THE QUATERNARY GEOLOGY
OF THE
GRAND FORKS - RED LAKE FALLS AREA
NORTH DAKOTA - MINNESOTA

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INTRODUCTION

This report was compiled for the 1987 Minnesota Association of Professional Soil Scientists' field trip. It is intended to serve as a field trip guide to the Quaternary geology of the Red Lake Falls, Minnesota area. Summaries of the surface geology and near-surface stratigraphy of the area are provided. Two cutbanks along the Red Lake River were selected to illustrate the outcrop characteristics of the near-surface stratigraphic units present in this area.

The efforts of a number of UND Quaternary geologists have been important in recognizing and developing the near-surface stratigraphy in this region. Walter Moore was the first to recognize the importance of the stratigraphy exposed along the Red Lake River. His reconnaissance fieldwork led to the recognition of persistent, identifiable stratigraphic units. His curiosity and effort in "cleaning the outcrops" exposed this stratigraphic detail to the eyes of other Quaternary geologists.

Lee Clayton, Steve Moran, and Alan Cvancara conducted detailed investigations of some of the outcrops along the river. They further developed characterizations of the stratigraphic units, described the fossils present, and age dated some of the material recovered during their investigations (Moran, Clayton, and Cvancara, 1970). Their work stimulated the interest of several of their graduate students who later conducted thesis research in the area.

Howard Hobbs and Kenneth Harris conducted theses research on the sediments exposed in the Red Lake River trench. Harris (1973) developed a stratigraphic framework based on field identifiable and textural characteristics of the units exposed. Hobbs (1973) described the heavy mineral associations present in the stratigraphic units exposed in the area.

Subsequently several workers conducted theses research involving surface mapping and further refinements to the Quaternary stratigraphic framework. They included Kenneth Harris (1975), Donald Sackreiter (1975), Curtis Anderson (1976), and Roderic Perkins (1977).

The surface geologic map used in this report (Plate 1) was modified from Harris (1975) and Hobbs and Goebel (1982); the near-surface stratigraphy was developed with the use of computer assisted till correlation software being developed by the North Dakota Geological Survey (NDGS)(Harris, in preparation). About 600 till samples, located within the Minnesota portion of the Grand Forks, North Dakota-Minnesota AMS map sheet (scale 1:250,000), were used in this analysis. All samples and sample data are on file with the North Dakota Geological Survey.

It should be stressed that the computer assisted stratigraphic correlations presented here are preliminary results. They represent a first trial of a new technique in an area where we have some initial understanding of the stratigraphy. It is encouraging that these results agree as well as they do with the interpretations of previous workers.

SURFACE GEOLOGY

The General Setting

The surface geology of the area, shown in Plate 1, can be subdivided into three categories based on the presence of similar landforms (fig. 1).

The Lake Agassiz Plain

The flat floor of glacial Lake Agassiz consists of flat-bedded, laminated silts and clays and areas of eroded glacial sediment. The most common landforms present on this level plain are very low relief (generally < 1 mm) ice-drag grooves and compaction ridges.

The Shoreline Complex

The near-shore and shoreline area of glacial Lake Agassiz consists of flat-bedded and cross-bedded silt, sand, and gravel as well as areas of wave-eroded glacial sediment. The most common landforms here are beach ridges, near-shore bars, spits, wave-planed areas, and wave-cut scarps.

The Glacial Upland

This is the glaciated area adjacent to the glacial lake plain that hasn't been modified by any lake associated processes. The sediment present here is generally pebbly, sandy, silty clay (till, boulder clay, diamicton, etc.) or sand and gravel. The most common landforms on the glaciated upland are meltwater channels, eskers, and undulating to hummocky topography, characterized by rolling hills and closed depressions containing bogs or lakes.

The distribution of these landforms is a function of the geologic history of the area. This history, for about the last two million years, can be summarized as follows (approximate dates are from Bluemle and Clayton, 1982):

1) An unknown number of glaciers advanced over and retreated from this area during the pre-Wisconsinan portion of the Pleistocene. These glaciations were punctuated by interglacial episodes with mild climates. There is no near-surface evidence for these glaciations in the Red Lake Falls area (about 2,000,000 to 70,000 yrs. ago(?)).

2) The glaciers that deposited the Gervais, Marcoux, and Red Lake Falls Formations advanced over the area and retreated. It is likely that "Lake Agassiz" occupied the "Red River Valley" numerous times between these glacial advances (about 70,000 to 14,000 yrs. ago).

