

**Article XXXIII.—THE HELL CREEK BEDS OF THE UPPER
CRETACEOUS OF MONTANA:**

THEIR RELATION TO CONTIGUOUS DEPOSITS, WITH FAUNAL AND FLORAL
LISTS AND A DISCUSSION OF THEIR CORRELATION.

BY BARNUM BROWN.

In the plains region of Montana east of the 108th meridian there is a series of Mesozoic strata overlain by fossil-bearing fresh-water deposits and lignite beds of unknown thickness. These beds are eroded into very rough badlands near the Missouri River north of Miles City.

The attention of Professor Osborn was first called to this locality by Dr. W. T. Hornaday, Director of the Bronx Zoölogical Garden, New York, who while hunting near the Missouri in 1901 discovered numbers of large bones in the bad lands. One of these bones, brought home for a paper weight, turned out to be the point of a horn of the large dinosaur *Triceratops*. In 1902 Professor Osborn sent the writer out to this region with such good results that the three succeeding years, 1903–6, were spent in the same general region. Thus a large collection of vertebrate, invertebrate and plant remains has been secured. Most of the exploration was in the Hell Creek region where continuous work has served to elucidate several seemingly complicated stratigraphical sections.

SOUTH OF THE YELLOWSTONE.

Between Miles City and Dickinson along the Yellowstone and south-eastward extending into Wyoming, and into North and South Dakota, are more or less continuous exposures composed of alternating sandstones and clays at base with several hundred feet of lignite and buff-colored shales toward the top. In most of these badlands remains of vertebrate animals are rare. The weathered fore limb of a *Triceratops* was identified by myself in the badlands near Glendive at an elevation of about 50 feet above the railroad track. Several other fragments of *Triceratops* and Trachodont dinosaurs were seen in this locality but not sufficiently preserved for specific determination.

South of Miles City, on Powder River, about twelve miles above Hockett, part of a *Triceratops* skeleton was found in dark shale near the level of the river. Several other fragmentary dinosaur bones were noted in this locality

but insufficient time was spent there to determine the relation of the different strata. Unconformably overlying the dinosaur-bearing clays west of Spring Creek there is a line of white cliffs, locally known as "Chalk Buttes," that extend into Wyoming. These beds are of Tertiary origin, probably Miocene, and resemble the Rosebud formation in lithological character. No fossils were found in them. However, in the First National Bank of Miles City there is a well preserved femur of a mastodon which is said to have been found in Powder River below the mouth of the Mizpah. It was undoubtedly washed down from this Tertiary bed, as all the surrounding strata at that point are older than the Fort Union.

Near Ekalaka the Field Columbian Museum expeditions have secured a collection of dinosaur remains which determine the dinosaur-bearing beds of that area as a continuation of those north of the river to be described later.

NORTH OF THE YELLOWSTONE.

Between the Yellowstone and the Missouri Rivers north of Miles City the surface of the country presents a rolling prairie, for the most part grassed over. Glacial drift is abundant over the region and near the Yellowstone, where it covers the ridges, is several feet in thickness. Near the Missouri it has been mostly eroded off and only the larger boulders remain.

On the divide between the two rivers there are few denuded areas; the largest exposure was found near the 21-mile road ranch on the stage road between Miles City and Jordan. Here the identified Fort Union has been eroded off, leaving the upper lignite clays. Another similar exposure was found on Thompson Creek. Both of these localities are barren of fossils where examined.

A few abrupt hills capped by sandstones stand out as monuments on the plains along the Little Dry at the road crossing and near Red Butte ranch. Near the Little Dry these sandstones contain unusually well preserved impressions of a rich flora that has been determined by Dr. F. H. Knowlton as of Fort Union age. The single specimen collected near Red Butte is a new species of *Cornus*, age uncertain. Lithologically these beds are of the same structure and are of about the same level, representing the middle and lower part of the Fort Union. Near the head of Crow Rock and Timber Creeks there is a range of light-colored higher hills, known as Sheep Mountains. They are probably of Tertiary origin.

In this longitude the Yellowstone is about 350 feet higher than the Missouri and its current is much swifter. It has cut through the identified Fort Union and a part of the lignite and sandstones which I believe belong

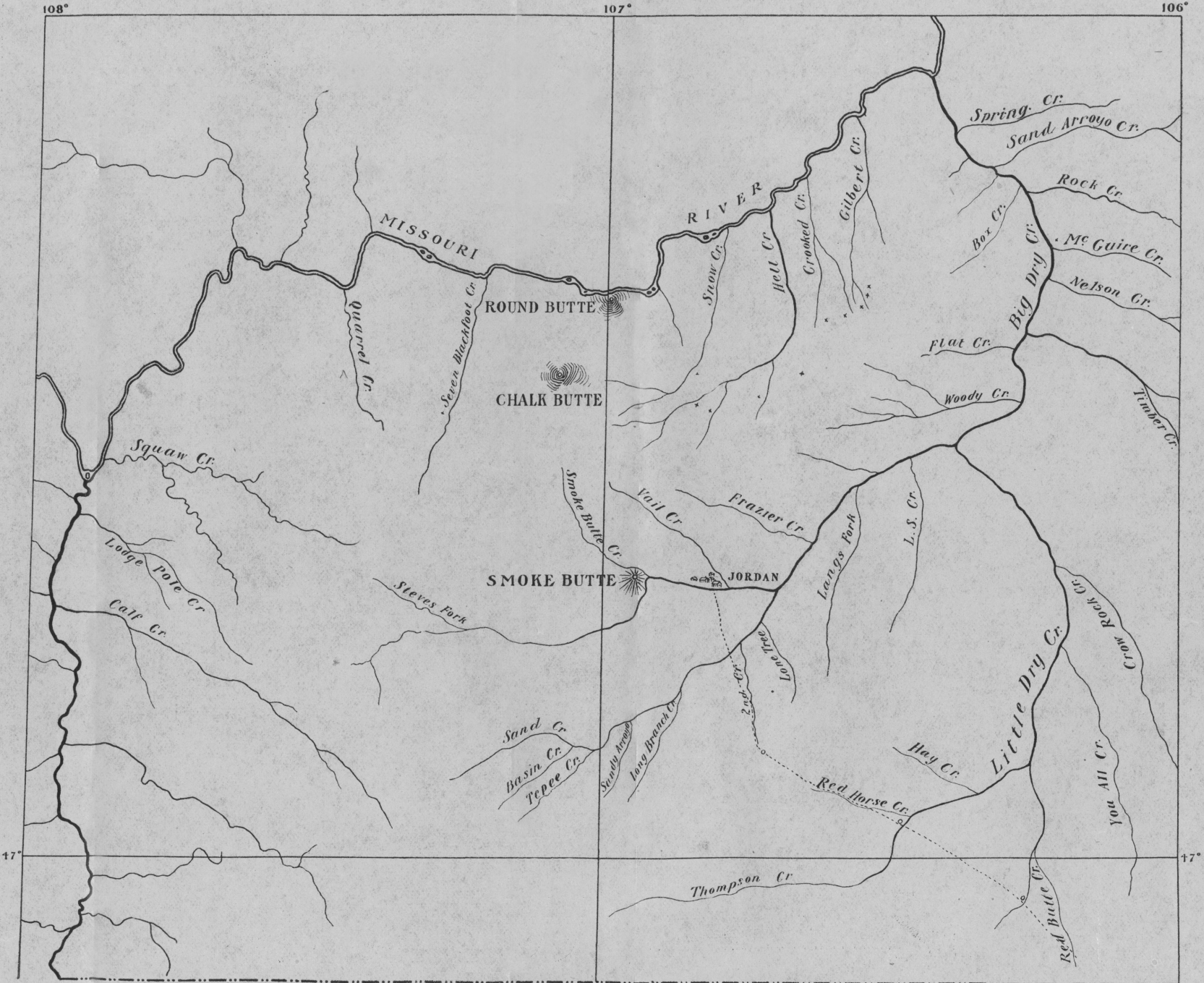


Fig. 1. Sketch map of western half of Dawson County, Montana. The crosses (X) indicate the location of important discoveries of vertebrate fossils. Scale, 11 miles to 1 inch.

to the lignite series exposed on Hell Creek. No fossils were secured from this locality, however, and the determination is based on its lithological structure and position.

