N. Dakota

NORTH DAKOTA GEOLOGICAL SURVEY

Wilson M. Laird, State Geologist

MISCELLANEOUS SERIES NO. 10

Guidebook

Ninth Annual Field Conference

Mid-Western Friends of the Pleistocene

MAY 17-18, 1958

East-Central North Dakota

by
Wilson M. Laird
Richard W. Lemke
Miller Hansen

GRAND FORKS, NORTH DAKOTA
1958

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Narrow Linear Drumlins Near Velva, North Dakota, Richard W. Lemke reprinted from American Journal of Science, April, 1958, [illegible]

Maps

Voltaire Quadrangle -- North Dakota - Montana [illegible]
(Topographic) Edition of 1949, Shaded Relief Printed 1954, U. S. Geological Survey.

Geologic Map of North Dakota, 1956, North Dakota Geological Survey.

Highway Map of North Dakota, 1958, North Dakota [illegible]

East-Central North Dakota - May 17-18, 1958

Sponsored by North Dakota Geological Survey

Introduction
by

Wilson M. Laird, State Geologist and
Miller Hansen, Assistant State Geologist

It is a pleasure to welcome the Friends of the Pleistocene to North Dakota for your 9th Annual Meeting. We wish to thank the State Survey Staff and all those who have helped to make arrangements for the field trip and especially to those who have contributed papers for the guidebook. Among these are Morris M. Leighton, John A. Elson, Roger Colton, and D. R. Moir. Richard Lemke in particular has contributed several papers, and also wrote a large portion of the road log. We hope that the meetings and the trip will contain something of special interest to each one of you.

Objectives

There are only a few areas known in North Dakota where tills can be differentiated by age, and for this reason the attention of the conference will be directed chiefly to the general distribution of drift sheets and associated glacial lakes. The extent of the last lobes of ice as shown by the land forms they created will be emphasized, as well as directions of ice movement and differentiation of the several ice lobes.

Due to the low relief many land forms are not easy to pick out on the ground. Washboard moraines for example are difficult to see on the ground but can be seen distinctly on aerial photographs. Photographs have been used extensively by Colton and Lemke in glacial mapping in Montana and North Dakota.

Route of Field Conference

As can be seen from the maps the general route of the field trip is from Grand Forks to Minot via highway 2, and from Minot back to Grand Forks via Highway 52, county roads and Highways 7 and 81. In the pocket of your guide book there is a North Dakota highway map and the route of the field trip is shown on Plate 2 in the pocket. Plate 1 in the pocket shows a portion of the route on a larger scale.

The first day of the trip we will travel about 245 miles. Part of the time there will be many glacial features within a few tenths of a mile and then there will be distances of several miles over relatively featureless ground moraine. Due to the fact that we have to do most of our travelling on main highways, we will not see some of the best exposures. With that thought in mind the road log has been expanded to provide information on some of the features that we will not see. Additional papers in the guide book also help in this respect.

During the first day we will cross many of the beaches of Lake Agassiz and our first stop will be at a stream cut in glacial till about twenty miles west of Grand Forks in the Turtle River State Park. After leaving the old lake bed we will pass through areas of end moraines and ground moraine before reaching the outcrops in the Devils Lake area where till overlies Pierre Shale.

Our lunch stop has been chosen off the highway in a wooded area containing many kettle holes. Washboard moraines and old shore lines of Devils Lake are the next features to be seen, followed by till and recessional moraine of the Leeds lobe. Farther west we will cross the old lake bed of glacial Lake Souris with associated kames and conspicuous dunes as well as numerous outwash channels cut in ground moraine.

Our first stop on the second day will be at the southeast outskirts of Minot to inspect till of the Souris lobe after which we will see some rather well developed terraces along the Souris river which contain comparatively large deposits of gravel for this area. Along the river we will also see landslide topography, kame terraces, diversion channels, kames, and an outcrop of the Cannonball marine formation of the Fort Union group (Paleocene).

The next prominent feature is the Max moraine - a vast complex of end moraines which as you can see from the state geologic map, arcs across North Dakota from the northwest corner to the south central part of the state.

The linear drumlins are unusual in their length and regularity and we think you will find them thought provoking and worth close observance.

The rest of our return trip to Grand Forks will be across moraines, outwash channels, terraces, eskers, and finally back to the Lake Agassiz beaches which are much less distinct than those about 30 miles to the north which we saw on the first day of the trip.

We want to mention the material that you will find in the pocket of your guide-book. There is a glacial map (Plate 1) of North Central North Dakota which takes in the areas of the Souris River loop and Devils Lake by R. W. Lemke. Plate 2 is a portion of a glacial map of North Dakota by Roger Colton and R. W. Lemke on which the route of the field trip is shown. The western portion of the route is also shown on Plate 1. R. W. Lemke also contributed his relief map of the Voltaire quadrangle and a paper on the linear drumlins in the Velva area. John Elson's paper on Lake Agassiz and the Mankato-Valders problem is also to be found in the pocket, along with a North Dakota highway map contributed by the State Highway Department and the North Dakota Geological Survey geologic map of North Dakota.

CONVOY SAFETY

The lead car in our convoy is marked with a large number 1 on the trunk lid. Please do not pass the lead car. Please try to maintain about 100 yards between vehicles. We will usually be travelling slower than other traffic and a 100 yard interval will permit other cars to pass. It is to our advantage to avoid piling up traffic within or behind our convoy. The last car in our group is marked with a red flag on the radio aerial. The driver will maintain his position in last place and is ready to help you if you have car trouble of any kind.

ROAD LOG MILEAGES

In checking mileage between points we have noted that our cars record from .15 to .5 miles more than actual mileage over a measured ten mile course. Most cars should check the listed mileages between points within .1 of a mile, except perhaps for distances exceeding 10 miles.

ROAD LOG

MIDWESTERN FRIENDS OF THE PLEISTOCENE FIELD TRIP

Mileage		
0		Assemble on Columbia Road between 2nd Ave. North and University Avenue, with cars heading north.
	.75	
.75		Highway No. 2 turn west (left).
	1.00	
1.75		Railroad crossing. Proceed westward across floor of Lake Agassiz. See papers in guidebook by Leighton and Elson on Lake Agassiz.
	1.30	
3.05		Lake Agassiz silt in road ditch to north.
	5.60	
8.65		Bridge. Till outcrop to north in coulee.
	3.70	
12.35		Kelly Slough alkali flat.
	.70	
13.05		Leave Kelly Slough.
	1.70	
14.75		Road to Emerado to left. Keep on Highway No. 2.
	.60	
15.35		Emerado Beach. Elevation 900 feet. Sand and gravel pits to south.
	.40	
15.75		Railroad crossing.
	2.45	
18.20		Hillsboro beach. Elevation 930 feet. Note the gradual increase in beach elevations to the west.

	.25	
18.45		Second Hillsboro beach.
	.50	
18.95		Blanchard beach. Elevation 940 feet.
	.20	
19.15		Second Blanchard beach. Elevation 950 feet.
	.40	
19.45		Third Blanchard beach. Elevation 960 feet.
	.35	
19.80		Road to Gilby.
	.55	
20.35		McCauleyville beach. Note meander scar. Elevation 980 feet.
	.40	
20.75		Campbell beach, elevation 1000 feet. Gravel pits to north.
	.65	
21.40		Entrance to Turtle River Park. Turn north (right).
	.70	
22.10		Stop #1 in parking area. Cut in glacial till near picnic ground. Note oxidized zone and laminated till near top. This section was measured in July, 1957.

Top soil (leached)	2' 0"
Sub soil-sandy(partially leached)	2' 6"
Sand, brown, medium grained	2' 9"
Clay till, with pebbles of limestone, shale, granite, and metamorphic rocks. Till is in alternating layers of brown and gray about 1' thick.	48' 0"
	55' 3"

		Climb to the top and walk to other side of the hill. Note meander scar on plain below.
	.65	
22.75		Turtle River bridge.
	.10	
22.85		McCauleyville beach.
	.30	
23.15		Campbell beach, note old gravel pits.
	.40	
23.55		Junction with Park Road going west near caretakers house. Note second Campbell beach 10' higher than other one.
	.60	
24.15		Highway #2 turn west (right).
	.45	
24.60		Cross Turtle River.
	.60	
25.20		Boulders. Water cut ground moraine.
	1.70	
26.90		Boulders.
	.25	
27.15		Tintah beach. Elevation 1050 feet. Note the boulders along the beach ridge. This is the approximate outer margin of an ice lobe that advanced from the northeast; margin marked in places by the Edinburg moraine (see paper "Summary of Pleistocene Geology of North Dakota").
	.50	
27.65		Edge of Elk Valley delta.

	.40	
28.05		Norcross beach. Very sandy. Elevation 1080 feet.
	.20	
28.25		Turtle River bridge.
	.30	
28.55		Upper Norcross beach. Elevation 1090 feet.
	.95	
29.50		Lowest Herman beach.
		Approaching road junction, keep to right on Highway #2.
	1.1	
30.60		Lowest Herman beach, indistinct.
	.50	
31.10		Recrossing lowest Herman beach.
	1.15	
32.25		Note terrace on Turtle River.
	.80	
33.05		Crossing lowest Herman beach, third time.
	.90	
33.95		Middle Herman beach.
	.50	
34.45		Middle Herman beach. Note cross bedding. Stop #2 10 minutes.
		No more rest stops for 80 miles.
	1.75	
36.20		Railroad crossing.
	.95	
37.15		Town of McCanna to east (right).

2.50

39.65 Probable highest Herman beach elevation about 1150 feet. Leaving Lake Agassiz and proceeding on ground moraine characterized by swell and swale topography, youthful topography with unintegrated drainage. This drift was deposited by ice that advanced from a generally northwest direction.

2.20

41.85 Channel in till trending east to Turtle River.

1.50

43.35 Approaching indistinct end moraine trending north-south. Probably equal to Fergus Falls moraine of Upham.

1.7

45.05 Niagara corners.

3.50

48.55 Good till outcrop to right. Chiefly ground moraine from here to Devils Lake. The indistinct arcuate washboard moraines, best seen on aerial photos indicate that the Leeds lobe retreated to the northeast.

.90

49.45 Overpass, Petersburg ahead on right.

7.7

57.15 Entering town of Michigan.

11.1

68.25 Approaching town of Lakota.

7.8

76.05 Stratified ice contact deposit. Kame or esker on left side of road.

2.45

78.50 Road north (right) to Doyon. From the vicinity of Doyon and for some distance west, topography is more end morainic in character.

4.75

83.25 Road to north to Crary. From here west route can be followed on Plate 1 in pocket.

3.15

86.40 Small end moraine trending north and northwest.

1.25

87.65 View to southwest (left) of Devils Heart Butte and other hills of glacial material blanketed over bedrock highs.

1.80

89.45 Unevenly crested esker; contains poorly sorted sand, gravel, laminated silt, and till.

2.95

92.40 View of east Bay of Devils Lake to south.

2.60

95.00 Road right to Devils Lake, keep on U. S. Highway #2.

.40

95.40 Turn south (left) on Route #57.

.40

95.80 Old shore line of Devils Lake. See summary of papers on Devils Lake area in guidebook.

2.45

98.25 Old shore line behind houses on west.

2.10

100.35 Route 20 turns east. Proceed south on route #57.

.70

101.05 Pole showing various lake levels.

1870 - 1438'	1910 - 1420'
1880 - 1435'	1940 - 1402'
1890 - 1425'	1950 - 1415'

2.00

103.05 Concrete sectional Culvert Co. cement block & pipe plant.

1.00

104.05 Cut on south side of road. Till overlying Pierre shale gravel.

.70

104.75 Stop #3. Outcrop of Pierre shale overlain by till.

Top - Stony clay till containing shale, limestone and granite pebbles, and a few boulders.	47'
Pierre shale	20'
	67'

Near the top is a small slump scarp. No leached zones were found in the till.

.70

105.45 Outcrop of Pierre shale overlain by gravel and till.

.60

106.05 Good outcrop of till. Pierre shale in road cut.

.70

106.75 Good outcrop of Pierre shale and Pierre derived gravel.

.90

107.65 Road left to Ft. Totten, keep on highway 57.

1.80

109.45 Start Tokio (?) end moraine.

	1.20	
110.65		Turn south (left) on gravel road.
	.40	
111.05		Stop #4 - Lunch stop. Sharply crested morainic ridges and steep sided kettle holes of North Viking moraine. 20 minute stop.
	.85	
111.90		Kettle hole to south.
	1.65	
113.55		Turn north (right).
	.55	
114.10		Kettle hole (?) or undrained depression to west.
	1.00	
115.10		Route #57 turn west (left).
	.90	
116.00		Kettle hole on north.
	.50	
116.50		Gravel pits to north probably outwash, consisting chiefly of Pierre Shale.
	.70	
117.20		Junction, turn right on #281.
	3.95	
121.15		Lallie to west. Keep right (north) on #281.
	.70	
121.85		Kame to west about 1/2 mile.
	1.25	
123.10		Several arcuate washboard moraines.

	1.15	
124.25		Washboard moraines arcuate to northeast washboard moraines indicating retreat of this part of the Leeds lobe to northeast. One of a series of several such moraines present in this area.
	.50	
124.75		Round Lake to west. Part of glacial distributary.
	.70	
125.45		Kame moraine to west.
	.55	
126.00		Old shore line of Devils Lake to northeast (right). Elevation 1453'.
	1.60	
127.60		Entering Minnewaukan.
	.80	
128.40		Old shore line of Devils Lake. Elevation 1453'.
	1.80	
130.20		Note shore line (Elevation 1453') to left near red barn. We are travelling on lake bottom here.
	1.50	
131.70		Junction with route #19. Continue north. Indistinct "Brinsmade' moraine to east in lake and to west for many miles.
	1.00	
132.70		Lake sediments of Devils Lake in road ditch to the east.
	.40	
133.10		High level (1453') shoreline of Devils Lake. Till of Leeds lobe exposed in roadcut.
	1.70	
134.80		Railroad crossing.

1.55

136.35 Road to Brinsmade to the west.

2.00

138.35 Indistinct washboard moraines of Leeds lobe. These moraines, which can be seen more clearly on aerial photographs, are mostly arcuate to the northeast and indicate recession of the Leeds lobe in that direction in this area. (See paper on "Narrow linear drumlin near Velva, North Dakota" for discussion of washboard moraines and related features as indicators of direction of ice movement.)

4.40

142.75 Junction with Highway No. 2. Turn west. We are travelling on ground moraine of Leeds lobe.

10.20

152.95 East limit of town of Leeds. Note on Plate 1 (in pocket) that north of Leeds there are linear drumlins that trend southwest and also numerous washboard moraines that are arcuate to the northeast. These features indicate that the ice of the Leeds lobe in this area advanced from the northeast and retreated in the same direction. These features are too indistinct to be seen from the highway and can best be seen on aerial photographs.

6.55

159.50 East limit of York.

1.70

161.20 Approximate proximal edge of a relatively small recessional moraine of the Leeds lobe (see Plate 1 in pocket).

1.25

162.45 Distal edge of the recessional moraine.

2.40

164.85 Proximal edge of a narrow sharply defined recessional moraine of the Leeds lobe.

.55

165.40 Distal edge of the recessional moraine.

.25

165.65 Knox.

2.50

168.15 Proximal edge of terminal moraine of the Leeds lobe.

.80

168.95 Kame to the south (not shown on Plate 1). The kame consists chiefly of sand and fine gravel. Granitic and gneissic rock types are most abundant followed by carbonate rocks. There are some shale chips but no lignite chips.

1.50

170.45 Approximate distal edge of terminal moraine of Leeds lobe. In this area and to the north and northeast it is difficult to separate the drift of the Leeds lobe from that of the Souris River lobe. Separation is made mostly on the basis of the orientation of the arcuate washboard moraines and of the linear drumlins and on the basis of the slight difference in composition of the till of the two lobes. The washboard moraines of the Leeds lobe in this area are mostly arcuate to the northeast and the trend of the linear drumlins is to the southwest. The till of the Leeds lobe is clayey and contains numerous chips of Pierre shale, but few lignite chips. The washboard moraines of the Souris River lobe, on the other hand, are mostly arcuate to the northwest and the linear drumlins trend southeast indicating that the ice of that lobe advanced from the northwest and receded back in the same direction. The till of the Souris River lobe contains only a few shale chips but contains numerous chips of lignite derived from the Fort Union formation over which the glacier passed.

Northeast of the area we are now riding over there was apparently some overlapping of the deposits of the Leeds and Souris River lobes as indicated by the conflicting pattern of washboard moraines and linear drumlins (see Plate 1 in pocket). Thus the boundaries of the two lobes as shown on the map are somewhat arbitrary.

.80

171.25 Broken Bone Lakes. Outcrop of Fox Hills sandstone (?). This outcrop of bedrock is found in a narrow strip presumably lying between the terminal moraines of the Leeds lobe and the end moraines of the Souris River lobe where only a small amount of drift has been deposited. Elsewhere in this area the drift cover in most places exceeds 100 feet.

.25

171.50 Approximate distal edge of end moraine of Souris River lobe. The proximal edge of this moraine is not well defined and grades imperceptibly to the west into swell and swale topography of the ground moraine of the Souris River lobe.

5.70

177.20 Crest of small discontinuous recessional moraine of the Souris River lobe.

3.45

180.65 Rugby. Monument marking geographical center of North America.

GAS STOP

5.20

185.85 Road to Tunbridge.

6.00

191.85 East shoreline of glacial lake Souris. Note flat topography of the lake bottom to northwest. Most of the next 40 miles will be on the lake floor. For glacial history of the lake refer to paper on "Glacial history of the Souris River area, North Dakota".

.60

192.45 Berwick.

7.50

199.95 Towner.

5.00

204.95 Souris River. The Souris River flows into the United States from Canada about 60 miles northwest of Minot. Thence, it flows southeast nearly to Velva where it bends northeastward and then northward to again enter Canada about 60 miles northeast of Minot in the vicinity of Westhope. Its waters finally empty into Hudson Bay. The Souris River and its tributary the Riviere des Lacs were cut in Pleistocene time and were ice marginal streams to as far downstream as Verendrye during recession of the Souris River lobe. In the vicinity of Verendrye the meltwaters of the Souris River during deglaciation of the Souris River lobe drained into glacial Lake Souris. It was only during the final drainage of the lake northward and subsequently that the segment of the river downstream from Verendrye came into existence. This accounts for the lack of well-defined valley walls in the lake area in contrast to the river being entrenched in a valley 100 to 150 feet below the upland in the segment upstream from Verendrye.

1.90

206.85 Ice contact deposit (not shown on Plate 1) laid down in the lake. This deposit was probably laid down in shallow waters of the lake and spread out by wave action as a nearly flat-topped north trending ridge that is 5 to 15 feet high, less than a mile long and 1/4 mile wide. The deposit consists chiefly of fine gravel and sand but also contains medium size gravel and cobbles.

.65

207.50 Beginning of dune area (not shown on Plate 1). These dunes are most prevalent in the southern part of the bed of glacial Lake Souris. Individual dune groups range in areal extent from small patches a few hundred yards long to large tracts several miles long and 1 to 2 miles wide. Each dune group consists of closely spaced or partly coalesced individual dunes. Both individual dunes and dune groups are elongate in a northwesterly direction. Individual dunes range in height from barely perceptible rises to features as much as 50 feet high. The dunes, the material of which was derived from the floor of glacial Lake Souris, probably began to form soon after the lake drained. Most are now fairly stable but are slowly migrating southeast.

.50

208.00 Higher dunes to the north about 1/2 mile.

.20

208.20 "Blowout" area. Source of some of the dune material. Most of the "blowout" areas are confined to sand size material from toward the western shoreline of glacial Lake Souris.

1.30

209.50 Kames to the north. These were deposited in the lake but were not completely submerged.

.20

209.70 Conspicuous dunes to the south.

.8

210.50 Denbigh.

2.95

213.45 Sandhills Experiment Station to the south. Studies are being conducted at this station in connection with dune stabilization. An auger hole in this area penetrated 73 feet of sand and ended in bluish gray unoxidized till of unknown thickness. No lake clays or silts were encountered.

4.20

217.65 Hills to the north are kames (not shown on Plate 1). One of these, Buffalo Lodge Butte, is a kame 125 feet high. The presence of an indistinct shoreline about 35 feet above the base of the deposit shows that the kame was deposited in the lake but was for the most part not submerged. A gravel pit on the crest of the kame exposes poorly sorted sand and gravel. The beds are tilted nearly parallel to the slope of the hill and are cut by small faults and other collapse features Till is exposed along the bottom 25 feet of the eastern side of the feature; possibly the core of the hill also consists of till.

4.15

221.80 West shoreline of glacial Lake Souris. Although not very conspicuous, this is one of the best defined parts of the entire shoreline of the lake.

In most other places there is an almost imperceptible change from lake floor to surrounding ground moraine and the limits of the lake can be determined only on the basis of change in lithology - from sand of the lake deposits to till of the ground moraine.

From here nearly to Minot we will be riding on nearly level ground moraine of the Souris River lobe modified by numerous relatively small bifurcating outwash channels. The ground moraine in the Souris River area, in most places, is unusually thick in comparison with other glaciated areas in the Great Plains. In general it is thinnest near the Max moraine and thickens progressively to the northeast. In the area we are now crossing it is 100 to 150 feet thick. North of Mohall it is about 250 feet thick and in some buried channels it exceeds that thickness.

The numerous bifurcating outwash channels are related to a series of long rough parallel southeast draining outwash channels (see Plate 1 in pocket) that were formed in successive ice-marginal positions along the southwest flank of the northwest receding Souris River lobe (see paper "Summary of glacial history of the Souris River area, North Dakota"). The regional slope in this area is to the northeast so that the meltwaters in the channels were forced to flow normal to the regional slope. These large ice-marginal channels are commonly 40 to 70 miles long, half a mile to more than a mile wide, 10 to 30 feet deep, and are mostly flat-floored or have gently rounded bottoms. Channel segments that are flat floored generally contain 5 to 15 feet of sand and gravel whereas segments having gently rounded bottoms are mainly incised in ground moraine and are floored with only a thin veneer of outwash.

.60

222.40 Granville.

15.20

237.60 Surrey. (Not shown on Plate 1)

6.35

243.95 East city limits of Minot.

1.50

245.45 Highway No. 2 and Main Street.

GAS UP HERE TONIGHT - DINNER 7:30 at the CLARENCE PARKER HOTEL.

SECOND DAY

Corner of Main Street and Highway No. 2. Go east.

.35

245.80 Turn right on Highway No. 52 at west end of overpass.

.75

246.55 STOP #5. Cross railroad and stop at till outcrop. This is till of the Souris River lobe. Note that the till is not very stony. About 25 percent is of clay size, 40 percent of silt size, 30 percent sand size, and 5 percent gravel size or larger. Carbonate rocks predominate and granitic and gneissic rocks are next in order of abundance. Lignite chips are fairly abundant in contrast to the till of the Leeds lobe in which lignite chips are rare. Intercalated lenses of sand and gravel and silt are present in the till. The till in the exposure is oxidized but unleached. The oxidized buff till generally extends to depths of 30 to 50 feet. The underlying unoxidized till is bluish gray. Note vertical prismatic fractures, characteristic of till with a fairly high clay content. See paper "Two tills in the Donnybrook area" for comparison with an older till. Upon leaving the till outcrop we will be proceeding down the valley of the Souris River, a valley cut in Pleistocene time but prior to the last glaciation as shown by the fact that till mantles the bedrock walls and underlies valley fill more than 100 feet in thickness.

1.15

247.70 Coming up onto a glacial terrace.

.70

248.40 Cross new Highway No. 52.

.35

248.75 STOP #6. Turn left into Soo Line gravel pit in large glacial terrace. This is one of a number of terrace remnants along the valley walls of the Souris River upstream from Verendrye and also along the valley of the Riviere des Lacs. The terraces were formed by ice-marginal streams flowing along the southwest side of the northwest receding Souris River lobe and they range in altitude from about 1800 feet along the upper reaches of the Riviere des Lacs to about 1470 feet in the vicinity of Verendrye. Some grade to the three large diversion channels southeast from Velva. Some terrace surfaces are completely studded with boulders concentrated by erosion of the upper surfaces of the terraces by late meltwaters that removed the finer material and left the boulders. However, the terrace here at the Soo Line gravel pit is nearly flat and contains few boulders on the surface although boulders as much as 8 feet in length are found in the deposits. Pieces of lignite are found throughout the deposits. A terrace deposit 2 miles west of Minot contains conspicuously large chunks, many 1 to 4 feet long. One chunk weighed 2 tons and was burned as fuel. Nearly all chunks are roughly tabular and have relatively sharp edges and show little evidence of transportation for more than short distances. The marked angularity of the lignite chunks, the large size of the boulders, and other evidence (to be discussed orally) suggest that all or parts of the deposits may be kame terraces. On the other hand there is little or no evidence of collapsed bedding characteristic of kame terraces.

.60

249.35 Cross new Highway No. 52. Keep on old highway.

.60

249.95 Coming off terrace into valley bottom. Upper two-thirds of valley walls consist of till underlain in most places by 1 to 15 feet of sand and gravel representing a buried kame terrace characterized by collapsed bedding. The kame terrace deposits are underlain by 20 to 50 feet of till identical in general appearance and composition to the till overlying the kame terrace deposits. It has not been determined whether the underlying till belongs to an older substage of glaciation or whether the kame terrace was formed during a minor recession of the last substage of glaciation. The lower one-third of the valley walls consist of the Fort Union formation thinly veneered by till in most places.

1.30

251.25 Pit on the right exposes partially exhumed kame terrace deposit of sand and gravel that exhibits extreme deformation of bedding due to collapse of one or more supporting ice walls. Deposit is overlain by till. Building to the east is the Buffalo Steam Plant.

.80

252.05 Join new Highway No. 52.

3.25

255.30 Route to Logan.

3.45

258.75 Small landslide on valley wall to the right. Landslide formed by sliding of till on bedrock.

3.20

261.95 North limit of Sawyer.

.30

262.25 Turn left (northeast).

.10

262.35 Railroad crossing.

.30

262.65 Bridge across the Souris River. Ten ton load limit.

.30

262.95 High level diversion channel through which the meltwaters flowed when the Souris River valley at Sawyer was still blocked by ice and water was diverted out of the valley for a distance of about two miles.

.85

263.80 Turn right at cemetery. Riding over typical ground moraine of Souris River lobe.

1.05

264.85 Look to the South. Due south one-half mile is a conical-shaped kame (known as Black Butte) that is 115 feet high, about one-third mile in diameter, and consists of poorly sorted sand, gravel, till balls, and intercalated till lenses. The bedding of the sand and gravel is roughly parallel to the slope. A small undrained depression at the top of the kame shows that the feature has not been lowered to any extent by erosion. This may be a moulin type of kame.

.75

265.60 Turn around in farm yard and return to Sawyer.

1.80

267.40 Cemetery at right.

1.40

268.80 Railroad crossing.

.10

268.90 Turn left on Highway No. 52.

1.30

270.20 Cannonball member of the Fort Union formation poorly exposed on the right. This member was first recognized by R. W. Brown and R. W. Lemke in 1947. Prior to this time the northernmost known outcrop was along the Missouri River in the vicinity of Washburn, North Dakota. The presence of sharks teeth and other marine fossils, including diagnostic foraminifera distinguish it readily from the continental Tongue River member of the Fort Union formation.

4.70

274.90 City limits of Velva.

.70

275.60 Rising out of the Souris River valley and riding into the Velva diversion channel. The channel was formed by meltwaters that flowed down the valley of the Souris River and were diverted out of the valley by ice of the Souris River lobe that still covered the valley below Velva. The water was diverted along the southwest flank of the ice lobe and into the southern part of Glacial Lake Souris which was just coming into existence. Upon further melting back of the southwest flank of the ice lobe, the Velva diversion channel was abandoned and the slightly lower Lake Hester diversion channel (see Plate 1 in pocket) came into existence marginal to the ice. Upon still further recession of the flank of the ice lobe the Lake Hester diversion channel was abandoned and the somewhat lower Verendrye diversion channel was incised. During the early life of this last channel, the meltwaters drained southeastward into the southern part of glacial Lake Souris. During the later life of the channel, the waters drained eastward into the lake which had by this time expanded northward. Still later the Verendrye channel was abandoned and water flowed directly down the Souris River valley and emptied into the lake about 7 miles northeast of Verendrye.

1.70

277.30 The east wall of the Velva diversion channel is due east about 1/2 mile where the white house is located.

.85

278.15 Turn right at Central Power Electric Co-op steam plant. This plant furnishes power for 8 REA Co-ops in central North Dakota. Up to 660 tons of lignite is burned to make the peak production of 44,000 KW per hour.

1.15

279.30 Railroad crossing.

.55

279.85 Outwash channel to left. We are now driving over a ground moraine plain that is rising 60 to 80 feet to the mile toward the Martin moraine (about 8 miles to the south and just barely visible on the skyline).

2.95

282.80 Turn right (west).

2.00

284.80 Turn left (south).

1.70

286.50 Three miles to the west is the Truax-Traer Coal Company Lignite strip mine. Forty to seventy feet of overburden is stripped for about 13 feet of lignite. This is one of the largest lignite mines in North Dakota. North Dakota produces about 90% of the total lignite production in the United States.

