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GENERAL GEOLOGY AND ENGINEERING GEOLOGY OF RIVAL NO. 1 QUADRANGLE, NORTH DAKOTA

By R. C. Townsend

Introduction

Rival No. 1 quadrangle is an area of approximately 200 square miles adjacent to the Dominion of Canada in northwestern North Dakota. The center of the area is 65 miles east of the border of Montana. Two small railroad towns are in the quadrangle; Lignite, near the center, is noted for its excellent water supply, and Portal, near the northeast corner, is a Port of Entry. The east-west State Highway No. 5 bisects the quadrangle.

Bedrock is exposed in small outcrops in coulees in the southern part of the quadrangle but elsewhere it is mantled with glacial deposits. The nature of these surficial deposits, together with prevailing climatic conditions, have largely determined the cultural development of the area. For this reason, emphasis in this report is on the classification and description of surficial deposits.

The geologic map is the basis of the report. The map explanation includes descriptions of the material that makes up the various deposits as well as the distinctive topographic and lithologic characteristics. The deposits are further described in tabular form below so that specific information may be easily found. Data on depth relations at certain points are given in the map explanation.

Most of the subsurface data in this report are inferred from drill hole logs and water well information provided by the North Dakota Geological Survey, the U. S. Bureau of Reclamation, and the Ground Water Branch of the U. S. Geological Survey.

Physiography

Rival No. 1 quadrangle is in the glaciated Missouri plateau section of the great plains physiographic province. Two topographic features dominate the region; the first is a vast ground moraine plain which includes the northeasterly two-thirds of the quadrangle. In this area the surface of the plain is generally at an altitude of 1,900-2,000 feet above sea level and dips gently to the northeast. The plain is abruptly terminated on the southwest by the escarpment of the second major topographic feature, the Coteau du Missouri. The Coteau du Missouri, which covers the southwest one-third of the quadrangle, is 10-25 miles wide and extends many miles northwest and southeast. The moraine on the Coteau consists of a disorderly arrangement of rugged but smoothly-rounded hills and undrained depressions at an altitude in this area of 2,300-2,500 feet above sea level. Near the escarpment, the plain is inclined upward toward the Coteau to an altitude of 2,100-2,200 feet. The hills of the Coteau are conspicuous, giving the appearance of a mountain range when viewed from a distance.

The mantle of glacial debris throughout the quadrangle is so new that drainage is only poorly developed. Surface runoff in the moraine on the Coteau collects in undrained depressions. In a few places on the ground moraine plain water flows intermittently in shallow valleys cut in Pleistocene time, but nowhere is the drainage integrated enough to warrant the naming of a stream.

The rigorous northern continental climate is characterized by a wide temperature range, limited precipitation, low humidity, and strong winds. Droughts are common, and the dry winds prevailing from the northwest often cause blizzards and dust storms. Average frost penetration is approximately four feet and reaches a maximum of six and one-half feet.

Geologic History

The Fort Union formation is the oldest formation exposed in Rival No. 1 quadrangle. Alternating layers of clay, marl, silt, and fine sand were deposited in the Paleocene epoch in swamps, lagoons, and shallow lakes. The position and size of the shallow bodies of water gradually shifted and changed during accumulation of the sediments, which caused the resulting layers to be uneven in thickness and discontinuous in extent. Lush vegetation grew in some of the swamps and lagoons and in places this organic matter was buried by the accumulating sediments. Chemical action and the compaction of the beds turned the organic matter to lignite and also changed some of the clays and silts to shale and the fine sand to sandstone. Near the end of the Paleocene epoch, 500-1,000 feet of sediments had been deposited in this area and deposition of the bedrock Fort Union formation stopped.

Between the end of the Paleocene and the beginning of the Pleistocene epoch or ice age, two geologic processes affected the Fort Union formation. One, the beds were folded and faulted at least locally in the southern part of the quadrangle and perhaps over a much wider area. Two, the beds were eroded by streams which dissected the formation to a badlands-type of topography not unlike the present North Dakota badlands near the Little Missouri River.

Erosion continued until the Pleistocene epoch when glaciers moved southward over the area. The effect of continental glaciation on the topography was to modify the surface by filling valleys with rock debris moved by the ice and by rounding hills by plucking and abrasion. This area was blanketed with ice at least once. When the glacier flowed from areas in Canada, it picked up rock material of all sizes and transported it to the south where it remained after the ice melted. The ice also dammed rivers and sediments were deposited in the valleys.