The Missouri River has long since cut through the Fort Union and underlying strata far into the Pierre. Erosion is rapid in these shales, consequently the banks of the lateral streams are steep. Most of the tributaries of the Missouri on the south side between the Musselshell and the Big Dry are short streams confined by steep cañons.

This area is unsurveyed and all published maps are inaccurate in name, course and size of most of the streams. A prominent landmark, such as Smoke Butte, is placed at least twenty miles from its true position on these maps. The accompanying sketch map (Fig. 1) was made from data secured during four years of field work in this region. Although inaccurate in many respects it approximately gives the true course and relation of streams.¹

All the exposures examined on the tributaries of the Big Dry above the mouth of Woody Creek were found to be of Fort Union age; the country is open and for the most part grassed over. But as soon as the high divide bounding the short tributaries of the Missouri is crossed, the country takes on a more rugged character; the surface is eroded into badlands of wonderful beauty, the short deep cañons often presenting perpendicular walls from one to three hundred feet high with short lateral cañons that make the country almost impassable for riders. Many of these cañons, like Seven Blackfoot, are very narrow at the bottom. The torrents of water that flow down them in the spring freshets carry away the loose talus, leaving clean-cut, nearly vertical sections several hundred feet thick along streams not more than twenty miles in length, thus giving clean contact of different strata. The following barometrical measurements were taken from one of these sections on Hell Creek by Dr. A. G. Leonard, State Geologist of North Dakota.

Fort Union	. . . . .	115 feet
Lignite beds	. . . . .	100 "
Hell Creek beds	. . . . .	310 "
Fox Hills	. . . . .	100 "
Pierre	. . . . .	150 "

These measurements agree with estimated thickness of sections on Crooked Creek and Gilbert Creek, with the exception of the Fox Hills, which on cañon sides frequently seems to be much thicker than they are, on account of slipping. Where I have seen clean sections of the Fox Hills

¹ Since this paper was prepared a very accurate map of this region has been published in the July issue of 'The Auk' (Vol. XXIV, 1907, facing p. 244) by Mr. E. S. Cameron.

on Crooked Creek and Seven Blackfoot it was never more than sixty feet in thickness.

Fort Pierre.

In this locality the river has cut into the Pierre shales to a depth of nearly two hundred feet. At the mouths of the tributaries and on some of the intervening points the overlying beds are eroded off leaving the shales weathered into low ridges or rounded hillocks of drab-colored gumbo. Where newly exposed they are composed of dark, almost black fissile shales and loosely joined ferruginous-stained clays. Gypsum crystals are numerous toward the top of the formation. Concretions of different sizes are found in nearly every stratum, though not in great numbers. They are always in distinctly bedded planes unlike those in the later fresh-water deposits. These concretions are calcareous and are usually traversed in all directions by cracks filled with amber-colored calcite crystals. Invertebrates are found in the shale but more often embedded in calcareous concretions.

On the west side of Hell Creek, five miles from its mouth and about one hundred feet below the Fox Hills, numbers of small elongate and lozenge-shaped concretions occur. They are calcareous but seldom show calcite reticulations. Where weathered out they are light gray in color and nearly always contain large invertebrates such as *Baculites ovatus* or *Inoceramus sagensis*. A lobster-like crustacean was also common in this horizon. This is the form described by Prof. R. P. Whitfield as *Hoploparia browni*,¹ closely related to a species of that genus described from the green sand Cretaceous of England.

In this same valley, twenty feet below the base of the Fox Hills and one hundred feet below the base of the fresh-water Hell Creek beds, the remains of a large Trachodont dinosaur were discovered. This specimen was found *in situ*, partly embedded in a large calcareous concretion that was weathered out and broken; the humeri were still covered with shale and well preserved. A collection of characteristic invertebrates was secured on this same level and from a few feet above, all from the undisturbed black shales. They have been identified by Prof. R. P. Whitfield as follows:

<i>Inoceramus sagensis</i> E. & S.,	recognized from Pierre.
<i>Cardium</i> (<i>Leptocardia</i>) <i>subquadratum</i> E. & S.,	“ from Fox Hills.
<i>Yoldia evansi</i> M. & H.,	“ from Fox Hills and Pierre.
<i>Pteria</i> (<i>Oxytoma</i>) <i>nebrascana</i> M. & H.,	“ from Fox Hills and Pierre.
<i>Aporrhais biangulata</i> M. & H.,	“ from Fox Hills and Pierre.
<i>Anchura</i> (<i>Drepanochilus</i>) <i>americana</i> E. & S.,	“ from Fox Hills.

¹ This Bulletin, Vol. XXIII, 1907, p. 459, pl. xxxvi.

<i>Cinulia (Oligoptycha) concinna</i> H. & M.,	recognized from Fox Hills and Pierre.
<i>Natica (Lunatia) concinna</i> H. & M.,	" from Fox Hills and Pierre.
<i>Dentalium gracile</i> ? H. & M.,	" from Pierre.
<i>Scaphites conradi</i> Morton,	" from Fox Hills.
<i>Baculites ovatus</i> Say,	" from Fox Hills and Pierre.

This characteristic fauna was found nearly to the top of the black shale.

Fox Hills.

This formation was found to be about forty feet thick at the Cook ranch on Crooked Creek, but it increases in thickness to the westward. On Hell Creek it is about eighty feet thick where exposed in clean-cut sections. It consists of soft arenaceous shales and interstratified beds of clay, usually with a capping of sandstone. The clays are grayish yellow and of a decidedly lighter color than the Pierre shales (Fig. 2). They conformably overlie and merge into the darker shales below but a distinct structural change is immediately apparent. On Hell Creek and in that vicinity the apparent unconformity is due entirely to slipping and never shows in a clean-cut section. The clays are highly gypsiferous and the difference in color is most striking. Toward the summit of the clays, thin strata of hard, fine-grained sandstone frequently occur, but are not continuous; they usually show lamellar structure. On Hell Creek this zone is marked by a heavy bed of sandstone six feet thick. Capping the top of the formation there is usually a thin layer of ferruginous, flat concretions of small size. Rounded concretions occur at different levels but always in well stratified planes unlike those in the fresh-water Hell Creek beds above. They are calcareous and formed like those found in the Pierre. No fossils were secured from these beds on the eastern exposure; but on Hell Creek, below the Sensiba Brothers' ranch, the following collection was secured from concretions below the basal sandstones of the Hell Creek beds:

<i>Cardium (Protocardium) subquadratum</i> E. & S.,	recognized from Fox Hills.
<i>Nucula cancellata</i> M. & H.,	" " " "
<i>Tellina scitula</i> M. & H.,	" " " "
<i>Yoldia evansi</i> M. & H.,	" " " "
<i>Crenella elegantula</i> M. & H.,	" " " "
<i>Piestochilus culbertsoni</i> M. & H.,	" " " "
<i>Anchura (Drepanochilus) americana</i> E. & S.,	" " " "
<i>Lunatia concinna</i> H. & M.,	" " " "
<i>Cylichna scitula</i> ? M. & H.,	" " " "
<i>Baculites ovatus</i> Say,	" " " " and Pierre.
<i>Scaphites conradi</i> Morton,	" " " "
<i>Chemnitzia cerithiiformis</i> M. & H.,	" " " "
<i>Maetra ? nitidula</i> M. & H.,	" " " "
<i>Actaeon (Oligoptycha) concinnus</i> H. & M.,	" " " "

