North Dakota Geological Survey

Wilson M. Laird, State Geologist

Miscellaneous Series #39

GEOLOGY OF NORTHEASTERN NORTH DAKOTA

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Editors

Guidebook and short summaries prepared for the annual meetings of the North Central Section, National Association of Geology Teachers, Grand Forks, North Dakota, April 25-26, 1969.

PREFACE

This guidebook was prepared for the field trip associated with the meetings of the North Central Section, National Association of Geology Teachers, held at the University of North Dakota April 25-26, 1969. The guide book was written so that some of the individual stop descriptions could be used for one-stop field trips. The value of one-stop field trips has long been recognized by the NAGT members at the University of North Dakota and some have already been prepared for selected areas. On the basis of a list of Earth Science teachers in North Dakota who wish to take their students on these one-stop field trips, students and faculty of the Department of Geology are reviewing the geology of each teacher's area and writing a short guide to that area with specific reference to a particular exposure or landform. It is hoped that NAGT members will be convinced of the value of such guide and that they will prepare them for selected areas within their own state.

This particular field trip includes some of the most interesting geology in the Red River Valley area. The sites are located primarily in Grand Forks and Walsh Counties (Fig. 1), but are also related to the physiography of Nelson County and the rest of the state. For a more precise location, a road map of the three counties (Fig. 2), and a more detailed map of the field trip route (Fig. 3) are also included.

We wish to express our appreciation to all the students and faculty in the Department of Geology who assisted in the preparation of this guidebook. The names of special contributors appear after the section for which they assumed responsibility. The manuscript was read by Drs. Cvancara, Holland, Clayton, and Laird and suggestions from each were gratefully included. The Department of Geology and the North Dakota Geological Survey are pleased to present the guidebook, and we extend an invitation to visit us at the University of North Dakota.

D.T.P. AND J.R.R.

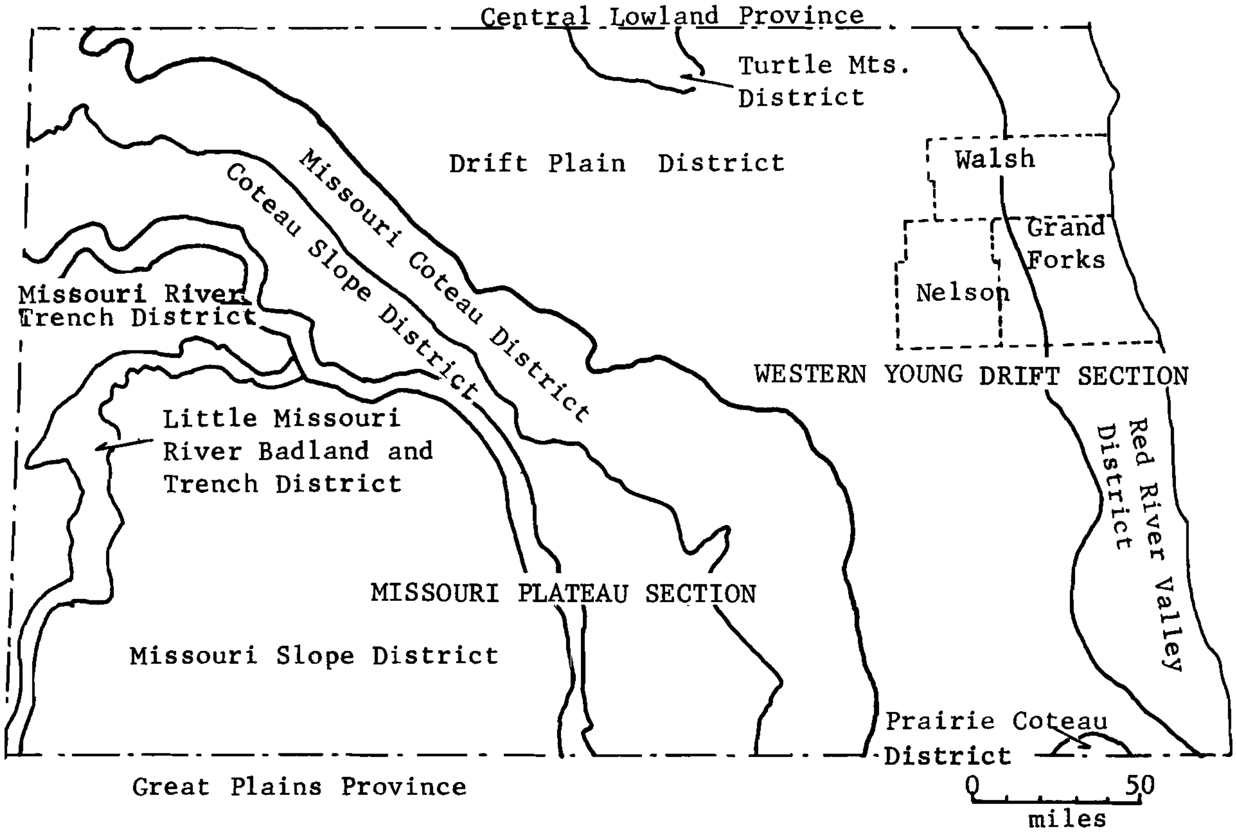

Figure 1. Location of Grand Forks, Walsh, Nelson counties and the several physiographic subdivisions of North Dakota.

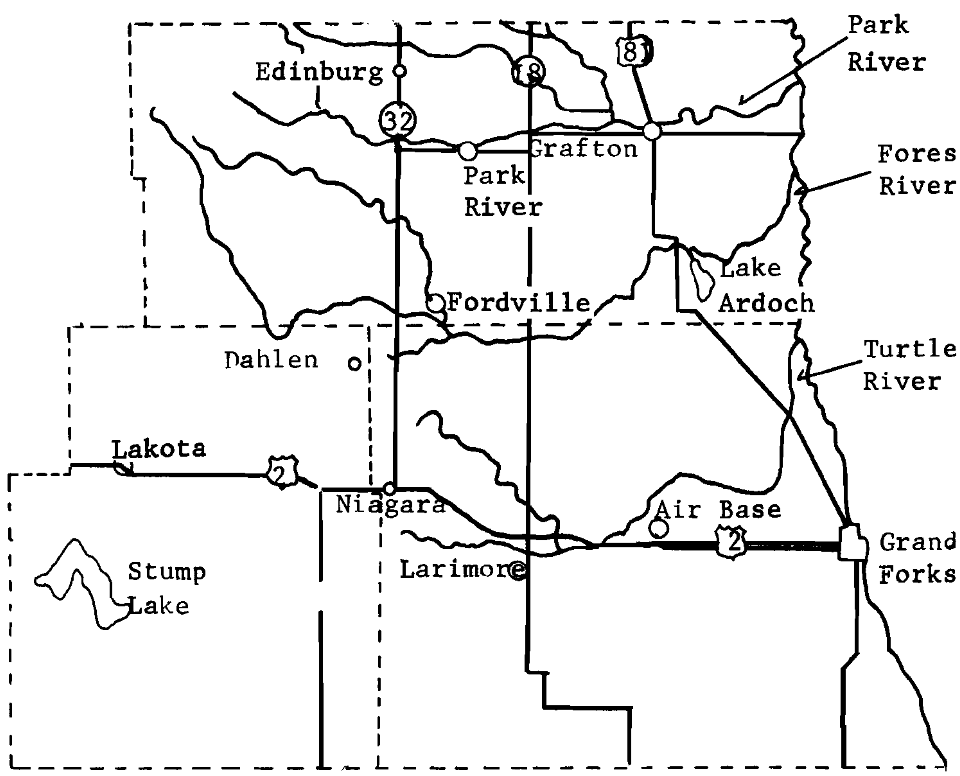

Figure 2. General road map of Nelson, Walsh and Grand Forks counties.

