NORTH DAKOTA GEOLOGICAL SURVEY

WILSON M. LAIRD, STATE GEOLOGIST

REPORT OF INVESTIGATION

NO. 44

NOTES ON PLEISTOCENE STRATIGRAPHY OF NORTH DAKOTA

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GRAND FORKS, NORTH DAKOTA

1966

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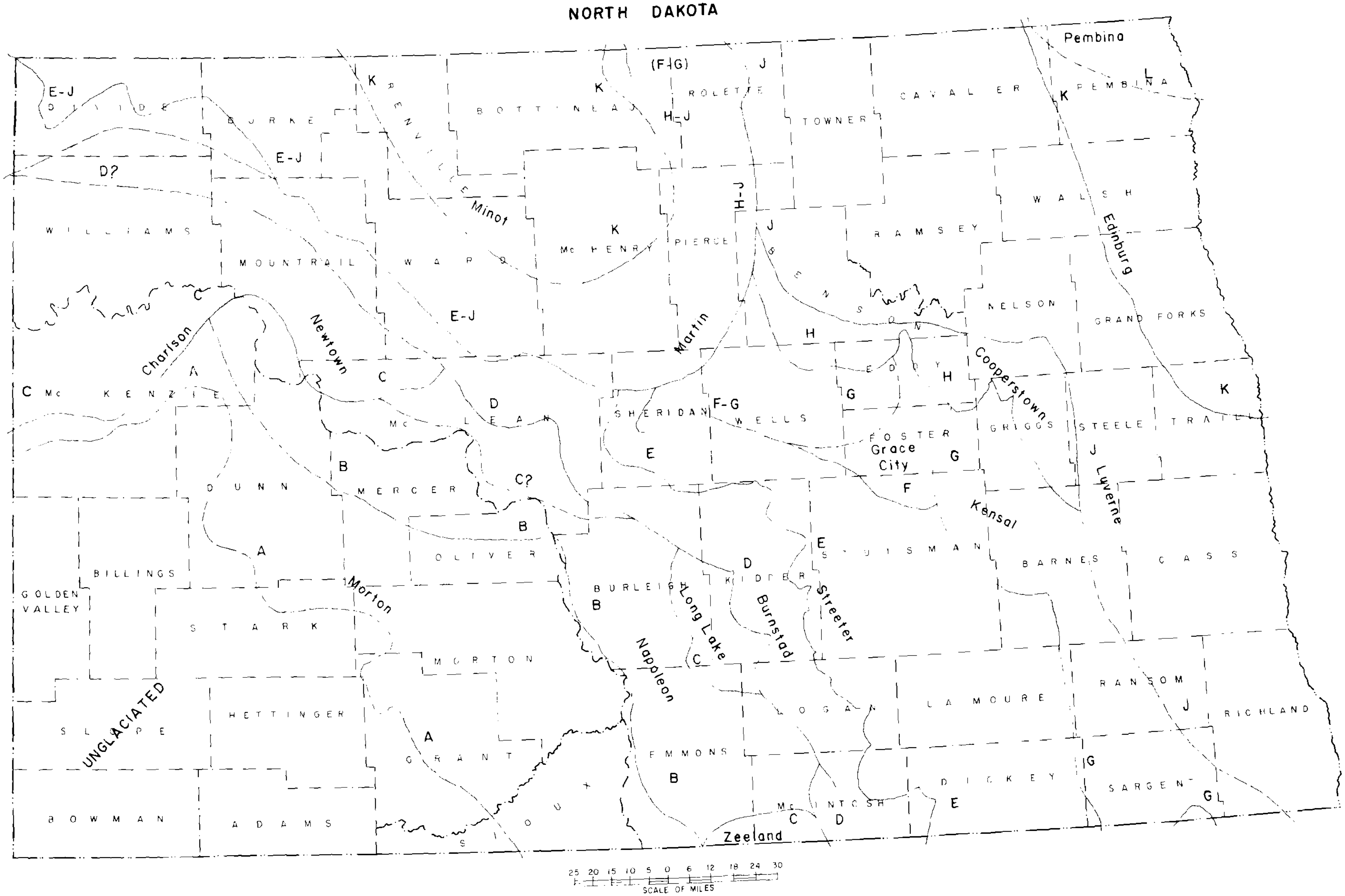
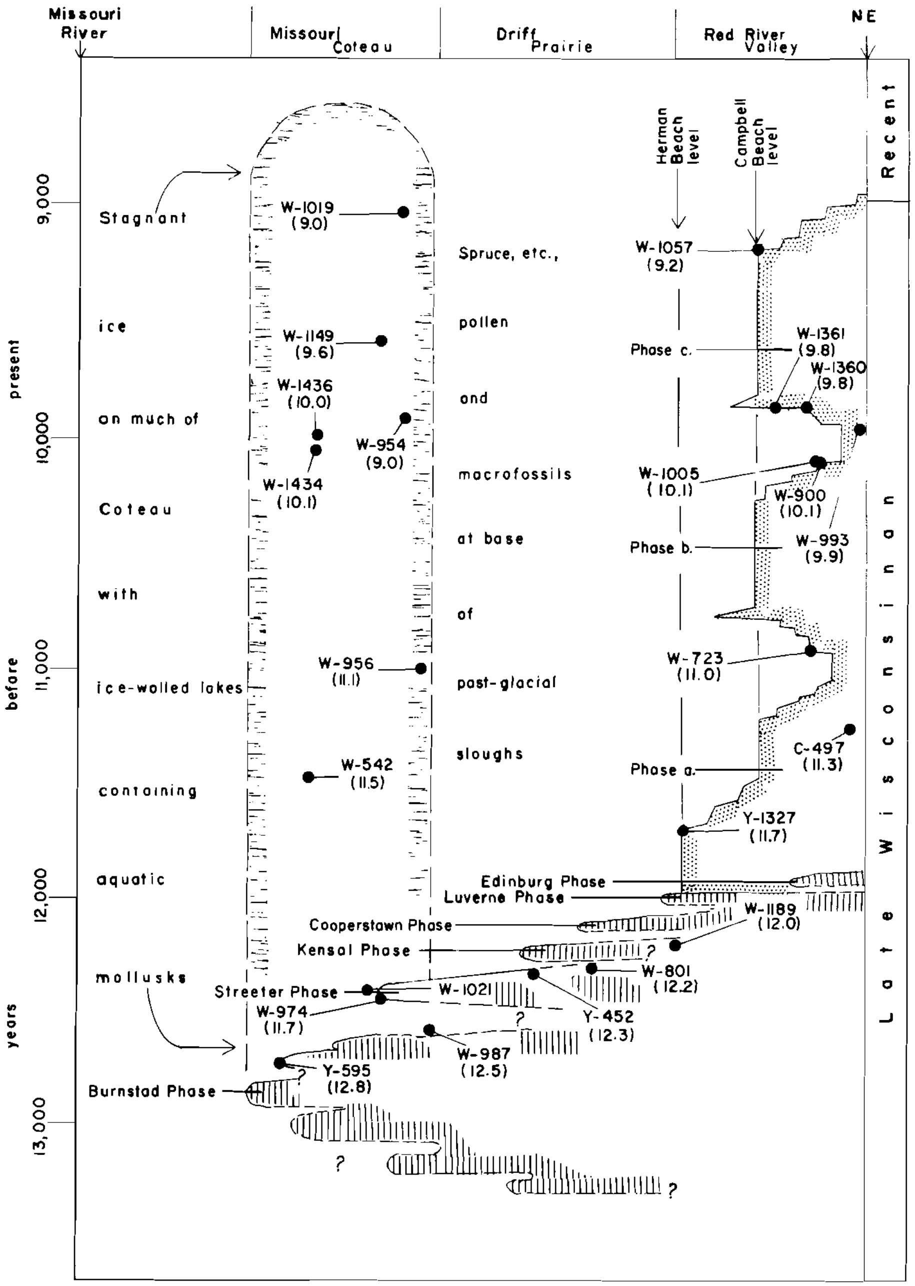
Purpose.--This publication is a progress report and supplement to the recent summary of the Pleistocene stratigraphy of North Dakota by Lemke and others (1965). They concluded (tab. 2, p. 22) that the "tenuous nature of stratigraphic information on glacial deposits makes correlation of radiocarbon-dated localities with...ice advances impractical at present." A more optimistic view is taken here; most of the radiocarbon dates from the state are correlated with named phases of glaciation or phases of Lake Agassiz, and an attempt is made to correlate these with dated events in surrounding areas.

