GEOLOGY OF NORTHEASTERN MONTANA.

By ARTHUR J. COLLIER.

INTRODUCTION.

REGION EXAMINED.

A large region in northeastern Montana has never been thoroughly explored by geologists, owing to the fact that it is a part of the Great Plains and the belief that it is too monotonous and uninteresting to tempt anyone to turn aside from the pronounced geologic features a little farther west, for which Montana is noted. This region includes parts of Sheridan, Valley, Phillips, and Blaine counties. Its investigation was begun by Smith [1] in 1908, when he made a geologic survey of the Fort Peck Indian Reservation. Beekly [2] explored a strip of land along the Montana-North Dakota line from Missouri River to the international boundary, and Bauer [3] examined the townships in which Plentywood and Scobey are situated.

Their results are here included with those of the writer, who during the field seasons of 1915 and 1916 was engaged in an investigation of the lignite resources of the remainder of this region, which extends from a line within 12 miles of the Montana-North Dakota boundary westward about 200 miles. In the western half of the region very little lignite was found, and the work was of the nature of a hasty reconnaissance extending from the international boundary to Missouri River. A few townships are covered by old land surveys, and the corners are located with difficulty, other townships are still unsurveyed, and in some the work has not yet been completed; though the corners were found in the field, no plats were available. The townships in the eastern part of the region have been surveyed by the General Land Office within the last six or seven years. In the examination of the lignite beds in this area the plane table and telescopic alidade were in constant use, and the locations of the outcrops were tied to the section corners, which are usually marked by iron posts and are easily found.

ACKNOWLEDGMENTS.

W. T. Thom, jr., and R. F. Baker were assigned to the field party in 1915, and H. R. Bennett accompanied the writer in 1916. Edwin T. Conant was employed as teamster and assistant during both seasons. Much of the information contained in this report is the result of the faithful work done by these men.

W. C. Alden, who in 1916 began an investigation of the glacial features of eastern Montana, visited the party in the field and has frequently been consulted in the office. He has made many valuable suggestions, used in the preparation of this paper.

Acknowledgment is also due to Mr. Barnum Brown, of the American Museum of Natural History, for suggestions made in the course of the field season of 1916.

As the work in many parts of the region was more or less of a reconnaissance nature the only available maps were township plats made by the General Land Office. The Bowdoin, Saco, Hinsdale, and Cherry Ridge topographic maps of the United States Geological Survey; the maps to be published by the International Boundary Commission; the topographic maps of the Fort Peck Indian Reservation made by the General Land Office in connection with the township surveys and published by the Geological Survey; and the maps published by the Missouri River Commission have all been used in preparing this report.

[1] Smith, C. D., The Fort Peck Indian Reservation lignite field, Mont.: U. S. Geol. Survey Bull. 381, pp. 40-59, 1910.

[2] Beekly, A. L., The Culbertson lignite field, Valley County, Mont.: U. S. Geol. Survey Bull. 471, pp. 319-358, 1912.

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

The base map (Pl. I) is compiled from the township plats, with additions from the few topographic maps available and the field notes made by the writer and his assistants.

PREVIOUS PUBLICATIONS.

1875.

Dawson, G. M., Geology and resources of the 49th parallel, British-North American Boundary Commission.

1886.

McConnell, R. G., On the Cypress Hills, Wood Mountain, and adjacent country: Geol. Survey Canada Ann. Rept., vol. 1.

Cope, E. D., The vertebrates of the Swift Current Creek region of the Cypress Hills: Idem, pp. 79–85.

McConnell discovered the interesting Oligocene mammal remains in the Cypress Hills, a few miles north of the international boundary, and Cope's report is on the fossil remains of the region.

1891.

Cope, E. D., The species from the Oligocene or lower Miocene beds of the Cypress Hills: Canada Geol. Survey Contr. Paleontology.

1896.

Weed, W. H., and Pirsson, L. V., Geology of the Little Rocky Mountains: Jour. Geology, vol. 4, pp. 399–428.

1906.

Calhoun, F. H. H., The Montana lobe of the Keewatin ice sheet: U. S. Geol. Survey Prof. Paper 50.

1907.

Brown, Barnum, The Hell Creek beds of the Upper Cretaceous of Montana: Am. Mus. Nat. Hist. Bull. 23. In this paper Brown refers to an extension of the "Hell Creek beds" northward across Missouri River, and hence in this field.

1909.

Dowling, D. B., Coal fields of Manitoba, Saskatchewan, Alberta, and eastern British Columbia: Canada Geol. Survey Pub. 1035.

1910.

Pepperberg, L. J., The Milk River coal field, Mont.: U. S. Geol. Survey Bull. 381, pp. 82–107.

Smith, C. D., The Fort Peck Indian Reservation lignite fields, Montana: U. S. Geol. Survey Bull. 381, pp. 40–59.

1912.

Beekly, A. L., The Culbertson lignite field, Valley County, Mont.: U. S. Geol. Survey Bull. 471, pp. 319–358.

1914.

Rose, Bruce, Willowbunch coal area, Saskatchewan: Canada Geol. Survey Summ. Rept. for 1913, pp. 153–164.

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

1915.

Rose, Bruce, The Wood Mountain coal area, Saskatchewan: Canada Geol. Survey Summ. Rept. for 1914, pp. 64–67.

1916.

Stebinger, Eugene, Possibilities of oil and gas in north-central Montana: U. S. Geol. Survey Bull. 641, pp. 49–61.

Rose, Bruce, Wood Mountain-Willowbunch coal area, Saskatchewan: Canada Geol. Survey Mem. 89.

1917.

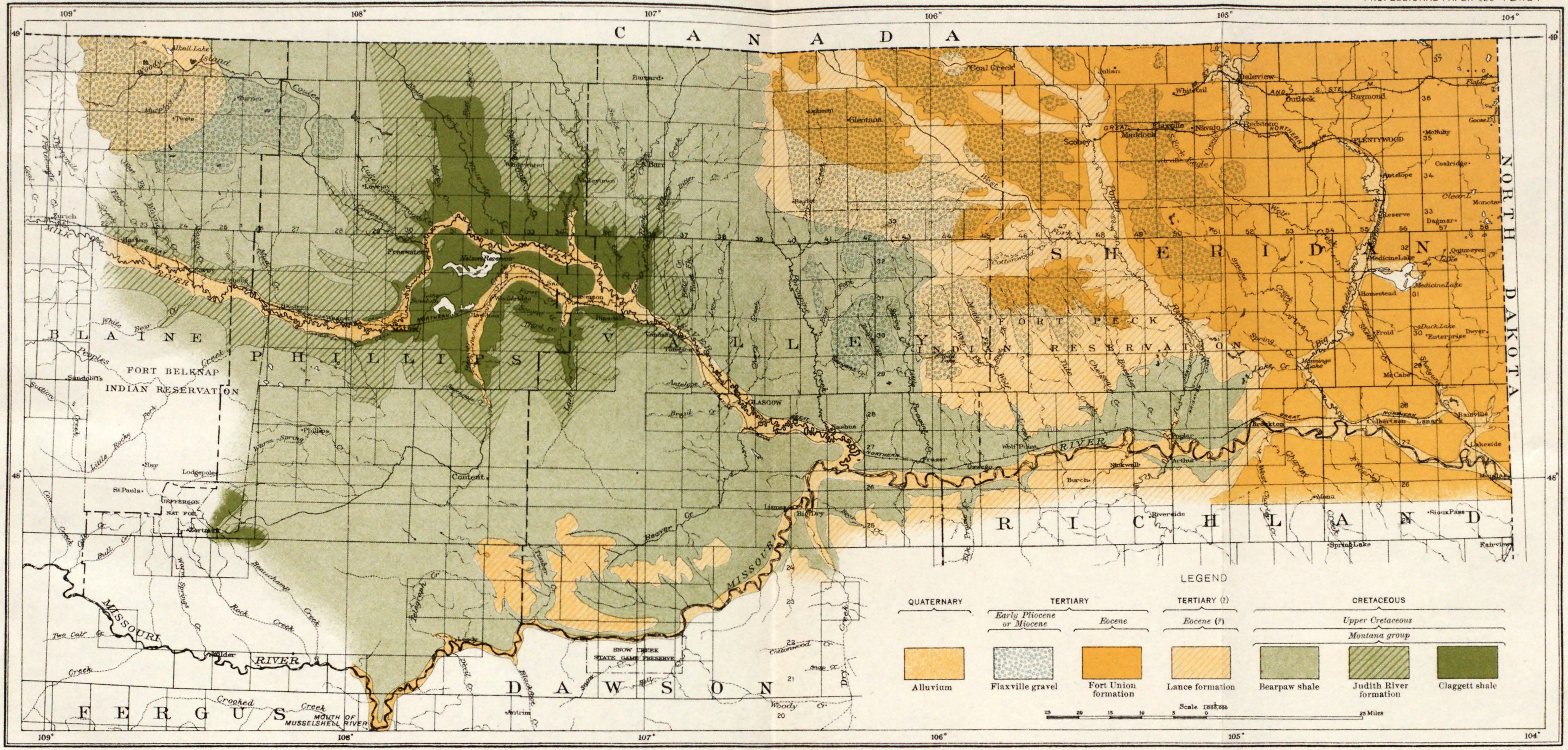
Collier, A. J., The Bowdoin dome, Montana, a possible reservoir of oil or gas: U. S. Geol. Survey Bull. 661, pp. 193–209 (Bull. 661–E).

Collier, A. J., and Thom, W. T., jr., The Flaxville gravel and its relation to the other high-terrace gravels of the northern Great Plains: U. S. Geol. Survey Prof. Paper 108, pp. 179–184 (Prof. Paper 108–J).

SURFACE FEATURES.

The region here described is a part of the Great Plains of North America. By this designation it is not intended to imply that the whole area consists of only one plain, for in fact there are at least three levels at which remnants of fairly well marked surfaces approaching plains can be discovered and between which there are more or less irregular slopes and escarpments. It can be assumed that at some very remote time the whole of the Great Plains constituted one plain, which was subsequently elevated and probably warped. The increased slope made it possible for the streams to sink their channels into the plain and as time went on to destroy most of its even surface by the headward cutting of the tributaries. Other periods of uplift and erosion have made possible the production of partial plains below the original one, until the region to-day is marked by a series of terraces or remnants of these plains. Adjacent to the southwest corner of the region described are the high peaks of the Little Rocky Mountains, which owe their origin to a totally different cause, namely, an intrusion of igneous rocks with which the underlying strata not elsewhere exposed are brought to the surface. Except for the Little Rocky Mountains the relief between the lowest point and the highest in this region is about 1,400 feet.

The highest points are in a series of plateaus near the Canadian line which are capped and protected from erosion by gravel. The plateau in the western part of the region stands at



Base from U. S. Geological Survey map of Montana

GEOLOGIC MAP OF NORTHEASTERN MONTANA

By Arthur J. Collier

1918

Geology compiled from the work of C. D. Smith, A. L. Beekly, C. A. Bauer, and A. J. Collier
Surveyed in 1908-16

3,000 to 3,400 feet above the sea, as is indicated on the Cherry Ridge topographic map of the Geological Survey; east of it, for about 30 miles, no remnants of the high plateau are found, but in the neighborhood of Opheim there is another extensive plateau at an altitude of about 3,100 feet, east of which the elevation declines to about 2,700 feet in a plateau south of the town of Redstone.

The Larb Hills,[1] near Missouri River, also consist of an undulating plateau about 3,000 feet in altitude but differing from the plateau farther north in not having a thick gravel cover.

Outside of the areas occupied by these plateaus there is a marked bench of rolling land from 200 to 500 feet below the higher level. This bench can be seen to good advantage from Big Muddy Creek, northeast of Redstone, to the North Dakota line, as shown in the maps of the Boundary Commission, and ranges in altitude from 2,300 to 2,500 feet. At the international boundary the Big Muddy Valley has steep walls rising 260 feet to the comparatively level plain. West of Big Muddy Creek this bench continues with varying altitudes, and along the forks of Poplar River it consists of long slopes extending from the upper escarpment down within 200 feet of the river level. West of Opheim it consists of level-topped areas, of sloping grass-covered hills, and of badlands in which the shale is exposed. It ranges in altitude from 2,500 feet near Milk River to 3,000 feet at the international boundary near the crossing of Frenchman Creek. The valleys of Rock, Frenchman, Whitewater, Cottonwood, and other creeks cut across this bench and are especially deep near Milk River. A view of the gorge of Rock Creek is given in Plate II, *A*, and the valley of Cottonwood Creek is shown in Plate III, *A*. South of Milk River the elevated areas are generally somewhat lower, and the streams cutting across them occupy broad valleys from 100 to 400 feet in depth.

[1] The name Larb Hills has been applied to the uplands immediately south of Saco and has been published on the Bowdoin, Saco, and Hinsdale topographic maps of the United States Geological Survey. That this is an error is affirmed by many of the old inhabitants of the region. Messrs. Henry Carpenter and L. W. Gibson, who resided near the Missouri for many years, assert that the name was first applied to a relatively small area east of Timber Creek. It is applied to the whole group of highlands near Missouri River on the map by Calhoun published in U. S. Geol. Survey Prof. Paper 50.

The valleys of Missouri and Milk rivers, ranging in altitude from 1,900 to 2,300 feet and lying from 100 to 500 feet below the level of the bench just described, together with the valleys of the smaller streams, constitute the lowest land in this region. The valley of Milk River is bordered by pronounced bluffs. It is in places several miles in width and was probably formed by a much larger stream than that which now occupies it. Calhoun[2] is authority for the statement that this valley was once occupied by Missouri River and that it was completely filled with ice during the glacial epoch so that the river was forced to cut for itself a new valley (the present course) 50 miles to the south.

The present valley of Missouri River near the mouth of the Musselshell is cut from 300 to 500 feet in the bench described and is not more than 3 miles across from rim to rim. (See maps published by the Missouri River Commission.) The river flows eastward in this narrow valley for many miles to the mouth of Big Dry Creek, in whose former valley it flows back to its original channel at the mouth of Milk River.

The effect produced by the moving of the continental ice sheet across this region is interesting and varied. In some areas the evidence of glaciation is almost entirely lacking, but even in such areas, if the surface has not been covered by deposits made since the glacial epoch, boulders of granite brought from the far-away shores of Hudson Bay, or large bodies of boulder clay, in part from the same source, can be found here and there. In addition to this evidence there are several glacial moraines marked by small irregularly placed lake beds separated by rounded hills. There are two large areas of this kind near the Canadian boundary—one in the eastern part of the region and the other extending from Whitewater Creek to the west side of the region mapped.