1.50

288.00 Escarpment of the proximal edge of Martin moraine, about 1 mile southwest.

1.40

289.40 Starting up proximal edge of Martin moraine. To the right is a re-entrant that marks position of a buried channel of probably pre-Pleistocene age. For about the next 15 miles you will be driving on the Martin moraine. Townsend and Jenke (1951, p. 842-858) have designated the conspicuous morainal belt, 10 to 25 miles wide and extending from the vicinity of Bismarck to several hundred miles northwestward into Canada, as the Max moraine. Throughout its length the moraine is the surface deposit of the Coteau du Missouri. In the past the moraine has been referred to variously as the Altamont moraine, Altamont terminal moraine, an end moraine, a terminal moraine, so-called Altamont moraine, and Coteau du Missouri. It is also known locally as "The Hills" or "Coteau". Townsend and Jenke (op. cit.) introduced the name "Max moraine" to avoid genetic connotations and to leave room for future differentiation. The moraine is not continuous with the true Altamont moraine in South Dakota and the two are not believed to be correlative. See paper "Summary of the Pleistocene geology of North Dakota."

The Martin moraine in this area rises 200 to 300 feet above the surrounding ground moraine plain. The proximal edge is marked by a fairly abrupt escarpment whereas the distal edge tends to merge rather imperceptibly into ground moraine. Much of the altitude of the Martin moraine is due to the greater height of bedrock under the moraine than under the surrounding ground moraine. As a result in most places the drift composing the moraine is probably not any thicker than that composing the ground moraine to the north.

Souris River lobe, the last phase of this glaciation, is interpreted to have extended in places onto the Coteau du Missouri and, therefore, deposits of that lobe, locally, constitute part of the Max moraine.

3.65

293.05 Crossing into McLean County.

	.60	
293.65		Town of Ruso.
	.25	
293.90		Railroad crossing.
	.10	
294.00		Turn left (east).
	5.90	
299.90		Turn right (south).
	.60	
300.50		Turn left (east).
	1.90	
302.40		At right is Dogden Butte, a conspicuous morainal covered hill which has a bedrock core.
	.60	
303.00		Start down abrupt escarpment of proximal edge of Max moraine.
	.30	
303.30		Sandstone of the Tongue River member of the Fort Union formation in road cut to the right. This bedrock exposure together with numerous bedrock exposures high up on the Coteau du Missouri indicates that the Max moraine owes much of its elevation to underlying bedrock.
	.50	
303.80		Base of escarpment. We are now driving over ground moraine of the Souris River lobe.
	3.15	
306.95		Turn left into Butte. REST STOP.

.40

307.35 Turn right.

.20

307.55 Turn left.

1.00

308.55 Crossing southeast trending esker.

.60

309.15 Series of coalescent kames on both sides of road.

.50

309.65 Steep-walled kettle on left.

1.05

310.70 Cottonwood Lake on left. Lake probably occupies a kettle hole.

1.30

312.00 Kame one half mile to left (west).

.40

312.40 We are now in a shallow southeast trending meltwater channel that is about ½ mile wide that has very indistinct walls.

4.75

317.15 Entering a glacial meltwater channel that flowed to southeast.

.95

318.10 Crossing a southeast trending linear drumlin.

.10

318.20 Entering a southeast trending diversion channel that is about one-half mile wide. This channel was first incised by water flowing down the Velva diversion channel and later was used by water flowing down the Lake Hester diversion channel. The lakes fill depressions left by chunks of ice, stranded and partially buried in the floor of the channel, and melting after the channel was abandoned.

.70

318.90 Junction with Highway No. 52. Turn left.

.50

319.40 Turn right.

.10

319.50 Northeast wall of diversion channel.

2.10

321.60 Turn left (west).

.90

322.50 Turn right (north).

3.10

325.60 Turn right (east).

.20

325.80 Crossing a southeast trending sinuous esker. Deposits of the esker consist of poorly sorted gravel and intercalated till lenses.

.50

326.30 STOP #7. We are now on crest of the longest and most conspicuous linear drumlin. This drumlin extends in a straight line southeast from the Souris River valley at Verendrye for a distance of 13 1/2 miles. It is breached in two places near Verendrye by gaps eroded by meltwater flowing down the Verendrye diversion channel and in one place by a small tunnel valley (half a mile northwest of where we now are) cut by a subglacial stream that formed the esker that we just crossed. The drumlin decreases in height from about 50 feet near its

Stoss end (northwest end) to less than 5 feet near its lee end. Throughout much of its length it is about 30 feet high, is evenly and sharply crested and has a remarkable symmetrical cross-profile. It resembles nothing so much as a large railroad or highway grade. Its average base width is about 300 feet which gives it a length to width ratio of about 240 to 1, At the southeast end of this drumlin and slightly an echelon to it is a second ridge, about 3 miles long, which extends to a point about 1 1/2 miles southeast of Balfour. The drumlin we are now on appears to consist predominantly of stratified sand and incorporated irregular bodies of till. Till also forms the flanks of the ridge and in some segments the upper 2 or 3 feet of the crest. The incorporated till bodies and the till forming the surface deposits range from compact till similar to the adjacent ground moraine to a predominantly sandy till that contains just enough clay to bind it. Some of the till has an indistinct fissile pressure structure. Figure 5 of the paper entitled "Narrow linear drumlins near Velva, North Dakota" (in pocket of guidebook) shows a cross section of the drumlin at our present location as reconstructed from 11 auger holes. The paper also discusses the relation of the linear drumlins to the linear grooves and to the arcuate washboard moraines as well as the problem of the origin of the drumlins.

1.50

327.80 Crossing a low linear drumlin. Drumlins less than 5 feet high in this area appear to consist entirely of till similar in composition to that of the intervening ground moraine. From here eastward we will be crossing some very shallow linear grooves that are parallel to the drumlins. Most, however, are too indistinct to see without the aid of aerial photos.

.60

328.40 Crossing a low linear drumlin.

.10

328.50 Entering a branch of the Verendrye diversion channel.

.15

328.65 Turn right (south).

.10

328.75 Outwash gravel of diversion channel.

1.90

330.65 Note large linear drumlin to west about one-half mile. This is same drumlin as at previous stop.

.85

331.50 Note small linear drumlin on flank of larger drumlin.

.20

331.70 Crossing continuation of large drumlin of Stop #7. Note that ridge here consists of sand and fine gravel.

3.30

335.00 Turn left.

.25

335.25 Railroad crossing.

.05

335.30 Highway No. 52. Turn left (east).

4.20

339.50 Turn right (south).

.20

339.70 Turn left (east).

.15

339.85 STOP #8. LUNCH STOP. Road cut through linear drumlin. This drumlin is about 3 miles long and is the one that lies slightly en echelon to the conspicuous drumlin of the last stop. Figure 4 of the paper on linear drumlins shows a cross section of the ridge as exposed in the southeast side of the roadcut. The northwest side of the roadcut is poorly exposed but appears to consist almost entirely of sand.

.15

340.00 Balfour. Continue eastward on Highway 52. You may proceed with the group from this point on, or at your own pace as you may prefer.

2.80

342.80 Verendrye diversion channel. Glacial meltwaters flowed southeast.

.95

343.75 Confluence of Velva-Lake Hester diversion channel (to right) and Verendrye diversion channel (to left).

1.00

344.75 Bentley Lake to right.

3.05

347.80 Drake on the left. We are travelling on ground moraine of the Souris River lobe.

6.40

354.20 Southeast draining glacial channel of Souris River lobe.

.85

355.05 Town of Anamoose. We are now starting up proximal edge of Martin moraine which is the terminal moraine of Souris River lobe. We will be on this moraine for the next 10.7 miles. Esker complex to the left about half a mile away.

6.85

361.90 Martin.

3.30

365.20 Distal edge of Martin moraine which marks outer limit of advance of Souris River lobe. From here eastward we will be driving over ground moraine deposited by ice that advanced from the northwest prior to the advance of the Souris River lobe.

5.80

371.00 Harvey city limits. GAS STOP.

1.50

372.50 North Fork of Sheyenne River - first incised as an outwash channel.

7.50

380.00 Note proximal edge of the Coteau du Missouri ahead and to the right about six miles.

.70

380.70 Junction with Highway No. 3.

14.30

395.00 Fessenden city limits. A few washboard moraines can be seen south of Fessenden.

3.80

398.80 Low kame with gravel pit to left (east).

3.80

402.60 Crossing Rocky Run, and outwash channel. Meltwater flowed eastward.

	5.80	
408.40		Junction with Highway No. 7. Proceed east on 7 and 52.
	3.90	
412.30		Crossing an outwash channel that is a tributary of Pipestem Creek.
	6.75	
419.05		Sykeston to left.
	1.40	
420.45		The Coteau du Missouri is 8 to 10 miles to the south.
	5.70	
426.15		Crossing Pipestem Creek outwash channel which drained southeast to James River.
	5.70	
431.85		Carrington city limits.
	1.15	
433.00		Turn left.
	.55	
433.55		Turn right (east) on Highway No. 7. The land surface is ground moraine of the Leeds lobe.
	11.40	
444.95		Starting up onto low end moraine which becomes higher to the east.
	1.55	
446.50		Starting up onto more distinct end moraine bordering the James River on the west.
	1.80	
448.30		Recessional moraine. Begin to cross glacial outwash channel of the James River. This channel was incised by meltwaters draining from

the Leeds lobe.

.50

448.80 Terrace along James River. Only a thin veneer of outwash.

.40

449.20 Coming off terrace and starting up onto ground moraine, and then onto the Kensal moraine. There are many well developed washboard moraines in this area.

10.05

459.25 Railroad crossing.

.55

459.80 Glenfield. Junction with Highway No. 20.

8.20

468.00 Bald Hill Creek outwash channel which flowed southeast into Sheyenne River.

3.30

471.30 Outwash.

.95

472.25 Junction with Highway No. 1.

1.30

473.55 Starting up indistinct distal edge of Cooperstown moraine.

1.75

475.30 Indistinct esker.

.85

476.15 Esker - mostly removed for road material.

.40

476.55 Small indistinct esker. For a number of miles between here and

		Cooperstown there are numerous stratified ice-contact deposits.
	1.35	
477.90		STOP #9. Approximate proximal edge of Cooperstown moraine.
	.65	
478.55		Junction, Highway 1 goes south. Continue east on #7.
	.30	
478.85		Kame.
	1.15	
480.00		Kames to left (north).
	.70	
480.70		Cooperstown.
	4.65	
485.35		Sheyenne Valley. Note Pierre shale outcrop on both sides of valley. Also note high terrace about 50' above present valley. This channel drained Glacial Lake Souris down to an elevation of 1510'.
	4.45	
489.80		Ascending Alta ridge. (Fergus Falls moraine of Upham).
	2.50	
492.30		Leaving Alta ridge.
	2.45	
494.75		Turn left (north).
	4.75	
499.50		Entering Finley.
	.55	
500.05		Turn right (east) on Highway 7.

	8.90	
508.95		Middle branch of the Goose River.
	1.30	
510.25		Edge of Glacial Lake Agassiz, Herman shoreline. Upham's map shows this as part of Elk Valley delta.
	4.95	
514.20		Exposure of lake silt.
	2.70	
516.90		Tintah Beach (?) according to Upham.
	.65	
517.55		Junction with Route 18 continue on #7 south and east.
	3.30	
520.85		Branch of Goose River, Campbell beach crosses near here according to Upham map.
	1.30	
522.15		Entering Portland.
	2.20	
524.35		Entering Mayville.
	7.65	
532.00		Gravel pit in Blanchard beach. We are now back in the area of the ice lobe that advanced from the northeast. Leverett mapped a moraine in this vicinity.
	4.90	
536.90		Junction Route 81. Turn north on 81.
	1.05	
537.95		Road west to Cummings.

	2.00	
539.95		Gravel deposits associated with Hillsboro beach. Configuration here suggests bar or spit extending eastward into lake.
	3.90	
543.85		Hillsboro beach indistinctly shown here. Road to Buxton to left.
	5.30	
549.15		Road to Reynolds.
	7.10	
556.25		Road to Thompson.
	9.20	
565.45		South city limits of Grand Forks.

Summary of the Pleistocene geology of North Dakota [1]

by Richard W. Lemke and Roger B. Colton

INTRODUCTION

All of North Dakota, with the exception of the southwestern corner, was glaciated during the Pleistocene epoch. No definite evidence of pre-Wisconsin glaciation has been found in the state but glacial deposits tentatively identified as ranging in age from the Iowan substage of the Wisconsin to at least the Two Creeks interstadial have been recognized. Because of the difficulty of differentiating the glacial drift sheets on the basis of lithology, color, or degree of weathering, the absence of loess deposits interbedded with the drift sheets, and the paucity of radiocarbon dates, it must be emphasized that the Pleistocene chronology expressed in this paper is tentative and subject to revision as more data become available.

The facts and interpretations presented here are based in part upon glacial studies by numerous workers in and adjacent to North Dakota, as well as upon the results of mapping about 10,000 square miles by the writers. Although the writers have drawn freely upon these many other sources, the responsibility for the final interpretations rests with the writers. Of the 10,000 square miles mapped in detail, Lemke mapped approximately 6,000 square miles in the Souris River area and Colton mapped about 4,000 square miles in northeastern Montana which contributed to a better understanding of the glacial history in North Dakota. In addition, the writers made numerous automobile traverses across the State and made aerial photo interpretation studies in connection with the compilation of the glacial map of the State.

PHYSICAL SETTING

The eastern and northern parts of North Dakota lie in the Western Lake section of the Central Lowland; the remainder of the State lies in the Missouri Plateau section of the Great Plains province (see fig. 1). The northeastern strip of the Missouri Plateau is known as the Coteau du Missouri. Its prominent northeast-facing escarpment rises 300 to 500 feet above the adjacent Central Lowland. The Coteau du Missouri in most places owes much of its prominence to topographically high underlying bedrock that acted as a buttress to advancing ice sheets and influenced the areal distribution and land form characteristics of the drift deposited on and beyond it. The Turtle Mountains, a drift-covered mesa-like bedrock-cored highland, lying partly in Canada and partly in North Dakota, controlled the direction of movement of the last ice sheet that advanced into the area. The Lake Agassiz basin, the Devils Lake basin, the Souris River basin, and the Lake Dakota basin are topographically low areas that served as catchment areas for glacial lakes.

PREGLACIAL DRAINAGE

Flint (1955, pl. 7) has demonstrated by his work in South Dakota that the Cheyenne River and all streams north of it flowed into Hudson Bay in preglacial time. Work in North Dakota has substantiated this interpretation. Figure 2 shows the preglacial drainage pattern in North Dakota as interpreted from studies by Alden (1932, map, pl. 1), Benson (1952, p. 165-175), the writers, and others.

Drill-hole data and detailed geologic mapping indicate that the ancestral Missouri and Yellowstone rivers flowed northeastward across the northwestern corner of the State. They were deeply incised where they cut through the Coteau du Missouri; the bottom of the buried channel of the preglacial Yellowstone near Crosby is more than 500 feet below the present surface. Meneley, Christiansen, and Kupsch (1957, p. 441-447), believe that the two rivers joined about 15 miles northeast of the International Boundary. Downstream from their confluence, the flow of the combined streams was to the east and northeast.

The ancestral Knife River and its tributaries headed in the southwest part of the State. The indicated course of this stream was northeast across the Coteau du Missouri through a deep valley. A low sag, known as the Lincoln Valley sag (see pl. 1, in pocket), marks the buried channel. Beyond the Lincoln Valley sag, the channel is completely obscured by ground moraine and its trend has not been determined. It may extend eastward to join a buried valley under Devils Lake or it may extend northwestward to become the ancestral Souris River.

The ancestral Souris River, which flowed northward and probably joined the ancestral Missouri-Yellowstone River a few miles north of the International Boundary, trended roughly parallel to and a few miles west of the east loop of the present Souris River.

The tributaries of the ancestral Red River probably consisted of the ancestral Grand, Moreau, and Cheyenne rivers that headed in northern South Dakota, and possibly the ancestral Knife and Cannonball rivers in North Dakota. The combined tributaries, as pointed out by Flint (1955, pl. 7), flowed eastward to the James River lowland and then northward into the southeastern corner of North Dakota. The Red River then flowed northward (its channel location not accurately known) beneath the present floor of Lake Agassiz and entered Canada along a course probably coincident with the present channel of the Red River. Work by Horberg and Anderson (1956, fig. 1) and Elson (unpublished Ph. D. thesis, Yale University) show that the river probably joined the ancestral Missouri-Yellowstone River in Manitoba about 75 miles north of the International Boundary.

PRE-WISCONSIN DEPOSITS

North Dakota might have been glaciated in pre-Wisconsin time. A few scattered granitic boulders have been found several miles beyond the Iowan drift border as mapped by W. E. Benson (written communication). However, the presence of some of these boulders can be explained by ice rafting in a lake west of the Iowan ice, or by having been brought in by man. Boulders in other localities whose presence cannot be explained by either of the above two methods might have been derived from the White River formation of Tertiary age which, according to Benson, contains a few granitic rocks from the Black Hills.

Evidence of Illinoian stage glaciation in South Dakota was presented by Warren (1952, p. 1143-1156) and accepted by Flint (1955, p. 30) who placed the Illinoian drift border along the east side of the Missouri River in that State. If this interpretation is correct, at least the southeastern part of North Dakota also was glaciated in Illinoian time.

WISCONSIN STAGE

General Statement

A review of recently published literature of the Pleistocene of the midwest indicates that there is considerable divergence of opinion on correlating and dating Wisconsin drift sheets. Moreover, recent changes in nomenclature and changes in stratigraphic position of formerly accepted terminology have added to the problem (table 1). Because of the paucity of radiocarbon dates in North Dakota and the uncertainty of being able to accurately correlate drift borders mapped in that State over long distances eastward and southeastward to type or dated localities, the writers feel that many of these problems cannot now be properly evaluated in the State. Thus, the presence or absence of Farmdale loess in the State, especially in view of the present uncertainty of whether it is pre-Iowan or post-Iowan as suggested by Ruhe, Rubin, and Scholtes (1957, P. 671-689) cannot now be ascertained. Likewise, the writers can only speculate on the validity of adding another substage, the Mankato as used by Leighton (1957, p. 1-2), between the Cary substage and the Two

Creeks interstadial. Moreover, discrepancies still remain to be resolved in the dating and the lateral tracing northwestward from Wisconsin of the Valders drift border to Thwaites (1943, p. 87-144) and in determining its equivalency with drift formerly mapped elsewhere as Mankato (post-Two Creeks interstadial). Part of this problem is pointed up by the following differences in interpretation: (1) Leighton suggests (1957, p. 1-2) that the Big Stone moraine in west-central Minnesota marks the outer border of the Valders of Thwaites (1943); (2) Wright (1957, copy of a paper presented at Fifth Congress of the International Quaternary Association, Madrid) indicates that the Valders border extends via the Superior lobe to Mille Lacs Lake in central Minnesota and, thence, toward northwest Minnesota as the margin of the St. Louis lobe--presumably north of the drift border suggested by Leighton; and, (3) Elson's (1957, p. 999-1002) interpretation that the Valders ice border never reached Minnesota but extended northward across Lake Superior, past the west side of Lake Nipigon, north-northwest to Sachigo Lake, and thence west to the Pas moraine in west central Manitoba. Apparent inconsistencies in radiocarbon dates for the age of Lake Agassiz and the lack of knowledge of the age of the glacial deposits in northwestern Minnesota further complicate the problem of using midwestern nomenclature in North Dakota. However, a number of strong end moraines can be correlated between North Dakota and adjacent States and also northward into Canada. These correlations will be discussed under appropriate headings.

Figure 3 2/, shows the outer margin of Wisconsin glaciation as tentatively interpreted, and the limits of major ice advances within that stage in North Dakota, South Dakota, and northeastern Montana. Seven distinct advances of glacier ice are indicated in North Dakota (fig. 4) on the basis of positions of prominent end moraines and ice marginal channels, of crosscutting relations of washboard moraines, drumlins, and eskers, and on the relative development of established integrated drainage.

Figure 5 shows the prominent end moraines of these advances. Because of the problems already expressed in correlating drift sheets in North Dakota with present midwestern nomenclature, the drift sheets will be discussed under the following headings: (1) Iowan (?) drift; (2) Tazewell (?) drift; (3) post-Tazewell - pre-Two Creeks drifts; and, (4) post-Cary maximum drifts. This method of presentation is intended only for discussion purposes and in no way constitutes a proposal for a new terminology for subdividing the Wisconsin.

Iowan (?) drift

The outermost border of Wisconsin drift, the position of which is based largely upon the work of Benson (1952, p. 184-194) and A. D. Howard (written communication), is drawn in most places upon the southernmost limit of glacial erratics which are sufficiently abundant to fix fairly accurately the position of the drift border. This drift, according to Benson is Iowan in age. It correlates with the Iowan drift as interpreted by Flint (1955, p. 95) in South Dakota and by Ruhe in southwestern Minnesota and in Iowa (Flint, 1955, p. 95; Ruhe, 1952, Fig. 1; Ruhe, Meyer, and Scholtes, 1957, p. 672). In Iowa, radiocarbon dates support this assignment.

The Iowan (?) drift sheet is exposed in North Dakota in a northwest-trending belt, interpreted by the writers to be in most places 20 to 40 miles wide, that lies mostly south of the Missouri River. The till over most of this belt is thin and patchy owing to erosion and nondeposition. The advance of the ice over much of the area can be attested to only by the presence of erratic boulders and scattered stratified ice-contact deposits. The orientation of the drift border and the position of the ice-marginal channels suggest that ice of this substage advanced from a northeasterly direction.

Tazewell (?) drift

The area of exposed Tazewell (?) drift in North Dakota, as tentatively interpreted, lies mostly north and east of the Missouri River and forms a belt 15 to 30 miles wide in most places. The ice of this drift sheet seems to have advanced from the northeast except in the northwestern part of the State where the advance is indicated from the position of moraines to have been from the north and northwest. A thin to moderately thick blanket of till covers most of the area and integrated drainage is fairly well established.

Benson (written communication) did not attempt to separate the Tazewell drift from the Iowan drift. The writers suggest that the Krem moraine (fig. 5) mapped by Benson in Mercer County and the moraine mapped by A. D. Howard (written communication) in northern McKenzie County might represent end moraines of the Tazewell substage. This interpretation is based on the tenuous evidence that these hummocky morainal areas have a less integrated drainage pattern than drift further to the south.

As now interpreted by the writers, this drift is completely overlapped a few miles north of the North Dakota-South Dakota boundary in McIntosh County by drift of one or more younger ice advances. Flint (1955, pl. 1) shows no exposed Tazewell drift on the western side of the lobes that moved down the James River Lowland in South Dakota. However, he does show a band northeast of the Sioux River in the northeastern part of that State which has been correlated with the Tazewell drift in Iowa (Flint, 1955, p. 95; Ruhe, 1952, fig. 1; Ruhe, Meyer, and Scholtes, 1957, p. 672). Whether this is the same drift that the writers interpret to be Tazewell in North Dakota is conjectural but the correlation seems reasonable.

Post-Tazewell - pre-Two Creeks drifts

A series of prominent northwest trending end moraines (includes the Burnstad, Belden, White Earth, and Alamo moraines shown on fig. 5), that extends from the south-central to the northwestern part of the State, mark the margin of a drift sheet whose youthful topography is in marked contrast to the Tazewell (?) drift to the southwest. The hummocky moraines and associated ground moraine deposits of this drift show little integration of drainage in contrast to the well integrated drainage established on the Tazewell (?) drift. The drift border, thus established can be easily differentiated on aerial photographs and when traced into South Dakota forms the outer margin of the drift sheet mapped as belonging to the Mankato[3/] substage by Flint (1955, p. 95), which correlates with the Altamont moraine in northeastern South Dakota, southwestern Minnesota, and with that moraine in the Des Moines lobe in Iowa (Flint, op. cit.; Ruhe, Rubin, and Scholtes, 1957, p. 672). Ruhe, Rubin and Scholtes (op. cit.) show by radiocarbon dates that the Altamont moraine in Iowa marks the margin of the Mankato as used by Leighton (1957b, p. 1037-1038). Flint (op. cit., p. 78) states that the Mankato in South Dakota was identified by tracing it from Mankato, Minn. The drift at Mankato, Minn., on the basis of radio-carbon dating (Ruhe, Rubin, and Scholtes, op, cit.) in Iowa, now appears to be of Mankato age as used by Leighton and no incompatibility in correlation between the states of Iowa and Minnesota seems to exist. Thus, there is evidence that the drift sheet in North Dakota, whose terminus is marked by the Burnstad and associated moraines, is correlative with the Mankato drift (as used by Leighton) in Iowa (Ruhe, Rubin, and Scholtes, op. cit.). If this is so, then the equivalent of the Cary drift as used by Ruhe, Rubin, and Scholtes, (op. cit.) in Iowa is not exposed in North Dakota but is overlapped by the Burnstad moraine and associated drift. This supposition is supported by the fact that the Cary as used by Ruhe, et. al. whose terminus in Iowa and Minnesota is marked by the Bemis moraine, when traced into South Dakota, correlates with the Cary drift of Flint (op. cit.) which, when traced northward along the west margin of the lobe, is overlapped by drift of the Burnstad moraine before reaching North Dakota. Presumably this overlapping continues throughout North Dakota.

The outer margin of the drift associated with the Burnstad moraine lies about 20 miles southwest of a radiocarbon locality in Kidder County (Moir, this guidebook) dated as of Two Creeks age. The till underlying the dated material is believed to belong to the drift sheet associated with the Burnstad moraine and, therefore, antedates the Two Creeks interstadial.

Post-Cary maximum drifts

<u>Advance No. 1</u>.-- The Streeter moraine (fig. 5) a few miles northeast of the Carbon 14 locality in Kidder County, and associated moraines to the northwest mark the drift border of a major ice advance. The drift of this ice advance is exposed in a northwesterly trending belt 10 to 15 miles wide in the central and southeastern part of the State. The positions of end moraines and washboard moraines indicate that the ice advanced from a northeasterly direction but local lobations deviated considerably from this trend. Because of the present lack of knowledge of the stratigraphic relations of the deposits overlying the radiocarbon dated material to the southeast, it cannot now be ascertained whether this drift sheet antedates or post dates the Two Creeks interstadial. However, inasmuch as at least the drift of the Cary maximum as previously discussed, does not seem to be exposed at the surface in North Dakota, it can be assumed that the drift of the Streeter moraine is younger than the Cary maximum. This drift, when traced northwestward, is found to be overlapped by the Martin moraine of the Souris River lobe (see fig. 5). When traced southeastward, it correlates with the B-1 drift of Flint (1955, p. 119) which he indicated as an important readvance within Mankato time. In carrying Flint's B-1 drift into southwestern Minnesota, it apparently correlates with the Gary moraine of Leverett (1932,

p. 1) which, when projected into Iowa fall within the Mankato (as used by Leighton) and lobe outlined by Ruhe, Rubin, and Scholtes (1957, p. 672) and possibly ties to the prominent moraine at Algona.

Advance No. 2.-- A major readvance of ice, following the one that deposited the Streeter moraine, is indicated by a discordance in the trend of the Grace City, Kensal, and Oakes end moraines (fig. 5) of this drift sheet with those of the previous advance. The drift of this advance extends in a belt, 15 to 40 miles wide, from the vicinity of Harvey, in Wells County, to near the southeast corner of the State. The positions of the well-defined Grace City and Kensal moraines and of numerous washboard moraines suggest that the ice came as two sublobes, one from the northeast and the other from the northwest. Whether these two sublobes were exactly contemporaneous is not known but they were probably essentially so inasmuch as no cross-cutting relations between the two lobes are indicated. Tracing of the Grace City moraine northwestward shows that it is overlapped by the Martin moraine of the Souris River lobe. Tracing of the Oakes moraine southward into South Dakota indicates that it is correlative with the prominent moraine at Britton which when traced into Minnesota is tentatively correlated with the Big Stone moraine of Leverett (1932, pl. 1) It will be recalled that Leighton (1957, p. 1-2) suggests that the Big Stone moraine marks the maximum advance of the Thwaites' Valders ice. If Leighton's interpretations are accepted, and if the lateral tracing of moraines into North Dakota is correct, then the Two Creeks interstadial separates the drift of the Grace City, Kensal, and Oakes moraines from the Streeter readvance. Elson (1957, p. 999-1002), however, believes that the Valders ice of Thwaites (1943) never reached northwestern Minnesota or North Dakota, and thus, according to him, this interpretation would not be possible. The writers cannot at present contribute toward the solution of this problem.

Advance No. 3.-- The next major readvance of ice following the lobes that deposited the Grace City, Kensal, and Oakes moraines was that which deposited the Martin, Heimdal, Cooperstown, and Wahpeton moraines. The Martin moraine marked the terminus of the Souris River lobe, the Heimdal moraine the limits of the Leeds lobe, and the Cooperstown and Wahpeton moraines the border of the lobe that pushed down the Lake Agassiz Basin into the southeastern part of the State. The Cooperstown and Wahpeton moraines correlate well with the Erskine moraine of Leverett (1932, pl. 1) in western Minnesota.

