PROCEEDINGS

OF THE

WASHINGTON ACADEMY OF SCIENCES

VOL. XI, No. 3, PP. 179–238 August 14, 1909*

THE STRATIGRAPHIC RELATIONS AND PALEONTOLOGY OF THE "HELL CREEK BEDS," "CERATOPS BEDS" AND EQUIVALENTS, AND THEIR REFERENCE TO THE FORT UNION FORMATION.[1]

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CONTENTS.

*Author's separates of this paper were distributed June 25, 1909.

[1] Published with the permission of the Director of the U. S. Geological Survey.

This paper was read before the National Academy of Sciences on April 22, 1909, under the title: "Stratigraphic relations and Paleontology of the lower member of the Fort Union Formation," the title finally selected having been decided upon too late for printing in the Programme of the Academy meetings.

Introduction.

Problem and conclusion.

The present paper deals with the extensive series of fresh-water deposits of the northwest (*i. e.*, broadly, the region east of the Rocky Mountains and between Wyoming and the valley of the Mackenzie River) comprising what is 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"[2] 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.

Historical Summary.

To all students of the late Cretaceous and early Tertiary formations of the northwest, the Fort Union formation is a familiar term. The name was originally given by Dr. F. V. Hayden[3] in 1861 to his great lignite group which: "Occupies the whole country around Fort Union, extending north into the British possessions, to unknown distances; also southward to Fort Clark." At the same time it was stated that the formation had also been observed under the White River group on the North Platte River above Fort Laramie, and on the west side of the Wind River Mountains. The beds were described as consisting of clays and sands, with round ferruginous concretions, and numerous beds, seams and local deposits of lignite. The fossil contents were very abundant, consisting of great numbers of dicotyledonous leaves, fresh-water shells of several genera, scales of *Lepisosteus*, together with bones of *Trionyx*, *Emys*, *Compsemys*, crocodiles, etc. The abundant fossil plants obtained by Doctor Hayden were submitted to Dr. J. S. Newberry for study, and his report on them was published in 1868.[4] The plants were collected at various points on the Missouri River, at Fort Clarke, at Red Spring thirteen miles above, at Fort Berthold, at Crow Hills, one hundred miles below Fort Union, at the mouth of the Yellowstone, on O'Fallon's Creek one hundred miles above the mouth of the Yellowstone, and in the valley of that stream. On account of their association with invertebrates reported by Professor Meek to be of Miocene age, as well as from their agreement with plants stated by

[2] In this paper the terms "Hell Creek beds," "Ceratops beds," "Lance Creek beds," "Somber beds," "Upper Laramie" and "Black Buttes beds" are placed within double quotation marks because these terms have not been formally adopted by the U. S. Geological Survey. In other cases, *e. g.*, 'Fox Hills,' 'Laramie' etc., single quotation marks are used only when the beds are not regarded by the writer as properly identified.

[3] Proc. Acad. Sci. Phila., 1861, p. 433.

[4] Ann. N. Y. Lyc., vol. 9, April, 1868, pp. 27–76.

Heer to be of this age from the mouth of the Mackenzie River, in Greenland, Spitzbergen, and various European localities, Doctor Newberry was led to refer them to the Miocene. Subsequent events have shown, however, that the position assigned the above mentioned beds by Heer was too high, and as a consequence it has come to be recognized that the Fort Union beds are beyond question of Eocene age. This result, however, was not reached without much diversity of opinion and conflict of authority.

It is largely to the efforts of Dr. J. S. Newberry that we are indebted for keeping alive the question of the distinctness of the Fort Union from the typical Laramie. From the beginning of his studies of the Fort Union flora, until his latest utterance on the subject, he insisted upon their separation. His last words concerning it are as follows:[5]

> 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 flora 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. . . . Moreover, the grouping of the plants comprising it gives it a facies which enables one to recognize it at a glance. The abundance of species 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.

That it is of Tertiary age is no longer seriously questioned.

Areal Distribution and Lithologic Character of Fort Union Formation.

The Fort Union formation, as now known, covers a vast area in the central Canadian provinces and, as predicted by Doctor Hayden, touches the Arctic Ocean in the valley of the Mackenzie River, while to the southward it is the surface formation over much of the western

[5] Trans. N. Y. Acad. Sci., vol. 9, 1889, pp. 30, 31.

half of North Dakota, eastern Montana as far west as the Bridger Range, western South Dakota, eastern and central Wyoming, and northwestern Colorado. It is a fresh-water formation, consisting of comparatively fine material, mainly clay shale, sands and soft sandstones, with numerous beds of lignite and occasional thin beds of impure limestone. Owing to the many alternations of soft rocks with thin hard layers extensive erosion has given rise to the well-known bad-land topography so characteristic of much of the area covered by the formation in Montana, North Dakota and Wyoming. The maximum thickness of the Fort Union exceeds 8000 feet. It rests, sometimes in apparent conformity and in other cases with unconformity, on various underlying formations. The relationship with lower beds will be discussed later.

Division of Fort Union Formation into Two Members.

In many cases—notably in the vicinity of Hell Creek, along the Yellowstone River at Miles City and Glendive, Montana, adjacent southwestern North Dakota, and east of the Bighorn Mountains in Wyoming—it is possible to separate the Fort Union into two members on the ground of a marked difference in lithologic character. The upper member is composed in the main of light-colored, yellowish sandstones and clays, while the lower member is made up of many alternating beds of clay shale and sandstone of a dark gray or somber hue, whence, as a convenient field term, they have often been designated the "somber beds." The contact of the lower and upper members is so sharp, and the contrast in coloration so marked, that they may usually be recognized at a distance and traced with little difficulty. In certain parts of the area a thick bed of coal, or a bed of red baked clay due to the burning out of the coal, marks the point of contact. The present paper deals only with the stratigraphic relations and paleontology of the lower member.

The dark gray so-called "somber beds" of eastern Montana naturally attracted the attention of those who visited this region. From their stratigraphic position and the sharp lithologic contrast between them and the overlying beds, they were presumed to belong to the Laramie, but recently secured paleobotanical and stratigraphic data shows that they have little or no relation to the Laramie,

and must be considered as the lower member of the Fort Union. So far as known to the writer the Laramie is not present in this general region.

Areal Distribution and Paleontologic Contents of Lower Member of Fort Union Formation.

1. Hell Creek, Montana.

In 1907 Mr. Barnum Brown[6] published a valuable contribution on the geology of the Hell Creek region of northeastern Montana. To the beds in this area which contain a rich dinosaur fauna he gave the name Hell Creek beds, and also stated that:

> These beds are exposed on the Yellowstone River at Sentinel [Castle?] Butte near Forsyth; at Glendive; near Eklaka; and at Hockett P. O., south of the Yellowstone. They are probably continuous with the dinosaur-bearing beds of the Little Missouri, and of the Grand and Moreau Rivers.

The "Hell Creek beds," which are between 300 and 400 feet in thickness, are stated by Brown to rest unconformably on the Fox Hills, and are composed of two members, a basal massive sandstone, and an upper member of alternating dark arenaceous clays, carbonaceous shales and sandstones. Overlying the dinosaur clays, and forming an "uninterrupted continuation" of them, are the so-called lignite beds 100 feet in thickness which are characterized by the presence of numerous beds of coal; they are referred by Brown with question to the Fort Union. Above the lignite beds without apparent break are the light-yellow sandstones and clays of the "identified Fort Union." At several points in the "Hell Creek beds," but particularly in the massive basal sandstone, Brown records the presence of numerous concretions which are sometimes of very irregular shape, but often resemble huge tree-trunks. It is perhaps noteworthy that similar concretions occur in approximately the same stratigraphic position at widely scattered localities within this lower member of the Fort Union, as at Forsyth, Miles City, near Glendive, Montana,

[6] Bull. Am. Mus. Nat. Hist., vol. 23, 1907, pp. 823–845.

between the Grand and Moreau Rivers, South Dakota[7] and Converse County, Wyoming.

The fauna of the "Hell Creek beds" is a comparatively rich one, comprising a few mammals, numerous dinosaurs belonging to the families Ceratopsidæ, Trachodontidæ, etc., together with crocodileans, turtles, scales and vertebræ of fishes, and some thirty species of invertebrates, mainly Unios. On the basis of the identity of many genera and species of both vertebrates and invertebrates, as well as on the striking lithologic similarity, the "Hell Creek beds" of Montana are correlated by Brown with the "Ceratops beds" of Converse County, Wyoming, a correlation confirmed by Hatcher and Lull in the recently published monograph of the Ceratopsia.[8]

Up to the time of the publication of Brown's paper (1907), but few fossil plants had been found in the "Hell Creek beds," and these in only the upper member. Dr. Arthur Hollick, to whom they were submitted, identified *Equisetum lævigatum* Lesq., *Rhamnus salicifolius* Lesq., *Ficus spectabilis* Lesq., *Pterospermites* sp., *Sequoia heerii* Lesq., and a mass of seeds resembling *Sabalites fructifer* Lesq. To these I was able to add a peculiar undescribed *Ficus* fruit, which has also been found in Converse County and at Forsyth. In the past season, however, Mr. Brown was fortunate in securing a fine collection of leaves in direct association with the skeleton of a dinosaur. This collection, which he has kindly permitted me to study, embraces the following species:

Big Dry Creek, 60 miles south of Glasgow, Montana. Clays between middle and basal sandstones and in association with skeleton of a dinosaur.

Sequoia nordenskiöldi Heer.
Taxodium occidentale Newb.
Ginkgo adiantoides (Ung.) Heer.
Populus cuneata Newb.
Populus amblyrhyncha Ward.
Quercus sp. (Same as at Glendive.)
Ficus artocarpoides Lesq.
Sapindus affinis Newb.

East side of Big Muddy Creek, 28 miles south of Lisner, Montana. 250 feet above Fox Hills.

Sequoia heerii Lesq.

[7] Todd, Am. Geol., vol. 17, 1896, pp. 347–349.
[8] Mon. U. S. Geol. Surv., No. 49, 1907, p. 184.

Ficus sp. (Same as found at Forsyth, Montana, and Ceratops beds of Converse County.)
Viburnum antiquum (Newb.) Hollick.

2. MILES CITY, MONTANA AND VICINITY.

In 1907 Messrs. A. J. Collier and C. D. Smith, while engaged in coal classification work, surveyed about 1000 square miles of country comprising the so-called Miles City, Montana, coal field. With the exception of some unimportant alluvial deposits in the valleys, all the rocks of the region were found to belong to the Fort Union formation, which they show is comprised of two members. The lower member, which corresponds to the "Hell Creek beds" just described, is about 500 feet in thickness, but the base is not exposed; however, from the comparison of the Miles City section with that at Glendive, about 70 miles to the northeast, it is inferred that the base is not very deeply buried. Collier and Smith[9] give the following detailed section of the lower member of the Fort Union formation at Miles City, which is here presented entire to show not only the varied character and coloration of the beds but the relative positions of the paleontological material obtained.

Section of the lower member of the Fort Union formation near Miles City, Montana.

	ft.	in.
Limestone at base of upper member	3	
Shale, white	7	
Coal and shale, dark		6
Shale, gray	20	
Limestone, weathering brown	1	
Shale, light gray	10	
Shale, dark gray	8	
Limestone, weathering reddish brown		6
Shale, dark yellow	6	
Coal	6	
Shale, gray	21	
Limestone, weathering light red	1	
Shale, gray	25	
Sandstone, white, with limestone concretions	8	
Shale	2	
Sandstone	8	
Shale, white	2	

[9] Bull. U. S. Geol. Surv., 341A, 1908, pp. 39, 40.

	ft.	in.
Shale, gray	5	6
Sandstone, gray	20	
Limestone, weathering red		3
Sandstone, gray	4	
Limestone, weathering red		6
Sandstone, gray	4	
Coal and shale	1	10
Sandstone, gray	3	6
Limestone, weathering light red	1	6
Shale, dark	3	
Limestone, weathering red		3
Sandstone, gray	2	
Coal		8
Shale, yellow	5	
Limestone, weathering light red		8
Shale, gray	13	
Limestone, weathering red		6
Sandstone, fine gray	3	
Limestone, weathering red		2
Sandstone, gray	2	
Limestone, weathering red		2
Sandstone	5	
Coal (Weaver bed) (D)	2	4
Shale		5
Coal	1	3
Shale		10
Coal		6
Shale		6
Coal		3
Shale, sandy, dark yellow	6	
Limestone, brittle		6
Shale, dark gray	5	
Shale, fissile, dark brown	4	6
Coal		6
Shale, gray, with numerous limestone concretions	17	
Limestone, weathering red		6
Shale, dark, with thin layers of red limestone	10	
Sandstone, brown, containing fragments of carbonaceous material	7	
Coal	1	6
Shale, light gray	9	
Limestone, red		2
Shale		3
Coal		3
Shale, blue	8	
Coal, with three small streaks of bone	3	4
Sandstone	6	
Shale	4	

	ft.	in.
Sandstone	2	6
Shale	3	
Coal		7
Shale		6
Coal, dirty, with several white partings, one-half inch to 1 inch thick (Laneybed) (C)		5
Shale	1	
Sandstone	2	
Shale	4	
Limestone, weathering red		6
Sandstone, gray with some thin layers of shale	25	
Limestone, weathering red		6
Shale, sandy, yellowish gray	8	
Coal		8
Shale	3	
Sandstone, friable, gray	20	
Shale, sandy, many concretions	5	
Limestone, weathering red	3	
Sandstone, coarse, gray	17	
Limestone, weathering light red		6
Sandstone	3	
Shale, brown with blue bands	10	
Sandstone	6	
Coal and shale	2	
Shale, sandy, gray, usually cross-bedded	50	
Coal		6
Shale, sandy	5	
Coal (Kircher bed) (A)	5	
	465	3

The lower member is "conformably overlain by more homogeneous rocks, mainly sandy shale, which as exposed by erosion are generally of a light-yellow color," thus making the typical upper member.