A description of the surface would not be complete without some reference to the Little Rocky Mountains, adjacent to the southwestern part of the region. These mountains, as has

[2] Calhoun, F. H. H., The Montana lobe of the Keewatin ice sheet: U. S. Geol. Survey Prof. Paper 50, pp. 38–42, 1906.

been shown by Weed and Pirsson,[1] are of a peculiar type in that they have a central core of very old rocks covered by a mass of porphyry (a laccolith) intruded at some time very much later than the formation of the sedimentary rocks and are flanked by the upturned edges of the deep-seated strata. They furnish the only clue that can be obtained in this region to the strata that lie far beneath the surface. The Black Hills of South Dakota and Wyoming[2] present a much better known example of this form of mountain uplift, and the Little Rocky Mountains can be described as a miniature reproduction of the Black Hills. On the Little Rocky Mountains there is a comparative abundance of timber, not only yellow pine and cedar but in many places fir, tamarack, and lodgepole pine.

SETTLEMENT OF THE REGION.

From the days of Lewis and Clark (1804–1806) to the completion of the Northern Pacific Railway (1883) Missouri River was the great northern route of communication between the East and the West. Steamboats plied regularly on its muddy waters, bringing in supplies of all kinds and taking out pelts that the great fur companies had collected from the Indians and trappers. At that time many forts were built on the banks of the river to guard against attacks by the Indians, and one of the most important of these was Fort Union, which stood in this area opposite the mouth of Yellowstone River.

The building of the first railway ended the river traffic, and as the region adjacent to the international boundary was out of the ordinary line of travel, it was little visited until the completion of the Great Northern Railway about 1889. Up to that time the only inhabitants were Indians, trappers, traders, and woodcutters for the river steamers. After the building of the Great Northern Railway the country was practically given over to the raising of cattle and sheep. The railway stations became distributing points and have been the principal settlements for many years. Small irrigation plants have been established at many of these places, the principal crop being blue-joint hay. The Milk River irrigation project of the Reclamation Service, begun many years later, has improved large areas of low-lying land. About seven years ago a tide of new life in the guise of "dry land" homesteaders set in and is still swelling, though the more desirable land has been occupied. To meet this sweep of immigration, townships have been surveyed, branch railroads built or projected, and new towns established. The best land, from the farmer's point of view, is that on the flat surfaces of the higher plateaus, where the soil is easily worked and produces good crops of grain and flax. The bench lands are usually more rolling in character and are generally strewn with glacial boulders which must be gathered up before plowing. The soil on the benches in the eastern part of the region is derived largely from sandy formations and is easily cultivated and fully equal to that of the plateaus. (See Pl. II, *B*.) Large areas in the western part are underlain by shale, which forms a gumbo soil difficult to cultivate and on which the surface forms are more varied, but there are at many places large areas in which the invasion of ice during the glacial epoch has left a sandy soil that is easily tilled. The new homestead law, passed in 1917, which enables the settler to acquire 640 acres of land for grazing, will certainly encourage further settlement and will force the abandonment of the methods of the old stock-raising days.

The principal towns in this region are Culbertson, Poplar, Wolf Point, Glasgow, Vandalia, Hinsdale, Saco, and Malta, on the main line of the Great Northern Railway; Plentywood and Scobey, on a branch of the Great Northern; Outlook and Whitetail, on the St. Paul, Minneapolis & Sault Ste. Marie Railway; and Glentana and Opheim, on proposed railroads not yet built.

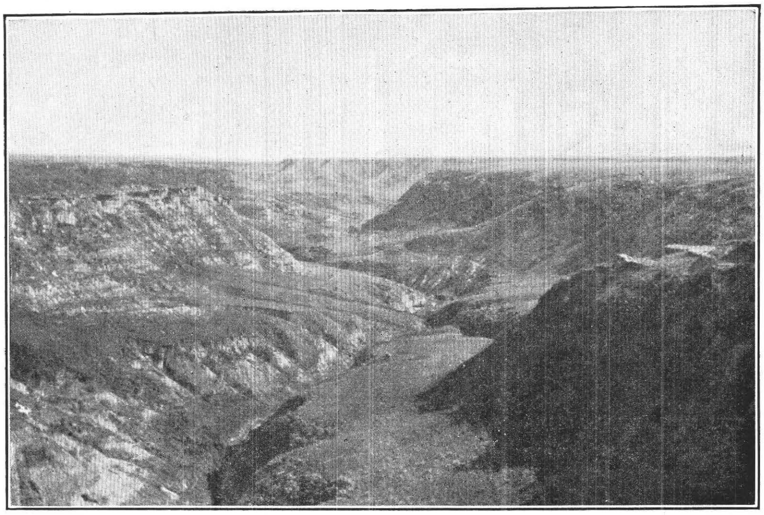
STRATIGRAPHY.

GENERAL SECTION.

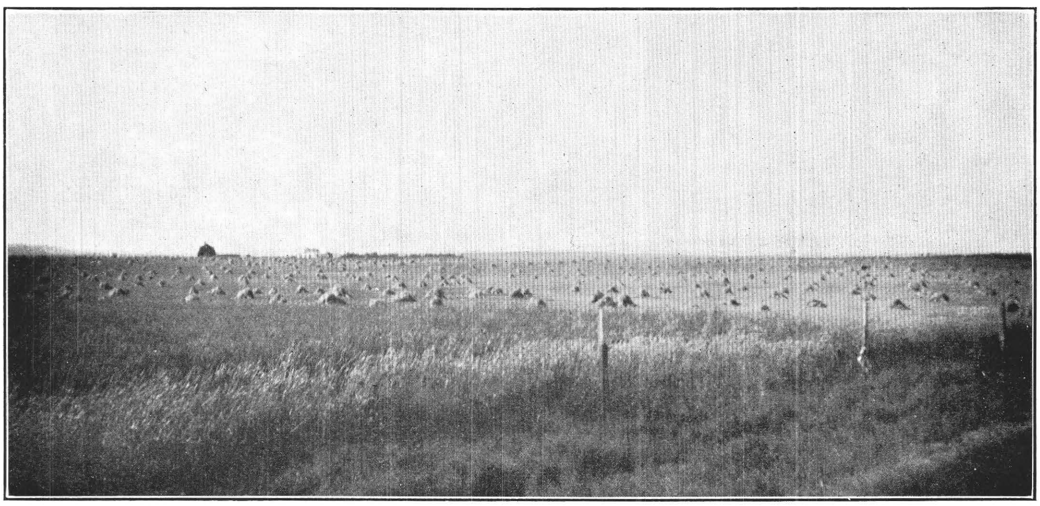
The sedimentary rocks range from the pre-Cambrian core of the Little Rocky Mountains to the Recent alluvium of the existing streams. The source of the information regarding the rock from the pre-Cambrian to the Carbonifer-

[1] Weed, W. H., and Pirsson, L. V., Geology of the Little Rocky Mountains: Jour. Geology, vol. 4, pp. 399–428, 1896.

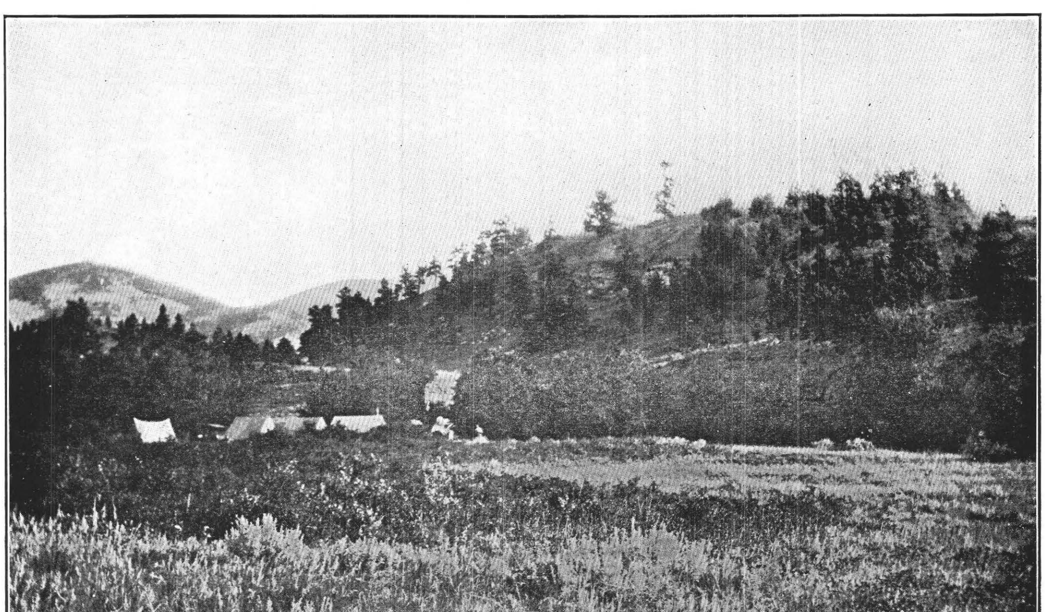
[2] Darton, N. H., U. S. Geol. Survey Geol. Atlas, Sundance folio (No. 127), 1905.



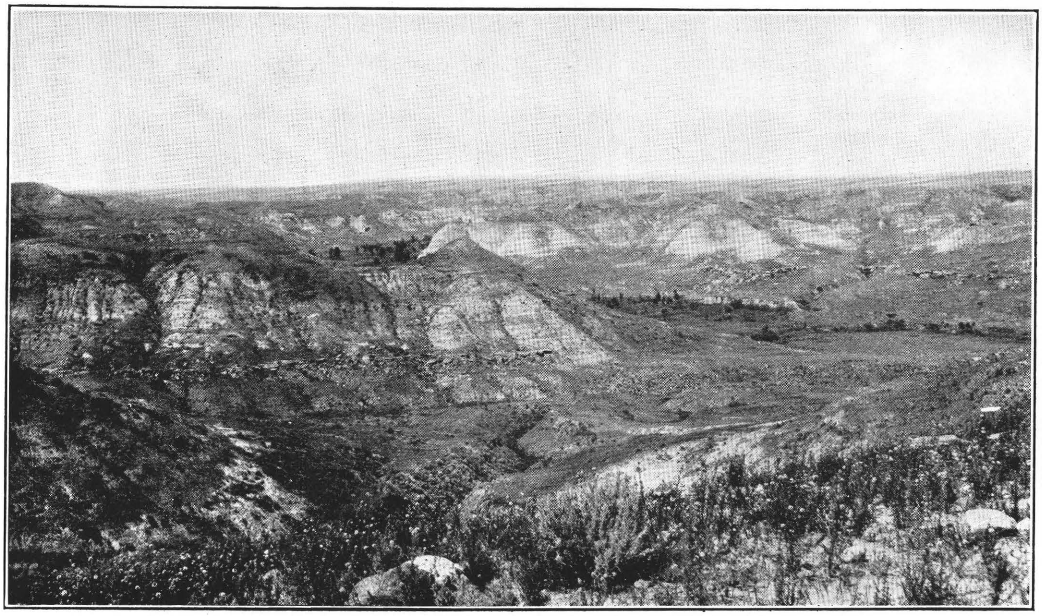
A. GORGE OF ROCK CREEK, VALLEY COUNTY, MONT.



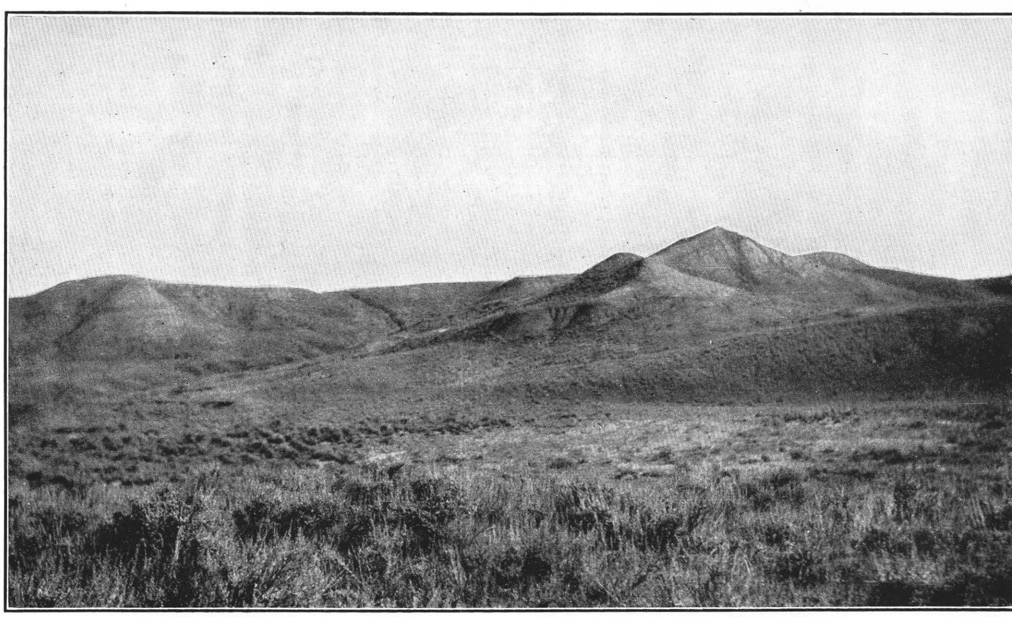
B. GRAIN FIELD NEAR SCOBEY, MONT.



C. CAMP IN THE FOOTHILLS OF THE LITTLE ROCKY MOUNTAINS, PHILLIPS COUNTY, MONT.



A. VIEW UP THE VALLEY OF COTTONWOOD CREEK, PHILLIPS COUNTY, MONT.



B. BADLANDS OF BEARPAW SHALE NEAR LISMAS, MONT.

ous is an article by Weed and Pirsson,[1] from which the following remarks on the rocks below the Carboniferous are adapted. The section from the Carboniferous to the Claggett shale of the Cretaceous system was examined during the field season of 1916. Only one measurement of the section exposed was made, and it may be found to be more or less inaccurate owing to undetected variations in the dip. The areal distribution of the formations is shown in figure 2.

The descriptions of the formations above the Claggett shale are the results of work done by the writer and his assistants in 1915 and 1916, and the areal distribution of these formations is shown in Plate I. The geologic section is as given on page 22.

