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by

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GEOLOGY ALONG THE PORTAL PIPELINE, LAKE AGASSIZ PLAIN[1]

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INTRODUCTION

The Portal pipeline was completed between Lignite, North Dakota, and Clearbrook, Minnesota, during the summer and fall of 1962. The entrenching of this pipeline offered a unique opportunity to observe continuous exposures across the Glacial Lake Agassiz Plain. These observations were made by geologists of the North Dakota Geological Survey. The purpose of this paper is to report these observations and to compare some of them with previous reports.

The close of the last major glaciation (Wisconsinan) is marked in this area by the deposits of the Glacial Lake Agassiz. No definite age has been determined for the beginning or final drainage of the lake, but some deposits underlying Lake Agassiz sediments at Moorhead, Minnesota, have been dated at 9,930 $\pm$ 280 (13) and 11,238 $\pm$ 700 (7) years before the present. The lake was formed as the ice receded from the Red River Valley and the meltwaters were dammed by the ice front lying to the north and east. During this period drainage developed to the south through the Glacial River Warren. The lake was gradually lowered and the successively lower levels are

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marked by the Herman, Norcross, Tintah and Campbell beaches. The most prominent of these is the Campbell beach which is thought to have been formed when the River Warren had cut down to bedrock, thus slowing considerably the rate of lowering of the lake. Elson (1) referred to this period of southward drainage as the Lake Agassiz I stage.

Upham (9) included the McCauleyville beaches in the southward drainage stage of the lake. He thought that the ice then gradually receded and a lower outlet to the north and east was opened. The successively lower levels of this stage are marked by the Blanchard, Hillsboro, Emerado, Ojata and Gladstone beaches.

Elson believed that following the Lake Agassiz I stage the lake was completely drained by the northeastward drainage. Then a readvance of ice, interpreted by him to be the Valders advance, again blocked the northeast drainage and his Lake Agassiz II stage be-

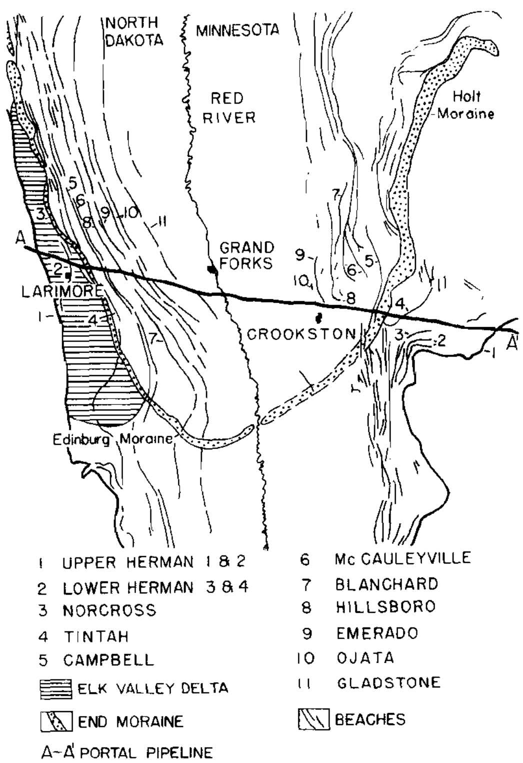

FIGURE 1—Index map showing route of Portal Pipeline across the Glacial Lake Agassiz Plain. North Dakota geology after Lemke and Colton (4). Minnesota geology after Leverett, (6).

gan (1). At this time the basin was again filled, temporarily as high as the Tintah or Norcross stand; but as the overflow cut through alluvial deposits near Browns Valley, the lake level rapidly subsided to the second Campbell strandline. During this interval the drainage was again to the south, but as the ice receded the lower outlets to the north and east were again opened and the lower beaches were formed at this time. Finally drainage was to the north through what is now Lake Winnipeg and the Nelson River.

