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Missouri River Basin
Geologic Mapping and Mineral Resource Investigations
Missouri-Souris Unit
Areal Geology

Preliminary Report on the Geology of the Zahl No. 4 Quadrangle North Dakota

By

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1947

48-7

Boardman - Int. 3491

U.S. Geological Survey
Events (Open file report)

DEPARTMENT OF THE INTERIOR

INFORMATION SERVICE

GEOLOGICAL SURVEY

For release SEPTEMBER 30, 1948.

REPORT AND MAP ISSUED ON GEOLOGY OF ZAHL NO. 4 QUADRANGLE, NORTH DAKOTA

W. E. Wrather, Director of the U. S. Geological Survey, announced today that a preliminary report on the Zahl No. 4 quadrangle in North Dakota has been put in open file for public inspection.

This report and accompanying preliminary geologic map are the result of surveys made in the summer of 1946 by Garland Gott as a part of the Interior Department program for development of the Missouri Basin.

Nearly the entire quadrangle is mantled by glacial deposits of Pleistocene age. Rocks of Tertiary age containing lignitic coal are exposed in a few places and elsewhere underlie the glacial deposits at relatively shallow depths. Economic deposits of lignite, sand and gravel, and riprap are briefly described in the report.

The report may be examined at Geological Survey offices 1033 (Library) and G-228 Federal Works Agency Building, Washington, D. C.; at Building 12-B, Denver Federal Center, Denver, Colo.; and at the office of the State Geologist, University of North Dakota, Grand Forks, N. Dak.

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INTRODUCTION

The geology of the Zahl No. 4 quadrangle was surveyed in the summer of 1946, in connection with the Missouri-Souris Unit of the Missouri Basin Development Program. The quadrangle includes part of southern Divide County as well as a portion of southern Williams County. Both counties are in northwestern North Dakota.

GENERAL GEOLOGY

The larger part of this quadrangle is covered by terminal moraine and outwash sand and gravel of the late Wisconsin stage of Pleistocene glaciation. The southern and southwestern part, however, is covered by the smooth, gently sloping ground-moraine surface referred to in earlier reports as early Wisconsin ground moraine (1, Pl, 1). The Tongue River member of the Fort Union formation (Paleocene) is composed of soft clays, silty shales, and slightly consolidated sand, and is so well mantled with glacial deposits that it crops out only for a short distance along Pat's Coulee. For this reason, the surface is almost entirely of glacial deposits. Deposits of outwash sand and gravel floor the wide valley of Little Muddy Creek, and are extensive in the northcentral part, and in the northwestern corner of the quadrangle. Numerous ice-contact fluvioglacial deposits are distributed throughout the quadrangle. All integrated drainage flows into the Little Muddy Creek which in turn flows into the Missouri River twenty-five miles to the south.

The natural vegetation is the "long grass" prairie type. The principal cultivated crops are wheat and other small cereals. The climate is semi-arid with precipitation averaging about fifteen inches per year. As a result of the small amount of rainfall little or no leaching is in process at present. Throughout this quadrangle the till contains a thin zone of white caliche which is generally just below the grass roots. It represents calcium carbonate dissolved, mainly, from the limestone and dolomite within the till, brought toward the surface by ascending ground water through capillary action, and precipitated by evaporation of the water and removal of the moisture by the plant roots. This calcium-enriched zone is often as much as three or four feet thick. In many places, flat-lying pebbles have accumulated a calcium carbonate coating as much as one-eighth inch thick on their undersides.

TERTIARY ROCKS

Fort Union formation (Tongue River member)

The Tongue River member is the only bedrock which crops out within this quadrangle. Although the ground moraine is thin over the southern and southwestern part, there are very few good exposures of Tongue River. This is because the slightly consolidated beds of clays, shales, and sand are so soft that they stand up no better in exposures than the till. The best exposure of Tongue River within the quadrangle is along Pat's Coulee within the immediate vicinity of the Norveson lignite mine. Here, in sec. 9, T. 158 N., R. 101 W., the following section was measured:

