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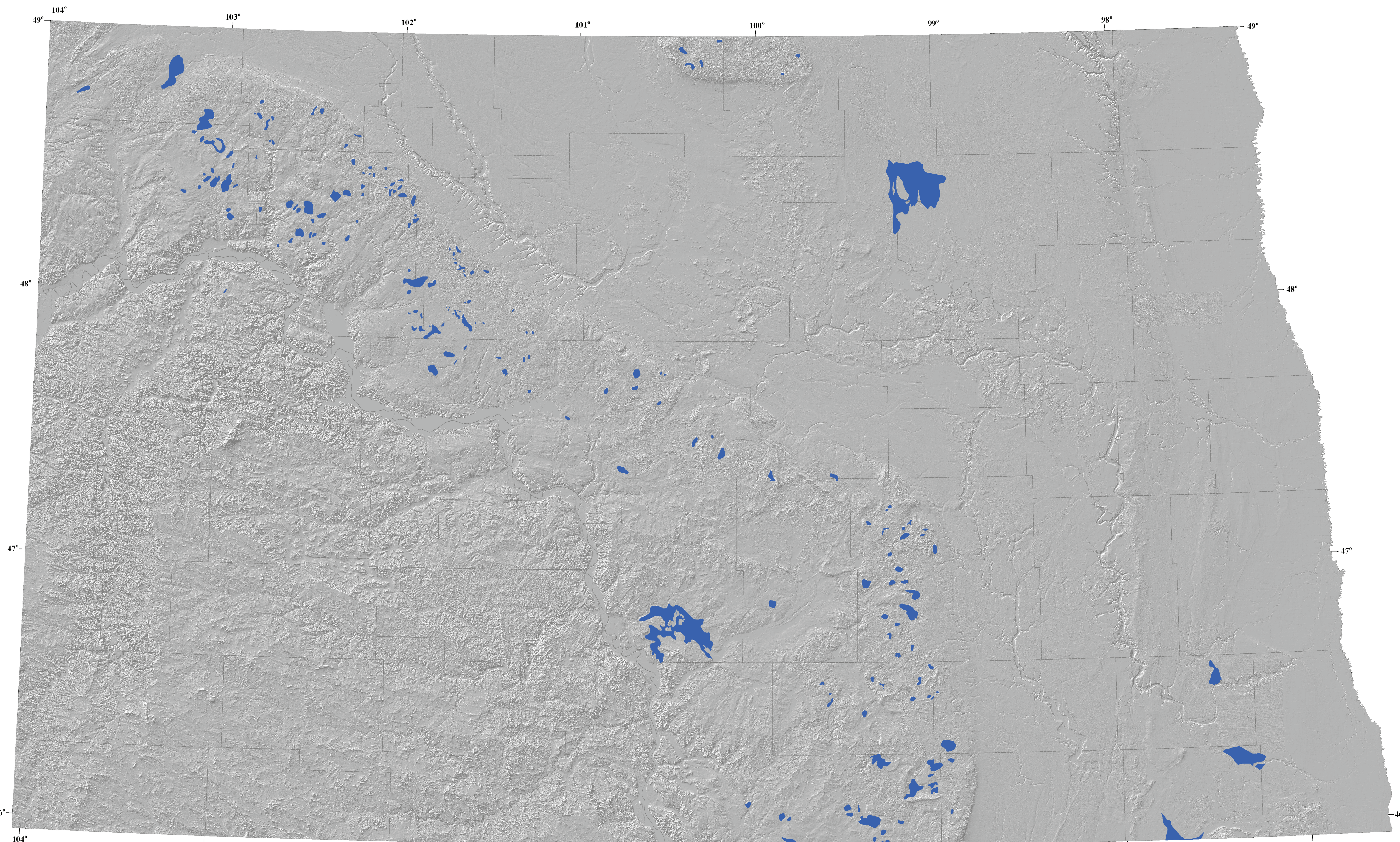
PLEISTOCENE ICE-WALLED-LAKE PLAINS IN NORTHWEST-CENTRAL NORTH DAKOTA

LORRAINE A. MANZ
2006

Distribution of Ice-Walled-Lake Plains in North Dakota



Ice-Walled-Lake Plains

County Boundaries

Approximately 170 ice-walled-lake plains, at least 1km in width, are depicted on this map. many smaller ones exist, which are not shown.