The Souris River lobe and the Leeds lobe, which are believed to be essentially contemporaneous, had a common ice source in Manitoba and Saskatchewan. This ice advanced from the northwest and split into two lobes when it reached the north flank of the Turtle mountains just north of the International Boundary.

The Souris River lobe[4/] occupied the Souris River area west and south of the Turtle Mountains. The ice of this lobe moved southeastward as indicated by southeast-trending linear drumlins and grooves southeast of Velva[5/], and formed the conspicuous Martin end moraine[6/] (see pl. 1 in pocket of guidebook). Washboard moraines, arcuate to the northwest, indicate a northwestward recession of the ice front. The Leeds lobe, advanced around the east flank of the Turtle Mountains and spread out radially. The Heimdal moraine (see pl. 1 in pocket of guidebook) was formed as the end moraine of this advance. Probably during a slight readvance of the receding front of this lobe, the North Viking moraine was formed. The trends of linear drumlins, end moraines, and arcuate washboard moraines provide a good record of the direction of advance and retreat of the Leeds lobe.

During the time of maximum advance and early deglaciation of the Souris River and Leeds lobes, meltwater flowed for a short time from these lobes into the James River and drained eventually into the Gulf of Mexico. Upon further deglaciation, topographically lower outlets were uncovered and the melt water for a considerable period of time then drained down the Sheyenne River and into Lake Agassiz. Glacial Lake Souris was lowered at this time down to an altitude of 1,510 feet by drainage down the Sheyenne River into Lake Agassiz. The forming of the southern part of Lake Agassiz at this time apparently antedates the Lake Agassiz I interval of Elson (1957, p. 1001). During the time of major drainage down the Sheyenne River the ice lobe that had pushed down the Lake Agassiz Basin and built up the Cooperstown moraine maintained a front just northeast of the Sheyenne delta. This is indicated by the abrupt ice contact face at the northeast edge of the delta and by the fact that the Lake Milnor Beach (20 feet higher than the highest Herman Beach) does not continue north of the Sheyenne River delta and was probably formed when ice covered all the Lake Agassiz Basin north of the Sheyenne River (see Leverett, 1932, p. 121-127).

As the margin of the Souris River lobe receded into Canada, glacial Lake Souris, which by then occupied only a small area in North Dakota, expanded into southwestern Manitoba. Further deglaciation north of the Turtle Mountains permitted the draining of the lake down the Pembina trench in Manitoba and into the northern part of glacial Lake Agassiz. According to Elson (this guidebook, figs. 5 and 6) the ice front at this time lay in the Lake Agassiz Basin just northeast of the outlet of the Pembina trench; the Darlingford moraine marked its southwest margin.

Advance No. 4.-- The location of the last lobe of ice to occupy North Dakota is outlined by a looping discontinuous end moraine in northwest Minnesota and northeast North Dakota with continuation northwestward into Manitoba. The segment of the moraine that lies in Minnesota was designated the Holt moraine by Leverett (1932, p. 117) and the segment in North Dakota has been designated the Edinburg moraine by the writers. The Darlingford moraine of Elson (1955, unpublished Ph. D. Thesis at Yale) in Manitoba is believed by the writers to be a continuation of the Edinburg moraine. The position of the end moraine segments shows that a southward moving lobe of ice pushed down the Lake Agassiz Basin to as far as Hillsboro, about 35 miles south of Grand Forks. As shown by Leverett (1932, p. 130-131), the Holt moraine and, the Edinburg moraine to near the northern limits of Grand Forks County, were submerged by Lake Agassiz. Several beaches are shown as crossing the Edinburg moraine in Grand Forks County but, in southern Walsh County it is shown as surrounded but not completely covered by lake deposits.

Elson (this guidebook) indicates that ice stood along the northeast edge of the Darlingford moraine and along the north border of the Pembina delta during the time Lake Souris was draining down the Pembina trench into glacial Lake Agassiz. He (this guidebook, figs. 1-6) shows that the ice had stood at essentially this position for a considerable period of time prior to the draining of Lake Souris down the Pembina River. If so, the Edinburg and Holt moraines would probably represent merely a halt in the recession of the ice lobe outlined by the Wahpeton moraine in the southeastern part of the state. However, the Edinburg moraine definitely truncates a series of washboard moraines (arcuate to the northwest) in the vicinity of the Pembina delta. Thus, a definite readvance of the lobe is indicated but the distance and length of time of the readvance cannot be ascertained. Melting of this ice sheet back to the north end of the Pembina Mountains in Manitoba marks the Lake Agassiz I interval of Elson (this guidebook, fig. 10). During this interval, according to Elson, the Campbell 1 strandline was formed at a time when deepening of the southern outlet of the lake was retarded by bedrock. He further suggests (manuscript of a paper read at the Fifth Congress of the International Association on Quaternary Research, Madrid, 1957) that ice recession north of Lake Superior during the Two Creeks interstadial opened low-level eastern outlets so that Lake Agassiz I subsided and may have drained. Then, according to Elson, the advance of Valders ice of Thwaites (1943) and perhaps crustal uplift, closed eastern outlets of the basin and formed Lake Agassiz II.

By Elson's interpretation, Valders ice of Thwaites (1943) never reached North Dakota. By this interpretation the ice lobe outlined by the Edinburg and Holt moraines would be pre-Two Creeks in age. However, if Leighton's interpretation (1957b, p. 1037-1038) is accepted (that the Big Stone moraine marks the maximum limits of the Valder's advance of Thwaites), then the lobe would represent an advance that followed at least two earlier and further advances of Thwaites' Valders ice. It is not clear what relation the lobe bears to Thwaites' Valders ice margin as interpreted by Wright in Minnesota. His belief, however, that the Valders maximum of Thwaites was marked by the St. Louis lobe whose margin extended toward northwest Minnesota (1957, paper presented at 5th Congress of the International Quaternary Association, Madrid), suggests to the writers that his Valders drift border might possibly correlate with the position of the Holt and Edinburg moraines.

Radiocarbon dates in Lake Agassiz sediments and associated deltaic deposits are not helpful in determining the age of this last ice lobe that occupied North Dakota. The dates range from 12,400 ± 420 years (Sample Y-165, dating by acetylene method is accepted as most accurate) to 8,020 ± 100 years (Sample Y-416) and, thus, span stadials of glaciation elsewhere that range from Cary glaciation in Iowa (Ruhe, Rubin, and Scholtes, 1957, p. 686) to well into Thwaites' Valders glaciation in the western Great Lakes region (Wright, 1957, paper presented before 5th Congress of the International Quaternary Association, Madrid).

The radiocarbon dates of 9,930 ± 280 years (Sample W-388) and 11,283 ± 700 years (Sample C-497) for wood underlying Lake Agassiz deposits at Moorhead, Minn. also do not accurately date the ice lobe that deposited the Holt and Edinburg moraines whose borders lay 40 miles north of the radiocarbon locality. The dated material, found beneath 25 feet of varved lake deposits (1,800 varves) and at a depth of about 45 feet below the lake plain (Wright and Rubin, 1956, p. 626, from Rosendahl, 1948, p. 289), obviously does not date the surface deposits of Lake Agassiz in this area. Even if the dating of the surface deposits was found to be reasonably close to that of the date of wood at the carbon-14 site, only a minimum date would be furnished for the lobe that deposited the Holt and Edinburg moraines inasmuch as these moraines stratigraphically underlie the surface deposits. The exact stratigraphic relation the moraines bear to the carbon-14 site is unknown.

It might be postulated that the presence of deltaic deposits of glacial Lake Agassiz in the Assiniboine Valley near Rosendale, Manitoba, which have not been overridden by ice and which are interpreted from radiocarbon dates to be of Two Creeks age (Elson, 1957, p. 999), does not necessarily preclude the ice lobe that deposited the Holt and Edinburg moraine from being Thwaites' Valders ice. If Thwaites' Valders ice moved southwestward and south across southwestern Ontario and southeastern Manitoba, it is possible that the northwest margin of the lobe did not extend sufficiently far west to cover the dated deposits in the Assiniboine Valley. The writers make no attempt to defend this hypothesis; it is presented merely for speculation and future investigation.

1/ Publication authorized by the Director, U. S. Geological Survey.

2/ This figure is an abridgment of detailed maps that have been compiled in connection with the preparation of a glacial map of the United States east of the Rocky Mountains by the Flint, et al, Committee.

3/ Flint in his mapping in South Dakota (1955, p. 55) divided the Wisconsin stage into the Iowan, Tazewell, Cary, and Mankato substages. In this fourfold subdivision, the Mankato as used prior to 1957 by Wright (1956, p. 19) and others was regarded as younger than the Two Creeks interstadial and equivalent to the Valders of Thwaites (1943, p. 87-144). Leighton (1957b, 1037-1038) proposed that Mankato be made a new substage (no longer equivalent to the Valders) antedating the Two Creeks interstadial and following the Cary. This revised classification was accepted by Wright (1957, p. 3-6). To avoid confusion, henceforth in this paper the new proposed substage antedating the Two Creeks interstadial will be referred to as the Mankato as used by Leighton.

4/ The glacial history of the Souris River lobe is discussed in greater detail by Lemke (1958b, this guidebook).

5/ See separate in pocket of guidebook entitled "Narrow Linear drumlins near Velva, North Dakota" by R. W. Lemke for a detailed description of the drumlins and grooves and their significance to the glacial history of the area.

6/ As the Martin moraine is traced northwestward up onto the Coteau du Missouri, its position becomes increasingly obscure in the very hummocky morainal "dead ice" topography that characterizes the surface deposits of much of the Coteau du Missouri. These surface deposits, which were formerly known as the Altamont moraine and later designated the Max moraine by Townsend and Jenke (1951, p. 842-858), are believed to be stagnation features or "dead ice" moraine in many places, rather than distinct end moraines and represent more than one major ice advance. For this reason they are differentiated from the end moraines on figure 5.

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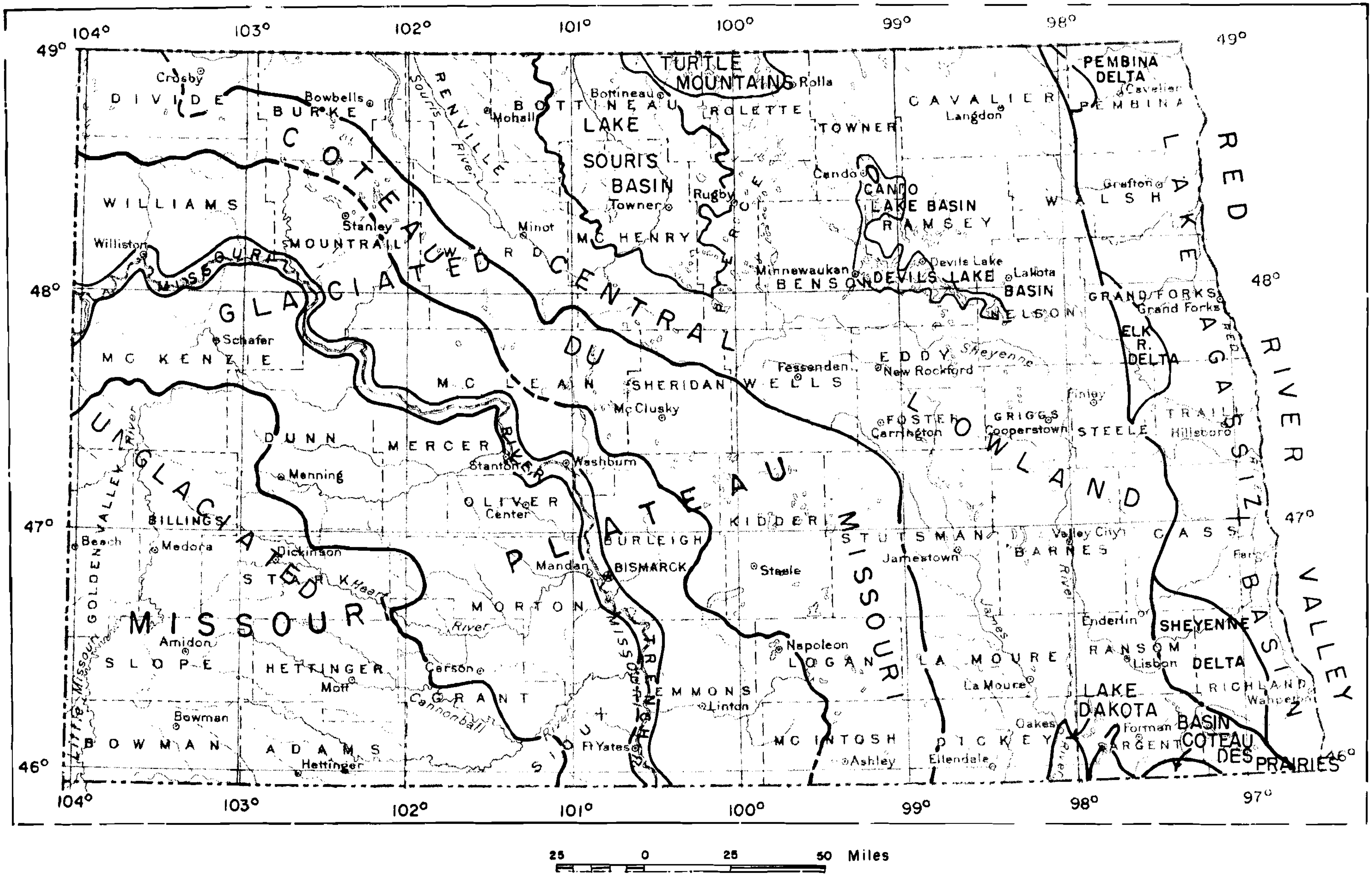


FIGURE 1. GENERALIZED MAP SHOWING SELECTED PHYSICAL SUBDIVISIONS OF NORTH DAKOTA.

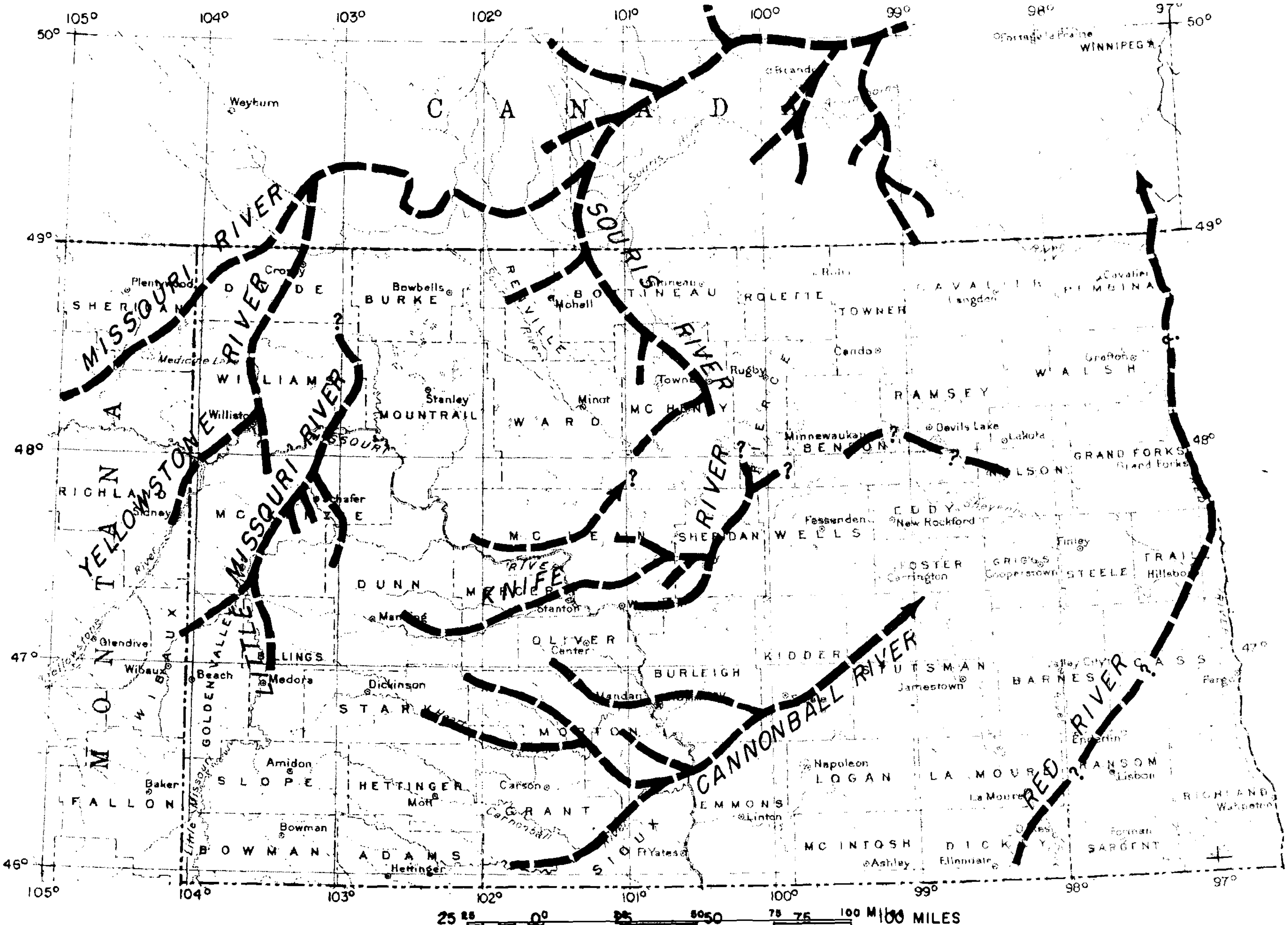


FIGURE 2. GENERALIZED MAP SHOWING ELEMENTS OF THE INFERRED PREGLACIAL DRAINAGE COURSES OF NORTH DAKOTA, NORTHEASTERN MONTANA AND SOUTHERN CANADA. COMPILED BY R. B. COLTON FROM ALDEN (1932, MAP), MENELEY, CHRISTIANSEN, AND KUPSCH (1957), AND UNPUBLISHED MAPS BY R. W. LEMKE, W. E. B. BENSON, A. D. HOWARD, AND J. A. ELSON.

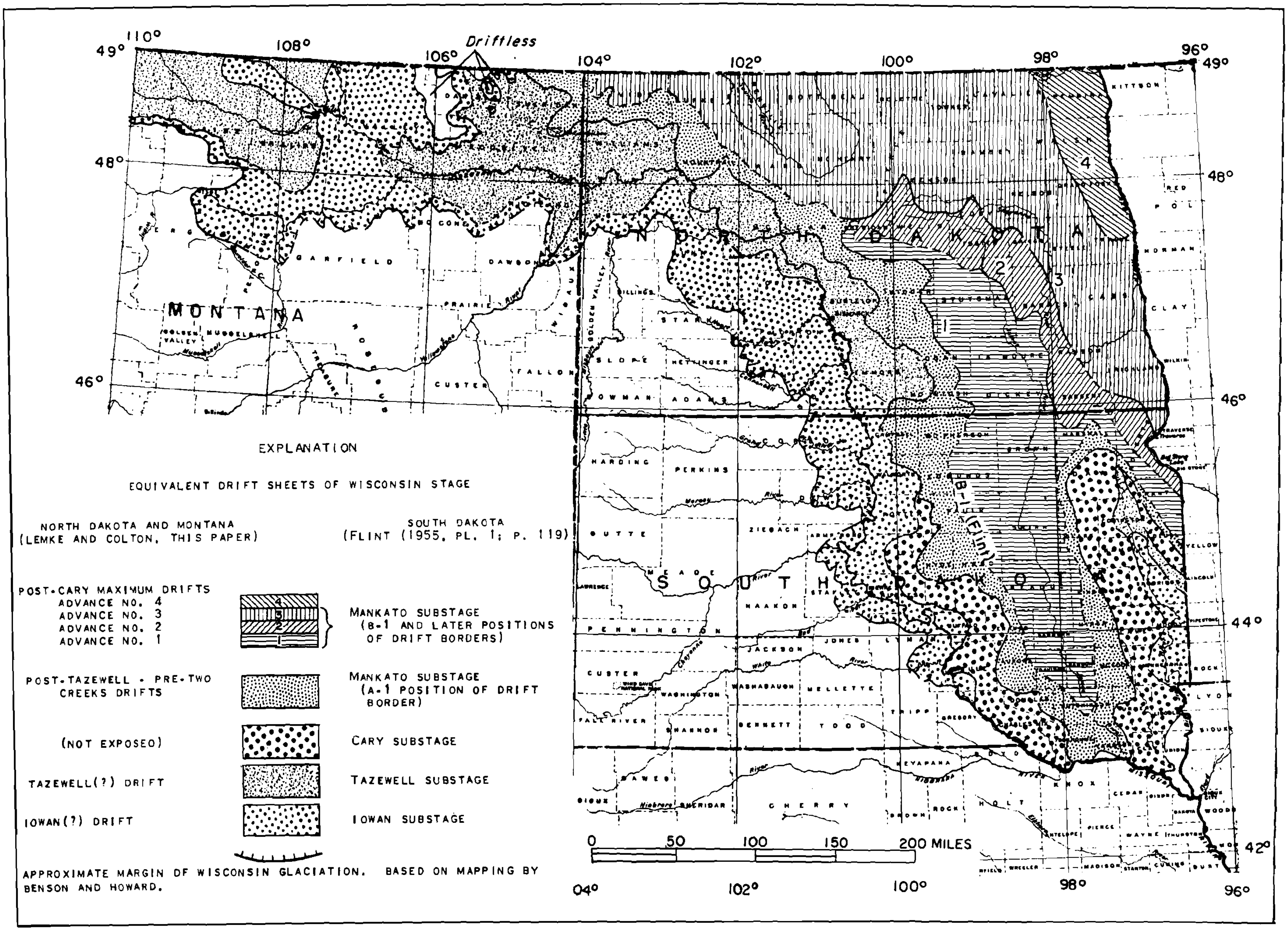
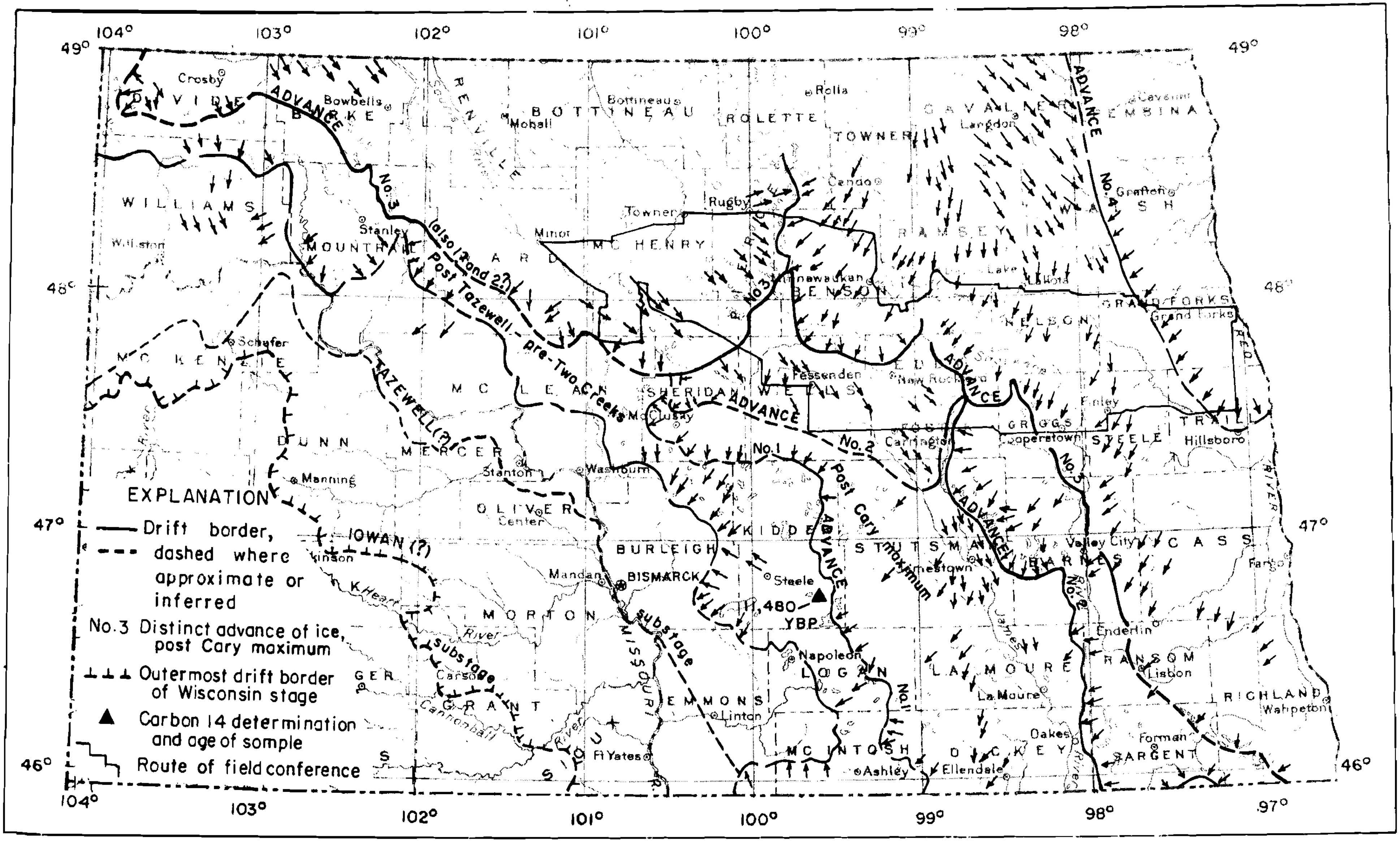


FIGURE 3. GENERALIZED MAP SHOWING APPROXIMATE BORDERS OF EQUIVALENT WISCONSIN DRIFTS SHEETS IN NORTH AND SOUTH DAKOTA AND MONTANA.



0 50 100 150 200 MILES

FIGURE 4. GENERALIZED MAP SHOWING APPROXIMATE LOCATION OF KNOWN AND INFERRED WISCONSIN STAGE DRIFT BORDERS AND DIRECTIONS OF ICE MOVEMENT ASSOCIATED WITH EACH ADVANCE. LOCAL DIRECTIONS OF ICE MOVEMENT SHOWN BY ARROWS ARE BASED ON ORIENTATION OF DRUMLINS AND END MORAINES.

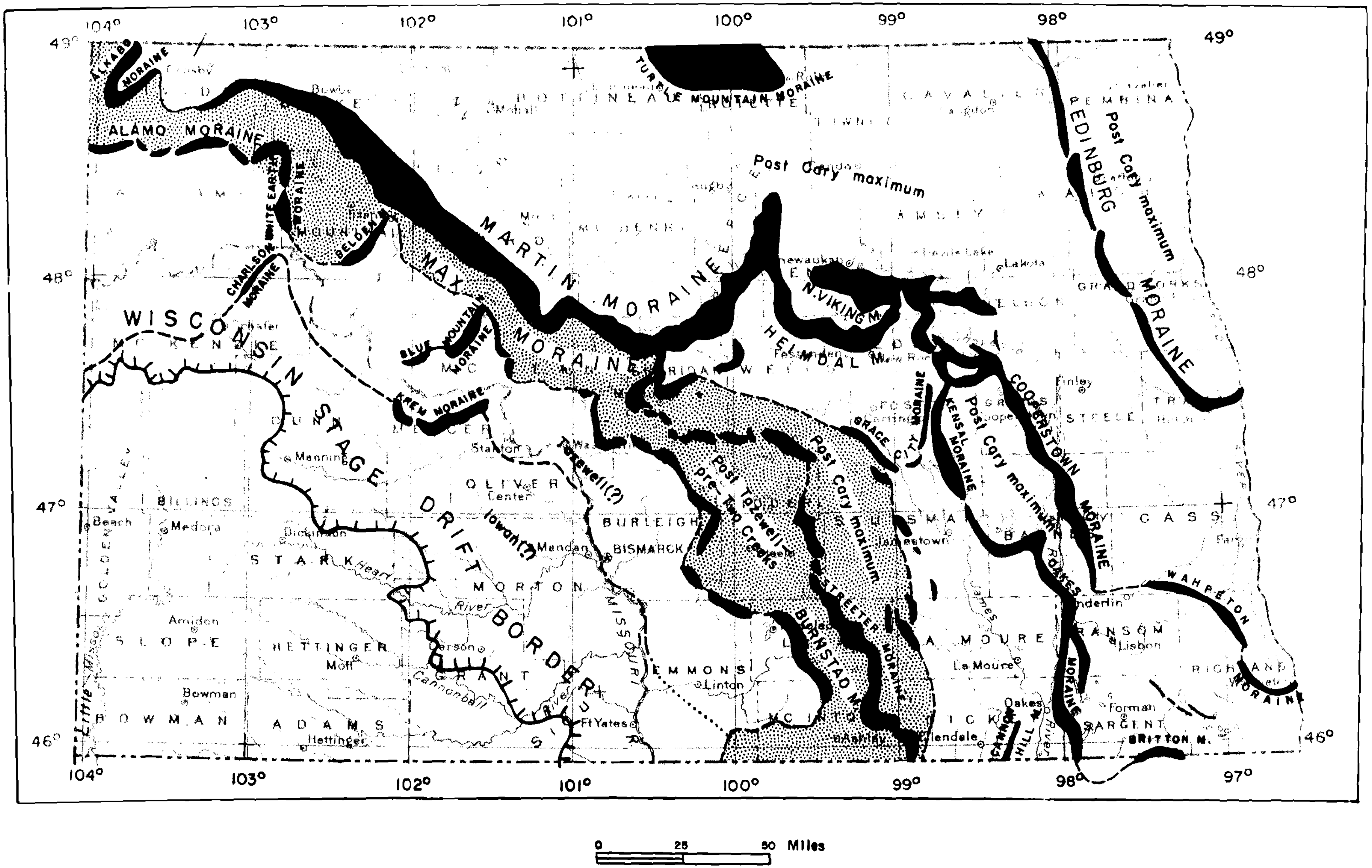


FIGURE 5. MAP SHOWING PROMINENT MORAINES IN NORTH DAKOTA. BROAD AREAS OF "DEAD ICE" MORAINE (STIPPLED) ON THE COTEAU DU MISSOURI, SUCH AS THE "MAX MORAINE," ARE NOT SHOWN AS DISTINCT MORAINES (THESE MORAINAL BELTS ARE BELIEVED TO REPRESENT STAGNATION FEATURES RATHER THAN END MORAINES). DASHED LINES CONNECTING MORAINAL AREAS SHOW POSITIONS OF LOW NARROW END MORAINES OR MARGINS OF "DEAD ICE" MORAINAL AREAS.