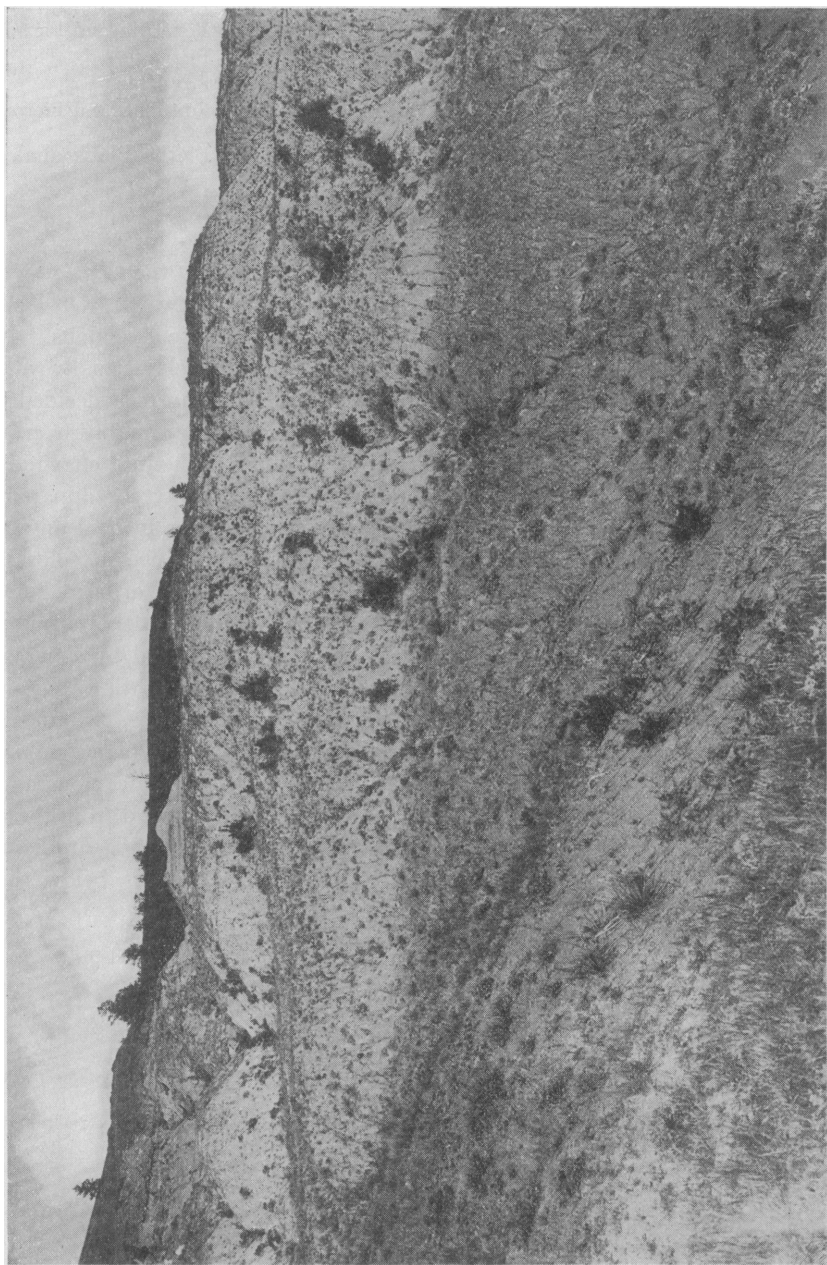


Fig. 2. Fox Hills formation overlying dark-colored Pierre shales, Crooked Creek, Montana.

Fig. 3. Diagrammatic section of Hell Creek beds and contiguous formations. Scale, 100 feet to 1 inch.

Fort Union			<p>"Populus arctica Heer"</p> <p>" amblyrhyncha Ward</p> <p>" cuneata Newb.</p> <p>" nebrascensis Newb.</p> <p>" craspedodroma Ward</p> <p>" daphnogenoides Ward</p> <p>" nervosa Newb.</p> <p>Platanus haydenii Newb.</p> <p>"Paliurus colombi" Heer as determined by Ward</p> <p>Sapindus affinis Newb.</p> <p>" grandifolius Ward</p> <p>Cocculus haydenianus Ward</p> <p>Calycites polycapalus Newb.</p> <p>Leguminosites arachnoides Lesq.</p> <p>Taxodium occidentale Newb.</p> <p>Sequoia nordenskiöldi Heer</p> <p>Glyptostrobus europaeus (Brgt.) Heer</p> <p>Corylus macquarrii (Forbes) Heer</p> <p>" sp. ?</p> <p>Hicoria antiquorum (Newb.) Knowlton</p> <p>Ginkgo adiantoides (Unger) Heer</p>
Lignite	Champsosaurus laramiensis ambulator		<p>Rhamnus salicifolius Lesq.</p> <p>Pterospermites sp.</p> <p>Sabalites fructifer ? Lesq.</p>
Hell Creek Beds	<p>Ptilodus sp.</p> <p>Meniscoëssus conquistus sp.</p> <p>Triceratops serratus</p> <p>" brevicornis sp.</p> <p>Trachodon ? sp.</p> <p>Trachodon sp.</p> <p>Tyrannosaurus rex</p> <p>Ornithomimus altus?</p> <p>Aublysodon sp.</p> <p>Palæoscincus sp.</p> <p>Champsosaurus laramiensis</p> <p>Crocodylus sp.</p> <p>Basilemys sinuosa</p> <p>Adocus lineolatus</p> <p>Compsemys victa</p> <p>" obscura</p> <p>Aspideretes (Trionyx) foveatus beecheri</p> <p>Scapherpeton tectum?</p> <p>Diphyodius sp.</p> <p>Rhineastes sp. indet.</p> <p>Pappichthys sp. indet.</p> <p>Lepidosteus occidentalis</p> <p>Lana sp.</p>	<p>Unio æsopiformis Whitf.</p> <p>" corbiculoides Whitf.</p> <p>" pyramidellus Whitf.</p> <p>" verrucosiformis Whitf.</p> <p>" retusoides Whitf.</p> <p>" browni Whitf.</p> <p>" percorrugata Whitf.</p> <p>" postbiplicata Whitf.</p> <p>" aldrichi White</p> <p>" danae White</p> <p>" holmesiana White</p> <p>" vetusta Meek</p> <p>" cryptorhynchus White</p> <p>" biasopoides Whitf.</p> <p>" cylindricoides Whitf.</p> <p>" letsoni Whitf.</p> <p>" gibbosoides Whitf.</p> <p>" pyramidaloides Whitf.</p> <p>" subtrigonalis Whitf.</p> <p>Sphærium planum M. & H.</p> <p>Corbicula subelliptica M. & H.</p> <p>Campeloma multilineata M. & H.</p> <p>" vetula M. & H.</p> <p>" producta White</p> <p>Vivipara plicapressa White</p> <p>Cassiopella turricula White</p> <p>Thaumastus limnæiformis White</p> <p>Bulinus rhomboideus M. & H.</p>	<p>Equisetum lævigatum</p> <p>Rhamnus salicifolius</p> <p>Ficus spectabilis</p> <p>Sequoia heerii ?</p>
Fox Hills		<p>Cardium (Protocardium) subquadratum</p> <p>Nucula cancellata</p> <p>Tellina scitula</p> <p>Yoldia evansi</p> <p>Crenella elegantula</p> <p>Plestochilus culbertsoni</p> <p>Anchura (Drepanochilus) americana</p> <p>Lunatia concinna</p> <p>Cylichna scitula ?</p> <p>Baculites ovatus</p> <p>Scaphites conradi</p> <p>Chemnitzia cerithiformis</p> <p>Maetra? nitidula</p> <p>Actæon (Oligoptycha) concinnus</p>	
Pierre	Trachodont	<p>Inoceramus sagensis E. & S.</p> <p>Cardium (Leptocardia) subquadratum E. & S.</p> <p>Yoldia evansi M. & H.</p> <p>Pteria (Oxytorma) nebrascana M. & H.</p> <p>Aporrhais biangulata M. & H.</p> <p>Anchura (Drepanochilus) americana E. & S.</p> <p>Cinulia (Oligoptycha) concinna H. & M.</p> <p>Natica (Lunatia) concinna H. & M.</p> <p>Dentalium gracile ? H. & M.</p> <p>Scaphites conradi Morton</p> <p>Baculites ovatus Say</p>	

Hell Creek Beds.

Overlying the Fox Hills there is a fresh-water deposit that is rich in vertebrate fossils. These beds are exposed on the Yellowstone River at Sentinel Butte near Forsyth; at Glendive; near Ekalaka 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, judging from the fauna of the latter districts. These beds, with overlying and underlying deposits, are typically exposed on Hell Creek and nearby tributaries of the Missouri River; hence they have been designated the Hell Creek beds. (Fig. 3.)