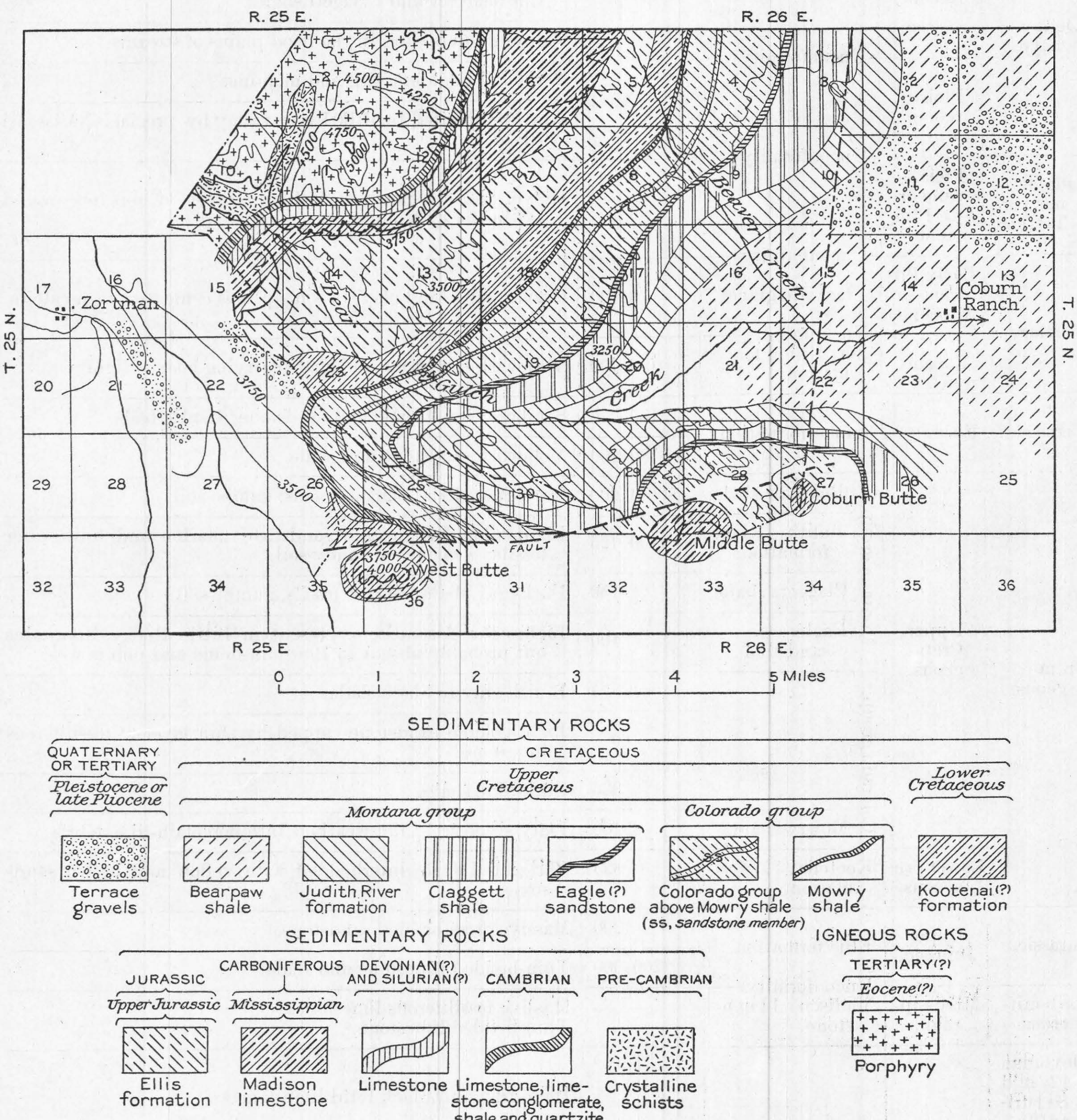


FIGURE 2.—Sketch map of the geology of T. 25 N., Rs. 25 and 26 E. principal meridian, Mont.

[1] Weed, W. H., and Pirsson, L. V., op. cit., pp. 399-428.

Section of formations in northeastern Montana.

System.	Series.	Group and formation.	Thickness (feet).	Character.
Quaternary.	Recent.			Sandy soil derived from Flaxville gravel, Fort Union, Lance, and Judith River formations. Gumbo soil derived from the Bearpaw and Claggett shales.
				Alluvium deposited in the flood plains of streams.
		Unconformity		
	Pleistocene.			Scattered boulders, till, and moraines.
				Gravel deposited in Milk River valley by preglacial Missouri River.
		Unconformity		
Quaternary or Tertiary.	Pleistocene or late Pliocene.			Gravel and silt north of Malta. Gravel on benches around Little Rocky Mountains.
		Unconformity		
Tertiary.	Early Pliocene or Miocene.	Flaxville gravel.	0–100	Gravel, sand, and clay, in some places cemented with calcite.
		Unconformity		
	Eocene.	Fort Union formation.	0–1,400	Yellowish sandstone and shale carrying beds of lignite.
Tertiary)?).	Eocene(?).	Lance formation.	180–200	Somber-colored shale and sandstone; lignite beds.
			80–200	Yellowish sandstone and shale.
Cretaceous.	Upper Cretaceous.	Montana group. Bearpaw shale.	800–1,000	Dark-gray shale; marine fossils; gumbo soil.
		Montana group. Judith River formation.	400–425	Light-colored shale and sandstone; marine and fresh-water fossils; a somewhat sandy soil.
		Montana group. Claggett shale.	750	Dark-gray shale, marine fossils, gumbo soil.
		Montana group. Eagle (?) sandstone.	100	Light-colored sandstone present in Little Rocky Mountains but probably absent in Bowdoin dome and points west.
		Colorado group.	875	Bluish-gray to black shale.
		Colorado group.	60±	Light-colored sandstone capped by thin layer of fossiliferous limestone.
		Colorado group.	325	Dark-blue shale.
		Colorado group. Mowry shale.	100	Platy siliceous shale; weathers into porcelain-like débris.
	Lower Cretaceous.	Kootenai (?) formation.	825	Variegated shale interbedded with yellow and brown sandstone.
Jurassic.	Upper Jurassic.	Ellis formation.	200	Massive cross-bedded sandstone.
			200–300	Thin-bedded limestone and shale.
		Unconformity		
Carboniferous.	Mississippian.	Madison limestone.		Massive fossiliferous limestone. Thin-bedded limestone.[a]
Devonian (?) and Silurian(?).				Dark-gray and black fetid limestone.[a]
Cambrian.				Thin-bedded limestone.[a] Limestone conglomerate. Green shale. Quartzite.
Pre-Cambrian.				Black crystalline amphibole schist.[a]

[a] Adapted from Weed, W. H., and Pirsson, L. V., Geology of the Little Rocky Mountains: Jour. Geology, vol. 4, pp. 399-428, 1896.

PRE-CAMBRIAN ROCKS.

The core of the Little Rocky Mountains is composed of crystalline schist (fig. 3). The type most usually seen is a fine-grained, dense, compact black crystalline amphibole schist or amphibolite, which splits into fragments with bright surfaces. These rocks are reported by Weed and Pirsson as being clearly altered sandstones. They are certainly older than the Cambrian.

PORPHYRY LACCOLITH.

Overlying the pre-Cambrian core of the Little Rocky Mountains is a great lenslike mass or laccolith of porphyry (see fig. 3), which was intruded at a much later date and which arched the overlying rocks into a dome. The exact thickness of the porphyry has not been measured, but it is known to be 300 or 400 feet on the principal summits, where it rests upon black mica schist into which the streams have cut their gorges. The outlying buttes, like those shown in figure 3, probably represent local thickenings or possibly separate intrusions of porphyry from which, in many places. the overlying rocks have not been eroded.

CAMBRIAN SYSTEM.

Cambrian rocks, of which Weed and Pirsson give the following section, lie upon the laccolith just described.

Section of Cambrian rocks in Little Rocky Mountains, Mont.

	Feet.
Thin-bedded fissile limestone, pure limestone with shell remains alternating with impure sandy and more or less conglomeratic beds; general color gray	25
Limestone conglomerates and gray shale, greenish sandy layers alternating with pure argillaceous beds. There are some thin beds of limestone from which a few fossils were taken	40
Green shale carrying limestones and conglomerates	50
Green or copperas-colored shale	30
Interval in which the beds are not exposed	300
Quartzite changing to conglomerate near the base, generally flesh-colored, mostly brecciated and rusty	75
	520

Fossils collected by Weed and Pirsson from the limestone mentioned in the section were examined by Walcott, who identified *Ptychoparia oweni* Hall and *Obolella nana* Meek and Hayden. Both are Middle Cambrian forms.

SILURIAN AND DEVONIAN SYSTEMS (?).

Above the Cambrian rocks (figs. 2 and 3) are slate-colored and black fetid limestones possessing the general characteristics of the Silurian and Devonian rocks as developed in the Rocky Mountain region to the west. No fossils were found in these rocks, and their tentative reference to the Silurian and Devonian systems by Weed and Pirsson is based on their lithologic character and position between the Cambrian and Carboniferous rocks.

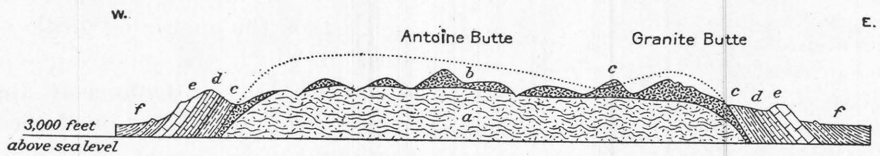


FIGURE 3.—Section of the laccolith of the Little Rocky Mountains, Mont. (After Weed and Pirsson.) *a*, Crystalline schists; *b*, granite porphyry; *c*, Cambrian; *d*, Silurian (?) and Devonian (?); *e*, Carboniferous; *f*, Mesozoic.

CARBONIFEROUS SYSTEM.

MADISON LIMESTONE.

The Carboniferous rocks (fig. 2) consist of several hundred feet of somewhat thinly bedded limestone at the base, capped by several hundred feet of massive, thick-bedded limestone which appears to be characteristic of the Mississippian Madison limestone throughout the Rocky Mountain region. From this formation Weed and Pirsson report five species of fossils collected by E. S. Dana and pronounced lower Carboniferous by Whitfield.[1]

Several collections of fossils, made principally by H. R. Bennett, have been examined by G. H. Girty, who has identified at least 22 species and who declares that the formation is identical with the Madison limestone of other parts of Montana. His report follows:

Sec. 33, T. 25 N., R. 24 E. (lot 19):
- Zaphrentis sp.
- Syringipora surcularia.
- Rhipidomella aff. R. burlingtonensis.
- Schuchertella chemungensis?
- Productus ovatus.
- Productus aff. P. viminalis.
- Productus gallatinensis?
- Productus (Strophalosia?) sp.
- Spirifer aff. S. incertus.

[1] Ludlow, William, Reconnaissance from Carol, Mont., to Yellowstone National Park, p. 129, Washington, 1876.

Sec. 33, T. 25 N., R. 24 E.—Continued.
- Brachythyris suborbicularis?
- Martinia? sp.
- Syringothyris carteri.
- Athyris lamellosa.
- Euomphalus sp.

Sec. 36, T. 25 N., R. 15 E. (lot 21):
- Zaphrentoid corals.
- Euomphalus sp.

Same location as above but lower in section (lot 22):
- Triplophyllum sp.
- Schuchertella chemungensis.
- Chonetes ornatus.
- Spirifer centronatus.
- Reticularia cooperensis.

Sec. 27, T. 25 N., R. 26 E. (lot 25):
- Leptaena analoga.
- Schuchertella chemungensis.
- Chonetes loganensis.
- Chonetes ornatus.
- Chonetes logani.
- Pustula n. sp.
- Productus ovatus.
- Productus arcuatus?
- Productus sp.
- Camarotoechia metallica.
- Camarotoechia sp.
- Dielasma aff. D. burlingtonense.
- Spirifer centronatus.
- Syringothyris carteri.
- Martinia rostrata.
- Spiriferina solidirostris.
- Reticularia cooperensis.
- Composita humilis.
- Cliothyridina cf. C. crassicardinalis.
- Platyceras sp.

Same location as above but higher in the section (lot 26):
- Triplophyllum sp.
- Schuchertella chemungensis.
- Chonetes logani.
- Chonetes ornatus.
- Spirifer centronatus.
- Spiriferina solidirostris.

Sec. 22, T. 25 N., R. 25 E. (lot 36):
- Triplophyllum sp.
- Fenestella, several sp.
- Pinnatopora sp.
- Batostomella sp.
- Rhombopora sp.
- Cystodictya sp.
- Schuchertella chemungensis?
- Schizophoria? sp.
- Chonetes ornatus.
- Chonetes logani.
- Chonetes loganensis.
- Productus arcuatus?
- Pustula n. sp.
- Camarotoechia aff. C. herrickana.
- Camarotoechia metallica.
- Spirifer centronatus.
- Camarotoechia mysticensis.
- Camarotoechia sp.
- Spiriferina solidirostris.

Sec. 22, T. 25 N., R. 25 E.—Continued.
- Reticularia cooperensis.
- Martinia rostrata.
- Composita sp.
- Cliothyridina incrassata?
- Eumetria aff. E. vera.
- Entolium shumardianum.
- Platyceras sp.
- Griffithides? sp.

It is probable that all six collections are of lower Mississippian age and belong to the Madison limestone, though they show several different faunal facies. Lots 22, 25, 26, and 36 are typical Madison faunas. Lot 21 shows too little for definite identification of the horizon. Lot 19 suggests a typical Burlington more than a typical Madison fauna, yet the Madison is in part of Burlington age, and collections from it sometimes show a markedly Burlington facies, like this one.

The Madison limestone is the most striking formation surrounding the Little Rocky Mountains. It is the encircling girdle of the mountains, in which the picturesque canyons are cut. Seen from a distance it appears like a great horizontal bed, but on closer examination it is found to be turned up at high angles and its edge cut by deep canyons. The three small outlying domes shown in figure 2 are made up wholly of this limestone.

JURASSIC SYSTEM.

ELLIS FORMATION.

Overlying the Madison limestone in the Little Rocky Mountains is a formation made up of shale and shaly and sandy limestone (fig. 2), which was described by Weed and Pirsson. A fauna from it, determined by T. W. Stanton as Jurassic, consisted of the following forms:

- Ammonite fragments of undetermined species.
- Belemnites densus Meek and Hayden.
- Pleuromya subcompressa Meek.
- Astarte meeki Stanton.
- Modiola subimbricata Meek.
- Gryphaea calceola var. nebrascensis Meek and Hayden.

Larger collections from this formation were made by H. R. Bennett during the field season of 1916 and were identified by J. B. Reeside, jr., as follows:

9832. Sec. 27, T. 25 N., R. 26 E. From shale above thin-bedded shale and limestone which overlies the Madison limestone:
- Ostrea strigilecula White.
- Belemnites densus Meek and Hayden.
- Pleuromya sp.?
- Indeterminable casts of pelecypods.