Terminology.--All of the named surface drifts of North Dakota are shown in table 1. Corresponding ice-margin positions are shown in figure 1. The named drifts are ecostratigraphic units (Krumbein and Sloss, 1963, p. 51), a variety of which has been called morphostratigraphic units by Frye and Willman (1960). The drifts were deposited during named phases (minor advances), which are subdivisions of stades, which are a kind of ecochronologic unit called "geologic-climate units" by the American Commission of Stratigraphic Nomenclature (1961, art. 39). (Geologic-climate units are not ecostratigraphic units, as stated by Krumbein and Sloss, 1963, p. 51, because they are referred to as episodes or units of time rather than as bodies of rock.) These phases are shown in figure 2. The named surface drifts are lithologically indistinguishable on a regional scale and therefore belong to a single lithostratigraphic unit that will be defined in a later report.

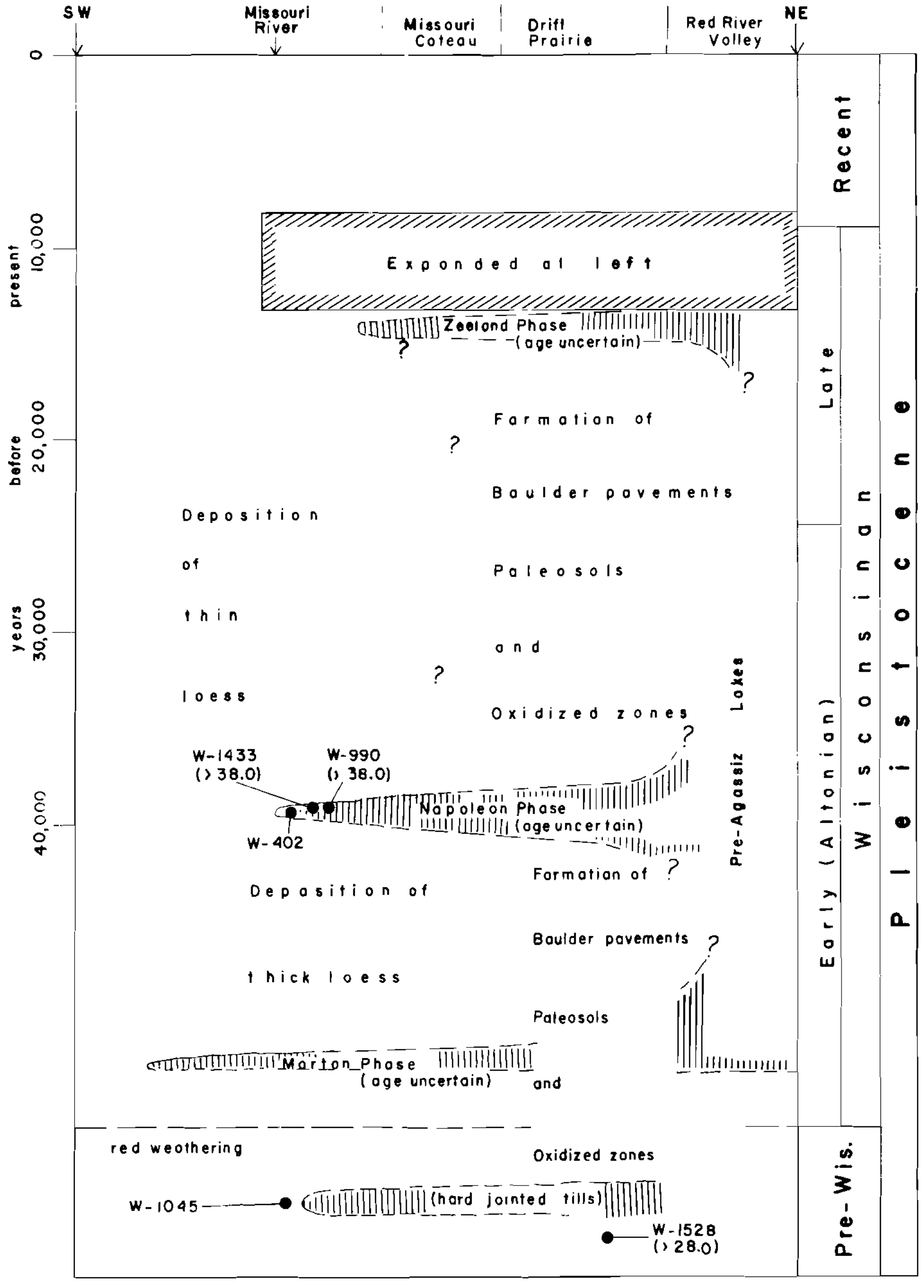
Figure 1.--Significant late Pleistocene ice-margin positions in North Dakota. Letters correspond to phases indicated in figure 2. Modified from Colton and others (1963).

