The Fort Union Formation of Montana and Adjacent Areas

Charles Christman
THE FORT UNION FORMATION OF
MONTANA AND ADJACENT AREAS

by

Charles Christman

A thesis
submitted to the Department of Geology
in partial fulfillment of the requirements
for the Degree of Bachelor of Science
in Geological Engineering

Montana School of Mines
Butte, Montana
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INTRODUCTION

The Fort Union formation is one of the most important and best known geologic formations of the northern Great Plains, and is found lying almost horizontal at the surface over large areas in this region. (See Plate 1). With the Fort Union and the associated Wasatch formation the conformable series of sediments stops, and the formations representing the later history of the region are surficial deposits of limited extent laid down during favorable inter-erosional periods. The Cypress Hills gravels and the Flaxville gravels which cap a series of plateaus upon eroded surfaces of the Fort Union, Lance and Bearpaw formations are typical of these later deposits in Montana.

Almost the entire eastern half of Montana is underlain by beds of good lignite and coal, and about 90% of the total tonnage of these fuels is found in the Fort Union formation, making it by far the most important coal bearing horizon in this region. The only known locality where Fort Union rocks in Montana do not contain important workable coal is in Teton County in the northwest part of the State where only a few very thin and scattered coal
seams occur.

In order that the depth of potential oil bearing horizons may be accurately predicted it is important to the petroleum geologist to have an estimate of the thickness of the strata to be penetrated. The construction of the modified isopach map of the Fort Union formation was chosen as the subject for an undergraduate thesis largely as an aid in making these predictions. However, in this report the writer has speculated on the original thicknesses of this formation as shown on the accompanying isopach.

The area under consideration includes all the State of Montana, the northern part of Wyoming and the western half of North Dakota. The information upon which the isopach map is based was obtained from various reports of State and Federal surveys and from articles in technical journals. In construction of the isopach map, no account was taken of the irregularities in thickness caused by erosion and therefore the map must be considered as so modified.

The suggestions and help offered by Dr. E. S. Ferry of the Department of Geology of Montana School of Mines have greatly aided the writer in preparing this report, and the writer wishes to express his gratitude and appreciation.

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The Fort Union formation receives its name from a former military post on the Missouri River near Buford, North Dakota, about three miles from the Montana state line. It was originally described by Meek and Hayden in 1861 who stated that it "occupies the country around Fort Union extending north into the British possessions to unknown distances; also, southward to Ft. Clark".

More of the surface of eastern and central Montana is underlain by Fort Union strata than by any other formation and it covers approximately 25,000 square miles, or about one-quarter of the plain's area of the State, and eighteen counties of eastern and central Montana have rocks of the Fort Union formation within their boundaries. The main deposit is found in the eastern part of the State, but it also overlies about 1,200 square miles in central Montana in the area known as the Bull Mountains in Musselshell and Rosebud Counties and also is found in smaller amounts in Carbon and Sweet Grass Counties.

Members

Lebo Shale:

This member was first described by R. W. Stone, from its occurrence in the vicinity of the Crazy Mountains and the name "Lebo Andesitic member of the Fort Union formation" was first used by Stone and Calvert in 1910. How-
ever the Lebo shale member is described in preliminary reports by Woolsey who referred to the member as "Beds on Dean Creek" and by Richards who referred to the Lebo as "Somber colored beds". It is typically developed on Lebo Creek, Montana, northeast of the Crazy Mountains and consists of a tongue of andesitic rocks resembling the Livingston formation and the Lennep sandstone.

**Tongue River:**

The Tongue River member contains the chief coal bearing rocks in Montana and in some localities, as for example south of Roundup, as many as twenty-six different coal beds have been mapped within it. It is well exposed along the Tongue River between Carneyville, Wyoming, and Brandenberg, Montana, and derives its name from this river. Good exposures may also be found along the Yellowstone River between Glendive, Montana and Buford, North Dakota, and in the Missouri River Valley above Fort Clark, North Dakota.

**Kingsbury Conglomerate:**

The Kingsbury conglomerate member is one of the lesser divisions of the Fort Union formation and is found only in a limited area in northern Wyoming. It takes its name from Kingsbury Ridge, a prominent topographic feature about six miles southwest of Buffalo and is one of the most conspicuous and prominently exposed rock divisions in the Buffalo region.
Sentinel Butte:

The Sentinel Butte shale member derives its name from Sentinel Butte, North Dakota, where it is typically exposed. It resembles the Hell Creek member of the Lance formation, but is found above the Tongue River member of the Fort Union formation. This member is characterized by extensive beds of bentonite and bentonitic clays and does not contain nearly as many coal seams within it as the underlying Tongue River member. At Sentinel Butte, the member is 500 feet thick. However, in North Dakota the Sentinel Butte member is considered to be the lower unit of the Wasatch formation in this State (Ref. 32, p. 1414).