9832. Sec. 27, T. 25 N., R. 26 E.—Continued.
   Small ammonite distinct from described American forms but evidently a cardioceratid.
9833. Same locality as 9832 but lower in the section:
   Gryphaea calceola var. nebrascensis Meek and Hayden.
   Ostrea strigilecula White.
   Pleuromya subcompressa Meek.
   Astarte? sp.
   Rhynchonella sp. undescribed.
   Belemnites densus Meek and Hayden.
   Serpula sp. undet.
   Fragment of an undescribed ammonite, suggesting Perisphinctes.
9834. Sec. 7, T. 25 N., R. 26 E. From thin-bedded limestone above the Madison limestone:
   Fragments of an ammonite suggesting Perisphinctes.
   Gryphaea calceola var. nebrascensis Meek and Hayden.
   Pleuromya subcompressa Meek.
   Pholadomya kingi Meek.
   Lima cinabarensis Stanton.
   Cucullaea? sp. cf. C. haguei Meek.
   Camptonectes extenuatus Meek and Hayden.
   Thracia? sp. like T. arcuata Meek but very much larger.
   Rhynchonella sp. undescribed.
   Belemnites densus Meek and Hayden.
   Astarte meeki Stanton.
   Cyprina? sp.
9835. Sec. 7, T. 25 N., R. 26 E. From shale above thin-bedded limestone which overlies the Madison limestone:
   Dosinia? sp. undet.
   Eumicrotis curta Hall.
   Ostrea strigilecula White.
   Belemnites densus Meek and Hayden.
   Weathered casts of undetermined pelecypods.
   Small ammonite distinct from described forms but evidently a cardioceratid.

These fossils are Upper Jurassic. Most of the species are known in the Sundance and Ellis formations, but several ammonites and a *Rhynchonella* are unlike any known Sundance forms.

The detail of part of the Ellis formation which has been identified paleontologically is as follows:

Section of Ellis formation.

	Feet.
Shale with interbedded sandstone and limestone..	100±
Limestone, thin bedded, shaly, and calcareous shale	200
	300±

Above the shaly portion there is a more or less massive sandstone, which is tentatively considered as also belonging to the Ellis, though no fossils were found in it. It presents the following character in sec. 7, T. 25 N., R. 26 E.:

Section of the sandstone in the upper part of the Ellis formation.

	Feet.
Sandstone, massive, white, cross-bedded	50
Shale, variegated	50
Sandstone, yellowish, and thinner bedded	100
	200

The formation is almost identical with the Sundance formation of the Black Hills and the Ellis of other parts of Montana. As the Madison limestone is of Mississippian age, there is necessarily an unconformity between it and the Ellis (Upper Jurassic), but the actual contact of the two formations has not been recognized. A photograph (Pl. II, *C*) taken in the flanks of the Little Rocky Mountains in sec. 23, T. 25 N., R. 25 E., shows the camp situated on the outcrop of the Ellis formation in the foreground and the outcrops of the older formations in the background.

CRETACEOUS SYSTEM.

KOOTENAI (?) FORMATION.

The sandstone just described is overlain in the Little Rocky Mountain section by variegated shale interbedded with yellow and brown sandstones, which are believed to represent the Kootenai formation (Lower Cretaceous) of other parts of Montana, though they may possibly include the Morrison. The shale is in places blue, green, red, and gray. The approximate thickness, as determined by only one measurement, is 825 feet. From 100 to 200 feet above the massive sandstone there is an exposure of carbonaceous sandstone and sandy shale containing woody fragments and impressions of poorly preserved stems which may represent the coal beds occurring in the Kootenai in the neighborhood of Great Falls or the corresponding Lakota of the Black Hills. No fossils were found in this part of the section during the season of 1916, but Weed and Pirsson report that it contains *Goniabasis sublaevis* Meek and Hayden, *Corbicula cytheriformis* Meek and Hayden, and an *Ostrea*.

COLORADO GROUP.

MOWRY SHALE.

Above the Kootenai (?) formation is a well-marked siliceous shale (fig. 2) which has been recognized at several localities and is the highest formation described by Weed and Pirsson in their paper on the geology of the Little

Rocky Mountains. When freshly broken it is brown or black, but on weathering it becomes light colored and breaks into porcelain-like débris. It contains numerous fish scales and bones, some of which can be found on nearly every piece examined, and on some specimens the trails of small marine animals, probably crustaceans, were also found. Thin sections under the microscope show that the material of this shale consists of small, angular grains of quartz interbedded with a dark amorphous substance, probably carbon. Two distinct forms of Infusoria were seen, but their nature could not be determined in the material at hand. In appearance this shale resembles the shale of the Green River formation (Eocene) in Colorado and Utah, from which oil may be obtained by distillation, but a small fragment tested by distillation yielded only a trace of oil. On the basis of its lithologic similarity and content of fish scales, this shale is correlated with the Mowry shale, which occurs at several localities in Wyoming and southern Montana. Around the Little Rocky Mountains its outcrop is marked by a low ridge covered with pines. The thickness of the formation is about 100 feet.

COLORADO GROUP ABOVE THE MOWRY SHALE.

Above the Mowry shale, in the region surrounding the Little Rocky Mountains, there is about 325 feet of dark-blue shale which differs slightly in color from the dark-gray gumbo shale higher in the section. The exposures are not continuous, and little can be said of the details of this part of the section.

This shale is overlain by a sandstone capped by a foot or more of impure limestone containing fossil gastropods and pelecypods which have been identified by T. W. Stanton as of Benton age. J. B. Reeside, jr., who examined the collection, reports the following species: *Callista orbiculata* Hall and Meek, *Pachymelania?* sp. undescribed, *Amauropsis?* sp. undescribed. The stratigraphic position of this sandstone is not far from that of the Frontier formation of Wyoming and southern Montana. Its thickness could only be estimated and is given in the table as about 60 feet.

The sandstone noted above is overlain by about 875 feet of bluish-gray to black shale, much of which is concealed and in which sandy facies if present were not recognized. The only fossils found in it were baculites, a few of which, collected from limy concretions, were submitted to J. B. Reeside, jr., who reports upon them as follows:

> *Baculites* sp., usually referred to *B. asper* Morton. It is quite distinct from the related Pierre *B. asper* and from *B. anceps obtusus*. It has been collected from several localities in the Benton of Montana. (Collection 9841.)

MONTANA GROUP.

EAGLE (?) SANDSTONE.

The sandstone that lies above the shale just described in the region surrounding the Little Rocky Mountains is marked by a ridge about 30 feet high (fig. 2), the top of which is covered with large limestone concretions resting on sandstone. One poorly preserved specimen of *Nemodon*, referable to an undescribed species from the Claggett near Havre, was found (collection 9842). The same formation was seen at a locality about 3 miles southeast of the point where the section was measured, and although it was not closely studied it was thought to be about 100 feet thick. This sandstone is about 750 feet below the base of the Judith River formation, and if it is the Eagle sandstone it proves that the overlying formation varies a great deal in thickness, for the Eagle sandstone is described by Stebinger[1] as being from 350 to 500 feet below the base of the Judith River formation. Reports of drilling northeast of Malta, in the Bowdoin dome, seem to indicate that the Eagle sandstone is not present there as a mappable unit.

CLAGGETT SHALE.

The Claggett shale represents part of a marine formation called the Pierre shale in regions to the east and southeast, which to the west is represented by four formations—the Eagle sandstone, Claggett shale, Judith River formation, and Bearpaw shale. Of these formations the Judith River is of fresh-water origin. The Claggett shale on the east side of the Little Rocky Mountains, where its top and bottom are exposed, measures approximately 750 feet. In the center of the Bowdoin dome north of Saco about 500 feet of the upper part of the formation is exposed. Stebinger, working in the vicinity of Havre, about 90 miles to the west, reports the thickness of this formation

[1] Stebinger, Eugene, Possibilities of oil and gas in north-central Montana: U. S. Geol. Survey Bull. 641, p. 53, 1917.

as from 350 to 500 feet. It consists of a dark-gray shale which on weathering forms typical gumbo soil. Scattered through the formation in many places are concretions or masses of impure limestone, many of which contain marine fossils, or of aragonite, a mineral resembling fossil wood. The formation also contains large flakes of selenite or transparent gypsum, and water in wells, springs, or small streams in the area of its outcrop is always more or less alkaline. This shale forms the lower slopes of the valley of Milk River between Hinsdale and Malta. Two collections of fossils from it were referred to J. B. Reeside, jr., who identified one species, *Baculites compressus* Say, regarded as characteristic of the Pierre shale.

About 70 feet of strata in the upper part of the Claggett shale appear to form a transition zone between the Claggett and the Judith River formation. This zone is found on the west side of the Bowdoin dome, north of Malta. On the north side of the dome, near Whitewater post office, it does not contain the characteristic sandstone, and it can not be recognized at all on the east side near Hinsdale. The following sections will illustrate this peculiarity:

Sections of the transition zone of the Claggett and Judith River formations.

West of the Bowdoin dome near the center of T. 31 N., R. 30 E.

	Feet.
Typical Judith River formation.	
Shale resembling the Claggett	50±
Sandstone resembling Judith River formation containing abundant marine fossils	20±
Typical Claggett formation.	
	70±

North of the Bowdoin dome in Tps. 34 and 35 N., R. 32 E.

Typical Judith River formation.	
Shale containing fossils similar to those of the marine sandstone of the preceding section	50±
Typical Claggett shale.	

The following lots of fossils collected from the upper part of the Claggett shale have been identified by Mr. Reeside, who finds that they are marine forms characteristic of the Pierre shale.

10016. Sec. 32, T. 35 N., R. 32 E.:
Lunatia subcrassa Meek and Hayden.

10017. Sec. 25, T. 33 N., R. 30 E.:
Tancredia americana Meek and Hayden (fragments).
Lunatia subcrassa Meek and Hayden.

9829. North half of T. 31 N., R. 30 E.:
Cardium speciosum Meek and Hayden.
Tancredia americana Meek and Hayden.
Lunatia subcrassa Meek and Hayden.
Haminea subcylindrica Meek and Hayden.

9830. Western part of T. 31 N., R. 30 E., south of Assinniboine Creek:
Anatina sp. undescribed.
Mactra alta Meek and Hayden.
Tancredia americana Meek and Hayden.
Cardium speciosum Meek and Hayden.
Anchuria sp. undet.
Lunatia subcrassa Meek and Hayden.
Placenticeras intercalare Meek.
Baculites compressus Say.

JUDITH RIVER FORMATION.

Above the Claggett shale lies the Judith River formation, estimated from several imperfect measurements to range from 400 to 425 feet in thickness. The outcrop of this formation surrounds the Bowdoin dome, standing out as a light-colored formation in the hill south of the railroad from Malta to Vandalia and north of the railroad near Valleytown and Lovejoy. It also crops out in one of the surrounding sandstone ridges of the Little Rocky Mountains. It probably extends east of the Bowdoin dome beneath the surface, at least as far as the mouth of Milk River, where it has probably been reached in an artesian well at a depth of 750 feet. To the southeast the Judith River formation is not recognizable as a distinct unit, as shown by the gas wells sunk on the Glendive anticline. A characteristic view of the Judith River formation is given in Plate III, *A*. The formation consists of extremely variable beds of hard brown sandstone, soft, friable light-colored sandstone, and light-gray shale; and on account of their variability no beds were found that would serve as horizon markers. In describing this formation Stanton and Hatcher[1] say:

> A detailed section taken at any point is of little value, since a similar section made at a distance of only a mile or two would give a quite different sequence of the alternating strata of sandstones and shales.

Some of the details of this formation may be seen from two sections which were measured in its upper part on the east side of Rock Creek, as follows:

[1] Stanton, T.W., and Hatcher, J. B., Geology and paleontology of the Judith River beds: U. S. Geol. Survey Bull. 257, p. 34, 1905.

Sections of part of the Judith River formation.

On east canyon wall of Rock Creek, in sec. 20, T. 34 N., R. 36 E.

	Feet.
Bearpaw shale above Judith River formation.	
Sandstone, massive, grayish, with iron concretions scattered or in beds; weathers yellowish; some red bands cross-bedded	32
Shale, brown, in places approaching lignite	2
Sandstone, soft, yellowish gray, and gray shale	23
Lignite	$\frac{1}{2}$
Shale, brown	1
Shale, gray	4
Shale, dark, carbonaceous	$\frac{1}{2}$
Shale, gray, and sandstone	5
Lignite	$\frac{1}{3}$
Shale, brown	$\frac{2}{3}$
Shale, gray	6
Shale, brown	3
Sandstone, soft, with iron concretions	1
Shale, sandy, brown	2
Sandstone, soft, gray	6
Clay, shale gray	4
Shale, brown	3
Sandstone, soft, gray, and sandy shale	9
Sandstone, concretion bed	1
Shale, soft, sandy, gray	5
Sandstone, iron-concretion bed	1
Shale, blue and gray	4
Concretions	1
Shale, gray	4
Shale, brown	2
Sandstone, soft, gray and yellow	17
Sandstone, massive; weathers brown; arkosic, containing much feldspathic and ferromagnesian material. This bed forms conspicuous ledges	7
Sandstone, soft, gray; some shale	20
Base of formation not exposed.	
	165

East canyon wall of Rock Creek, near line between sec. 32, T. 34 N., R. 36 E., and sec. 4, T. 33 N., R. 36 E.

	Feet.
Glacial gravel.	
Sandstone, massive, gray; weathers yellow or reddish; some thin beds; cross-bedded	47
Shale, gray	6
Sandstone, soft, gray	2
Shale, gray	4
Shale, brown	3
Shale, gray	2
Shale, brown	1
Sandstone, soft, gray	5
Shale, brown, with 3 inches of lignite	2
Shale, gray	5
Shale, brown	6
Shale, blue	2
Sandstone, soft	9
Shale, brown	$1\frac{1}{2}$
Sandstone, soft, gray	3
Shale, blue-gray	5
Concretions	6
Sandstone, soft, massive, gray	18
Shale, brown	$\frac{2}{3}$
Lignite	$\frac{1}{3}$
Shale, brown	5
Shale, blue-gray	12
Shale, brown	1
Shale, sandy	6
Sandstone, concretions	1
Shale, gray	10
Sandstone, soft, gray	13
Shale, dark	3
Sandstone, soft, gray, and sandy shale	14
Shale, brown	2
Sandstone, massive, soft, gray or yellowish, weathering yellowish; certain beds weather out as massive reddish layers or as huge concretions; shows some cross-bedding	101±
Base of formation not exposed.	
	296±

The base of this formation is not very definitely marked and can not everywhere be separated from the upper part of the Claggett shale, but its top can be readily recognized in the few places where it is well exposed. The upper part of the Judith River formation consists of a massive sandstone in the two sections cited and in the neighborhood of the Little Rocky Mountains, and is overlain by characteristic Bearpaw shale. At other places in the region the massive sandstone is not prominent, and in one or two localities a small bed of lignite within a few feet of the top has been mined. Stanton and Hatcher report a layer of shell breccia consisting of shells of *Ostrea subtrigonalis* near the top of the Judith River formation as its most persistent horizon marker, but such beds were not seen in the neighborhood of the Bowdoin dome. Invertebrate fossils collected from the formation during the season of 1916 have been examined by Mr. Reeside, who reports that six lots consist of marine forms and one lot from the flanks of the Little Rocky Mountains contains fresh-water forms of Judith River types. The species identified are as follows:

9826. Sec. 36, T. 33 N., R. 37 E., on road:
- Plates of an undescribed barnacle.
- Tancredia americana Meek and Hayden.
- Cardium speciosum Meek and Hayden.
- Protocardia sp.?, large form.
- Mactra sp.?
- Inoceramus sp.?, very young individual.
- Nucula sp.?
- Lunatia subcrassa Meek and Hayden.