Scale 1:1,000,000

0 20 40 60 80
Miles

0 20 40 60 80
Kilometers

Source: Clayton, L., Moran, S. R., Bluemle, J. P. and Carlson, C. G., 1980, Geologic Map of North Dakota (scale 1:500,00), U. S. Geological Survey

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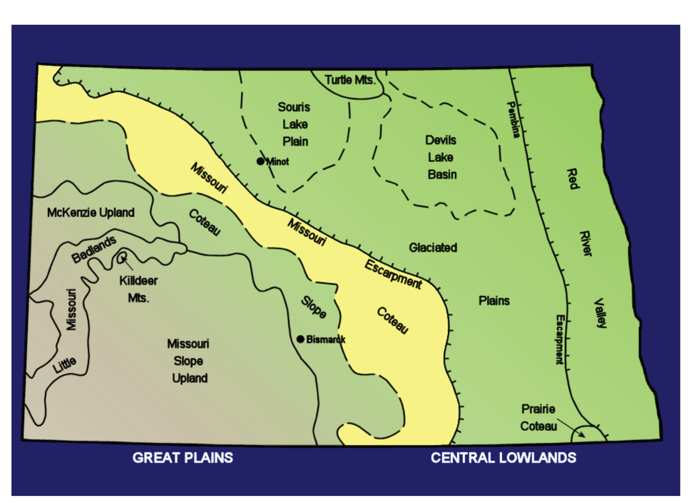

Figure 1. Physiographic Regions of North Dakota showing the extent and location of the Missouri Coteau.

Introduction

The Missouri Coteau is an approximately 50-kilometer-wide upland that extends for more than 1,000 kilometers through southern Saskatchewan, North Dakota and South Dakota. It forms the northeastern edge of the Missouri Plateau and is bounded on the northeast by the Missouri Escarpment, a 100 to 150-meter rise, which separates the Coteau from the lowlands to the east.

In North Dakota the Missouri Coteau is recognized as a distinct physiographic region (fig. 1). It is geomorphologically similar to the Turtle Mountains in north central North Dakota and the Prairie Coteau in the southeastern part of the state, the landforms in all three areas having been created by the same glacial processes. The common outstanding characteristic of these regions is their rugged topography. It consists of closely-spaced hummocks or knobs alternating with marshy depressions known locally as "sloughs" or "prairie potholes". There is an almost complete absence of streams or any form of integrated drainage and the topography is almost entirely glacial in origin. The glacial sediment, which is more than 150 m thick in places, generally obscures the preglacial topography.

Most of the landforms on the Missouri Coteau are the result of the glacial ice, which melted down between about 9,000 and 13,000 years ago. Typical landforms include hummocky collapsed topography (hummocky moraine, dead-ice moraine), ice-walled-lake plains, collapsed-stream- and collapsed-lake-sediment topography, and associated disintegration ridges and trenches.

The Pleistocene glacial deposits in North Dakota are part of the Coleharbor Group (Bluemle, 1971). This unit is distinguished from other regional late Cenozoic deposits by the presence of crystalline material derived from the Canadian Shield and the Paleozoic rocks surrounding it. It includes all sediments deposited from the first glacial advance from the northeast to the Holocene/Wisconsinan boundary, spanning a time frame of several hundred thousand years. The Coleharbor Group consists of up to 200 m of a highly complex series of interbedded layers of mainly glaciolacustrine silt and montmorillonite clay, fluvial sand and gravel, and till. Pebbles, cobbles and boulders consist of hard granitoids, gneisses, and basalt from the Canadian Shield, dolomites and