The deposit is bounded, roughly speaking, on the west by the Mussel-shell River. Its eastern and southern boundaries have not been determined. The beds on the northern exposure generally dip to the south and east at an angle of nearly 15° but in some places they are normally horizontal.

The beds may be divided into an upper and a lower member. The former is composed of arenaceous clays alternating with sandstones and carbonaceous matter. The lower member consists of massive sandstone.

Basal sandstone.—This is the most constant of the series. It unconformably overlies the Fox Hills, as shown near the Cook ranch on Crooked Creek; also on Hell Creek. This unconformity is erosional in character. On the east fork of Hell Creek it measures 160 feet in thickness but thins out toward the east. On Gilbert Creek the minimum was found to be less than 40 feet. The average thickness over this whole area is about 80 feet. On the north side of the Missouri most of the upper strata are eroded away and the dip of the beds brings the basal sandstone on the same level with the buff-colored Fort Union on the south side of the river. On account of the similarity in color the Fox Hills on the north side of the river may be mistaken for a continuation of the buff-colored Fort Union on the south side. The sandstones extend on an average about ten miles beyond the river, north of which the Fox Hills and Pierre come to the surface.

The sandstones are fine-grained, massive and usually cross-bedded and composed of angular grains of quartz loosely cemented with carbonate of lime. A characteristic feature of this deposit is the presence of numerous concretions (Fig. 4) that are composed of the same material as the surrounding sandstone but are harder and more compact. They are found throughout the beds. Some are almost perfect spheres and vary from the size of a marble to several feet in diameter. Others are irregular in form. It is not an infrequent sight to see a group of spheres weathered out in a depression like a nest of eggs, or in another place several parallel concretions, circular in cross-section and a hundred feet in length, like fallen trees.

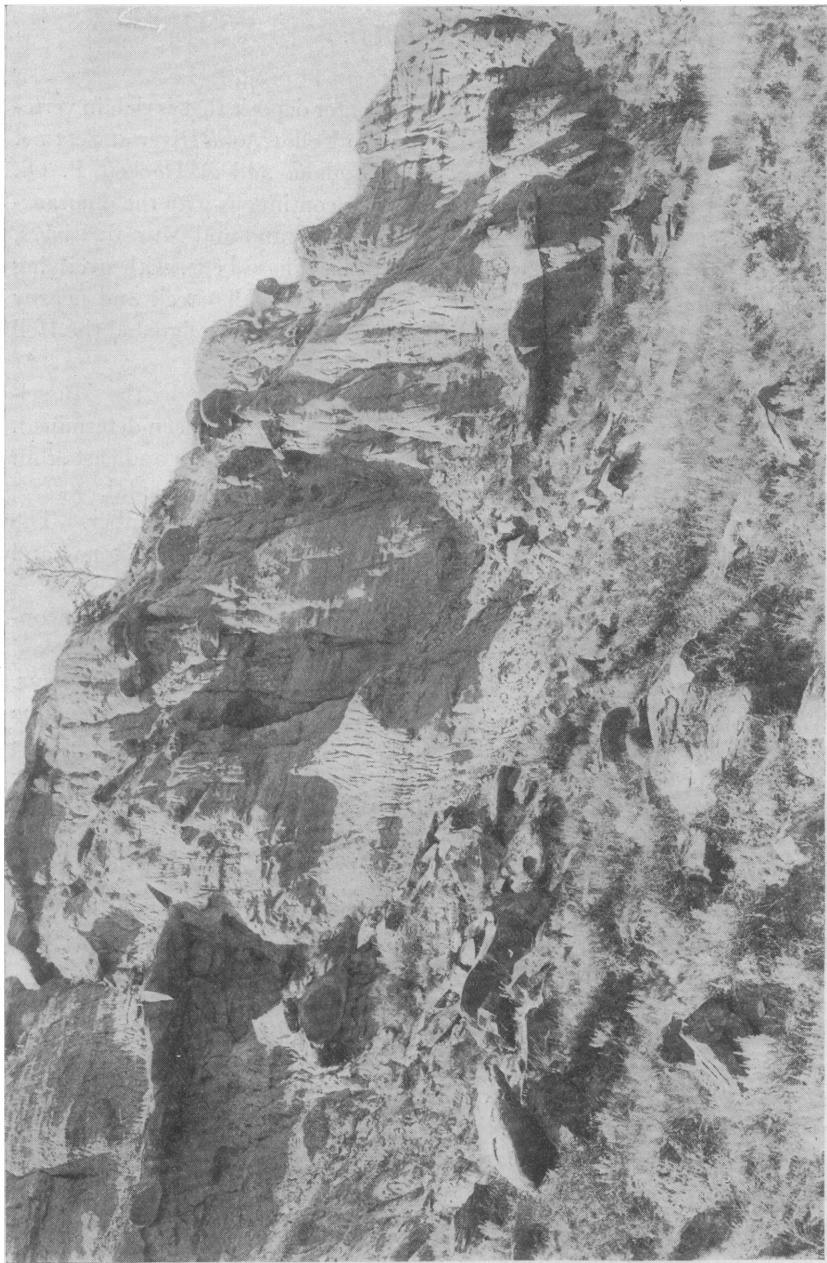


Fig. 4. Basal sandstone showing concretions, Hell Creek beds on Crooked Creek, Montana.

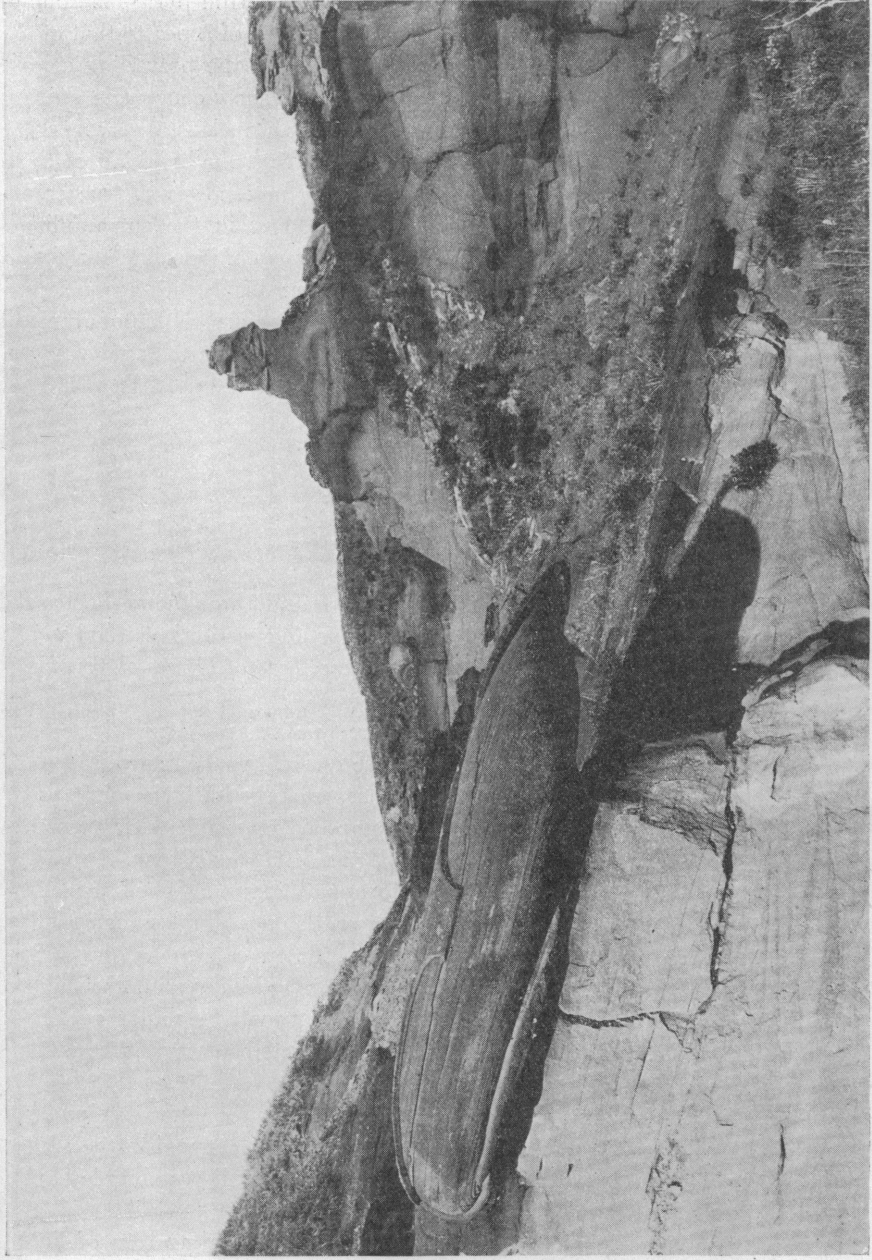


Fig. 5. Sandstone concretion showing concentric structure, Hell Creek beds.