3) The "Red River Valley" was flooded by meltwater ponded south of the glacier that deposited the Red Lake Falls Formation. The sediment deposited in the lake is the Wylie Formation (about 14,000 to 13,500 yrs. ago).

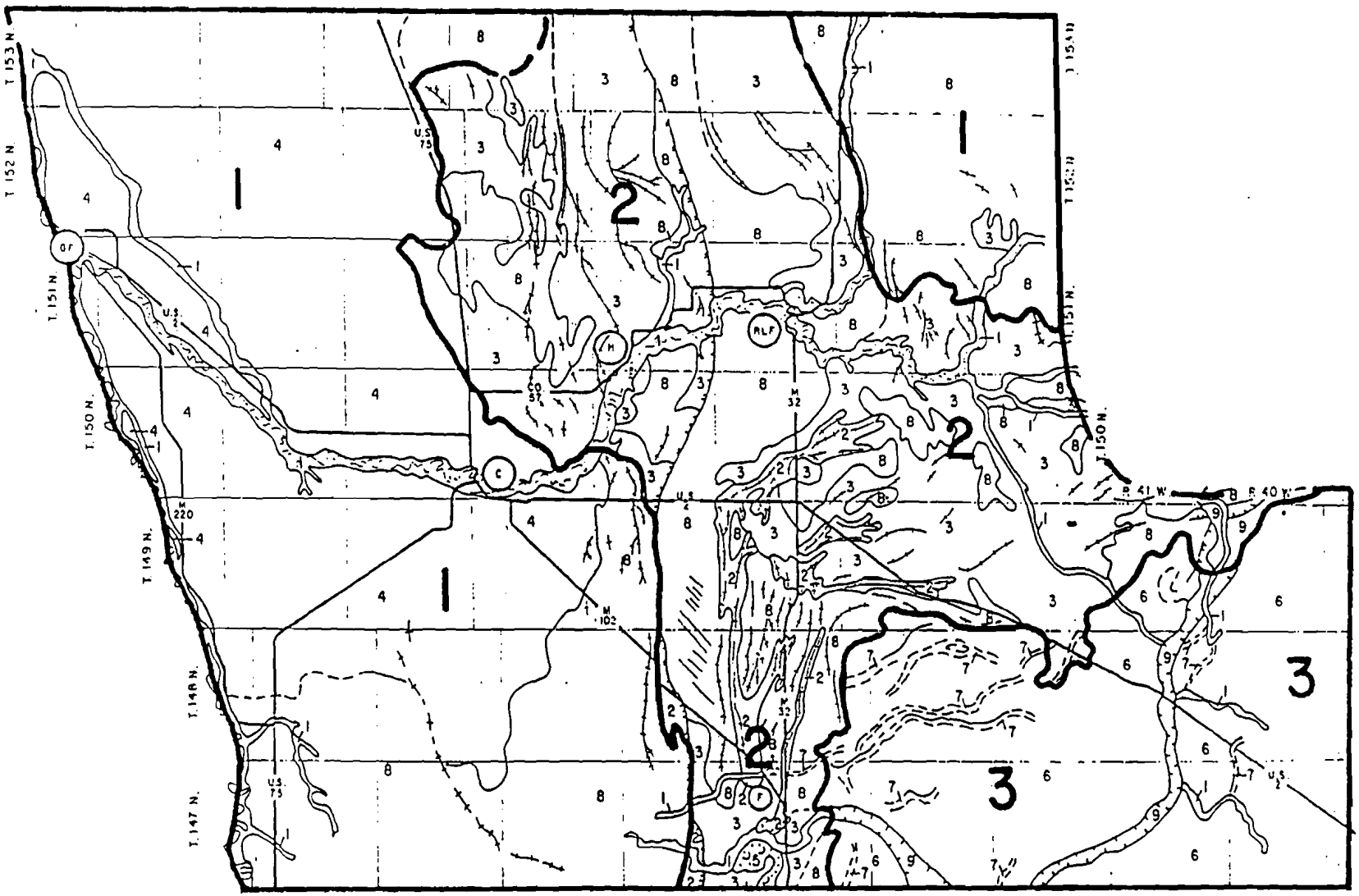


Figure 1. Areas of similar landforms: 1) Lake Agassiz Plain; 2) Shoreline Complex; 3) Glacial Upland.

4) Glacial ice readvanced into the "Red River Valley" as far south as Caledonia, North Dakota (Shelly, Minnesota). This advance deposited the glacial sediment of the Huot Formation (about 13,500 to 13,000 yrs. ago).