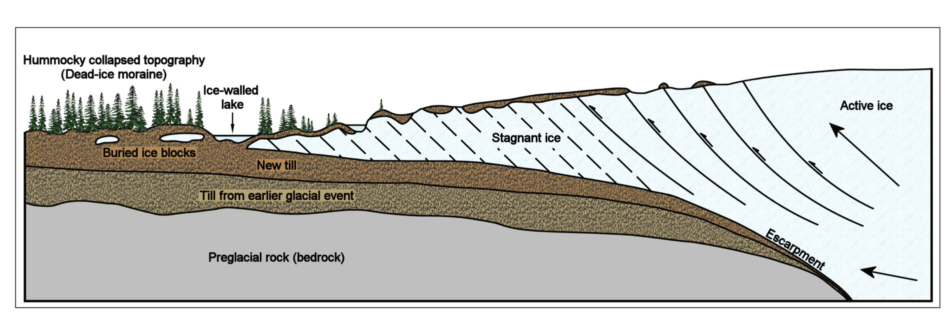

Figure 2. Schematic cross-section through the edge of a glacier (modified from Clayton, 1967). This illustration depicts a situation similar to that which developed when glaciers moved over the Missouri Escarpment and on to the Missouri Coteau. As the glacier advanced upslope the resultant compression caused shearing within the ice, which brought enormous amounts of sediment to the glacier surface. The insulating effects of this thick cover of superglacial material slowed the rate of melting of the underlying ice to the extent that plant and animal communities were able to flourish on top of the deeply buried glacier. The formation of hummocky collapse topography was the end result of this melting

Landscape development

The surface unit over most of the Missouri Coteau was deposited by Late Wisconsinan glaciers between about 13,000 and 9,000 years ago (Clayton, 1972). The maximum extent of this glaciation, which roughly coincides with the extent and width of the Missouri Coteau, is marked by a series of ice margins that extend northwest- and southeastwards across North Dakota and which, based on geomorphic and lithologic evidence, appear to mark the maximum extent of Late Wisconsinan glaciation.

When south- and southwestward-moving glaciers reached the Missouri Escarpment they were forced into an uphill climb over grades as steep as 12% before advancing onto the Coteau. The resultant compressive flow and marginal thrusting within the ice, caused by deceleration as the ice flowed uphill, brought enormous quantities of sub- and englacial debris onto the surface of the glacier (fig. 2). When glacial movement finally ceased, about 13,000 years ago, sediment continued to accumulate on top of the stagnating ice, eventually forming a nearly continuous blanket of superglacial till, many tens of meters thick, over most of the Coteau. During the early stages of melting, this layer of till was spread over an almost unbroken sheet of ice, hundreds of meters thick. Its insulating effect caused the ice to melt very slowly, to the extent that much of it persisted for at least 3,000 years, until 9,000 B.P.

The layer of superglacial till was unevenly distributed over the stagnant and dead ice, and consequently its rate of melting was quite variable. The superglacial topography thus became hilly and pitted with depressions as water-saturated, highly fluid till slid from high points on the ice into depressions, insulating the underlying ice in these areas and causing it to melt more slowly than the newly exposed ice higher up, resulting in continual topographic inversions. The final outcome was a landscape of closely spaced, roughly equidimensional, hills and depressions known today as

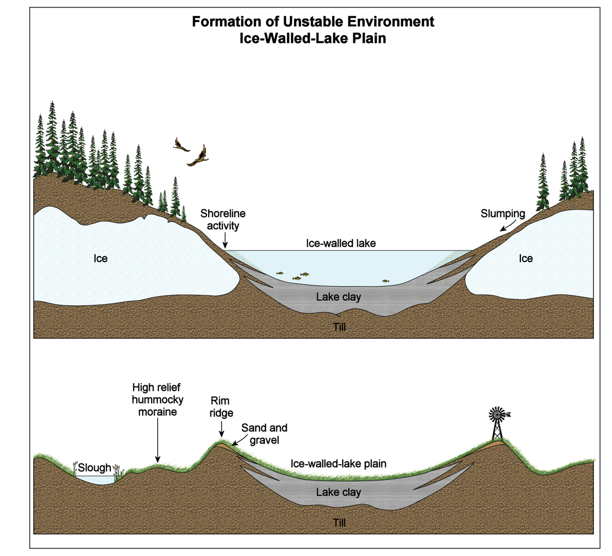

Figure 3. Formation of unstable environment ice-walled-lake plains (modified from Clayton and Cherry, 1967). Sediment is thin on the surrounding ice, causing it to melt rapidly. The large amounts of meltwater thus produced result in lakeward slumping of the confining walls and the deposition of much sediment into the lake itself.