The area of investigation lies almost wholly within the Lake Agassiz Plain district, Western Lake section of the Central Lowland province (2). A subdivision of this, the Elk Valley Delta subdistrict, was crossed by the pipeline trench in western Grand Forks County. The lowest elevation of the trench was where it crossed the Red River at an elevation of about 790 feet and the highest elevations were at about 1220 feet on the North Dakota side and about 1180 feet on the Minnesota side of the River.

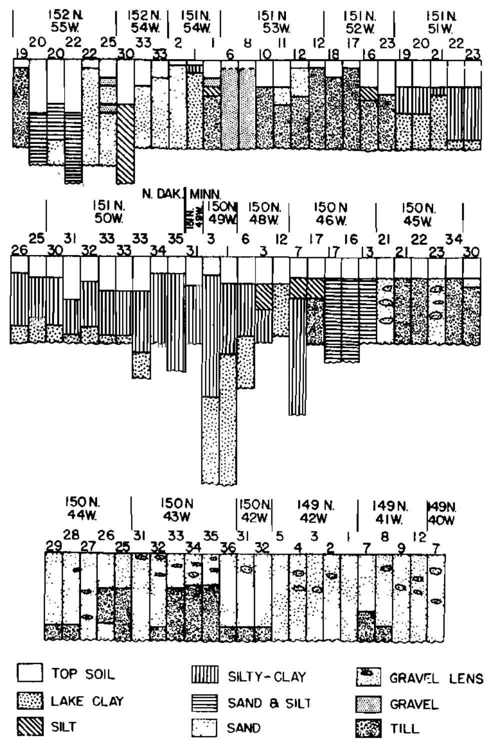

FIGURE 2—Columnar sections at selected points along Portal Pipeline trench.

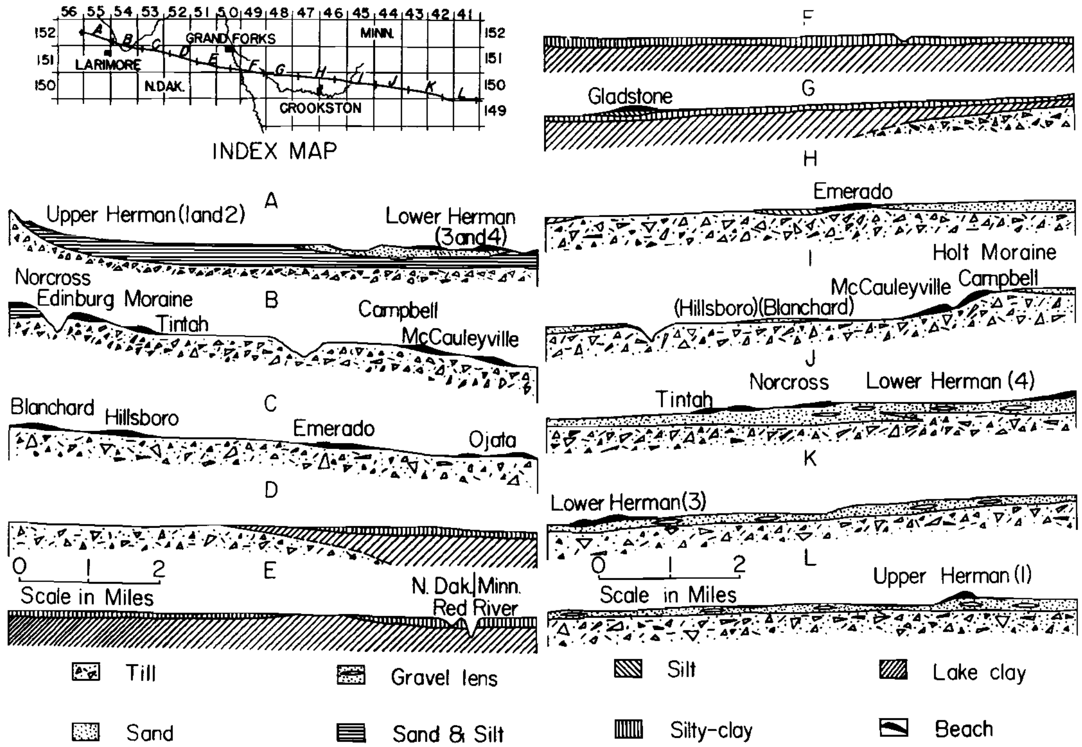

FIGURE 3—Schematic cross section of Lake Agassiz Basin as observed along the Portal Pipeline trench.