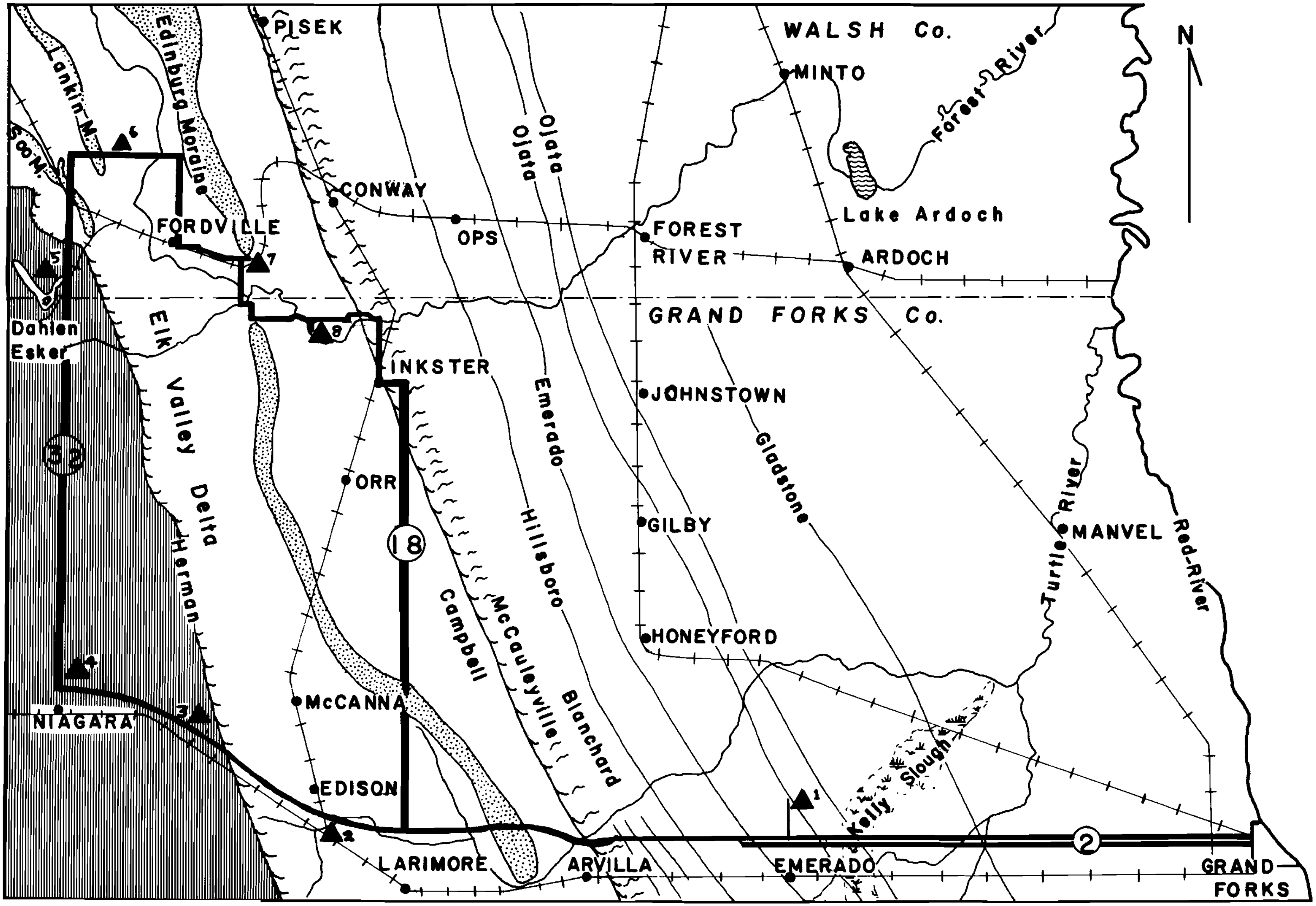

FIGURE 3. Fieldtrip Route.

▲ NUMBER & STOP

DRIFT PLAINS

MORAINES

LAKE PLAIN with strandlines

0 5 10 MILES

GENERAL SETTING

Glacial Lake Agassiz

Grand Forks is located on the floor of former glacial Lake Agassiz. The extent of the lake is shown in Figure 4. For the first part of the field trip we will be driving on the lake bottom and crossing the various beaches formed at the numerous margins of the lake.

During the Ice Age huge continental glaciers advanced out of Canada into the northern areas of the United States. These glaciers covered all except the southwestern corner of North Dakota. In the Red River basin, the regional slope was (and still is) to the north and as the glacier terminus retreated and uncovered the Red River Valley, it acted as a huge dam for the Red River and its tributaries. Glacial Lake Agassiz, which resulted, was larger than all the Great Lakes combined (Fig. 4).

The highest level of the lake was reached about 12,500 years ago and is marked by the Herman beach (Fig. 5). At this time the water in what is now Grand Forks was approximately 340 feet deep and the direction of drainage was southward via Lake Traverse and Big Stone Lake into the Minnesota River. The outlet continued to be eroded until a lag concentrate of boulders stabilized the channel (Wright and Ruhe, 1965; Laird, 1964). The Sheyenne, Elk Valley and Pembina deltas were formed at this time by rivers discharging into the lake (Elson, 1967). The Edinburg moraine was deposited along the margin of the ice lobe about the same time (Elson, 1967) (see p. 9).

The retreat of the terminus eventually opened lower drainage channels to the east and the lake level fell in response. The removal of the weight of the ice mass allowed the earth's surface, which had been depressed beneath the ice, to rebound. The thicker ice to the north caused greater rebound there; this is suggested by the tilted and bifurcated strandlines in the northern part of the basin. The bifurcated strandlines resulted when refilling of the lake to previous outlet levels produced relatively lower beaches in the north (because of intervening rebound) but reinforced the same beaches in the south (no rebound).

Readvance of the ice subsequent to about 12,000 years ago blocked the eastern outlets and the lake rose again to the Norcross level in the

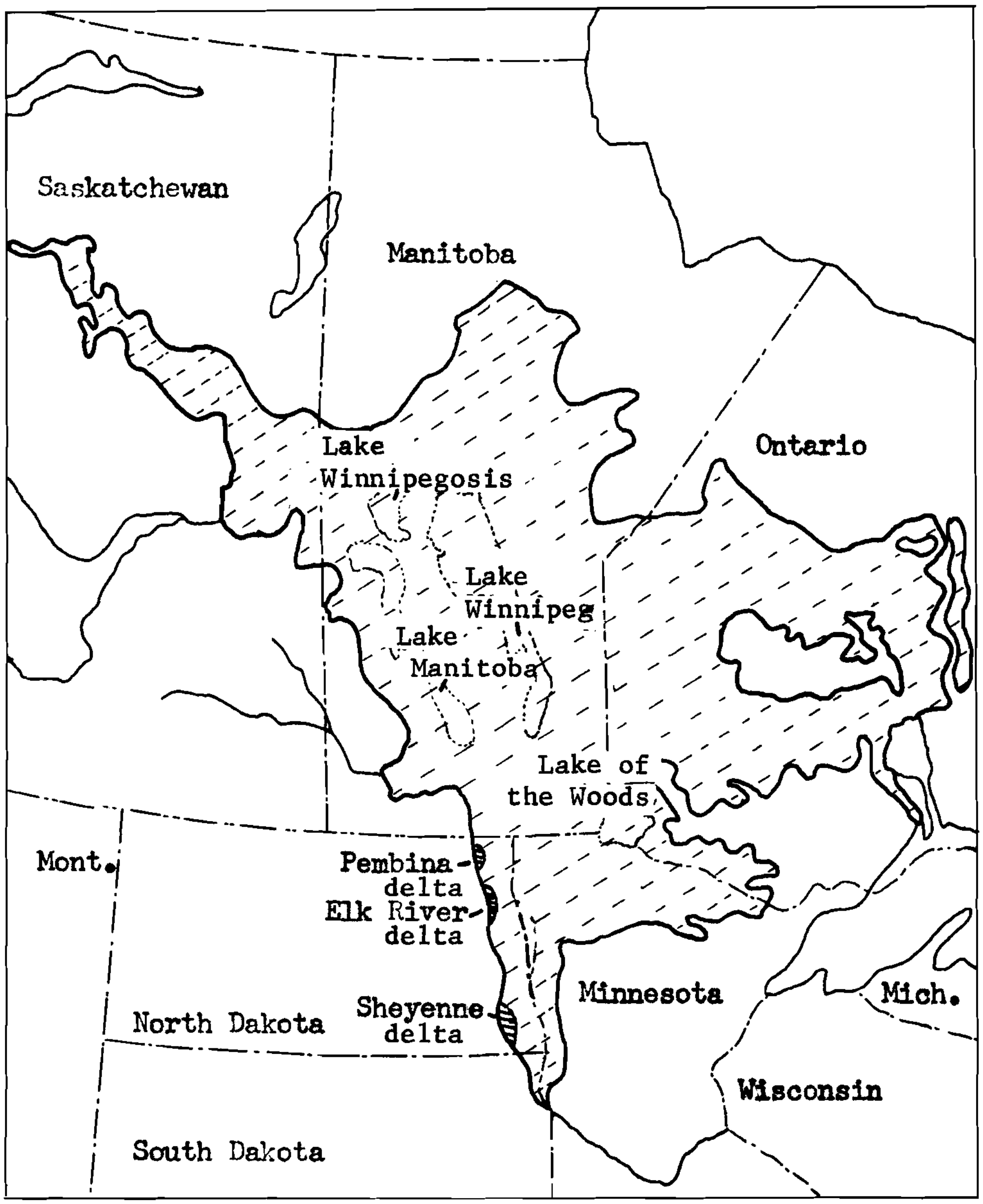

Fig. 4. Generalized map showing greatest extent of glacial Lake Agassiz and location of deltas