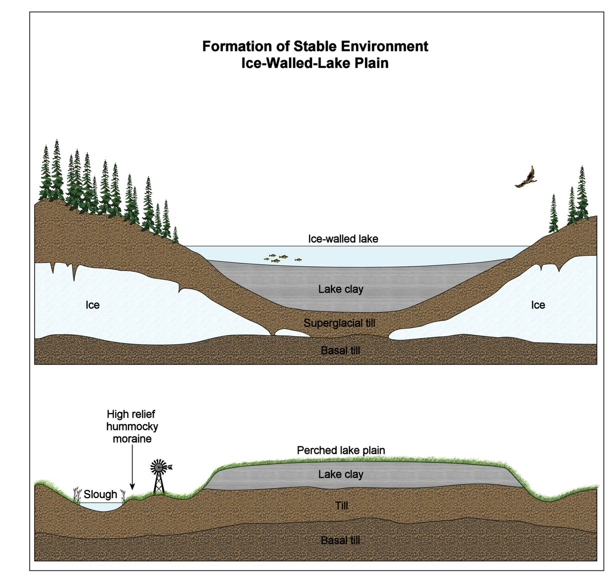

Figure 4. Formation of stable environment ice-walled-lake plains (modified from Clayton and Cherry, 1967). A thick, insulating cover of sediment on the surrounding ice slows its rate of melting resulting in a low energy, quiet water environment, dominated by fine-grained sedimentation. These lakes tend to be long-lived and show a general absence of the mass movement of water-saturated till. Stable-environment ice-walled-lake plains typically do

Origin and morphology of ice-walled-lake plains

Innumerable lakes, up to 3 kilometers in width, filled the depressions on the insulated glacial ice of the Missouri Coteau. Clayton and Cherry (1967) recognized two types: superglacial lakes, which were surrounded and floored by ice; and ice-walled-lakes, which were bottomed on solid ground. The latter were further classified as having formed in either stable or unstable environments.

In "unstable" environments the cover of superglacial sediment was thin (a few tens of meters or less) and the ice melted rapidly (fig. 3). The topography on the stagnating glacier was thus continuously shifting and mass movement of the water-saturated superglacial till was common. Sediment delivery to lakes in this active environment came in the form of slumping, flowage, and from meltwater streams. Rates of deposition were generally high and redistribution of sediment by wave action resulted in the development of sand and gravel beaches along the lake margins and the offshore relocation of finer material. Currents derived from meltwater moving through the lake frequently removed the finest suspended particles leaving behind an overall coarser assemblage of sediments than those found in stable-environment ice-walled-lake plains.

Unstable-environment ice-walled-lake plains tend to have fairly low relief (< 20m) and are often concave-upward as a result of the deposition of the large amount of coarse, near-shore material relative to finer, mid-lake sediment. They are often surrounded by a distinct rim ridge that divides the lake bed from the surrounding dead-ice moraine. The central part of the lake bed is typically underlain by laminated clay, silt and fine sand, which coarsens shoreward into beach sand and gravel. These shoreline and nearshore sediments are frequently interbedded with slumped material derived from debris flows of water-saturated peripheral till (Clayton and Cherry, 1967; Ham and Attig, 1997; Johnson, 2000; Syverson, 2005).

Stable-environment, or perched, ice-walled-lake plains formed under conditions where a thick layer of superglacial sediment reduced the rate of melting of the confining ice (fig. 4). Slow melting meant that these types of lakes were relatively long-lived and the amount of sediment deposited in them was consequently greater than that found in unstable-environment lakes (Clayton and Cherry, 1967; Syverson, 1998). These essentially quiet water, low flow regime environments allowed for deposition of fine-grained sediments and a general absence of the mass movement of water-saturated till. For this reason stable-environment ice-walled-lake plains do not have rim ridges. They stand between about 20 and 50 m above the landscape and the meters-thick cap of lake sediment shows that they are, indeed, lacustrine remnants rather than flat-topped hills covered with a veneer of postglacial sediment (L. Clayton, written commun., 2006).