The trench was generally excavated to a depth of five feet except where it passed under drainageways. In these areas the trench was generally excavated to about eight feet and in some cases as much as 15 feet. Where it crossed major drainages, such as the Red River, the trench was excavated to depths about 35 feet blow the general surface. However, many of the deeper excavations were obscured by water in the trench. The detailed lithology at selected points along the trench is shown in the columnar sections (fig. 2).

TABLE I

LOCATION AND ELEVATION OF GLACIAL LAKE AGGASSIZ BEACHES

	NORTH DAKOTA		MINNESOTA	
Beach	Location	Elevation (feet)	Location	Elevation (feet)
Gladstone[1]	———	———	SESESec Sec. 4	840
Ojata, lower[2]	NE Sec. 22 T151N, R52W	870	———	———
Ojata, upper[2]	SW Sec. 16 T151N, R52W	880	———	———
Emerado	NENE Sec. 18 T151N, R52W	900	SWNE Sec. 17 T150N, R46W	900
Hillsboro[2]	SWNE Sec. 10 T151N, R53W	930	———	———
Blanchard[2]	NENW Sec. 9 T151N, R53W	948	———	———
McCauleyville	SESE Sec. 6 T151N, R53W	980-990	SWNW Sec. 23 T150N, R45W	990-995
Campbell, lower[1]	SWSE Sec. 6 T151N, R53W	1000-1010	SENW Sec. 23 T150N, R45W	1000
Campbell, upper	———	———	SWNE Sec. 23 T150N, R45W	1012-1015
Tintah	SENE Sec. 33 T152N, R54W	1060	SWNE Sec. 28 T150N, R44W	1055
Norcross, lower	NENE Sec. 32 T152N, R54W	1080-1090	NESW Sec. 27 T150N, R44W	1090
Norcross, upper	NENW Sec. 32 T152N, R54W	1100-1110	NWSE Sec. 27 T150N, R44W	1100
Lower Herman 4	SESW Sec. 30 T152N, R54W	1120	SWNE Sec. 31 T150N, R43W	1135
Lower Herman 3	SESW Sec. 25 T152N, R55W	1130	NESE Sec. 32 T150N, R43W	1145
Upper Herman 2[2]	SENE Sec. 19 T152N, R55W	1150	———	———
Upper Herman 1	SE NW Sec. 19 T152N, R55W	1160	SENW Sec. 9 T149N, R41W	1170

1. These beaches not seen in North Dakota.
2. These beaches not seen in Minnesota.

The field procedure was to drive or walk along the trench. Lithologic changes were noted, samples were collected, and an effort was made to locate plant or animal remains which might be used to date the sediments. A relatively abundant molluscan fauna was found at one locality, but the rest of the samples were barren.

The elevation of the beaches (Table I) were determined by plotting the beaches on topographic sheets. Elevations in North Dakota are from the United States Geological Survey 15 minute topographic maps for Emerado and Larimore Quadrangles. For the Minnesota area elevations are from the Army Map Service 1/250,000 series, Grand Forks, North Dakota; Minnesota Sheet (NL-14-3). These elevations are generally in close agreement with those of previous surveys, but a few of them are slightly different.

Thickness of top soil was measured along the pipeline in North Dakota to the nearest one quarter foot. The thickness of top soil in the clay and delta deposits was fairly consistent but in the till it was variable. Top soil in the silty-clay of the lake basin averaged about 1.5 feet, while the top soil of the delta averaged 2.8 feet. Till which lies at an elevation between the clay and delta has an average thickness of 0.7 feet. The variation in thickness is probably accounted for, mainly, by the different lithologies; although the time of exposure to weathering may be a minor factor.