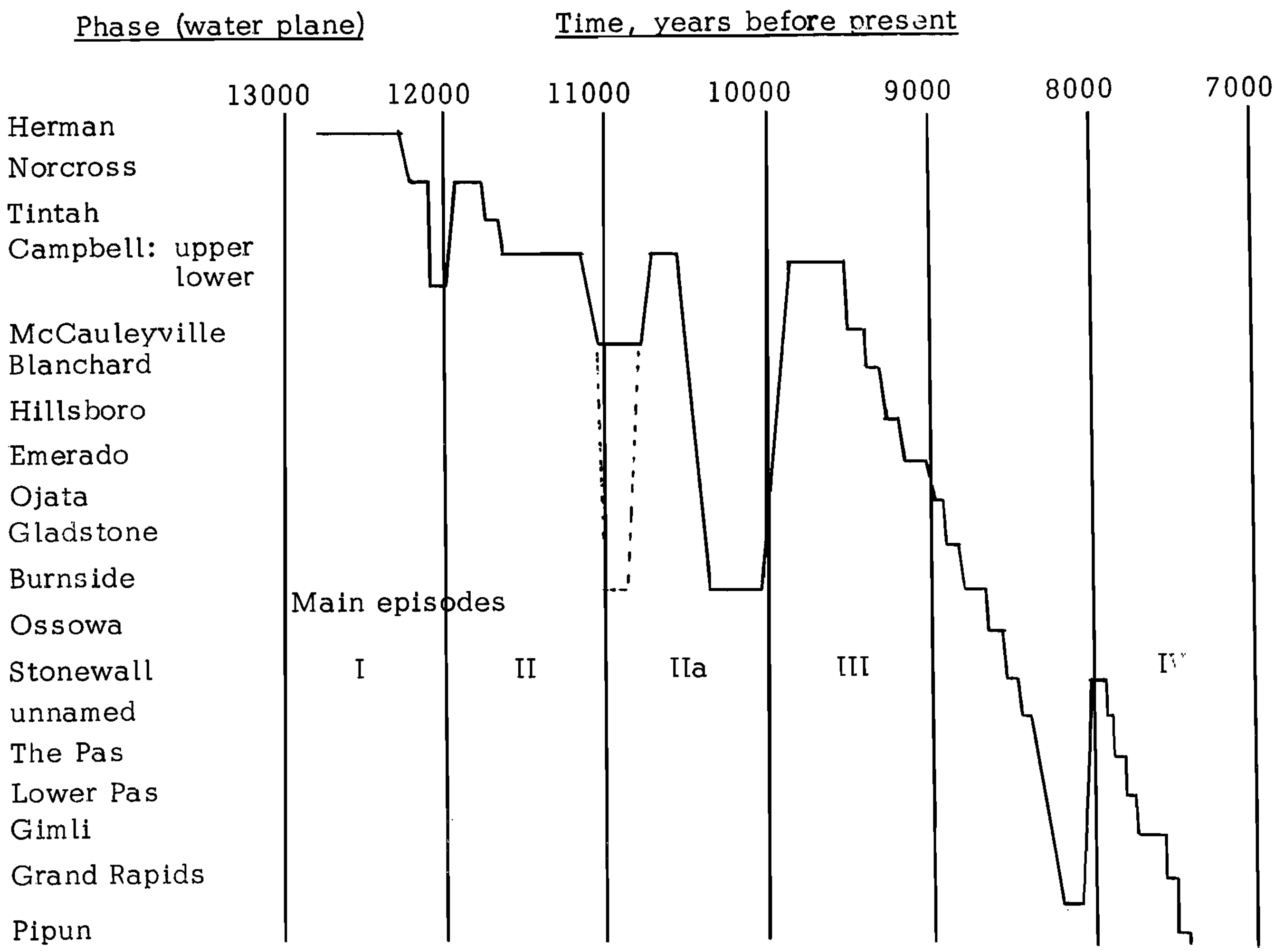

Figure 5. Hypothetical sequence of water levels of Glacial Lake Agassiz. (Note: This figure has been revised since the accompanying text was written and shows five main lake episodes rather than the four described.) Elson (1967).

south. Renewal of downcutting of the Lake Traverse-Big Stone outlet continued until a new lag concentrate accumulated. This stabilized the lake briefly at the Tintah level (Elson, 1967). Renewed erosion of the outlet as a result of increased discharge of meltwater continued until exposure of a bedrock sill stabilized the lake at the Campbell level about 11,500 years ago (Elson, 1967).

Retreat of the ice margin eventually opened major drainage outlets to the east into Lake Superior by way of Lake Nipigon. The resulting low water level apparently exposed the lake clays and caused desiccation in the southern part of the basin.

Another readvance of the ice about 10,000 years ago again blocked the eastern drainage outlets and the lake rose first to the McCauleyville level, then the Campbell level. This phase of the lake may have been stable for 200 to 500 years.

Subsequent retreat of the ice opened successively lower drainage outlets with corresponding declines in lake level. Lake Agassiz drained completely about 7,300 years ago with restoration of normal flow of the Red River into Hudson Bay.

The extreme flatness of the lake bottom was caused by two main mechanisms. The most important probably was density or turbidity currents. The cold, sediment-laden water discharging into the lake flowed to the low topographic areas and ponded with resultant settling of the suspended sediment and filling of the depressions on the lake floor. Wave action, acting to a depth of one-half the wave length of the waves, planed off the ridges and hills on the lake bottom. The result of these two mechanisms leveling the surface is the striking phenomenon of trees and buildings disappearing over the flat horizon as you drive (like ships at sea disappearing over the horizon).

Intersecting Minor Lineations on Lake Agassiz Plain

The intersecting, low-relief ridges and grooves on the nearly flat plain of glacial Lake Agassiz in North Dakota, Minnesota, and Manitoba have previously been considered to have formed by one of a variety of different processes. The lineations are seldom noticeable from the ground but are often conspicuous from the air and on soil maps (Fig. 6). As a result of a study of air-photo stereopairs of the North Dakota and Minnesota part of Lake Agassiz plain (Fig. 7) by Clayton (U.N.D.) and a detailed field and air-photo study of the Oak Point area at the southern end of Lake Manitoba by Klassen (Geological Survey of Canada), a new theory on their origin was proposed (Clayton, et al. 1965).

The intersecting lineations on the Lake Agassiz plain are primarily ridges 3 to 10 feet high, 75 to 100 feet wide, and up to 6 miles long. The great majority are oriented approximately N. 30° W. and some have a pronounced hook-like curvature. The lineations are parallel to the axis of the deepest, last-drained part of Lake Agassiz and lie within the bounds of the lowest strandlines on the flattest part of the plain.

New Theory

More recent studies of air-photos of Great Slave Lake show a pattern of grooves on the lake bottom sediments nearly identical to the pattern on the floor of glacial Lake Agassiz. Weber (1958) stated that these grooves were formed by ice blocks, which broke off from the thick ice cover in the spring and were driven shoreward by the prevailing storms. The ice blocks dragged over the soft lake sediments producing the intersecting lineations which became curved as the wind direction shifted.

The grooves in the Great Slave Lake sediments are 180 feet wide, about 1 mile long and 1 1/2 feet deep. The fact that the lineations are grooves in Great Slave Lake but ridges in the Lake Agassiz plain does not invalidate the proposed theory. In most parts of Lake Agassiz plain there are many definite grooves parallel to and intersecting the ridges and many of the ridges may be merely the areas remaining between parallel grooves. No significant difference exists between the shape and pattern of intersecting grooves and ridges in Lake Agassiz and the pattern of the ice-drag grooves at Great Slave Lake (Clayton, et al., 1965).

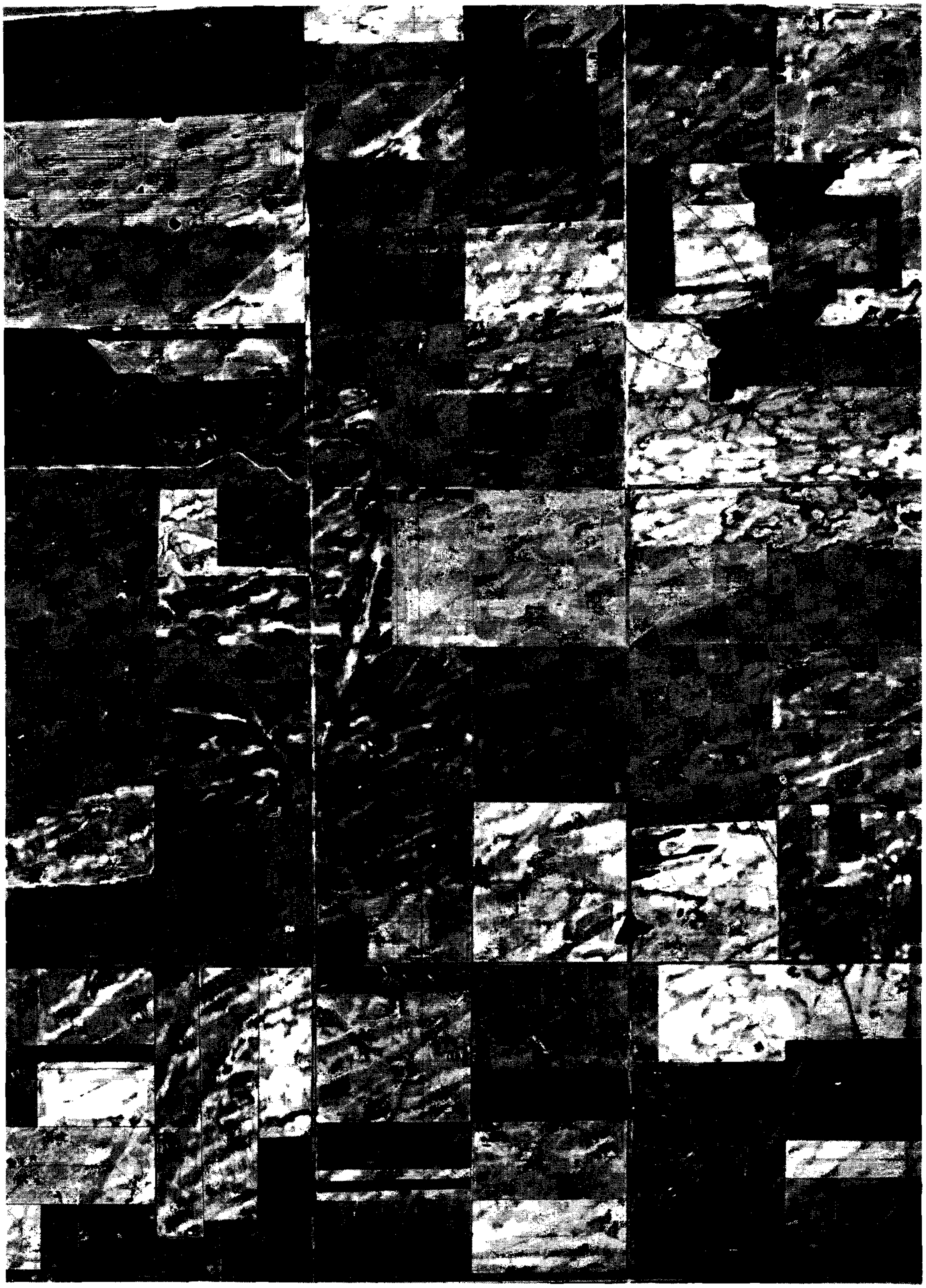

Fig. 6. Ice drag lineations on the floor of glacial Lake Agassiz, Eastern Pembina Co., N.D. (U.S. Army Map Service, U.S.G.S., #1975, 1952)