On the Missouri Coteau in North Dakota, ice-walled-lake plains are easily identified both on the ground and on aerial photographs because their level, boulder-free surfaces often appear as isolated areas of cultivated land surrounded by rangeland or native prairie. Their elevated positions in the landscape and/or the presence of a well-defined rim ridge are also common

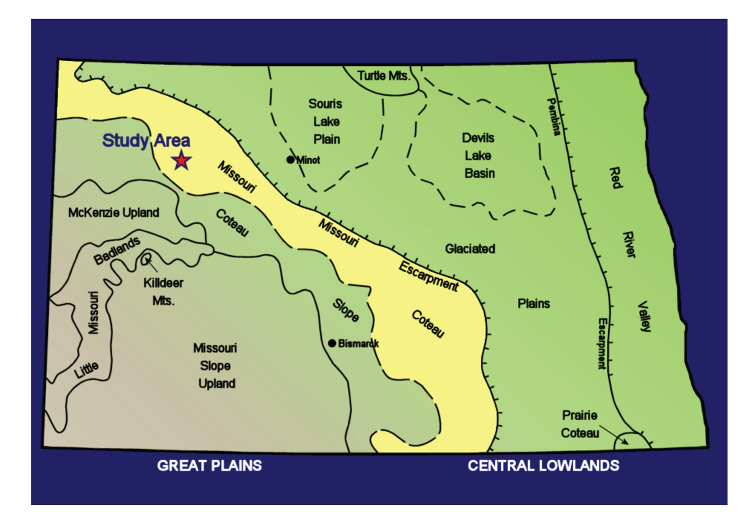

Figure 5. Location of study area.

This study

One of the largest concentrations of ice-walled-lake plains in North Dakota occurs in Mountrail County in the northwestern part of the state. The area selected for this study (fig. 5) lies approximately 18 km southwest of the town of Ross, and is located in T154N, R93W, secs. 6 swsw and 7 nwnw; and T154N, R94W, secs. 1 sese and 12 nene. It is clearly visible from the air (fig.6), the cultivated lake bed contrasting sharply with the hummocky collapsed topography surrounding it. This feature is a typical example of a low-relief, unstable-environment ice-walled-lake plain. It is clearly dish-shaped, even at ground level, with a maximum relief from the center of the basin to the highest point on the rim ridge (east) of about 10 m. The basin is inclined slightly to the west where the rim ridge is absent, indicating a possible breach point.

Four cores were collected, using a split-spoon sampler and hollow-stem auger, along a transect from the top of the north rim ridge to the center of the lake basin (fig. 7), covering a horizontal distance of about 0.5 km. Cores ND05-011 and ND05-012 revealed well-sorted dark grayish-brown (2.5Y 4/2) silty lake clay (fig. 8) to a depth of 4.1 and 3.6 m respectively overlying an olive-brown (2.5Y 4/3) clayey till (fig. 9). A very dark grayish brown (2.5Y 3/2) organic-rich (1.85%) band between 4.4 and 4.7 m in core ND05-012 was tentatively identified as a buried soil horizon (M.G. Ulmer and others, written commun., 2005).

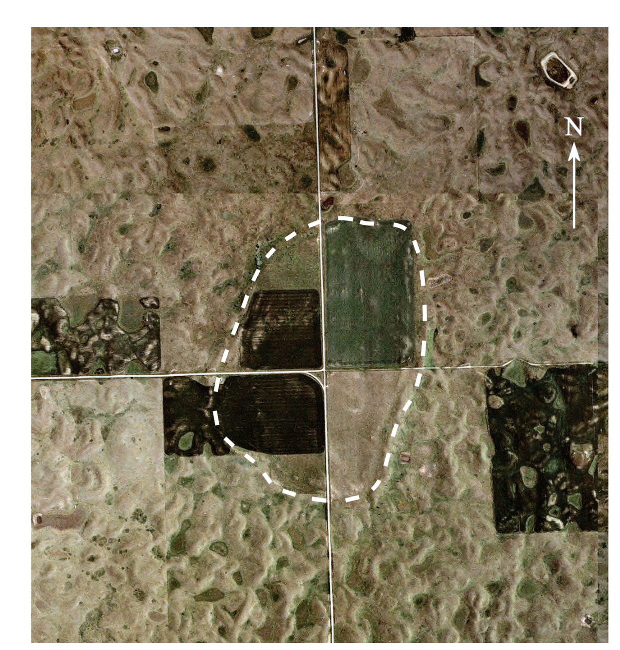

Figure 6. Aerial photograph of the study area. The dashed line marks the edge (ice-contact face) of the ice-walled-lake plain. Note the contrast between the cultivated lake plain and the surrounding hummocky collapse topography.