The general tone of color is a light sepia brown. Iron pyrites is abundant, usually formed into perfect spheres from the size of a pea to that of a baseball. The oxidization of the iron probably gives the prevailing color to the sand. The sandstone concretions frequently show concentric structure, as clearly shown in Fig. 5. They often enclose a nucleus of clay lenses, brecciated pebbles or bones, and are so compact that the breaking of the concentric layers gives a loud report. They are not, however, true concretions but centers of solidification. Cross-bedding in the surrounding soft sandstone is frequently carried through the concretions line for line. On the outside they are stained a dark rusty brown; inside they are usually a flinty blue sandstone having a specific gravity nearly equal to that of granite and composed of irregular grains of quartz. This material analyzes as follows.

Carbonate of lime	. . . . .	60 %
Siliceous and feldspathic matter	. . . . .	35 %
Andesytic matter	. . . . .	05 %

Thin strata of carbonaceous matter were found throughout the basal sandstones, and usually imperfect casts of stems and sections of wood were abundant in the concretions. *But nowhere were beds of lignite observed in this member.*

Irregular beds of limestone of an impure quality are frequently found low down, and where exposed in the course of streams have arrested the cutting, forming waterfalls. Near the base, cross-bedding is more pronounced, and numerous thin strata are composed of rounded clay lenses.

Near the eastern border of the outcrop, east of Gilbert Creek, the basal sandstone changes considerably in color, form and texture. The light sepia color changes to a gray, and the massive sandstones are less compactly cemented. They weather rapidly into steep, fluted cañons as shown in Fig. 6. These sandstones simply melt away before a driving rain, like sugar. Concretions are numerous in this zone and are usually globular or lens-shaped. Compact, hard sandstones, showing laminated structure, frequently occur in this eastern region.

Upper beds.—The strata above the basal sandstone are not continuous, but two thin beds of sandstone are usually present, occupying the same relative position wherever found. Both are rich in fossil vertebrates; and consequently were traced for miles.

Immediately overlying the basal sandstone there is a stratum of light blue or slate-colored clay about twelve feet thick which in local sections,

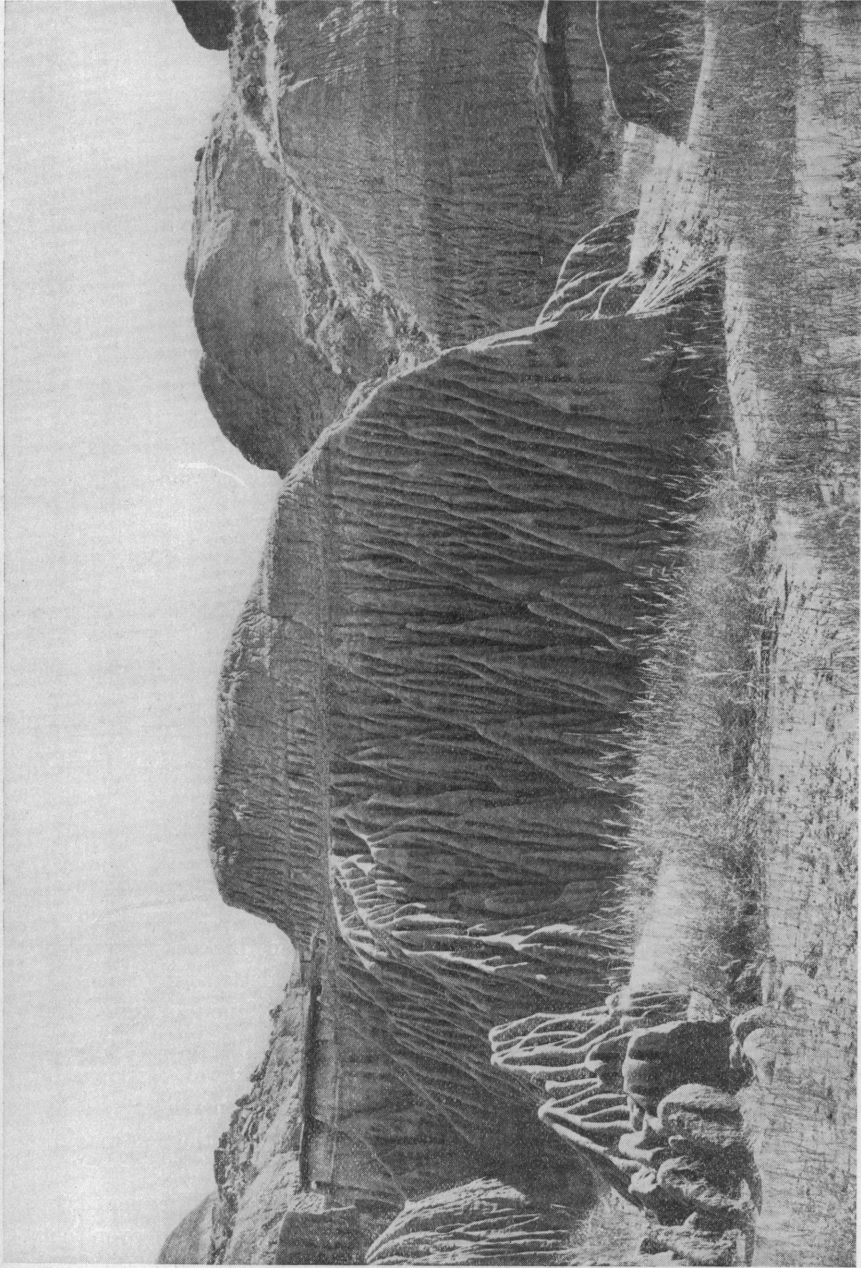


Fig. 6. Basal sandstone, corrugated phase, west fork of Crooked Creek.

as on the east fork of Crooked Creek, increases to a thickness of thirty feet, where it is highly colored, purple at base and light blue above.

Next come the two sandstone strata before mentioned. They are each from twelve to fifteen feet thick and are separated by forty feet of banded clays similar to those above. Both of these strata are considerably lighter in color than the basal sandstone, and cross-bedding is not as marked. Concretions are numerous and similar in form and composition to those found in the basal sandstone. Beds of river-sorted gravel occur in these two strata. They invariably contain waterworn fragments of bones and shells. An example may be seen near Mr. Oscar Hunter's fence near Crooked Creek where the gravel is cemented into a conglomerate capping a low ridge. This bed is a hundred yards long and stained a dark rusty color contrasting with the light color of the surrounding beds. Between these sandstone strata and below them invertebrates are frequently found.

Above the sandstones are a hundred and sixty feet of bluish clays, of a somewhat flocculent structure, composed approximately as follows:

Clay	60 %
Siliceous and feldspathic material	38 %
Tendrulous organic substances	02 %

Mica scales are present and all strata contain a great deal of vegetable substances.

In some localities the clay gives place to pockets of heavy sandstone. On the east fork of Hell Creek the sandstone is capped by a stratum of impure limestone which cleaves into angular fragments at right angles to the bedding plane.

Fort Union?

Lignite beds.—Overlying the dinosaur clays are the lignite series which apparently represent an uninterrupted continuation of the former. These beds on Hell Creek are 100 feet thick, increasing in thickness toward the south. At Miles City over 400 feet are exposed, and I was informed by a well-driller of that town that he had bored through a four foot vein of coal over a hundred feet below the river level in the valley of the Yellowstone.