Ludlow and Cannonball:

The Cannonball and Ludlow members are interfingering contemporaneous sediments of Fort Union and Lance times. The Cannonball member becomes gradually thinner towards the west and is not found as far west as the Montana-Dakota state line. It consists of greenish marine sandstones and dark gray shales and attains a thickness of 300 feet. The Cannonball member is typically exposed in the bluffs of the Cannonball river in Morton County, North Dakota and numerous round concretions commonly known as "cannonballs" which accumulate upon weathered surfaces of the member probably account for this member's name. Towards the west the Cannonball merges into, and
overlies the non-marine Ludlow member.

The Ludlow member derives its name from its type locality, Ludlow, South Dakota, and here consists of 350 feet of loosely consolidated buff and cream-colored calcareous sandstone and shale with interbedded lignite (Ref. 26, p. 528). The numerous beds of lignite distinguish the Ludlow from the Cannonball and the member contains the majority of the lignite of South Dakota. The Ludlow varies in thickness from 40 feet near Breien, North Dakota, to 250 feet near Marmarth, North Dakota (Ref. 32, p. 1417).

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Fig. 1 Correlation chart of Upper Cretaceous and Tertiary formations.
Equivalent Formations

In most localities the Fort Union formation which is lowermost Tertiary or Paleocene in age, constitutes the upper few hundred feet of the sedimentary series, and only in a few scattered districts are younger rocks found above the Fort Union. In the southeastern corner of Montana small areas of chalk-like clays and sands of the White River formation are found deposited on top of the Fort Union and in northeastern Montana the Flaxville gravel which is composed of gravel, clay, volcanic ash and mud, is found capping a series of plateaus upon eroded surfaces of the Fort Union and other formations. Near the Wyoming state line southeast of Billings the Wasatch formation overlies the Fort Union.

The Lebo strata in eastern Montana are the stratigraphic equivalent of the upper part of the Livingston formation, which at the type locality Livingston, Montana, is in excess of 1400 feet in thickness and represents nearly the whole of the Montana group, the Lance formation and the lower part of the Fort Union.

Other stratigraphic equivalents of the Fort Union formation are: the Ludlow formation in northeastern Wyoming, eastern Montana and western North Dakota, the Reece formation in the Cooke City-Cardiner region, the Sphinx conglomerate near Ennis, Montana, the Torregon formation in Mexico, and the Thanetion formation in Western
Conditions of Deposition

Sedimentation in the Rocky Mountain region was continuous and uninterrupted from the beginning of Cretaceous Lance to and through the Tertiary Fort Union, and consequently the beds of the Fort Union formation frequently closely resemble those of the underlying Lance formation (Ref. 21, p. 331).

Nearly all the beds of the Fort Union formation are continental deposits consisting of shale and fine-grain sandstone, occasionally alternating in some areas with thin beds of calcareous sandstone that may be fossil-bearing. The formation has resulted from sediments derived from the erosion of the Rocky Mountains and deposited on a coastal plain by rivers flowing away from the Rocky Mountain region.

Changing conditions of deposition were prevalent during Fort Union time and occasionally swamps favorable to the accumulation of vegetable matter were formed. Sooner or later, however, these swamps were buried by sand, mud and silt, and new swamps formed elsewhere. These variable conditions led to the deposition of beds that are very irregular in their distribution and extent, just as one might expect of river deposits on a flood plain.

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Lithology of the Sediments

As a whole, the Fort Union formation consists of a variable thickness of yellowish, grayish sand and sandstone, interbedded with gray clays, shales and coal. A noticeable feature of the formation is the very irregular character of the beds, which often change abruptly in a horizontal direction. Clastic deposits predominate, but at several places in the upper portion of the formation thin beds of non-marine, buff limestone, one to three feet in thickness, occur. The limestone is generally fine in texture resembling lithographic limestone and consequently preserves excellent impressions of leaves of plants of the formation period. Fort Union beds contain a flora of over four hundred species and a fauna comprising both vertebrates and invertebrates, however, vertebrate fossils are rarely found. Leaves from deciduous broad-leaved trees very similar to present existing species are the most common forms met with.

Generally the rocks of the Fort Union formation are classified into two divisions: the lower gray beds known as the Lebo shale member, and the upper yellow beds which are known as the Tongue River member. However, two other members, the Kingsbury Conglomerate and the Sentinel Butte member are also recognized.