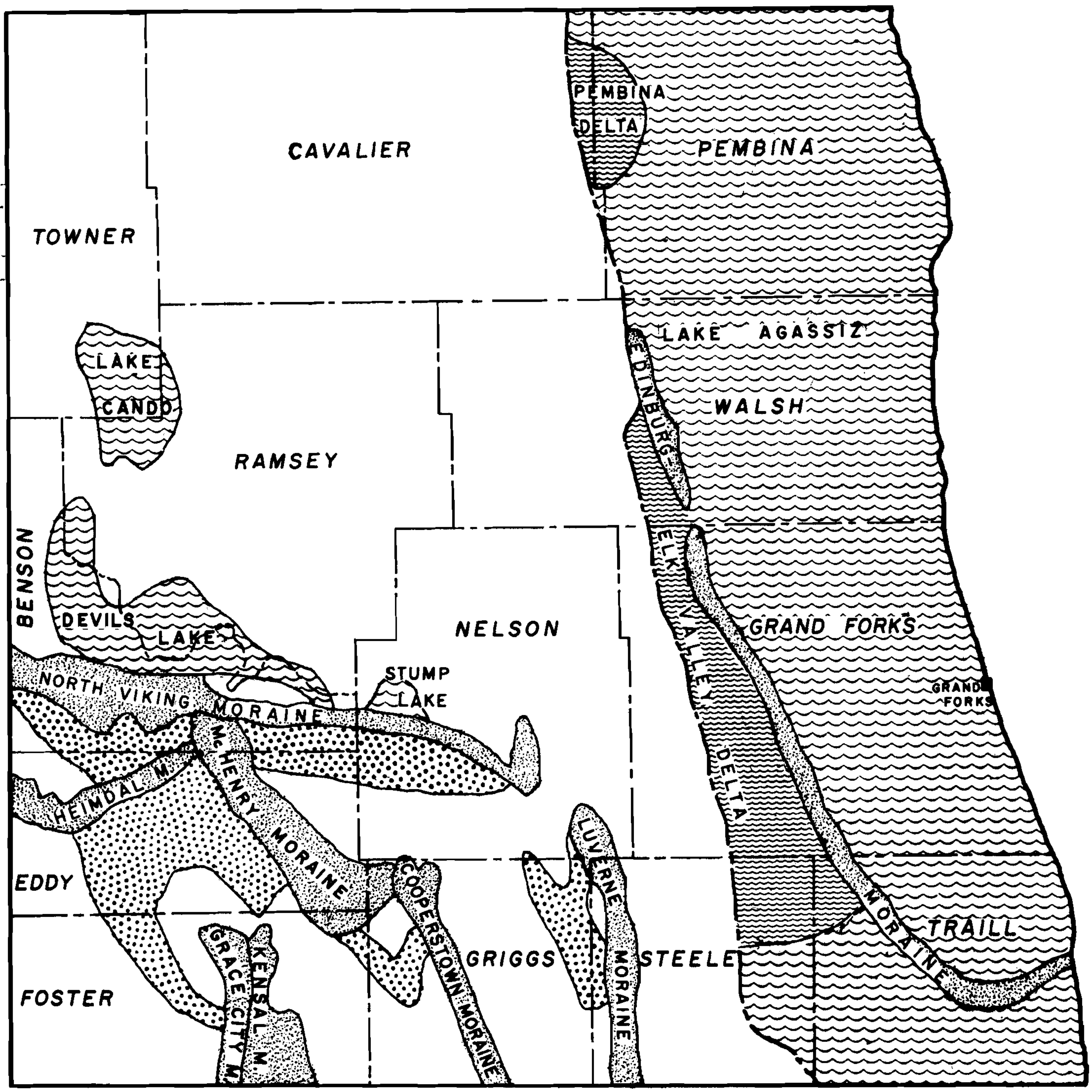

Fig. 7. Generalized map of northeastern North Dakota showing the glacial features and the deltas associated with Lake Agassiz. Outwash areas are shown by dotted pattern. Blank areas represent ground moraine (modified from U.S.G.S. Misc. Inv. map I-331)

It is therefore concluded that most of the intersecting ridges and grooves on Lake Agassiz plain were formed by the dragging of thick slabs of wind-driven lake ice on the nearly flat bottom of glacial Lake Agassiz (Roger J. Reede).

Bedrock Geology

In eastern North Dakota, Paleozoic and Mesozoic sedimentary rocks ranging in thickness from about 200 feet to 2100 feet overlie Precambrian crystalline rocks (Fig. 8). Paleozoic rocks are all of Ordovician age; they include shale, sandstone, and limestone of the Winnipeg Group and limestone of the Red River and Stony Mountain Formations. Mesozoic rocks are comprised of sandstones, siltstones, and shales of the Dakota Group and shales and marlstone of the Colorado and Montana Groups. There is an angular unconformity between the Mesozoic and the underlying Paleozoic rocks; Paleozoic rocks dip about 25 feet per mile to the west while the Mesozoic rocks average only about 8 feet per mile. The overburden is up to 220 feet thick near Grand Forks (C. G. Carlson).

ROAD LOG

Mileage	(Distance)	
00.0		Start Field Trip: Junction of Highway 2 and Interstate 29 at the Skelly Gas Station (Elev. 833 ft.).
	(0.4)	
00.4		Beaded windbreaks to the north, 1 mile. This is a region of saline groundwater discharge, where micro-relief on the lake plain has produced some interesting plant growth. As water from rain and spring meltwater runs off the high topographic areas it collects in the low areas resulting in local recharge of the water table. As water infiltrates and percolates downward it dissolves salts in the soil. The soil formed in these low areas is a Chernozem. Flow of the water brings these dissolved salts to the high areas where capillary action concentrates the salts. The soil formed here is a Solonchak. The trees grow best in the low areas where the concentration of salts in the soil is less.
	(3.2)	
03.6		A flowing artesian well from the Dakota Group is present on the south side of the road. Grand Forks International Airport is to the north.
	(0.8)	
04.4		Beaded windbreak 1 mile to the southwest.
	(0.3)	
04.7		Beaded windbreaks paralleling road on either side.
	(1.3)	
06.0		Approximate position of Gladstone strandline not visible at this location.
	(0.4)	
06.4		Freshwater coulee.
	(1.1)	
07.5		Bridge over coulee.
	(1.4)	

09.9 Kelly Slough. Section 33, T. 152 N., R. 52 W., (Elev. 850 ft.).

An approximate 10-foot drop in elevation marks the eastern margin of a northeast-southwest linear depression about 7 miles long and up to 1 1/2 miles wide (Fig. 3). The depression is characterized by saline water, soils, and vegetation. Kelly Slough, a national wildlife preserve, is one of several saline bodies of water located within this linear depression. The salts in the soils inhibit growth of vegetation here; even hay crops are rare. Glasswort (*Salicornia rubra*), a salt-tolerant plant, is conspicuous in this area. The salinity of the ground water is the result of a deep, regional, ground water discharge system.

The depression has been attributed to saline water discharging upward from the subsurface Dakota Group (Laird, 1959) (Figs. 8, 9). Sapping by this upward movement of water has resulted in erosion of the overlying sediment. Recently, an alternate hypothesis has been suggested that during glacial occupation of this area water flowing beneath the glacial ice was forced into the permeable Dakota sandstones because of the hydrostatic and geostatic pressure of the overlying water and ice (Joe Downey, U.N.D.). Upon deglaciation, large quantities of water were released from the contact between the Dakota sandstones and the underlying Paleozoic rock. The rapid movement of this water resulted in the erosion of the overlying lake sediment. The discharging water was at a maximum immediately after deglaciation and has since decreased to its present rate.

In summary, this linear depression is a landform feature expressing the subsurface location of the Dakota sandstones and is the result of ground water discharge from an artesian flow system (John R. Tinker, Jr.).