Table 1. Partial history of classification of the Wisconsin stage in the Midwest.*

Leverett 1915, 1929, 1932	Leighton 1933	Thwaites 1943, 1946	Bretz 1951	Flint 1955	Wright & Rubin 1956; Zumberge & Wright 1956	Leighton 1956, 1957	Wright 1957	Elson 1957
LATE: 5th-Big Stone Moraine 4th-Port Huron; Bemis; red till in NE Wisconsin	MANKATO	5th-Mankato (or Valders) 4th-Valders (red till NE Wisc.	VALDERS	MANKATO GLACIAL SUBAGE	VALDERS	VALDERS (Big Stone moraine)	VALDERS (Lake Agassiz)	VALDERS (Lake Agassiz II formed
INTERSTADIAL	INTERSTADIAL?	TWO CREEKS	TWO CREEKS	CARY-MANKATO INTERVAL	TWO CREEKS	TWO CREEKS (Lake Agassiz I)	TWO CREEKS (Lake Agassiz)	TWO CREEKS Lake Agassiz
MIDDLE 3rd-Kalamazoo moraine	CARY	3rd-CARY	CARY [Port Huron Lake Border & older moraines	CARY GLACIAL SUBAGE	CARY [Late (Mankato) Maximum	MANKATO (Port Huron; Altamont moraines) INTERSTADIAL	MANKATO (Big Stone, Altamont; Mille Lacs, Highland; Port Huron moraines) INTERSTADIAL	MANKATO Cowan moraine on Duck Mtn. formed Tintah & Norcross levels L.Agassi Lake Agassiz I forms. Altamont and Port Huron moraines formed.
INTERSTADIAL	INTERSTADIAL			INTERVAL		CARY (Lake Border & older moraines) INTERSTADIAL	CARY (Bemis, St. Croix; Lake Border and older moraines)	
EARLY 2nd-Bloomington moraine 1st-Shelbyville	TAZEWELL	2nd-Tazewell		TAZEWELL GLACIAL SUBAGE		TAZEWELL		
PEORIAN INTERGALCIAL	INTERSTADIAL			INTERVAL		INTERSTADIAL		
IOWAN	IOWAN	1st-Iowan		IOWAN		IOWAN INTERSTADIAL FARMDALE		

* Taken from Wright, H. E. Jr., 1957, Fig. 1, Paper presented before the Fifth Congress International Quaternary Association, Madrid, 1957
Additions of Elson and Flint made by the writers.

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Some Reflections on

Certain Aspects of the Problems of the

Des Moines Lobe and Lake Agassiz

In planning for this field conference Dr. Wilson M. Laird has suggested that I give my views concerning some problems of the Des Moines lobe and Lake Agassiz. Inasmuch as I am preparing a formal paper with some new dates for publication on this subject, I offer the following in an "off the cuff" spirit, hoping that it will promote discussion during the course of the field trip.

It is clear to most of us that the Des Moines lobe is more complicated than we had thought and that the older deposits beneath the drift of the Des Moines lobe hold an intriguing record of events that took place prior to the last glacial transgression. The recognition of the problems involved in this part of the classic Pleistocene area of the world should stimulate a high interest, especially since the wide deployment of phenomena offers superior advantages to those of other areas. There is great need for a systematic program of research under auspices that will insure devoted and continuous attention. When one recalls the early research activities of the 70's, 80's, 90's, and the early part of the present century, we should be moved to a scale of effort commensurate with present large means and personnel. If a measure were taken of present efforts and present programs, the need for a more effective program by state, federal, university, or foundation agencies and organizations would be apparent.

An examination of some of our scientific points of view may also be in place. Processes and resulting phenomena, rather than criteria, need emphasis. More attention might also be given to an appraisal of the relative importance of events in the natural history of things, as a basis of classification. The employment of the various sciences--no one of which is singled out by Nature--should be marshalled to the achievement of a better understanding of things, less to the development of specialties exclusive of the other. Hand in hand with the foregoing is the matter of character and quality of publications, marshalling and weighing of the evidence as a whole, not just a part of it. The evil of undue haste is hardly a part of science. "Suspended judgment is the greatest triumph of intellectual discipline," says W. K. Brooks.

Returning to the specific topic of the Des Moines lobe, is it possible that it and the Lake Michigan lobe are counter-parts in two different ice fields, expressive of the same succession of climatic controls that prevailed during the Cary, Mankato, and Valders? Inasmuch as the Lake Michigan lobe has had protracted systematic study, with good coverage by topographic maps, a field review of its features, I believe, would be good strategy on the part of those who will study or will continue to study the Des Moines lobe. Not only does the Lake Michigan lobe present a record of the Cary, Mankato, and Valders substages, but it affords striking evidence of variations of climatic control during the Cary substage, a firm basis for dividing the Cary into early, middle, and late episodes. Are these possibly represented in the Des Moines lobe?

Besides their similarities, the Des Moines and Lake Michigan lobes have their differences. The Des Moines glacier had greater opportunity for deployment. The Lake Michigan lobe was opposed in its lateral movements on both sides by the opposing forces and the resisting masses of the Green Bay and Saginaw lobes, the results favoring excavation of the Lake Michigan basin.

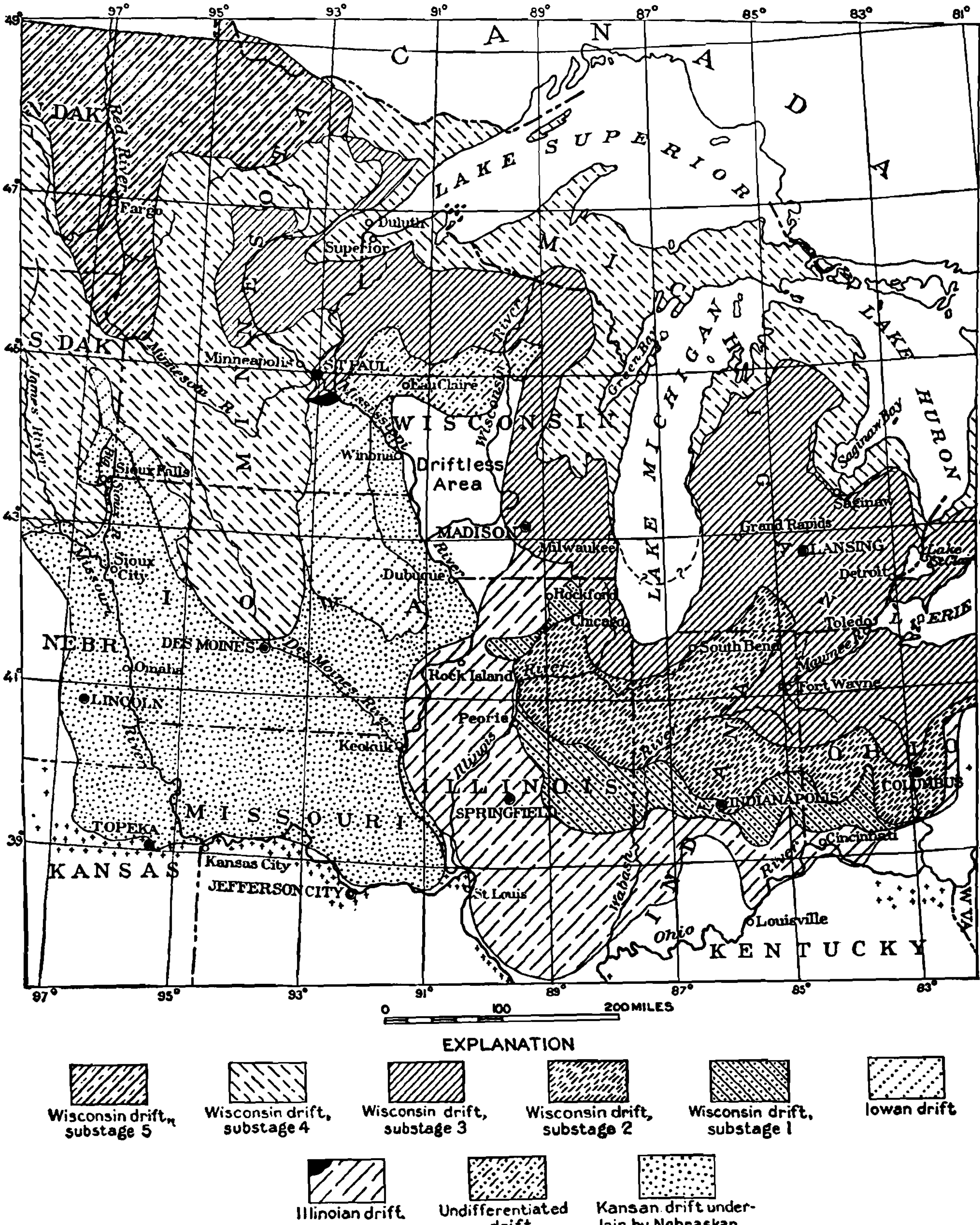
Unfortunately the morainal sequence on the floor of Lake Michigan cannot be observed. We know little or nothing about the form or topography of the floor of Lake

Michigan when the Mankato ice protruded into it, neither do we know how much the Mankato ice modified it in favor of a greater protrusion of the Valders ice.

If my readers were to regard these reflections as an epistle to the profession I could not dissent. But before I close I wish to refer to Leverett's work. No one today in the field of glacial geology can match his record of profound and extensive field studies. He did his mapping on the ground. Doubtless if aerial-photographs had been available they certainly would have been of aid, but I am quite sure that he would have used them with caution. In the period since the First World War, we have had a rash of enthusiasm over aerial-photographs. This was followed by similar or greater enthusiasm for radiocarbon dating. There is reason for some elation in regard to either, but there is no substantial reason for that which goes beyond good science.

As long as we are human, no one dare risk absolute confidence in the work of a colleague, even though his respect for him is high. My regard for the work of Leverett is of such an order of assurance that when someone proposes a revision I desire to know whether or not the new worker possessed a close knowledge of Leverett's area and product, and has strong evidence with which to oppose his views. Especially is this my feeling about Leverett's mapping and interpretation of the Big Stone moraine. He has given us a complete description of it and plausible reasons for regarding it as Substage 5 of the Wisconsin stage. My own field observations, such as they have been, accord with Leverett's. His classification of the Wisconsin stage is shown on the accompanying map, which is figure 5 from Leverett's "Moraines and Shorelines of the Lake Superior Basin," U. S. Geol. Survey Prof. Paper 154A, 1929.

<u>Radiocarbon dating.</u>-- Radiocarbon dates, it is believed, should be regarded for the present as radiocarbon years, provided of course that they are good dates.



Map of drifts in the northern United States, showing subdivisions of the Wisconsin drift. Crosses indicate outlying erratic boulders and patches of till. A small area of Illinoian drift south of St. Paul is indicated in solid black

The question as to whether or not they represent solar years should be left for the further development of our knowledge of the character of the Pleistocene epoch.

The question as to whether or not dates determined by the solid carbon method should be used as scientific evidence until they have been re-checked by the gaseous method is deserving of serious consideration. Most or all laboratories have abandoned it. There are some solid carbon dates from the Des Moines lobe at critical places that have not been checked. This applies to dates from the Cook Quarry, Story County, and from Lizard Creek, Webster County, Iowa. The writer has developed a feeling of confidence in the determinations made by the Washington laboratory and feels that this laboratory should not let the Iowa situation rest where it is.

In the literature, the two instances where dates have been re-checked, both the older and the newer dates are included. This is inexcusable. In another case where the date by the solid carbon method is indeterminate, a "greater than" date, the latter continues to be used alongside the new date, as if the former had specific significance.

A critical point of view should also be cultivated in another aspect of the matter. However good the date may be, if it is the date of a peat bog that overlies a drift deposit it should be used as the date of the peat and not as the date of the drift.

In concluding, I recall the time when the date of 11,283 ± 700 (solid carbon) was accepted for wood occurring at the base of a series of Lake Agassiz sediments at Moorhead, Minnesota. A recheck by the Washington laboratory revised it to 9,930 ± 280 years. The conclusions which were previously drawn must also be revised. The latter date lends plausibility to the view that the Big Stone moraine may be Valders. A setting up of this alternate view should be made for critical consideration along with Elson's interpretations.

Morris M. Leighton

Pleistocene History of Southwestern Manitoba 1/

by John A. Elson 2/

Introduction

This summary of the Pleistocene history of the area between Latitude 49° - 50° north and Longitude 98° - 101° west is a revised abridgment of part of a guide book prepared for a field excursion sponsored by the Geological Survey of Canada in October, 1954. The mapping was a project of the Geological Survey of Canada; a detailed account of the geology is being prepared. The writer is grateful to the Geological Survey for permission to present this advance report of the results, to Dr. R. C. Anderson for his assistance in preparing the original guide book while in the field, and to Jeanne B. Elson for editing and typing this revision.

Early work was done on this area by Warren Upham (1896) who thought that the ice receded generally northeast over the whole area, rather than mainly northwestward. Subsequently the area was remapped by W. A. Johnston (1934) who apparently accepted Upham's hypothesis without question as far as southwestern Manitoba was concerned, but postulated two phases in the history of Lake Agassiz (Johnston, 1916, 1946).

Preglacial features.

A large preglacial valley (the ancestral Assiniboine) trends east at Brandon and probably extends northwest from Brandon and then west along the present Qu'Appelle valley in Saskatchewan. The former Missouri River valley enters Canada near Estevan, Saskatchewan (Meneley, Christiansen, and Kupsch, 1957) and trends east and northeast to join the ancestral Assiniboine valley west of Brandon. A tributary from North Dakota (the former Knife River) flowed north past the west end of Turtle Mountain and joined the ancestral Missouri Valley near Oak Lake, Manitoba.

Turtle Mountain was divided near the center by a small valley which extended north to Whitewater Lake, east to Killarney and southeast across the International Boundary.

Early glaciations.

The early Pleistocene rivers from the west carried gravel derived from the Rocky Mountain area. Most of the stones are well-rounded quartzites and argillites from the Belt Series. Such gravel is exposed one mile east of the town of Souris, Manitoba. The presence of granite stones, which were not derived from the Cordillera but which probably were carried south from the Canadian Shield during an early glaciation, indicates that some of this gravel may be early Pleistocene in age. Other quartzite-argillite gravels containing higher proportions of granitoid stones from the Canadian Shield occur at Qu'Appelle, Saskatchewan and in the Souris Valley east of Estevan, Saskatchewan. The increase in the proportion of granitoids may represent redeposition after an increasing number of glaciations.

The last glaciation.

There is sparse evidence of Wisconsin substages other than the most recent ones in southern Manitoba. Widespread boulder pavements separating an upper sandy till from a lower clayey till suggest a period of subaerial erosion, but weathering of the lower till has not been observed. Probably the boulder pavement is the product of sub-glacial erosion. Spruce cones on Turtle Mountain and a piece of wood east of Holmfield have been reported in situations similar to that of the buried boulder pavement, but properly documented evidence is lacking.

Deglaciation.

Probably southern Manitoba was not deglaciated during the Wisconsin age until the final retreat of ice from the Port Huron-Altamont moraine system of Mankato age. The boulder pavement may represent the Mankato-Cary interval or an earlier interstadial.

The recession of the ice sheet was influenced by a general eastward shift of centers of outflow in northern Saskatchewan, Manitoba and Ontario so that the direction of ice movement across southern Manitoba shifted from southeast to south to southwest. As the glacier thinned uplands such as Turtle Mountain, Moose Mountain, Riding Mountain and the Pembina Mountains split it into lobes that occupied the low areas and deposited marginal and interlobate features.

Figures 1 to 12 are sketch maps showing the deglaciation of southwestern Manitoba. For simplicity only the moraines, lake basins, and meltwater channels in use at the time are shown. The towns of Virden, Brandon, Portage la Prairie, Melita, Killarney, and Morden, the International Boundary, and Turtle Mountain are located for reference.

Figure 1: When the ice margin receded to the International Boundary southwest of Morden it trended southwest, as is indicated by washboard moraines south of Pembina River. East of the Pembina Mountains the trend is unknown but it seems likely that the margin extended southeast along an ice lobe which moved southward in the Red River valley. As the southeast-flowing ice shrank the Red River valley lobe was more or less static or else advanced slightly, but did not obstruct the Pembina Valley for very long.

As the northwestern ice between Turtle Mountain and Pembina Mountains withdrew it uncovered part of the Pembina valley west of the Manitoba Escarpment and deposited an outwash train in it. This now forms the highest terraces. During a pause in retreat the ice margin lay on the west and north sides of Turtle Mountain and extended east and southeast from Boissevain to Cartwright, and northeast to meet the Red River lobe near Cardinal. Extensive outwash fans were deposited along the ice margin, and there was some ponding of meltwater and deposition of end moraine.

Meltwater passed through the Pembina valley for the eastern two-thirds of this portion of the ice margin, and southeast across an outwash plain west of Cartwright for the western third.

By the phase shown in Figure 1 the ice margin had withdrawn from the position just described and extended east from Killarney and northeast along end moraine on the north side of the Pembina valley. Meltwater discharged through the Pembina valley and its western tributary, Whitemud Creek. Minor moraines were deposited east of Killarney and north of Cartwright. The margin of the Red River valley lobe lay along the Manitoba Escarpment.

Figure 2: The splitting of the vigorous Red River valley lobe from the shrinking north-western lobe became more pronounced. A bedrock knob south of Brandon split the southeast moving ice north of Turtle Mountain. South of it the ice withdrew westward leaving a series of minor moraines, while east and southeast of it the ice withdrew northward very slowly and formed a major moraine on the east side of Pelican Lake. The Red River valley lobe advanced slightly to the position of the Darlingford moraine on the Pembina Mountains. South of Brandon an interlobate moraine, comprising the Brandon Hills and the ridge extending 15 miles south, was deposited. Later, as the northwestern retreat continued this became the end moraine of the Red River valley lobe. During the recession to the position shown, drainage was concentrated in the re-entrant between the two ice lobes and this retreating re-entrant determine the position of the Pembina valley.

A small glacial lake formed in the Whitewater Lake basin north of Turtle Mountain and discharged eastward past Killarney through Pembina River. Extensive outwash was deposited on the north side of the Pembina valley.

Figure 3: The margin of the Red River valley lobe fluctuated little during the next phases of the withdrawal of the northwestern ice. Southwest of Turtle Mountain, in

North Dakota, Lake Souris had been in existence for some time, discharging southwestward through Sheyenne River (Lemke, 1951). A slight withdrawal of the ice margin caused it to expand into Manitoba west of Turtle Mountain and also opened lower western outlets for the small glacial lake north of Turtle Mountain. The eastern outlet of this small lake was abandoned.

South of the Brandon Hills interlobate and end-moraine continued to accumulate. The division between the northwestern ice and the Red River Valley ice became more distinct, the latter taking the form of a sub-lobe flowing westward up the re-entrant in the Manitoba Escarpment created by the ancestral Assiniboine valley. At the head of the Pembina trench a glacial lake formed in an interlobate position. (Note: the deep, flat-bottomed valley that extends eastward from south of Brandon to the Manitoba Escarpment is referred to as the Pembina trench. The Pembina River system occupies most of the trench, but the upper part of the trench is part of the Souris River system).

Figure 4: The northwestern ice receded to a north-facing escarpment at Dand, about 15 miles north of Turtle Mountain. The small glacial lake north of Turtle Mountain became a non-glacial feature. Glacial Lake Souris expanded north of the International Boundary; its deposits west of Turtle Mountain now have an altitude of about 1,560 feet. Antler River, Gainsborough Creek, and Graham Creek, Jackson Creek, and Stony Creek were successive ice-marginal streams on the west side of the ice-lobe in the Souris basin; all deposited large quantities of outwash in the basin of glacial Lake Souris. Ice-margin drainage along the escarpment north of Turtle Mountain near Dand flowed northeastward into the glacial lake at the head of the Pembina trench. As the ice margin moved north lower channels were opened. The lowest one became an outlet of glacial Lake Souris which subsequently abandoned its southern outlet.

The lake at the head of the Pembina trench expanded westward and northward. The northwestern ice probably separated from the Assiniboine sub-lobe which expanded westward but did not keep in contact with the retreating northwestern ice. It overrode sediments deposited in the lake between the two lobes.

The margin of the Red River Valley lobe along the Tiger Hills and Pembina Mountains was essentially unchanged.

<u>Figure 5:</u> Further retreat of the northwestern ice caused the glacial lake at the head of the Pembina trench to merge with Lake Souris. By this time Lake Souris had subsided so that it occupied only a fraction of the original lake basin south of the International Boundary. Lake Souris, at its maximum extent in Manitoba, stood at an altitude of about 1500 feet at the latitude of Melita. Because of post-glacial tilting which probably amounts to more than 2 feet per mile, and the lack of well-defined strandlines, the lake levels are not well known.

Rock knobs northeast of Virden caused crevassing of the thinning northwestern ice and in the crevasses the stratified drift of the Arrow Hills was deposited.

The southwestern margin of the retreating northwest ice was marked in succession by Jackson Creek, Stoney Creek, Pipestone Creek, Gopher Creek and smaller unnamed streams. Lake Souris, now mostly within Canada, discharged through the Pembina trench.

Except in the vicinity of Brandon where the Assiniboine sub-lobe advanced a few miles westward, the margin of the Red River valley lobe was stationary. In the re-entrant between Red River valley ice and the Manitoba Escarpment the debris eroded from the Pembina trench collected in an alluvial fan or delta.

<u>Figure 6:</u> As the northwest ice withdrew from the Souris basin successive margin positions were marked by Arrow River and Niso Creek, by Minnewashta Creek and by

numerous minor moraines. Meltwater from this ice discharged into Lake Hind through Pipestone Creek and Assiniboine River. Proglacial Lake Hind is named for Henry Youle Hind who explored southwestern Manitoba in 1858 and who made several contributions to glacial geology including the anticipation of pebble fabric studies in till. Lake Hind began when erosion deepened the Pembina trench and lowered the level of Lake Souris so that the basin became dry south of Melita. Several braided channels carried drainage from the southern part of the basin northward from the International Boundary to Melita. Sediment eroded from these channels accumulated to form a delta at Melita, and subsequently, younger deltas at Napinka and near Lauder as erosion lowered the Pembina trench outlet. The successive levels of Lake Hind represented by these deltas were about 1470, 1460, and 1435 feet respectively. Terraces representing the Melita and Lauder phases occur in the Pembina trench.

During the Melita and Napinka phases of Lake Hind the margin of the Red River valley ice was almost stationary. A lake ponded north of the Tiger Hills at the west end spilled southward across the moraine through what has since become part of the Souris Valley. Another small glacial lake formed north of the eastern part of the Tiger Hills and discharged across them through the Dry River valley into the Pembina trench.

Figure 7: The Assiniboine sub-lobe retreated northward from the Brandon Hills and a lake that had formed southwest of Brandon merged with the lake at the east end of the Tiger Hills; this larger lake discharged southward through the Souris Valley and Pembina trench. Then the ice further east withdrew and all the lakes north of the Tiger Hills merged to form the Brandon Lake (Upham, 1896). The Souris valley outlet was abandoned for the lower Dry River outlet. Assiniboine River flowed into the west end of the Brandon lake.

Farther west, in Saskatchewan, the ice sheet still extended south of the Qu'Appelle valley, and discharge from glacial Lake Regina flowed through the Souris valley across the dry bed of Lake Hind and through the Pembina trench.

In the east the Red River lobe was retreating northward across the basin of Lake Agassiz. However, Lake Agassiz apparently did not stand at its highest level at this time; probably an eastern outlet kept the lake at a level lower than its southern outlet at Lake Traverse, Minnesota.

Figure 8: Continued ice-margin retreat enlarged the Brandon Lake and opened an outlet channel eastward around the north end of the Pembina Mountains that was lower than the Dry River outlet. The resultant lowering caused the west margin of the Brandon Lake to shift eastward.

In the east the Lake Agassiz basin continued to enlarge as the ice shrank northward. In the west, north of Brandon, end moraine was deposited near Rivers and a body of ice became detached and stagnated in a basin that later became part of the present Assiniboine valley.

Figure 9: The ice margin retreated north from the Pembina Mountains and the Brandon Lake was drained. The present Assiniboine Valley west of Brandon was established. Lake Agassiz appears to have risen during this phase, possibly when a minor ice advance or crustal warping in western Ontario closed a lower outlet and shifted the drainage south to the higher Lake Traverse channel. 3/ Assiniboine River began to deposit a delta in Lake Agassiz.

By the end of this phase the northwestern ice margin in Saskatchewan stood north of Qu'Appelle valley, and glacial meltwater west of the Manitoba escarpment passed through Assiniboine River. As a result, the discharge of Souris River was greatly reduced.

Figure 10: Assiniboine River deposited large quantities of gravel, sand, silt, and clay in Lake Agassiz east of Brandon, forming the Assiniboine delta. High-level strandlines (scarps and beach ridges) of Lake Agassiz also formed. The Assiniboine and Qu'Appelle valleys were eroded to their present depths and the Assiniboine delta attained its present extent before the level of Lake Agassiz fell much below 1250 feet. As the southern (Lake Traverse) outlet was cut down the lake subsided forming a sequence of strandlines (Johnston, 1946). When bedrock stopped further lowering of the Lake Traverse outlet and the lake level remained constant, the Campbell strandline, generally a scarp with a large beach deposit at the toe, was formed. It represents a former water level of about 1040 feet above sea level at the International Boundary.

Figure 11: Opening of an eastern outlet caused by ice recession during the Two Creeks interval lowered the level of Lake Agassiz to 830 feet or less in the vicinity of Portage la Prairie, and the lake may have been drained. Valleys were initiated in the comparatively steep foreset slope of the Assiniboine delta, and Assiniboine River cut deeply into the delta. This delevelling gave impetus to the headward growth of a small tributary of Assiniboine River that grew southwestward towards the channel across the Tiger Hills moraine that was eroded early in the history of the Brandon Lake. The Pembina valley was deepened west of the escarpment and a valley cut through the Pembina delta (alluvial fan?).

At this time, about 11,000 (plus) years ago (Elson, 1957; Moir, 1957), the climate was such that modern freshwater and terrestrial gastropod fauna entered the region (Mozley, 1934); the flora suggests a climate similar to the present one (J. Terasmae, Geol. Surv. Canada, personal communication).

Figure 12: Advancing Valders ice closed the eastern outlet of the Agassiz basin and Lake Agassiz II was formed. Undoubtedly crustal warping also affected the eastern outlets and was partly responsible for the formation of this lake. The ice margin

probably advanced no farther than The Pas moraine on the west side of the Agassiz basin. Radiocarbon dates of alluvial fills in Assiniboine and Pembina valleys (Preston, Person, and Deevey, 1955; Barendsen, Deevey, and Gralenski, 1957) indicate that the lake attained a level of about 1140 feet about 8,000 years ago. Probably an alluvial fan deposited in the Lake Traverse outlet during the Lake Agassiz I - II interval caused the lake level to rise higher than the bedrock sill (and the Campbell shore), but once overflowed the alluvial dam was rapidly swept away and the lake subsided to the Campbell level.

Increased precipitation accompanying the Valders ice advance caused the small tributary of the Assiniboine at the west end of the Tiger Hills to erode headward through the spillway across the Tiger Hills moraine and capture Souris River. After this capture, alluvial fans of the major tributaries of the Pembina trench dammed it to produce the present lakes.

Early man hunted on the shores of Lake Agassiz II. Agate Basin (Long site) projectile points, dated at about 7,000 years, are found around but not within the basin. Older projectile points (Plainview, Folsom, Scotts Bluff) also have been found west of the Campbell strandline (R. S. MacNeish, unpublished). Younger preceramic points of a type dated elsewhere at about 3,400 years have been found in the Pembina trench (Vickers, 1948) and within the Lake Agassiz II basin (MacNeish, unpublished). Hence, Lake Agassiz II existed until perhaps 5,000 years ago.

Postglacial History.