GENERAL LITHOLOGY

The predominant lithology seen in a cross-section (fig. 3) of the lake basin is the till which underlies the lake sediments throughout the area of investigation. The till is generally a clayey till on the North Dakota side, but is generally somewhat silty to sandy on the Minnesota side of the River.

Lake clays and silts are confined to the central part of the basin and form a relatively thin veneer overlying the till. The clays and silts are yellowish-brown, contain common iron-staining and are generally calcareous. At two localities, where the trench crossed drainageways, the lowermost clays contained some white, calcareous nodules and thin, white, very calcareous seams.

The beach deposits generally consist of sand or sand and gravel. The individual sand and gravel units are generally lenticular in shape, and the coarsest material is concentrated near the crest of the ridges.

An area of silt and sand overlies the till in the area west of the Edinburg-Holt moraine in North Dakota. These deposits have been referred to as the Elk Valley delta. An area of silt and sand overlies the till in the area east of the Edinburg-Holt moraine in Minnesota, also. This unit is relatively thin, often only 2 to 3 feet thick along the line of the trench, and may be an area of outwash. The outwash may be associated with the Edinburg-Holt moraine, or it may be associated with the Erskine moraine which lies just to the south of that area.

BEACHES

The youngest beach observed along the trench was the Gladstone beach which was noted as a slight rise in the Minnesota segment of the trench. No beach deposits were present, so this is probably what Upham referred to as a wave cut beach (11). There was no indication of this beach in the North Dakota segment.

The Ojata beach was not observed in the Minnesota segment, but it was observed as two distinct wave cut beaches with no sand deposits in the North Dakota segment.

The Emerado beach is a rather inconspicuous ridge composed of silt and sand on the Minnesota side of the basin. In North Dakota this beach is a very prominent ridge about 500 feet wide, rising about 10 feet above the surrounding area; and it is composed of sand and gravel. About 250 feet in front of the main ridge the beach deposits feathered out above the underlying till.

The Hillsboro beach was not present in the Minnesota segment but is represented by a distinct ridge composed of sand and gravel in the North Dakota segment of the trench. Likewise, the Blanchard beach was not present as a distinct topographic feature in the Minnesota segment. However, an area of sand overlying the till a few miles west of the McCauleyville beach may marke this lake level. In North Dakota, the Blanchard beach is a prominent ridge composed of sand and gravel.

In Minnesota, the McCauleyville beach is a conspicuous ridge composed of sand and gravel which lies about a quarter of a mile west of the upper Campbell beach. Both the lower and upper Campbell beaches are prominent ridges composed of sand and gravel. The lower areas between the beach ridges are composed of sand and are now swampy areas. Similarly, in North Dakota, the McCauleyville and Campbell beaches are within a quarter of a mile of each other and are marked by distinct ridges composed of sand and gravel; but only one Campbell beach was noted along the trench.

The Tintah beach is a prominent ridge composed of sand and gravel in the Minnesota segment. Two smaller ridges, composed of sand and gravel (perhaps offshore bars?), lie to the west of the main beach ridge. The lower areas between the ridges are composed of sand and are swampy areas. In North Dakota, the Tintah beach is composed of sand; and the beach deposits overlie the till.

The Norcross beach is about a mile east of the Tintah beach in Minnesota. The lower beach is marked by a slight rise composed of sand and the upper beach is a prominent ridge composed of gravel and sand. In North Dakota, the Norcross beaches were crossed where they border the Turtle River. Both beaches are composed of sand; and, as in Minnesota, the upper beach is the most prominent. The upper beach lies on Elk Valley delta deposits and the lower beach lies on the margin of the delta deposits.