NORTH DAKOTA





Missouri River
Missouri Coteau
Drift Prairie
Red River Valley
NE
Recent
Late Wisconsinan
years before present
9,000
10,000
11,000
12,000
13,000
Stagnant ice on much of Coteau with ice-walled lakes containing aquatic mollusks
Spruce, etc., pollen and macrofossils at base of post-glacial sloughs
Herman Beach level
Campbell Beach level
W-1019 (9.0)
W-1149 (9.6)
W-1436 (10.0)
W-1434 (10.1)
W-954 (9.0)
W-956 (11.1)
W-542 (11.5)
W-1057 (9.2)
Phase c.
W-1361 (9.8)
W-1360 (9.8)
W-1005 (10.1)
W-900 (10.1)
Phase b.
W-993 (9.9)
W-723 (11.0)
C-497 (11.3)
Phase a.
Y-1327 (11.7)
Edinburg Phase
Luverne Phase
W-1189 (12.0)
Cooperstown Phase
Kensal Phase
W-801 (12.2)
Streeter Phase
W-1021
W-974 (11.7)
Y-452 (12.3)
W-987 (12.5)
Y-595 (12.8)
Burnstad Phase



SW
Missouri River
Missouri Coteau
Drift Prairie
Red River Valley
NE
0
10,000
20,000
30,000
40,000
years before present
Recent
Late
Early (Altonian)
Wisconsinan
Pleistocene
Pre-Wis.
Expanded at left
Zeeland Phase (age uncertain)
Formation of Boulder pavements Paleosols and Oxidized zones
Deposition of thin loess
Pre-Agassiz Lakes
W-1433 (> 38.0)
W-990 (> 38.0)
W-402
Napoleon Phase (age uncertain)
Deposition of thick loess
Formation of Boulder pavements Paleosols and Oxidized zones
Morton Phase (age uncertain)
red weathering
W-1045
(hard jointed tills)
W-1528 (> 28.0)

Figure 2.--Time-distance (ecochronologic) diagram of Pleistocene events from northeastern to southwestern North Dakota. Left-hand diagram is an expansion of latest Wisconsinan part of the right-hand diagram. Time-stratigraphic units are shown on the right-hand side of each diagram. Values of radiocarbon dates in parentheses are in thousands of years. Named phases of glaciation have a vertical-line pattern and correspond to named drifts shown in table 1 and to named ice-margin positions shown in figure 1. The presence of stagnant glacial ice on the Missouri Coteau until about 9,000 B.P. is shown in the area with a horizontal-line pattern. The phases of glacial Lake Agassiz are shown with a dotted pattern.

All radiocarbon dates mentioned are from Lemke and others (1965) or Reid and Rubin (in preparation) unless otherwise stated. They are shown in figure 2.

Old drifts.--Knowledge of old (and presumably pre-Wisconsinan) drifts in North Dakota is scattered. Red weathered and cemented outwash occurs beneath the oldest surface drift in Logan County (Clayton, 1962, p. 55) and in Mountrail County a mile north of the Four Bears Bridge. The color is similar to that resulting from supposed Sangamon weathering in other parts of the midcontinent area, though the red color in North Dakota may be related to local groundwater conditions. Radiocarbon date W-1045 (28,700 B.P.) is from organic material beneath (not in; Lemke and others, 1965, tab. 2), red cemented and highly leached and weathered outwash gravel (not till; Lemke and others, 1965, tab. 2), underlying the Napoleon Drift in Logan County. The organic material may be Paleocene lignite containing Recent rootlets; it appears to be conformable with the underlying bedrock.