Retreat of Valders ice in western Ontario again opened low outlets, Lake Agassiz subsided intermittently, and its area decreased. Ultimately a northern outlet opened and the lake was drained. During pauses in subsidence many strandlines were formed at levels lower than the Campbell shore. These were tilted southward as the land in the north recoiled from glaciation, but the tilting is much less than that of the strandlines higher than the Campbell.

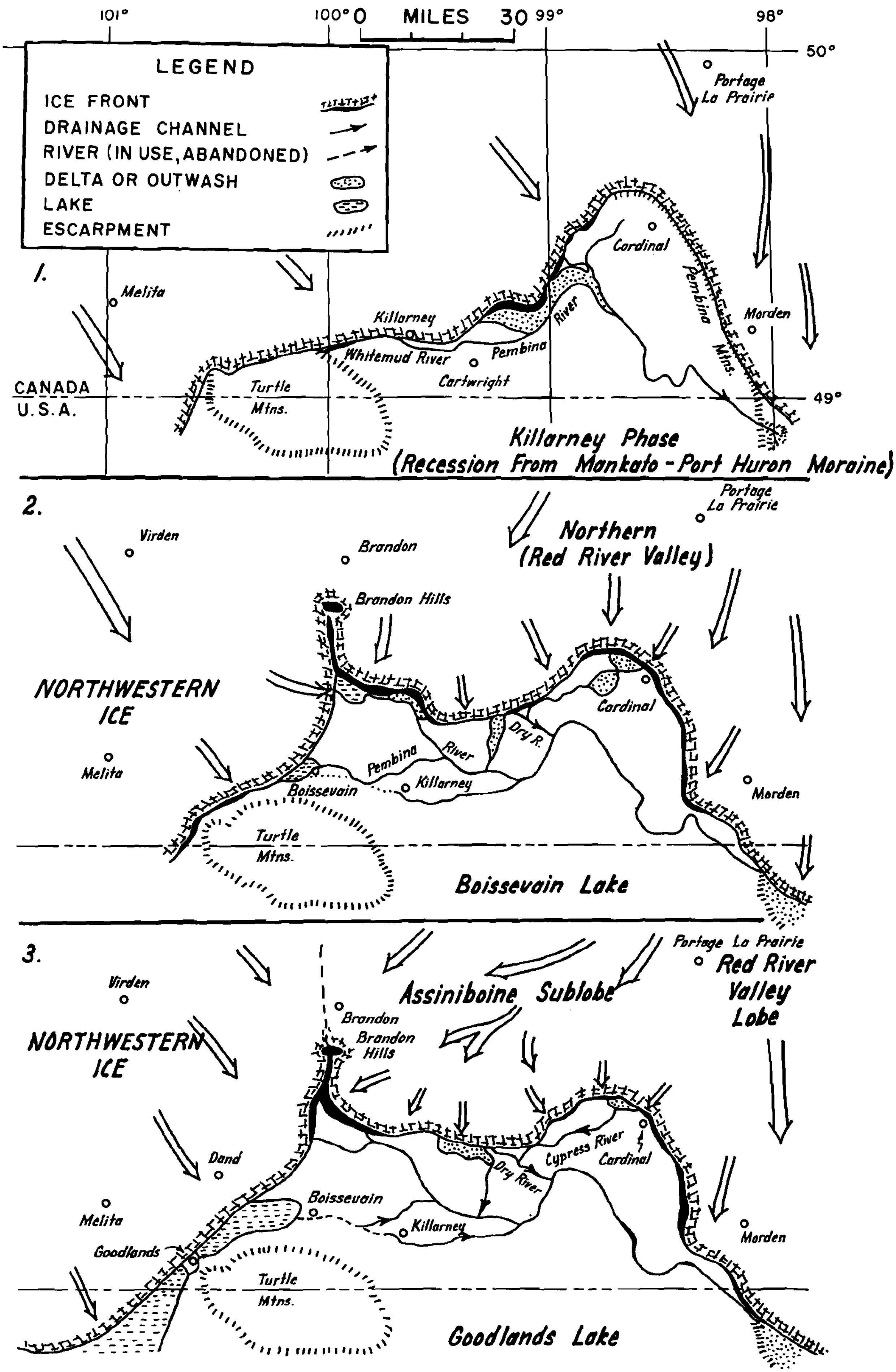
Assiniboine River and Pembina River eroded their valley fills, leaving paired and non-paired terraces. Eolian sand derived from the Assiniboine delta drifted across some of the paired terraces in the Assiniboine valley.

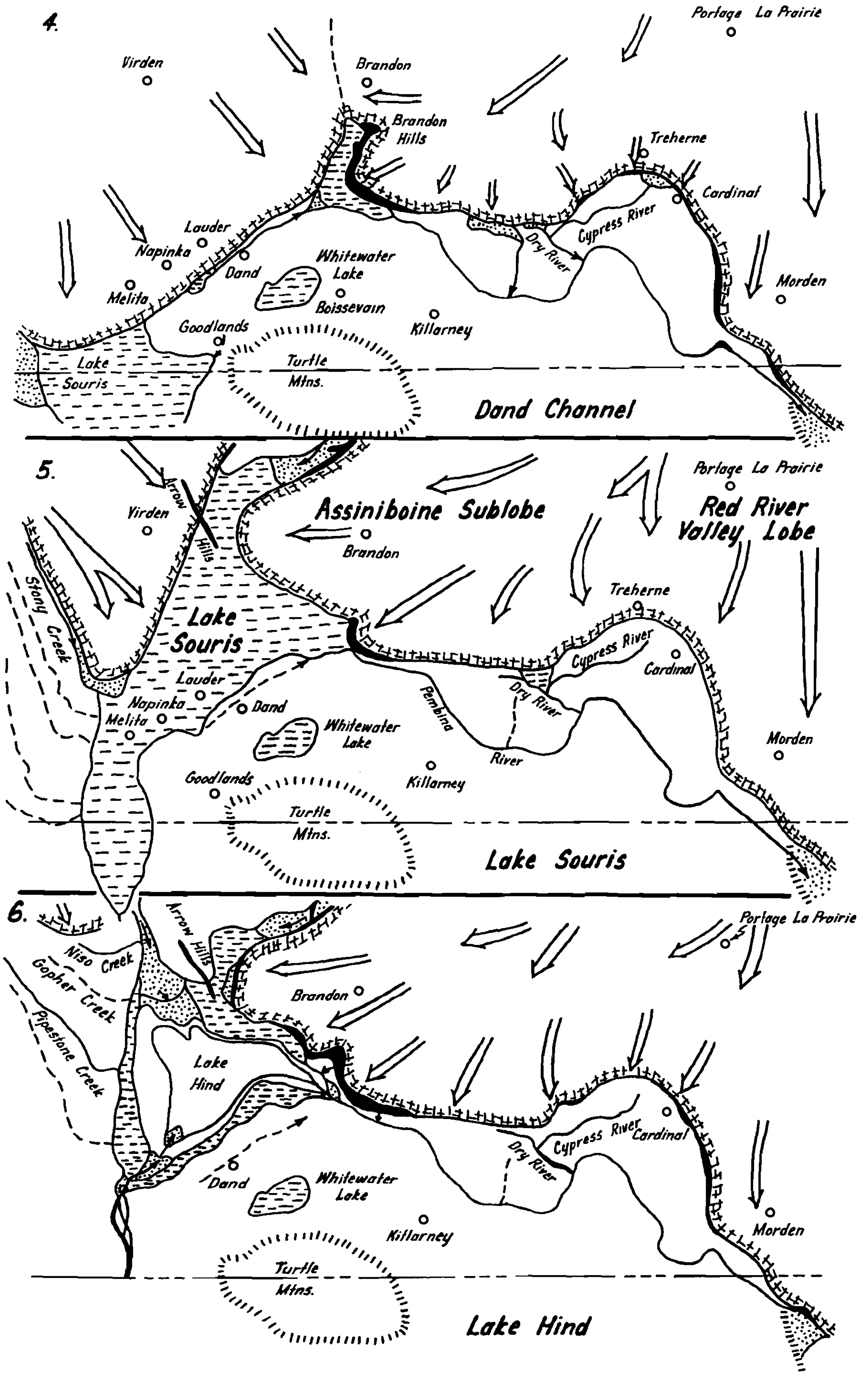
Postglacial phenomena include the accumulation of alluvium (still taking place) on river flood plains and on alluvial fans wherever there is an abrupt change of slope; Assiniboine River east of Portage la Prairie, several small streams flowing down the Manitoba Escarpment (Pembina Mountains), Cypress River, and Pipestone Creek all are depositing alluvial fans. Several buried soil profiles representing periods of stability between periods of wind erosion and deposition have been observed in sand dunes. An azonal soil was buried in the Cypress River alluvial fan approximately 3,000 years ago (Preston, Person, and Deevey, 1955). Several lakes in the Tiger Hills lack outlets and their basins have multiple strandlines that reflect changes in climate of the region. Lake levels are now comparatively low but not as low as they were prior to settlement of the region in the 1860's. Small involutions and fossil ice wedge forms occur, but these may form under the present climatic conditions. Humified polygonal patterns in the B horizon in clayey silt may originate either as frost or as dessication features, and also may be produced by the present climate. More data are necessary before these phenomena can be integrated into a coherent history of postglacial events.

1/ Presented with the permission of the Director, Geological Survey of Canada.

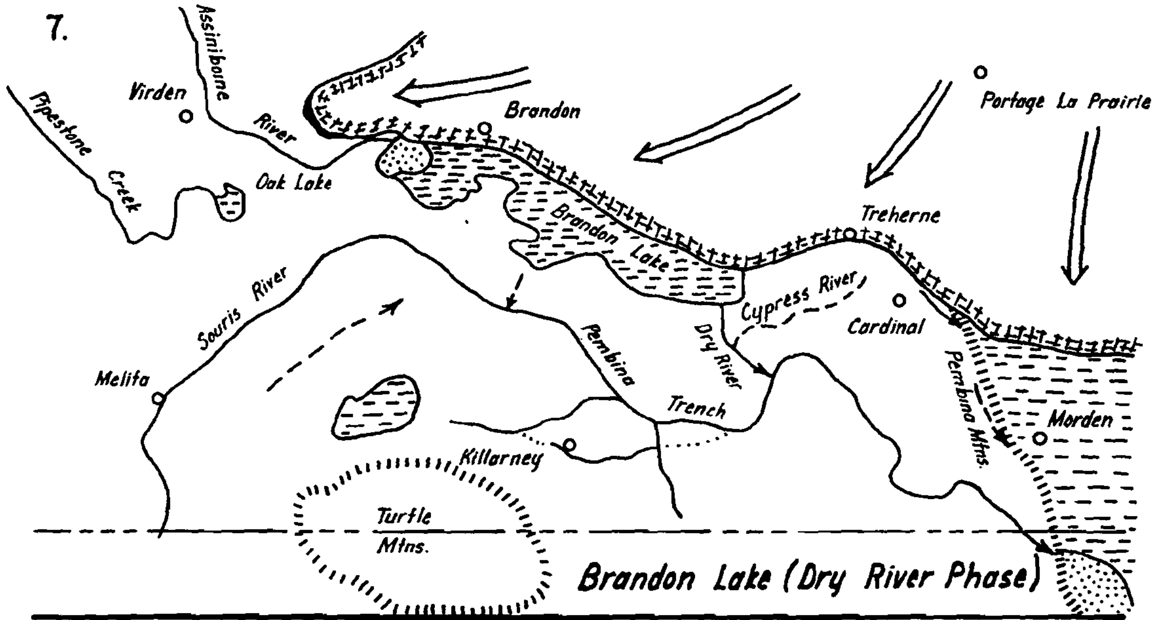
2/ Department of Geological Sciences, McGill University, Montreal, Canada.

3/ The writer's early hypothesis (Elson, 1955) of a low level or dry phase in the history of Lake Agassiz I was based on a mass of permissive evidence and now takes second place to a hypothesis of Lake Agassiz I having a generally falling level with fluctuations. The evidence, still not conclusive, involves stratigraphy in the lake basin, the character of the Assiniboine and Pembina deltas, alluvial fills in the Pembina and Assiniboine valleys, and probable eastern outlets, and is too detailed for presentation here.

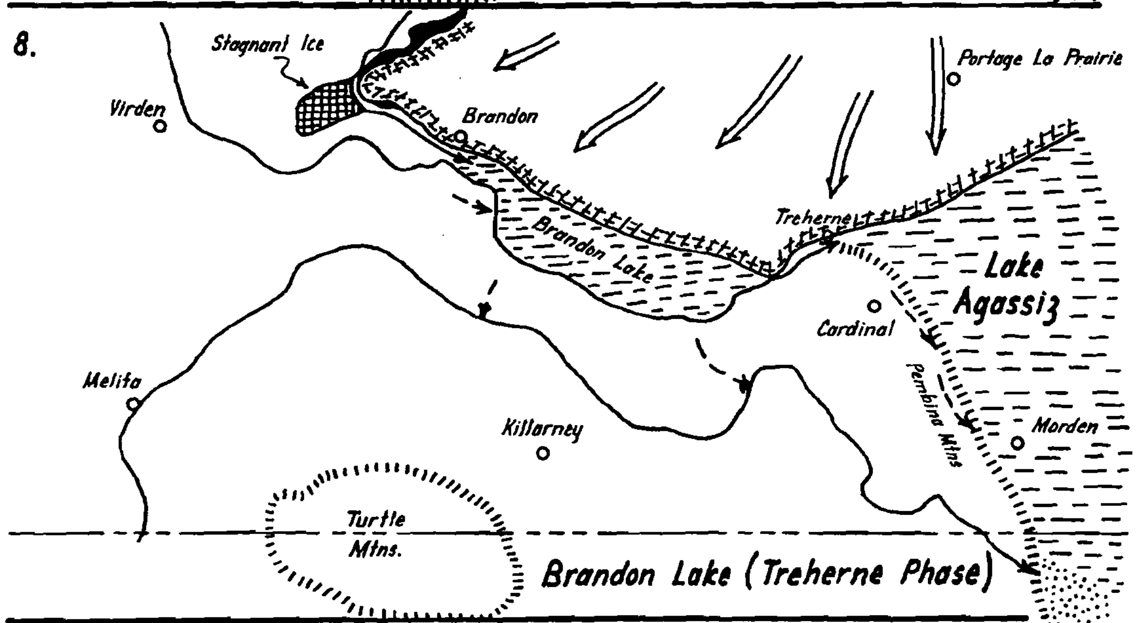

101°
100°
0 MILES 30
99°
98°
50°
49°
LEGEND
ICE FRONT
DRAINAGE CHANNEL
RIVER (IN USE, ABANDONED)
DELTA OR OUTWASH
LAKE
ESCARPMENT
1.
Portage La Prairie
Cardinal
Melita
Killarney
Pembina River
Pembina Mtns.
Morden
Whitemud River
Cartwright
CANADA
U.S.A.
Turtle Mtns.
Killarney Phase
(Recession From Mankato - Port Huron Moraine)
2.
Portage La Prairie
Virden
Brandon
Northern (Red River Valley)
Brandon Hills
NORTHWESTERN ICE
Cardinal
Dry R.
Pembina River
Melita
Killarney
Boissevain
Morden
Turtle Mtns.
Boissevain Lake
3.
Portage La Prairie
Red River Valley Lobe
Virden
Assiniboine Sublobe
Brandon
Brandon Hills
NORTHWESTERN ICE
Cypress River
Cardinal
Dry River
Dand
Boissevain
Melita
Killarney
Morden
Goodlands
Turtle Mtns.
Goodlands Lake


4.
Virden
Brandon
Portage La Prairie
Brandon Hills
Treherne
Cardinal
Lauder
Napinka
Melita
Dand
Whitewater Lake
Boissevain
Cypress River
Dry River
Morden
Goodlands
Killarney
Lake Souris
Turtle Mtns.
Dand Channel
5.
Virden
Arrow Hills
Portage La Prairie
Assiniboine Sublobe
Red River Valley Lobe
Brandon
Stony Creek
Lake Souris
Treherne
Cypress River
Cardinal
Lauder
Napinka
Melita
Dand
Whitewater Lake
Pembina River
Dry River
Morden
Goodlands
Killarney
Turtle Mtns.
Lake Souris
6.
Arrow Hills
Portage La Prairie
Niso Creek
Gopher Creek
Pipestone Creek
Brandon
Lake Hind
Cypress River
Cardinal
Dry River
Dand
Whitewater Lake
Killarney
Morden
Turtle Mtns.
Lake Hind

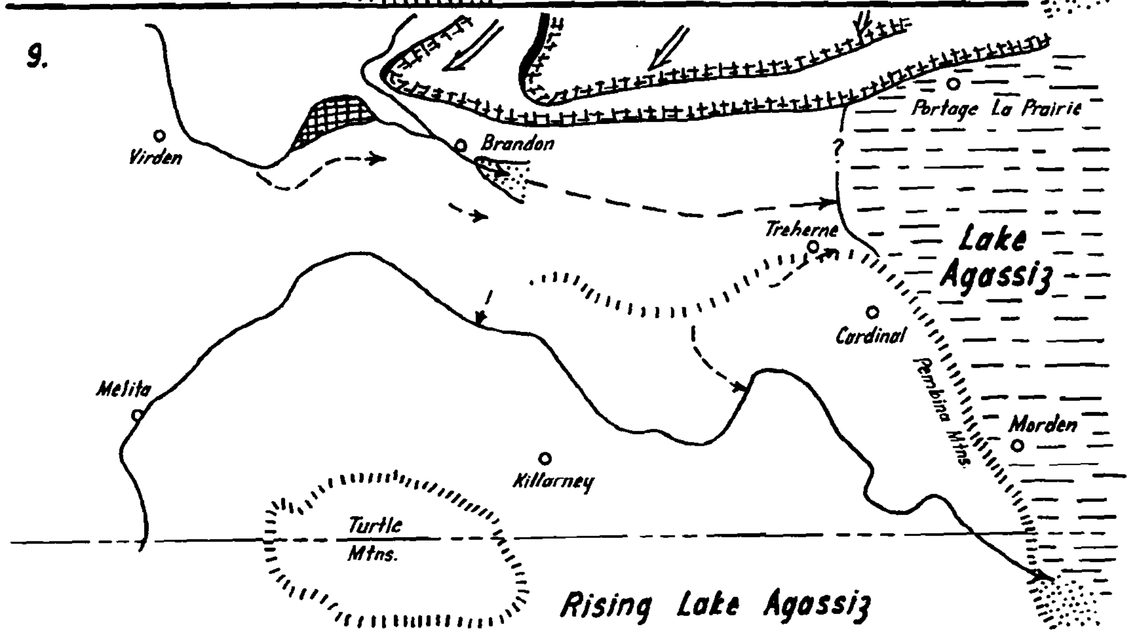
7.


Assiniboine
Virden
River
Brandon
Portage La Prairie
Pipestone Creek
Oak Lake
Brandon Lake
Treherne
Souris River
Cypress River
Cardinal
Dry River
Pembina
Melita
Trench
Pembina Mtns.
Morden
Killarney
Turtle Mtns.
Brandon Lake (Dry River Phase)

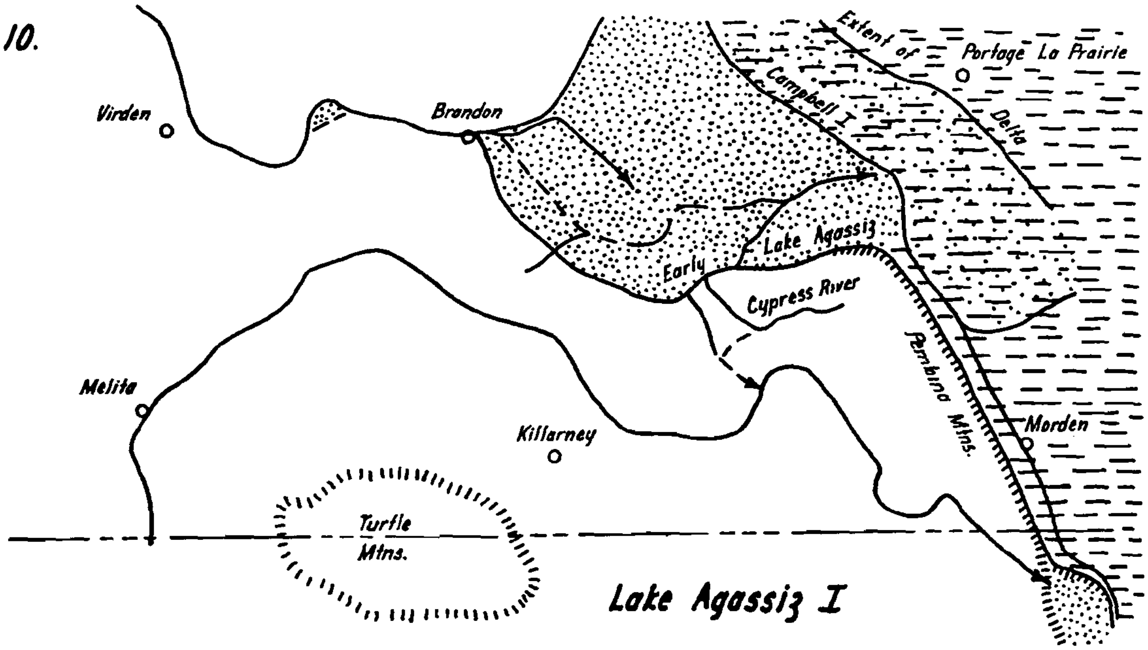
8.


Stagnant Ice
Portage La Prairie
Virden
Brandon
Treherne
Brandon Lake
Lake Agassiz
Cardinal
Melita
Pembina Mtns
Killarney
Morden
Turtle Mtns.
Brandon Lake (Treherne Phase)

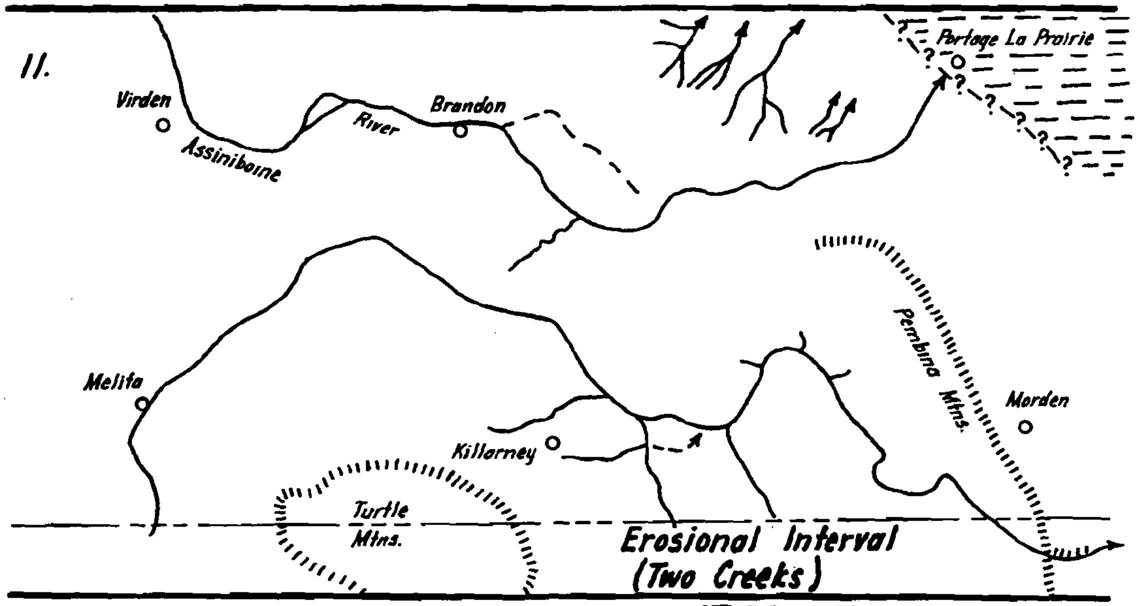
9.


Portage La Prairie
Virden
Brandon
?
Treherne
Lake Agassiz
Cardinal
Melita
Pembina Mtns.
Morden
Killarney
Turtle Mtns.
Rising Lake Agassiz

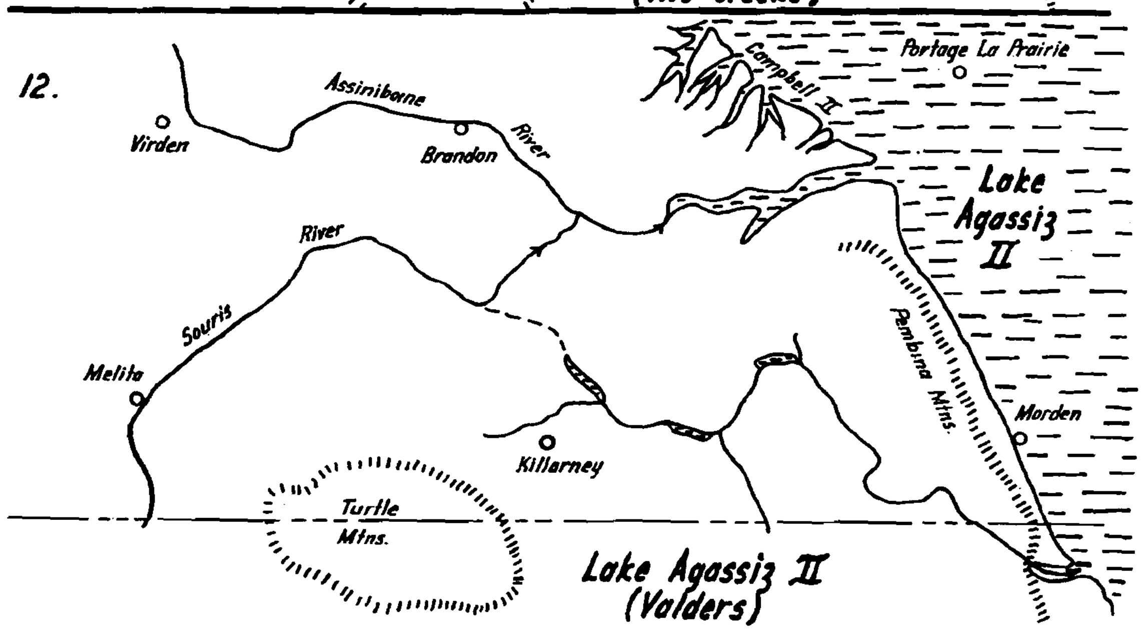
10.


Virden
Brandon
Extent of
Portage La Prairie
Campbell I
Delta
Lake Agassiz
Early
Cypress River
Melita
Killarney
Pembina Mtns.
Morden
Turtle
Mtns.
Lake Agassiz I

11.


Portage La Prairie
Virden
Brandon
Assiniboine
River
Pembina Mtns.
Melita
Morden
Killarney
Turtle
Mtns.
Erosional Interval
(Two Creeks)

12.


Portage La Prairie
Campbell II
Assiniboine
Virden
Brandon
River
Lake
Agassiz
II
River
Souris
Pembina Mtns.
Melita
Morden
Killarney
Turtle
Mtns.
Lake Agassiz II
(Valders)

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Lake Agassiz Basin, North Dakota 1/

by

[illegible]

In 1948, Leland Horberg spent a month studying a system of low intersecting ridges in the basin of former Lake Agassiz in eastern North Dakota (Horberg, 1951). The belt of ridges as described by Horberg is 10 to 25 miles wide and extends northward from Fargo nearly to Winnipeg in the lowest and flattest part of the basin along the Red River. These ridges are described in the abstract of his paper as follows:

"Low, intersecting ridges, 3 - 10 feet high and 75 - 500 feet wide, with intervening depressions form a fracture pattern which is strikingly revealed on airplane photos of the flat Lake Agassiz plain. The ridges occupy the axial part of the old lake basin and are known to extend from Fargo, North Dakota, northward to well beyond the Canadian boundary. Because the ridges are composed entirely of the underlying lake clays and surface soils, they cannot be explained by ordinary agents, such as wind, waves and currents, or glaciers.

"It is proposed that the ridges represent frozen-ground structures formed during retreat of the late Wisconsin ice. This is supported by the occurrence of periglacial involutions, fossil ice wedges, and polygonal and network soil patterns in the lake sediments".

Horberg found that the low ridges stand out on the aerial photographs as light colored strips and the intervening depressions as angular dark-colored areas; the contrast is due to moisture and vegetation (see figure 1).

Horberg mapped on U. S. Dept. of Agriculture 1:20,000 scale aerial photos. I used part of this same coverage in 1951 while studying somewhat similar features in northeastern Montana. After studying the photos in the office (field work in the area has not been possible) I agree with most of Horberg's paper except for the statement (1954, p. 4) which indicates he found no evidence of superposition. On the aerial photos of Pembina and Walsh Counties I found abundant evidence of ridges cutting across previously formed ridges. An interpretation of one such area is shown in figure 1. Other cross-cutting relationships are shown on aerial photos covering the following localities.