(1.8)

11.7 Church on Ojata strandline.

(0.7)

12.4 Turn north (right). Road to the south leads to Emerado.

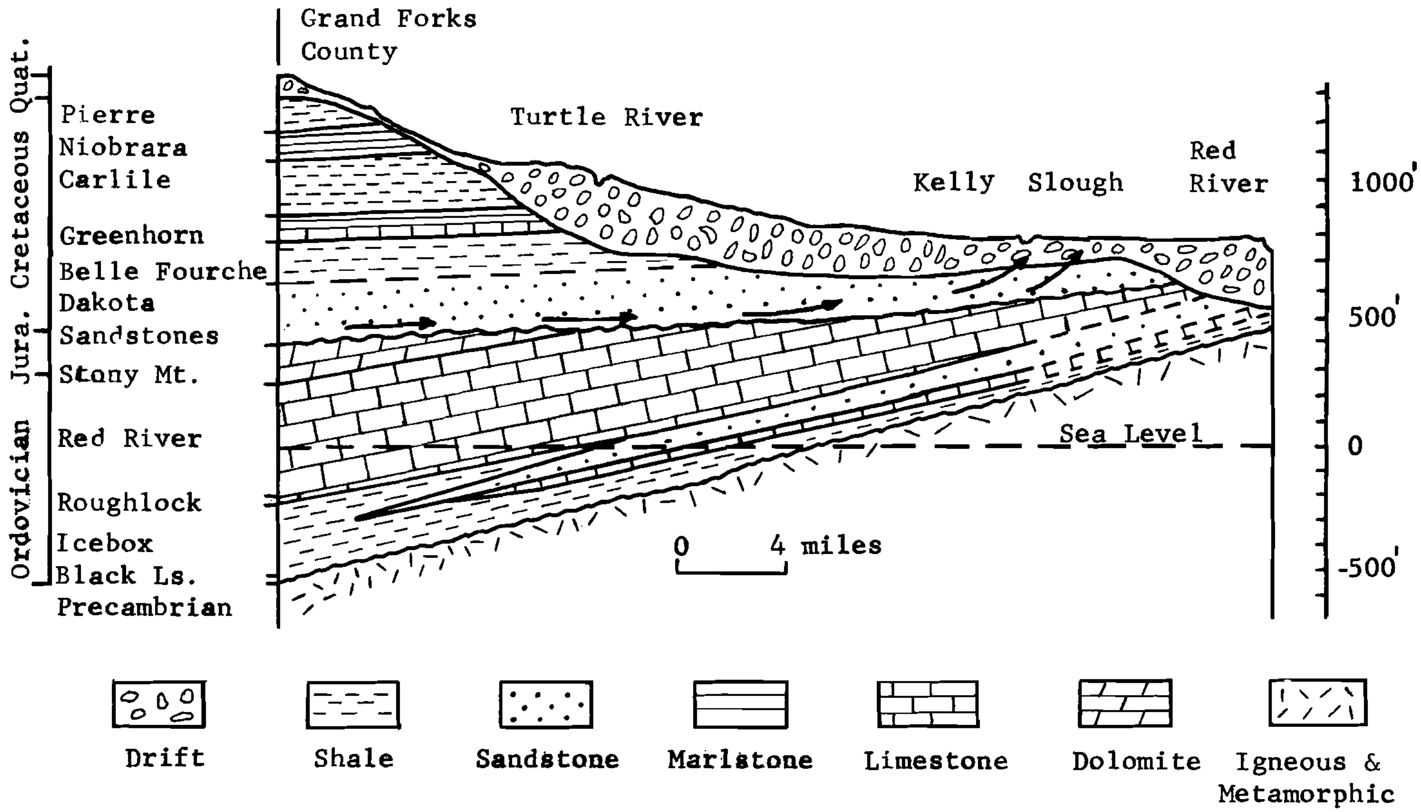

Fig. 8. Cross section of Kelly Slough area showing bedrock lithology and structure, and the seepage of groundwater (from Dan E. Hanson, N.D.G.S. Bull. 53, in prep.)

SEQUENCE	SYSTEM	GROUP OR FORMATION		DOMINANT LITHOLOGY
TEJAS	TERTIARY	GLACIAL DEPOSITS		Glacial Drift
		WHITE RIVER		Clay, Sand and Limestone
		GOLDEN VALLEY		Clay, Sand and Silt
		FORT UNION GROUP	TONGUE RIVER	Shale, Sandstone and Lignite
			CANNONBALL	Marine Sandstone and Shale
			LUDLOW	Sandstone, Shale and Lignite
ZUNI	CRETACEOUS	HELL CREEK		Sandstone, Shale and Lignite
		MONTANA GROUP	FOX HILLS	Marine Sandstone
			PIERRE	Shale
		COLORADO GROUP	NIOBRARA	Shale, Calcareous
			CARLILE	Shale
			GREENHORN	Shale, Calcareous
			BELLE FOURCHE	Shale
		DAKOTA GROUP	MOWRY	Shale
			NEWCASTLE	Sandstone
			SKULL CREEK	Shale
			FALL RIVER	Sandstone and Shale
			LAKOTA	Sandstone and Shale
	JURASSIC	MORRISON		Shale, Clay
		SUNDANCE		Shale, green and brown and Sandstone
		PIPER		Limestone, Anhydrite, Salt and red Shale
ABSAROKA	TRIASSIC	SPEARFISH		Siltstone, Salt and Sandstone
	PERMIAN	MINNEKAHTA		Limestone
		OPECHE		Shale, Siltstone and Salt
	PENNSYLVANIAN	MINNELUSA		Sandstone and Dolomite
		AMSDEN		Interbedded Dolomite Limestone, Shale and Sandstone
KASKASKIA	MISSISSIPPIAN	BIG SNOWY GROUP	HEATH	Shale
			OTTER	Sandstone and Limestone
			KIBBEY	
		MADISON		Interbedded Limestone and Evaporites
				Limestone
		BAKKEN		Siltstone and Shale
	DEVONIAN	THREE FORKS		Shale, Siltstone and Dolomite
		BIRDBEAR		Limestone
		DUPEROW		Interbedded Dolomite and Limestone
		SOURIS RIVER		Interbedded Dolomite and Limestone
		DAWSON BAY		Dolomite and Limestone
		PRAIRIE		Halite
		WINNIPEGOSIS		Limestone and Dolomite
TIPPECANOE	SILURIAN	INTERLAKE		Dolomite
	ORDOVICIAN	STONEWALL		Dolomite and Limestone
		STONY MOUNTAIN FM.	GUNTON MEMBER	Limestone and Dolomite
			STOUGHTON MEMBER	Argillaceous Limestone
		RED RIVER		Limestone and Dolomite
		WINNIPEG GROUP	ROUGHLOCK	Calcareous Shale & Siltstone
			ICEBOX	Shale
			BLACK ISLAND	Sandstone
SAUK	CAMBRIAN	DEADWOOD		Limestone, Shale and Sandstone

Fig. 9 North Dakota Stratigraphic Column (from Carlson and Anderson, 1966, N.D.G.S. Misc. Ser. #28)

(1.0)

13.4 East entrance to Grand Forks Air Force Base.

(1.0)

14.4 STOP #1. Air Base drainage ditch exposure. NE 1/4, NE 1/4, sec. 30, T. 152 N., R. 52 W., (Elev. 880 ft.).

A typical soil profile is exposed on the south side of the drainage ditch about 100 feet east from the corner of the ditch. The soil has been identified as an Aeric Calciaquoll ($CaCO_3$ Solonchak) probably of the Ulen series (Fig. 10). The stirred and oxidized zone is the result of the deep frost action which occurs in this area (up to 6 feet). The mottled zone was below the water table prior to the excavation of the drainage ditch, which lowered the water table. Subsequent oxidation has produced the mottling. Wood recovered from the peaty driftwood layer has been dated at $10,960 \pm 300$ radiocarbon years old. The ripple sequence above the wood horizon is probably the result of wave action. The Ojata beach extends through this area.

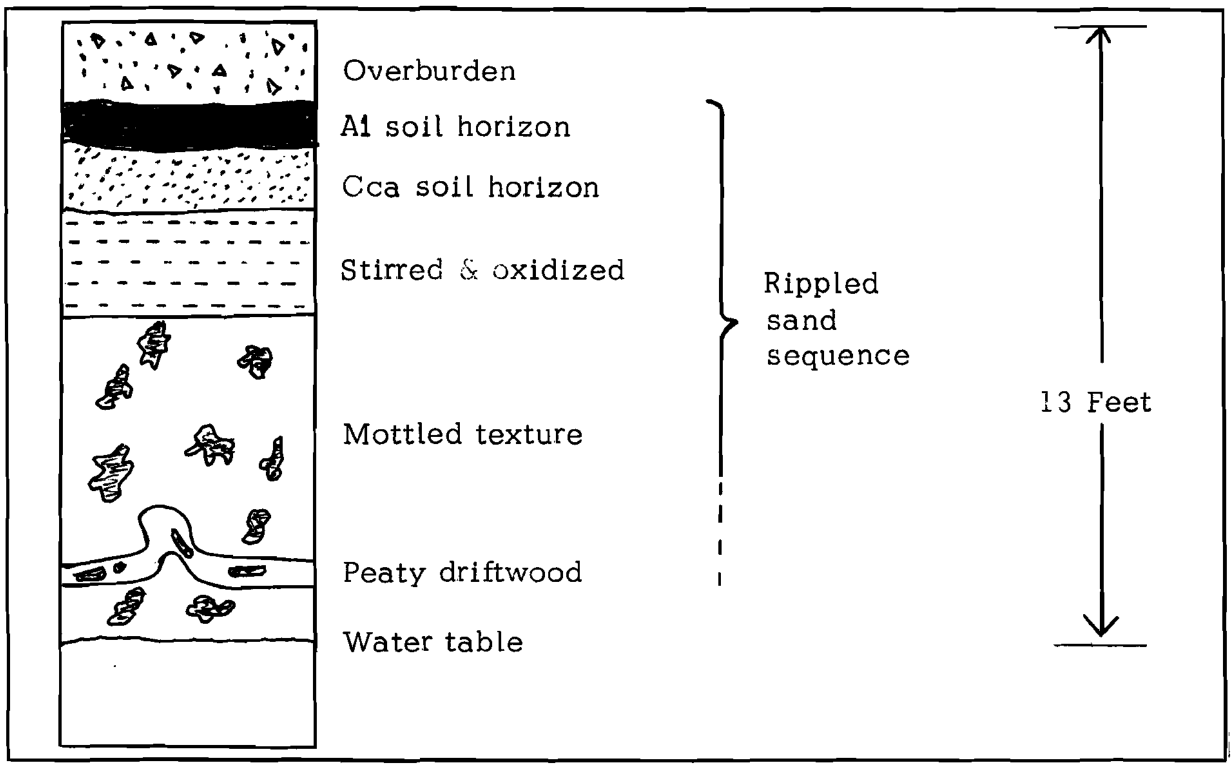

Figure 10. Sketch of features seen at Stop #1.