The Lebo shale member consists of dark gray, brown and black shale with occasional beds of light gray and
yellow sandstone and is often bentonitic. In the west, the member grades into the Livingston formation which is composed of andesitic detridal and tuffaceous material. In these western exposures, the member is generally referred to as the Lebo andesitic member of the Fort Union formation. The presence of this andesitic or volcanic material in the Lebo is still evident as far east as Forsyth, Montana, but in its eastern exposures, the member consists principally of dark clays and shales and is appropriately called the Lebo shale member within these eastern areas. Some of the beds, especially those composed of sandstone, are fairly resistant and tend to form rimrocks; but the member as a whole is soft and suffers rapid erosion. In some areas, the Lebo is characterized by beds that carry brown "ironstone" concretions in great abundance. They are composed essentially of iron carbonate but upon weathering are converted into brown iron oxide. These nodules, which range in size from one-quarter inch up to one foot in diameter, when released by the weathering of the enclosing shale, slump down and give the surface a "coffee grain" appearance.

In some areas, the Lebo member is strikingly different from the strata above and below and it is easily distinguished from these sediments. It is a mapable
unit, and is commonly shown on geologic maps. In other areas, however, the Lebo grades upwards into a transition zone of sandy shale and is separated only with difficulty from the overlying Tongue River member. In western North Dakota this transitional phase may be designated as the Ludlow lignite member.

The beds of the Tongue River member consist largely of impure arkosic sandstone. In places, they are interbedded with gray to black shale and with numerous thick coal seams. Generally, the sandstones are loosely cemented with clay, so that the beds weather readily. Occasionally, however, the sandstones are so firmly cemented that massive layers may resist erosion and form ridges and escarpments.

Porosity in the sandstone differs with the amount of cementation and with the purity of the sand. In some very impure sands, porosity may be less than eight per cent, whereas in some pure sandstones it may reach thirty per cent. An average porosity would probably be between fifteen and twenty per cent. As stated before, a few thin beds of limestone also occur in this member.

Near Buffalo, Wyoming, the Kingsbury Conglomerate is considered as a member of the Fort Union formation. The conglomerate is composed of water-rounded gravel and boulders derived from older sedimentary rocks of the adjacent mountains and includes some granite derived
from the core of the range. The conglomeratic strata are generally thick and massive and are interbedded with finer-grained uniformly-bedded layers of sandstone and shale, greenish gray in color. This member is considered as a delta or alluvial fan deposit and is found only within a very limited area.

Above the Tongue River member in western North Dakota, there is a bed of dark hued sandy shale and clayey sandstone which upon weathering forms an adobe soil. This member is named the Sentinel Butte shale member and is limited mainly to western North Dakota, though a few isolated occurrences have been reported in Montana.

General Stratigraphy of the Area

The Fort Union formation covers a vast area east of the Rocky Mountains, stretching from Wyoming to the Arctic Ocean and the valley of the McKenzie River and including several Canadian provinces, much of western North Dakota, eastern and central Montana, northwestern South Dakota and northern Wyoming. Naturally, in such a large area of terrestrial sediments one would expect to find an infinite variety of topographical expressions. A brief resume of the Fort Union area in Montana follows.

The Fort Union region in eastern Montana and western North Dakota is a broad plain of nearly horizontal rocks, characterized by an extensive "bad land" topography a-
long the larger streams. A very conspicuous feature of the region is the red hills, benches, ridges and buttes that have been heated by burning coal beds. This heat has been intense enough to burn the overlying clays to a red or salmon pink color, and in many places to completely fuse them to slaglike masses. The beds of clinkers formed by the burning coal may attain a thickness of forty feet in some areas and can often be traced for long distances.

Discussion of Isopach Map

The isopach map of the Fort Union formation shows generally a progressive thinning of strata toward the east. This condition might well be expected, as the Fort Union sediments were, in all probability, derived from the Rocky Mountains on the west and deposited on a piedmont plain by eastward flowing rivers.

However, a more careful inspection of the isopach map reveals several outstanding features. First, there are two centers of major uplift which tend to disrupt and complicate this general pattern of thinning towards the east. The Sweet Grass arch in north central Montana, and the Black Hills uplift in South Dakota are two positive areas where no Fort Union strata are found. It is possible, or even probable, that the Fort Union formation was once continuous over these areas and now has been re-
moved by erosion. If this were the case, it would place the age of these two uplifts as post Paleocene.

However, at present definite data are lacking which would confirm or deny this hypotheses, and until further geological evidence regarding the age of these uplifts is brought to light, it may be presumed that the Fort Union formation was never deposited in these areas.