Plants have been obtained from the lower member in this area as follows:

Six miles east of Miles City and 15 feet above the Kircher coal (A of section, yielded:

Glyptostrobus europæus (Brongn.) Heer.
Populus cuneata Newb.
Populus amblyrhyncha Ward.
Viburnum sp.

Bluffs of Yellowstone opposite Miles City, 115–125 feet above river (C of section):

Marchantia pealei Knowlton.
Onoclea sensibilis ossilis Newb.

Corylus americana Newb.
Populus amblyrhyncha Ward.
Populus cuneata Newb.
Populus nebrascensis Newb.
Populus nervosa elongata Newb.
Populus rotundifolia Newb.
Cornus newberryi Hollick.
Nelumbo sp.
Trapa microphylla Lesq., as determined by Ward.
Cocculus haydenianus Wa d.

Nine miles west of Miles City, Mont. Near N. E. cor., T 7, R. 45. "C" coal.
Onoclea sensibilis fossilis Newb.
Sequoia nordenskiöldi Heer.
Populus cuneata Newb.
Populus daphnogenoides Ward.
Populus speciosa Ward.
Populus arctica Heer of Lesq.
Betula new (nearest *B. coryloides* Ward).
Viburnum antiquum (Newb.) Hol.

Miles City field, S. W. ¼ sec. 22, T. 8, R. 47, about 50 feet below the Big Dirty coal bed.
Celastrus pterospermoides Ward.
Celastrus alnifolius Ward.
Celastrus curvinervis Ward.
Elæodendron polymorphum Ward.
Sapindus randifoliolus Ward.
Grewiopsis populifolia Ward.
Grewiopsis platanifolia Ward.
Diospyros haguei Kn. (small leaf).
Viburnum antiquum (Newb.) Hol.
Populus amblyrhyncha Ward.
Populus sp.?

Klonders ranch, 18 miles east of Miles City; 100 feet below top of "somber beds."
Onoclea sensibilis fossilis Newb.
Gyptostrobus europæus (Brongn.) Heer.
Taxodium occidentale Newb.
Sequoia (cone).
Populus cuneata Newb.
Populus amblyrhyncha Ward.
Sapindus affinis Newb.
Hicoria antiquorum (Newb.) Knowlton.

Signal Butte, 5 miles east of Miles City, 225 feet above base of section:
Taxodium occidentale Newb.
Platanus raynoldsii Newb.

Same locality as last but in upper member of "somber beds:"
Glyptostrobus europæus (Brongn.) Heer.
Taxodium occidentale Newb.

Sequoia nordenskiöldi Heer.
Corylus americana Walt.
Corylus rostrata Ait.
Betula sp.
Populus acerifolia? Newb.
Populus genetrix? Newb.
Hicoria antiquorum (Newb.) Knowlton.
Hicoria sp.
Sapindus grandifoliolus Ward.
Planera sp.
Celastrus ovatus Ward.

At a point on Sheep Creek about 40 miles east of Miles City (Sec. 16, T. 6 N., R. 52 E.) Collier obtained from just above the "D" coal the following vertebrate remains which were determined by Mr. C. W. Gilmore of the United States National Museum:

Champsosaurus sp.
Crocodylus sp.
Dinosaur fragments.
Turtles.
Ganoid fish.
Also a mammal tooth which Mr. J. W. Gidley has identified as *Chriacus?* sp.

On Powder River, about 12 miles above Hockett, Montana, and a few miles south of the above mentioned locality, Brown[10] reports finding parts of a Triceratops skeleton in the dark shale near the level of the stream and states that other fragmentary dinosaur bones were observed. In the vicinity of the Chalk Buttes, 20 miles west of Eklaka, Montana, dinosaur and other vertebrate remains were obtained by an expedition from the Field Museum of Natural History of Chicago. I am informed by Mr. E. S. Riggs, who conducted the party, that the following forms were secured:

A fine skull of *Triceratops calicornis*, two skulls of other species, and a number of other specimens, of *Ceratopsia*, also a carapace and plastron of *Basilemys sinuosa*, and individual bones of *Trachydon* and *Champsosaurus*.

3. FORSYTH, MONTANA.

The characteristic dark sandstones and clays of the lower Fort Union are known to extend as the surface formation for a distance

[10] Bull. Am. Mus. Nat. Hist., vol. 22, 1907, p. 823.

of nearly 20 miles along both sides of the Yellowstone River west of Miles City, and apparently continue uninterruptedly to Forsyth, a distance of about 40 miles. Just south of the town the rocks rise in a steep bluff about 250 feet in height, and consisting mainly of sandy shales with three layers of indurated sandstones. The beds dip greatly to the northeast. In a sandy clay about 75 feet below the top the following rather fragmentary plants were collected:

Fern, probably a *Dryopteris*.
Quercus sp.
Quercus viburnifolia? Lesq.
Lauraceous leaf (same form found in white basal beds at Glendive, Montana).
Aralia sp.
Sapindus affinis Newb.

In the valley of Porcupine Creek, about 6 miles west of Forsyth, the characteristic dark shales of the marine Cretaceous are exposed, and in the usual concretions and lenses of limestone a considerable number of typical Pierre invertebrates were obtained. About one-half mile to the eastward of the fossiliferous marine Cretaceous are the lowest members of the "somber beds," there forming low bluffs and resting on the dark clay shales. The lowest bed is a soft yellowish-white sandstone, above which it becomes massive and brownish in color and often weathers into towers and irregular pinnacles. The beds at this point add probably 100 feet or more to the base of the section as exposed just south of Forsyth, while Chimney Butte on the west side of the Yellowstone, about 6 miles east of Forsyth, exposes beds apparently higher than those above mentioned, making a total thickness of the "somber beds" in this vicinity between 400 and 500 feet.

No plants were found in either the lower or higher beds north of the river, though at a point about 5 miles northwest of Forsyth, in the lower beds, vertebrate remains have been found, and it was probably at this locality that the bones of a large dinosaur were collected some fifteen years ago by Prof. I. C. Russell. In association with the bones were numerous specimens of the undescribed Ficus fruit already mentioned as occurring in the "Hell Creek" and "Ceratops beds."

4. CUSTER, MONTANA, AND VICINITY.

Beyond the point indicated above the conditions to the west and southwest of Forsyth are not definitely known, though the marine Cretaceous extends westward nearly to Myers; but from observations made from a train, it seems not improbable that the "somber beds" may be traced as far as Bighorn or Custer. In any event, beds known to be of this age were observed near the latter place by Mr. L. J. Pepperberg, of the United States Geological Survey, during the past season. The section, there several hundred feet in thickness and resting on one of the upper members of the Pierre, is made up of light colored sandstones and shales. At a point near the top of the exposed section the following small collection of plants was secured:

Four and one-half miles southeast of Bighorn, Montana.
Platanus nobilis Newb.
Populus cuneata Newb.
Sapindus sp.

5. BULL MOUNTAIN, MONTANA, AREA.

The so-called Bull Mountain coal field[11] of Montana covers an area of about 750 square miles, lying mainly to the south of the Musselshell River and some 20 miles north of the Yellowstone River. On the southeast the lower member of the Fort Union presumably connects more or less closely with the area just mentioned near Custer, while to the northeast it will probably be found to extend directly into the Hell Creek area. The beds in question, which are composed of usually light colored sandstones, clays and carbonaceous shales, are about 2000 feet in thickness and rest upon Pierre shale. They have usually been referred on stratigraphic grounds to the Laramie, but there is little question of their belonging to the lower Fort Union, though plants have not thus far been reported from them.

6. MELVILLE, MONTANA, AREA.

The area now to be considered lies east of the Crazy Mountains and about 25 miles north of Big Timber. The geological structure

[11] See Woolsey, Bull. U. S. Geol. Surv., 341A, 1908, p. 60.

in this general region is somewhat obscure—to judge by the different results obtained by the several geologists who have visited it—and owing to the lack of sufficient paleontological data at critical points in the section, it appears that the problem is still short of a complete and wholly satisfactory solution. Thus in 1896 Mr. W. H. Weed[12] published the record of a section taken along Lebo Creek in which he recorded the presence of over 7000 feet of Livingston beds, above which was a thickness of 4000 feet of Fort Union. A few years later Mr. Earl Douglass[13] visited this region, and although within a few miles of the Lebo Creek section of Weed, he failed to note the presence of Livingston rocks, referring this part of the section apparently to the 'Fox Hills' and 'Laramie.' The same area was surveyed by Mr. R. W. Stone[13a] and party in 1907, and while he recognized tentatively the presence of the Livingston it was presumed to be only a few hundred feet in thickness and is located in another part of the section. The succession as worked out by Stone is as follows: Above the highest marine Cretaceous (Bearpaw of the Montana) in the region is a series of red and greenish sandstones 200 to 460 feet in thickness which form a conspicuous ridge, and which was provisionally regarded as a part of the 'Laramie.' The succeeding beds, 1000 to 2400 feet thick, of soft shales and sandstones of a light-gray color, are regarded as the upper part of the 'Laramie.' At this point Stone says:

> 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.

The thickness of the 'Laramie' is approximately 5500 feet, above which comes nearly as great a thickness of Fort Union.

This section as interpreted by the writer is as follows: Above the Bearpaw is a series of shaley sandstones, at least several hundred feet in thickness, that unmistakably belongs to the Livingston, as plants identical with those found near the base of this formation

[12] Am. Geol., vol 18, 1896, pp. 201–211.
[13] Proc. Am. Phil. Soc., vol. 41, 1902, p. 217.
[13a] Bull. U. S. Geol. Surv., 341A, 1908, pp. 76–89.

southeast of Bozeman, Montana, have now been located,[11] and moreover the matrix is characteristically that of the Livingston. Between this point and the base of the upper member of the Fort Union according to Stanton is a thickness of 3000 to 5000 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 2000 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 1000 feet of the top, where the following species have been obtained:

Widdecomb Bros. ranch, northeast of Melville, Montana [sec. 29, T. 6 N., R. 16 E.]

Salix sp.
Populus amblyrhyncha Ward.
Populus cuneata Newb.
Populus genetrix Newb.
Populus daphnogenoides Ward.
Populus sp.
Aralia notata Newb.
Leguminosites arachioi'es Lesq.
Vitis xantholithensis Ward.
Credneria daturæfolia Ward.
Phyllites cupanoides Newb.
Carpites sp.

These plants occur about 1200 feet below the small mammals now being studied by Mr. Gidley and regarded by him as of Torrejon affinities, though scattering remains of mammals have been found down nearly to the horizon of the plants. The nearest point at which dinosaurs occur is stratigraphically about 600 feet below the mammal horizon, according to the collector, while according to Stanton the main Triceratops horizon may be 2000 to 3000 feet below this point.

[11] When this collection was first studied it proved very puzzling, and although no species were positively identified, it was tentatively regarded possibly Laramie or older. Subsequently, however, large collections were made and studied from the Livingston with the result of showing that it clearly belongs to the latter.

7. RED LODGE, MONTANA.

The Red Lodge coal field lies along the foot-hills of the Beartooth Mountains, on the extreme south-central border of Montana. The Fort Union beds in this area show the immense thickness of 8500 feet, the productive coals being confined to a middle portion only about 825 feet in thickness, below which are barren beds 5700 feet thick. According to Mr. E. G. Woodruff[15] who reported on the coals of this region in 1908, the

lowest member is composed mostly of yellowish sandstone and shale. Beginning 1650 feet above the bottom of the formation is a group of beds 1000 feet thick composed of vari-colored sandy shale, with a few beds of soft yellowish sandstone, numerous beds of carbonaceous shale, and in the upper part a few coal beds. Above this group carbonaceous shale and coal beds occur at diminishing intervals as the productive measure is approached.

The lowest point at which Fort Union plants have been found in the section above described is about 700 feet above its base, and on this account this basal 700 feet has sometimes been referred tentatively to the 'Laramie.' In the opinion of the writer it is an inseparable portion of the lower Fort Union.