The Herman beaches are low, gentle rises composed mainly of sand but with minor gravel deposits overlying sand in the Minnesota segment. Similarly, in North Dakota the lower Herman beaches are composed of sand with some gravel overlying silt and sand.

The upper Herman beaches are composed of sand and gravel overlying sand in Minnesota, whereas in North Dakota the upper

Herman beaches are noted as distinct topographic rises; but there are no beach deposits of sand and gravel.

EDINBURG — HOLT MORAINE

A moraine, first recognized by Upham (12), extending from Edinburg, North Dakota, to near Hillsboro, North Dakota, has been named the Edinburg moraine by Lemke and Colton (4). Similarily, a moraine which is clearly traceable from Lake of the Woods County to southern Polk County in Minnesota has been named the Holt moraine by Leverett (5). It is now thought that these moraine were formed by the same glacial advance and are called the Edinburg-Holt moraine (4). The Edinburg-Holt moraine is a well defined moraine on its northern end and decreases in prominence to the south. Leverett (5) thought parts of it were deposited in ponded waters especially near its southern end which could account in part for the decrease in prominence.

The Edinburg-Holt moraine is difficult to recognize where crossed by the pipeline in North Dakota and Minnesota. In North Dakota the pipeline crosses the moraine in the area of the Norcross and Tintah beaches. The moraine is indicated by a rise in slope, an abundance of boulders, and some local relief; this relief is generally less than five feet. In Minnesota, the pipeline crosses the moraine in the area of the Campbell beach. Here the features of the moraine are similar to those in North Dakota, except that it appears as a continuous linear element when seen from a few miles west.

DELTA AND OUTWASH DEPOSITS

Upham (10) applied the term "Elk Valley delta" to the silt and sand deposits which lie between the Edinburg-Holt moraine and the escarpment which forms the western shoreline of the lake. Since that time there has been some discussion as to whether these deposits are actually lake deposits or proglacial deposits which have been reworked by the lake during the Herman to Norcross interval of Lake Agassiz.

The silt and sand are generally well sorted deposits. A few gravel lenses were noted. The thickness of these deposits is not known, but they have been estimated to be about 30 feet thick in this area (3). The trench did not penetrate the complete thickness of these deposits at any locality.

Deposits of silt and sand extend from the Edinburg-Holt moraine to the Upper Herman beaches in Minnesota, also. These deposits are generally well sorted, but they are coarser, contain more gravel lenses, and are generally thinner than the deposits of the Elk Valley delta. Again, a question arises as to whether these are lake deposits or proglacial deposits which have been reworked by the lake. A molluscan fauna, which indicates permanent water, has been collected from these silt and sand deposits from the area about a mile east of the Norcross beaches. A study of this fauna was made by Tuthill (8).

SUMMARY

The lithologic observations along the trench generally confirm those made by previous investigators. However, the silt and sand deposits of Minnesota and of the Elk Valley delta suggest the following sequence of events. The silt and sand deposits of the Elk Valley delta, whether they be deltaic deposits or proglacial deposits, are clearly associated genetically to the deposition of the Edinburg-Holt moraine. Similarly, the distribution of the silt and sand deposits overlying the till in Minnesota suggests that these deposits are associated genetically with the Edinburg-Holt moraine although they might also be associated with the Erskine moraine which borders the lake basin on the east and south. If these deposits were laid down in the lake, then they must represent early Lake Agassiz I deposits; because the Herman to Norcross beaches in North Dakota and the Herman to Campbell beaches in Minnesota lie on these silt and sand deposits. The Campbell beach crosses the Edinburg-Holt moraine near where the trench crosses the moraine in Minnesota. This beach, as well as the Tintah, Blanchard, and Hillsboro beaches, crosses the moraine in the area south of the pipeline trench on the North Dakota side of the basin; this further dates the moraine deposits as either pre-Lake Agassiz I or contemporaneous with the pre-Tintah lake level. Precise dating must await radiocarbon dates from the lake and moraine deposits.

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