Thickness	Depth	Top of exposure
Feet	Feet	Description
6	6	Till, buff, calcareous; contains limestone, dolomite and granite pebbles.
6	12	Sandstone, cross-bedded, fine-grained, angular; contains calcareous concretions and heavy iron-stained streaks.
3.2	15.2	Shale, gray, somewhat sandy at top; weathers gray-white.
.6	15.8	Lignite; contains clay streaks at top and bottom.
2.4	18.2	Shale-clay, dark gray; contains thin limonite-stained streaks.
4.6	22.8	Shale-clay, dark gray, very thin lignite streaks.
6.0	28.8	Clay-shale, medium gray, plastic; slacks into small blocks.
6.0	34.8	Lignite
		Bottom of exposure

This is probably a closely representative section since the proportions of clay, shale, and sand are similar in other places.

Distinctive features of the Tongue River member in this general area, but absent in this quadrangle, are the clinker or "scoria" beds. These are baked, or fused shale, clay, or sand beds overlying burned lignite. It is believed that in most cases ignition of the lignite was caused by spontaneous combustion. Heat generated by the burning of the lignite caused rapid baking of the overlying beds resulting in the alteration of the inherent iron content to produce a series of conspicuous colors ranging from a light gray or cream through different shades of pink, to red and purple.

The lower part of the clinker bed, where the heat was most intense, often contains masses of completely fused clinker with total obliteration of all former bedding planes. Under the clinker bed there is usually a white or gray powdery ash ranging in thickness from a few inches to one or two feet. This variation results from the fact that the ash bed is residue from the original lignite bed which had a comparable variation.

PLEISTOCENE DEPOSITS

Morainal deposits

Pre-Altamont ground moraine.- A smooth, gently sloping surface of the ground moraine extends across the southern and southwestern part of this quadrangle, between the early Wisconsin morainal belt of Alden (1, Pl. I) and the "Altamont" moraine. This glacial cover, although thin, completely mantles the bedrock, except for those locations where the well-integrated drainage has exposed the underlying Tongue River member.

The till has a moderate degree of compaction and is composed of a calcareous, blue-gray to buff, sandy clay containing pebbles, cobbles, boulders, and locally, lenses of stratified sand and gravel. Well cuttings from depths several feet below the surface are blue-gray in color while the color of weathered exposures is tan, buff, or brownish.

"Altamont" moraine.- The name Altamont terminal moraine, was applied by Chamberlain (2, pp. 378-393) to what he believed to be the outermost moraine of the last glaciation, now known as late Wisconsin, in the vicinity of Altamont, South Dakota, as well as to the outermost moraine of the Dakota lobe. Leonard, Alden, and others adopted this terminology. More recently, Leverett (6, p. 67) has expressed doubt as to whether the moraine in North Dakota is equivalent to the Altamont moraine at its type locality. However, for convenience in nomenclature, usage of the term "Altamont" is continued in this report.

The "Altamont" moraine extends north from its type locality near Altamont, South Dakota, to southcentral North Dakota and then in a northwesterly direction to the northwest corner of the state where it crosses the international boundary and continues into Canada.

In northwestern North Dakota it comprises a broad belt, fifteen to twenty miles wide, consisting of irregular hills and hollows which give rise to a knob and kettle type of topography having no integrated drainage. The depressions vary in size and shape from small, circular or irregular pits a few feet in diameter and one to two feet deep, to large elongated lakelike depressions as much as fifty feet deep. The large size of the depressions and of the knobs imparts a coarse-grained texture to the morainal area, but locally the depressions are smaller and more closely spaced, with the resulting local effect of a much finer-grained texture.

The "Altamont" moraine is made up of unstratified and unsorted, tan, buff, or blue-gray sandy clay with pebbles, cobbles, boulders and, locally, lenses of stratified sand and gravel. The pebbles are similar to those found in the ground moraine and include limestone, dolomite, granite, basic igneous and crystalline metamorphic rocks. Lithologically, the sand and gravel contain the same rock types as the till. In some places there is a high concentration of boulders on the surface of the moraine.

In the SW 1/4 sec. 30, T. 159 N., R. 100 W., the till is 42 feet thick where exposed in Little Muddy Valley. Drillers' reports, however, indicate that the till under the "Altamont" moraine may be as much as 150 to 200 feet thick.