Old strongly-jointed tills have been exposed in cuts in many parts of the state, including northern Ward County (Lemke and Kay, 1958, p. 95), Logan County (Clayton, 1962, p. 55), Mountrail County, Barnes County (unpublished report by D. A. Block), and the northeastern part of the state (J. P. Bluemle, report in preparation). Bluemle has also found numerous buried boulder pavements, paleosols, buried oxidized zones, and exposures of oxide-cemented drift in the northeastern part of the state; he believes pre-Wisconsinan till exists in this area. Multiple drift exposures occur along most of the major streams in the eastern part of the state. Wood dated older than 28,000 B.P. (W-1528) was collected by Bluemle from the third drift from the surface at a depth of 44 feet in Ramsey County; it could be pre-Wisconsinan. Wood overlain by 58 feet of gravel and till and underlain by a darker, more compact till in Richland County (C. H. Baker, Jr., report in preparation) has been dated at older than 36,000 B. P. (W-1574); the lower till may also be pre-Wisconsinan in age. Buried oxidized zones have been found in some parts of the state, including Ward County (W. A. Pettyjohn, report in preparation); some are probably pre-Wisconsinan.

Morton Drift (Drift A).--The Morton Drift (drift A) consists of scattered erratic boulders and rare patches of till; little original morainic topography remains. There are no radiocarbon dates from this drift. It may be pre-Wisconsinan, but the lack of deep weathering suggests that it is Wisconsinan in age. However, as Ruhe and others (1965) have shown for the "Iowan" drift of Iowa, deeply weathered drift may be lacking because the weathered zone has been eroded away, leaving relatively unweathered pre-Wisconsinan drift exposed at the surface.

Napoleon Drift (Drift B).--In contrast to the Morton Drift, the Napoleon Drift, or drift B, retains much of its original morainic topography, though few closed depressions remain, and the drainage is largely integrated. The drift is a thin blanket, a few tens of feet thick at most, draped over the rolling pre-glacial topography; the drift was probably never thick enough to cause any significant amount of modification of preglacial topography.

Along the Missouri and its major tributaries, the Napoleon Drift has been completely eroded away. The Napoleon retains a few closed depressions on the uneroded drainage divides in Logan County and northeastern Mercer County and on the broad Strasburg moraine in south-central Emmons County. (The "Krem moraine" is not an end moraine as shown by Colton and others (1963), but merely a drainage divide; the drift does not thicken there.)

In McIntosh and southern Emmons Counties, the Napoleon till is strikingly more sandy and yellower than the till of the overlying drift C (Zeeland Drift): the ice that deposited it moved southwestward over 30 or 40 miles of the Fox Hills Formation, whereas the ice that deposited the Zeeland Drift moved southwest and then northwest over hundreds of miles of nothing but Pierre Shale and older drifts derived from it. Farther northwest in Burleigh County (Kume and Hansen, 1965, p. 50-59), the drift B (Napoleon Drift) and drift C (Long Lake Drift) are nearly identical because the directions of advance B (producing drift B) and advance C (producing drift C) were nearly identical.

Little or no loess is found on most of the Napoleon Drift, but several feet of loess occurs on Morton Drift on the east side of the Missouri River as far north as the outer margin of the Napoleon Drift (Strasburg moraine) in southwestern Emmons County. This suggests a significant break between the Napoleon and Morton Drifts.

Three samples of organic material from the Napoleon Drift in North Dakota have been radiocarbon dated. W-990 (earlier than 38,000 B.P.) definitely comes from the Napoleon outwash (Clayton, 1962, p. 59), but the carbonaceous material may have been eroded from pre-Napoleon deposits. Date W-402 (11,220 B. P.) from drift B in Mercer County seems anomalous because drift B has an almost completely integrated drainage, whereas Drift E, which has a completely nonintegrated drainage, is known to be about 12,500 years old. Date W-1433, earlier than 38,000 B.P. (Kume and Hansen, 1965, p. 59), is from terrestrial and aquatic mollusk shells in "Napoleon glaciofluvial sediments" in Burleigh County; the collection may have been slightly contaminated with

Paleocene shells, but probably not enough to change a late Wisconsinan date to an earlier than 38,000 B.P. date.

Thus, there are no completely reliable radiocarbon dates from the Napoleon drift. However, its drainage integration indicates that it is considerably older than drift C or D. In Logan County, stream erosion has removed the Napoleon Drift from within a few miles of either side of Beaver Creek (Clayton, 1962, p. 23-24). This belt of eroded topography is abruptly truncated to the east by the uneroded Burnstad moraine of phase D. This suggests that the Napoleon Drift is considerably older than the Burnstad Drift.

A partial jaw of Equus hatcheri from "Napoleon outwash" in Burleigh County may be pre-Wisconsinan in age (Kume and Hansen, 1965, p. 59). On the other hand, the Napoleon Drift has the same soil (the Williams series) developed on it as the Burnstad Drift (Omodt and others, 1961), so the Napoleon probably is not pre-Wisconsinan. The Napoleon Phase is therefore shown as early Wisconsinan on figure 2.

Drift C.--There are no radiocarbon dates from drift C. Its drainage is only slightly integrated in most areas, so it is considered to be closer in age to the Burnstad Drift (D) than to the Napoleon Drift (B). It differs from the Burnstad in generally lacking any strongly developed dead-ice moraine; its topography is dominantly that of ground moraine. No stagnant ice of phase C is known to have persisted until the time of phase D, suggesting a much longer interval than between phases D and E (see below).

The correlation of the Zeeland Drift in McIntosh and Emmons Counties, and the Long Lake Drift in Logan, Kidder, Emmons, and Burleigh Counties, with the rest of drift C in McLean, Mountrail, and Williams Counties is based on similarity of topography and relationships to other drifts; the Zeeland moraine, the Long Lake moraine, and the Newtown moraine in southern Mountrail County, and the Charlson moraine in northeastern McKenzie County are distinct bands of uneroded morainic hills a few miles wide, behind which is ground moraine with low local relief. Even though the ground moraine has been entirely eroded from large areas in northern McKenzie and southern Williams Counties, the Charlson moraine is probably as young as the Zeeland, Long Lake, and Osburn moraines because it has a fresh uneroded topography with disintegration ridges nearly as well preserved as those of the Burnstad Drift.