14.4		Return to Highway 2.
	(2.0)	
16.4		Turn west (left) on Highway 2.
	(0.2)	
16.6		Emerado beach rise ahead. Some of the strandlines that we will be crossing may have originated as offshore bars rather than as beaches. Note the cottonwood grove along the south side of the road. These trees are growing in sandy soil deposited during spill of floodwater from behind the Emerado beach in 1950.
	(0.4)	
17.0		Emerado beach ridge (Elev. 900 ft.). The corresponding beaches are usually more prominent along the east margin of the basin (in Minnesota) because of stronger wave action there.
	(0.3)	
17.3		Great Northern Railroad tracks.
	(0.4)	
17.7		CAUTION: Two-way traffic.
	(1.9)	
19.6		Grain bins to south located on Hillsboro strandline (Elev. 930 ft.).
	(0.9)	
20.5		Lower Blanchard strandline (Elev. 950 ft.). The ridge is marked by trees and a gravel mining operation.
	(0.2)	
20.7		Middle Blanchard strandline.
	(0.3)	
21.0		Upper Blanchard strandline (Elev. 960 ft.).
	(0.5)	
21.5		Margin of McCauleyville-Campbell beach complex (Elev. 1000 ft.). This complex represents a major level of Lake Agassiz. The Campbell strandline commonly is an escarpment with the McCauleyville beach existing as a subdued ridge in front of it.
	(0.5)	
22.0		Road to Arvilla. Till is very close to the surface here. Lake sediments are thin. Note boulders in gully ahead.
	(0.9)	
22.9		Entrance to Turtle River State Park. Pronounced terraces are present along the Turtle River in this park. Recent studies of the trees on the lowest floodplain here show scars formed by

rafted ice blocks thrown against the trees during the spring floods. There is a direct relationship between the height and age of the scars and the flood crest for that year. Some of the scars are older than the available river gage records (Harrison and Reid, 1967).

(0.4)

23.3 Turtle River.

(2.5)

25.8 Tintah strandline (Elev. 1045 ft.). Note presence of boulder piles; till is exposed at the surface here. This area, from here to the Herman strandline, was eroded by wave action, and only scattered patches of lake sediment were deposited.

(0.6)

26.4 Norcross strandline (Elev. 1080 ft.).

(0.4)

26.8 Turtle River.

(0.7)

27.5 We are now rising onto a till ridge. Note the difference in topography compared to the lake plain.

(1.1)

28.6 Junction of Highway 2 and 18. The town of Larimore is to the south.

(2.9)

31.5 STOP #2. Elk Valley Delta. (Elev. 1130 ft.). SW 1/4, sec. 27, T. 152 N., R. 55 W.

The Elk Valley Delta is a deposit, primarily sand in this location, which was formed when a glacial meltwater drainage system discharged into Lake Agassiz about 12,500 years ago (Elson, 1967). The cross-bedding at this stop (on south side of road) is characteristic of a deltaic deposit which has been reworked by wave action. We will see this same delta farther north where the sediment is coarser.

(0.1)

31.6 Great Northern Railroad tracks.

(2.1)

33.7 Herman strandline (Elev. 1170 ft.). This strandline represents the highest level of Lake Agassiz. Note the change in topography on the Drift Prairie.

(2.1)

35.8		Gully.
	(0.4)	
36.2		STOP #3. Niobrara Formation in road cut on west side of gravel road immediately south of river, north of Highway 2 (Elev. 1265 ft.). NE 1/4, NE 1/4, sec. 23, T. 152 N., R. 56 W. The Niobrara Formation (Upper Cretaceous) was described originally by F. B. Meek and F. V. Hayden (1862), and named for exposures along the Missouri River near the mouth of the Niobrara River, Knox County, Nebraska. About 18 feet of the upper part of the formation is exposed here, consisting of medium-gray calcareous shale or marlstone, which, upon weathering, has a yellowish or cream-colored, biscuit-like surface. The maximum thickness of the Niobrara in eastern North Dakota is 200 feet. A small oyster, Crassostrea congesta (Conrad), and fragments of a large bivalve, Inoceramus sp., have been collected from this outcrop (A. M. Cvancara, U.N.D.). Carlson (1964) has studied the Niobrara Formation in eastern North Dakota for its possible use in the manufacture of cement. Till caps the top of this bedrock exposure (Alan M. Cvancara).
	(3.9)	
40.1		Niagara Cemetary to south.
	(1.5)	
41.6		Turn north (right) onto Highway 32. The town of Niagara is to the south.
	(0.6)	
42.2		STOP #4. Pierre Formation in road cut on west side of road across gully (Elev. 1410 ft.). W 1/2, NE 1/4, sec. 6, T. 152 N., R. 56 W. The Pierre Formation (Upper Cretaceous) was first described by F. B. Meek and F. V. Hayden (1862), and named for exposures at old Fort Pierre, South Dakota. In eastern North Dakota, the Pierre consists of about 200 feet of light to dark gray to brownish-black shale, marlstone, and claystone. Common yellowish to whitish bentonite (clay) beds occur in the lower part of the formation, a product of the alteration of volcanic ash. Manganiferous ironstone and clayey limestone concretions are also common in parts of the formation. Recently,

five members of the Pierre have been recognized in eastern North Dakota (Gill and Cobban, 1965). The Pierre is widespread in North Dakota in the subsurface where it attains a maximum thickness of 2300 feet.

About 45 feet of the Pierre is exposed at this outcrop. The Pierre-Niobrara contact is about 100 feet below the base of this exposure. A few bentonite beds are present, one attaining a thickness of 14 inches. Flattened, clayey limestone concretions occur near the base of the section. Internal molds of Inoceramus sp., as well as other smaller bivalves, have been taken at this locality (A. M. Cvancara, U.N.D.). Overlying the Pierre at this outcrop is Pleistocene till. Therefore, the shale-till contact depicts an unrepresented rock record of at least 100 million years.

The Pierre and Niobrara Formations were deposited in seas that invaded the Williston basin, whose center is in northwestern North Dakota. In this area we are at the eastern margin of that great basin (Alan M. Cvancara).

	(1.0)	
43.2		Gully.
	(3.1)	
46.3		Minuteman II Missile site to the east. This is one of 150 sites in eastern North Dakota.
	(0.7)	
47.0		View of the Elk Valley delta to the east.
	(4.6)	
51.6		Minuteman II Missile launch control site to the west, 1/2 mile. Town of Dahlen, after which the Dahlen Esker was named, 3 miles to the west.
	(0.4)	
52.0		Forest River.
	(0.3)	
52.3		CAUTION: Severe bumps in road.
	(1.3)	
53.6		Whitman Dam 9 miles to the west.
	(0.4)	
54.0		Dahlen Esker on the skyline ahead.

Cumulative	Interval	
	(0.6)	
54.6		STOP #5. Dahlen Esker. S 1/2, sec. 32, T. 155 N., R. 56 W. Turn west to Dahlen Esker (Fig. 11).
		The Dahlen esker was interpreted by Friestad (1966) to have been deposited penecontemporaneously with the Edinburg moraine at or about the same time as the early phase of Lake Agassiz I. Radiocarbon dates of the upper Herman formed at this time give an age of 11,740+-300 radiocarbon years before present (Shay, 1965). The easternmost section of this esker is believed to have been formed as meltwater, flowing over the surface of the glacier here, disappeared into a crack in the ice ("crevasse"). After flowing along the bottom of the crack, for about 1/2 mile the meltwater drained through a tunnel to the northwest. Blockage of a portion of the channel caused the sediment-laden stream to be diverted to the more northern segment (Fig. 11) where it rejoined the original stream at a right angle (Friestad, 1966). This feature is therefore partly an interblock filling, but primarily an esker. The direction of stream flow was from southeast to northwest (Kume, 1966).
54.6		Return to Highway 32. Turn north (left) and cross into Walsh County.
	(0.4)	
55.0		Soo Line Railroad crossing.
	(0.8)	
55.8		Branch of the Forest River.
	(0.3)	
56.1		The town of Fordville is 3 miles to the east.
	(0.5)	
56.6		Soo moraine to the right parallels the road (Fig. 11). The Lankin moraine is 3 1/2 miles farther north.
		The Soo and Lankin moraines are interpreted to have formed at the edge of the ice sheet a short time after the Dahlen esker was deposited. The branching of the Soo moraine was probably due to the faster retreat of the glacier in the north than in the south. The ice front subsequently retreated less than a mile north-