Photo No.	Year	County	Section	Township	Range
ZX-2E-68	1948	Pembina	5	T. 162 N.	R. 51 W.
ZX-2E-137	"	"	17	"	"
ZX-2E-138	"	"	9	"	"
ZX-2E-138	"	"	21	"	"
ZX-2E-148	"	"	28	"	"

Horberg's theory (Horberg, 1951, p. 15) that the ridges might have formed as fracture fillings in lake ice seems to be more in accord with the evidence than the theory that the ridges are tundra polygons (op. cit. p. 17) produced by ridging along a system of ice wedges in the frozen ground. Such a pattern of cross-cutting ridges could have formed in a shallow lake whose depth fluctuated greatly each year. Horberg suggested (op. cit. p. 15) that the pattern of intersecting ridges appears to be the pattern of open fractures and leads which form at an early stage in the breakup of sea ice. "The open fractures result mainly from movement by the wind after initial melting near shore, but narrow fractures are caused by contraction at low temperatures...." Horberg stated "fractures in the ice may have been enlarged by lake water and ridges produced by movements of the ice blocks or deposition along the enlarged fractures. . . . . the hypothesis breaks down by its failure to explain the fact that at several places the ridges continue without interruption across shore lines and therefore are younger than the shore lines."

The writer believes that in a fluctuating lake covered by several feet of lake ice, in which are numerous long narrow leads, long narrow ridges would form when the lake level fell and the ice lay on the underlying soft lake sediments. The weight of the ice would force the soft sediments up into the cracks in the ice. These cracks would be of varying width and thus the great range in widths of the ridges can be explained. The squeezing of the laminated lake sediments up into the cracks would account for some of the disturbed bedding. The hypothetical events must have occurred during the last fluctuations of Lake Agassiz during a slight readvance of the ice front in Canada when the lake level rose slightly above the previously formed Assowa Beach. In this way, the presence of the ridges across the beach could be explained. The cross-cutting relationships displayed on the photos formed during successive years as the lake rose and fell each summer and winter. New leads formed and their outline was impressed across older lead impressions as the lake level fell. This process also accounts for the poor preservation and irregular outline of some of the older ridges. The weight of the ice pressing down on the older ridges would tend to flatten and subdue them. In places at least 5 generations of ridges can be seen.

One of Horberg's conclusions (op. cit. p. 16) is: "The ridge pattern can be explained most directly by inheritance from irregularities due to fractures in the lake ice. In this case fracture systems from more than one freeze-over of the lake could have been superposed to form the complex intersection, but the consistent trends of the ridges and their continuity across shorelines remain major objections." The writer believes the field evidence supports the first half of this statement but that the two objections are not valid.

1/ Publication authorized by the Director, U. S. Geological Survey.

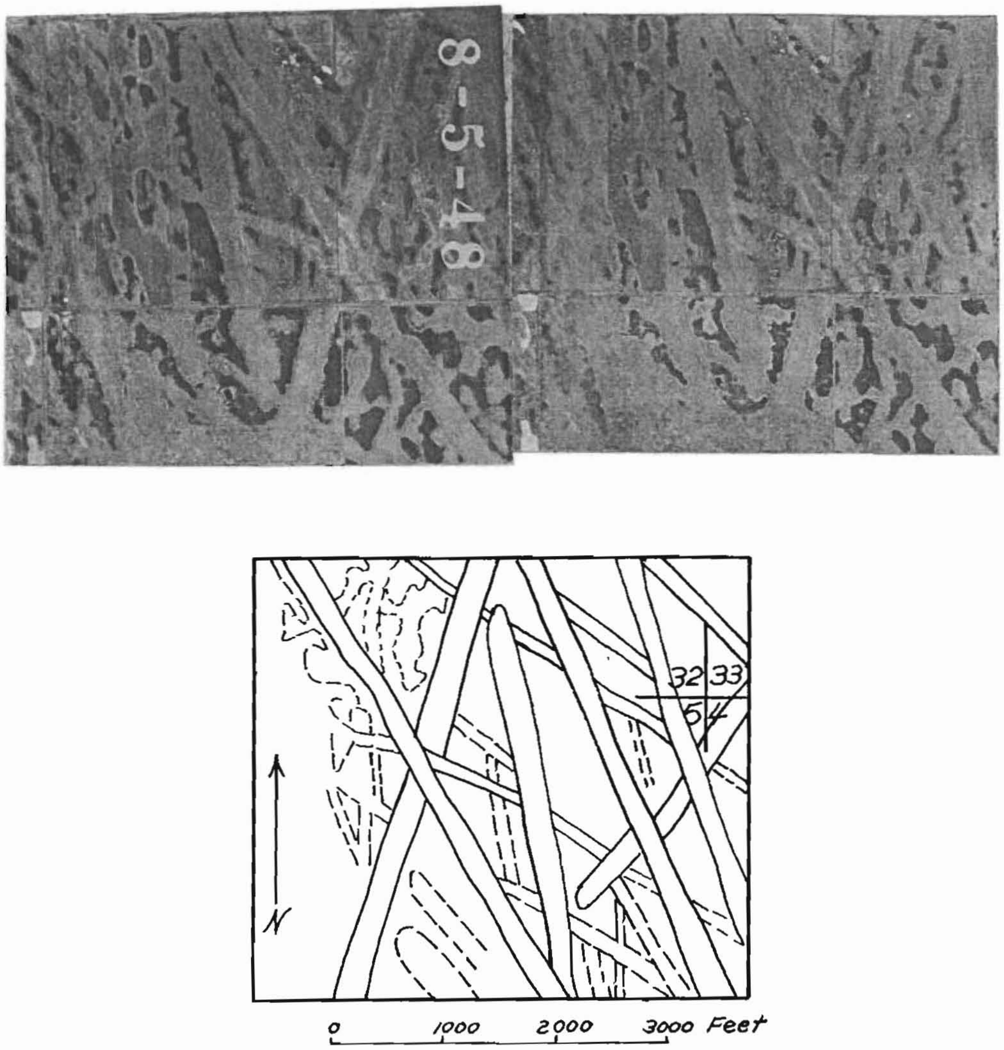

Figure 1. Stereopair and sketch showing Colton's interpretation of crosscutting relationships of minor ridges in northeast part of secs. 5, T. 162 N., R. 51 W., Pembina County, North Dakota. Photos by U. S. Department of Agriculture, Commodity Stabilization Service, Photo ZX-2E-58 (to right) used by Horberg (1951, pl. 1).

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Use of Photogrammetry in Mapping Beach Ridges of Glacial Lake Agassiz in Traill County, North Dakota

By J. W. Brookhart [1]

In 1957 the U. S. Geological Survey, in cooperation with the North Dakota State Water Conservation Commission and the North Dakota Geological Survey, started an investigation of the ground-water resources of Traill County, North Dakota. Earlier ground-water studies by Dennis[2] and Dennis and Akin[3] and a preliminary reconnaissance by the author indicated that the only source of relatively large amounts of ground water of good quality would be the beach deposits of glacial Lake Agassiz, and that a detailed map of the beach ridges would be needed. There is no topographic-map coverage of the county. Upham's map[4] shows the approximate location of the beach ridges but is not sufficiently detailed for locating well sites. The beach ridges can be identified easily in the field at some locations, but at others postlake erosion and cultivation have masked the ridges to the extent that they can be detected only by running a level line across the area, or by drilling test holes.

Aerial photos of the county were studied, but they were of little help except where the beach ridges were topographically prominent. It was decided, therefore, to try photogrammetric projection to see if the beach ridges could be detected.

The U. S. Geological Survey made diapositives for a Kelsh projector from U. S. Army photos taken at 30,000 feet. When a model was set up, about 26 to 30 square miles could be seen stereoscopically. Twenty-eight models were used to cover the western and central parts of the county where the beach ridges occur. By careful study of the model it was possible to trace the beach ridges in areas where otherwise they could be found only by running level lines or drilling. Where the beach ridges have this subdued topographic expression they can be detected on the model by slight differences in vegetal growth and in color of the topsoil. The differences in the growth of vegetation are probably due to soil differences which in turn are due to the greater percentage of sand in the beach ridges.

At this writing, only about 15 percent of the area mapped by photogrammetric means has been checked in the field by leveis, augering, and test drilling, but, wherever a check has been made, the subdued ridges have been found as mapped from the photogrammetric model. Should this method prove successful in the rest of the area and in others on the Lake Agassiz plain, the big advantage would be in the amount of time saved. It took about 5 working days to map all the beach ridges in Traill County by photogrammetry, whereas it would take at least 50 working days to do the same job in the field.

1/ District geologist, Ground Water Branch, U. S. Geological Survey, Grand Forks, North Dakota.

2/ Dennis, P. E., 1947, Ground water near Buxton, Traill County, North Dakota: North Dakota Ground Water Studies No. 5

3/ Dennis, P. E., and Akin, P. D., 1950, Ground Water in the Portland area, Traill County, North Dakota: North Dakota Ground-water Studies No. 15.

4/ Upham, Warren, 1896, The glacial Lake Agassiz: U. S. Geol. Survey Mon. 25, pls. 28 and 29.

A Summary of the Pleistocene and Recent History of the Devils Lake Area

by
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Abstract

Retreating glaciers deposited end moraines and outwash south of the Devils Lake area. Devils Lake was formed when the ice front withdrew still farther, freeing of ice the pre-glacial channel north of the till-mantled Sully's Hill and Crow Hills areas. Devils Lake received a flood of meltwaters which overflowed to the south through several channels into the Sheyenne drainage. When inflow diminished so that the lowest divide was no longer topped by the lake waters, Devils Lake became an undrained basin. Since that time the lake level has generally declined, and the lake waters have become increasingly mineralized.

If present plans materialize, water from the Missouri River Basin project will be diverted through a series of canals to restore Devils Lake to the 1425' level, and an outlet will be provided via Stump Lake to the Sheyenne River.

Introduction

Devils and Stump lakes occupy a portion of a pre-glacial drainage system which during glacial time was scooped out by the ice in some places and filled with glacial debris in others.

The several papers available on the Devils Lake region of North Dakota are shown in the bibliography. Since not all of the reports are accompanied by maps, the reader is referred to the numerous topographic and geologic maps of this area. This paper is intended only as a review of existing publications and no new material is presented.

Last Glaciation in the Devils Lake Area

Outwash deposits, glacial spillways, and end moraines are conspicuous in the Flora, Oberon, and Tokio quadrangles just south of Devils Lake. All these features were formed during the final withdrawal of the glacier. South of the Sheyenne river the Heimdal moraine marks an ice front which was maintained for some time with advance and wastage of the glacier nearly at equilibrium. North of the Sheyenne river the ice front was again stabilized forming the North Viking moraine after a recession during which the ice melted very rapidly. Between these two prominent end moraines the main area covered by outwash lies north of the Sheyenne River. An exception to this statement is noted in the western part of the Tokio quadrangle where the Heimdal and North Viking moraines are separated only by the channel of the Sheyenne. There is a large outwash area south of the river and southeast of the Heimdal moraine in the Tokio and eastern Oberon quadrangles.

There are prominent spillways in each of the three quadrangles mentioned above, which carried meltwaters into the Sheyenne drainage. Since the elevations of the divides of most of the spillways are about 100' higher than the highest known level of Devils Lake, it seems likely that these watercourses were used only while the ice front was at or near the line of the North Viking moraine. In the north-central part of the Oberon quadrangle, Crow Hills coulee with a divide elevation of about 1470' probably continued to drain meltwaters to the south for a longer period.

Origin and Early History of Devils Lake

As the ice front continued to recede to the north away from the Sully's Hill-Crow Hills area in the northern part of the Tokio and Oberon quadrangles, a portion of a pre-glacial river channel was finally freed of ice and in this long irregular basin Pleistocene Devils Lake and Stump Lake were formed, resulting in a chain of lakes which exceeded 40 miles in length. Trending east southeast this group of lakes consisted of the West Bay of Devils Lake (now dry) Main Bay, East Bay and Lamoreaux Bay which is now called East Devils Lake. From East Devils Lake an outlet carried overflow from Devils Lake to Stump Lake which in turn overflowed at various times through three different channels into the Sheyenne drainage.

As the flood of meltwaters declined the various channels were successively abandoned. It is probable that the last spillway to be abandoned was the one which flowed from the south end of the west bay of Stump Lake into the Sheyenne through Big Stoney Coulee.

With the abandonment of the last spillway the Devils and Stump lake area became an undrained basin and the water of the lakes has become increasingly mineralized.

Various figures, most of which vary within reasonable limits, have been given for the elevation of the highest strand line of the lake. It appears that the 1450' contour can be taken as a rough average and considered the highest level at which the lake maintained itself long enough to develop a well defined strand line which can be traced around both Devils and Stump lakes. A second strand line, best developed around Devils Lake, is found at 1445' and below this elevation are several more which are not easily traced for more than short distances.

Cliffs were developed along the strand lines on the south shore of Devils Lake, where the beaches consist of Pierre shale fragments and lesser amounts of sand and gravel from the drift. Along the greater portion of the shoreline however, the beaches were cut in till, and residual boulders pave the old beaches in several areas.

The higher of the two old strand lines can be seen just west of State Highway 20 about half a mile south of the junction of highways 2 and 20 south of the city of Devils Lake. At that place several buildings are built on and near the old beach.

About three miles south of the same junction mentioned the old shore line is well shown near a group of houses west of the road.

When the lake stood at the 1450' elevation it covered an area more than three times as great as at present, and the area covered by the lake when it stood at the 1445' elevation was not appreciably less.

With the final wastage of the glaciers so that inflow was dependent upon annual precipitation alone the lake level declined. At least one wet cycle resulted in inundation of stands of timber which encroached on the old lake floor during dry cycles. During a decline in the lake level prior to 1900 stumps still standing as they grew were exposed by the receding waters in the shallower areas of both Devils and Stump lakes. Logs in great numbers had been washed up on the beaches of Stump Lake and had been used for fuel and fence posts. From annular rings it was determined that some of the logs had grown for 120 years or more and radio carbon determinations on one specimen showed that the tree had been dead for from 3 to 7 hundred years.

Recorded History of Levels of Devils Lake

Since records have been maintained the irregular but steady decline of the lake level is shown by a high at an elevation of 1438 feet in 1867 which receded to a low of 1401 feet in 1940. The wet cycle which began about 1940 resulted in a rise of the lake level to an elevation of about 1418 feet in 1956. Barring unusually wet or dry cycles it may be assumed that the level of Devils Lake will continue to decline if nature is allowed to take its course.

Proposed Reclamation Project for the Devils Lake Area

The U. S. Bureau of Reclamation has plans for supplying water to Devils Lake from the Garrison reservoir of the Missouri River Basin Project. A series of canals is contemplated which will carry water from Garrison reservoir to Devils Lake. According to present plans, water will be fed into Devils Lake via Round, Stoney, and Long lakes south of Minnewaukan and the lake will be restored to the 1425' level. A feeder canal to Stump Lake and an outlet canal from Stump Lake to the Sheyenne drainage are also to be built as part of the proposed project. If these plans materialize, the mineralized water in Devils and Stump lakes will be freshened and eventually flushed out altogether. The city of Devils Lake will be able to use the lake water for domestic purposes and the recreational facilities of the area will be improved.

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Maps

U. S. Geological Survey 7 1/2' (1:24,000) quadrangle maps and Army Map Service Maps (1:250,000) which can be obtained from the U. S. Geological Survey are available for the Devils-Stump Lake region.

Glacial history of the Souris River lobe, North Dakota[1/]

By Richard W. Lemke

INTRODUCTION

The Souris River ice lobe covered all of the terrain now drained by the Souris River and its tributaries in north-central North Dakota. This paper discusses the glacial history of this lobe and its relation to the contemporary Leeds lobe to the east. Plate 1 (in pocket of guidebook) shows the relation of these two lobes to each other and the major glacial features formed by them.

The Coteau du Missouri, a topographically-high glaciated part of the Great Plains Province, forms the southwest margin of the Souris River lobe area. All of the remainder of the area lies in the Central Lowland Province. The escarpment of the Coteau du Missouri, about 300 feet high in this area, forms a well-defined boundary between the two physiographic divisions. Northeast of the escarpment the surface in most places slopes gently to the northeast toward the floor of glacial Lake Souris. The highest point on the Coteau du Missouri that could have been covered by the Souris River lobe is at an altitude of about 2300 feet. The lowest point in the area is in the Souris River valley at the International Boundary and is at an altitude of 1410 feet. The Turtle Mountains, a drift covered mesa-like highland northeast of glacial lake Souris which separated the Souris River lobe and the Leeds lobe, locally exceeds 2500 feet. The Souris River flows southeastward into North Dakota from southeastern Saskatchewan. Below Velva it turns northward and enters Manitoba to drain into Lake Winnipeg. The area within this bend is known informally as the Souris River loop area. The Riviere des Lacs, the main tributary of the Souris River, heads in Saskatchewan about 2 miles north of the International Boundary and joins the Souris River about 7 miles northwest of Minot.

It is not known whether the area covered by the Souris River lobe in North Dakota was glaciated in pre-Wisconsin time. However, at least three and possibly four periods of glaciation of substage rank occurred in Wisconsin time in the area. (see paper in this guidebook "Summary of the Pleistocene geology of North Dakota"). The drift of the Souris River lobe everywhere in the Souris River area forms the surface deposits except near Donnybrook (about 35 miles northwest of Minot) where exposed till of a probable older substage underlies the drift of the Souris River lobe (see paper in this guidebook "Two tills in the Donnybrook area").

The Souris River lobe and the Leeds lobe, both of which had the same source of ice nourishment in Canada, advanced into north-central North Dakota from the northwest. The Leeds lobe moved around the east flank of the Turtle Mountains and spread out radially to the south. The Heimdal moraine marks its maximum advance. The Souris River lobe moved southeastward from southeastern Saskatchewan and covered the Souris River area. Its culmination is marked by the Martin moraine. North of Knox the Souris River apparently truncates or overrides end moraines of the Leeds lobe. In this same area there are randomly oriented sets of washboard moraines that probably represent overlapping by the two lobes during minor fluctuations of their ice fronts. Thus, it has been necessary to make an arbitrary separation of the drift of the two lobes in this area.

Comparison of the tills of the Souris River and Leeds lobes

The tills of the Souris River and the Leeds lobe are nearly identical in appearance. Both are light gray to grayish tan where oxidized and dark bluish gray where unoxidized. Oxidation generally extends to depths of 30 to 50 feet, but leaching does not extend below the B horizon of the soil. Both tills typically consist of about 25 percent clay size, 40 percent silt, 30 percent sand, and 5 percent of particles larger than sand size. Both are highly calcareous. More than 50 percent of the pebbles longer than half an inch are of carbonate rock types. Granitic and gneissic rocks are next most abundant. Two materials, lignite chips and limonite blebs, are minor but characteristic constituents of the till of the Souris River lobe, but are rare or absent in till of the Leeds lobe. The till of the Leeds lobe, on the other hand, in many places examined, contains a much larger proportion of shale chips than does the till of the Souris River lobe. Whether these differences in minor constituents can be used successfully in differentiating the tills where the two lobes overlapped has not yet been ascertained.

History of Souris River lobe

Work by Christiansen (1956, p. 1-35) in the Moose Mountain area in southeastern Saskatchewan shows that the advance of the Mankato ice sheet, which produced the Souris River lobe in North Dakota, moved across southeastern Saskatchewan from a northwesterly direction. As it moved into North Dakota, it occupied all the area between the Coteau du Missouri and the Turtle Mountains and may have extended up onto the Turtle Mountains themselves. Its terminus is marked by the Martin moraine that extends southward from the southeast end of the Turtle Mountains to the vicinity of Lincoln sag and then up onto the Coteau du Missouri where the identity of the Martin moraine westward becomes lost in the hummocky morainal topography that includes earlier drift. This moraine is distinctly concave to the northwest and suggests an advance of the ice lobe from that direction. More convincing proof of the direction of ice movement is afforded by southeast-trending linear drumlins and grooves in the Velva area (Lemke, 1958)[2/]. These features were formed at the base of the ice parallel to the direction of movement. Low, arcuate washboard moraines, concave to the northwest in the same area, mark still stands of the ice front during its retreat to the northwest.

During deglaciation, the areas on top of the Coteau du Missouri and along the west and south flanks of the Turtle Mountains were probably the first strips of land to emerge from beneath the southwest and northeast flanks of the melting Souris River lobe. As the northeast flank of the lobe withdrew from the Turtle Mountains, a kame terrace, especially well developed in the vicinity of Dunseith, was formed along the southwest edge of the Mountains. When the lobe had melted back several miles from the escarpment of the Coteau du Missouri, southeast-trending, ice-marginal channels were formed along the southwest flank of the lobe. After further recession of this side of the lobe, the valley of the Riviere des Lacs and the segment of the Souris River valley from its confluence with the Riviere des Lacs to Velva were used as ice-marginal channels, but below Velva, the Souris River valley was still blocked by ice and the meltwater was diverted southeastward. The diverted meltwater carved the Velva diversion channel (altitude of floor at head of channel is 1,590 feet) and then emptied through the Aylmer diversion channel into the southern part of glacial Lake Souris, which was just coming into existence as the ice front melted back from the Martin moraine. As the southwest flank of the ice lobe receded further to the northeast, the Velva channel was abandoned in favor of the lower Lake Hester channel (altitude of floor at head of channel is 1,575 feet). The Lake Hester channel first drained southeastward through the Aylmer diversion channel, and later through the Antelope Valley diversion channel into glacial Lake Souris. Later, after further recession of the southwest side of the ice lobe, meltwater flowed through the Verendrye diversion channel (altitude of floor at head of channel is 1,555 feet) and into glacial Lake Souris, first down the Antelope valley diversion channel and later through a broad flat watercourse northeast of Karlsruhe. Later, when the front of the ice lobe had receded to a line just north of the Souris River east of Verendrye, the Verendrye diversion channel was abandoned and meltwater flowed directly down the Souris River valley into the lake which was expanding northward as the ice receded.

When the southwest side of the lobe was receding in the vicinity of Velva and Verendrye, meltwater was diverted from the Souris River valley in Canada through a shallow trench (floor altitude of 1,850 feet) into the Riviere des Lacs valley (see fig. 1). This diversion occurred when a bend in the Souris River at about 102° meridian in Canada was still blocked by ice. The volume of water discharging through this shallow trench seems to have been large for a short time and according to Christiansen (1956, p. 28) this large discharge may have taken place when glacial Lake Arcola along the south flank of Moose Mountain in southeast Saskatchewan drained southward into the head of the Riviere des Lacs. The lower segment of this watercourse, from the shallow trench to the vicinity of Velva, was about 100 miles long and had an average gradient of about 3 feet to the mile.

As the southwest side of the lobe melted back in the vicinity of the International Boundary, the bend of the Souris River in Canada was freed of ice. The shallow trench between the Souris River and the Riviere des Lacs was abandoned and water flowed down the Souris River into North Dakota. According to Christiansen (1956, p. 25) the Souris River valley during its late-glacial phase was used as a drainageway to partly drain glacial Lake Regina in Saskatchewan. Because of the difficulty of correlating terrace remnants in the Souris River valley, it is not known whether this lake water discharged into one of the diversion channels between Velva and Verendrye or whether it all emptied directly into glacial Lake Souris east of Verendrye.

During early deglaciation of the lobe only the southeast end of glacial Lake Souris was in existence. Meltwater flowing down the Aylmer diversion channel and off the ice front was ponded to a height of about 1,560 feet. For a short time lake water probably overflowed down the North Fork of the Sheyenne spillway (floor altitude at head of spillway is about 1,550 feet), and thence, was diverted through the Heimdal diversion channel into the James River valley to drain eventually into the Gulf of Mexico. As far as is known this is the only time when water drained from the Souris River area into the Gulf of Mexico. Most of the flow down the Heimdal diversion channel, however, was probably from the front of the Leeds lobe which at that time was marginal to the channel. This diversion down the Heimdal diversion channel was possible only because the front of the Leeds lobe still stood at the Heimdal moraine. Because all the lower ground to the north was still covered by ice, water could not flow through the lower outlet later used by meltwaters flowing down the Sheyenne River valley to glacial Lake Agassiz. The Leeds lobe, therefore, was still at or near its maximum extent after considerable shrinkage of the Souris River lobe had already occurred. The southwest side of the Souris River lobe at that time probably had melted far enough back so that meltwater flowed down the Riviere des Lacs valley then down the Souris River valley to the Velva diversion channel.

As the front of the Souris River lobe shrank, the edge of the lake followed the ice front back and progressively increased in size northward. By the time the Antelope valley diversion channel was formed, the Girard Lake spillway was probably just beginning to come into existence. This spillway continued to be used until its threshold was cut down to an altitude of 1,510 feet. By this time the lake extended far enough northward so that meltwaters flowing down the Souris River valley could empty directly into the lake a few miles east of Verendrye. This is indicated by the fact that north of this point the high shoreline of the lake is at an altitude of about 1,510 feet; whereas, the high shoreline south of this point rises progressively to a maximum of about 1,560 feet at the southern end of the lake.

When the Girard spillway came into use, the front of the Leeds lobe had receded to about the position of the North Viking moraine. The Heimdal diversion channel was abandoned in favor of lower ground to the north and the spillway waters, together with meltwater from the Leeds lobe, incised the Sheyenne River valley and drained into glacial Lake Agassiz.

When the southwest side of the Souris River lobe had shrank to a position northeast of the Souris River above its confluence with the Riviere des Lacs, meltwater cut many outwash channels, some more than 50 miles in length, along successive positions marginal to the southwest side of the ice lobe in the Souris loop area. Their flow to the southeast into the constantly northward expanding glacial Lake Souris was transverse to the slope of the ground moraine surface. Thus, each channel, as the flank of the lobe receded to the northwest, was abandoned successively in favor of a lower channel closer to the ice margin and downslope to the northeast. In the complex braided network of outwash channels east of Minot, it appears that several channels may have carried meltwaters simultaneously and that the meltwaters flowed between numerous blocks of stagnant ice.

As the front of the Souris River lobe receded into southeastern Saskatchewan, the low area along the Souris River in southwestern Manitoba was uncovered. Glacial Lake Souris expanded into this area and then drained eastward north of the Turtle Mountains into glacial Lake Agassiz down the Pembina trench. By this time the Leeds lobe had receded completely from North Dakota and far enough northward in southern Manitoba to permit the eastward drainage of glacial Lake Souris in Manitoba.

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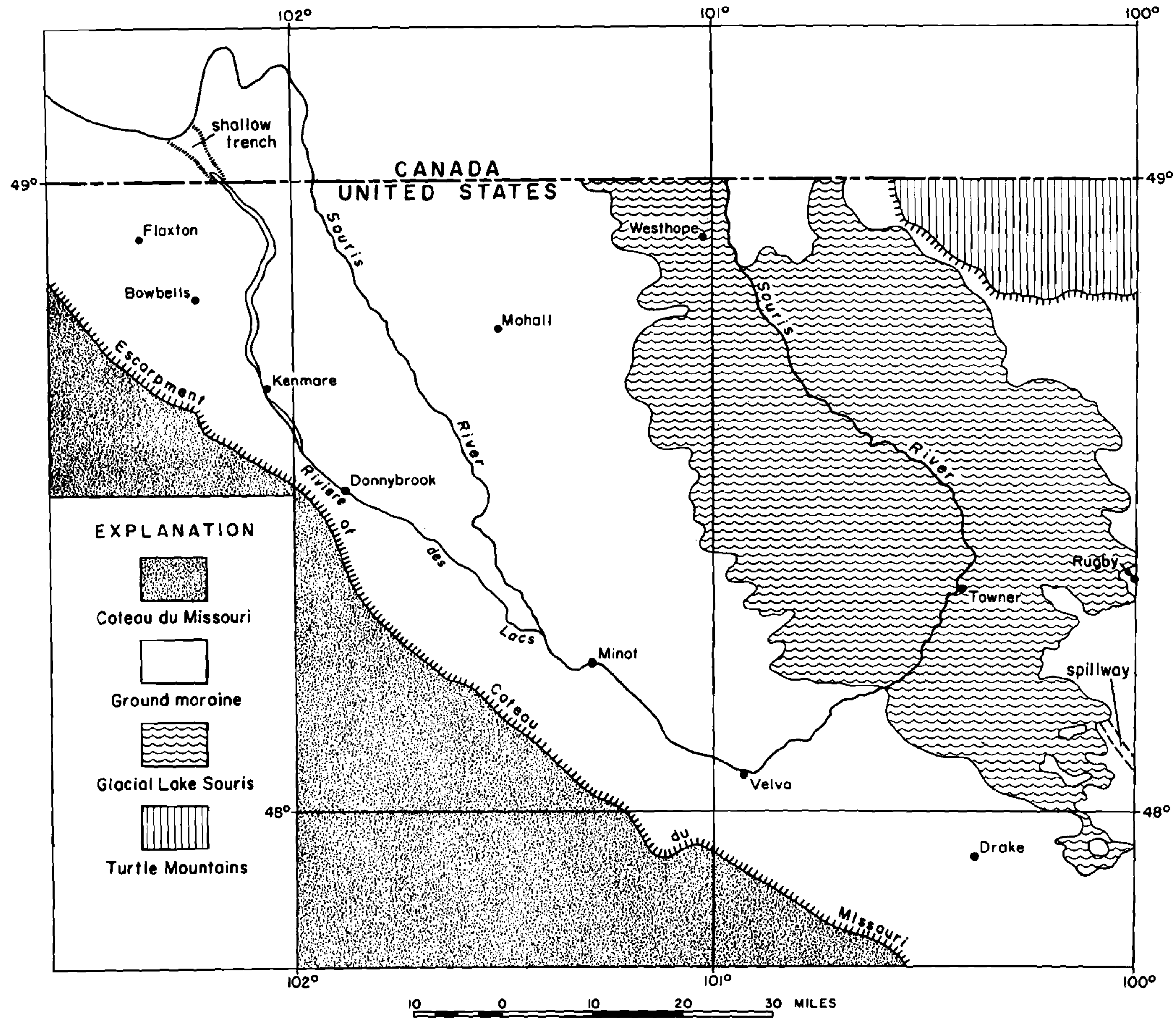

Figure 1. Generalized map of Souris River area showing major physiographic features.