5) Glacial ice retreated north, into Canada. Lake sediment was deposited in the Lake Agassiz basin (Sherack Formation). This is the surface sediment over much of the "Red River Valley" today (about 13,000 to 9,000 yrs. ago).

6) Glacial ice wanes, Lake Agassiz drains, warm conditions prevail complete with warm rains (about 9,000 yrs. ago to present).

The Geologic Map

A map of the surficial geology of the Red Lake Falls area is provided on Plate 1. This map shows the geologic setting of the field trip area. A description of the map units and map line symbols used is provided in Figures 2 and 3. The interpreted relationship between sediment age, sediment origin, and map units is shown in Figure 4. This map is a modification of maps constructed by Harris (1975) and Hobbs and Goebel (1982).

DESCRIPTION OF THE MAP UNITS

QUATERNARY

OAHE FORMATION: clay, sand, silt, and gravel commonly containing dispersed organic debris.

RIVER SEDIMENT

1 — OVERBANK SEDIMENT: clay, silt, sand, and disseminated organic debris; obscurely bedded; dark colored; often associated with sand and gravel of older, river-channel sediment; usually less than a metre (3 feet) thick; deposited on the flood plains of modern rivers.

LAKE SEDIMENT

2 — SHORELINE SEDIMENT: sand and gravel; moderately to well sorted; plane bedded and cross bedded; as much as 5 metres (15 feet) thick; deposited along the shoreline of a lake, usually on eroded till; beach ridges are shown by line symbols.

3 — NEARSHORE SEDIMENT: silt and sand; moderately to well sorted; cross bedded to flat bedded; as much as 5 metres (15 feet) thick; deposited in shallow water near the shore of a lake, usually on eroded till; nearshore bars are shown by line symbols.

4 — OFFSHORE SEDIMENT: clay with thin silt laminae; flat bedded, usually laminated; as much as 60 metres (200 feet) thick; deposited in deep, quiet water of a lake; compaction ridges are shown by line symbols.

WINDBLOWN SEDIMENT

5 — DUNE SEDIMENT: sand; medium to fine grained; well sorted; obscurely bedded; associated with older lake and river deposits; dunes are as much as 10 metres (30 feet) high and generally stabilized by vegetation; active blowouts are common; windblown sediment with a hummocky, wind scoured surface.

COLEHARBOR GROUP: sand, silt, and clay; pebbly; unsorted; unbedded; and clay, silt and gravel; bedded; as thick as 200 metres (600 feet).

GLACIAL SEDIMENT

6 — GLACIAL SEDIMENT: sand, silt, and clay; pebbly; unsorted, unbedded; contains abundant cobbles and boulders; as much as 30 metres (100 feet) thick (multiple-event deposits as thick as 200 metres [600 feet]); the surface is flat or very hilly; deposited by glacial ice.

7 — GLACIAL SEDIMENT OVERLYING SAND AND GRAVEL: sand, silt, and clay; pebbly; unsorted; unbedded; 1 to 5 (?) metres (3-15 [?] feet) of glacial sediment overlying sand and gravel; glacial sediment deposited on older river sediments.

8 — WAVE-ERODED GLACIAL SEDIMENT: sand, silt, and clay; pebbly, unsorted; unbedded; glacial sediment that has been eroded (washed) by the action of waves in a lake; the surface of the eroded glacial sediment is flat or undulating; a veneer of nearshore or shoreline sediment is commonly present.

RIVER SEDIMENT

9 — RIVER CHANNEL SEDIMENT: sand and gravel; moderately to poorly sorted; cross bedded to flat bedded; as much as 30 metres (100 feet) thick; deposited by meltwater rivers.

Figure 2. Description of Map Units.

MAP LINE SYMBOLS

- confident contact
- approximate contact
- uncertain contact
- continuous scarp
- discontinuous scarp
- sharply defined fluvial channel
- obscure, partially buried fluvial channel
- obscure, mostly buried fluvial channel
- ridges apparent on airphotos; see description of map units for interpretation of origin
- any lineation apparent on airphoto