These beds are characterized by the large amount of carbonaceous matter and frequent veins of lignite. A section taken on the east fork of Hell Creek shows as follows: Capping the dinosaur clays there is a vein of lignite about 4 feet thick, followed by 25 feet of arenaceous clays interlined with very thin strata of sandstone, usually cross-bedded. Frequent layers of flattened chert pebbles, having skins of limonite encrusted over them, are found at the base and more or less throughout the lignites. These peb-

bles have the lustre of gun-metal and when struck ring like steel. They were probably formed on the floor of shallow ponds or in bog land. Above this stratum is another vein of lignite followed by 20 feet of clays and sandstone of a dark grayish brown color, which are capped by a third vein of lignite about three feet in thickness. This is the purest vein exposed on Hell Creek. It burns to a light ash with few clinkers and under forced draft will fuse steel. Above this vein there are about 40 feet of very light-colored sand which merges into a light ochreous-yellow or buff-colored clay.

A few indeterminable casts of shells were found in the lignite associated with the chert. Also a few distorted leaves identified by Dr. Arthur Hollick as *Rhamnus salicifolius* Lesq. and *Pterospermites* sp.; also a mass of seeds resembling *Sabalites fructifer* Lesq. These came from just above the lowest vein of lignite. Crocodile, turtle and rhynchocephalian remains were found all through the lignite but most abundant and best preserved near the base. This is the horizon in which *Champosaurus laramiensis*¹ and *C. ambulator* were discovered.

It is a most remarkable and significant fact that in no instance has a fragment of dinosaur bones been found in or above the lignite series by any of our party during five years' work in this region.

For this reason I have considered the lignites separately. They probably belong to the Fort Union age. Species of such genera as *Champosaurus*, *Adocus* and *Crocodylus*, which have persisted unchanged through two or more long geological periods, cannot be considered as diagnostic of a formation. But the sudden termination of the many highly specialized forms of dinosaurs indicates a considerable time hiatus or a sudden and marked change in geological conditions.

Throughout this whole region the lignite veins have been fired in different places, sometimes burning over considerable areas. The beds have probably taken fire by spontaneous combustion, prairie fires or lightning. The overlying and underlying rocks have thus been altered to a considerable degree. Frequently the strata have been fused, developing both flow and vesicular structure, closely resembling lavas. North of Jordan many of the hill tops are covered with such fused material which stand out as monuments. In a less fused condition, where the strata have simply been hardened, it has arrested degradation leaving hills capped with rose colored, indurated shales.

Fort Union.

The identified Fort Union, which is distinguished by its light buff color, overlies the lignites. The beds are composed of very fine-grained sand-

¹ Brown, Mem. Am. Mus. of Nat. Hist., Vol. IX, pt. I, 1905.

stone, impure limestones and highly micaceous shales with occasional veins of lignite. The sandstones are lamellar in structure and in most places are rich in impressions of a characteristic Fort Union flora. Leaf impressions are found in many places over the divide between the Missouri and the Yellowstone Rivers, on the head of Hell Creek, on the Little Dry, at Red Butte ranch, and near the top of Signal Butte, south of Miles City. These impressions are in most instances perfectly preserved. They have been identified by Dr. F. H. Knowlton as follows:

From Smoke Butte Creek, 14 miles northwest of Jordan.

<i>Populus arctica</i> Heer, as identified by Lesq.	<i>Platanus haydenii</i> Newb.
<i>Populus amblyrhyncha</i> Ward.	<i>Paliurus colombi</i> Heer, as determined by
<i>Populus cuneata</i> Newb.	Ward.
<i>Populus nebrascensis</i> Newb.	<i>Sapindus affinis</i> Newb.
<i>Populus craspedodroma</i> Ward.	<i>Sapindus grandifoliolus</i> Ward.
<i>Populus daphnogenoides</i> Ward.	<i>Cocculus haydenianus</i> Ward.
<i>Populus nervosa</i> Newb.	<i>Calycites polycephalus</i> Newb.
<i>Platanus raynoldsii</i> Newb.	<i>Leguminosites arachioides</i> Lesq.

From Vail Creek, 100 feet above Hell Creek beds.

<i>Taxodium occidentale</i> Newb.	<i>Glyptostrobus europæus</i> (Brgt.) Heer.
<i>Sequoia nordenskiöldi</i> Heer ?	

From Little Dry, 24 miles southwest of Jordan.

<i>Glyptostrobus europæus</i> (Brgt.) Heer.	<i>Corylus</i> sp. ?
<i>Corylus macquarrii</i> (Forbes) Heer.	

From ridge 50 miles northwest of Miles City.

<i>Hicoria antiquorum</i> (Newb.) Knowlton.	<i>Ginkgo adiantoides</i> (Unger) Heer.
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The strata containing this flora are horizontal and were evidently laid down under more uniform conditions than the underlying Hell Creek beds. On Signal Butte, near Miles City, a four-foot ledge of sandstone separates the lignites from the buff-colored Fort Union. This sandstone is not continuous but the light color and finer grained material always defines this zone. About 120 feet of identified Fort Union forms the top of Signal Butte, which is capped, like the surrounding hills, with rose-red indurated shales altered by fired veins of lignite, as noted in the lignite beds.

About six miles above Jordan on the Big Dry there is a landmark famous in that section of the country, named Smoke Butte (Fig. 7). It is visible for many miles and stands out as a monument, nearly 200 (estimated) feet

above the surrounding country. It was near here that the last of the great buffalo herds was killed.

The butte is of igneous origin and is connected with lesser buttes on either side by a dyke. The dyke is composed of highly vesicular andesyte. The vesicles are uniformly parallel, pyriform or cylindrical, and lined with calcite crystals. Some of the vesicles are half an inch in diameter and more than an inch in length. All are vertical. The dyke varies from one to three feet in width. Apparently its extrusion caused little if any alteration in the confining sedimentary strata and no displacement of the buff-colored Fort Union beds, which are perfectly horizontal on either side (Fig. 8). The buttes, which are cones, are simply large plugs, and there is no evidence of a flow anywhere in the country.

Several other dykes were seen on the west side of Smoke Butte Creek but were not examined. The buttes and dykes were evidently formed subsequent to the deposition of the lignites, probably during the latter part of the Fort Union age.

PRESENCE AND CONDITION OF FOSSILS IN HELL CREEK BEDS.

Invertebrates.

Invertebrate fossils were found in several localities in the upper clays. East of the main branch of Hell Creek, about two miles southeast of Sensiba Brothers' ranch, they are especially abundant and so well preserved that even the hinge ligament is often present. This locality furnished representatives of nearly all the species collected. The basal sandstone contains few invertebrates and they are rarely well preserved. Unios were invariably the common forms found in the lower levels.

The invertebrates of the Hell Creek beds are a purely fresh-water fauna with the exception of the brackish or fresh-water genus *Corbicula* and the land genus *Bulinus*. The collection is especially rich in Unios, both in numbers and species. In the list given below a large number of the Unios have been found only in the Hell Creek beds, while three species have been found in the Converse County beds also.

Unio æsopiiformis Whitf.
 " *corbiculoides* Whitf.
 " *verrucosiformis* Whitf.
 " *retusoides* Whitf.
 " *browni* Whitf.
 " *percorrugata* Whitf.
 " *postbiplicata* Whitf.
 " *aldrichi* White.

Unio letsoni Whitf.
 " *pyramidellus* Whitf.
 " *gibbosoides* Whitf.
 " *pyramidatoides* Whitf.
 " *subtrigonalis* Whitf.
Sphærium planum M. & H.
Corbicula subelliptica M. & H.
Campeloma multolineata M. & H.