Two tills in the Donnybrook area, North Dakota[1]

By Richard W. Lemke
and Clifford A. Kaye

INTRODUCTION

Two tills, separated by a boulder pavement and believed to belong to two different substages of the Wisconsin stage of glaciation, are exposed near Donnybrook in northwestern North Dakota. Figure 1 shows the location of exposures in respect to the rest of the State. These exposures are of particular interest because they are the only places in northwest and north-central North Dakota where tills of two distinct glaciations can be differentiated. The purpose of this paper is to discuss the stratigraphic relations, compositions, and ages of the two tills.

SETTING

These tills are best exposed in a road cut of U. S. Highway 52, 1 1/2 miles southeast of Donnybrook in the SW/4 sec. 24, T. 158 N., R. 87 W. The exposure is along the southwest valley wall of the Riviere des Lacs, a valley cut by glacial meltwater pre-last glaciation and used again by meltwater during deglaciation of the last ice sheet to cover the area. The boulder pavement that separates the two tills is discernible in several places about one-third of the way up the northeast valley wall directly across from the road cut. It also is well defined for a distance of about 3 miles upstream from Donnybrook on the northeast side of the valley. The boulder pavement is less conspicuous on the southwest valley wall but is discernible from the road cut upstream for about 1,000 feet where it projects into a lime-enriched bed in a gravel pit.

STRATIGRAPHIC RELATIONS

Figure 2 shows the stratigraphic relations of the materials exposed in the road cut. A maximum thickness of about 30 feet of older till is exposed. Intercalated in the lower till and contemporaneous with it are glaciofluvial deposits. The zone of boulders and cobbles separating the two tills is generally less than 3 feet thick. It dips down-valley and apparently represents a lag concentrate left by erosion of the lower till, as shown by the fact that it clearly truncates the glaciofluvial deposits in that till. The younger till that overlies the boulder zone has a maximum thickness of 50 feet. It contains no fossil soil horizons, or other evidence to suggest more than one substage of deposition after formation of the boulder zone.

As mentioned previously, when the boulder zone in the highway cut is traced up-valley for about 1,000 feet, it ties into a conspicuous lime-rich zone about 6 inches thick in the southwest face of a gravel pit. Here the younger till directly overlies the lime-rich zone. Directly underlying the lime-rich zone is a thick section, possibly as much as 200 feet, of steeply dipping and contorted beds of gravel, sand, and silt that apparently represent collapsed ice-contact deposits. Although much thicker and much more distorted, these deposits are similar in composition to stratified deposits intercalated in the lower till in the road cut and are believed to be part of the same deposits. None of the older till is exposed in this part of the pit, but, in the northeast part of the pit, till that resembles in composition the older till in the road cut overlies the collapsed ice-contact deposits. Apparently this is a mass of the older till that intercalates with the ice-contact deposits and wedges out toward the southwest end of the pit (see figure 3). The beds of the stratified ice-contact deposits are nearly vertical to slightly overturned, presumably owing to collapse as a result of melting of supporting ice after deposition. The direction of drag of beds in contact with the till show that the overriding ice that deposited the till moved in a southwesterly direction. The orientation of lineations in the till also supports this assumption.

DESCRIPTION OF THE TWO TILLS AND RELATED DEPOSITS

Superficially, the two tills are similar. The older till, however, is light gray to light tan, whereas the upper till is considerably darker. The color difference appears to be due to the fact that the older till is more oxidized although there has not been sufficient weathering to decompose any of its contained pebbles. Both tills are highly calcareous and show no leaching effects. The older till is more compact than the younger till but contains numerous small irregular fractures 2 to 4 inches apart coated with a thin orange-brown film of iron oxide, or less commonly brownish-black manganese oxide. The few fractures in the younger till are not coated.

The two tills are nearly identical lithologically. They appear to differ only in the amount of shale each contains. Of pebbles larger than half an inch about 60 percent from each till are composed of limestone and dolomite. Granitic and gneissic pebbles are next most abundant and constitute about 15 percent. Shale chips, a minor constituent in both tills is more than twice as abundant in the older till than in the younger till. The shale chips presumably were derived from the Pierre shale, either from Canada or northeastern North Dakota. Many of the pebbles in the older till are speckled and mottled with manganese dendrites but such mottling is almost totally absent in the younger till. As shown in table 1, mechanical analyses of the minus six mesh fraction of both tills show a remarkable similarity in grain size. Both tills also have a plasticity index of about 21.

Table 1. Mechanical analyses of younger and older tills.

Sieve (U. S. Standard)	Younger till	Older till
	Percent passing	
10 mesh	94	96
30 mesh	90	90
40 mesh	88	87
60 mesh	82	81

100 mesh	76	74
200 mesh	67	66
270 mesh	64	63

Grain size (silt and clay range determined by hydrometer method)

0.04 mm.	61	61
.005 mm.	23	24
.002 mm.	15	16
.001 mm.	9	9

Glaciofluvial deposits intercalated in the older till consist predominantly of cross-bedded sand beds and lesser amounts of finely laminated buff-colored silt beds and poorly to well-sorted gravel beds. Many of the pebbles are mottled with dendrites identical to those in the older till. The composition of the deposits is similar to that of the older till. The gravel fraction in both the highway cut and in the gravel pit contains abundant shale chips. Lignite chips also are abundant in both the sand and gravel fractions in the pit.

The zone of boulders and cobbles that separates the two tills forms a well-defined pavement in some places. It contains boulders 4 1/2 feet long, although the average size is about 2 feet. Many of these are polished and striated on their top surfaces.

The lime-enriched zone in the gravel pit consists chiefly of angular gray shale fragments embedded in a calcareous clay matrix; both the shale and the clay are white when dry. Partly embedded in the lime-enriched bed and extending slightly into the overlying till are a few cobbles and boulders that are probably the continuation of the boulder zone in the road cut. It is speculative whether the lime-enriched zone represents a poorly drained surface where lime-rich sediments accumulated while the boulder pavement was being formed elsewhere or whether it is an eroded C horizon of a soil profile and represents a considerable interval of time between deposition of the two tills.

Speculation on the ages of the two tills.

As pointed out by Lemke and Colton (this guidebook) the Donnybrook area probably was glaciated at least during the Iowan, Tazewell, and Cary substages of the Wisconsin and may have been glaciated as late as post Two Creeks time. By tracing end moraines northwestward from the carbon 14 site in Kidder County dated as Two Creeks age (see Moir, this guidebook), it can be demonstrated that the surface till in the Donnybrook area is at least post early Cary and could be as young as post Two Creeks.

The surface till in the Donnybrook area was deposited by the southeast moving Souris River lobe (Lemke, this guidebook). Inasmuch as the exposure in the road cut extends nearly to the top of the valley wall, it is reasonable to assume that at least the upper part of the till overlying the boulder belt was deposited by the Souris River lobe. The general overall homogeneity of the till section above the boulder pavement together with the absence of any fossil soils or erosional surfaces within it leads one to the conclusion that only one substage of deposition is represented by this upper till although it may represent readvances within this substage.

The age of the till below the boulder pavement is also speculative. That this till does represent an older substage than the till above the boulder pavement is supported by: (1) the greater oxidation of the lower till, (2) the markedly greater shale content of this till than of the younger till suggesting a different direction of ice advance or an earlier advance of some distance from the same direction, and (3) the presence of the boulder pavement and possible partial soil profile. If the lime-enriched zone in the gravel is, indeed, a partial soil profile, strong support is furnished for the assumption that the two tills belong to different substages. The fact that the ice which deposited the lower till moved in a southwesterly direction, as indicated from the exposure in the northeast part of the gravel pit, is not helpful in determining to what substage the till belongs. As discussed by Lemke and Colton (this guidebook) the overall direction of ice advance of the Iowan, Tazewell, and Cary substages were all to the southwest. Moreover, the direction of ice advance within the Riviere des Lacs valley probably was controlled by the valley walls and had little or no regional significance.

In summary, there is good evidence that the till overlying the boulder belt was deposited in post early Cary time and possibly as late as post Two Creeks. The till underlying the boulder belt probably belongs to an older substage and could be as old as Iowan.

1/ Publication authorized by the Director, U. S. Geological Survey.

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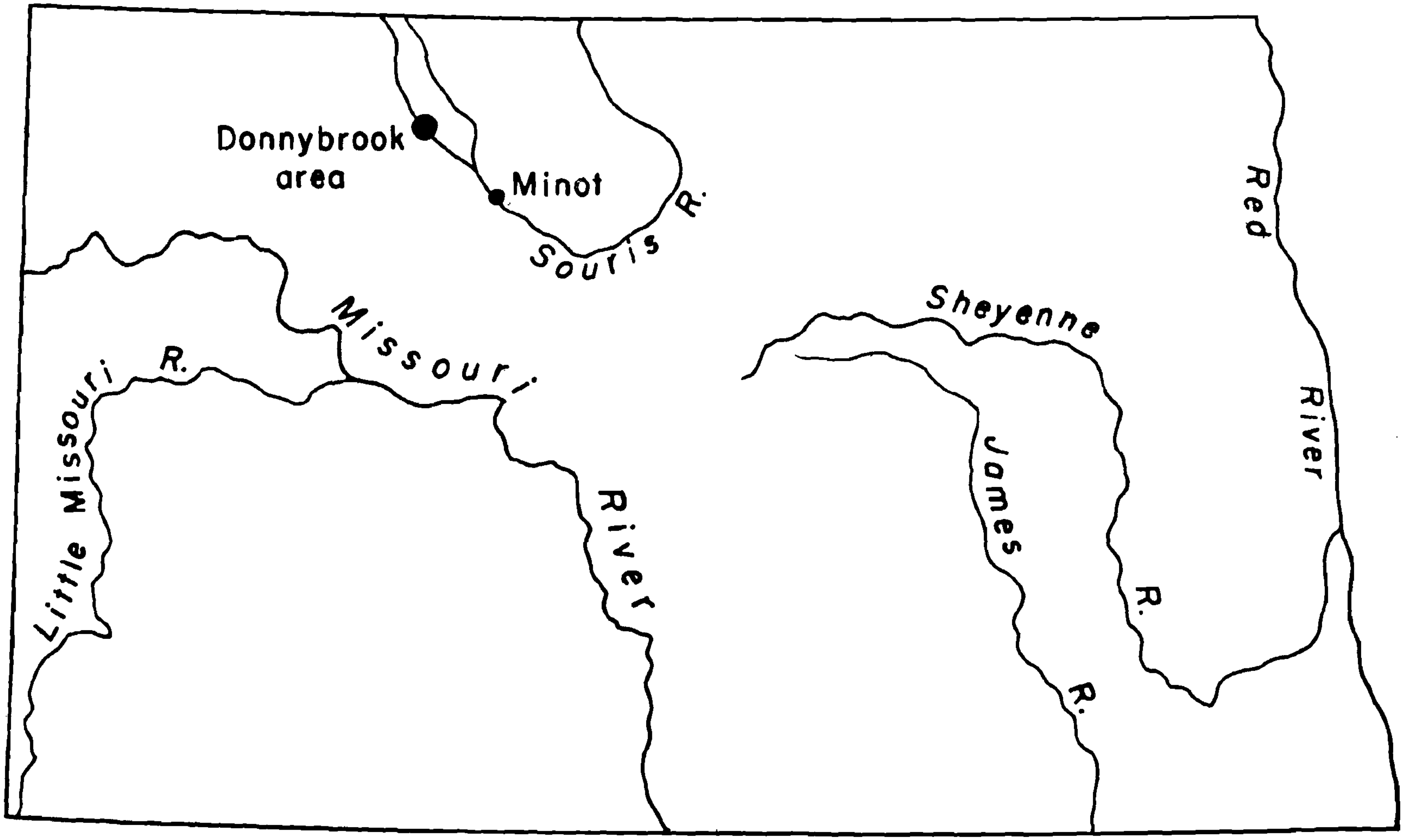

Figure I. Index map of North Dakota showing location of Donnybrook area.

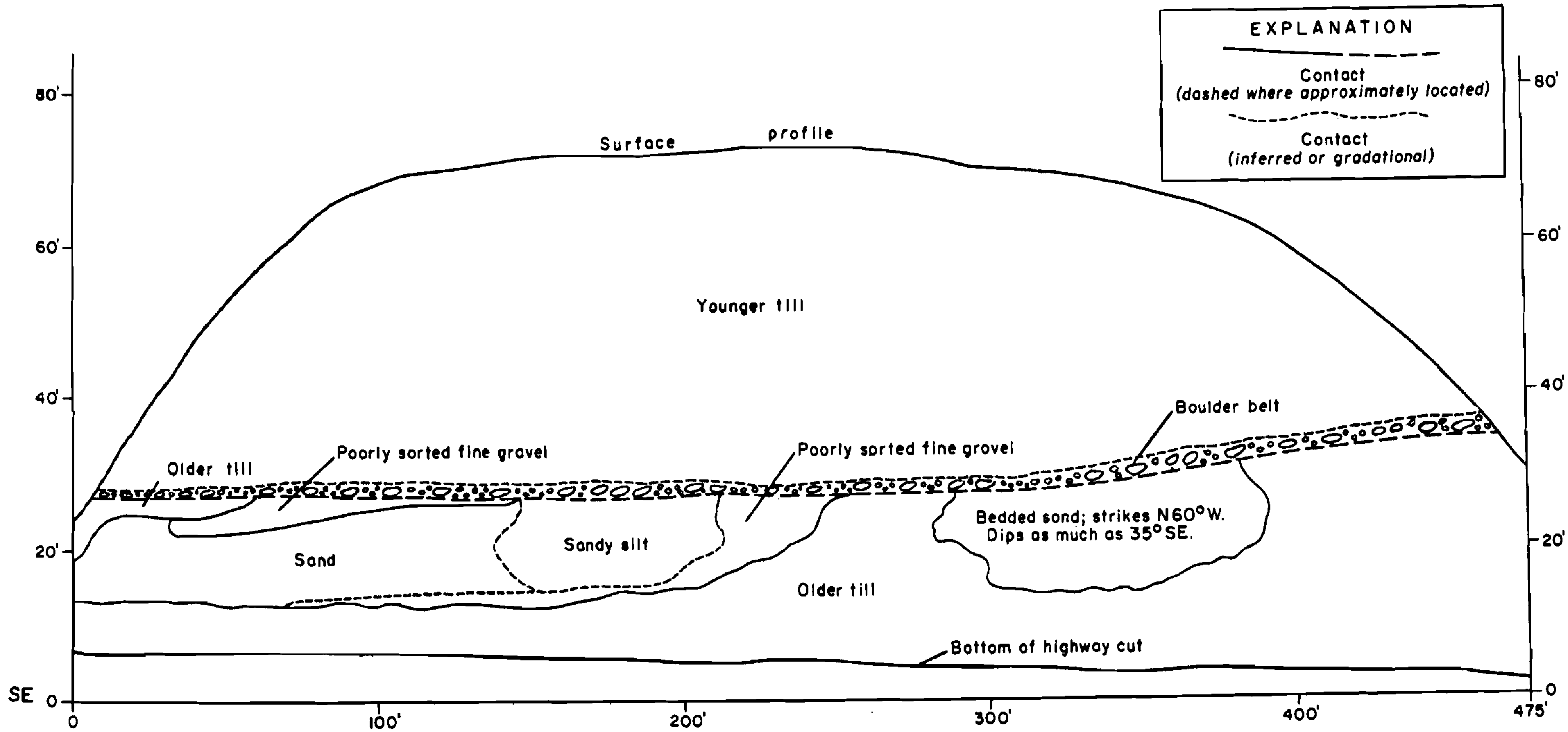

Figure 2. Section along highway cut 1½ miles southwest of Donnybrook.

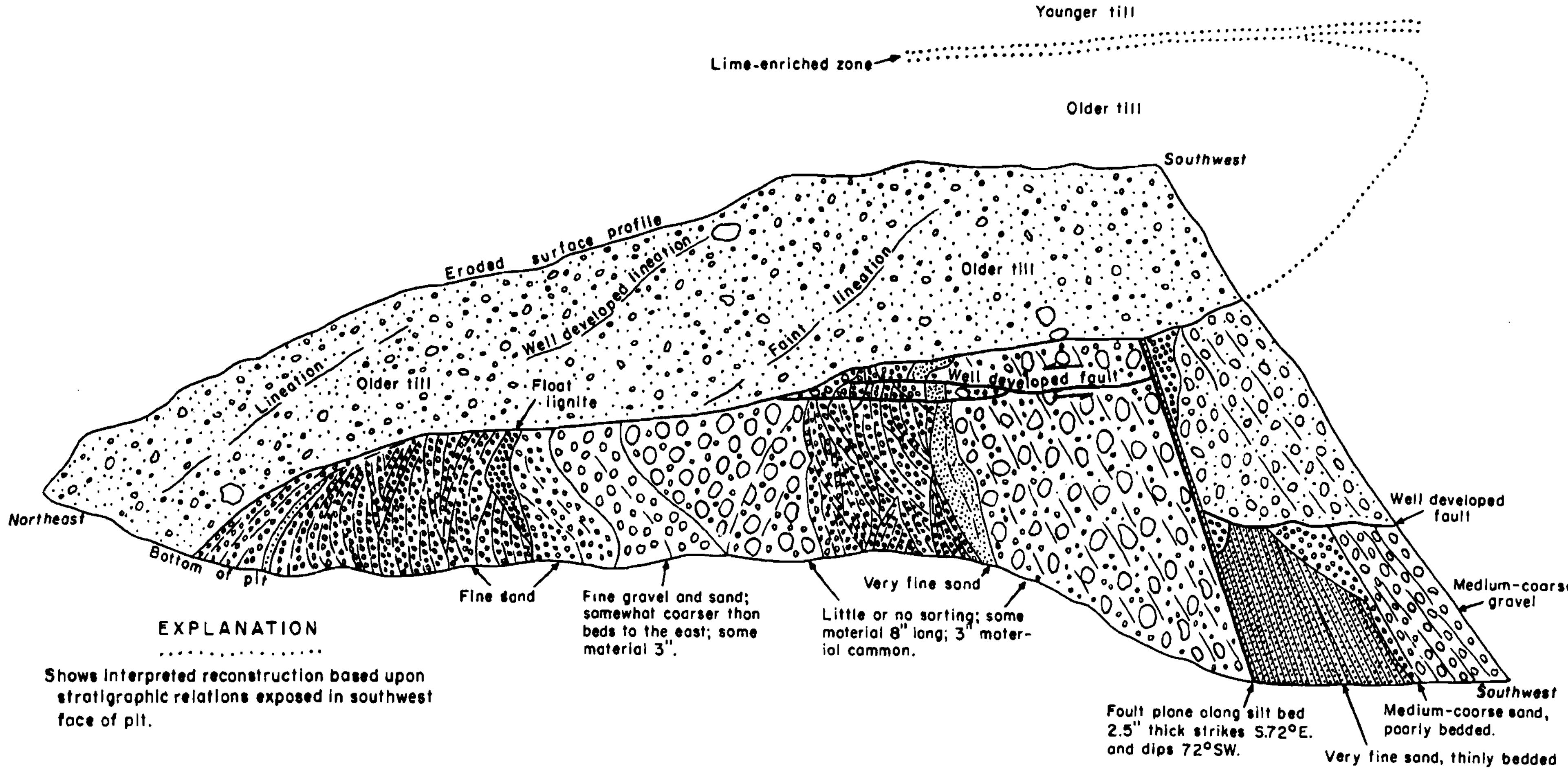

Figure 3. Cross section in gravel pit in SW¼ sec. 24, T. 158 N., R. 78 W.
(Near northeast edge of pit, looking southeast.)

Ice-crack moraines in northwestern North Dakota and northeastern Montana[1/]

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Introduction

An unusual pattern of long narrow till ridges characterizes drift of Tazewell (?) age in northwestern North Dakota and northeastern Montana. These ridges are interpreted to be ice-crack moraines formed as subglacial crevasse fillings. The purpose of this paper is to discuss the distribution, shape, and composition of these ridges, to speculate anew on their origin, and to point out their significance as indicators of the direction of ice movement.

The pattern of ice-crack moraines was studied by several members of the U. S. Geological Survey during the course of detailed mapping in northwestern North Dakota and northeastern Montana. Colton's attention was called to these features in 1949 by Fred S. Jensen who mapped the Frazer, Nashua, and Glasgow quadrangles in Montana while Colton was mapping the Otter Creek quadrangle south of Plentywood, Montana. The pattern was then called "the waffle pattern" (fig. 1). A few of the ridges of till occurred in the Otter Creek quadrangle but they were then thought to be recessional moraines. Both Arthur D. Howard and Irving J. Witkind mapped similar features north of Medicine Lake but thought they were recessional moraines (written communication).

Mapping actually began at both ends of the Montana belt of ice-crack moraines. Colton was assigned the area which remained to be mapped in 1950 and thus was in the position of having the overall picture available because most of the mapping had been done. However, it was not until 1956 when high-altitude photographs were obtained that an overall map of the ice-crack moraines was made and the origin of these features became apparent.

Distribution

The preglacial valleys of the Yellowstone and Missouri Rivers were the main avenues of advance each time glaciation of the area occurred. What actually occurred was valley glaciation on a grand scale. The lobe of ice that flowed southwest and westward up the ancestral Missouri River Valley in Montana probably was 25 miles wide and approximately 150 miles long. The lobe that moved up the ancestral Yellowstone River Valley probably was 100 miles long and approximately 20 miles wide. Not included in the above approximations are the areas of slowly moving and almost stagnant ice along the edges of these two main avenues of ice movement.

Four drift sheets have been mapped in northwestern North Dakota and northeastern Montana. The oldest has been much eroded and consists of scattered patches of till and a lag concentrate of erratics. This drift may have been deposited in pre-Wisconsin time or in earliest Wisconsin time. A much younger looking drift, of Tazewell (?) age, is characterized by long narrow ridges of till called ice-crack moraines. In the northeastern part of the area, this drift sheet is overlain by very youthful drift of Cary age. Reconnaissance mapping elsewhere in North Dakota has indicated that an ice front advanced a short distance into the area in Valders (?) time. The distribution of these drift sheets is shown on plate 3 (in pocket).

Nearly all the ice-crack moraines are in two discontinuous belts that roughly follow the margins of the preglacial valleys of the Yellowstone and Missouri Rivers. The belt in the ancestral Missouri River Valley is 110 miles long and extends from Nashua to Coalridge, Montana. Only a few gaps occur in the amazing continuity of pattern and these occur because the ridges have been eroded away or have been covered by younger deposits. The width of the Nashua-Coalridge belt ranges from 5 to 20 miles. The average width is 7 miles. Typical of this belt are the areas west and northwest of Oswego, Montana shown in figures 1 and 2.

The belt in the preglacial and present valley of the Yellowstone is very discontinuous and contains less than half as many ice-crack moraines as are in the Nashua-Coalridge belt. The belt in the Yellowstone Valley extends from Burns, Mont. nearly to Alamo, N. Dak., a distance of 85 miles. Nearly all the ice-crack moraines in the Burns-Alamo belt are in three groups. The southernmost group, between Burns and Sidney, is only a few miles wide. The second group, northeast of Cartwright, N. Dak. is near the junction of the Missouri and the Yellowstone. The third group, 10 miles northeast of Williston, covers 5 townships. Most of the third group is outside of the Yellowstone River Valley. The ice-crack moraines east of the margin of the Yellowstone River Valley and north of Epping in T. 155 N., and R. 99 W. are on a plain and the ice had probably stagnated over the whole plain quickly. However, the presence of the ice-crack moraines there is somewhat anomalous and more work needs to be done in that area.

Shape and composition

The ice-crack moraines of the Tazewell (?) drift are straight ridges composed of pebbly clayey till. They are 50 to 100 feet wide and as much as 20 feet high and 2 1/2 miles long. The longer ridges are parallel, 650 to 1,200 feet apart and average 5 ridges per mile. Most of the ridges are long and parallel, others are short and intersect the long ridges at angles of 30°, 45°, and 90°. In several areas the ridges form a geometric pattern (informally called "the waffle pattern") which resulted from a set of conjugate fractures (fig. 1).

Several mechanical analyses were made of samples of till from the ice-crack moraines near Wolf Point and Poplar, Mont. They indicate that 25 to 30 percent of the till is clay, 26 to 37 percent of the till is silt, 25 to 40 percent is sand, and only 2 to 6 per cent includes sizes larger than sand.

Some ice-crack moraines west of Oswego look as if they are younger than others. They were studied under the Kelsh plotter using high-altitude aerial photographs (scale 1:60,000). The stereo image studied was at a scale of 1:12,000. Some ice-crack moraines cut across and drape over older ones (fig. 2). In a few areas there were at least three intervals of ice-crack moraine formations. These cross-cutting relations are best shown a few miles west of Oswego, both north and south of U. S. Highway No. 2. Details of this area are illustrated in figure 2.

Ice-crack moraines are easily seen on aerial photographs where cultivation has occurred but are difficult to see in uncultivated areas because in plowed fields the dark A and B soil zones have been blown or otherwise eroded off the ridges and the white lime-enriched C zone is exposed. This zone contrasts with the surrounding dark soil and consequently shows in pictures as a white line against a darker background (fig. 1).

Previous work

The term "ice-crack moraines" was first used by Sproule (1939, p. 104) to describe narrow, generally sharp, ridges of sandy moraine crossing the country at right angles to the direction of ice movement in the Cree Lakes area, Saskatchewan, Canada. In that area, they are as much as 3 miles or more in length. The width of only a few is more than 100 yards and the majority are much narrower. The highest measured were 35 feet high. In most places, they are parallel although separate sets converge at acute angles.

Ice-crack moraines in northeastern Montana were first described by F. A. Swenson (written communication, 1946). The same conclusions were presented in 1955 (Swenson, 1955, p. 27 and 28): "These low gravelly ridges very likely represent fillings of crevasses that resulted from a system of joints developed in the fracture zone of the ice mass while it was still in motion. When the ice sheet stagnated, probably because the main ice mass was no longer able to move southward over the divide between Hudson Bay and the Gulf of Mexico, it thinned mainly by surface melting. Streams flowing across the surface of the ice sheet deposited their loads into the existing crevasses; as melting continued, these deposits were lowered onto the land underlying the ice. The finer grained materials remained in suspension longer and escaped with the water as it found its way beneath the melting ice sheet. According to Flint (1947, p. 17), stagnation of an ice sheet occurs when the rigid upper zone (zone of fracture) of a glacier extends down to the subglacier floor. This zone is believed to extend down to depths of 100 feet to 200 feet, and thus we have a rough measure of ice thickness at the time the materials were accumulating in the crevasses. It is apparent that the ice mass was in a stagnant condition over a wide area; otherwise, the ridges would have been disturbed by further movement of the ice sheet."

I agree with Swenson that the ridges represent fillings of crevasses in ice. However, the features are not gravelly, but are composed of till. No stratified drift has been found in them and, therefore, they were not formed by streams which flowed across the surface of the ice and washed their loads into the crevasses. Swenson's idea on the approximate thickness of the ice at the time of formation of the ice-crack moraines seems reasonable but current thought on the depth of crevasses (Seligman, 1955, p. 514) limits them to a depth of 100 feet. I agree with Swenson (1955, p. 28) "that the ice mass was in a stagnant condition over a wide area." Swenson goes on to say, (1955, p. 28) "otherwise, the ridges would have been disturbed by further movement of the ice sheet." In a previous paragraph, I have explained that some of the ridges have been slightly disturbed by later movement as well as being superimposed on each other.

Colton and Jensen (1953, p. 1542-1543) indicated erroneously, that the long axes of the long ridges (over 90 percent of the ice-crack moraines) are normal to the direction of ice movement. The orientation of the drift borders and the general shape of the ancestral Missouri Valley indicate that nearly everywhere the direction of ice movement was at an angle of 45° to the long axes of the long ice-crack moraines.

The pattern made by the ice-crack moraines is comparable to the herring bone-like lateral shear crevasse patterns in many valley glaciers (fig. 3). Nye (1952, p. 89-91) indicated that if lateral stresses were negligible the principal axes of stress are everywhere at 45° to the edge. Hopkins (1862, p. 706) arrived at a mathematical conclusion that in a simple case of a valley glacier, marginal fissures should make angles of 45° with the axis of the glacier. Cloos (1929, p. 68) discussed the distribution of crevasses along the edges of valley glaciers and illustrated the fact that such cervasses are usually oriented approximately 45° to the valley wall and the direction of the flow of the glacier (fig. 3). Charlesworth (1957, p. 46) stated that crevasses "point obliquely up the glacier from the edge, usually at 45° but actually at an angle which varies with the glacier's thickness and velocity." These relationships are shown in figure 3.