9826. Sec. 36, T. 33 N., R. 37 E., on road—Continued.
  Cf. Trachytriton vinculum Meek and Hayden.
  Scaphites sp., fragment suggesting S. nicolleti Morton.
  Baculites sp.?, fragment.

Most of this lot consists of casts lacking essential details. The *Protocardia?*, *Lunatia*, and *Scaphites* suggest Bearpaw rather than typical Judith River.

9843. SW. ¼ sec. 21, T. 33 N., R. 37 E., on Eagle Creek; upper part of Judith River formation:
  Liopistha undata Meek and Hayden.
  Pteria nebrascana Edwards and Solander.

Marine; Pierre fauna.

41. Sec. 4, T. 33 N., R. 37 E., on Bitter Creek; upper part of Judith River formation:
  Natica sp.?
  Mactra sp.?
  Serpula sp.?

The only fresh-water forms are found in the following lot:

9837. Sec. 21, T. 25 N., R. 26 E., sandstone about middle of Judith River formation at east end of Little Rocky Mountains:
  Unio cf. U. primaevus White.
  Unio cf. U. supragibbosus Whiteaves.

This lot consists of fragments which suggest a reference to the Judith River but are too poor to be conclusive. *Unio supragibbosus* occurs in the Canadian Belly River and in the Judith River formation. *U. primaevus* is a Judith River species.

Inasmuch as this lot of fresh-water forms is from the middle of the formation, while the majority of the fossils found are marine, it is probable that the Judith River formation of this area is marine at the top and bottom.

Bones of fresh-water dinosaurs were collected at several localities and were examined by C. W. Gilmore, of the National Museum, who found them too fragmentary for specific determination.

Specimens of petrified wood, described by F. H. Knowlton as that of cone-bearing trees, were collected at several places in the Judith River formation, but no determinable fossil leaves were found.

This formation contains small lenticular beds of lignite or subbituminous coal which are too thin to be of value. Local mines from which the farmers have obtained a small amount of fuel were examined at the points where the following sections were measured:

Sections of Judith River formation in northeastern Montana.

Location.			Section.		
Sec.	T. N.	R. E.		*Ft.*	*in.*
21	33	37	Bearpaw shale.		
			Sandstone	20±	
			Lignite		8
			Sandstone and shale	15±	
			Shale, carbonaceous, and lignite	2±	
4	33	37	Bearpaw shale.		
			Sandstone and shale	59	0
			Lignite		6
			Sandstone and shale	22	0
			Shale, carbonaceous	2	0
			Lignite		8
			Shale, carbonaceous	2	0
5	33	37	Shale, blue	4	6
			Shale, carbonaceous		6
			Lignite	1	2
			Shale, carbonaceous		6
15	32	37	Sandstone	10	0
			Lignite	1	4
			Shale, sandy gray	3	0
16	32	37	Lignite, a few inches.		
7	34	36	Shale, gray	5	0
			Lignite	1	4
			Shale, brown	1	0
12	34	35	Lignite		6
32	34	35	Shale, gray	5	0
			Shale, brown		2
			Lignite		8
			Shale, brown		4
			Shale, gray.		
6	33	35	Shale, gray	5	0
			Lignite		10
			Shale, brown		8
			Shale, gray.		
20	34	34	Shale	10	0
			Lignite		6
			Shale, brown.		
			Shale, gray	1+	
5	35	34	Lignite		6
9	35	34	Lignite		8
9	28	32	Lignite		6–10
9	28	34	Bearpaw shale.		
			Judith River formation	50±	
			Clay, black, carbonaceous	1	6
			Lignite		10

BEARPAW SHALE.

The Bearpaw shale, from 800 to 1,000 feet thick is, as shown on Plate I, the most widespread formation exposed in the region described, and overlies the Judith River formation. It consists essentially of dark-gray shale which forms a gumbo soil and presents an uninteresting and monotonous landscape. This shale is exposed in many places along escarpments and canyons and forms badlands which lack the variety due to the presence of harder beds. A characteristic view of the badlands of the Bearpaw shale is given in Plate III, *B*. The fossils are all of marine types; *Baculites*, *Inoceramus*, and oysters are very abundant, and occasionally the remains of a gigantic marine saurian are found. The formation in places contains limy concretions, in which the lime is in the form of aragonite showing cone in cone structure or appearing like the stumps of large trees. Calcite also is present in many of these concretions, and smaller masses of barite were noted in several localities. The formation contains more or less gypsum, which at some places is transparent and at others occurs in uncrystallized forms replacing the calcite of oyster shells. The water from the Bearpaw shale, like that from the Claggett, is usually alkaline.

The following invertebrate fossils were collected during the field season of 1916 and were identified by J. B. Reeside, jr.:

9825. SW. ¼ sec. 22, T. 33 N., R. 37 E.:
    Inoceramus sagensis Owen.
    Heteroceras sp. related to H. newtoni Meek but probably undescribed.
  Pierre fauna; fossils not distinctive of Bearpaw shale.

9827. Sec. 36, T. 36 N., R. 36 E.:
    Ostrea patina Meek and Hayden.
  So far as known this form is confined to the Bearpaw shale.

9828. Sec. 5, T. 36 N., R. 26 E.:
    Chlamys nebrascensis Meek and Hayden.
    Baculites compressus Say.
    Cf. Trachytriton vinculum Say.
    Membranipora sp. undescribed (identified by R. S. Bassler).
  Pierre fauna.

9838. Sec. 21, T. 25 N., R. 26 E.:
    Ostrea patina White

9839. Sec. 21, T. 25 N., R. 26 E.:
    Inoceramus sagensis Owen.
    Baculites sp., fragments.
  Pierre fauna.

10020. Sec. 10, T. 23 N., R. 36 E., 150 to 200 feet below top of Bearpaw shale:
    Scaphites nodosus var. plenus Meek.
    Baculites compressus Say.
    Cyprimeria ? sp., single weathered individual.
  Pierre fauna.

10021. Southwestern part of T. 23 N., R. 36 E., 50 to 100 feet below top of Bearpaw shale:
    Baculites compressus Say.
  Pierre fauna.

10024. Northeastern part of T. 23 N., R. 34 E., 50 feet below top of Bearpaw shale, on Timber Creek:
    Baculites compressus Say.
  Pierre fauna.

10025. T. 26 N., R. 34 E., along Larb Creek; middle of Bearpaw shale:
    Baculites sp., fragments.
  Pierre fauna.

10028. T. 24 N., R. 41 E., near top of Bearpaw shale:
    Inoceramus sagensis Owen.
    Protocardia subquadrata Edwards and Solander.
    Anomia sp., fragments.
    Yoldia evansi Meek and Hayden.
    Lunatia sp., fragments.
    Dentalium gracile Meek and Hayden.
    Anchura sp., fragment.
    Actaeon attenuatus Meek and Hayden.
    Scaphites sp., probably young S. nodosus plenus Meek.
  Bearpaw shale.

Parts of skeletons of two large marine reptiles collected in this region, one found several years ago by Ira Taylor; were submitted to C. W. Gilmore, who identified one of them (from sec. 23, T. 37 N., R. 35 E.) as consisting of numerous parts of vertebrae, limb bones, fragmentary teeth, jaws, and other fragments of a large plesiosaurian reptile; and the other (from sec. 23, T. 34 N., R. 38 E.) as consisting of numerous vertebrae and other parts of the skeleton of a mososaurian reptile. Neither of these forms was otherwise determinable. The remains of both animals are found only in marine or brackish-water formations

TERTIARY (?) SYSTEM.

LANCE FORMATION.

The Lance formation, which overlies the Bearpaw shale, as here identified, is composed of two more or less distinct members in the eastern and southern parts of the region described. In the northwestern part, in the Cherry Ridge quadrangle, the exposures are too meager to indicate their character.

The lower member has been described by Dawson,[1] who estimated the thickness at 80 feet and referred it to the Fox Hills sandstone. Figure 4, reproduced from Dawson's report, shows the relation of the two members near the international boundary northwest of Opheim. The lower member is here composed of yellowish and rusty sands grading into arenaceous clay toward its base. It is characterized by large, irregular sandy concretions which in places approach a more or less spherical form and are slightly darker than the prevailing color of the formation. So far as the writer knows marine fossils have not been obtained from this member within the region described. Rose,[2] in his description of beds he designated Fox Hills sandstone in the Wood Mountain district of Canada, gives a list of the fossils found by R. G. McConnell in beds designated Pierre and Fox Hills formations in the Cypress Hills, but as no effort is made to distinguish between the formations the list is probably of little value.

A very good exposure of yellowish sandstone, resembling that at the boundary, covers 2 or 3 square miles in and around sec. 34, T. 36 N., R. 39 E. In this sandstone, which surely lies only a short distance above the Bearpaw shale, was found a well-preserved fossil bone which Gilmore identified as "the proximal half of the left ischium of a trachodont dinosaur. So far as it can be compared it appears identical with the same element in *Trachodon annectens* Marsh, from the Lance formation." The finding of this fossil justifies the belief that the lower part of the Lance is a fresh-water deposit and should not be classified as the Fox Hills sandstone, which in the type locality is marine. It may, however, be contemporaneous with the Fox Hills sandstone of South Dakota. Small exposures of this member are found in T. 37 N., R. 40 E., and T. 35 N., R. 44 E., where it is similar in lithologic character to the rocks northeast of Opheim.

In the Larb Hills, in the southern part of the region described, a similar member having a thickness of about 100 feet where measured in sec. 13, T. 24 N., R. 32 E., rests upon the Bearpaw shale and is capped by a harder sandstone. The same succession of beds is exposed south of Missouri River, where Brown[3] reports collecting 14 species of marine invertebrate fossils, identified as the Fox Hills fauna, from concretions found on Hell Creek. He further reports[4] that in the same valley, 20 feet below the base of the sandstone he calls Fox Hills, the remains of a large trachodont dinosaur were discovered. The specimen was found in place partly embedded in a large calcareous concretion that was weathered out and broken. The humeri were still covered with shale and well preserved.

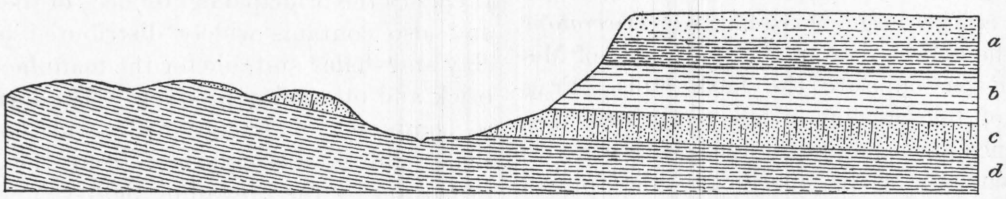


FIGURE 4.—Section in badlands south of Wood Mountain, Saskatchewan, Canada, showing the relation of Fort Union formation (*a*), upper part of Lance formation (*b*), lower part of Lance formation (*c*), and Bearpaw shale (*d*).

This member northwest of Opheim is probably the same as that found on Missouri River in the southeastern part of the region here described and called the Fox Hills sandstone by Smith.[5] (See Pl. IV, *A*.) It is described in a later report by Beekly[6] as the Colgate sandstone member of the Lance formation, consisting of 50 to 150 feet of buff sandstone interstratified with somber-colored and yellow clay. The type locality is the vicinity of Colgate station on the Northern Pacific Railway, described by Calvert.[7]

The upper member of the Lance formation is composed of shale and argillaceous sandstone and is characteristically of somber color. Its

[1] Dawson, G. M., Geology of the 49th parallel, British North American Boundary Commission, Montreal, 1875.

[2] Rose, Bruce, Wood Mountain-Willowbunch coal areas, Saskatchewan: Canada Geol. Survey Mem. 89, p. 32, 1916.

[3] Brown, Barnum, The Hell Creek beds of Montana: Am. Mus. Nat. Hist. Bull. 23, p. 827, 1907.

[4] Idem, p. 826.

[5] Smith, C. D., The Fort Peck Indian Reservation lignite field, Mont.: U. S. Geol. Survey Bull. 381, p. 42, 1908.

[6] Beekly, A. L., The Culbertson lignite field, Valley County, Mont.: U. S. Geol. Survey Bull. 471, pp. 329, 330, 1912.

[7] Calvert, W. R., Geology of certain lignite fields in eastern Montana: U. S. Geol. Survey Bull. 471, pp. 194, 195, 1912.

thickness is from 180 feet northwest of Opheim to 250 feet where measured in the Larb Hills. At some places the argillaceous sandstone shows cross-bedding, due to wind action while it was being deposited (Pl. IV, *B*). Its erosion results in many picturesque badlands or isolated pinnacles capped by hard concretions (Pl. V, *A*) or interesting corrugated forms resembling organ pipes (Pl. V, *B*). The Lance formation in many places contains loglike sandstone concretions and carries near its top one or more somewhat irregular lignite beds. The bed mined northeast of Opheim has a maximum thickness of about 6 feet; that near Daleview is over 12 feet thick and extends with varying thickness throughout the outcrop of the Lance formation on Big Muddy Creek. In other parts of the region there are lignite beds too thin to be of commercial value.

Brown [1] has described numerous fossil vertebrates, mostly dinosaurs, the most striking of which is the large three-horned *Triceratops*, which he collected from the south side of Missouri River opposite the Larb Hills. Fragments of dinosaur bones collected in 1916 from the Lance formation in the Larb Hills were not good enough to be specifically determined. C. W. Gilmore reports that a small collection made northwest of Opheim in sec. 23, T. 37 N., R. 39 E., consists of

> foot bones, vertebra, chevrons, etc., of *Thescelosaurus neglectus* Gilmore; caudal vertebra of a carnivorous dinosaur, not determinable; two fragments of a turtle shell, probably pertaining to the genus *Aspidontes*. The presence of *Thescelosaurus neglectus* would indicate that these fossils came from the Lance formation, for the four or five specimens of the genus known at this time are all from the Lance.

A single vertebra collected near the top of the Lance formation in sec. 27, T. 37 N., R. 46 E., is that of *Champosaurus* sp., characteristic of both the Lance and Fort Union formations.