Burnstad Drift (Drift D).--Drift deposited by active ice of the Burnstad Phase (D) has not been radiocarbon dated in North Dakota. Lynn Hedges of the South Dakota Geological Survey (report in preparation) has shown that moraine D (the Venturia or Burnstad moraine) probably bends sharply westward in McPherson County to join advance 2 of Lemke and others (1965, fig. 1) in Campbell County. If this is true, the following radiocarbon dates from South Dakota (fig. 1 of Lemke and others, 1965) probably correlate with the Burnstad or Streeter Drifts. Dates Y-595 (12,760 B.P.) from Turner County, W-987 (12,530 B.P.) from Jerauld County, and Y-452 (12,330 B.P.) from Turner County may be from drift equivalent to the Burnstad Drift (D), and W-801 (12,200 B.P.) from Miner County and W-1189 (12,050 B.P.) from Hutchinson County may be from drift equivalent to the Streeter Drift (E) in North Dakota. Phase D is known to have occurred only slightly before phase E because stagnant ice of phase D persisted until after the ice of phase E stagnated in Logan and McIntosh Counties (Clayton, 1962, p. 63). The same was true in central Kidder County (most of the outwash in this area is collapsed phase E outwash that had been deposited on stagnant phase D ice), in northern Burleigh County (Kume and Hansen, 1965, p. 31-32), and in Mountrail, Burke, Divide, and Williams Counties (work in progress by the North Dakota Geological Survey).

Streeter Drift (Drift E).--The Streeter Drift or drift E is characterized by the looped ridges of the Streeter moraine on the Missouri Coteau. The only radiocarbon date from known active-ice deposits in North Dakota is W-974 (11,650 B.P.) from the front edge of the Streeter moraine in McIntosh County, not from perched lake silts as stated by Lemke and others (1965, table 2; see Clayton, 1962, p. 68). Though this date is slightly younger than the presumed age of the Streeter Phase (fig. 2), it is within the range of error to be expected for the radiocarbon dates of drifts D through L--which were deposited about 12,000 or 12,500 B.P. Two dates from South Dakota, W-801 (12,200 B.P.) and W-1189 (12,050 B.P.) may be from drift that is equivalent to the Streeter.

The above discussion of the Burnstad and Streeter Drifts has been restricted to active-ice deposition. However, the most widespread landforms of the Missouri Coteau are stagnant-ice features such as dead-ice moraine, collapsed outwash, and ice-walled lake plains. Thick superglacial drift prevented the stagnant Burnstad and Streeter ice on the Coteau from completely melting for nearly 3,000 years (fig. 2). The superglacial and ice-walled lakes and rivers were well insultated from the slowly melting buried stagnant ice. They supported large populations of aquatic mollusks; characteristic species were Amnicola limosa and Valvata tricarinata (Clayton, 1962, p. 63-67; Kume and Hansen, 1965, p. 93-109; various papers by Tuthill, including Tuthill and others, 1964). Shells of these mollusks have been dated at 11,070 B.P. (W-956 from Stutsman County), 10,100 B.P. and 9,990 B.P. (W-1434 and W-1436 from Burleigh County), 9,870 B.P. (W-954 from Stutsman County), 9,620 B.P. (W-1149 from McIntosh County), and 9,000 B.P. (W-1019 from Logan County). All of these dates are from outwash or lake silts deposited on top of or in basins formed by stagnant Burnstad or Streeter ice.

In some parts of the Coteau the ice melted much earlier and normal postglacial slough deposition began. Moir (1958) identified spruce at the base of a slough deposit on the Burnstad moraine in Kidder County; it was dated at 11,480 B.P. (W-402; fig. 2). No other postglacial lake or pond deposits in North Dakota have been radiocarbon dated. However, spruce, aquatic moss, and lime or marl have been observed at the base of many slough deposits within dead-ice moraine in the southern part of the Missouri Coteau (see, for example, Thompson, 1962).

Drifts F through L.--There are no radiocarbon dates from drifts F through L in North Dakota. Each drift has been recognized by the presence of an end moraine behind which is nearly flat ground moraine.

Ice-margin borders F through L each represent a change of glacial regimen of at least minor significance. Drift G truncates washboard moraines of drift E in eastern Stutsman County (Colton and others, 1963). The Luverne moraine (J) truncates the Cooperstown moraine (H) in northern Barnes County (D. A. Block, unpublished report). Lemke (1960, p. 112) has shown that the Luverne Drift is equivalent to the Martin Drift. The indistinct Minot ice border apparently truncates washboard moraines of phase J in northeastern Burke County; this border can be traced northwest into Saskatchewan (see below). The Edinburg moraine truncates washboard moraines of drift J in eastern Cavalier County.