The present ground surface in Rival No. 1 quadrangle was formed in Late Wisconsin time during the advance and recession of the last ice sheet. The erosion surface of the bedrock is higher in altitude under the moraine on the Coteau du Missouri than under the ground moraine plain to the northeast and this bedrock high was a barrier to extensive southward advance of the ice. Thus, the margin of the glacier remained longest in the vicinity of the Coteau and the relative height of the Coteau is due both to thick deposits of moraine and the bedrock high. The eskers in the southern part of the quadrangle were formed when ice covered most of the area. They are the deposits of streams in or under the ice. The ground moraine on the plain consists of material deposited under the ice during the advance of the glacier and of material that settled or was washed from the ice during the melting.

When the margin of the glacier began to retreat northward, several other features were formed on the surface of the ground moraine plain. Meltwater flowing between the ice front and the high Coteau eroded valleys and collected in shallow basins. These are called meltwater channels and in places they contain glacial outwash and stream deposits. The ever-changing front of the ice caused these valleys to be abandoned and the streams to be captured and as the volume of water decreased, sand bars were built. Violent streams flowing from the ice or in cracks in the ice washed coarse rock material into mounds, hills, and irregular masses called kames. Some of the kames are intimately mixed with ground moraine. Finally the glacier completely disappeared, leaving a surface without integrated drainage. This event was so recent that new streams can only follow the old meltwater channels and have barely dissected the surface.

Structure

The Fort Union formation or bedrock was deposited in horizontal layers, but in the southern part of the quadrangle the strata are tilted, folded, and broken (faulted) and displaced along the breaks. Bedrock is exposed only in meltwater channels in a zone parallel to and about 2 miles from the escarpment of the Coteau du Missouri where the mantle of glacial material is thin. The channels were cut through the ground moraine and into the bedrock which has been further exposed by the sapping action of present springs. The deformation is present in many of the exposures in this zone and east of Sec. 26, T. 162 N., R. 93 W. Close folds and high angle thrust faults are common. The closure of some of the folds may be as great as 200 feet.

The trend of the axes of the folds and faults is approximately N. 74° W., which is parallel to the escarpment of the Coteau. Well data and the elevations of the outcrops indicate that the bedrock is higher under the Coteau than under the ground moraine plain. Although the strata north of the zone of outcrops are probably nearly horizontal, it may be inferred that the beds in the southwestern one-third of the area are generally tilted upwards toward the crest of the Coteau and are part of a large monocline. The exposed folds and faults are, then, part of a wrinkled zone on the northeast margin of the monocline.

Ground Water Resources

by G. A. LaRocque, Jr.

Usable quantities of ground water may be developed from lignites and sandstones of the Fort Union formation, from sand and gravel lenses in the moraine on the Coteau and ground moraine, from kames and eskers, and from glacial channel deposits of sand and gravel.

The sandstones and lignites of the Fort Union formation generally yield moderate quantities of soft, highly mineralized water. Wells producing from these beds have been drilled from 12 feet to 300 feet in depth and generally furnish larger supplies than wells producing from glacial drift. Even though the deeper water is more highly mineralized than is that from shallow wells, it is commonly softer and preferable for laundry and other purposes except cooking. It contains up to 800 parts per million of sodium and up to 1,700 parts per million of bicarbonate.

In both the moraine on the Coteau and the ground moraine, water may generally be produced from extensive lenses of fine sand. Evidence indicates that the ground moraine contains three widespread, permeable, water-bearing zones. The permeability and altitude of these aquifers may vary markedly from place to place. Wells in these aquifers will generally yield 5 to 10 gallons per minute of water that is commonly hard but which contains only moderate amounts of dissolved solids. The most productive of these aquifers is the sand or sandy clay generally found above the contact between the glacial drift and the underlying Fort Union fomation. During rainy seasons, many springs issue from sand lenses along the high bluffs of the terminal moraine near the south border of the quadrangle, but few are perennial.

Kames and eskers can generally furnish small supplies of ground water of low mineral content. Where these are interconnected with channel deposits, they may yield considerable quantities.

In the northeast corner of the quadrangle, the water table is quite shallow being found at depths of 4 to 20 feet. The water is hard and that in the town of Portal is liable to be contaminated. West of Lignite, the water table is about 38 feet below the surface where ground water in considerable quantities is found in the glacial channel deposits. The most palatable water found in the quadrangle is obtained in large quantities from a deposit of coarse gravel at Lignite. Here the water table is 50 feet below the surface. The deposit is beneath glacial till except where it is exposed in the gravel pits northeast of the town.