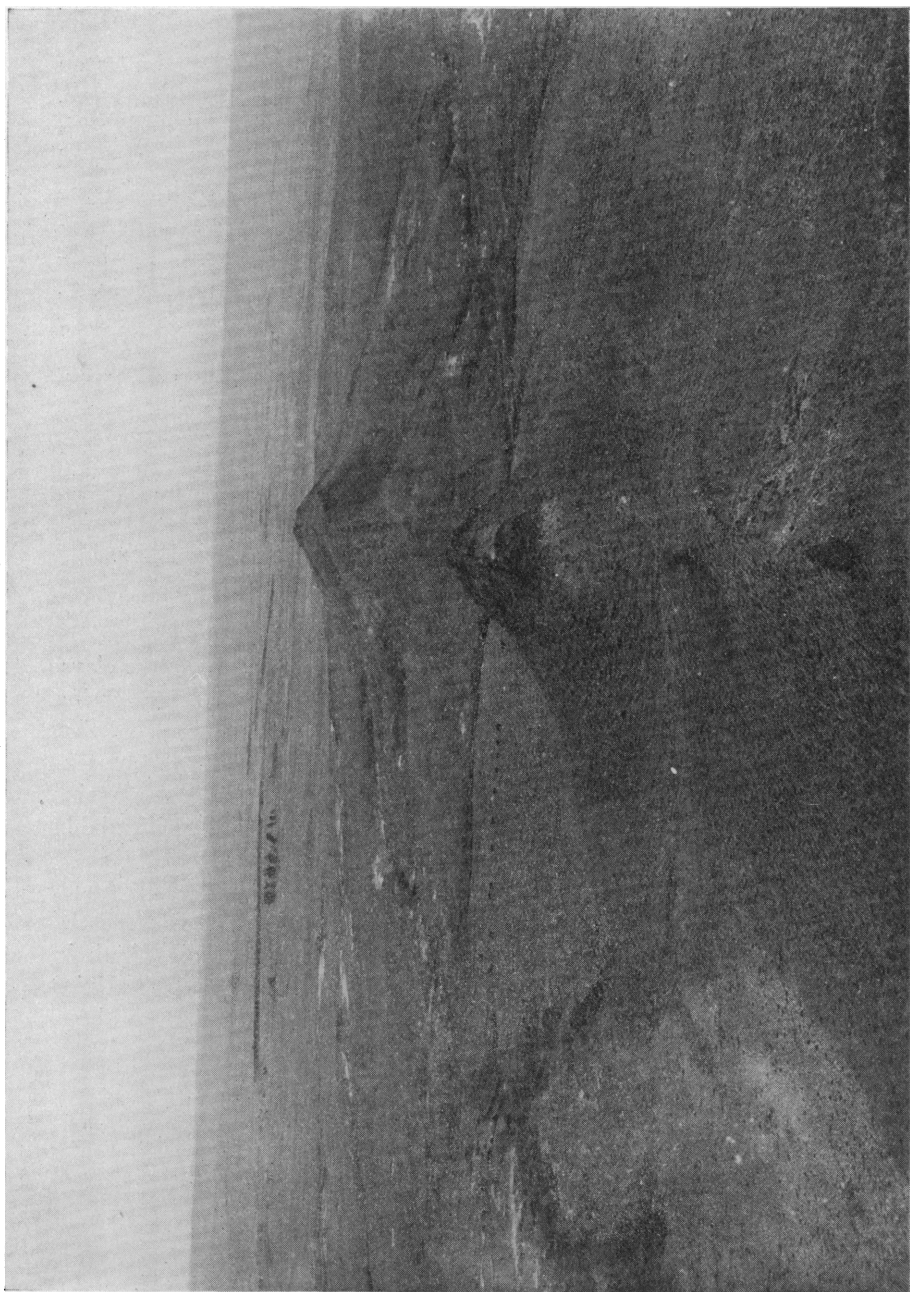


Fig. 7. Smoke Butte with dyke and lesser cones.



Fig. 8. Smoke Butte and undisturbed Fort Union strata on either side of dyke.

Unio danaë M. & H.

“ *holmesiana* White.

“ *vetusta* Meek.

“ *cryptorhynchus* White.

“ *biesopoides* Whitf.

“ *cylindricoides* Whitf.

Campeloma vetula M. & H.

“ *producta* White.

Vivipara plicapressa White.

Cassiopella turricula White.

Thaumastus limnæiformis White.

Bulinus rhomboideus M. & H.

In discussing this fauna and comparing it with living forms Prof. R. P. Whitfield says: “Considering all the similarities between these Laramie fossils and their representative species in the Mississippi and Ohio watersheds, I venture to state that these farther western waters of the Laramie times were the original home of much of the *Unio* fauna of these more eastern recent localities.”¹

Vertebrates.

Vertebrate fossils are found throughout the Hell Creek beds. Rarest of these are the remains of mammals, which are represented by single teeth with an occasional fragmentary limb bone or vertebra. These remains are nearly always associated with ganoid fish scales, vertebræ and washed bones, and in the Hell Creek region were always found at the base of the two prominent sandstone strata in the upper beds. The teeth are very small and difficult to see; frequently they are conspicuous on ant-hills favorably located in one of these beds of water-washed material, where they have been separated from the finer sand and carried out with pieces of small gravel.

The almost total absence of mammal remains from strata in which dinosaurs are common indicates a difference in habitat of the two groups. It is noteworthy that these remains have always been found in water-worn debris. They may represent river arboreal types. It is highly probable that the mammalian plains fauna of Laramie times has not yet been recognized. Several different forms of multituberculate and trituberculate teeth are represented, but as only a few of these can certainly be associated it would be hazardous to identify them with separate teeth that have been found in other localities. The genera *Ptilodus* and *Meniscoëssus* are represented by teeth indicating two or more species. *Ptilodus*, and *Polymastodon*, a genus closely related to *Meniscoëssus*, are found in the lowest Eocene and the species here represented indicate a closer affinity to the lower Eocene mammals than to the same genera of the Jurassic. The difference between the mammalian fauna of the Puerco and that of the Laramie series, however, is greater than between the Puerco and the Wasatch formations.

¹ This Bulletin, XXIII, 1907, p. 624.

Of the dinosaurs the Ceratopsia seem to have been most abundant. Remains of *Triceratops* are found from the very base of the sandstone to the top of the beds. At least two hundred skulls were found in this formation during our work, but in nearly every case they were so badly broken as to be of little value in specific determinations. Invariably when found in the soft clays the skulls are badly crushed and usually broken. The bones are nearly always scattered; seldom are there found in one place more than a skull or a few vertebræ and ribs, possibly a limb associated. Some of this material has not yet been identified, while in other cases it represents undescribed species. The genus *Torosaurus*, which frequently occurs in the Converse County beds of Wyoming, has not been found in the Hell Creek beds.

Next to the Ceratopsia in frequency of occurrence are found representatives of the Trachodontidæ. These forms usually have the greater part of the skeleton associated, which is probably due to two or more reasons: (1) Members of this family were probably primarily aquatic. (2) The great number of ossified tendons lying along the transverse processes of the vertebræ bound the skeleton together even after the flesh was decomposed. (3) The opisthocelus form of vertebræ with locking zygapophyses further bound the skeleton together. The fossils found in the Hell Creek beds so far are species having teeth with smooth borders, a character that is considered more specialized than those having crenulated borders. One of these species having teeth with smooth borders is common to the Converse County beds.

Carnivorous dinosaur remains are rare and are most frequently found in the lower sandstones, usually in concretions. The largest of these, *Tyrannosaurus rex*, has also been found in the Converse County beds of Wyoming.

During this period there were many small dinosaurs of which we know comparatively little. They are represented by single teeth, vertebræ and phalanges. Similar teeth have been found in the Converse County beds.

Turtles are quite common but complete shells are rare; nearly all the genera and species are common to the Converse County beds. Crocodiles and Champsosaur vertebræ are found in all upper levels but skeletons were confined to the overlying lignites.

Isolated fish scales, vertebræ and plates occur in the clays, usually at the base of the two prominent sandstone strata in the upper beds overlying the basal sandstone where they are found in quantities. Urodele vertebræ are usually associated with these fish scales. Dr. Charles R. Eastman and Dr. L. Hussakof have examined the fish remains, but report the material so fragmentary that only a few genera can be recognized with certainty. Of

these genera probably the most interesting is the shark *Lamna*, represented by a single tooth. This is the only known marine genus represented in the collection. Among living sharks, however, this form has been found in rivers far from the sea, so that its presence in this inland fresh-water deposit is not of especial import. In discussing these fragmentary remains Dr. Eastman writes me: "As a whole the collection does not have a decided Cretaceous aspect. Nevertheless, 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."