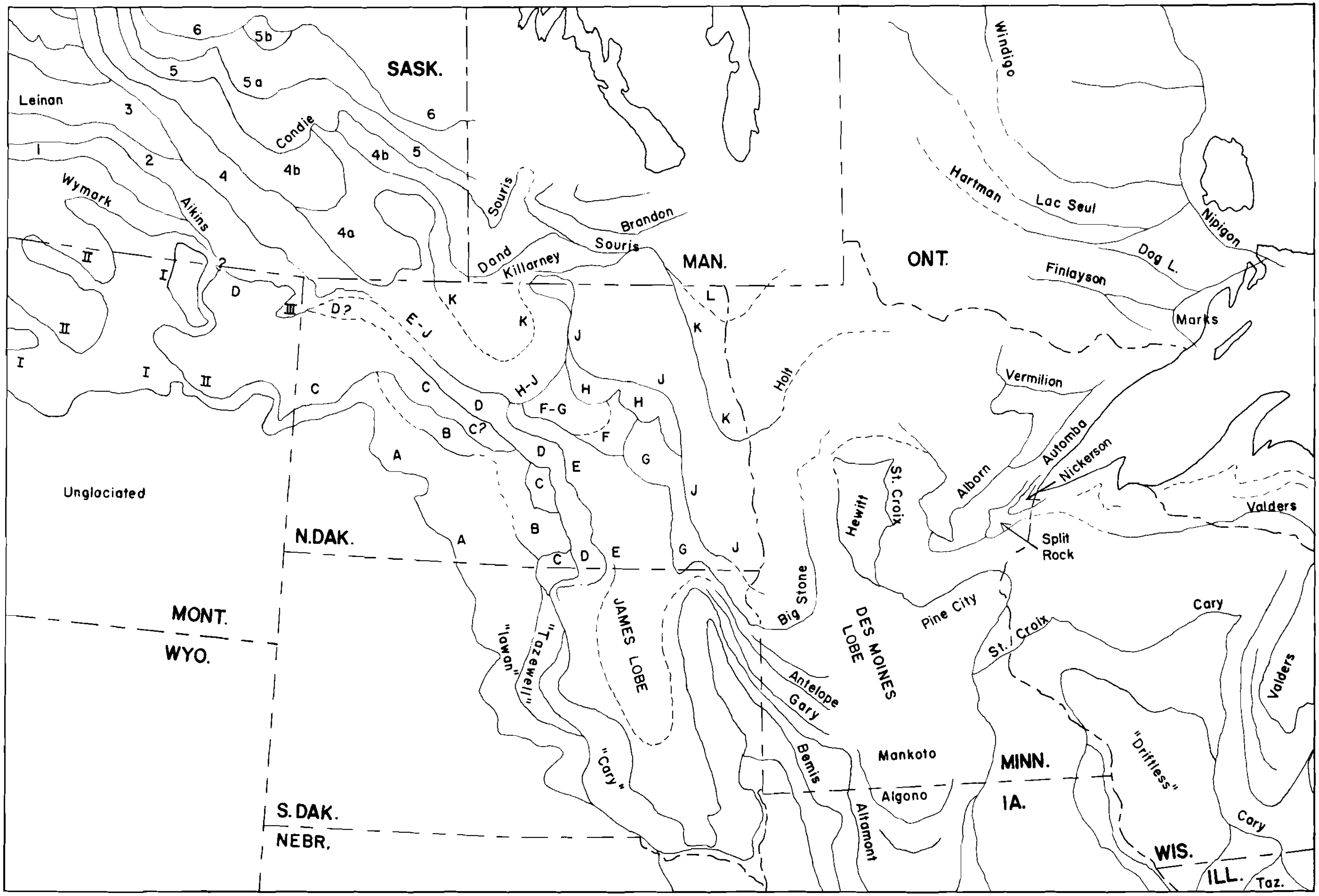
Phases F through L occurred around 12,000 years ago. Phase L occurred before the formation of the northern part of the Herman Beach of Lake Agassiz, which was abandoned by 11,740 B.P. (Y-1327; Wright and Ruhe, 1965, p. 39). Phase F occurred after phase E, which probably occurred about 12,000 or 12,500 B.P. (see above).

The stratigraphic positions of dates W-1020 (earlier than 38,000 B.P.; Stutsman County) and W-1369 (9,860 B.P.; Foster County) are unknown. Carbonaceous material dated at earlier than 38,000 B.P. (W-1021; Clayton, 1962, p. 69) from outwash in front of the Streeter moraine in Logan County was derived from older sediments.

Lake Agassiz.--Lake Agassiz fluctuations shown in figure 2 are in part from a summary presented by Elson (1965). Date Y-1327 (11,740 B.P.; Wright and Ruhe, 1965, p. 39) gives the time that the Herman Beach level was abandoned. W-1057 (9,200 B.P.; Wright and Ruhe, 1956, p. 40) gives the date when Lake Agassiz withdrew from the Campbell Beach for the last time. W-1361 (9,820 B.P.) from the Blanchard Beach and W-1360 (9,810 B.P.) from the Hillsboro Beach in Traill County were collected by H. M. Jensen of the U. S. Geological Survey. W-1005 (10,050 B.P.), and W-900 (10,080 B.P.), and W-723 (10,960 B.P.) are from the Ojata Beach in Grand Forks County. Dates C-497 (11,283 B.P.) and W-993 (9,900 B.P.) are from deep-water sediments. Literature on the history of Lake Agassiz has been summarized by Laird (1965).

Correlation.--The late Wisconsinan drifts and phases of glaciation in North Dakota can be correlated with many of those in adjacent areas. Ice-marginal positions in the Upper Midwest are shown in figure 3, and the suggested drift correlations are shown in table 1.

Figure 3.--Pleistocene ice-margin positions in the Upper Midwest. Modified from Lemke and others (1965), Wright and Ruhe (1965), Christiansen (1965), Zoltai (1965), Flint (1955, fig. 27), Elson (1958), Frye and others (1965), Prest (1963), and Steece and Howells (1965, fig. 6).


SASK.
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Dand
Killarney
Unglaciated
Holt
Windigo
Hartman
Lac Seul
Nipigon
Dog L.
Finlayson
Marks
Vermilion
Automba
Nickerson
Alborn
St. Croix
Hewitt
Valders
Split Rock
Big Stone
Pine City
Cary
DES MOINES LOBE
JAMES LOBE
"Iowan"
"Tazewell"
"Cary"
Antelope
Gary
Bemis
Mankoto
Algono
Altamont
"Driftless"
Taz.

