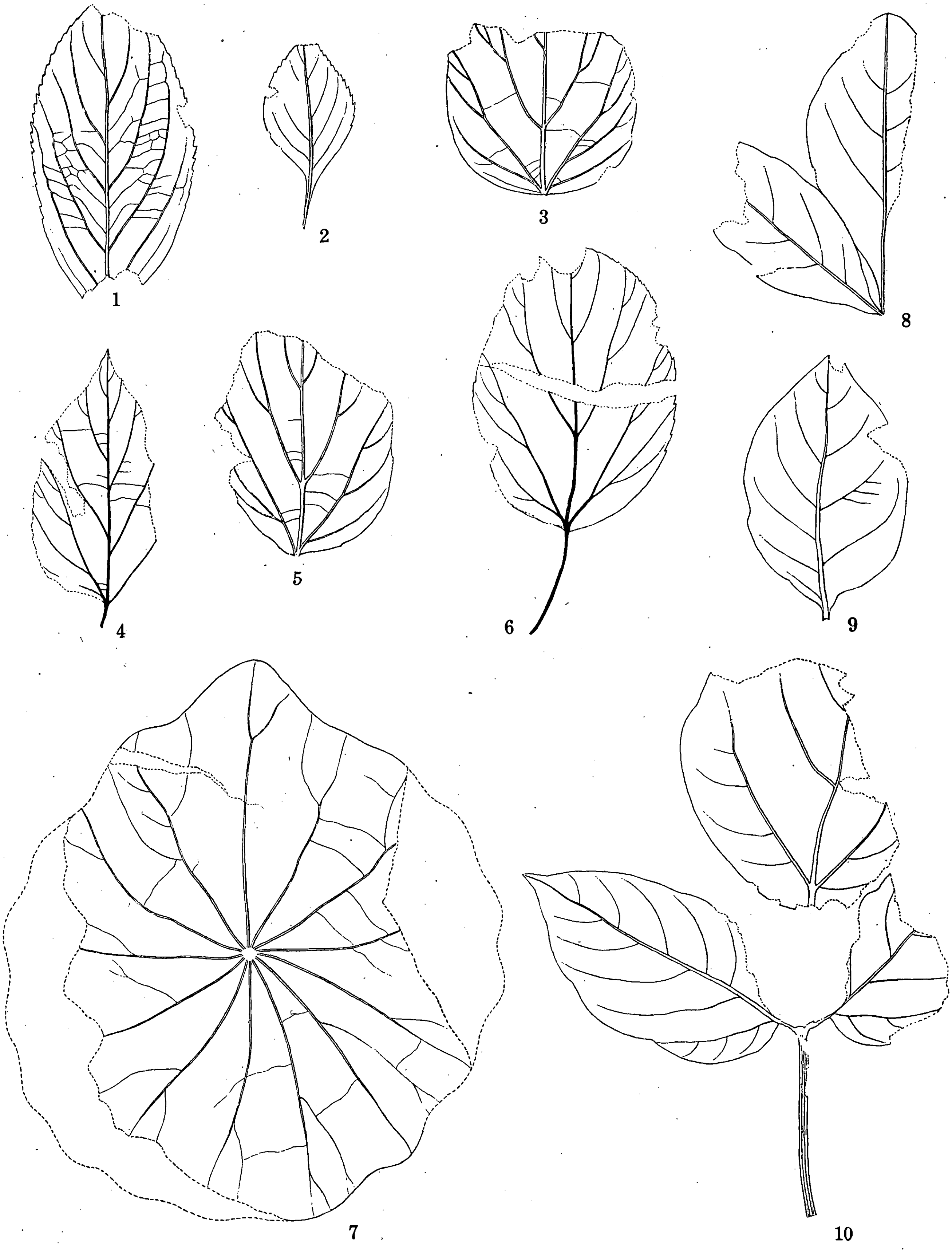
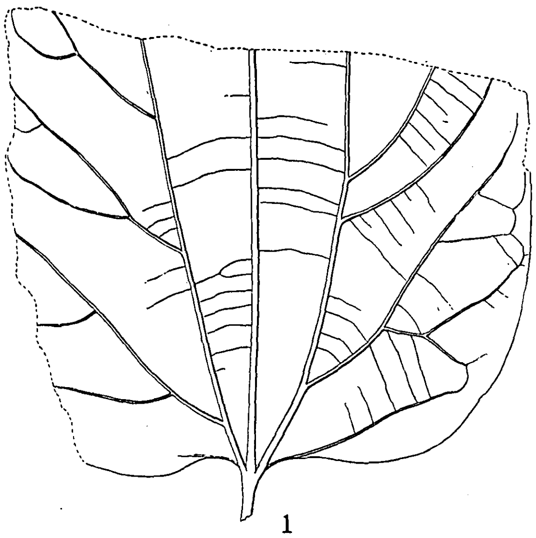
LARAMIE FLORA.