The exact area covered by the lower Fort Union in this vicinity has not been definitely determined, though it is known to extend to the west of Red Lodge for at least 25 miles, where it was found by Mr. W. R. Calvert resting conformably on the Livingston formation, while to the east it extends nearly to Bridger. To the southeast this area undoubtedly connects with the beds of this age exposed as a ring about the margin of the Bighorn Basin, Wyoming. Plants have been obtained in the Red Lodge area at the following localities:

About 8 miles west of Bridger, Montana.

Taxodium occidentale Newb.
Platanus nobilis Newb.
Platanus haydenii Newb.
Populus amblyrhyncha Ward.
Sapindus grandifoliolus Ward.
Laurus sp.?
Ficus sp.

[15] Bull. U. S. Geol. Surv., 341A, 1908, p. 92.

About 8 or 9 miles west of Bridger, Montana.
Platanus nobilis Newb.
Populus inæqualis? Ward.
About 25 feet below the last collection.
Taxodium occidentale Newb.
Populus cuneata? Newb.
Platanus sp.
About 25 miles northwest of Red Lodge, near center sec. 33, T. 6 N., R. 18 E. 300+ above base.
Platanus raynoldsii Newb.
Same area as last, sec. 36, T. 5 N., R. 18 E. Within 300 feet of contact with Livingston beds.
Aralia notata Newb.
Populus sp.

8. GLENDIVE, MONTANA, AND VICINITY.

Returning to the Miles City field, as already set forth, the conditions are known for 40 miles to the east. Down the valley of the Yellowstone identical conditions prevail to near the vicinity of Iron Bluff where, at the mouth of Sand Creek, some 12 miles southwest of Glendive, an anticlinal fold brings the marine Cretaceous to the surface. The exposure is about 100 feet in thickness above the level of the river, on both sides of which it may be observed. It is upper Pierre (Bearpaw) in age and contains a rich fauna which has been listed by Dr. T. W. Stanton.[16] This exposure, which is known to continue for some distance to the southeast, is thought by Prof. A. G. Leonard[17] to be connected with a similar area along the extreme eastern edge of Custer County, Montana, and adjacent counties in North Dakota.

Immediately above the Pierre, and in apparent conformity, are 150 feet of beds the lower half of which is made up of sandstones and shales, and the upper half of a brownish sandstone. While these beds are in the position of the Fox Hills, their age is in doubt. No invertebrates have been found, the only fossils being two or three small collections of dicotyledonous plants which are so fragmentary as to be undeterminable. According to Leonard[18] they do not

[16] Bull. U. S. Geol. Surv., 316, 1907, p. 196.
[17] L. c., p. 197.
[18] Loc. cit., p. 197.

agree with the Fox Hills beds of the Hell Creek section, and should probably be referred to the lower member of the Fort Union as exposed in this region. The absence of invertebrates and presence of plants in a measure supports this view. On this point Leonard says:

The line of contact between the Pierre and the overlying dinosaur-bearing beds, while not discordant so far as structure is concerned, may possibly represent a time break in which most of the upper fresh- and brackish-water beds of the Cretaceous are wanting.

Overlying the last mentioned beds is a very conspicuous white, massive sandstone 35 to 50 feet in thickness, which first appears at the north end of Eagle Bluff, 2 miles west of Glendive, and persists for many miles up Sand Creek. The upper surface is somewhat uneven, suggesting the possibility of an unconformity, though this may be only local and of little importance. In the middle of this white sandstone, at a point about 5 miles up Cedar Creek, Dr. A. C. Peale collected fragmentary plants, among them *Populus cuneata* Newb., while in the upper portion at Eagle Bluff the following forms were obtained:

Ginkgo adiantoides (Unger) Heer.
Quercus sp.
Lauraceous leaf.
Ficus trinervis Kn.
Ficus or *Sapindus* sp.
Viburnum whymperi Heer.
Viburnum n. sp.

Other localities for plants in the Glendive area are as follows:

Bluff east of Sand Creek, 6 miles above Glendive, Montana, 420 feet above the Pierre.

Taxodium sp.
Ginkgo adiantoides (Unger) Heer.
Salix angusta Al. Br.
Quercus breweri Lesq.
Populus cuneata Newb.

Mouth of Cedar Creek, $11\frac{3}{4}$ miles above Glendive, Montana, 400 feet above Pierre.

Glyptostrobus europæus (Brongn.) Heer.
Sequoia sp.

Populus genetrix Newb.
Corylus rostrata Ait.
Pterospermites minor Ward.
Pterospermites whitei Ward.
Cocculus haydenianus Ward.
Elæodendron polymorphum Ward.

Eight or nine miles above Glendive, Montana, 100 feet above Pierre.

Taxodium sp.
Platanus raynoldsii Newb.
Platanus sp.
Populus amblyrhyncha Newb.
Corylus americana Walt.
Carpolithes lineatus Newb.

Bluffs of Yellowstone River 1½ miles from Glendive, Montana, 400 feet above Pierre.

Onoclea sensibilis fossilis Newb.
Sequoia nordenskiöldi Heer.
Ginkgo adiantoides (Unger) Heer.

Bluffs ¼ mile east of town of Glendive, Montana. Base of bluff or 350 feet from top.

Sequoia sp.
Aralia notata Lesq.

Same locality as last, 195 feet below top.

Carpites sp.
Populus sp.

Same locality, 125 feet below top of bluff.

Equisetum sp.
Thuya interrupta Newb.
Sequoia nordenskiöldi Heer.
Ficus sp.
Carpites sp.

Bluff on west side of Yellowstone River opposite Glendive, Montana, about the same horizon as the last.

Thuya interrupta Newb.
Sapindus grandifoliolus Ward.

Bluffs along Yellowstone River at Harpster's ranch, 10 miles northeast of Glendive, Montana. In upper portion of lower Fort Union.

Equisetum sp.?
Glyptostrobus europæus (Brongn.) Heer.
Populus cuneata Newb.
Populus sp.
Populus sp.
Platanus raynoldsii Newb.
Platanus guillelmæ Göpp.
Sapindus grandifoliolus Ward.
Polygonum n. sp.

A few fragmentary remains of vertebrates have been found in the Glendive area. Thus, Barnum Brown[19] records having found the weathered fore limb of a Triceratops "in the badlands near Glendive at an elevation of about 50 feet above the railroad track," which would bring its position at about 275 to 300 feet above the top of the Pierre. He also adds that "several other fragments of *Triceratops* and Trachodont dinosaurs were seen in this locality but not sufficiently preserved for specific determination."

In the bluffs just east of Glendive Dr. A. C. Peale and the writer secured, in 1907, fragmentary remains of turtles and a single mammal jaw near the base of the bluff, and remains of turtles and fragments of a large dinosaur at a point about 100 feet above the base. It is probable that more careful search in this vicinity would disclose the presence of other localities for vertebrate remains, of which we heard vague rumors from the residents.

9. GLENDIVE, MONTANA, TO MEDORA, NORTH DAKOTA.

The lower member only of the Fort Union is exposed in the immediate vicinity of Glendive, the beds dipping at a very slight angle to the northeast, and it is 12 or 15 miles down the Yellowstone and some miles back from the river, before the yellow beds of the upper member appear. Thus in the valley of lower Seven Mile Creek, which enters the Yellowstone from the north about 10 miles below Glendive, one first passes from near the level of the stream over the dark sandy shales and clays of the lower member for a distance of 6 or 8 miles before the yellow sands and sandy clays of the upper member appear in the bluffs on either side. Probably about 15 miles to the east (the exact point was not noted) of Glendive the lower member has disappeared and the upper member is the surface formation, a condition continuing probably to the valley of the Little Missouri River. Sentinel Butte, North Dakota, which rises 650 feet above the level of the plain in which it stands is entirely in the upper beds (except for a very thin capping of supposed Oligocene containing fish remains), as are at least the upper portions of the bluffs bordering the

[19] Bull. Am. Mus. Nat. Hist., vol. 23, 1907, p. 823.

Little Missouri River. The valley of this stream, according to Leonard and Smith,[20] has a depth of 420 to 440 feet below the surface of the plain in which it has been eroded, and may have cut into the beds of the lower member, though the deep well sunk at Medora carries the section down for a distance of 940 feet below the lowest beds exposed in the region, and this, on the basis of the thickness at Glendive, must be near to the base of the section. The entire thickness of the section in this area, including the beds passed through by the Medora well, is 1720 feet, and it is possible that the upper portion of the lower member of the Fort Union may be exposed, but as this is not definitely known it is omitted from present consideration. In any event all of the numerous finely preserved plants obtained in this region are distinctly of Fort Union age.

10. BISMARCK, NORTH DAKOTA, AND VICINITY.

To the eastward of Medora along the line of the Northern Pacific Railroad Fort Union plants have been collected at a number of points, as at Lehigh, Dickinson, Sims, etc., but as the stratigraphic relations are not definitely known through this region, we may pass on to Bismarck, North Dakota, where the lower member is undoubtedly present. Near the mouth of Apple Creek, about 10 miles southeast of Bismarck, are exposures of soft sandstones and clays of dark-gray color which form a bluff 75 to 100 feet high. Near the base of this bluff at a point 1½ miles above the mouth of Apple Creek the following very fragmentary plants were obtained:

Adiantum? sp.
Salix sp.
Quercus sp.
Ficus sp.
Laurus? sp.
Carpites sp.

The beds mentioned above are not the base of the lower member of the Fort Union, but at a point on the west side of the Missouri River about 20 miles below Mandan, Dr. T. W. Stanton obtained the fol-

[20] Bull. U. S. Geol. Surv., 341A, 1908, p. 15.

lowing plants in shaley sandstone about 100 feet above the top of the Fox Hills:

Taxodium sp.
Populus amblyrhyncha Ward.
Sapindus affinis Newb.
Quercus sp.
Sassafras sp. (Same found in Ceratops beds of Converse County, Wyoming).
Ficus sp. new?
Ficus sp. new.

About 25 miles to the northward of Bismarck, near the town of Washburn, the yellow sands and sandstones of the upper Fort Union appear and become the surface formation as far at least as Coal Harbor. At old Coal Harbor in the bluffs overlooking the Missouri typical Fort Union plants and invertebrates were collected.

II. YULE, BILLINGS COUNTY, NORTH DAKOTA, AND VICINITY.

I am informed by Prof. A. G. Leonard that near Yule, in western Bowman County, North Dakota, the lower member of the Fort Union (dinosaur-bearing beds) again makes its appearance, and is there about 600 feet in thickness. He has kindly prepared the following section:

Section of lower member of Fort Union (dinosaur beds) in the vicinity of Yule, North Dakota.

Typical buff and light-gray shales and sandstones of the Fort Union outcropping on the Little Missouri in the vicinity of Yule, where they are seen resting on the "somber beds."

Somber beds	75 to 100
Shales and sandstones carrying leaves	25 to 50
Somber shales and sandstones	200 to 250
Somber beds containing dinosaur bones. These lie as near as could be estimated, about 200 feet above the unconformity. The vertical range of the dinosaurs was not determined.	
Somber shale and sandstones to unconformity	200
Unconformity	
Sandstone and andy shale; no fossils found in these beds, but they are perhaps Fox Hills	80
Pierre shale yielding abundant typical Pierre shells, exposed	60

This section, it will be observed, is strikingly similar to that at Glendive, Montana, and it is extremely probable, as already pointed out, that it is the same anticlinal fold which brings up the marine Cretaceous in both areas. From the shales and sandstones indicated as carrying leaves in the above section, the following species were obtained:

Taxodium occidentale Newb.
Populus amblyrhyncha Ward.
Pla anus haydenii Newb.
Juglans rugosa? Lesq.
Hicoria antiquorum (Newb.) Kn.
Sapindus affinis Newb.
Viburnum whymperi Heer.
Trapa microphylla Lesq. of Ward.
Cocculus haydenianus Ward.

Professor Leonard has sent specimens of the dinosaur obtained from near Yule to the United States National Museum, and it has been identified by Mr. Gilmore as *Triceratops horridus* (Marsh), this species being the type of the genus.

12. PROBABLE AREA OF LOWER FORT UNION IN NORTHWESTERN SOUTH DAKOTA.

The exact outline of the area covered by the lower member of the Fort Union in southwestern North Dakota is not at present definitely known, nor has its extension to the southward been thoroughly traced, though I am informed by Mr. J. W. Gidley that he has observed dinosaur-bearing beds that are stratigraphically and lithologically similar to the "Ceratops beds" of Converse County, Wyoming, in the country between the Grand and Moreau rivers in South Dakota, on both the east and west sides of Long Pine Hills. From these beds near the eastern base of Long Pine Hills remains of gigantic Trachodont dinosaurs have been exhumed.

Since the above was written Mr. W. R. Calvert has sent in (under date of May 2, 1909) the following collection from McCord coal bank in N. W. ¼, Sec. 5, T. 129 N., R. 88 W., on the north side of the Cannonball River in the Standing Rock Indian Reservation. The

horizon is about 250 feet above the Fox Hills and embraces the following list of species:

Thuya interrupta Newb.
Sequoia nordenskiöldi Heer.
Populus amblyrhyncha Ward.
Populus daphnogenoides Ward.
Sapindus grandifoliolus Ward.
Aristolochia cordifolia Newb.
Celastrus curvinervis Ward.
Pali rus pealei? Ward.
Viburnum sp., cf. *V. antiquum* (Newb.) Hol.