Saskatchewan (Christiansen, 1965)	Montana (Lemke, and others 1965)	Manitoba (Elson, 1958)	North Dakota (This report)	South Dakota (Flint, 1955; Steece and Howells, 1965)	Minnesota-Iowa (Wright and Ruhe, 1965)	Ontario (Zoltai, 1965)	Wisconsin-Illinois (Frye, and others 1965): Drifts (or interstadial units)	Wisconsin-Illinois: Time-Stratigraphic units (irregular time scale)
retreat		retreat	Lake Agassiz: drain(9.2)		Lake Agassiz	retreat(9.0±)	Valders drift	Valderan Substage (Wisconsinan Stage)
Cree L.		The Pas?	Lake Agassiz: c(9.5±)			Nipigon		
			Lake Agassiz: drain			retreat		
6(>10.1)			Lake Agassiz: b(10.5±)			Hartman-Marks(>10.2)		
			Lake Agassiz: drain					
			Lake Agassiz: a(11.5±)			Eagle-Finlayson	(Two Creeks forest bed)	
5b 5a 5 =Condie(>11.0)		Souris-Hind	L=Pembina (12.0±)					Twocreekan Substage
4b		Dand						
4a(12.0)		Killarney	K=Minot-Edinburg (12.0±)		(Holt)			
			J=Martin-Luverne		Alborn-Nickerson (>11.6)			
			H=Cooperstown (12.5±)					
			F-G=Kensal-Grace City (12.5±)	Big Stone	Mankato			
				Antelope				
4(13.0)			E=Streeter (12.5±)	Gary	Algona(13.0)		Port Huron drift	
?3=Leinan	?III (Pinedale)		D=Burnstad	Altamont	Pine City-Split Rock(>12.7)			Woodfordian Substage
					Automba-Vermilion			
?2 Aikins(<20.0)	II		?C=Zeeland-Charlson	Bemis(14.0)	St Croix(>13.3)		Cary drifts	
							Tazewell drifts	
?1(>27.7) ?Wymark			?B=Napoleon(>38.0)	?"Tazewell"	?Hewitt			Farmdalian Substage
Oldest drift	I(Bull L.)		?A=Morton	?"Iowan"	("Iowan")		Winnebago drift	Altonian Substage
			Pre-Wis. drifts	Pre-Wis. drifts	Pre-Wis. drifts			Pre-Wis.

Table 1.--Tentative correlation of Upper Midwest drifts. Radiocarbon ages in thousands of years. Horizontal lines represent significant ecostratigraphic breaks.

Surface drifts in the northwestern part of the state can be correlated with those of Christiansen (1965) in southeastern Saskatchewan. Drift K (Minot Drift) is equivalent to drift 4a of Christiansen, which is about 12,000 years old. Drift J through E (Martin Drift) and possibly also drift D correlate with Christiansen's drift 4, which is about 13,000 years old (S-173). Drift D is equivalent to drift III of Lemke and others (1965) in northeastern Montana, which apparently correlates with drift 2 (Aikins Drift) of Christiansen; however, the Aikins Drift is thought to be nearly 20,000 years old because it overlies material dated at 20,000 B.P. (S-176) and 21,000 B.P. (S-228), whereas drift D is about 12,500 or 13,000 years old. Drift C is equivalent to drift II of Lemke and others (1965) in Montana (earliest Pinedale in western Montana). Drift II, in turn, apparently correlates with the Wymark Drift south of Christiansen's ice position 1 shown in figure 3 (S. H. Whitaker, report in preparation). However, the Wymark Drift is considered to be Altonian in age because it is overlain by material dated at 27,750 B.P. (S-96); the Wymark may therefore be equivalent to the Napoleon drift of North Dakota. Drift A is equivalent to drift correlated with drift I in eastern Montana and the Bull Lake in western Montana (Lemke and others, 1965).

Later ice-marginal positions may be correlated through Manitoba. Phase K west of the Turtle Mountains (Minot Phase) is equivalent to the Killarney or Boissevain Lake Phase of Elson (1958), which is equivalent to phase K in the Red River Valley (Darlingford-Edinburg-Elk Valley delta). Christiansen's phase 4b in Saskatchewan is equivalent to Elson's Dand Channel Phase in Manitoba, which is equivalent to phase L (Pembina delta) in North Dakota. Christiansen's phase 5 is equivalent to Elson's Lake Souris-Lake Hind (Pipestone Creek) Phase, which is also equivalent to phase L.

Christiansen's phase 5 (Condie) occurred between 13,000 B.P. (S-173) and 10,275 B.P. (S-165); he suggests that it occurred about 11,000 B.P. However, the Herman beach of Lake Agassiz, which formed before 11,740 B.P. (Y-1327; Wright and Ruhe, 1965, p. 39), is present well north of the Pembina delta; phase L, and presumably also phase 5, would therefore have been before 11,740 B.P. if these correlations are correct. This first phase of Lake Agassiz is called phase a in figure 2 and table 1.

The ice then melted back far enough in Ontario to open a Lake Agassiz outlet into the Superior basin about 11,000 B.P. when sub-Campbell beaches were formed. A readvance to the Hartman-Dog Lake-Marks moraine during the Valders maximum (or before 10,200 B.P.) in Ontario (Zoltai, 1965, 267-268) again blocked the eastern outlet into the Superior basin raising Lake Agassiz until it drained southward again, cutting through the fan of the Little Minnesota River until it again stabilized at the Campbell beach. This is called phase b in figure 2 and table 1. Phase b may have occurred at the same time as phase 6 in Saskatchewan, which was slightly before 10,150 B.P. (S-97; Christiansen, 1965). The ice margin retreated again, opening the eastern outlet into the Lake Superior basin and lowering Lake Agassiz again to sub-Campbell levels. A readvance to the Nipigon moraine raised Agassiz to the level of the Minnesota River spillway for the last time (phase c of Lake Agassiz), and a retreat between 9,530 B.P. and 8,610 B.P. (Zoitai, 1965, p. 268) again lowered Agassiz from the Campbell beach level 9,200 B.P. (W-1057, Wright and Ruhe, 1965, p. 40). The equivalent ice-marginal position in Saskatchewan is at the northern end of the Campbell beach, near the southern edge of the Canadian Shield (Elson, 1965).