1, 2. *Dombeyopsis? sinuata* Knowlton, n. sp.; p. 163.
3. *Ceanothus ovatifolius* Knowlton, n. sp.; p. 153.
4, 5. *Celastrinites alatus* Knowlton, n. sp.; p. 148.



LARAMIE FLORA.

1. *Celastrinites alatus* Knowlton, n. sp.; p. 148.
2. *Celastrinites eriensis* Knowlton, n. sp.; p. 149.
3-6. *Ceanothus eriensis* Knowlton, n. sp.; p. 152.
7. *Nelumbo tenuifolia* (Lesquereux) Knowlton; p. 141.
8-10. *Negundo brittoni* Knowlton, n. sp.; p. 149.



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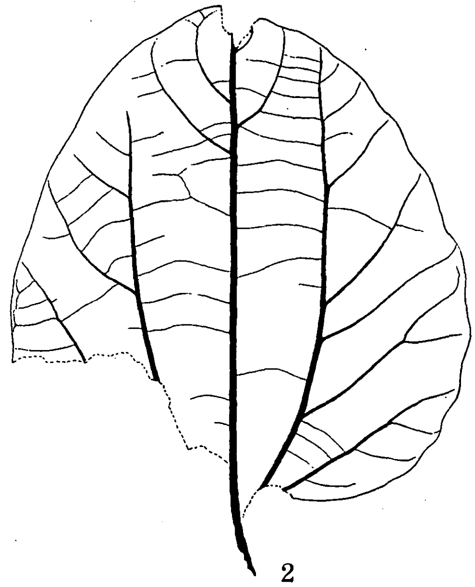

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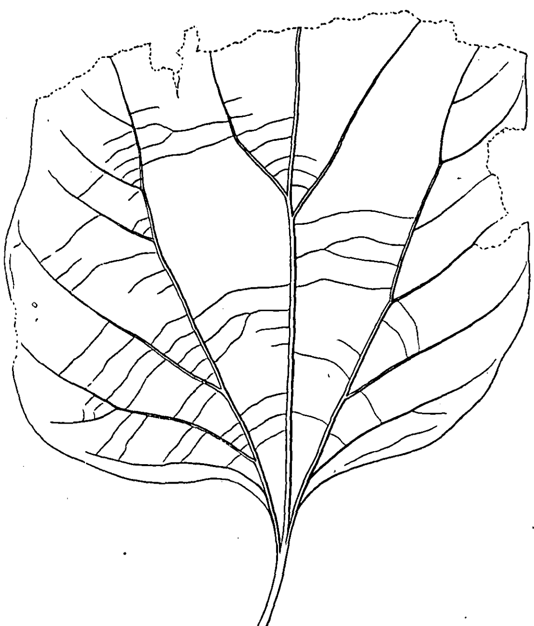