13. AREA IN WESTON COUNTY, WYOMING.

It is quite probable, however, that the beds under consideration can be traced from the area last considered in more or less continuous exposures into Weston and Converse counties, Wyoming. In the southwestern portion of the Newcastle quadrangle which lies mainly in the extreme southwestern corner of Weston County, Mr. N. H. Darton[21] has described as 'Laramie' the beds in question which overlie the Fox Hills.

Although Darton does not mention an unconformity between the Fox Hills and the 'Laramie,' he speaks of the difficulty of drawing the line between them. However, Mr. Barnum Brown found unconformable relations between them. He says:[22]

On Alkali Creek, about 35 miles northwest of Edgemont, S. D., and 6 miles north of the Cheyenne River the dinosaur-bearing beds do rest on the marine Fox Hills. In 1901 I obtained characteristic fossils from both formations near their contact at that locality. At that place the conditions are similar to those in the Hell Creek region.

From the base of the "series of lignite beds overlying the Converse County beds similar to those overlying the Hell Creek beds" on Seven Mile Creek, 40 miles northwest of Edgemont, Brown obtained the following plants:

Taxodium occidentale Newb.
Sequoia nordenskiöldi Heer.

[21] U. S. Geol. Surv., Folio 120, 1904.
[22] Bull. Am. Mus. Nat. Hist., vol. 23, 1907, p. 844.

Dammara? sp.
Platanus raynoldsii Newb.
Platanus sp.
Quercus sp.
Carpites sp.

From the same locality on Seven Mile Creek, "but lower and associated with a dinosaur skeleton (*Claosaurus annectens* Marsh)," the following plants were collected by Brown:

Sequoia heerii Lesq.
Taxodium distichum miocenum (Brongn.) Heer.
Ginkgo adiantoides (Ung.) Heer.
Musophyllum sp. (probably new).
Flabellaria eocenica Lesq.
Sabalites grayanus Lesq.
Palmocarpon palmarum (Lesq.) Kn.
Platanus rhomboidea Lesq.
Platanus sp.
Ficus spectabilis Lesq.
Viburnum sp.

14. NORTHWARD EXTENSION OF WESTON COUNTY AREA CONNECTING WITH THE MILES CITY AREA.

It is now possible, through the work of Mr. E. S. Riggs of the Field Museum of Natural History, to extend the known distribution of the dinosaur-bearing beds to the northward of the Weston County area, and make practical connection with the beds of similar age in the Miles City, Montana, field. Mr. Riggs informs me that on passing northward from New Castle, Wyoming, these beds were first encountered on the head waters of the Little Missouri River 20 miles west of Devil's Tower. Again, on the east fork of Little Powder River, in Montana, he found a weathered skeleton of *Trachydon*, partial skulls of *Ceratopsia* and fragments of a large carnivorous dinosaur, probably a *Tyrannosaurus*. The formation was thence traced along the east bank of Powder River from Powderville, Montana, to a point on Sheep Creek some miles northeast of Mizpah, which brings it well within the area studied by Collier and Smith. During the past season (1908) Mr. R. W. Stone of the U. S. Geological Survey, found remains of *Ceratopsia* in the vicinity of Moorecroft, Wyoming, which makes an additional point connecting the areas.

15. CONVERSE COUNTY, WYOMING, AREA.

We may now take up the consideration of the celebrated "Ceratops beds," a direct northern extension of which are those just mentioned in Weston County.

In 1889 Marsh[23] gave the name of "Ceratops beds" to a series of beds characterized by the presence of an extensive fauna of the then little known group of quadrupedal, horned, herbivorous dinosaurs. He did not then, nor indeed subsequently, give any very definite account of either the geographic location or stratigraphic position of the beds, beyond stating that they were in the 'Laramie of Woyming,' and that the horizon "has now been traced for nearly 800 miles along the eastern flank of the Rocky Mountains." Of the position he says:

> 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.

It was reserved for Professor Marsh's assistant, Mr. J. B. Hatcher, to give the first definite and precise information on these points. The principal, and what may be called the typical, "Ceratops beds" are really of very limited extent, occupying a strip about 15 miles in width from east to west, by 30 miles in length from north to south, in the northeastern part of Converse County, Wyoming, along Lance Creek and the area drained by the lower portions of Doegie, Cow, Buck, and Lightning creeks. This area furnished not only all of the Ceratopsidæ described by Marsh from Wyoming, but fully 95 per cent of the entire group known at that time. The "Ceratops beds" are best exposed along the eastern and southern borders of a synclinal basin, and according to Hatcher are 3000 feet in thickness, though Dr. T. W. Stanton and myself, when we visited the area in 1896[24] concluded that they could hardly exceed 2000 feet, but as a large portion of the beds are exposed at a low angle in a broad, flat, grassy plain, it is impossible to measure the beds with a great degree

[23] Am. Jour. Sci. (3), vol. 38, 1889, p. 501.
[24] Bull. Geol. Soc. Am., vol. 8, 1896, pp. 128–137.

of accuracy. The entire section of the region, which begins with several hundred feet of soft, bluish shales of the Pierre, up to and including the acknowledged Fort Union, was supposed by Marsh and Hatcher to be one of continuous deposition; that is to say, no actual unconformity had been detected. The Fox Hills, with an estimated thickness of 500 feet, consists of an alternating series of sandstones and shales. The massive sandstones at the top contain numerous large concretions and a rich marine fauna of characteristic Fox Hills species. The line between the Fox Hills and the overlying beds is a difficult one to draw, Hatcher, at first, placing it arbitrarily at a six-inch band of hard sandstones which separates the fossil-bearing Fox Hills sandstone below from the very similar but non-fossiliferous sandstones above.

Later, however, Hatcher appears to have changed his mind regarding the lower limits of the "Ceratops beds," for he says:[25]

> 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.

This point was apparently well taken, for Stanton and I found four species of brackish-water invertebrates in clays above a forty-foot bed of massive sandstone over 400 feet above the highest fossiliferous Fox Hills horizon in that particular section. The fact remains, however, that the fossiliferous portion of the "Ceratops beds" is mainly the upper portion, the highest point at which dinosaurs were found, being only 100 to 150 feet below the Fort Union.

The fossil-bearing members of the "Ceratops beds" consist, as described by Hatcher,[26]

> 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 especially true of the upper two-thirds of the beds. This lack of continuity in the different strata has rendered it well nigh impossible to establish any definite horizons in the upper members of the series.

[25] Am. Nat., vol. 30, 1896, p. 117.
[26] Am. Jour. Sci. (3), vol. 45, 1893, p. 137.

Following is the list of plants thus far obtained from the "Ceratops beds" of Converse County:

Alga (Gen. et sp. nov.)
Aralia sp. (Like species from Forsyth).
Carpites 2 sp.
Cyperacites sp.
Equisetum sp.?
Ficus 5 sp.
Flabellaria eocenica Lesq.
Grewiopsis eocenica (Lesq.) Kn.
Fern (Gen. et sp. nov.).
Hicoria sp.
Juglans 2 sp.
Lysimachia sp. (new).
Myrica torreyi Lesq.
Ottelia? sp. (new).
Palmocarpon palmarum (Lesq.) Kn.
Phyllites 3 sp.
Platanus raynoldsii Newb.
Platanus raynoldsii integrifolia Lesq.
Populus subrotundata Lesq.
Populus amblyrhyncha Ward.
Quercus cinereoides Lesq.
Quercus viburnifolia Lesq.
Quercus 3 sp. (new?).
Sabal rigida Hatcher.
Salix angusta Al. Br.
Salix 3 sp. (new?).
Salvinia sp.
Sassafras sp. (New; same found below Mandan, N. D.)
Sequoia nordenskiöldi Heer.
Taxodium distichum miocenum Heer.
Trapa microphylla Lesq.
Ulmus sp.
Viburnum sp. (new).
Viburnum whymperi Heer. (Also found at Glendive, Hell Creek, and below Mandan.

In 1896 Dr. T. W. Stanton and the writer spent about three weeks in the study of the "Ceratops beds" of Converse County, our results being set forth in a joint paper under the title: "Stratigraphy and Paleontology of the Laramie and related formations in Wyoming."[27] After reviewing the stratigraphy and local development in this region, so far as our observations permitted, the "Ceratops beds" were

[27] Bull. Geol. Soc. Am., vol. 8, 1897, pp. 127–156.

correlated with the dinosaur-bearing beds at Black Buttes, Wyoming, and both were then concluded to be of Laramie age. For several years past, however, data having a distinct bearing on the problem have been accumulating in adjacent and more remote areas, which have induced the present writer to completely change his opinion concerning the relations and age of the beds in question. When the invertebrate fauna and the flora of the "Ceratops beds" are compared with those of Black Buttes alone, it is true that a certain degree of relationship can be established. Among the invertebrates, for instance, it was shown that 9 species—7 of which belong to *Unio*—of the 28 species found in the "Ceratops beds," occur also at Black Buttes, while of the 24 forms of plants then recognized it was possible to identify only 8 specifically, one of which was from an unknown locality, thus leaving less than one-third of the total number on which to ascertain the bearing on the question of age. Of the remaining 7 species, 3 were found at Black Buttes, one in the Montana at Point of Rocks, 2 in the Laramie at Golden, Colorado, and one in the Raton Mountains of New Mexico, then supposed to be of Laramie age but now thought to be higher.

Of the undescribed forms I wrote at that time as follows:

> The affinity of the undescribed forms is also quite clearly with the true Laramie flora, and thus as nearly as can be made out, the plants confirm the Laramie age of the Ceratops beds.

This statement was based on tenative comparisons with beds then supposed to be Laramie in age, but which subsequent investigation has shown belong to higher horizons. Since the publication of the above-mentioned paper the plants have been more thoroughly studied, with the result of increasing the number to 48 forms, as already listed, though still showing a large proportion of new forms, with more modern affinities. Of the 14 species having an outside distribution, 9 are found in the Fort Union, 5 in the Shoshone, and 4 each in the Laramie and Montana, thus slightly modifying the distribution as given in Brown's paper.[28] On these grounds the correlation of the "Ceratops beds" with the beds at Black Buttes is no longer admitted by the writer, and the Laramie age of the "Black Buttes beds" is held in abeyance.

[28] Bull. Am. Mus. Nat. Hist., vol. 23, 1907, p. 844.

The vertebrates and invertebrates found in the typical "Ceratops beds" will be considered later.

16. AREA TO THE EASTWARD OF THE BIGHORN MOUNTAINS, WYOMING.

To the northwest of Converse and Weston counties, Wyoming, the beds under consideration occupy a vast area in the central Great Plains region between the Black Hills and the Bighorn Mountains, extending into Montana for an unknown distance, and completely encircling the Bighorn Basin. The complete areal distribution in this region is not yet a matter of published record, though the presence of the beds at numerous points is attested. Mr. N. H. Darton[29] to whom we are indebted for most of the published knowledge concerning this area, made the following disposition of the Upper Cretaceous and Tertiary rocks of the region. The name of Parkman sandstone was given to the several hundred (about 350) feet of soft sandstone overlying the more typical Pierre shale, which, from its position, was supposed to represent the Fox Hills, but according to Dr. T. W. Stanton it may be as old as the Claggett—one of the lower members of the Pierre. Immediately above the Parkman but separated from it with difficulty, is the Piney formation, a name proposed

> for the lowest formation of the thick series of fresh-water sandstones and shales of later Cretaceous age, formerly designated 'Laramie,' lying in the great Basin adjoining the Bighorn uplift.

The maximum thickness of the Piney, according to Darton, is about 3000 feet, but according to Mr. C. A. Fisher this does not constitute a lithologic unit, only the lower 600 to 800 feet of sandstones being properly referable to this formation, while the remainder, composed of gray sandstones, dark shales and coal streaks, belongs to the lower Fort Union (somber beds). Whatever its proper limits, so far as present facts indicate, the whole section above the marine Cretaceous is to be regarded as belonging to the Fort Union.

Unconformably overlying the Piney as defined by Darton, but probably without the intervention of any considerable erosional interval, is a great thickness of conglomerate to which the name

[29] Geol. Bighorn Mts., U. S. Geol. Prof. Paper, No. 51, 1906.