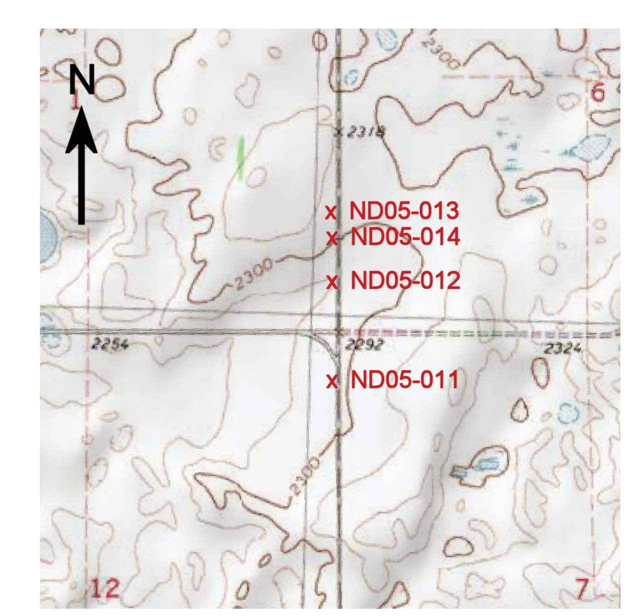

Figure 7. Topographic map with hillshading enhancement showing sampling locations. Rat Lake Quadrangle, 7.5 minute series (topographic) 1981. Scale as shown.

Figure 8. Varved lake sediments from core ND05-011. Depth: ~ 2 m. Individual varves average about 3 mm in thickness.

Figure 9. Till from core ND05-012. Depth: ~ 4 m. This material lies directly below the zone tentatively identified as a buried Ab horizon.

Figure 10. Bottom of core ND05-013. Note the abrupt color change on the extreme left of the core from light olive-brown (2.5Y 5/3) to very dark gray (2.5Y 3/1) that marks the transition to an organic-rich zone, which may be a buried soil horizon.

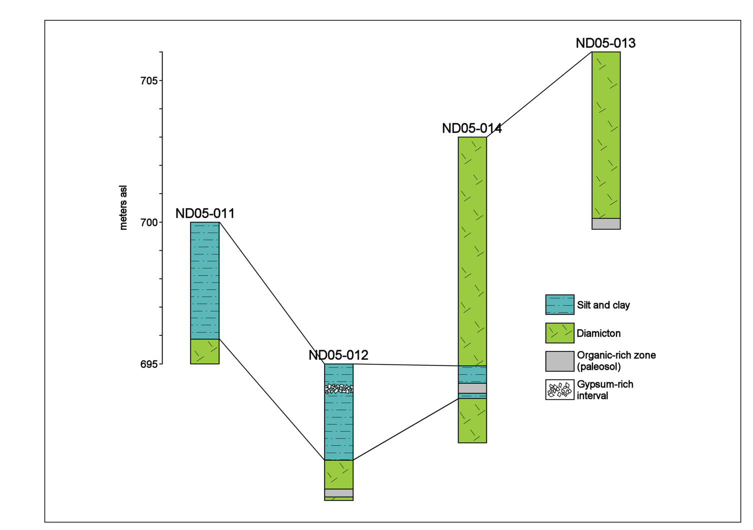

Figure 11. Fence diagram showing stratigraphic relationships between sediments in cores ND05-011 - ND05-014.