Several small collections of invertebrate fossils, made in the Larb Hills, have been identified by Mr. Reeside as follows:

10022. Sec. 29, T. 24 N., R. 35 E.
Unio brachyopisthus.
Unio holmesianus.

10023. Sec. 29, T. 24 N., R. 35 E.
Unio cf. U. brachyopisthus White.
Sphaerium subellipticum Meek and Hayden.
Viviparus sp., fragment.

10026. Sec. 29, T. 24 N., R. 35 E.
Tulotoma thompsoni White.

10027. Sec. 25, T. 25 N., R. 34 E.
Sphaerium subellipticum Meek and Hayden.
Campeloma multilineata Meek and Hayden.

All are probably from the Lance formation.

Fossil wood from the Lance formation has been identified by Knowlton as that of coniferous trees, but no identifiable fossil plants were collected.

TERTIARY SYSTEM.

FORT UNION FORMATION.

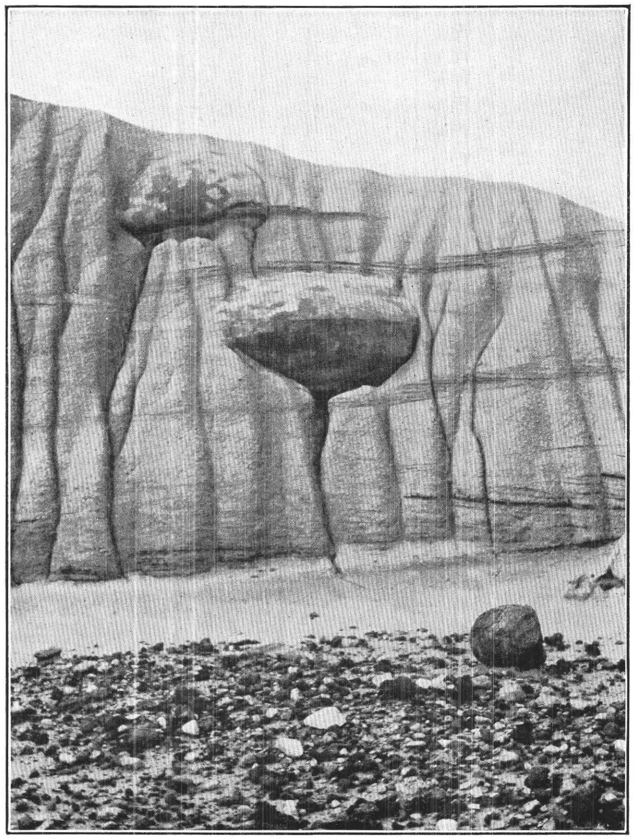
Overlying the somber-colored shale of the Lance formation is the Fort Union formation, of Eocene age, which is exposed along the North Dakota line and extends more or less continuously westward as far as Opheim. It carries the principal lignite beds of the region and also contains widely distributed beds of clay and shale [2] suitable for the manufacture of brick and other clay products. The formation is composed of fine-grained sandstone and shale and is distinguished from the Lance formation by the prevailing light-yellow color. Like the Lance formation, it has, especially in its lower part, concretions of hard sandstone resembling fossil logs. (See Pl. VI, *C*.) Observations made along the contact of the Lance and Fort Union formations indicate that the change in color is not always noticeable at exactly the same horizon. The mapping of the contact of these formations on Plate I is based on the judgment of the geologists making the examination in each locality. According to Beekly [3] the thickness of the Fort Union remaining at the southeast end of the region mapped is about 1,400 feet. The lower part is probably equivalent to the Lebo shale member of the Fort Union, described by Rogers.[4] The following section of the Lance and Fort

[1] Brown, Barnum, op. cit., pp. 823–845.

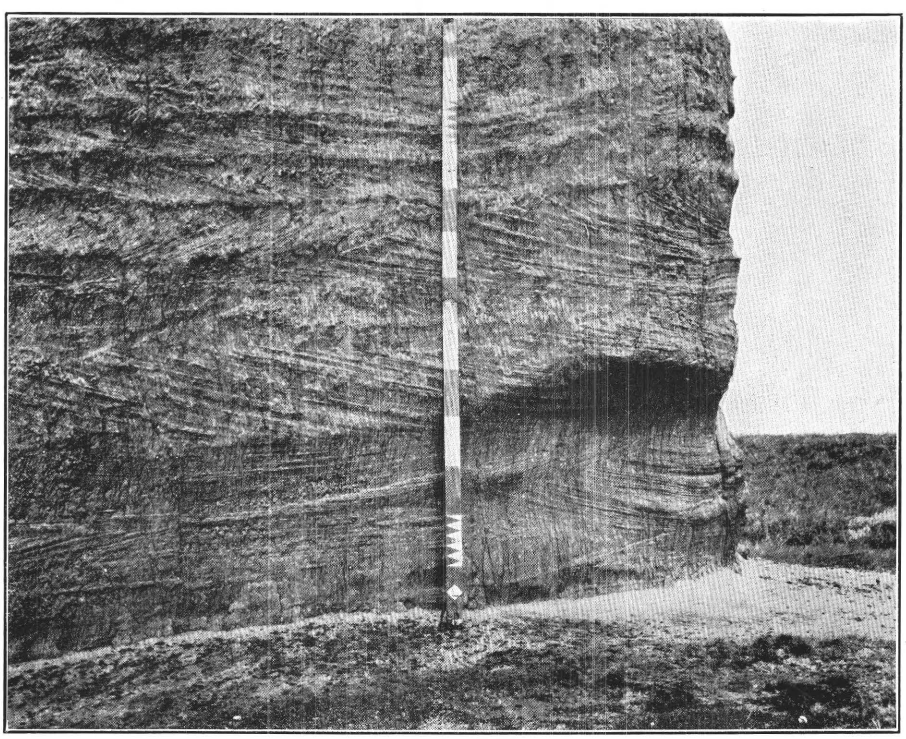
[2] Rose, Bruce, Wood Mountain-Willowbunch coal areas, Saskatchewan: Canada Geol. Survey Mem. 89, pp. 69–83, 1916. Bauer, C. M., Clay in northeastern Montana: U. S. Geol. Survey Bull. 540, pp. 369–372, 1914.

[3] Beekly, A. L., The Culbertson lignite field, Valley County, Mont.: U. S. Geol. Survey Bull. 471, pp. 326, 331, 1912.

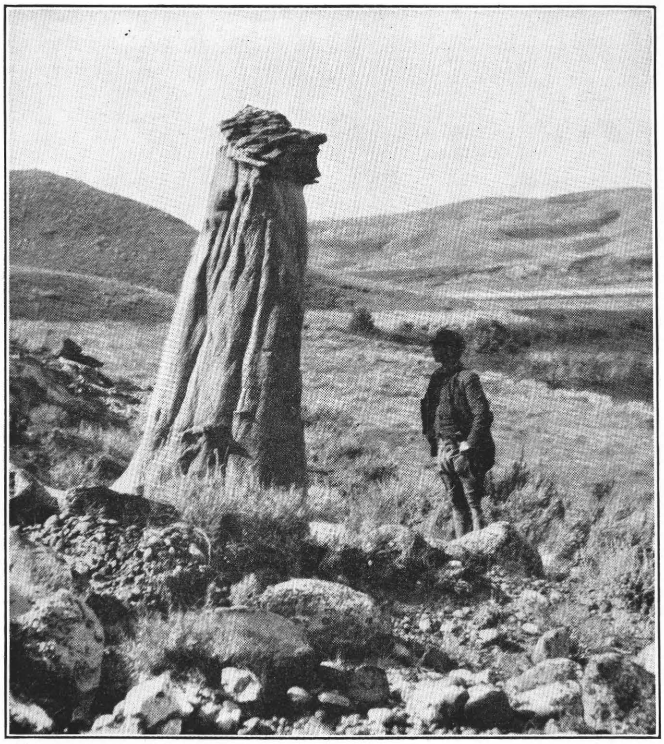
[4] Rogers, G. S., The Little Sheep Mountain coal field, Dawson, Custer, and Rosebud counties, Mont.: U. S. Geol. Survey Bull. 531, pp. 12, 13, 1913.



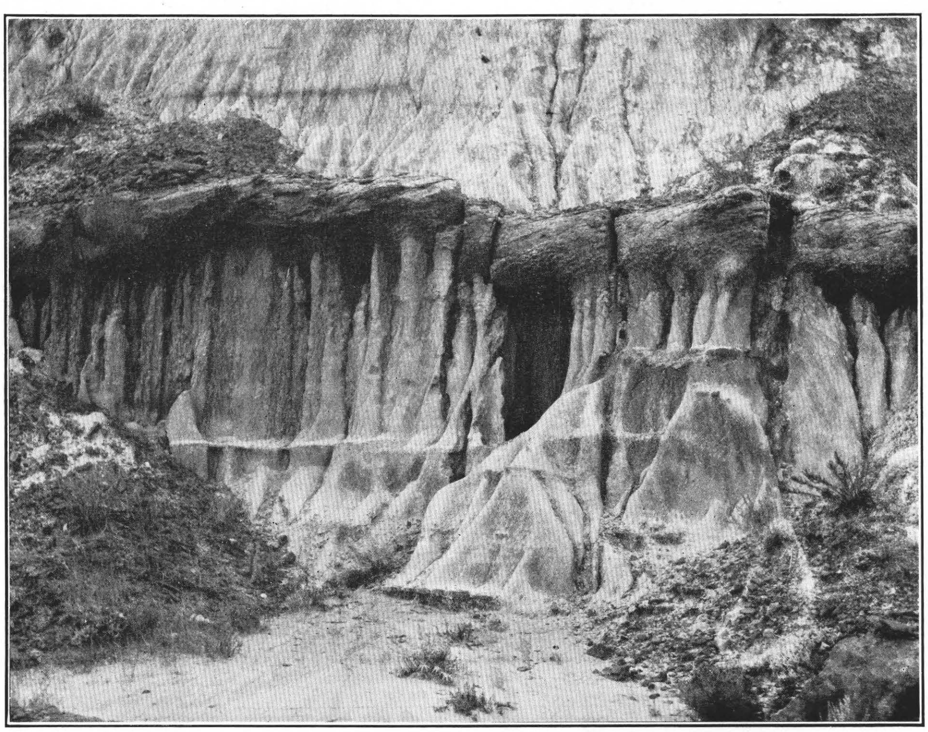
A. LOWER PART OF THE LANCE FORMATION, SHOWING SPHERICAL CONCRETIONS.



B. ARENACEOUS SANDSTONE, SHOWING EOLIAN CROSS-BEDDING.



A. PINNACLE OF SOFT SANDSTONE OF LANCE FORMATION.



B. EROSION FORM OF LANCE FORMATION.

Union formations exposed from Redstone to Plentywood (Pl. I) is much generalized:

Generalized section of the Lance and Fort Union formations between Redstone and Plentywood, Mont.

	Ft.	in.
Fort Union formation:		
Sandstone and shale	81	0
Lignite		6
Sandstone and shale	67	0
Shale	52	0
Lignite, Richardson bed	6±	
Sandstone and shale more or less concealed	320±	
Lignite, upper Eagles Nest bed	6	3
Shale and sandstone, yellowish	50±	
Lignite, lower Eagles Nest bed	4	0
Shale and sandstone, yellowish	70	0
Lignite		10
Shale and sandstone, yellowish	19	0
Lignite	1	2
Shale and sandstone, yellowish	18	0
Lignite		4
Shale, grading upward into sandstone, yellowish	20	0
Lignite	1	6
Shale and sandstone, yellowish	60±	
Lignite, Redstone bed	6	0
Shale and sandstone, yellowish	22	0
Lignite	2	0
Lance formation:		
Shale and sandstone, somber color	30	0
Lignite	1	10
Shale and sandstone, somber color	27	0
Lignite	6	0
	872±	

The following generalized section of the Fort Union and its lignite beds as exposed on Missouri River in the southeastern part of the region is taken from Beekly's report:[1]

Generalized section showing the distribution of lignite beds in the Fort Union formation.

Culbertson field, 2 miles east of Lakeside.

	Ft.	in.
Clay and shale	125	0
Lignite, bed H	4	0
Clay and shale	70	0
Lignite, bed G	4	0
Clay and sandy shale	150	0
Lignite	1	10
Sandstone and clay	30	0
Lignite	1	2
Sandstone and shale	55	0
	441	0

Culbertson field, sec. 3, T. 27 N., R. 56 E.

	Ft.	in.
Lignite, bed F	7	0
Sandstone and shale	45	0
Lignite, bed E	6	4
Sandstone with some shale	121	0
Lignite	1	0
Sandstone and shale	24	0
Lignite, bed DD	4	4
Sandstone and shale	70	0
Lignite, bed CC	2	5
Sandstone and clay	130	0
Lignite	5	7
	416	8

[1] Beekly, A. L., op. cit., p. 331.

Fort Peck field west of Big Muddy Creek.

[C. D. Smith, 1908.]

	Ft.	in.
Clay	6	0
Lignite, bed D	9	0
Sandstone and clay	95	0
Lignite, bed C	2	0
Sandstone and clay	115	0
Lignite, bed B	3	0
Sandstone and clay	275	0
Lignite	5	0
Clay	15	0
Lignite, bed A	7	7
Somber-colored beds (Lance).		
	532	7
	1,390	3

The following section, measured in sec. 18, T. 24 N., R. 33 E., shows the relations of the Fort Union, Lance, and Bearpaw formations in the Larb Hills:

Section showing the relation of the Fort Union, Lance, and Bearpaw formations in the Larb Hills, Mont.

	Ft.	in.
Fort Union formation:		
Sandstone, yellowish	50	0
Lignite		3
Sandstone, soft, yellowish	20	0
Lignite	1	0
Sandstone, soft, yellowish	11	0
Lignite	1	0
Sandstone, soft, yellowish	20	0
Lignite	6	0
	109	3
Lance formation:		
Shale and sandstone, somber color	50	0
Lignite		6
Shale and sandstone, somber color; contains dinosaur bones	100	0
Concealed	100	0
Shale, sandy	100	0
Bearpaw shale.		
	350	6
	459	9

The relations of these sections are shown graphically in figure 5.

Full descriptions of the lignite beds in each township are given in other reports.[2]

[2] U. S. Geol. Survey Bull. 381, pp. 40–59, 1910; Bull. 471, pp. 319–358, 1912; Bull. 541, pp. 293–315, 1914; and a report not yet published.