Kingsbury conglomerate has been given. It occupies a narrow band only 6 or 8 miles in width and 25 to 30 miles in length, adjacent to the mountains, and strikes approximately north and south. Its north and south extent coincides very nearly with faults which, according to Darton, attended an uplift of some 9000 feet of this portion of the Bighorn Mountains. This uplift, which involved also the Piney formation, resulted in a sharp fold, or in some cases probably a break, of the underlying beds resting against the granite mass, while the increased elevation of the mountain mass accelerated erosion and precipitated the debris which forms this conglomerate, embracing as it does rocks of all ages from the granites to and including the Piney. That the unconformity at the base of the Kingsbury is not of wide significance is shown by the fact that it was not detected in a section made at Parkman, only about 25 miles north of the northernmost extension of the Kingsbury, nor has it been found a few miles to the southward of the southern limits of the formation. Along the eastern margin of the Kingsbury it may be observed fingering into the soft shales and sandstones of the De Smet formation, the name given by Darton to the 5000 feet or more of beds overlying the Piney, and with which sedimentation was apparently continuous; in fact the Kingsbury was regarded by Mr. J. A. Taff, who surveyed this area for coal in 1907, as merely the near-shore phase of the upper member of the Fort Union. At a number of horizons in the Kingsbury Fort Union plants have been collected, and at a point about 650 feet above its base Mr. H. S. Gale obtained a mammal jaw which Mr. Gidley identifies as identical with a Fort Union species found at Fish Creek, Montana.

The first two of the following lists of plants are from the Kingsbury conglomerate, and are given to show how similar is the flora of the upper and lower members of the Fort Union; the others are from the lower member:

Sequoia sp.?
Cyperacites sp.
Populus sp.?
Platanus haydenii Newb.
Ficus plani ostata? Lesq.
Cinnamomum affine Lesq.
Sapindus grandifoliolus Ward.
Diospyros ficoidea Lesq.

Cissites parrotiæfolia Lesq.
Berchemia multinervis Al. Br.
Aristolochia cordifolia Newb.
Cornus newberryi Hollick.
Viburnum sp.
Viburnum whymperi Heer.
Carpites sp.

Seven miles southwest of Buffalo, Wyoming.

Dryophyllum subfalcatum Lesq.
Ficus planicostata Lesq.
Diospyros ficoidea Lesq.
Carpites sp.

On road from Buffalo to Klondike, Wyoming. [Sec. 6, T. 49 N., R. 82 W.] Piney formation.

Sequoia nordenskiöldi Heer.
Populus arctica Heer of Lesq.
Populus amblyrhyncha Ward.
Populus nobilis Newb.
Sapindus grandifoliolus Ward.

About 1½ mile northeast of Dayton, Wyoming.

Glyptostrobus europæus.
Populus arctica Heer.
Platanus guillelmæ Göpp.
Platanus sp.
Fruit, gen. et sp.?

Two and one-quarter miles northeast of Ranchester, Wyoming. Lower De Smet or Piney.

Taxodium occidentale Newb.
Sequoia sp.?
Sparganium stygium Heer.
Populus acerifolia Newb.
Platanus nobilis Newb.
Sapindus affinis Newb.
Acacia sp. [new].
Bauhinia sp. [new].
Nelumbo sp.?

Two and one-half miles southeast of Ranchester, Wyoming; 75 feet below top of lower member.

Platanus sp.
Hicoria antiquorum (Newb.) Kn.
Sapindus grandifoliolus? Ward.

Slater Creek, 6 miles northeast of Monarch, Wyoming; 40 feet below top of lower member.

Populus amblyrhyncha Ward.
Populus genetrix Newb.
Populus sp.?

Platanus nobilis Newb.
Leguminosites arachioides Lesq.
Sapindus sp.
Viburnum whymperi Heer.

17. BIGHORN BASIN, WYOMING.

The following discussion of the lower Fort Union in this area is based on the published work of Mr. C. A. Fisher's,[30] personal observations made during the seasons of 1907 and 1908, and the work of United States Geological Survey field parties under the charge of Mr. E. S. Woodruff, made during the same years. In the extreme northwestern part of the Basin the lower Fort Union undoubtedly connects with the area about Red Lodge, Montana. At the time Mr. Fisher's paper was prepared sufficient paleontologic data had not been obtained to fix definitely the limits of this, as well as underlying and overlying beds, and the whole series, aggregating more than 5000 feet in thickness, was described and mapped as 'Laramie and associated formations.' As shown on Fisher's map, these beds are exposed continuously about the outer edge of the Basin, having their maximum areal extent in the northeastern portion and their minimum exposure along the northwestern border just below the Montana state line.

The lowest member of the aggregated 'Laramie and related formations,' resting upon the Pierre, is composed of about 300 feet of a "massive gray to buff sandstone," which lithologically resembles the supposed 'Fox Hills' on the eastern side of the Bighorn Mountains, and for this reason was tentatively referred to the 'Fox Hills.' The few invertebrates do not serve to fix definitely the age, according to Stanton,[31] since they may occur below the Judith River as well as in Fox Hills. Above these beds, whether with or without an erosional interval is not definitely known, comes the great thickness of Fort Union which Fisher has shown may be divided into two parts. The lower member, which corresponds to the beds already so extensively traced, is composed of dark sandstones, shales and clays with occasional seams of coal and coaly shales. Throughout the lower por-

[30] Geol. and Min. Res. Bighorn Basin, Wyoming: U. S. Geol. Surv., Prof. Paper 53, 1906, p. 31 et seq.
[31] In Fisher, Bull. U. S. Geol. Surv., Prof. Paper, 53, p. 32.

tion the sandstones are usually fine-grained and massive, and sandstone concretions are of frequent occurrence. The line between the lower and upper members is a lithologic one, the sedimentation being continuous.

At various localities in the Basin vertebrate remains have been obtained in this lower member, but they are usually so fragmentary that little can be said concerning them beyond the fact that they belong to dinosaurs. Plants are abundant in many places, as the following lists attest.

The following localities for plants are known within the Bighorn Basin:

Near I o P. O., Bighorn County, Wyoming; above 500 feet above base of beds.

Onoclea sensibilis fossilis Newb.
Sequoia nordenskiöldi Heer.
Sequoia sp.
Protophyllocladus? sp. new.
Populus cuneata Newb.
Populus daphnogenoides Ward.
Populus arctica Heer of Lesq.
Populus n. sp.
Populus amblyrhyncha Ward.
Juglans sp.
Corylus americana Wa'ter.
Platanus haydenii Newb.
Sapindus grandifoliolus Ward.
Celastrus taurinensis Ward.
Celastrus sp.
Paliurus pulcherrimus Ward.
Pal urus sp.
Diospyros sp.

Two miles north of Ilo P. O., Bighorn County.

Ginkgo adiantoides (Ung.) Heer.
Populus amblyrhyncha Ward.
Quercus sp.
Platanus nobilis Newb.
Magnolia tenuinervis? Lesq.
Ficus sp. (type of F. *planicostata*).
Celas rus sp.
Berchemia multinervis Al. Br.
Viburnum newberryanum Ward.
Viburnum antiquum (Newb.) Hollick.

Twelve miles west of Ilo P. O., Bighorn County.

Cocculus haydenianus Ward.

West of Winchester Hills, Bighorn Basin (Sec. 34, T. 45 N., R. 95 W.).

Platanus nobilis Newb.
Platanus haydenii Newb.
Sapindus affinis Newb.
Sapindus grandifoliolus Ward.

Three miles northwest of Meeteetse, Wyoming. Black Diamond Mine. About 50 feet above base of section.

Dryopteris sp. new.
Sequoia langsdorfii or near it.
Sapindus grandifoliolus Ward.
Lauraceous leaf, probably new.

Shoshone River, near Cody, Wyoming. [This and the following collection may be from the upper member.]

Sequoia langsdorfii (Brongn.) Heer.
Populus glandulifera? Heer.
Platanus nobilis Newb.
Sapindus grandifoliolus Ward.
Juglans sp.

Near Cody, Wyoming [Sec. 3, T. 53 N, R. 101 W.]

Platanus haydenii? Newb.
Populus speciosa Ward.
Hicoria antiquorum (Newb.) Kn.

Shoshone River at mouth of Sage Creek, 3 miles below Cody, Wyoming.

Platanus raynoldsii Newb.
Platanus haydenii Newb.
Platanus nobilis Newb.

Southeast of Rairden, Bighorn Basin [Sec. 5, T. 48 N., R. 91 W.]

Glyptostrobus europæus (Brongn.) Heer.
Sapindus grandifoliolus? Ward.
Sapindus affinis Newb.
Populus sp.

Bud Kimball mine, Bighorn County, Wyoming [T. 45, R. 89 W.]

Glyptostrobus europæus Heer.
Taxodium occidentale Newb.
Viburnum whymperi Heer.

Three-fourths mile west of Nowater mine [T. 44 N., R. 90 W.], Bighorn County, Wyoming.

Populus cuneata Newb.
Platanus raynoldsii Newb.
Hicoria antiquorum (Newb.)Kn.
Carpites sp.

Bluff on east side of Bighorn River, opposite Kirby, Wyoming; 200 feet above base of lower Fort Union.

Glyptostrobus europæus Heer.
Sequoia nordenskiöldi Heer.

Taxodium occidentale Newb.
Platanus guillelmæ Göpp.
Cocculus haydenianus Ward.

Same locality as last but about 300 feet above base of lower Fort Union.

Taxodium occidentale Newb.
Populus amblyrhyncha Ward.
Populus cuneata? Newb.
Populus genetrix Newb.
Viburnum perplexum Ward.

Same locality as last two, but near top of lower Fort Union.

Taxodium distichum miocenum Heer.
Berchemia multinervis Al. Br.
Celastrus ferrugineus Ward.

18. POSSIBLE DISTRIBUTION OF LOWER FORT UNION IN OTHER AREAS.

Having passed in review the areas where the lower member of the Fort Union is known to occur, a brief mention may be made of certain extra-limital areas where the evidence is incomplete or conflicting, and further data are to be looked for.

In the central Canadian provinces the Fort Union is known to be present over a wide area, and it is more than probable that it will ultimately be found possible to differentiate the lower and upper members; in fact it is thought that the Edmonton beds of the Canadian geologists may correspond to the lower member and their Paskapoo beds to the upper member. But the writer has seen no material from Canadian sources, and the above reference is tentative.

From scanty information at hand it seems likely that the lower Fort Union will be found spreading over a considerable area in northern Montana near Big Sandy, along the Missouri River in the Fort Peck Indian Reservation and in southern North Dakota and northern and northwestern South Dakota.

At Black Buttes, Wyoming, beds containing a Fort Union flora have been found resting with marked unconformity on the so-called "Black Buttes beds" (the beds containing *Agathaumas sylvestris*), while 20 miles to the southward they rest on the Lewis shale, this condition continuing to the outliers of the Uintas near the Wyoming-Colorado line. That these beds with a Fort Union flora are the beds described and mapped by King as Vermilion Creek or Wasatch,

is perhaps a sufficient excuse for omitting their further consideration until additional information, both paleobotanical and stratigraphic, is at hand.

To the eastward of Black Buttes, in the vicinity of Creston, Riner and Rawlins, and as far at least as the vicinity of Carbon, Fort Union plants and occasional dinosaurs have been found. The beds containing them belong to the so-called "upper Laramie" of Veatch and others, that is above the unconformity at the top of the Laramie, but whether or not this series of beds is a unit is an open question at present. It seems probable to the writer that the lower portion may belong to the recently established Shoshone group of Cross, and the upper portion only to the Fort Union. To the west in the vicinity of Evanston a few Fort Union species have been noted, but in all these cases further data are demanded.

Relations Between the Lower Member of the Fort Union and Underlying Formations.

Having traced the areal distribution of what is here called the lower member of the Fort Union formation, as completely as present facts seem to warrant a brief recapitulation of the relations that have been demonstrated of these to the underlying beds may be made. In the Hell Creek region of Montana, the vicinity of Yule, North Dakota, and on Alkali Creek, Weston County, Wyoming, the beds rest *unconformably* on the Fox Hills. At Forsyth, near Custer, the areas south and east of the Bull Mountains, and probably at Glendive, all in Montana, and at Buffalo, Wyoming, the beds rest directly on the Pierre, and not always its uppermost member. In Converse County, Wyoming, the basal conditions are not definitely known, though presumably the relations may be similar to those obtaining in adjacent Weston County. Throughout the Great Plains area the Fox Hills is usually, but not always present, and even when present has not always been satisfactorily separated from the overlying beds.

The evidence is conclusive where actual unconformity has been shown, as well as where the beds are found resting on a lower member (Pierre) of the Upper Cretaceous, and hence, in intermediate areas where discordance has not been observed, it is reasonably cer-

tain that a time interval is represented during which certain of the Upper Cretaceous sediments and, if my view be correct, also certain lower Tertiary beds, including the Arapahoe and Denver or their equivalents, were removed. It is therefore demonstrated beyond reasonable doubt that the beds under consideration are the same throughout the wide area over which they have now been traced. As they are above an unconformity they can, on the basis of stratigraphy, no longer be considered as a part of the 'conformable Cretaceous series.'

Relations Between Lower and Upper Members of the Fort Union.

With the exception of the limited area covered by the Kingsbury conglomerate east of the Bighorn Mountains, which as already shown was a comparatively local affair consequent upon the Bighorn uplift, the lower member of the Fort Union is conformably overlain by the upper member throughout the entire region. Of the many workers who have observed the field relations at hundreds of points, not one, so far as known to the writer, has recorded the presence of unconformity between them. The strong lithologic difference, as already described, makes it possible to separate them usually with little difficulty, but the sedimentation appears to have been continuous. The possibility of unconformity by overlap, always a difficult condition to demonstrate, has not been overlooked, but if present it should have been detected on the borders of the areas along the mountains, which does not seem to have been done. Therefore, it appears that the lower and upper members cannot be separated on structural grounds.