The glacial phases of Wright and Ruhe (1965) in Minnesota and Iowa can be tentatively correlated with the North Dakota phases. The last phase of the St. Louis and Superior lobes was the Alborn-Nickerson Phase, which, based on radiocarbon dates, is approximately equivalent to phase J (Luverne) in North Dakota; the Alborn Phase is older than 11,635 B.P. and the close of the Nickerson Phase was perhaps 11,500 years ago (Wright and Ruhe, 1965, p. 39, 40). Phase K (Edinburg) and L (Pembina) may therefore by equivalent to or older than the Eagle-Finlayson Phase of Ontario (Zoltai, 1965). Phases D and E are approximately equivalent to the Algona Phase of the Mankato Stade of the Des Moines lobe, which is dated at 13,000 B.P. (Wright and Ruhe, 1965, p. 39). Drift C in North Dakota may be equivalent to the "Cary drift" of Flint (1955) in western South Dakota, which Flint correlated with the Bemis Drift in eastern South Dakota, which has been dated at 14,000 B.P. (Wright and Ruhe, 1965, p. 39) in the Des Moines lobe; this is the age of the Cary drift of the Lake Michigan lobe.

An obvious problem in interpretation arises if the Burnstad (D) or Streeter (E) phases of the James Lobe were contemporaneous with the Pine City Phase of the Des Moines Lobe (fig. 3) as suggested above. The margin of the Streeter and Burnstad ice rose to elevations of at least 2,200 feet in North Dakota and northern South Dakota; the crest of the Streeter moraine is up to 2,275 feet in Logan County in southern North Dakota. Yet the elevation of the eastern-most Des Moines Lobe drift deposited during the Pine City Phase at the same latitude (Ottertail County) is only about 1,500 feet. At this time the ice was very sensitive to topographic differences; the Prairie Coteau, which separated the Des Moines Lobe from the James Lobe, is less than 1,000 feet high. Therefore the Des Moines Lobe should have spread eastward into the relatively low land (at 1,500 feet elevation or less) in the area of the Hewitt Drift in central Minnesota. Another lobe from the east could have prevented this; that is, the band of dead-ice moraine in the Alexandria-Detroit Lakes area could be an interlobate moraine formed between the Des Moines Lobe and the Wadena lobe, which moved from the northeast to deposit the Hewitt Drift. However, Wright and Ruhe (1965) indicate that the Hewitt Phase occurred much earlier than the Pine City Phase. Further work is needed to solve these possible conflicts.

Future work.--It can be seen that the general outline of latest Wisconsinan history in North Dakota is known in considerable detail and can be approximately correlated with events in adjacent areas. However, many gaps in our knowledge remain, and little is known about Pleistocene events before the late Wisconsinan.

A few more radiocarbon dates are needed to tie down the ages of some of the units. However, the dates should be from horizons that are stratigraphically significant. A date from wood found 30 feet beneath the surface of the Long Lake ground moraine, for instance, would be of no significance unless it were known that the wood is definitely from the Long Lake Drift or was within or between other recognizable drift sheets. Until it can be shown that a drift is distinct enough to be recognizable in the subsurface, samples from subsurface drifts will not be worth dating. Care should also be taken in North Dakota to avoid peaty material that was derived from older deposits, especially Tertiary lignites; several such samples from late Wisconsin drift have been dated at earlier than 38,000 B.P.

The details of glacial Lake Agassiz are still to be worked out. More subsurface and detailed lithologic studies are needed. A few more radiocarbon dates could be used from the beaches, especially the upper beaches--Herman through McCaulleyville. On the Drift Prairie a few more well placed radiocarbon dates might be used; drifts F through L have not been dated in the state. However, all of these drifts were probably deposited within a thousand years; the precision of radiocarbon dating is not fine enough to permit any useful correlations within this period. Drift C is probably young enough to be radiocarbon dated; the basic field mapping of part of this drift is complete, but no suitable organic material has yet been found. Drift B appears to be too old to be radiocarbon dated, but this has yet to be positively proven. Drift A is yet to be mapped; little is known about it. The ice-marginal channels west of the Missouri River will probably yield much information on Pleistocene history when they are studied in detail. Little is known about pre-Wisconsinan and younger buried drifts in the state. The loess in southern Emmons County and areas west of the Missouri is yet to be studied. High-level nonglacial gravels, Wisconsinan and Recent alluvial fills, and related erosion surfaces in the southwestern part of the state will require many years of study; buried soils, ash deposits, fossil mammals, fossil mullusks, and artifacts have been found, but they are almost completely unstudied. Mineralogic, geochemical, and paleontological (including palynological) studies of the sediment in the thousands of lakes and sloughs in the glaciated part of the state have just begun; the peat bogs of the Turtle Mountains and the numerous closed depressions on the prairies must contain a detailed record of late Wisconsinan and Recent stratigraphy.

Acknowledgments.--I thank the people who were persuaded to read the manuscript of various versions of this report, including John R. Reid of the University of North Dakota, and John P. Bluemle, Theodore F. Freers, Dan E. Hansen, Jack Kume, Wilson M. Laird, and E. A. Noble of the North Dakota Geological Survey.

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