Within this quadrangle the topographic expression between the "Altamont" moraine and that of the ground moraine is gradational. This causes considerable difficulty in mapping the exact boundary of the "Altamont". The boundary as drawn here is a few miles farther south than that mapped by Alden (1, Pl. I).

The present boundary was mapped on the basis of the following evidence:

(1) The kettles in secs. 32 and 33, T. 159 N., R. 100 W. are at a lower elevation than the "Altamont" outwash plain just to the north, implying the former presence of a block of ice (in the kettle-filled area) which prevented the outwash from covering this portion of the moraine.

(2) There are numerous kettles within the outwash train along the lower reaches of Little Muddy Creek in the southern quarter of the quadrangle, indicating that ice also covered that part of the valley.

(3) In secs. 29, 30, 31, and 32, T. 159 N., R. 99 W., Little Muddy Creek is deeply entrenched, whereas upstream from this portion of its course it has a more mature valley. The same condition is also true at the point where the "Altamont" boundary crosses the small stream in sec. 12, T. 159 N., R. 101 W. The trenching of these two streams over only restricted segments of their courses is interpreted to mean that the "Altamont" ice covered the portions that are now entrenched. Following the withdrawal of the ice it was necessary for the streams to cut through the ice-deposited filling in order to attain gradients comparable to the unaffected portions of the streams.

In view of these facts, the "Altamont" boundary has been drawn to include within the "Altamont" moraine the area between the Little Muddy Valley and the abandoned east-west coulee in the southeastern section of the quadrangle.

Fluvio-glacial deposits

Zahl Outwash Plain.- The Zahl Outwash Plain is a broad, irregular, outwash train lying in the bottom of a wide topographic sag. It extends from the northcentral part of the quadrangle south to the Little Muddy Valley, at which point it coalesces with the outwash train which occupies Alamo Valley. The two then extend as one down Little Muddy Valley toward the Missouri River twenty-five miles to the south. The surface of the outwash is gently undulating and slopes toward the south at about ten feet per mile. In many places it is densely pitted with kettles which range from a few feet to several hundred feet along their long axes and vary in shape from circular to irregular, with variations in depth from a few feet to fifty feet. In some places the outwash is higher than the adjoining till. Numerous terrace scarps and abandoned glacial stream channels are present within the outwash.

The outwash consists of stratified, cross-bedded, and interbedded sand and gravel with the average gravel size being about one inch in diameter. The gravel contains limestone, dolomite, granite, gneiss, quartz, chert, and all the igneous and crystalline metamorphic rocks found in the till. Lignite slack is sometimes present. The predominant mineral in the sand is quartz.

The outwash was evidently deposited immediately in front of the "Altamont" ice. That the "Altamont" ice was present during outwash deposition is indicated because the outwash surface is in places higher than the adjacent till and contains numerous kettles.

The Stady Channel.- This is another outwash train filling a low, gentle sag which crosses the extreme northwest corner of this quadrangle and extends toward the west for at least twenty miles. It has a gently undulating surface with some kettles of moderate depth and size. Along the north edge of the channel in NE 1/4 sec. 32, T. 161 N., R. 101 W., the ice-contact face is well preserved. This, together with the kettles, indicates that "Altamont" ice was still present during deposition of the outwash. The outwash consists of stratified sand and gravel, is similar in character and composition to the Zahl Outwash Plain and was undoubtedly deposited in much the same manner.

Eskers.- There are several short eskers in this quadrangle, ranging in length from one-fourth of a mile to three miles, and in height from only a few feet to sixty-five feet. In many places they are discontinuous for short distances with till burying portions of some.

The longest esker in the quadrangle extends from sec. 2, T. 160 N., R. 100 W., to the SE 1/4 sec. 8, T. 159 N., R. 100 W., a total distance of about three miles. A complete cross-section is exposed in the road-cut at about the N. 1/16 corner between secs. 3 and 4, T. 159 N., R. 100 W. In this exposure, crudely stratified sand and coarse gravel dip away from the center, roughly conforming to the surface slope. A wedge-shaped mass of till, as much as four feet thick with the thin edge pointing toward the crest, covers the north side of the esker. In other places, till completely buries it. The southwest end of the esker disappears under the outwash.