Stratigraphic Relations of the Lower Member of the Fort Union to the Laramie.

The beds that are here regarded as constituting the lower member of the Fort Union have usually been—and by many are still—called 'Laramie,' but when it is recalled that, by original definition, the Laramie is the uppermost member of the conformable Cretaceous series above the Fox Hills, it is seen at once that they cannot be so considered since they are separated from the Cretaceous by an uncon-

formity. Mr. Barnum Brown[32] has clearly recognized the validity of this position, concerning which he writes as follows:

> Strictly following King's definition of Laramie, neither of these deposits ["Hell Creek beds," "Ceratops beds," etc.] 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.

This interpretation by Brown makes the unconformity at the base of the lower member of the Fort Union the same as that demonstrated by Mr. Whitman Cross as occurring at the top of the Laramie in the Denver Basin of Colorado. In the latter area, while an unknown thickness (estimated by Cross at 12,000 to 15,000 feet) has been removed, a considerable thickness of Laramie beds still remain, whereas in the areas covered by the lower Fort Union, the Laramie, as well as the Arapahoe and Denver, or their equivalents, if ever present, has been entirely removed so far as known, and the beds rest on other members of the Upper Cretaceous series. A comparison of the conditions of sedimentation in the two sets of beds, as indicated by their invertebrate fauna, confirms their distinctness. Thus, the Laramie is described as a series of brackish- and fresh-water beds, indicating transition from estuarine or marine conditions, while the Fort Union was laid down in fresh water, and affords little or no convincing evidence of even temporary or occasional incursions of the sea.[33]

Paleontological Characters of the Lower Fort Union.

1. PLANTS.

We may now proceed to the consideration of the various lines of paleontological data, beginning with that of the plants. On reviewing the foregoing account it appears that plants have been obtained

[32] Bull. Am. Mus. Nat. Hist., vol. 33, 1907, p. 845.

[33] The possible exceptions are a single species of *Corbicula* reported by Whitfield from the upper portion of the "Hell Creek beds," this genus being found in both brackish and fresh waters, and *Ostrea glabra* reported from the section near Yule, North Dakota.

at over fifty localities, and when these are brought together in a single list we have no less than 193 forms that have thus far been found in the lower member of the Fort Union. After eliminating the new forms, and those not specifically named, we have the following 84 species that are positively identified:[34]

a List of plants identified in lower Fort Union.

**Aralia notata* Lesq.
**Berchemia multinervis* (Al. Br.) Heer.
**Carpolithes lineatus* Newb.
**Celastrus alnifolius* Ward.
**Celastrus curvinervis* Ward.
**Celastrus ferrugineus* Ward.
**Celastrus ovatus* Ward.
**Celastrus pterospermoides* Ward.
**Celastrus taurinensis* Ward.
**Cinnamomum affine* Lesq.
**Cocculus haydenianus* Ward.
**Cornus newberryi* Hollick.
**Corylus americana* Walt.
**Corylus rostrata* Ait.
**Credneria daturæfolia* Ward.
**Diospyros haguei* Kn.
**Elæodendron polymorphum* Ward.
**Equisetum prelævigatum* Cockerell.
**Ficus artocarpoides* Lesq.
**Ficus spectabilis* Lesq.
Ficus trinervis Kn.
Flabellaria eocenica Lesq.
**Ginkgo adiantoides* (Ung.) Heer.
**Glyptostrobus europæus* (Ung.) Heer.
**Glyptostrobus europæus Ungeri* Heer.
Grewiopsis eocenica (Lesq.) Kn.
**Grewiopsis platanifolia* Ward.

[34] It should not be supposed that when the several undoubtedly new species, together with such of the unnamed forms as may be subsequently allocated, shall have been worked up in detail, the relation to the upper member of the Fort Union will be less marked. On the contrary it is likely to increase the number of species common to the two members, especially as there are large unworked collections, belonging certainly to the upper member, with which they may be compared. It will be observed that the unnamed forms in the lists belong largely to such genera as Populus, Platanus, Viburnum, Hicoria, Planera, Quercus, Sequoia, Taxodium, Carpites, etc., which are strongly represented in the Fort Union; indeed, certain of these genera (*e. g.*, Taxodium, Planera, Glyptostrobus) are not known to be present in the Laramie.

**Grewiopsis populifolia* Ward.
**Hicoria antiquorum* (Newb.) Hollick.
**Juglans rugosa* Lesq.
**Leguminosites arachioides* Lesq.
Marchantia pealei Kn.
Myrica torreyi? Lesq.
Magnolia tenuinervis Lesq.
**Onoclea sensibilis fossilis* Newb.
Paliurus pulcherrimus Ward.
Palmocarpon palmarum (Lesq.) Kn.
**Phyllites cupanoides* Newb.
**Populus acerifolia* Newb.
**Populus amblyrhyncha* Ward.
**Populus arctica* Heer. of Lesq.
**Populus cuneata* Newb.
**Populus daphnogenoides* Ward.
**Populus genetrix* Newb.
**Populus glandulifera* Heer.
**Populus inæqualis* Ward.
**Populus nebrascensis* Newb.
**Populus nervosa elongata* Newb.
**Populus rotundifolia* Newb.
**Populus subrotunda* Lesq.
**Populus speciosa* Ward.
**Platanus guillelmæ* Göpp.
**Platanus haydenii* Newb.
**Platanus marginata* (Lesq.) Heer.
**Platanus nobilis* Newb.
**Platanus raynoldsii* Newb.
**Platanus raynoldsii integrifolia* Lesq.
**Platanus platanoides* (Lesq.) Kn.
**Platanus rhomboidea* Lesq.
**Pterospermites minor* Ward.
**Pterospermites whitei* Ward.
Quercus breweri Lesq.
Quercus cineroides Lesq.
Quercus viburnifolia Lesq.
Rhamnus salicifolius Lesq.
Sabal rigida Hatcher.
Sabalites fructifer Lesq.
Sabalites grayanus Lesq.
Salix angusta Al. Br.
**Sapindus affinis* Newb.
**Sapindus grandifoliolus* Ward.
**Sequoia langsdorfii* (Brongn.) Hr.
**Sequoia heerii* Lesq.
**Sequoia nordenskiöldi* Heer.
**Sparganium stygium* Heer.
**Taxodium dictichum miocenum* Heer.

**Taxodium occidentale* Newb.
**Thuya interrupta* Newb.
**Trapa microphylla* Lesq.
**Viburnum antiquum* (Newb). Hol.
**Viburnum newberryianum* Ward.
**Viburnum perplexum* Ward.
**Viburnum whymperi* Heer.
**Vitis xantholithensis* Ward.

[In the above list the species marked with an asterisk (*) are found also in the upper member of the Fort Union.]

To any one familiar with the flora of the Fort Union, it needs but a glance at the species here listed to show how overwhelming is the preponderance of the elements of this flora. As Doctor Newberry long ago stated, it has a botanical facies which is unique and unmistakable. Attention is especially directed to the great development of the genus Populus with 13 species, and the presence of such distinctive genera as Celastrus, Pterospermites, Elaeodendron, Grewiopsis, Cocculus, Marchantia, etc., while of the species it may be stated that nearly half (37) have never been found outside this formation, at least in this country. The following table presents graphically the relations that exist between the flora of the lower member of the Fort Union and that of other formations:[35]

Total known Fort Union flora (including lower and upper members) about	500
Total forms known from lower member	193
Forms specifically identified in flora of lower member	84
Of these 84 species there are common to upper member	61
Common to lower member and Laramie	11
Common to lower member and Montana	11

[35] To the possible criticism that too much dependence has been placed in a statistical comparison, rather than one based on relative abundance, the following facts may be pointed out. The presence of a species in the list does not, of course, indicate its abundance as an element of this flora, but on turning back to the lists of species recorded under each locality, it will be noted that the frequent repetition of names shows the extent to which many of the commonest and best known species are distributed. Thus *Populus amblyrhyncha* occurs at 15 localities; *P. cuneata* at 11 localities; *Sapindus grandifoliolus* and *Tazodium occidentale* at 12 localities each, etc.; indeed, very few are present at a single locality only. In most cases the plants are neither so well preserved nor so abundant in the lower member as they are in the upper, and large collections are secured with more difficulty.

Common to lower member and Arapahoe and Denver	22
Common to lower member and Shoshone	35
Common to lower member and other Eocene	15
Common to lower member and Cretaceous [including Laramie and Montana.]	16
Common to lower member and Tertiary [Eocene to Miocene]	68

From the above table it appears that of the entire number of forms now known in the lower member of the Fort Union only 16 species are common to it and the Cretaceous, this including both Laramie (11) and Montana (11), and of these there are 7 species which run from the Cretaceous through the lower Fort Union into or above the upper member of the Fort Union, thus leaving really only 9 species confined exclusively to the beds under consideration and the Cretaceous below. Following is the list of the 16 species, the asterisk indicating Montana species and the dagger Laramie species:

*†*Ficus trinervis.*
†*Flabellaria eocenica.*
*†*Juglans rugosa.*
*†*Myrica torreyi.*
* *Magnolia tenuinervis.*
†*Palmocarpon palmarum.*
†*Platanus haydenii.*
*†*Platanus marginata.*
* *Platanus platanoides.*
†*Platanus raynoldsii.*
†*Quercus viburnifolia.*
*†*Rhamnus salicifolius.*
*†*Sabalites grayanus.*
* *Salix angusta.*
* *Trapa? microphylla.*
* *Viburnum whymperi.*

A close analysis of the distribution of these species shows that, for one reason or another, comparatively little weight is to be attached to certain of them. Thus, *Ficus trinervis*, which occurs only in the lower beds at Glendive, Montana, is a species of wide distribution in the Montana and Laramie, and has been found in the Shoshone. *Flabellaria eocenica*, reported from Converse and Weston counties, finds its main distribution in the Laramie and occurs also at Black Buttes. *Juglans rugosa*, of which there is but a single specimen in the dinosaur beds at Yule, is of very wide distribution,

occurring at Point of Rocks, Rock Springs, Black Buttes, Evanston, and Carbon, Wyoming, Marshall, Colorado, and the Livingston of Montana. *Myrica torreyi* is present in the lower Fort Union of Converse County, where a single specimen was doubtfully so determined; its principal distribution is in the Montana and Laramie, and also at Black Buttes. *Magnolia tenuinervis* was originally described from the Denver, has been found at Black Buttes and Hodge's Pass, Wyoming, and doubtfully in the Montana at Coalville, Utah. *Palmocarpon palmarum* is a fruit of uncertain status. Of the four species of *Platanus*, two (*P. haydenii* and *P. raynoldsii*) are very abundant and widely distributed in both lower and upper members of the Fort Union, and of rare or exceptional occurrence in the Laramie. Of the others, *Platanus marginata* is found at Point of Rocks and Black Buttes, and in the Laramie at Crow Creek, Colorado, and *P. platanoides* at Black Buttes and the supposed Montana of the Grand Mesa region of Colorado. *Quercus viburnifolia* is found in Arapahoe and Denver and the Laramie of Crow Creek. *Rhamnus salicifolius*, reported only from the "Hell Creek beds," is mainly a Laramie species but has been found in the Montana at Rock Springs, Wyoming. *Saballites grayanus* is of wide distribution in the Montana, Laramie, Denver, and Livingston; it is usually obscurely preserved and difficult of certain identification. *Trapa microphylla* has now been found at so many points from Montana to upper Fort Union that it is of little value in fixing the age of beds. *Viburnum whymperi* has been found at Point of Rocks, Black Buttes, and in the upper Fort Union.

It is significant that of the 84 species found in the lower Fort Union only 16 are distributed into the Cretaceous, while no less than 68 are confined to the Tertiary.

As might be expected, the relationship between the flora of the Arapahoe and Denver and that of the lower Fort Union is much stronger, there being some 22 of the 84 species that are common. As the flora of the Arapahoe and Denver now numbers about 200 species, it is seen that the species common to the lower Fort Union is not strong enough to bring them together, though, as most of the common species come from the areas nearest to the Denver Basin, it may be shown that the relationship is closer when larger collections from intermediate points are available for comparison, but for the

present they are regarded as being slightly older than the beds under discussion, though of Eocene age.

It is not deemed necessary in the present connection to attempt a further analysis of the relations between this flora and that of other Eocene and the Miocene. The number of common species show the direction in which the affinities lie.

b Paleobotanical Proof of the Eocene Age of the Fort Union Flora.