The following small collections of fossil plants have been examined by F. H. Knowlton, who reports that they are of Fort Union age:

7001. Sec. 3, T. 35 N., R. 44 E.:
Sequoia nordenskioldii Heer.

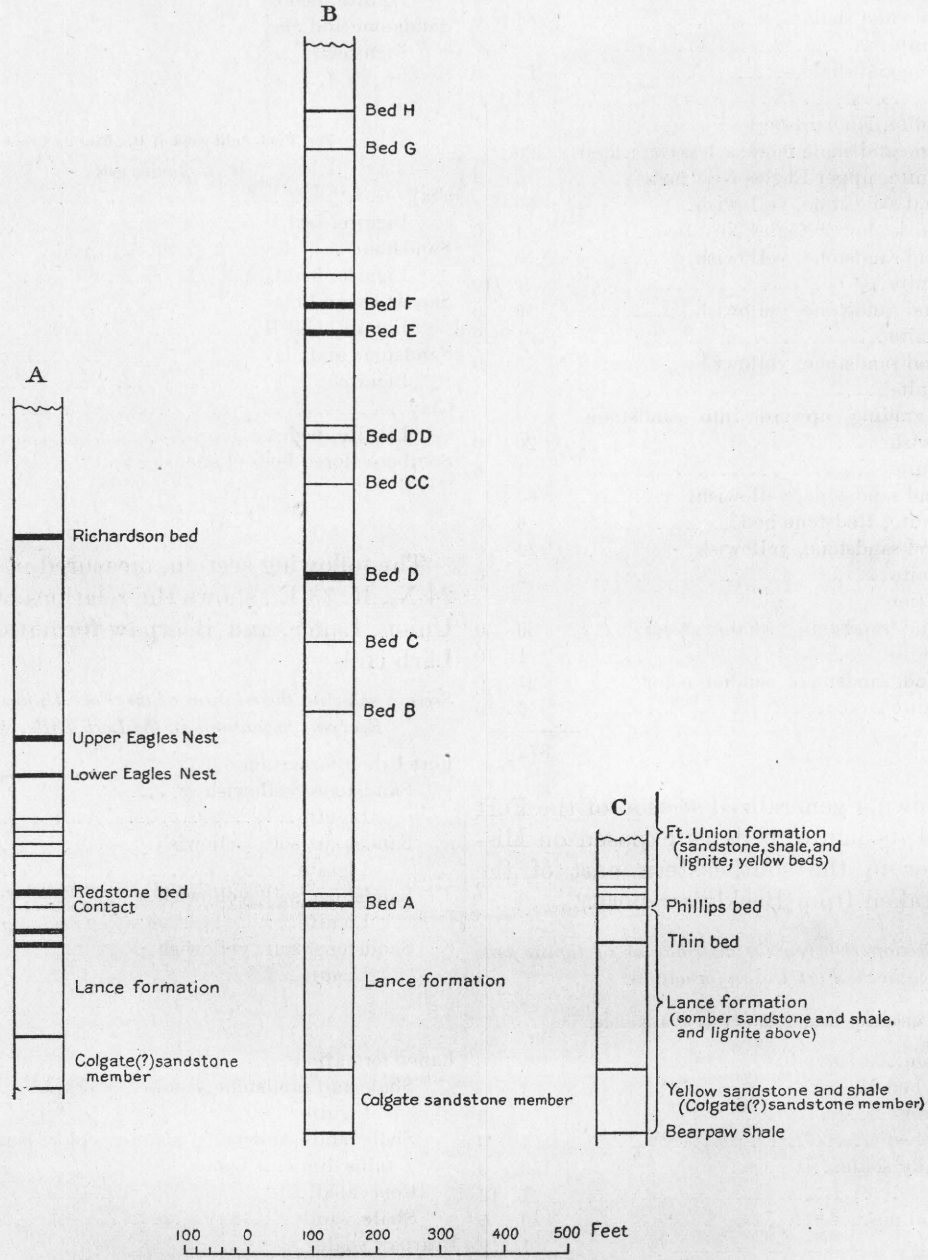


FIGURE 5.—Generalized sections of Fort Union and Lance formations, showing their relation to the Bearpaw shale from its outcrop northwest of Opheim to Plentywood, Mont. (A); north of Missouri River from Brockton to the Dakota line (B); and in the Larb Hills, in T. 24 N., R. 33 E. (C).

Glyptostrobus ungeri Heer.
Dicotyledon, gen. and sp.?

7002. NE. ¼ sec. 31, T. 36 N., R. 45 E.:
Sequoia nordenskioldii Heer.

7004. Sec. 33, T. 37 N., R. 47 E.:
Alga.

Onoclea sensibilis fossilis Newberry.
Trapa microphylla Lesquereux of Ward.
Selaginella collieri Knowlton,[1] n. sp.
Potamogeton n. sp.

7005. Canada, near the north line of sec. 4, T. 37 N., R. 49 E.:
Onoclea sensibilis fossilis Newberry.
Taxodium occidentale Newberry.
Sequoia nordenskioldii Heer.
Platanus sp.

[1] Knowlton, F. H., A new fossil *Selaginella* from the lower Tertiary of Montana: Torreya, vol. 16, pp. 101–103, 1916.

7505. Canada, near the north line of sec. 4—Continued.
Grewia sp.
Persea sp.
7006. SE. ¼ sec. 21, T. 36 N., R. 52 E.:
Taxodium occidentale Newberry.
Sequoia nordenskioldii Heer.
Grewia pealei Ward.
7272. NE. ¼ sec. 36, T. 37 N., R. 39 E.:
Sequoia nordenskioldii Heer.
Glyptostrobus europaeus Unger.
Fragments of a dicotyledon.

Collections of invertebrates, on which T. W. Stanton has reported, were made at the following localities:

9837. SW. ¼ sec. 6, T. 35 N., R. 45 E.:
Unio sp. fragments.
Campeloma producta White.
Campeloma multilineata Meek and Hayden.
Fort Union.
9380. T. 36 N., R. 46 E.:
Viviparus sp.
Probably Fort Union.
9381. Sec. 13, T. 34 N., R. 50 E.:
Unio sp.
Campeloma multilineata Meek and Hayden.
Fort Union.

FLAXVILLE GRAVEL.

With the Fort Union the conformable series stops, and the formations representing the later history of the region are surficial deposits of rather small extent laid down during favorable intervals between great time breaks when erosion was prevalent and no sediments were deposited.

The Flaxville gravel,[1] shown in several areas along the international boundary, is a few feet to 100 feet thick and caps a series of plateaus upon eroded surfaces of the Fort Union, Lance, and Bearpaw formations at altitudes ranging from 2,600 feet at the east end to 3,200 feet at the west end of the region described, near the international boundary. It is composed of gravel, sand, clay, volcanic ash, and marl and in places is cemented with calcite. The gravel consists of pebbles derived from the quartzite and argillite of the Rocky Mountains.

Fragments of fossil vertebrates found at 25 widely distributed localities have been submitted to J. W. Gidley, who states that the beds which contained them can not be older than Miocene or younger than early Pliocene and that they are probably upper Miocene. The time break between the Fort Union formation (Eocene) and the Flaxville gravel (Miocene) is in part represented by the Oligocene deposits found on a still higher plateau in the Cypress Hills in Canada, 50 miles away.

[1] Collier, A. J., and Thom, W. T., jr., The Flaxville gravel and its relation to other high terrace gravels of the northern Great Plains: U. S. Geol. Survey Prof. Paper 108, pp. 179–184, 1917 (Prof. Paper 108–J).

TERTIARY OR QUATERNARY SYSTEM.

LATE PLIOCENE OR EARLY PLEISTOCENE DEPOSITS.

Below the Flaxville level there are extensive areas across which the present streams have eroded valleys from 100 to 500 feet in depth. Stratified silt and gravel are to be found in a very few places on this level, and from one of these exposures of gravel in sec. 23, T. 33 N., R. 35 E., a single fossil tooth was collected which Dr. Gidley identified as that of a horse resembling the living species. As the gravel from which it came is clearly older than the last advance of ice during the glacial epoch, the formation is regarded as of either late Pliocene or early Pleistocene age.[2]

Extensive benches slope gently away from the Little Rocky Mountains at several levels. These benches are capped with gravel containing many pebbles of limestone and porphyry derived from the neighboring mountains and are almost surely of Tertiary age, for in some places the gravel on them is overlain by glacial drift. The lowest bench is probably equivalent to the late Pliocene or early Pleistocene bench in the region north of Milk River with which it is tentatively correlated. The presence of undissolved limestone pebbles seems to forbid the assignment of these benches to an earlier period.

QUATERNARY SYSTEM.

ALLUVIUM OF PREGLACIAL RIVERS.

Since late Pliocene or early Pleistocene time streams have been at work eroding the present valleys. The effects of this erosion can be seen in the escarpments north and south of Milk River between Tampico and Malta, where at one place 300 feet of beds belonging to the Claggett and Judith River formations, capped by late Pliocene or early Pleistocene gravel, are exposed. The cutting of the river valley must have occurred early in Pleistocene time, when the valley of Milk River was occupied by

[2] Idem, p. 182.

a much larger river, the Missouri,[1] and along its banks and flood plains gravel, silt, and sand were deposited. Some of this material can be seen in pits northwest of Saco and north of Malta. The gravel here differs from the Flaxville gravel in that it contains numerous fragments of porphyry.

Similar deposits occur at several points in the first benches above the flood plain of the Missouri between Milk River and the North Dakota line, and are best exposed where gravel pits are operated by the Great Northern Railway. In the summer of 1917 a pit was operated at Wolf Point, where a new freight division of the railway was being installed and where the photograph reproduced in Plate VI, *B*, was taken. Wolf Point lies about 25 feet above the Missouri, and the gravel pit is in the second bench, about 20 feet higher. The section exposed is about as follows:

Section exposed in gravel pit at Wolf Point.

	Feet.
Soil, with a few scattered granite boulders on the surface	1
Glacial till, containing granite cobbles	5
Gravel, chiefly quartzite but containing fragments of sandstone, porphyry, and near the bottom shale	13
Shale, Bearpaw.	
	19

The gravel is interstratified with lenses of sand, and the bedding planes are nearly horizontal. The gravel consists for the most part of well-rounded pebbles of quartzite, probably derived from the Flaxville gravel, but it contains some pebbles of porphyry and fragments of sandstone and of fossiliferous Bearpaw shale near the bottom. A thorough search failed to reveal any glacial material such as granite pebbles. It was evidently deposited by Missouri River in preglacial time, for it is overlain by glacial till containing many more or less angular fragments of granite. Another gravel pit 2 miles west of Brockton shows finely laminated sand. The bedding at the west end of the pit lies nearly horizontal, whereas that at the east end dips east about 70°. The surface has been eroded irregularly and is covered with glacial till to a maximum depth of about 15 feet. The bottom of this pit is about 40 feet above the present river level.

[1] Calhoun, F. H. H., The Montana lobe of the Keewatin ice sheet: U. S. Geol. Survey Prof. Paper 50, pp. 34-45, 1906.

GLACIAL MORAINES AND DRIFT.

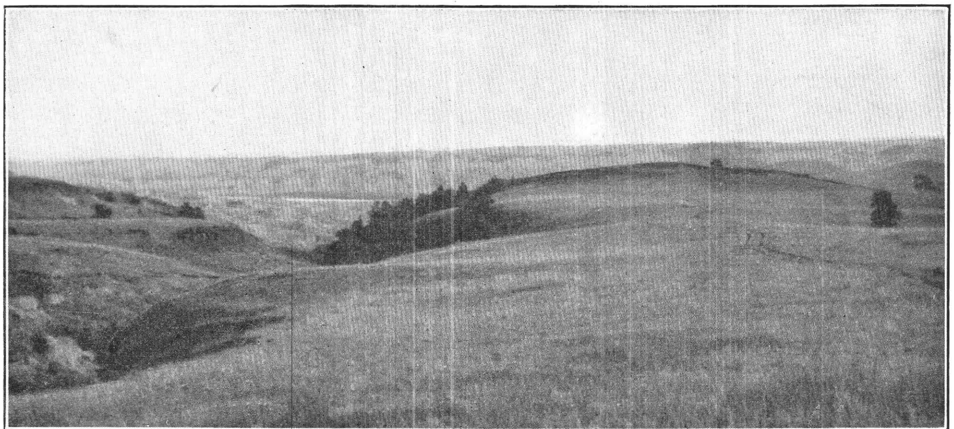
Overlying the gravel in the Milk River valley as well as the Flaxville gravel and all the higher benches described there is in many places a sprinkling of glacial boulders, among which specimens of limestone from Lake Winnipeg and of granite from the Hudson Bay region are abundant. One large limestone erratic about 20 feet long was found by W. C. Alden and the writer just north of Nelson Reservoir. At the time this glacial drift was introduced the Missouri was probably forced out of the Milk River valley and compelled to flow through a narrow valley south of the Larb Hills. When the glacial epoch was over and the ice sheet had retreated for the last time the waters that could collect in the old channel formed Milk River, which flows in a very meandering course over the old valley floor. In addition to the scattered boulders there are in the northern part of this region accumulations of glacial material in which the topography is suggestive of moraines. There are also in the southern part of the region some large areas covered by till or boulder clay.

ALLUVIUM.

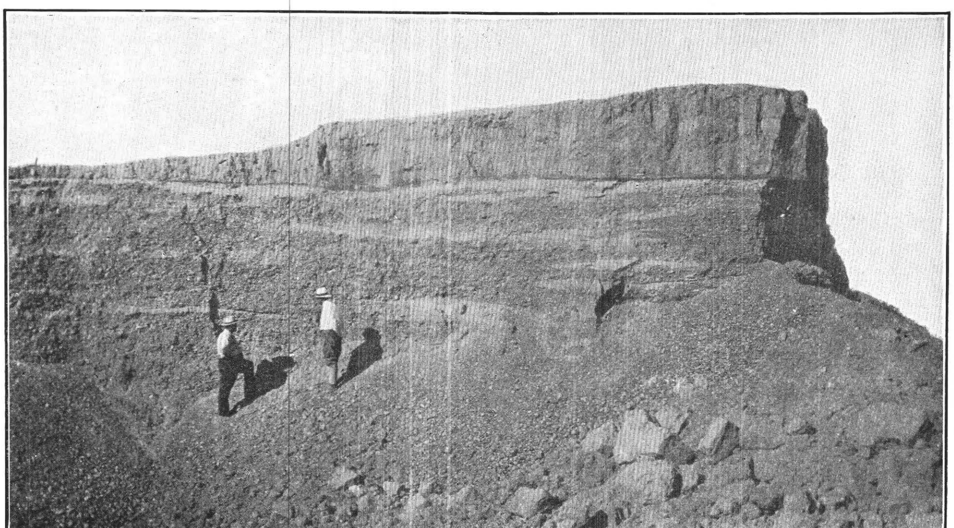
Soil of various kinds, brought in since the glacial epoch, has been deposited along Milk River and other streams of the region. On the flood plains of Milk River there is usually a gumbo soil, derived from the shale of the country, which forms a sticky mud when wet. The river has brought down a small quantity of sand in some places, and where this is deposited the soil is more easily cultivated than the gumbo.