DESCRIPTION OF MAP UNITS

(See explanation on facing page for description of materials)

MAP UNIT	DISTRIBUTION AND THICKNESS	TERRAIN AND NATURAL SLOPES	DRAINAGE AND PERMEABILITY	WORKABILITY AND COMPACTION	STABILITY	POSSIBLE USE	ORIGIN OF DEPOSIT
GLACIAL CHANNEL	Form complex network over ground moraine plain. Channels trend generally in two directions, northwest and northeast. Wide, shallow channels common just south of center of quadrangle. Sand, silt, and gravel known to be at least 15 feet thick in most channels, but deposits less than 6 feet thick common in narrow channels. Marly clay present in some wide, shallow channels.	Valleys generally sinuous in pattern and have flat floors. Wide, shallow basinlike areas very flat with inconspicuous and indefinite boundaries. Valleys trending away from moraine on the Coteau are V-shaped with steep slopes and landslides and soil creep are common.	Materials deposited in channels generally permeable but poorly drained because surrounding ground moraine is impervious; permeability low in clays. Undrained sloughs and marshy areas common; subject to flooding. Water in primary channels moves slowly by seepage and discontinuous intermittent streams. Narrow northerly trending channels in southern part of area fairly well drained.	Easily worked with hand tools above water table; depth to water table 3-7 feet. Foundations below water table may require unwatering. Quicksand reported in shallow farm wells. Moisture control necessary for compaction.	Relatively stable when dry. Stability depends on sand and gravel content. Frost heave moderate to high in silty material; slight in sand and gravel.	Sand and gravel deposits may be present locally. Shallow water wells productive except in dry cycles. Roads in channels subject to flooding.	Valleys cut by 1) meltwater from glacier or isolated ice blocks, 2) water from heavy snows and rains during and immediately after glacial period. Northwest trending channels cut along ice margin during melting of glacier. Material in valleys carried off glacial ice or from glacial deposits.
KAME	Widely scattered over ground moraine plain but particularly abundant in two areas; one, northwest trending zone near center of quadrangle, and, ~~two, zone~~ two miles north of Lignite. Indistinct and very small deposits not mapped. Thickness includes topographic height and in most kames material extends to unknown depth below ground level of surrounding deposits.	Knobs, low mounds, and irregularly-shaped hills which generally have a definite topographic outline. Slopes very gentle to fairly steep. Large kames have gently undulating surface, with undrained depressions.	Drainage generally fair to excellent except in large kames where undrained depressions have impervious clay floors. Drainage may be poor in deposits composed largely of silt and clay. Sand and gravel highly permeable. Clay lenses locally make perched water tables. Water table may be encountered at level of surface of surrounding deposits.	Easily excavated with light machinery but boulders may be abundant enough to require special handling. Gravel may be removed by drag line or power shovel. Special equipment necessary to compact silt or silty sand.	Low to high strength depending on material. Road cuts in kames generally stable at 1 on 1. Frost heaving: none in coarse material; slight to high in sand and silt.	Source of sand and gravel for concrete aggregate, pervious fill, and highway material. Material for aggregate requires washing. Overburden can be removed by tractor. Kames north of Lignite have high silt content. (See analyses of samples from kames below.)	Material washed from glacial ice and deposited in holes and cracks in glacier or in reentrants in margin of ice.
ESKER	One esker mostly in Sec. 13, T. 162 N., R. 93 W. and Sec. 19, T. 162 N., R. 92 W.; another in Secs. 22 and 27, T. 162 N., R. 92 W. Deposits are narrow and sinuous and are superposed on ground moraine. Thickness; 10 to 25 feet.	Narrow ridges with rolling, uneven tops and moderate to steep sides characteristic; few undrained depressions.	Drainage very good except where impervious till closely underlies surface. Material generally very permeable.	Same as kame except clay and silt not abundant.	Same as kame.	Same as kame except overburden slight.	Deposited by a glacial stream flowing in or under glacial ice.
GROUND MORAINE	Most widespread deposit in quadrangle and probably underlies all glacial features except moraine on the Coteau du Missouri. Thickness: maximum probably 100 feet, and generally less than 50 feet; commonly trace to 20 feet.	Surface flat to gently rolling and contains numerous undrained depressions and glacial kettles. Surface rolling to hilly in two parts of area; one, northern one-half of northwest quarter of quadrangle, and, two, the region including Lignite and the area 1-2 miles south and southeast of Lignite. Surface inclined downward slightly from moraine on the Coteau du Missouri.	Surface drainage poor; marshy areas and undrained depressions common. Permeability and subsurface drainage low to negligible because of high clay content. Water movement largely by capillary action. Vertical drainage and permeability locally fair where till cover very thin over Fort Union formation, and where covered with mantle of silt. Hilly areas in northern one-half of NW quarter of quadrangle and near Lignite well drained where material consists of sand and gravel.	Hard, compact, tough; plastic when wet and breaks into blocky fragments when dry. Difficult digging with hand tools, but easily worked with power tools. Local "hardpan" or caliche zone from 6 inches to 3 feet thick. Scattered large boulders may require special handling. Sheepsfoot and rubber-tired rollers make good compaction. Subject to wind erosion where not compacted and sod cover absent. Sand and gravel in hilly areas same as kames.	High stability in road cuts but may gully. When compacted properly, has high strength. Good foundation material; settling negligible. Tends to break into blocky masses when dry; plastic and sticky when wet. Frost heave: medium. Hilly areas same as kames.	Good impervious fill if compacted. Unsurfaced roads: stable when dry, very difficult trafficability when wet. Subgrade: good if drainage controlled. Scattered boulders and cobbles are possible source of riprap, pervious fill, and crushed rock.	Glacial debris deposited under the glacier.
MORAINE ON COTEAU DU MISSOURI	Covers southwestern corner of quadrangle. Thickness: generally less than 100 feet, but locally may be 150 feet or more. Differs from ground moraine in 1) rougher terrain, 2) abundant boulders, 3) origin (see origin of deposit).	Terrain rough; abundant knobs, irregular ridges, kettles and other undrained depressions. Slopes steep to moderate.	Generally same as ground moraine except kettles and other undrained depressions deeper. Minor surface drainage 1-2 miles south of contact with ground moraine; all drainage in northerly direction.	Same as ground moraine except boulders more abundant both on surface and buried in till.	Same as ground moraine.	Same as ground moraine except roads may require cut and fill because of rough terrain.	Glacial debris deposited in front of, at margin of, or under glacier.
FORT UNION FORMATION	Underlies surficial (glacial) deposits in entire quadrangle. Exposed in valley sides of glacial channels in two mile wide zone trending northwest through southern one-third of area. Data on thickness meager but formation is at least 500 feet thick and may be as much as 1,000 feet thick.	Exposures generally have steep slopes along valleys of glacial channels.	Drainage fair in silt and fine sandstone; clays impervious. Seepage springs present at base of outcrops. Many lignite beds and fine sandstone are water-bearing.	Difficult excavation with hand tools but easily worked with power tools except for scattered large masses of hard limy siltstone. Where excavation intersects lignite, unwatering may be necessary. Moisture control necessary to compact clays and silty clays, but silts and clays compact fairly well with roller equipment.	Subject to landsliding near exposures in southern one-third of area; moisture control necessary for stabilization. Partially cemented silts weather easily due to leaching of lime cement. Frost heave: bad in silts.	Clays may be good fill if moisture controlled. Lignite and sandy layers are sources of water. Lignite is strip mined in areas where overburden is generally less than 50 feet. Sandy layers too fine and variable for most uses. Poor road metal because silts and clays unstable when wet. Subgrade poor because of probable frost heave.	Lake, lagoon, and swamp deposits.