In secs. 8 and 17, T. 160 N., R. 100 W., is a short, braided, and sinuous esker composed predominantly of coarse gravel. A fan has been built up from the esker terminal and extends over the whole of the SE 1/4 of sec. 18 and part of the N 1/2 of sec. 19. Finer sand extends on westward into secs. 13 and 24 in the next township and probably represents the farthest limits of the fan. Along the western border the sand tapers to a feather edge.

An esker in sec. 31, T. 160 N., R. 99 W., which is about 1 1/2 miles in length, has an apron of outwash sand and gravel attached to the northwest side. The esker ridge was probably formed first, and as the enclosing ice receded, outwash material from the subglacial stream was deposited on its lower side. In places, the esker ridge is covered with till and boulders.

A short esker between half a mile and one mile in length is in secs. 13, 23, and 24, T. 160 N., R. 100 W. Although short, it has as much as sixty-five feet of relief on an already high base. A spur, which may be part of the esker running north into sec. 12, has a maximum relief of eighty feet. The southern part, in sec. 23, is covered with till but an exposure in the east side shows a till-gravel contact with the till wedging out towards the top.

Crevasse-fillings.- Half a mile northeast of Zahl, in secs. 24 and 25, T. 159 N., R. 101 W., is a long narrow sand- and gravel-filled ridge with a large, linear depression through about one-half of its length. It stands thirty-five to forty feet above the water level of Lake Zahl on its east side and several feet above the general level of the outwash plain. It is thought that this represents a crevasse-filling or deposition around and between blocks of ice. Later, the outwash was deposited around the crevasse-filling.

In T. 160 N., R. 99 W., is a series of esker-like ridges of obscure origin. They are made up of fluvio-glacial material with a high boulder concentration on the surfaces. These ridges are arranged in echelon and the longest of them is not more than a few hundred yards in length. They have tentatively been considered as crevasse-fillings or as deposits of streams flowing on the ice.

Ice-contact deposits.- The term, ice-contact deposit, is intended to refer to those fluvio-glacial deposits that were deposited in direct contact with the ice and to which a more specific name has not been applied.

A group of irregular gravel hills, the highest of which is about eighty feet above the water level of Lake Zahl lies in secs. 19 and 30, T. 159 N., R. 100 W. The general ground surface has a rough, pitted texture due to numerous gravel knobs. Some of the larger hills have a noticeable northeast trend. No exposures are present in the area, and consequently no evidence of slumping was observed. Numerous shallow test holes showed the entire area to be composed of sand and gravel. The higher hills, and, in general, the whole mass are several feet higher than the level of the outwash plain. The indications are that the sand and gravel were deposited either as alluvial cones along the margin of the ice front or as a filling between ice blocks. In either case, these deposits must have been formed before the deposition of the outwash. Later, when the outwash was deposited, it did not attain a thickness equivalent to the height of the older deposits.

In the NE 1/4 - NW 1/4 sec. 10, T. 160 N., R. 99 W., is a well-rounded knob twenty feet high and 150 feet in diameter. A gravel pit in the top is eight by forty feet. The material is composed approximately of 10 percent gravel, 10 percent boulders, and 80 percent sand. The bedding dips away from the center of the deposit and conforms to the surface slope.

Kame terrace.- A gravel deposit with a steep slope on the side bordered by outwash and with a very gentle slope or flat surface on the west side bordered by till is located in secs. 21 and 28, T. 160 N., R. 100 W. The length of the deposit is about 1 1/2 miles with a relief of thirty to forty feet on the steeper side. There are no good exposures and consequently all evidence of possible slumping is concealed. However, the characteristics and expression of the deposit as a whole are that of a kame terrace.

RECENT ALLUVIUM

The alluvial deposits consist largely of clays and silts in the floodplains of Little Muddy, Pat's Coulee, Scorio Valley, and along the margins of many of the kettle lakes. Along the Little Muddy floodplain in secs. 32, 33, 34, 35 and 36 sand and gravel are most abundant.