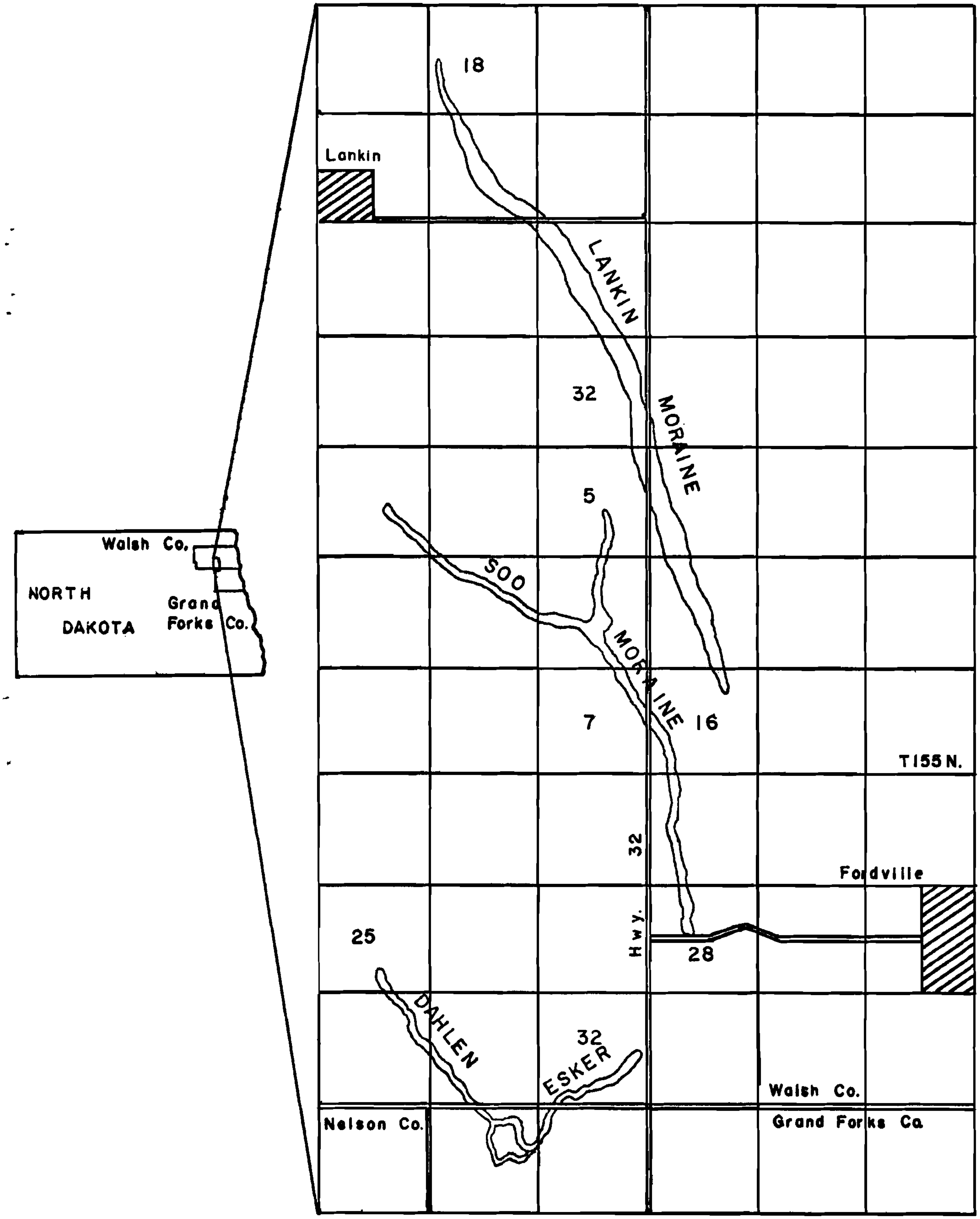

Fig. 11. Location and morphology of the Dahlen esker, and the Soo and Lankin moraines (Friestad, 1966)

ward and deposited the Lankin moraine. A lag concentration of boulders is typical of the surfaces of both moraines (Friestad, 1966).

	(1.1)	
57.7		Soo Line Railroad tracks.
	(0.4)	
58.1		Road cut through the Soo moraine.
	(0.4)	
58.5		Turn east (right) onto gravel road.
	(0.5)	
59.0		Cross the Lankin moraine. Note Edinburg moraine ahead on skyline.
	(0.7)	
59.7		<u>STOP #6</u>. Elk Valley delta pit (Elev. 1200 ft.). SW 1/4, sec. 10, T. 155 N., R. 56 W.

The Elk Valley delta (Fig. 7) is one of three deltas, identified in an early work by Upham (1896), which formed along the western shoreline of glacial Lake Agassiz. The Elk Valley delta is situated between the Drift Prairie to the west and the Edinburg moraine to the east and extends from six miles north of Fordville in Walsh County to the northern part of Steele and Traill Counties and covers an area of approximately 250 square miles. The deposit ranges in thickness from 1 foot near the western edge to slightly over 50 feet near the Edinburg moraine.

In general, the Elk Valley delta (Fig. 12) consists of interbedded silt, sand, and gravel which were deposited during and near the end of the last glacial period both by a stream flowing from the northwest and by glacial meltwater from the east. The sediments were deposited upon an older glacial till surface.

The Elk Valley delta is composed of two distinct units: a lower shale-sand and an upper granitic sandy gravel. Cross-bedding and other features of the sequence confirm deposition by running water. The lower shale-sand appears to be the result of erosion of the Pierre Shale which crops out to the west of the Elk Valley delta. Test drilling indicates that this unit is continuous beneath the Edinburg moraine and is, therefore, older than the moraine.

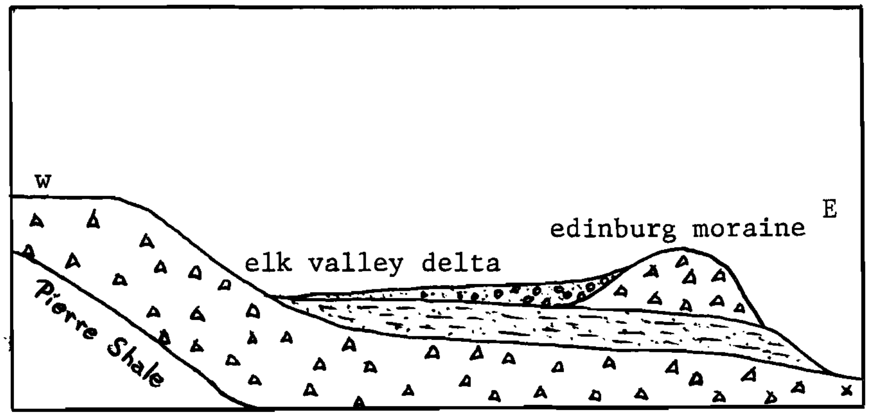

Figure 12. Generalized east-west cross section thru the Edinburg moraine and the Elk Valley Delta north of Fordville, Walsh County, North Dakota
Till Granitic sand and gravel Shale sand

The younger unit, the granitic sandy gravel, apparently was deposited during and slightly after the construction of Edinburg moraine. Because a source is unknown in the general area of the Elk Valley delta, it can be assumed that the granitic sand and gravel was derived from rocks transported to the area by glacial ice and its meltwater. The geologic features displayed by this upper unit suggest deposition by meltwater flowing from an ice sheet located to the east.

The Elk Valley delta is considered to be one of the best sources of ground water in eastern North Dakota. The presence of saturated coarse-grained sediments along with ample recharge areas makes the delta deposits important sources of water for high capacity wells. To date there has been little development of the delta deposits as a major source of water.

The water from the delta sediments is of the calcium bicarbonate type. Total dissolved solids varies from 350 to near 600 milligrams per liter and averages near 450 milligrams per liter in the samples taken to date. It is relatively low in total dissolved solids compared with most water in eastern North Dakota.

At this stop can be seen some of the typical features of the delta, including cross-bedding, gravelly sand, shale pebbles, and caliche (Joe Downy).

(1.6)

61.3 Forest River.

(0.2)

61.5 Turn south (right) toward Fordville.

(2.5)

64.0 A spring is found in the city park to the west of the road. Such springs are common along the Edinburg moraine; water flows from the contact of the till and the overlying sediment or from the contact of two till units. Town of Fordville. Turn east on paved road.

(1.0)

65.0 Turn south (right) onto gravel road. The small shed approximately 100 feet north of this intersection is a U. S. Geological Survey station to record water level fluctuations in the Elk Valley delta sediments.

(0.3)

65.3 Take road paralleling the Soo Line Railroad tracks.

(1.1)

66.4 STOP #7. Lake Agassiz spit (Elev. ca 1140 ft.). NE 1/4, NW 1/4, sec. 32, T. 155 N., R. 55 W. Turn to right into pit area.

This gravel pit is located in a spit which formed off the tip of the Edinburg moraine around which we just came. The Edinburg moraine has been described by Schulte (1965) as a very pronounced ridge extending from the town of Edinburg (20 miles to the north) to this locality. In his studies, Schulte traced the lower Herman and the Tintah strandlines across the Edinburg moraine, placing the time of deposition of the Edinburg moraine as immediately pre-lower Herman. Other workers recognize the continuation of the moraine much farther to the south where it crosses the valley into what is now Minnesota (Fig. 7).