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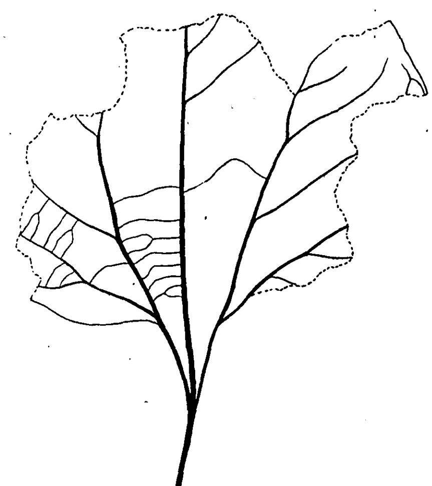
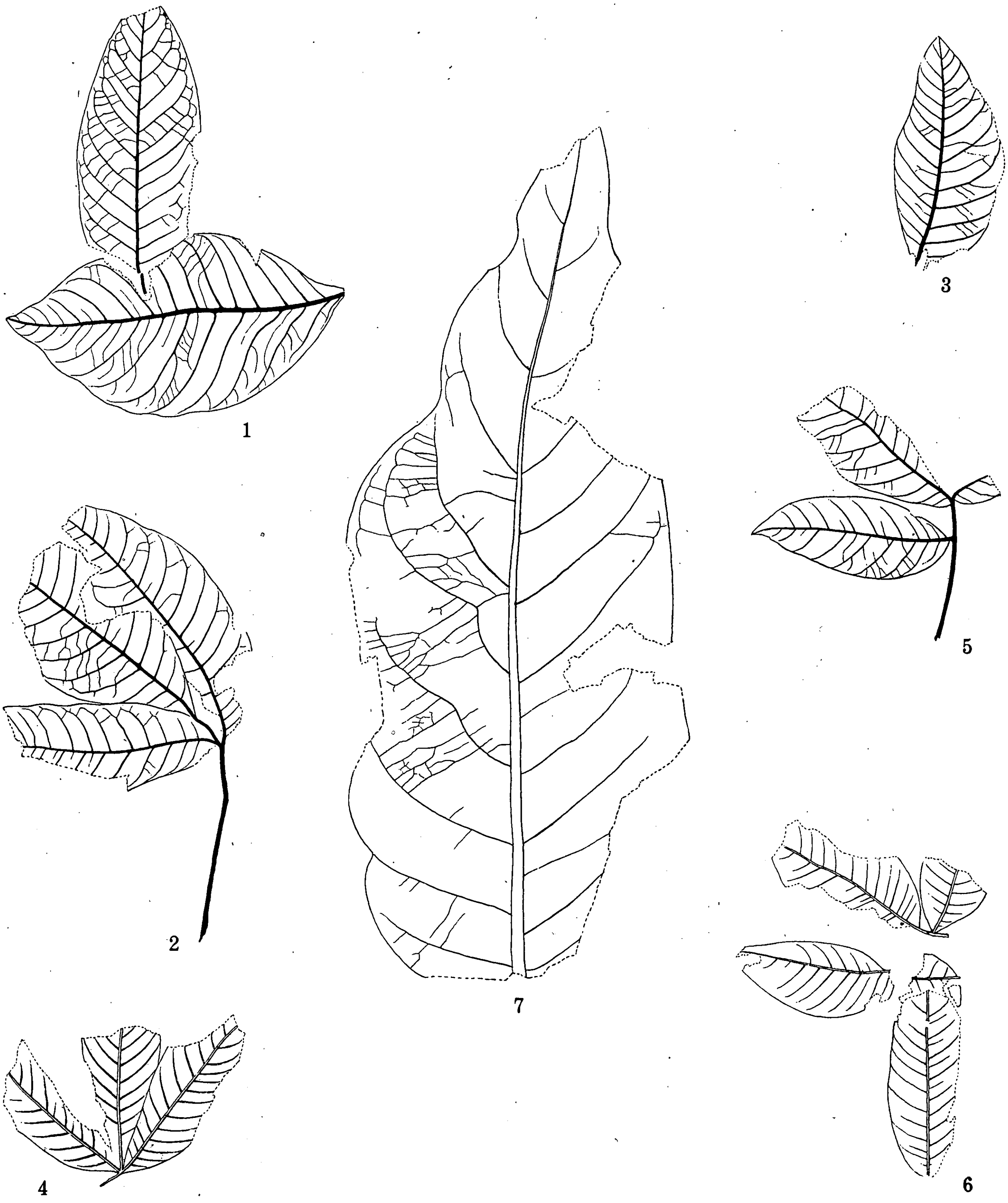


4

LARAMIE FLORA.

1-4. *Dombeyopsis obtusa* Lesquereux; p. 162.



LARAMIE FLORA.

1-4. *Pistacia eriensis* Knowlton, n. sp.; p. 150.
5, 6. *Pistacia hollicki* Knowlton, n. sp.; p. 151.
7. *Phyllites marshallensis* Knowlton, n. sp.; p. 165.

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[Names in *italic* are synonyms; figures in **black face** refer to descriptions.]