GLACIAL HISTORY AND GEOMORPHOLOGY

It is difficult, if not impossible, to reconstruct the glacial history of the area until the stratigraphy of the various tills has been worked out in adjacent areas or until petrographic criteria have been found for distinguishing them. The earlier investigators believed that one or more glacial advances covered the area prior to the last invasion by the late Wisconsin ice. The distinction between them was made largely on topographic evidence. Alden (1, Pl. I) believed that the limit of the "Iowan or Illinoian" stage, extended along an east-west line thirty-five to forty miles south of the Missouri River. He placed the limit of the early Wisconsin ice along an east-west line six to eight miles south of this quadrangle. Leonard (5, p. 532) earlier believed that the area between the "Altamont" moraine and the present Missouri River was covered by pre-"Altamont" Wisconsin drift.

Direct evidence of Kansan or Nebraskan drift is lacking but the conclusion of many geologists that the northeastward-flowing preglacial Missouri River was diverted to the east and south by an ice sheet earlier than the one which formed the present drift border would indicate that one or both had been present.

If, as has been suggested (1, Pl. 1), the preglacial Yellowstone River flowed north along the present course of the Little Muddy Creek, which now flows south, an early ice sheet probably diverted it to the east, perhaps carving Alamo Valley which crosses the adjoining Kermit No. 3 quadrangle. Likewise the diversion of the preglacial Missouri River may have been responsible for the original carving of the present Scorio Valley which crosses the divide between the Little Muddy on the east and the Big Muddy on the west. The course of the preglacial Yellowstone under the "Altamont" moraine can only be conjectured but it probably occupied the broad sag which is now partially filled with outwash, and continued northeast through a partly filled sag within the moraine in secs. 25, 26, and 27, T. 160 N., R. 100 W. and secs. 17, 18, and 19, T. 160 N., R. 99 W.

In addition to these large filled valleys there are several narrow, short, till-filled channels. These channels contain kettles and in places are closed at both ends. It is believed that most of them were formed as ice marginal channels in front of the advancing "Altamont" ice.

The last advance of the ice into this area produced the "Altamont" moraine, the outwash deposits, eskers, kame terraces, and most of the ice-contact deposits within the quadrangle.

ECONOMIC GEOLOGY

Lignite

The lignite-bearing rocks of this area belong to the Tongue River member of the Fort Union formation which is the only pre-Pleistocene formation exposed. The lignite contains impurities such as pyrite, gypsum, clay seams, and silicified plant-remains. Beds of lignite are distributed throughout the formation but crop out only along Pat's Coulee in the southwestern part of the quadrangle. At the Norveson Mine, in sec. 9, T. 158 N., R. 101 W., where the lignite is about eight feet thick there has been intermittent mining over a number of years. There are several strip pits here that are abandoned for most of the year. The lignite is about eight feet thick.

Test drilling may prove mining to be feasible in other areas lightly mantled by glacial drift.

Sand and gravel deposits

There are very large supplies of sand and gravel in the large outwash plain near Zahl, the Stady Channel, and in the numerous crevasse-fillings, eskers, and ice-contact deposits. The outwash material is made up chiefly of limestone, dolomite, granite, basic igneous and crystalline metamorphic rocks, with a small amount of agatized wood and some of the varieties of chert. All this material is suitable for road metal. In recent years, it has been found that concrete structures deteriorate rapidly where normal high alkali Portland cement is used with aggregates containing opal, chalcedony, tridymite, intermediate to acid glassy volcanic rocks and some phyllites (7, p. 1216). Since the fluvio-glacial deposits contain some of these possibly deleterious materials they should not be used in large structures with high alkali cement without investigation of their properties. The gravel in the deposits has been used for concrete aggregate with high alkali cement on small scale construction work.

Riprap

There is no bedrock within this area sufficiently hard to be useful for riprap. There is, however, a supply of glacial boulders, which, in the absence of a more suitable material, might be adapted to this type of construction material. These boulders have in many places been cleared from the land and in almost every square mile are numerous piles ranging from one to fifty tons in size.

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