When found in the sandstones, vertebrate fossils are well preserved and rarely crushed, but in the clays they are almost invariably crushed and badly broken. The genera and species of vertebrate fossils identified from the Hell Creek beds are as follows:

List of Vertebrates.

<i>Ptilodus</i> sp.	<i>Crocodylus</i> sp.
<i>Meniscoëssus conquistus</i> Cope.	<i>Basilemys sinuosa</i> Riggs.
<i>Meniscoëssus</i> sp.	<i>Adocus lineolatus</i> Cope
<i>Triceratops serratus</i> Marsh.	<i>Compsemys victa</i> Leidy.
<i>Triceratops brevicornus</i> Marsh.	<i>Compsemys obscura</i> Leidy.
<i>Triceratops</i> sp.	<i>Aspideretes (Trionyx) joveatus</i> Leidy.
<i>Trachodon</i> ? sp.	<i>Aspideretes beecheri</i> Hay.
<i>Trachodon</i> sp.	<i>Scapherpeton tectum</i> ? Cope.
<i>Tyrannosaurus rex</i> Osborn.	<i>Diphyodus</i> sp.
<i>Ornithomimus altus</i> ? Lamb.	<i>Rhineastes</i> sp. indet.
<i>Aublysodon</i> sp.	<i>Pappichthys</i> sp. indet.
<i>Palæoscincus</i> sp.	<i>Lepidosteus occidentalis</i> Leidy.
<i>Champsosaurus laramiensis</i> Brown.	<i>Lamna</i> sp.

Flora.

Although fossil leaves, stems and fruits are of common occurrence in these beds very little of the material is sufficiently well preserved for identification. All the identifiable material comes from the upper beds, above the basal sandstone. So far only three or four identifiable species have been preserved, as *Equisetum lævigatum*, *Rhamnus salicifolius* Lesq., *Ficus spectabilis* Lesq. Only one of these, a fruit identified by Dr. Knowlton as *Ficus*, is common to the Converse County beds.

There is a series of lignite beds overlying the Converse County beds similar to those overlying the Hell Creek beds. In 1900 I obtained a collection of leaf impressions near the base of these beds on Seven Mile Creek, 40 miles northwest of Edgemont, S. D. At that time I was unable to define the limits of the dinosaur horizon and the fossils were marked "Ceratops beds?" Dr. Knowlton has identified the collection as follows:

Taxodium occidentale Newb.
Sequoia nordenskiöldi ? Heer.
Dammara sp.
Platanus raymoldsii Newb.

Platanus sp.
Quercus sp.
Carpites sp.

They are said to be a typical Fort Union flora from near the base of the formation. As far as identified the species agree with those found in the Fort Union near Hell Creek, Mont. Another collection from the same locality on Seven Mile Creek, but lower and associated with a dinosaur skeleton, *Claosaurus annectens* Marsh, were identified as follows.

Sequoia heerii Lesq.
Taxodium distichum miocenum (Brongn.)
 Heer.
Ginkgo adiantoides Heer.
Musophyllum sp. probably new.
Flabellaria eocenica Lesq.
Sabalites grayanus Lesq.

Palmocarpom palmarum (Lesq.) Knowlton.
Platanus rhomboidea Lesq.
Platanus sp.
Ficus spectabilis Lesq.
Viburnum sp.

Although the horizons from which these two collections were obtained are separated by less than two hundred vertical feet the species are not common to both horizons. Dr. Knowlton has kindly furnished me with the following data regarding the latter flora: "*Sequoia heerii* was described from the supposed Green River group at Sage Creek, Mont., and has been found in the upper Clarno beds (upper Eocene) of Bridge Creek, Oregon, as well as Bull Mountains, Montana, in beds supposed to be lower Fort Union, but which may be similar in age to the beds on Hell Creek. *Taxodium distichum miocenum* is a species of wide distribution in the Miocene, but has also been found in the Fort Union beds, the Eocene beds of Elko, Nevada, and in the Ceratops beds of Converse County, Wyoming. The *Musophyllum* is not widely different from *M. complicatum* Lesq., but is probably new to science. *Flabellaria eocenica* was described from the supposed Laramie at Black Buttes, Wyoming, and has been found also in the Ceratops beds of Converse County, and in the Denver beds at Golden, Colorado. *Sabalites grayanus* is, generally speaking, a Laramie species, though it has also been doubtfully reported from Montana. *Palmocarpom palmarum*, *Sabalites fructifer*, *Platanus rhomboidea*, *Equisetum laevigatum*, and *Ficus spectabilis* are known only, or mainly, from the Denver beds at Golden, Colorado.

"The main point brought out by this small flora is the fact that it shows practically no affinity with the true Laramie, while it does indicate a strong agreement with the Denver beds of Colorado. It is proportionately very much stronger in this direction than is indicated by previous studies of the flora of the Ceratops beds of Converse County. Thus, of a total of 48

forms in the Ceratops beds of Converse County, 36 prove to be new to science, leaving only 12 species with an outside distribution. Of these 3 have been found in the Fort Union, 6 in the Post-Laramie, 5 in the Laramie, 6 in the Montana."

CORRELATION AND AGE.

Lithologically the Hell Creek beds of Montana are similar in almost every respect to the Ceratops beds of Converse County, Wyoming. Most genera and many species of vertebrates and invertebrates are common to both deposits, while the faunal facies may be considered a unit, taking into consideration the separation of localities, which may account for absence of common genera in the one or the other locality. They are therefore considered of contemporaneous deposition. Where I have examined the two deposits I have found that they have the same relation to contiguous formations. In an article entitled 'The Ceratops Beds of Converse County, Wyoming,'¹ Mr. J. B. Hatcher says: "Immediately above the Fox Hills is a very thin, but quite persistent, layer of hard sandstone, well stratified and quite cleavable along the lines of stratification. This stratum of sandstone is about six inches thick, and is regarded as the dividing line between the marine and fresh-water beds. It is overlaid by about 150 feet of yellowish brown, well stratified sandstones apparently non-fossiliferous. These are in turn overlaid by about 250 feet of almost white, fine-grained, massive sandstone with numerous concretions, but no fossils were found in them. Next comes the fossiliferous portion of the Ceratops beds, consisting, as before stated, of alternating sandstones, shales, and lignites." In the same article he says that the Ceratops beds conformably overlie the Fox Hills.

The non-fossiliferous beds described by Mr. Hatcher are not present in the Hell Creek region of Montana but may be represented on the Yellowstone between Huntly Flats and Forsyth by the barren sandstones that closely resemble in character the Hell Creek basal sandstones.

In another article entitled 'Laramie Mammals and Horned Dinosaurs,'² Mr. Hatcher says: "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 overlaid by strata which could be referred without doubt to the Laramie."

Now, the first part of this statement does not hold good for the northern border of those beds which are exposed in Weston County. On Alkali Creek, about thirty-five miles northeast of Edgemont, S. D., and six miles

¹ *Am. Jour. Sci.*, Vol. XLV, pp. 135-144, 1893.

² *Am. Nat.*, p. 117, 1896.

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.

Strictly following King's definition of the Laramie, neither of these deposits can be considered as such, for neither one represents a continuous sedimentation from the marine Fox Hills. They should therefore be grouped with the Livingston, Denver, and Arapahoe beds and may be considered Post-Laramie, if indeed the type locality of the Laramie does prove upon further investigation to represent a continuous sedimentation from the Fox Hills times.

The close relation of the vertebrate fauna and flora of the Denver beds to the Converse County beds and Hell Creek beds, as well as the presence of andesytic material in the latter, indicates that the three are of contemporaneous age, the two last-named representing plains zones where sedimentation was less rapid.

Considering the evidence of the organic remains, the invertebrates plainly foreshadow Tertiary and living species. The flora on the other hand shows very little affinity with that of the true Laramie and even less with the Fort Union above. The vertebrates are clearly of mesozoic affinity. The dinosaurs here represented in the Post-Laramie are the culmination of a practically uninterrupted line of highly organized vertebrates that have persisted with little change since the Judith River period, some, like *Clasaurus*, extending as far back as the Niobrara, and their relation to the earlier Jurassic forms is well established.