Summary

Ice-crack moraines or subglacial crevasse fillings are believed to have been formed under the following circumstances: As the lobes of ice moved southwest and west up the preglacial Missouri and Yellowstone River valleys, they blocked the rivers and lakes formed upstream from the lobes. The damming effect of the lobe was present west of Poplar, Montana, in the Missouri River Valley and northwest of Brockton, Montana. The edges of the ice floated in the lakes. The lake levels fluctuated and the floating ice broke along planes of weakness previously developed by valley wall confinement--somewhat regularly spaced shear crevasses. When the lake levels were high, the blocks of ice floated but during low stages the blocks pressed down on the soft saturated basal ablation till which was squeezed up into the crevasses. In some areas, patterns were stamped on patterns as the lake level fluctuated several times while the ice front was in that area. Examples of such features are in the center of sec. 17, T. 27 N., R. 45 E., Montana; in secs. 29 and 33, T. 27 N., R. 45 E., Montana; and in sec. 36, T. 28 N., R. 47 E., Montana. The width of ice-crack moraines depended on how far apart the blocks of ice drifted and accounts for the fact that some ice-crack moraines are much wider than others and that there had been movement and offsetting due to drifting. Where no damming of water was possible and thus no movement through floating possible, few or no cross ridges were formed as in the Homestead, Smoke Creek, and Coalridge areas, Mont., where only a somewhat regular shear pattern developed (fig. 4).

In the Coalridge area, Mont., the crevasses formed as shear planes in the ice (fig. 4). No lake existed in this area and thus the front part of the lobe of ice did not float and fracture. Relief of pressure exerted by the weight of the stagnant crevassed ice on the underlying till occurred along the crevasses as they widened by melting; the plastic till was extruded from underneath the ice and forced up into the crevasses. After the ice melted, the ridges of till were left. The situation is one analogous to the formation of clastic dikes. If the ice-crack moraines do represent shear planes in the Coalridge area, then the direction of ice movement prior to stagnation was nearly west.

Conclusions

The pattern of ice-crack moraines which characterizes the surface of the Tazewell (?) drift in Montana is apparently of regional significance. Such a uniform pattern extending from Wiota to Coalridge, Mont., suggests a steadily warming climate over a long period of time.

The long ice-crack moraines indirectly indicate the direction of ice movement. Their long axes are oriented approximately 45° to the direction of ice movement. This fact can be demonstrated in the Frazer-Westby areas because the till ridges are confined to a valley bottom between driftless highlands a few miles to the north and the outermost drift border 15 to 30 miles to the south. The topography of the area has not been radically changed by erosion since the last glaciation in the area, and it can be safely assumed that the flow of the ice was controlled by the topography and the greatest flow occurred in the deepest parts of the valley.

The similar pattern of ice-crack moraines characteristic of the Tazewell (?) drift indicates the same conditions affected the ice in the Yellowstone and Missouri River Valleys during the waning of the Tazewell (?) glaciation.

The fracture pattern represented by the ice-crack moraines indicates that a lobe of ice moved southwest from Westby to Poplar and then westward to Frazer up the Missouri River Valley. It also indicates the southwestward movement of the lobe of ice that pushed up the Yellowstone Valley.

Ice-crack moraines can be used to correlate the drift north and south of the Missouri River. Their distribution indicates one nearly continuous glacial event and the minimum extent of one drift sheet.

Obviously all the answers to these problems have not been found and more work needs to be done. This paper is merely a progress report.

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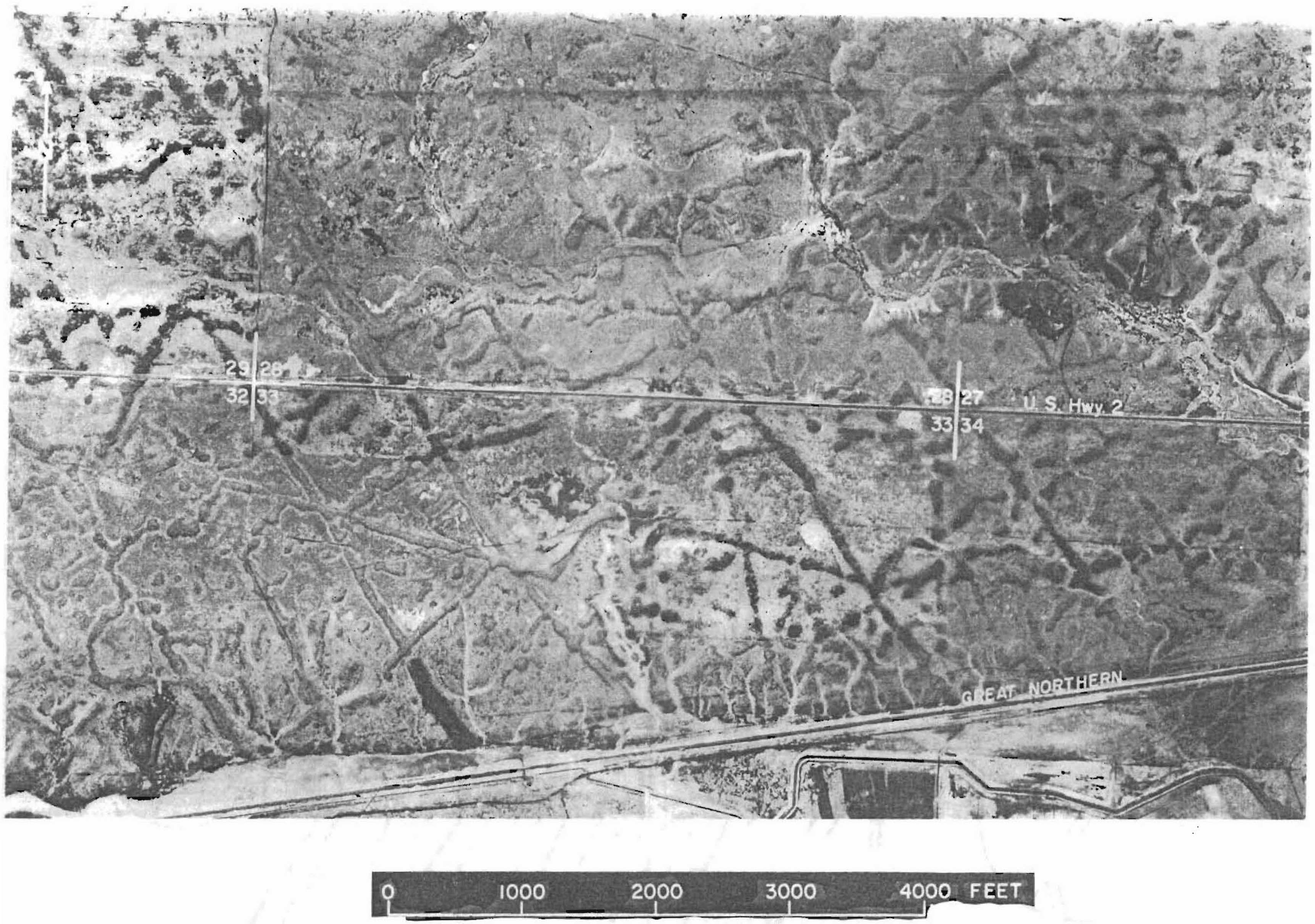


FIGURE 1. ICE-CRACK MORAINES WHICH FORM A "WAFFLE PATTERN" A FEW MILES WEST OF OSWEGO, MONTANA. THE RIDGES SHOW AS WHITE LINES WHERE THE LAND HAS BEEN PLOWED. NUMBERS INDICATE SECTION CORNER IN T. 28 N., R. 45 E.

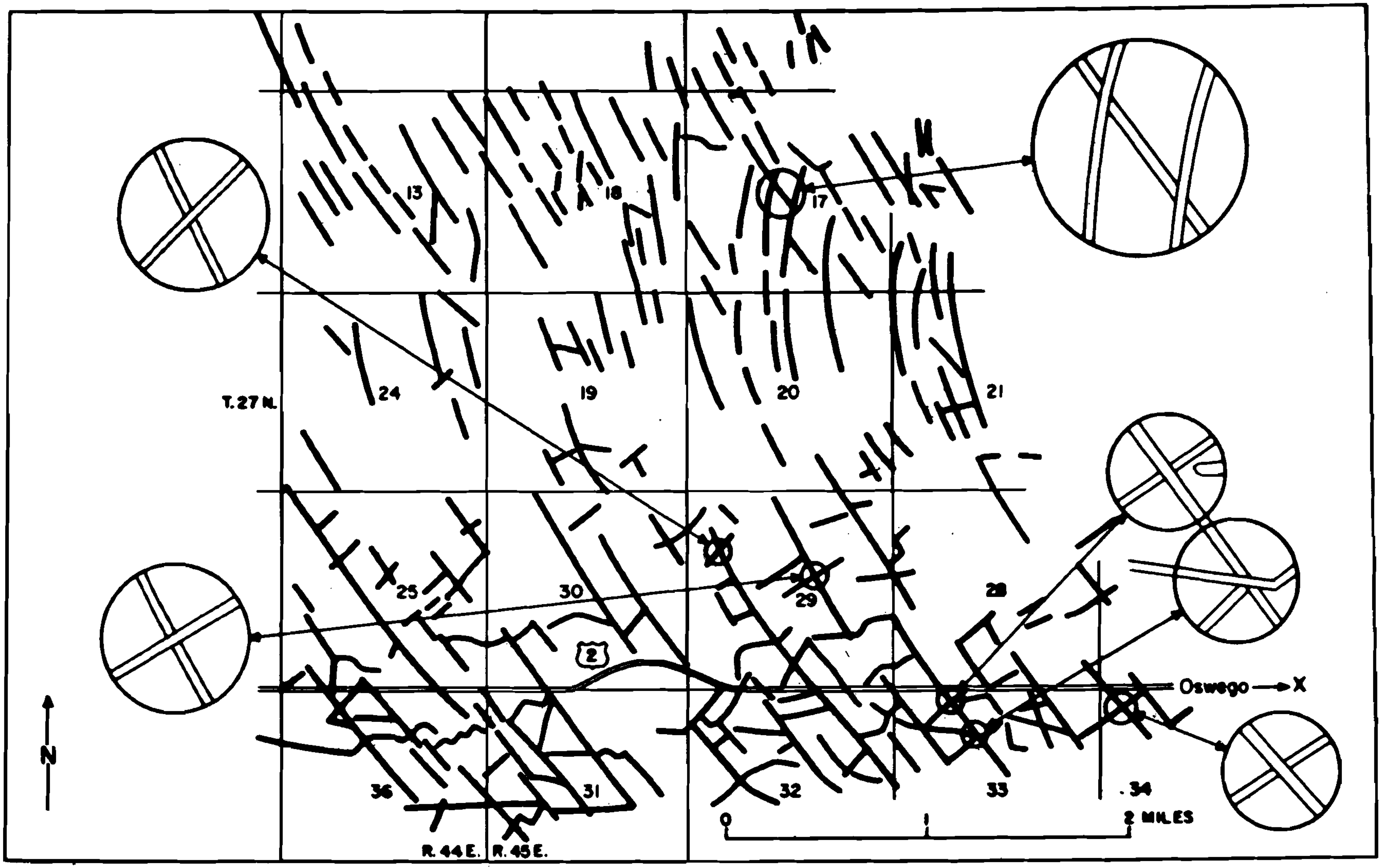
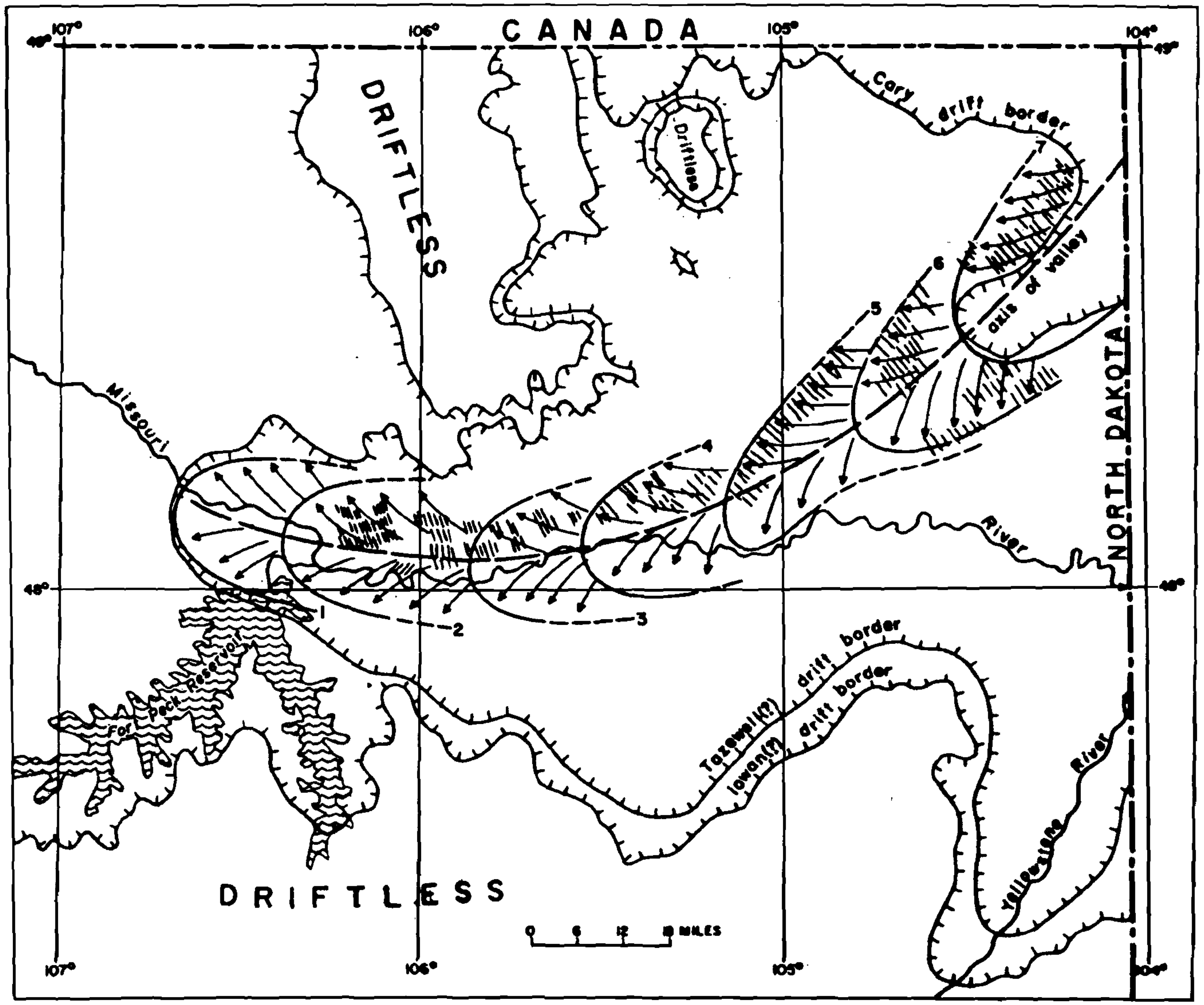


FIGURE 2. SKETCH MAP SHOWING AREAS NEAR OSWEGO, MONTANA WHERE YOUNGER ICE-CRACK MORAINES ARE SUPERIMPOSED ON OLDER ONES. ENLARGED AREAS IN CIRCLES ARE NOT TO SCALE.



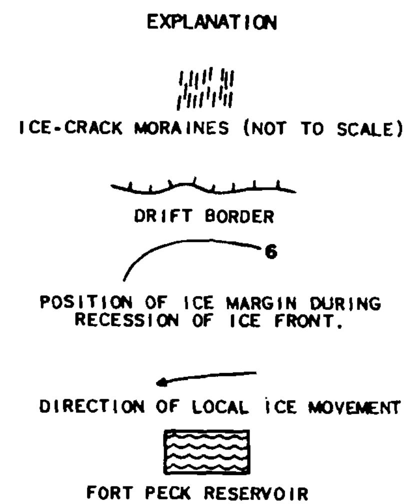


FIGURE 3. IDEALIZED RELATIONSHIP BETWEEN ICE MARGINS AND CREVASSES AS THE FRONT AND MARGIN OF THE VALLEY GLACIER IN THE MISSOURI RIVER VALLEY RETREATED NORTH-EASTWARD. LAKES WHICH EXISTED DURING THE FIRST FEW RECESSIONAL STAGES AGAINST THE ICE FRONT HAVE NOT BEEN SHOWN. DRAINAGE OF LAKE OCCURRED DURING THE FIFTH STAGE. STAGES ARE ARBITRARILY NUMBERED, AND MANY MORE COULD BE PLOTTED IF THE SCALE AND LEGIBILITY OF THE MAP PERMITTED.

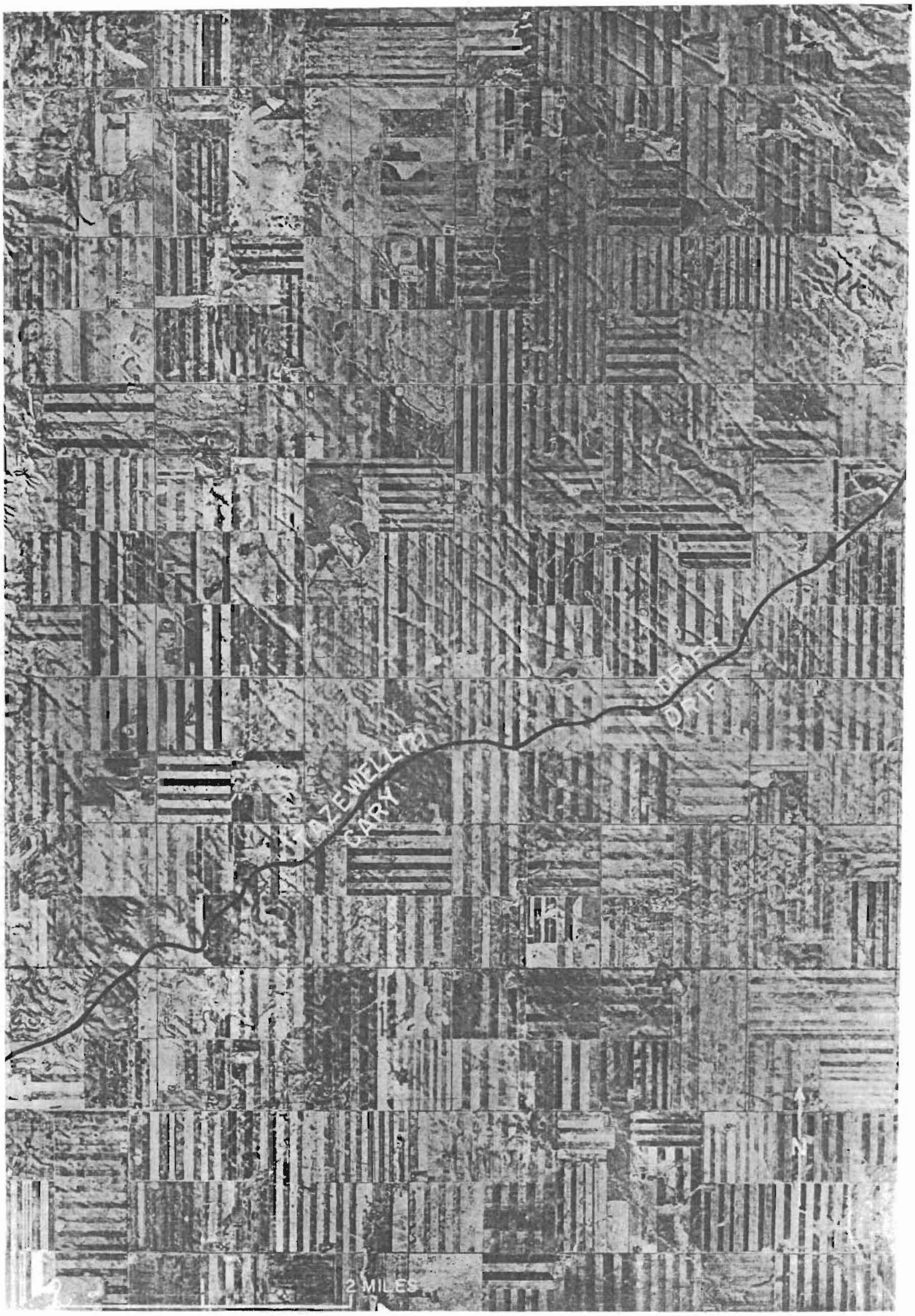


FIGURE 4. ICE-CRACK MORAINES 1 TO 8 MILES EAST OF RESERVE, MONTANA. THE SOUTHEASTERN PART OF THE AREA INCLUDED IN THE AERIAL PHOTOGRAPH IS THINLY VENEERED BY CARY DRIFT. NOTE THAT TAZEWELL(?) ICE-CRACK MORAINES ARE REFLECTED THROUGH THE YOUNGER DRIFT.

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1/ Publication authorized by the Director, U. S. Geological Survey.

Occurrence and radiocarbon date of coniferous wood in

Kidder County, North Dakota [1/]

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INTRODUCTION

The value of radiocarbon determinations as an aid in the establishment of late glacial chronologies has been demonstrated in numerous studies reported in recent literature. Relatively few such dates are available from North Dakota, so that the discovery of a site with buried coniferous wood in Kidder County has been of considerable interest.

This site was exposed in the fall of 1955 by a power-shovel operator while attempting to open up a possible water source in a pasture on the Wolt farm about 10 miles south of Tappen, North Dakota. The exact location is in a draw about 200 feet southwest of the center of section 25, T. 138 N., R. 71 W., in Kidder County. This draw carries intermittent surface drainage to the northeast from the gently rolling hills characteristic of this portion of the county.

At a depth of about 15 to 18 feet below the surface, the power shovel contacted a large stump with a diameter of approximately 10 inches, in an upright position. The base was embedded so firmly that it interfered with the operation of the power shovel and could not be removed. Large pieces of the stump and root material were broken away and brought to the surface with the wet sandy colluvium being removed from the excavation.

Some time after the excavation had been abandoned, it was observed that through drying and slumping of the sides of the pile of material removed from the excavation, coniferous cones were being exposed. Until this time the presence of the stump had not been considered to be of any significance, but the discovery of the cones in an area far removed from any native stands of coniferous trees attracted the attention of the land owner, who in turn brought the site to our attention.

PROCEDURE AND RESULTS

Samples of wood and cones were obtained from the site and wood sections were prepared for identification using standard sectioning techniques. The wood sections showed remarkably good preservation of cellular detail, and have been identified as spruce. As there is little structural difference between white and black spruce, identification as to species has not been definitely established. However, its association with cones definitely identified as white spruce, leaves little doubt that the wood is of the same species. The size of the growth rings indicate that environmental conditions favored rapid growth.

Samples of the sand and clay material from the level where the stump was located were examined for pollen content. These samples were obtained from the sandy debris adhering to the wood samples, and by using a soil augur to remove clay samples at a depth of approximately eighteen feet below the surface of the undisturbed valley floor in the vicinity of the excavation. Unidentified pollen and spores in low concentration were observed, but as yet no coniferous pollen has been found.

The stratigraphic column presented here represents the combined information from a drill log obtained by Dr. G. L. Bell, and a set of hand augur borings to a depth of 18.5 feet by the writer, both close to the excavated site.

From	To	Nature of Material
0'	1'	Turfy material in fine black matrix.
1'	9'	Sand, black to gray, uniform, well-rounded; variable water content.

9'	10'	Wood fragments, unidentified plant remains suggesting aquatic vegetation in a matrix of dark gray clay silt.
10'	15'	Gray sand as above, with gastropod shells and wood fragments from 12' - 15'.
15'	18'	Gray sand, fine, well sorted, rounded, becoming more compacte and with higher clay content approaching 18'. Wood samples obtained from this layer for radiocarbon determination (W-542).
18'	34'	Clay, light gray, top layer very sticky when wet, drying to a hard brick-like material (lowest level of hand-drilling 18.5).
34'	40'	Till, dark gray.
40'	47'	Gravel, pea size with gray sand lenses.
47'	54'	Gravel with cobbles, water.
54'	57'	Clay till.
57'	63'	Fox Hills sandstone.

Radiocarbon dating of a wood sample from this site submitted to the U. S. Geological Survey Geochronometric Laboratory by R. W. Lemke of the U. S. Geological Survey indicates an age of 11,480 years ± 300 years. (Sample W-542). The significance of this dating is discussed in the following section.

DISCUSSION OF RESULTS

The approximate maximum advance of the Wisconsin glaciation is marked in the Dakotas and adjacent Canada by a terminal moraine complex, extending in North Dakota from the northwest corner of the state in a generally southeast direction and passing into South Dakota about 150 miles west of the eastern boundary of the state in McIntosh County. This massive glacial feature forms a belt of hills varying in width from 10 to 20 miles, essentially uninterrupted through its entire length.

It has long been recognized that this moraine through its entire extent is not necessarily equivalent to the Altamont moraine at its type locality in eastern South

Dakota. Various workers, including Townsend (1), Townsend and Jenke (2), Flint (3), Leverett (4), and Chamberlin (5), have discussed the complexity of its origin, and even suggested alternate nomenclature for certain segments. A review of morainic systems in North Dakota and their tentative correlations in adjacent states is included in the summary paper on the pleistocene geology of North Dakota by Lemke and Colton (this guidebook). Their suggested nomenclature is being used for purposes of discussion in this paper. The buried wood site lies in the drift area designated as Post-Tazewell - Pre-Two Creeks, limited to the southwest at a distance of about 20 miles by the Burnstad moraine. (See Lemke and Colton, Fig. 4, this guidebook).

It is beyond the scope of this paper to review all reports on this moraine complex except to point out its anomalous structure in some segments as compared to the usual concept of a terminal moraine. In numerous places a bedrock high is present forming the core of the moraine. In the vicinity of the buried wood site the veneer of glacial till is variable, or even absent in some localities which show exposures of Fox Hills sandstone. From the limited data available, the pre-glacial topography of the area suggests a badlands aspect, with some very deep valleys, at present filled with glacial debris. Successive advances of the Wisconsin ice have greatly modified the pre-glacial topography, but it is not difficult to visualize earlier interstadials of more rugged topography than at present providing a great diversity of habitats and striking microclimatic differences. This would be especially true during the periods immediately following ice recession.

The presence of spruce in this area, not necessarily as continuous forest cover but more probably in scattered groupings in the more favorable habitats, suggests a climate cooler and moister than that experienced at the present time. The closest native stands of spruce in the current distribution pattern are in the Black Hills about 200 miles to the southwest; along the edge of the coniferous forest in Minnesota about

200 miles to the east; and in the Spruce Woods area of the Assiniboine River valley, again about 200 miles to the north in Manitoba. It is interesting that in this latter outlier of the northern coniferous forest the trees are not present as a continuous forest cover, but rather in an open woodland of separate stands of spruce.

Rowe (7) argues that survival of boreal species during glaciation of the western plains would be most likely along the borders of the complex of periglacial rivers and lakes formed successively as the ice advanced or retreated, rather than on the upland sites. As evidence he used Wickenden's (8) "fossil" spruce (which appears to be in alluvium and is near a periglacial stream associated with a moraine), Elson's (9) spruce and larch wood from early alluvium in Lake Agassiz, and the distribution of spruce in river valleys of Alberta and Saskatchewan today. Rowe (personal communication) points out an excellent example of white spruce growing in an isolated valley cut out of sandstone with "badland" topography near Castor, Alberta, demonstrating how spruce can survive where local conditions are satisfactory. This suggests that climatic conditions previous to the advance that terminated in the Burnstad moraine may not have been strikingly different to those occurring at present in such spruce outlets as mentioned above. A note of caution should be added however in the use of spruce as climatic indicator species. In some localities, if properly rooted, the species is very tolerant of extremes of wind, heat and cold. A good example of this is found in the Spruce Woods forest of southern Manitoba, where the forest maintains itself exposed to a truly prairie climate.

A satisfactory evaluation of the significance of the radiocarbon date of 11,480 years for the Tappen wood deposit and correlation with the Two Creeks interstadial awaits a more critical study of the deposits overlying the wood. Along with this is the possibility of obtaining other samples of plant remains from the upper strata in sufficient quantity for radiocarbon dating. It is recognized that until the overlying material is identified as till, outwash or merely alluvial-colluvial material, it can not be established that the trees were overridden or buried by material from an ice advance in the immediate area, although this is strongly suggested. A careful re-excavation of the site is planned for this spring as soon as weather conditions permit.

This find is of interest because relatively few datings are available from our region. A discovery discussed by Flint & Deevey (6) from a sewage disposal excavation in Lake Agassiz deposits on the banks of the Red River at Moorhead, Minnesota revealed a great variety of plant materials, including larch and white spruce. The first dating on this wood was 11,283 $\pm$ 700 years, but a more recent determination is 9970 years. It is suggested that this material was carried by the Buffalo River from beaches and moraines some 20 miles to the east.

SUMMARY

Samples of a coniferous tree stump and associated cones uncovered in an excavation in a moraine in Kidder County, North Dakota, have been identified as white spruce. Radiocarbon dating of a sample of the wood, believed to be *in situ*, yield an age value of approximately 11,480 years correlating closely with the Two Creeks interstadial. This material was evidently buried by sandy outwash or till that may date the maximum advance of the Mankato ice, and its presence here suggests a climate cooler and moister than is observed at present.

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