Milk River since the retreat of the ice has trenched its flood plain about 10 or 12 feet, developing intricate meanders, and back of the river there are oxbow lakes which show the extent of the flood plain.

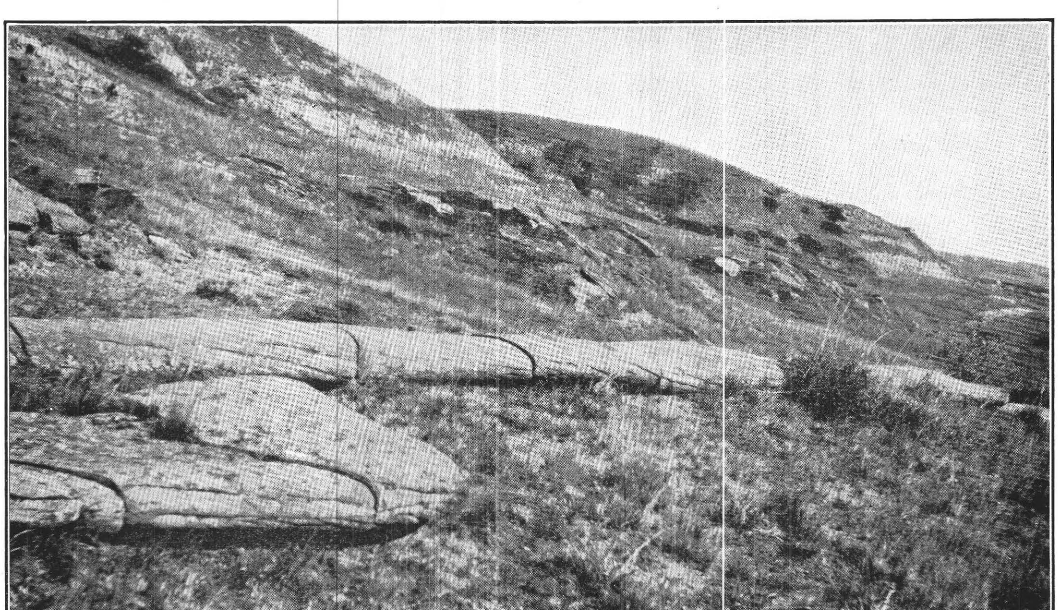
Big Muddy Creek, in the eastern part of the region, flows in a valley cut from 100 to 300 feet below the late Pliocene or early Pleistocene bench. Its flood plain is about a mile wide and is covered with fine silt, which provides the material that doubtless suggested the name for the creek and makes it difficult to cross on account of the muddy banks. The gravel terraces, from 20 to 50 feet above the



A. VIEW SOUTH ACROSS THE MISSOURI VALLEY, VALLEY AND DAWSON COUNTIES, MONT.



B. GRAVEL PIT AT WOLF POINT, MONT.



C. LOGLIKE CONCRETION IN FORT UNION FORMATION.

flood plain, were probably formed by the large river that occupied the Big Muddy Valley and received its water and load of sand and gravel directly from the front of the glacier to the north, near the end of the glacial epoch.[1] Along Eagle, Beaver, and Whitetail creeks, tributaries of the Big Muddy, there are at many places beaver dams, above which are long strips of flood plain called beaver-dam land.

The alluvium along the forks of Poplar River consists largely of reworked Flaxville gravel, and because of this gravel the streams can be easily forded at nearly all places.

Rock Creek has a long, narrow canyon so precipitous that it was considered to be too rough to survey by the surveyors of the Land Office. The upper end of this canyon is near Barr post office, above which the valley is broad and filled with alluvium.

Frenchman Creek, by far the largest stream entering Milk River from the north, rises far to the northwest in Canada and after crossing the international boundary flows in a comparatively narrow valley which has probably been eroded since the last glacial advance. The flood plain along it is in general narrower than the flood plains of most of the other streams.

Whitewater Creek, farther west than Frenchman Creek, was probably situated in about its present course before the advance of the large Wisconsin glacier. Its valley is at least a mile wide and is filled by an extensive glacial moraine. Cottonwood Creek in its lower part has a comparatively narrow flood plain; the upper part of its course is called Woody Island Coulee. The water in this coulee apparently at one time flowed eastward and entered the valley of Whitewater Creek, but its old channel was blocked with glacial drift, and only one or two lakes are left to indicate its former position.

Beaver Creek, which enters Milk River from the south, occupies a broad valley bedded with silt, making the stream difficult to ford. The lower part of this valley coincides with that of the Musselshell, which before the advance of the Wisconsin glacier flowed into the Missouri in the valley of Milk River. The upper part of the valley of Beaver Creek from T. 27 N., R. 30 E., to the Coburn ranch, in T. 25 N., R. 26 E., is largely filled with glacial till, in which the creek is at places intrenched about 20 feet. In preglacial time it probably reached the old channel of the Missouri by way of Alkali Creek. For about 12 miles from T. 27 N., R. 30 E., to T. 26 N., R. 32 E., Beaver Creek occupies a narrow valley cut in the Bearpaw shale.

Larb Creek, east of Beaver Creek, occupies a very broad valley, and its bed is cut in alluvium. There is an easy pass from its head over the divide to the present course of the Missouri, as there is also from Beaver Creek.

SOIL OF THE UPLANDS.

The soil on the plateau surfaces of the region varies with the character of the underlying rock. The most interesting soil is that which caps the Flaxville gravel. This soil is from a few inches to several feet thick and has a slightly dark color. It is bound together by grass roots in its upper part and contains the bones of the bison. With the exception of that on the Boundary Plateau, this soil does not appear to contain much glacial material. South of Glasgow there is an extensive upland surface beneath which lies the Bearpaw shale, but here there is a sandy soil which owes its origin in part to the advance of the ice. Over much of the western part of the area there is a gumbo soil derived directly from the Bearpaw shale which it overlies. The soil on the Larb Hills is sandy, being derived from the disintegration of the Lance formation underlying it, mixed with a small amount of glacial material. The soil overlying the Judith River formation is sandy and not quite so good as that which overlies the Fort Union and Lance formations.

In the parts of the region covered by glacial moraines many small lakes have been filled since the retreat of the ice. The filling is generally grass and other plants that have grown in the water, together with materials that have blown from the sides. These old lake beds are in many places used for farm lands. In the large moraine-covered area, which has its center around Whitewater Creek a great many of these lakes are still unfilled, and water persists in them throughout the average summer.

STRUCTURE.

The Bowdoin dome,[2] northeast of Malta, in the western part of the region, is the most obvious structural feature, and from it the

[1] Rose, Bruce, Wood Mountain-Willowbunch coal area, Saskatchewan: Canada Geol. Survey Mem. 89, p. 50, 1916.

[2] Collier, A. J., The Bowdoin dome, Montana, a possible reservoir of oil or gas: U. S. Geol. Survey Bull. 661, pp. 193–209, 1917 (Bull. 661–E).

strata dip away in all directions. The dips are usually less than 1°, and where they have been determined by careful instrumental surveys they are best recorded in feet to the mile. The Little Rocky Mountains, about 40 miles southeast of the Bowdoin dome, present an abrupt uplift of the strata accompanied by an intrusion of igneous rocks, forming a laccolith, but this disturbance does not extend far from the base of the mountain. The beds around this uplift are tilted at angles in some places as high as 70°. The relation of the Bowdoin dome to the structure prevalent in the Little Rocky Mountains is shown in figure 6.

In the area immediately surrounding the Bowdoin dome the field work has not been in sufficient detail to ascertain whether or not there are minor structural features, but such features are known to exist in the eastern part of the region. The Poplar dome, on Missouri River, described by Smith,[1] is evidently such a feature, as it brings up a large elliptical area of Bearpaw shale nearly surrounded by the Lance formation. The formations immediately concerned dip away from it in all directions. The lignite beds along the river east of Brockton dip eastward at about 100 to 135 feet to the mile. In directions other than east of the dome, where its presence only intensifies the general dip, its effect does not reach farther than 15 miles away and probably the dips are much lower than those to the east. Similar small undulations of the strata can be inferred from the distribution of the Lance and Fort Union outcrops north of the Poplar dome, and several such features, which are not readily detected, were found in the course of mapping the lignite beds.

In the vicinity of Scobey, where the general dip of the rocks is toward the east, there is a westward dip for about a mile. Northeast of Scobey, south of Coal Creek, a small dome having a maximum width of about 2 miles is present. In the valley of Big Muddy Creek similar variations occur in the strike and dip. Such features probably are present in the western part of the region but they are very difficult to find because most of the rocks exposed are shale, in which it is practically impossible to trace individual beds for any distance.

Two small faults having a displacement of less than 15 feet each may be seen on the north side of Coal Creek in T. 37 N., R. 45 E., and a third fault of similar proportions displaces one of the lignite beds near the northwest corner of T. 36 N., R. 52 E. No other faults are known in either the eastern or the western part of the area of flat-lying beds, though they may be present. In the escarpments of the Flaxville plateau and the late Pliocene or early Pleistocene bench large blocks of strata may break away from their natural position and slump, giving the appearance of a condition which might result from faulting. This has occurred at many places in the Judith River formation around the Bowdoin dome. Faults of great displacement were seen in the Little Rocky Mountains and in the writer's opinion are common there, but they can not be described without further work in the field.

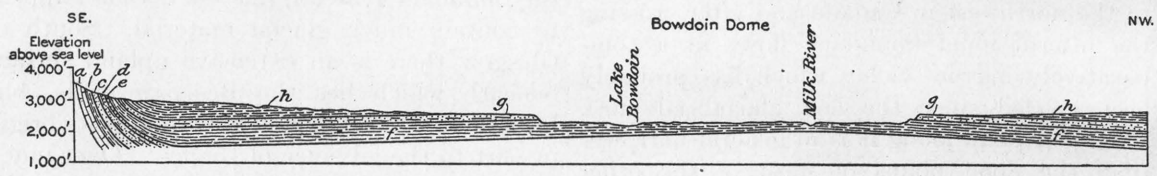


FIGURE 6.—Relations of the Bowdoin dome to the structure prevalent in the Little Rocky Mountains, Mont. *a*, Madison limestone; *b*, Ellis formation; *c*, Kootenai (?) formation; *d*, Colorado group; *e*, Eagle (?) sandstone; *f*, Claggett shale; *g*, Judith River formation; *h*, Bearpaw shale.

A word should be said in regard to the structure of the Larb Hills. Calhoun[2] makes the statement that these hills represent a dome whose character is similar to that of the Little Rocky Mountains but which is not eroded sufficiently to expose the underlying rocks. This statement is incorrect, for the Larb Hills are simply an outlier of the large area of Lance and Fort Union rocks exposed south of Missouri River, and the strata here have a uniformly low dip to the south. It is assumed, therefore, that Calhoun did not make a personal examination of these hills but relied on information obtained from some other source.

[1] Smith, C. D., The Fort Peck Indian Reservation lignite field, Mont., U. S. Geol. Survey Bull. 381, p. 44, 1910.

[2] Calhoun, F. H. H., op. cit., p. 12.

The major part of the present structure in both the large flat-lying portions of the formations and the highly upturned portions in the Little Rocky Mountains was introduced subsequent to the deposition of the Fort Union formation and before that of the Oligocene gravel in the Cypress Hills, for this gravel rests unconformably upon the eroded surfaces of the Fort Union, Lance, and Bearpaw formations indiscriminately. In other words, this revolution occurred in late Eocene time. That a minor part of the folding may have been accomplished since the deposition of the Flaxville gravel is indicated by the fact that some of the streams in the eastern part of the region occupy synclinal valleys and by the absence of the Flaxville gravel between Opheim and the Boundary Plateau, it being assumed that an uplifted portion of the plateau would be more subject to erosion than the lower-lying part.

ADJUSTMENTS OF DRAINAGE.

Most stream adjustments in northeastern Montana are due to the invasion of ice during the glacial epoch. One of the most obvious features of this kind can be seen on Wolf Creek, a tributary of the Big Muddy, for its headwaters have been diverted and captured by the South Fork of Eagle Creek, largely because of glacial drift piled across its valley in secs. 8 and 9, T. 34 N., R. 51 E. Reference has been made to the change in the course of Woody Island Coulee, in T. 36 N., R. 28 E., by the filling up of its valley with glacial drift and to a possible old course of the headwaters of Beaver Creek by way of Alkali Creek to Milk River, a short distance above Malta.

The most pronounced stream adjustment in this region, however, is the diversion of Missouri River from the Milk River valley, which Calhoun [1] has described. The present valley of the Missouri south of the Larb Hills is practically a canyon 800 feet deep and not more than 2 miles across from rim to rim, whereas its old valley, now occupied by Milk River, is much broader and shallower. Before the river was diverted Musselshell River flowed into it by way of the lower portion of the Beaver Creek valley. By this change about 70 miles of the lower part of Musselshell River was diverted. Larb Creek was probably a much larger stream heading south of the Missouri and passing through the Larb Hills by way of the Timber Creek valley. The glacier from the north filled the whole of the Milk River valley and was thick and active enough to cover the Larb Hills with glacial drift. At its front the great volume of water due to melting ice and an attendant moist climate easily eroded a new channel in the soft Lance formation and Bearpaw shale. A view south across the gorge of the Missouri, 700 to 800 feet in depth, is shown in Plate VI, *A*.

An old channel of the Missouri from Culbertson to Lakeside, which is followed by the Great Northern Railway, and a broad depression extending from the Big Muddy Valley at Medicine Lake northwestward, crossing the State boundary about 6 miles south of the Canada line, have been described by Beekly.[2] The course of the depression is marked by a chain of shallow intermittent lakes. Bauer [3] has assumed that this feature also is an old channel of the Missouri, in which it flowed northward to Hudson Bay by way of Souris and Assinniboine rivers before the glacial epoch. The south end of this depression near Poplar has recently been inspected by Alden, who states [4] that its floor is about 200 feet above that of the present valley of the Missouri, and that its topography blends with the long slopes which characterize the early Pleistocene or late Pliocene bench of this region. Alden suggests that the river probably occupied this valley as long ago as the Pliocene epoch and that it was diverted at the time of the first invasion of ice early in the Pleistocene. The late Pliocene or early Pleistocene gravel described on pages 35–36 was probably laid down in or near the channel of one of the streams which contributed to form this river.

[1] Calhoun, F. H. H., op. cit., pp. 34–45.

[2] Beekly, A. L., The Culbertson lignite field, Mont.: U. S. Geol. Survey Bull. 471, pp. 320–323, 1912.

[3] Bauer, C. M., A sketch of the late Tertiary history of the upper Missouri River: Jour. Geology, vol. 23, pp. 52–58, 1915.

[4] Alden, W. C., oral communication.