TABLES OF ANALYSES OF FOUR SAND AND GRAVEL SAMPLES

Location and description of material – per cent:

Map Number	Township	Range (W)	Section	¼ Section	¼ of ¼ Section	Accessibility	Geologic formation	Overburden (feet)	Limestone	Granite	Shale	Sandstone	Gneiss	Schist	Quartzite	Basalt	Rhyolite	Basic igneous (coarse-grained)	Porphyry	Caliche and iron oxide cement	Ironstone concretions	Chert	Coal fragments
S-1	163	92	26	NW	NE	Fair	Kame	½-1	39	15	17	3	3	5	4	3	1	2		1	5	1	1
S-2	162	92	12	NE	NE	Good	?	1-4	53	19	1		7	3	3	2		7	1		4		
S-3	162	93	11	NW	SW	Good	Kame	1-3	49	16	4	3	9	6	3	3		3			4		
S-4	162	93	13	NW	NE	Difficult	Kame	1-3	46	18	16		6	5		1	1	2	1		3	1	

Laboratory tests[1] – Mechanical Analysis (Per cent passing various sieves), Sieve Sizes or Numbers (U. S. Standard Series); Specific gravity; Unit weight lb./cu. ft.:

Map Number	2½"	2"	1½"	1"	3/4"	3/8"	#4	#6	#10	#30	#40	#60	#100	#200	Liquid limit	Plastic limit	Plasticity index	L. A. abrasion % loss, Grading A	Specific gravity: Bulk	Specific gravity: Apparent	Absorption %	Unit weight: Dry loose	Unit weight: Dry rodded
S-1	100	97	94	89	86	78	69	64	56	27	18	10	8	6	19	15	4	29.9	2.84	2.89	1	105.2	113.8
S-2		89	81	74	62	56	42	29	23	15	4	3	2	2	1	22	NP	NP	24.4	2.70	2.73	1	120.0	126.1
S-3	100	100	100	100	99	94	87	85	81	54	40	26	21	16	23	15	8	*	2.58	2.66	2	98.2	105.8
S-4	100	100	100	98	94	78	61	54	43	23	19	14	11	9	23	16	7	24.8‡	2.66	2.74	2	110.5	120.0

[1] Laboratory testing by Richard Van Horn; tests made in Public Roads Administration Laboratories, Denver, Colorado.

* Insufficient material to make test.

‡ Los Angeles abrasion % loss, grading B.