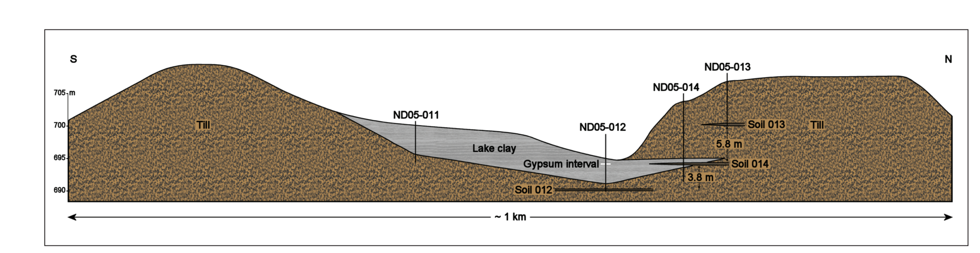

Figure 12. Proposed stratigraphy, based on cores ND05-011 - ND05-014 for the study area.

Upslope, core ND05-014 consisted of about 8 m of olive-brown (2.5Y 4/3) till overlying a one-meter-thick layer of interbedded till and olive-brown (2.5Y 4/4) to dark grayish-brown (2.5Y 4/4) silty lake clay. Below this was a very dark gray (2.5Y 3/1) till. A very dark grayish brown (2.5Y 3/2) organic-rich (1.13%) band between 8.7 and 9.0 m was tentatively identified as a buried soil horizon (M.G. Ulmer and others, written commun., 2005).

Core ND05-013, collected on top of the rim ridge, comprised only till grading in color to 5.9 m from olive-brown (2.5Y 4/3) to light olive-brown (2.5Y 5/3). An abrupt color change at this depth to very dark gray (2.5Y 3/1) marked the transition to a third, organic-rich (2.2%) zone, which continued to an unknown depth (fig. 10). The core descriptions and tentative correlations between units are shown in figures 11 and 12.

The vertical separation between the three organic zones (3.8 m between 012 and 014, and 5.8 m between 014 and 013) suggests that each represents a different pedogenic or depositional event. Those in ND05-012 and ND05-013, which developed in till, are most likely pedogenic in origin. The zone in ND05-014 may also be a paleosol. It is stratigraphically equivalent to an interval in core ND05-012 that is dominated by diagenetic gypsum, indicating that at some stage the lake dried up. This is supported by a complete absence of aquatic fossils (ostracodes) within this interval, but an increasing abundance with distance above and below it (B.B. Curry, unpub. data, 2006).

Attempts to radiocarbon date these zones were hampered by the presence of lignite and dark gray, organic-rich shale (Pierre Formation). However, based on dates obtained from other lakes in the region (E.C. Grimm, written commun., 2006) they are assumed to be late Pleistocene/early Holocene in age.

The lake sediments were well-sorted silty to fine-silty clays. Although poorly stratified for the most part, well-defined varves up to 3 mm thick were visible at intervals (fig. 8). Small, oxidized iron masses and iron stains were distributed fairly evenly throughout the matrix. Sand-sized gypsum crystals were also scattered throughout the matrix, with isolated, dense accumulations observed at infrequent intervals.

All of the tills were considered to belong to the same unit. They were visually similar with between 5 and 10% coarse fragments (> gravel size) consisting mainly of granitoids and gneisses with minor carbonates and shale (fig. 10). Oxidized iron masses, small (sand-size) gypsum crystals and lignite fragments were distributed unevenly throughout a clayey matrix. Reaction with 1N hydrochloric acid was variable, but mostly within the strong to violent range.

With such limited information there are many sequences of events that could explain the stratigraphy shown in figure 12. One possible scenario is as follows:

1. Original till surface was stable long enough to allow soil 012 to develop.
2. Burial of soil 012 by mass movement or a minor glacial readvance.
3. Formation of the lake, which filled to a level somewhere above the elevation of soil 014 then receded (dried up) long enough to enable soil 014 to develop.
4. The lake level rose again, burying soil 014.
5. Slumping of till into the northern end on the lake terminated deposition here.
6. Soil 013 developed and was subsequently buried by mass movement. Deposition continued elsewhere in the lake until it eventually drained (possibly via a breach along its western side).

This sequence of events is consistent with the concept of a dynamic and unstable environment produced by the differential rates of melting of buried versus exposed glacial ice. Nevertheless, it also raises some questions. For example, what caused the lake level to fluctuate, as it appears to have done?
Was it a response to a localized climate change such as those that so profoundly affect Devils Lake and other water bodies in eastern North Dakota, or was the lake fed by streams that either dried up or were forced by the shifting topography to

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