As stated in the opening pages of this paper little doubt is now entertained as to the Eocene age of the Fort Union. So long, however, as it was confused with the Laramie and other formations, attempts at interpreting its floral affinities could but lead to conflicting or indecisive results. Thus, in 1886 Professor Ward[36] instituted an elaborate investigation to ascertain the Cretaceous or Tertiary age of the 'Laramie,' which was destined to failure, as it included plants from beds now known to belong to the Montana, Laramie, Arapahoe, Denver, Livingston and Fort Union. It should not be supposed, however, that he failed to note the well-marked differences between the flora of the Fort Union and that of the other formations considered with it. He saw these clearly enough, and pointed them out, but was misled by the prevailing opinion of the time, mainly that of the invertebrate paleontologists, that it could not be separated from the 'Laramie,' just as Newberry had been earlier misled into referring the Fort Union to the Miocene, on the basis of the then current correlation of certain plant-bearing horizons in Greenland, England and elsewhere. But as early as 1875, Sir William Dawson and Dr. Geo. M. Dawson[37] maintained the Eocene age of the Fort Union (the "Upper Laramie" of Canadian geologists), and neither one, so far as known to the writer, ever changed this opinion as to its position.

The flora of the Fort Union, as Newberry stated, has a botanical facies that permits at a glance its separation from that of the Laramie. It clearly inaugurates a new order of events and witnessed

[36] Synopsis of the Flora of the Laramie Group; Sixth Ann. Rept. U. S. Geol. Surv., 1884, 1885 (1886), pp. 399–557, pls. 31–65.

[37] Brit. N. A. Bound. Com., Geol. & Resources Vic. 49th Parallel, 1875, pp. 183–202.

the introduction of the earlier representatives of certain important genera and species. For example, the Fort Union contains several species (*Onoclea sensibilis*, *Corylus americana*, *Corylus rostrata*, etc.) now living, a condition not known to obtain in any earlier American horizon, while others are so obviously close to living species as to be separated with difficulty.

Of the various Old World plant deposits containing identical or closely related species, mention may first be made of the English Eocene. Thus, from Ardtun in Mull, which is regarded by Gardner as referable to the lower Eocene and approximately of the same age as Gelinden, we have the following conifers common to the Fort Union: *Sequoia langsdorfii*, *Glyptostrobus europæus*, *Sequoia couttsiæ*, and *Ginkgo adiantoides*. Of the ferns from the same locality, *Filicites hebridicus* Forbes [*Onoclea hebridica* Gard. and Ett.] is identical with our *Onoclea sensibilis fossilis*, to which also is referred *Woodwardites arcticus* Heer, from Atanekerdluk, North Greenland. *Osmunda lignitum* (Giebel) from Bornemouth is apparently the same as *Asplenium magnum* Kn. Among the dicotyledons of the British Eocene, mention may be made of their *Platanites hebridica*, which is apparently the same as our great *Platanus nobilis*, while among identical species are *Corylus macquarrii*, *Populus arctica*, *Populus richardsoni*, etc., while many genera (*e. g.*, *Cinchonidium*, *Diospyros*, *Sapindus*, *Bauhenia*, *Ulmus*, *Ficus*, *Juglans*, *Laurus*, *Celastrus*, *Elæodendron*, *Zizyphus*, *Leguminosites*, etc.) show related and in some cases identical species.

From the well-known lower Eocene deposits of Sezanne in the Paris Basin, the following species have been identified in our Fort Union: *Monimiopsis fraterna* Sap., *M. ambrosiæfolia* Sap., and *Hamamelites fothergilloides* Sap., while *Marchantia sézannensis* Brongn., is very close to *M. pealei* Kn.; *Viburnum giganteum* Sap., to *V. antiquum* (Newb.) Hollick; *Grewiopsis credneriæfolia* Sap., to *G. populifolia* Ward; *Celastrinites hartogianus* Sap., to *Elæodendron polymorphum* Ward, etc. Among common genera with related species we have: *Pterospermites*, *Aralia*, *Celastrinites*, *Zizyphus*, *Cornus*, *Hedera*, *Laurus*, *Sassafras*, *Daphnogene*, *Populus*, *Ulmus*, etc.

The lower Eocene deposits at Gelinden in Belgium, regarded as about the same age as Sezanne, have *Aralia looziana* Sap. and Mar.,

common to the Fort Union, while their *Viburnum vitifolium* is not greatly different from our *V. antiquum*. Of common genera mention may be made of the following: *Celastrophyllum, Aralia, Hedera, Litsæa, Hamamelites, Laurus, Cinnamomum*, etc.

Other affinities could be pointed out, but space will be taken only for a brief conparison with the extensive plant deposits in North Greenland. The age of these beds was at first considered by Heer to be Miocene, but later students, among them Saporta, Gardner, Ettingshausen and many others, have quite generally referred them to the Eocene. There are many species in common with the Fort Union, such as *Sequoia langsdorfii, S. couttsiæ, Ginkgo adiantoides, Taxodium distichum miocenum, Glyptostrobus europæus, Populus arctica, P. glandulifera, Sparganium stygium, Corylus macquarrii, Juglans nigella, Paliurus colombi, Grewia crenata, Platanus aceroides, Diospyros brachysepala*, etc., etc.

It is perhaps hardly necessary to add that there can be no doubt as to reference of the European localities mentioned to the Eocene, their position being fixed by various lines of evidence.

2. INVERTEBRATE EVIDENCE.

The invertebrates of the lower member of the Fort Union are relatively much less numerous both in species and individuals than are the plants, yet, fortunately, considerable collections have been secured in the critical areas. By combining the list of species given by Dr. T. W. Stanton[38] for the "Ceratops beds," of Converse County, Wyoming, with that given by Dr. R. P. Whitfield[39] for the "Hell Creek beds" of Montana, we have an aggregate of 49 forms. It should be stated, however, that this total includes 8 unnamed but supposed new species of Unio mentioned by Stanton as occurring in the "Ceratops beds." The distribution of these invertebrates is shown in the accompanying table:

List of invertebrates from "Hell Creek" and "Ceratops beds."

[In the list the species marked with an asterisk are found in the "Hell Creek beds"; those marked with a dagger, in the "Ceratops beds." The

[38] Bull. Geol. Soc. Am., vol. 8, 1897, p. 135.

[39] Bull. Am. Mus. Nat. Hist., vol. 23, 1907, table facing p. 829.

species preceded by a cross (x) are common to these beds and the Colorado Laramie.]

**Unio æsopiformis* Whitf.
**Unio corbiculoides* Whitif.
**Unio pyramidellus* Whitf.
**Unio verrucosiformis* Whitf.
**Unio retusoides* Whitf.
**Unio brownii* Whitf.
**Unio percorrugata* Whitf.
**Unio postbiplicata* Whitf.
**Unio aldrichi* White.
*†*Unio danæ* M. and H.
*†*Unio holmsiana* White.
**Unio vetusta* Meek.
*†*Unio cryptorhynchus* White.
**Unio biasopoides* Whitf.
**Unio cylindricoides* Whitf.
**Unio letsoni* Whitf.
**Unio gibbosoides* Whitf.
**Unio pyramidatoides* Whitf.
**Unio subtrigonalis* Whitf.
†*Unio brachyopisthus* White.
†*Unio cou si* White.
†*Unio proavitus* White.
†*Unio endlichi* White.
[About 8 undescribed species, Stanton.]
†x*Anodonta parallela* White.
†*Anodonta propatoris* White?
*†*Sphærium planum* M. & H.
†*Sphærium* sp.
†*Viviparus trochiformis* M. & H.
*x*Viviparus plicapressus* White.
†x*Tulotoma thompsoni* White.
*†*Campeloma producta* White.
**Campeloma vetula* M. & H.
*†*Campeloma ultilineata* M. & H.
†*Goniobasis tenuicarinata* M. & H.
*†*Thaumastus limneiformis* White.
†*Physa copei canadensis* Whiteaves.
†*Helix vetusta* M. & H.
†*Limnæa* sp.
*x*Corbicula subelliptica* M. & H.
**Cassiopella turricula.*
**Bulinus rhomboideus* M. & H.

This table presents some interesting features. In the first place it is to be noted both the "Hell Creek" and the "Ceratops beds" afford 28 forms each, of which 7 are common to the two areas, mak-

ing the aggregate number 49, as stated above. It is very probable, however, that at least some of the undescribed Unios from Converse County may prove to be identical with those from Hell Creek. It is significant that of the 49 species only 4 species (8.3 per cent) are common to the Laramie of the Denver (Colorado) region. These are *Anodonta parallela*, *Tulotoma thompsoni*, *Corbicula subelliptica* and *Viviparus plicapressus*, the second species mentioned being found also in the Montana, and two of the others at Black Buttes,[40] Wyoming, which reduces their value as diagnostic markers for the Laramie. There are 8 species common to the "Hell Creek" and "Ceratops beds," and the acknowledged Fort Union, of which 7 fall within the 18 species other than Unios. The most remarkable feature of this fauna is the abundance of Unios, there being 31 of the 49 species that are referred to this genus, whereas in the Colorado Laramie there is but a single fragmentary Unio, which cannot be specifically identified. And, it may be added, these Unios are found in the Hell Creek and Converse County areas in direct association with both dinosaurs and plants, so there can be no question as to their having come from within the dinosaur-bearing beds.

Whitfield,[41] who described the Unios from the Hell Creek region, was so impressed with their evident affinity to species living in the Mississippi and Ohio watersheds, that he gave to many of them names designed to indicate this relationship (*Unio gibbosoides* Whitf., cf. *Unio gibbosus* Barnes; *U. retusoides* Whitf., cf. *U. retusus* Lam., etc.), and adds:

> Some of them are so nearly like the living species that it would do but little violence to specific features, to state that they were the same.

This indicates either that the "Hell Creek beds" are comparatively recent, or that Unios are not of great value as time markers. As Brown well says[42] "The invertebrates plainly forshadow Tertiary and living species."

[40] The fossiliferous, dinosaur-bearing bed at Black Buttes, Wyoming, is not here admitted as being certainly referable to the Laramie, but rather to post-Laramie, or Shoshone.

[41] Bull. Am. Mus. Nat. Hist., vol. 19, 1903, pp. 483–487; idem, vol. 23, 1907, pp. 623–628.

[42] Idem, vol. 23, 1907, p. 845.

3. VERTEBRATE EVIDENCE.

a Dinosaurs.

Basing their conclusions upon identity of forms as well as on general similarity, there seems to be substantial agreement among vertebrate paleontologists in regarding the dinosaur-bearing "Hell Creek beds" and "Ceratops beds" as being of the same age. Throughout the other areas described in this paper wherever the dinosaurs have been found sufficiently preserved to admit of identification, they have been shown to be identical with those from the principal deposits above mentioned. It may, therefore, be taken as also established by vertebrate paleontology that the beds under discussion are of identical age throughout the field over which they have been traced. It is very much to be regretted that the series of monographs planned by the late Professor Marsh on the several groups of dinosaurs are, with the exception of that on the Ceratopsia, still unpublished. A summary of present knowledge concerning their distribution would be very helpful at this time, but, so far as known to the writer, there is no place in the United States where they are known to occur in undoubted Laramie.

Vertebrate paleontologists have been so long accustomed to regard the presence of dinosaurs as *prima facie* evidence of Cretaceous age, that doubtless a storm of protest will be raised at the position here assigned them; yet it should need but a moment's reflection to show that there is apparently no inherent structural or physiological peculiarity which barred them from crossing the line—if there be such—between Cretaceous and Tertiary time. To the naïve statement that the dinosaurs possess "decided Mesozoic affinities" there cannot be the slightest objection, since, being without known descendants, it is possible to compare them only with their ancestors, which were of course Mesozoic. It has also been urged recently, in all seriousness, that the time-honored custom of denominating the Cretaceous as the "Age of Reptiles" will be broken down if the dinosaurs are permitted to pass into the Tertiary, yet even this objection does not seem serious, especially as there are other undoubted Tertiary as well as living reptiles. The Nestors of American vertebrate paleontology have all, at one time or another, admitted the possibility

of the dinosaurs passing up into the Tertiary, and it would seem that the time had come to demand something more tangible than mere assumption for the Cretaceous age of the dinosaurs.

Hatcher,[43] in speaking of the Ceratops fauna, frankly stated that

> 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.

In the Denver Basin, where, as already set forth, the relation of the Laramie to underlying and overlying formations has been thoroughly and satisfactorily elucidated, the dinosaurs have not been found in the Laramie, though they are found in both Arapahoe and Denver formations. During pre-Arapahoe time, as Cross has shown, there was inaugurated the profound orogenic movement which originated the Rocky Mountains and a period of erosion which cut through many thousands of feet of strata before the beginning of deposition in the Arapahoe Lake. The vertebrate paleontologists do not appear to appreciate the significance of this great erosional interval and its attendant phenomena. Mr. Cross[44] has so admirably stated these conditions and the inference to be drawn from them, that I cannot refrain from quoting his words:

> The dinosaurs of the Ceratops beds are highly modified and specialized forms unknown as yet in other parts of the world except, perhaps, in the Gosau[45] formation of Austria, and the conclusion that they necessarily indicate a Mesozoic age implies some reason why they may not have survived into the early Tertiary.
>
> In the light of the facts which have been presented concerning the

[43] Am. Jour. Sci. (3), vol. 45, 1893, p. 140.