Figure 3. Map Line Symbols

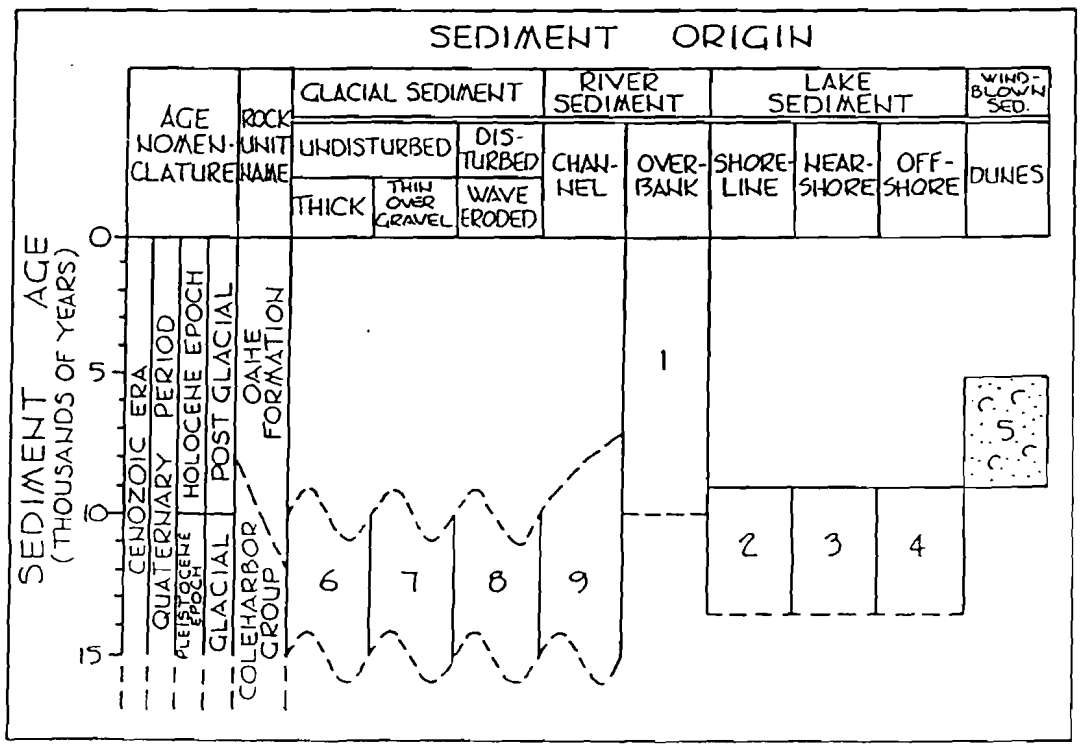


Figure 4. Age and Origin of the Sediments

THE NEAR-SURFACE STRATIGRAPHY

Methods Used

The correlation of these Quaternary sediments has involved the comparison of field identifiable, textural, and coarse-sand fraction lithologic characteristics. Other techniques may prove more useful elsewhere. We have used the percentage composition of sand, silt, and clay and the percentage composition of crystalline and metamorphic rock fragments, carbonate rock fragments, and shale rock fragments in the coarse sand fraction as correlation parameters.

In this report the six parameters (% sand, % silt, % clay, % XTAL, % CO3, and % SH) have been reduced to four (% sand, % NSLT, % NXTAL, and % SH) by normalizing the % silt and the % clay (% NSLT = % SLT/(% SLT + % CLY)) and by normalizing the % XTAL and % CO3 (% NXTAL = % XTAL/(% XTAL + % CO3)). This makes it possible to compare three of the original six parameters on a simple x-y plot and also simplifies the cross plotting of each parameter with each of the other parameters during the correlation process.

The cross plot diagrams shown here tally the number of coincident paired values on an x-y plot. For example, if a sample set contains four samples with % Sand = 20 and % Shale = 40 then the number "4" will be printed on the graph element (20, 40). These programs count "1" through "9" and then "a" through "f"; any levels of coincidence greater than 15 are represented by an "*".

Computer software which allows the rapid definition of the values and ranges of the correlation parameters for a stratigraphic unit; rapid identification of the stratigraphic position of a defined unit; and rapid presentation of the correlated data set in mappable form were used for this report (Harris, in preparation).

The General Stratigraphy

The Quaternary stratigraphic units known in the Red Lake Falls area include six formations that are composed largely of glacial sediment and four formations that are composed of lacustrine or fluvial sediment (Harris, Moran, and Clayton, 1974). These units are all thought to be Wisconsinan or younger in age (fig. 5). The outcrops we will visit expose all but four of the formations shown in Figure 5. Those we won't see are: 1) the Falconer Formation; glacial sediment that is the stratigraphic equivalent of the Huot Formation and present only outside the Lake Agassiz basin; 2) the Brenna Formation; lake sediment deposited in the pre-last Lake Agassiz; 3) the Poplar River Formation; river sediment deposited on the dry lake basin before Lake Agassiz flooded for the last time; and 4) the Sherack Formation; lake sediment deposited during the last flooding of the Lake Agassiz basin.