The excavation at this stop exposes the primary sedimentary structures developed in the spit. Top-beach sediments rest on backbeach sediments (Fig. 13). To the west was a bay protected from the open lake by this spit and the moraine. The Elk Valley delta was deposited in these relatively quiet waters. The crest of the spit can be seen about 200 feet farther east.

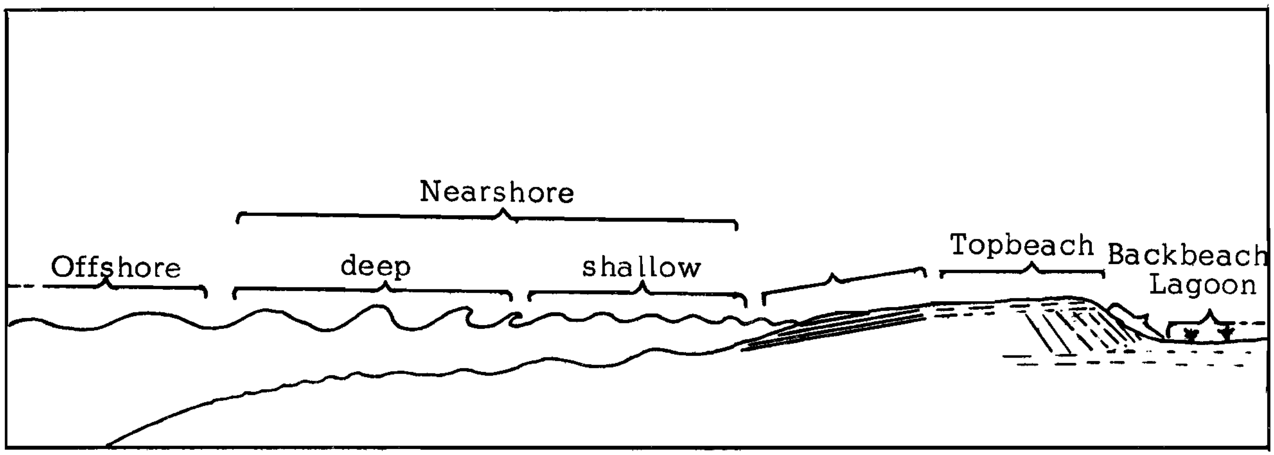

Figure 13. Beach profile.

A short walk onto the moraine provides an excellent view of some of the features we have been discussing.

66.4		Retrace route to the west.
	(0.5)	
66.9		Turn south (left) onto gravel road.
	(0.3)	
67.2		Soo Line Railroad tracks.
	(0.3)	
67.5		Forest River.
	(0.9)	
68.4		Turn east (left) onto gravel road. Cross branch of Forest River.
	(0.6)	
69.0		Turn south (right) on gravel road.
	(0.5)	
69.5		Turn east (left) on gravel road over crest of hill.
	(1.5)	
71.0		Take road straight ahead (east). Hutterite colony on north side of road.
	(0.3)	
71.3		Bridge over Forest River.

(0.1)

71.4 Bridge over Forest River tributary.

(0.2)

71.6 Forest River Cut visible to southeast.

(0.4)

72.0 STOP #8. Forest River Cut: Inkster, North Dakota (Elev. at crest of hill is 1080 ft.). NE 1/4, sec. 10, T. 154 N., R. 55 W., approx. 1 1/2 miles northwest of Inkster, North Dakota. The site is located between the Upper Herman Beach and the Campbell Beach.

The Forest River has cut through some Pleistocene and Holocene sediments northeast of Inkster, North Dakota. The sediments record various Lake Agassiz sedimentary environments (Fig. 13).

Near the base of the section silty lake sediments can be found that are rhythmically bedded, suggesting a pro-glacial lake. Overlying the lake sediments is a thick sequence of glacial till possibly contemporaneous with the Edinburg moraine which is west of the cut. Rippled cross-bedded sand overlies the till and is assumed to represent near-shore sediments of Lake Agassiz (Fig. 14).

As the water in Lake Agassiz receded, deltaic sediments were deposited by rivers entering the lake. The deltaic foresets are plainly visible and are about 5 feet thick. Beach sediment overlies the deltaic sediment. Very contorted sandy silt overlies the beach sediment and may or may not be fluvial sediment.

A buried soil horizon is exposed near the present surface. This paleosol is relatively young in age as evidenced by abundant roots and root hairs in the A horizon. The soil was probably buried by eolian sand and silt during the dry 1930's (Dennis N. Nielsen).

(1.0)

73.0 Turn north on gravel road.

(0.2)

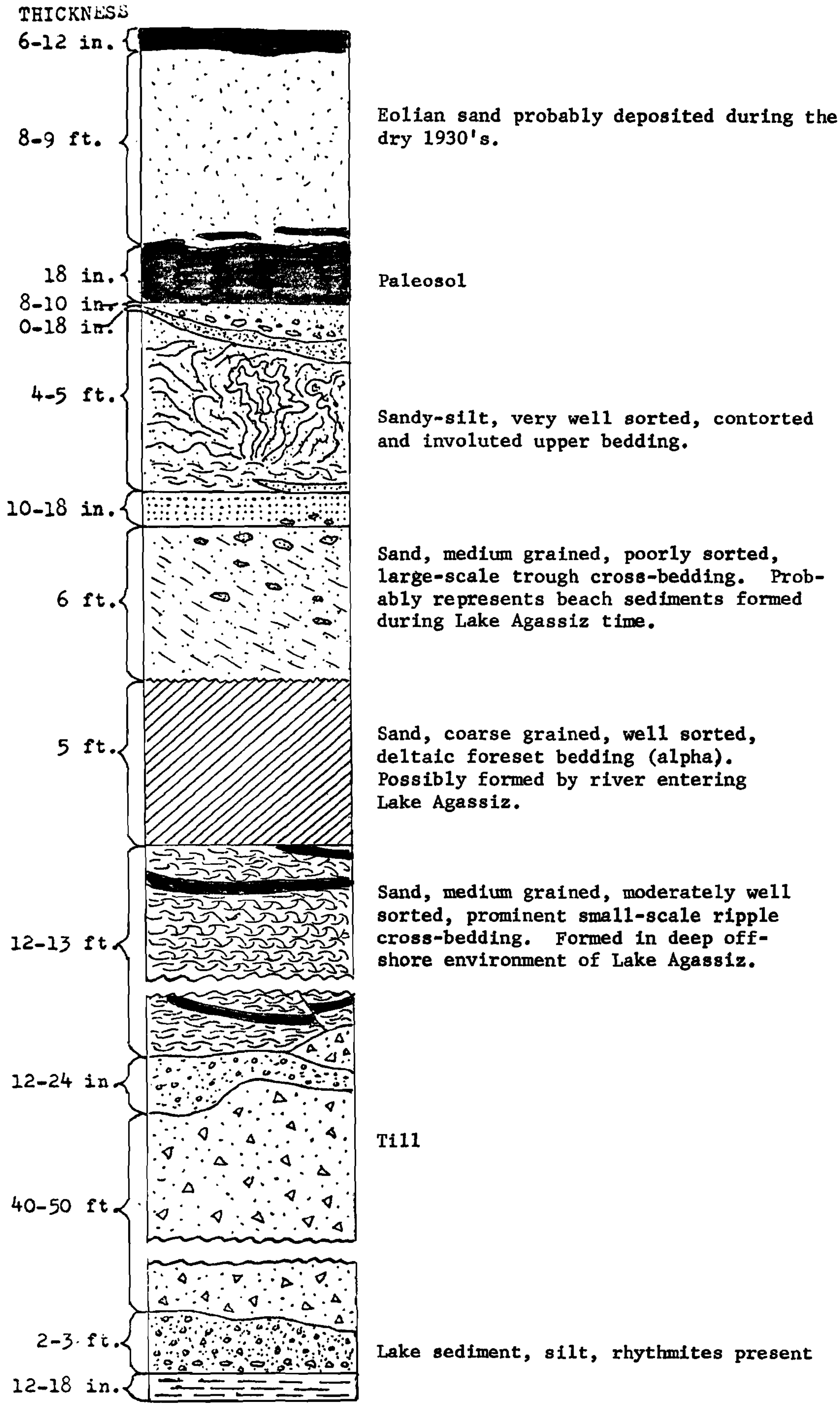

Fig. 14. Columnar diagram of Forest River section showing the strata and structure.

73.2		Turn east (right) on road.
	(0.5)	
73.7		Turn to south then southeast. Road parallels the Forest River.
	(0.3)	
74.0		Road veers to the east.
	(0.2)	
74.2		Turn south (right) toward Inkster. Bridge over Forest River just ahead.
	(1.3)	
75.5		Great Northern Railroad tracks.
	(0.7)	
76.2		Turn east (left) in town of Inkster at stop sign. We cross the Campbell strandline on the east edge of town, then the McCauleyville.
	(1.0)	
77.2		Turn south (right) onto Highway 18.
	(1.3)	
78.5		Gravel pits on left side of road in McCauleyville beach.
	(2.7)	
81.2		Town of Orr 2 miles to west.
	(1.0)	
82.2		Town of Gilby 7 miles to east.
	(3.2)	
85.4		Tintah strandline.
	(2.7)	
88.1		Bridge over branch of Turtle River.
	(0.3)	
88.4		McCanna to west 5 miles.
	(2.9)	
91.3		End of road log. Turn east (left) and return to Grand Forks via Highway 2 (approx. 25 miles).

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