[44] Mon. U. S. Geol. Surv., 27, 1896, p. 251.

[45] The Gosau beds near Vienna, Austria, are usually referred to the upper Turonian or lower Senonian. They are overlain by several hundred feet of fossiliferous marine Cretaceous, and the dinosaur fauna, together with the associated fossil plants, indicate an age that is approximately that of the Judith River.

Prof. R. S. Lull (*in litt.*, January 19, 1909) coincides with this conclusion as to the stratigraphic position of the beds.

several epochs succeeding the Laramie it is not clear to the writer why this belief that the dinosaurs, or, indeed, the whole vertebrate fauna, surely indicate a Mesozoic age should be so positively maintained as is done by the vertebrate paleontologists.

If the dinosaurs of the Ceratops fauna did actually live in the Laramie epoch of Colorado they survived a great orographic movement and its accompanying climatic changes, and continued through the Arapahoe and Denver epochs so little modified that Professor Marsh has not detected any changes corresponding to the stratigraphic time divisions. This is all the more remarkable since the fossil plants show a great modification during this time, and it has been commonly claimed that enormous and highly specialized vertebrate animals are particularly sensitive to conditions of environments. If the Laramie vertebrates were unaffected by the known dynamic phenomena of the Colorado region in post-Laramie times, it may well be asked what caused their extermination in the post Denver interval, where as yet no evidence of orographic movements comparable with that of the pre-Arapahoe have been found. And if their extinction was due in large measure to other causes than those associated with dynamic phenomena, may that extinction not have been deferred until the Eocene?

These considerations seem to the writer ample ground for the demand that the causes leading to the extinction of the Ceratops fauna should be definitely connected with some orographic disturbance at the close of the Denver epoch before their presence in the Arapahoe and Denver beds can be admitted as full proof of the Mesozoic age of these formations.

That the ground above taken is logical and irrefutable is shown by the occasional testimony of vertebrate paleontologists themselves. Thus, Mr. Earl Douglass[46] in a paper dealing with the dinosaur- and mammal-bearing beds near Melville, Montana, says:

> If we could point to any time when dinosaurs ceased to be and the higher orders of mammals took their places, then the matter would be easy; but heretofore most of the Cretaceous dinosaurs—in fact nearly all of them—have been supposed to come from the uppermost Cretaceous—the Laramie—but the other fossils found in these beds have not been of a character to settle the doubt concerning the horizon. There is no direct proof that the dinosaurs died out before the higher forms of mammals became numerous. Though they have not yet, so far as I know, been found in the same beds,

[46] Proc. Am. Phil. Soc., vol. 41, 1902, pp. 218, 219.

yet there seems good reason for believing that dinosaurs were contemporaneous with Puerco mammals.[47] . . . It is extremely unsafe to say when and where these strange reptiles breathed their last, for the presence of fossils is certain evidence of the existence of life, but the lack of them is no evidence of its absence. Dinosaurs may have continued long in the Eocene, but conditions in the places where so many mammalian remains have been found may not have been favorable for them.

The causes which led to the extinction of the dinosaurs are of course unknown and may always remain so. Being highly specialized and supposedly sensitive to environmental changes, it is difficult to imagine what could have caused their sudden and absolute decimation. An orogenic movement with the effect it would have had on climate and vegetation; the draining of the waters in which, or beside which, they lived; the sudden incursion of mammal enemies able to cope with them; the outpouring of volcanic material; these, or any one of them, might account for their disappearance, but we have no evidence of the occurrence of either of these phenomena. If there was a change in climate, it was not reflected in the flora; if there were enemies, their remains have not been found; if there were volcanic disturbances, the ejectamenta are not present in the sediments, and finally, the waters were not drained; for sedimentation

[47] A striking confirmation of this prediction has just been brought to the writer's attention, this being an important discovery made by Mr. Jas. H. Gardner, of the U. S. Geological Survey, during the field season of 1908. At a point near the head of Coal Creek, 1 mile southeast of Ojo Alamo, New Mexico (about 12 miles south of Farmington), in variegated sands, shales and conglomerates, indisputable above the unconformity at the top of the Laramie, and thus apparently of Puerco age, he found "near the top of the section" vertebrate remains which have been studied by Mr. C. W. Gilmore who reports the presence of *Triceratops*, *Trachodon*, *Tyrranosaurus*, *Aspidiretes*, and crocodiles. Of this fauna Mr. Gilmore says: "Appears to represent a typical fauna of the so-called Laramie, or better, Ceratops beds." The significance of finding a typical "Ceratops beds" dinosaur fauna in beds that are more than probably of Puerco age, is apparent. It is also of interest to note that this locality (Head of Coal Creek) is exactly the same as that given by Wortman (Bull. Am. Mus. Nat. Hist., vol. vii, 1895, p. 2) as one of the localities at which he obtained Puerco mammals. And in this connection it may be added that the writer has just been informed that dinosaurs have been found associated with mammals in the so-called Pyrotherium beds of South America, which, it is said, are of acknowledged Eocene age, and correspond approximately to our Puerco.

was continuous. No more plausible theory occurs to the writer than that they were suddenly removed by epidemic disease, so many examples of which among recent animals have been given by Professor Osborn.[48]

b Mammals.

There is, in the present connection, neither opportunity, nor particular occasion, for going exhaustively into the bearing of the mammals on the questions here involved, other than a general statement as to their apparently complete distinctness from the mammals of the Cretaceous, and argeement with those of undoubted Tertiary age. When the mammals of the "Ceratops beds" were first mentioned by Marsh he made the following statement[49] concerning them:

All the mammals are of small size. They are mainly Mesozoic in type, and more nearly related to the Jurassic forms below than to those in the Tertiary above. . . . These remains are not transitional between Mesozoic and Tertiary forms, but their affinities are with the former beyond a doubt; thus indicating a great faunal break between the time in the Cretaceous when they lived and the earliest known Tertiary, or between the Ceratops horizon and the *Coryphodon* beds of the Eocene Wasatch. The lower division of the *Coryphodon* beds, or lower Wasatch (Puerco) is clearly Tertiary, and the great break is between this horizon and the Ceratops beds of the Laramie.

In this connection he also makes the following vigorous statement:

Bearing in mind all that is known today of the development and succession of vertebrate life in America, from early Silurian on to the present time, it is safe to say that the faunal break as now known between the Laramie and the lower Wasatch, is far more profound than would be the case if the earlier Jurassic and Cretaceous below the Laramie were wanting.

On the other hand Prof. H. F. Osborn[50] in his "Rise of the Mammalia," published the same year as the above quotation from Marsh, and based on similar material, makes the evolutionary break much

[48] Am. Nat., vol. 40, 1906, pp. 829–837.
[49] Am. Jour. Sci. (3), vol. 43, 1893, pp. 249–251.
[50] Studies from Biol. Lab. Col. Coll., Zoöl., vol. i, 1893.

less marked between the mammals of the "Ceratops beds" and those of the Puerco. His statement is as follows:

Estimating the geological intervals by dental evolution and faunal succession, there is first the great gap between the Trias of Microlestes and Dromotherium and the Jurassic of the Stonesfield state; there is a relatively shorter interval, but still a considerable one, between this and the Purbeck or Atlantosaurus beds. Then follows another long and very important interval between the Atlantosaurus beds and the Laramie (Upper Cretaceous). The gap between the Laramie and Puerco was relatively short as indicated by the comparatively limited evolution both of the Plagiaulacidæ and Tritubercula tes.

Mr. J. W. Gidley, of the United National States Museum, who has had opportunity of studying much of the material seen by Marsh, together with that upon which Osborn based his conclusions as well as some new material, takes even stronger ground than Osborn as to the affinities between the Ceratops and Puerco and Torrejon mammals. He says:

I do not hesitate to say, judging from the known forms, that the differences between the mammals of the Jurassic and those of the Ceratops beds are at least ten times as great as they are between the mammals of the Ceratops beds and those of the Puerco. This conclusion is based on morphological ground rather than actual relationships. Leaving the multituberculates out of consideration at present the pattern of the tooth-crowns, especially of the upper molars, in the Jurassic mammals is fundamentally different from that of the known mammals of any later horizons, while most of the forms of the Ceratops beds have attained the typical tritubercu ate pattern, which, with very slight variations, has been repeated over and over again in every higher horizon where mammals are found, and is the dominant form in most of living orders. The natural inference follows, therefore, that the time interval between the Ceratops beds and the lowest acknowledged Tertiary above is very slight as compared with that between the Ceratops beds and the Morrison beds below.

The multituberculates show almost as wide a difference in time between the Morrison and Purbeck, and Ceratops beds, while the Ceratops beds and Torrejon probably contain at least three genera of mammals (*Ptilodus*, *Cimolomys* and *Meniscoessus*) in common, and there are no genera in common with the Puerco. It is thus

made plain, that, so far as present knowledge goes, the relationships of the mammals of the Ceratops beds are, with the exception of the two doubtfully placed Judith River forms, exclusively Tertiary and not Cretaceous. That they had an anterior period of development is, of course, probable, but we do not know at present what that was, or how far back we must go for their starting point.

From what Mr. Gidley has stated it appears that the mammals of the "Ceratops beds" cannot be considered as affording evidence against the reference of these beds to the Tertiary. The Ceratops mammals cannot be regarded as the direct ancestors of those in the Puerco—for this would imply a considerable time interval—but rather as a different, possibly slightly older, phase of the same evolutionary stage. Recently Mr. Gidley has been studying a very interesting mammalian fauna secured in the vicinity of Melville, Montana, in beds of the Fort Union, which are of undoubted Torrejon affinity, while in beds of the upper member about 1200 feet above its base is another fauna which is even more typical of the Torrejon. Mr. Gidley permits me to say that the mammals of the "Ceratops beds" are apparently more closely related to those of the Fort Union (Torrejon) than they are to those of the Puerco, there being among the multituberculates as already stated three genera in common with the former and none with the latter. The evidence afforded by the trituberculates in general is similar, that is, they show more affinities with those of the Torrejon than with the Puerco.

c Chelonians.

Remains of turtles appear to be of rather common and widespread occurrence in the lower Fort Union, but they are usually so fragmentary as to be difficult or impossible of satisfactory identification; in any event, among the numerous specimens brought in in recent years by the writer and others, it has not been found possible to make even generic determinations by the paleontologists to whom they have been submitted.

It has recently been confidently asserted on eminent authority that the turtles of the "Ceratops beds" are very closely related to those of the Judith River formation; in fact that several species are identical, and others so close as to be separated with difficulty.

Fortunately the work of Hatcher,[51] published as late as 1905, has left us with a very complete annotated list of the Judith River forms, which makes a valuable basis for comparison of the two faunas. It needs, however, but a cursory examination to show that at least half of the species listed as belonging to the Judith River do not belong to this fauna at all, but come from the Fort Union, Arapahoe, etc., or are so fragmentary as to be unidentifiable. When there is added to this the possibility of the truth of Professor Osborn's[52] conjecture that there has probably been a mixture of horizons in the so-called Judith River fauna, any comparison of the turtles of the Judith River formation with those of the "Ceratops beds" as tending to support the Cretaceous age of the latter, does not make a very impressive case.

d Fishes.

The few and fragmentary fish remains from the "Hell Creek beds" were studied by Dr. C. R. Eastman and Dr. L. Husakof. Concerning them Eastman says: "As a whole the collection does not have a decided Cretaceous aspect," and adds that "it would be useless to argue from this that the beds in question are of Eocene age, for there are numerous fishes of preponderating Eocene type in the Fort Benton Cretaceous of Wyoming." From this it appears that the fish remains are not likely to be much of a factor in fixing the age of these beds, though if anything they favor the Eocene age.

Line Between Cretaceous and Tertiary.

All things considered it seems that the logical point at which to draw the line between the Cretaceous and Tertiary is at the top of the true Laramie. If a locality could be found at which sedimentation was continuous, it would probably be necessary to draw an arbitrary line, but we do not yet know any section of such completeness in this country. In favor of placing it at the point indicated, we have the evidence of diastrophism as signalized by the upbuilding

[51] Bull. U. S. Geol. Surv., 257, 1905, pp. 72–80.
[52] Geol. Surv. Canada: Contr. Can. Pal., vol. 3, pt. 2, 1902, pp. 8, 9.

of the Rocky Mountains, the general elevation of the country, and the permanent banishment of the sea, as well as the change in the character of the sediments. Plants show distinctly the inauguration of a new order of things, extremely few of the forms passing over from the Laramie, while many new types are introduced, among them a number of species which are living today, a condition not known for the flora of any earlier American horizon. If, as has been suggested, the line between the Cretaceous and Tertiary be drawn at the point where the dinosaurs happened to disappear, we are left without the support of contributory data. Diastrophism, orogenesis, continuity of sedimentation, floral similarity, as well as the evidence of invertebrates and mammals, are nullified.

Summary and Conclusions.

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, cannot 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.

Note.—For assistance in the preparation of this paper, both in the field and in the office, I wish to acknowledge my great indebtedness to Dr. A. C. Peale of the U. S. National Museum.