Such is not the case, however, in Wyoming where the isopach map has been constructed to show deposition of Fort Union sediments across the area of the Big Horn and Pryor Mountains. Of course, today this formation has been completely removed by erosion in this area, but there is good reason to believe that it was once quite thick.

As evidence, the fact that Fort Union strata bend upward at angles of twenty and thirty degrees on the flanks of these mountains would show that this formation was involved in the folding, and is therefore older than the uplift. Second, the isopach map reveals a thickness distribution pattern that otherwise is extremely difficult to account for with an easterly drainage from the mountains to the west.

The distribution of these sediments is logically explained by postulating a drainage pattern northeast into Hudson Bay during Fort Union time. That this has been the case, is supported by the present drainage pat-
tern of the Tongue, Little Big Horn, Powder, Little Missouri, Big Horn and Yellowstone Rivers, all flowing in a northeasterly direction. (See Plate 2). Of course, with the coming of Pleistocene glaciation, the northern courses of these and other rivers were altered to the present pattern.

The deep canyons formed by the Little Big Horn, Big Horn and Tongue Rivers in the Big Horn and Pryor mountain ranges of Montana, and the Owl Creek Mountains of Wyoming give evidence that these are all antecedent streams, and therefore the drainage pattern that existed during Fort Union time in this region was essentially the same as now, but had its outlet to the northeast.

Economic Geology

Coal

About ninety per cent of the total amount of lignite and coal found in Montana occurs in the Fort Union formation, and practically everywhere in eastern Montana and western North Dakota this formation contain beds of good lignite. The lignite grades from the ordinary brown and black, easily slacking varieties to the darker, heavier subbituminous varieties of coal. The beds range in thickness from an inch and less to forty feet or more, and beds eight and ten feet thick are common. Most of the seams are nearly horizontal, and in numerous places are not deeply buried, and are suitable for
stripping methods of mining. The coal beds are present from top to bottom of the formation, and are not confined to any particular horizon or horizons. Montana has a reserve of 340,000,000,000 short tons of lignite and subbituminous coal in the Fort Union formation.

**Clay**

Over a large area in southwestern North Dakota, the Fort Union formation contains beds of white, very pure plastic clays suitable for manufacture of ceramic products. These clay beds lie about 600 feet above the base of the Fort Union and attain a maximum thickness of 150 feet. Elsewhere good clay deposits are rarely found in the Fort Union formation.

**Water**

Wells penetrating sandstone and coal beds of the Fort Union formation, if not located too near the outcrop, nearly always yield water. The quality is variable, and the mineral content often reaches prohibitive values, especially in water coming from the Lebo member. Water found in the coal seams is usually relatively pure, however. Since, in most localities the Fort Union formation constitutes the upper few hundred feet of the sedimentary series, few flowing wells are found in the formation.

The Tongue River member with its large number of sandstone beds constitutes a good reservoir for water. The sandstone water is usually mineralized however,
but few wells yield poor water. Shallow wells, seldom exceeding 300 feet in depth, usually obtain adequate supplies for domestic use.

The Lebo member is a poor source of water. Though some springs occur, much of the water is highly mineralized, especially with iron, and is therefore unfit for domestic purposes.

**Oil and Gas**

The Fort Union formation is not known to be a reservoir for commercial amounts of either gas or oil. The formation is of interest to the oil and gas industry only in that it is at the surface throughout most of eastern Montana and western North Dakota, and test wells penetrating to deeper and more favorable horizons must pass through the Fort Union formation.

**Summary**

Overlying the Lance formation of uppermost Cretaceous age is the Fort Union formation of Paleocene age. Since this formation is the youngest of the sedimentary series common throughout the area studied, it occurs almost entirely in great structural basins, and only where uplift has taken place, or where rivers have cut deep valleys, has it been removed by erosion. The formation, which is composed almost entirely of continental clastic deposits, has resulted from the deposition of sediments
on a coastal plain by northeastward flowing rivers. It covers a vast area stretching from central Wyoming on the south to Alaska on the north, and from central Montana on the west to Opheim, North Dakota on the east. Attention is called to the probable decrease in thickness in a northeastward direction, as shown by the modified isopach map, and also to the postulated drainage during Fort Union time northeastward toward Hudson Bay.

The Fort Union formation everywhere contains numerous beds of lignite or subbituminous coal, and has 90 per cent of Montana's 380,000,000,000 tons of coal within its formational boundaries. Besides carrying the principal lignite beds of the region, the formation also contains scattered beds of shale and clay suitable for the manufacture of brick and other clay products. No oil or gas has been found in the Fort Union formation, and the possibility that some will be found in it in the future is slight.
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