The spacial relationship of these stratigraphic units exposed along the Red Lake River Valley is shown in Figure 6. Progressively younger sediments are exposed as we move downstream (from NE to SW). The location of the two outcrops

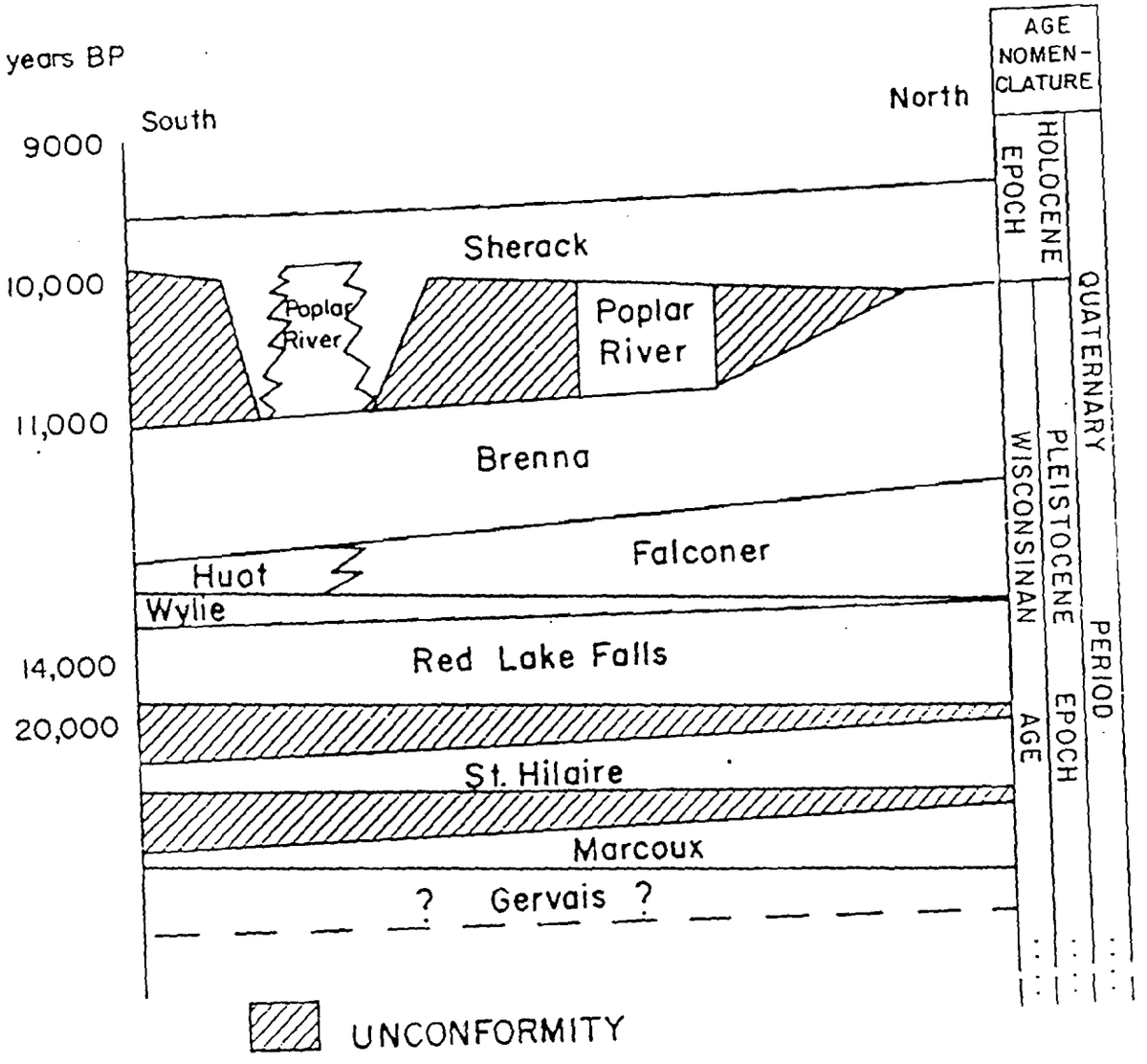


Figure 5. Schematic time-distance diagram showing periods of deposition of the formation discussed in this report. (Modified from: Harris, Moran, and Clayton, 1974.)

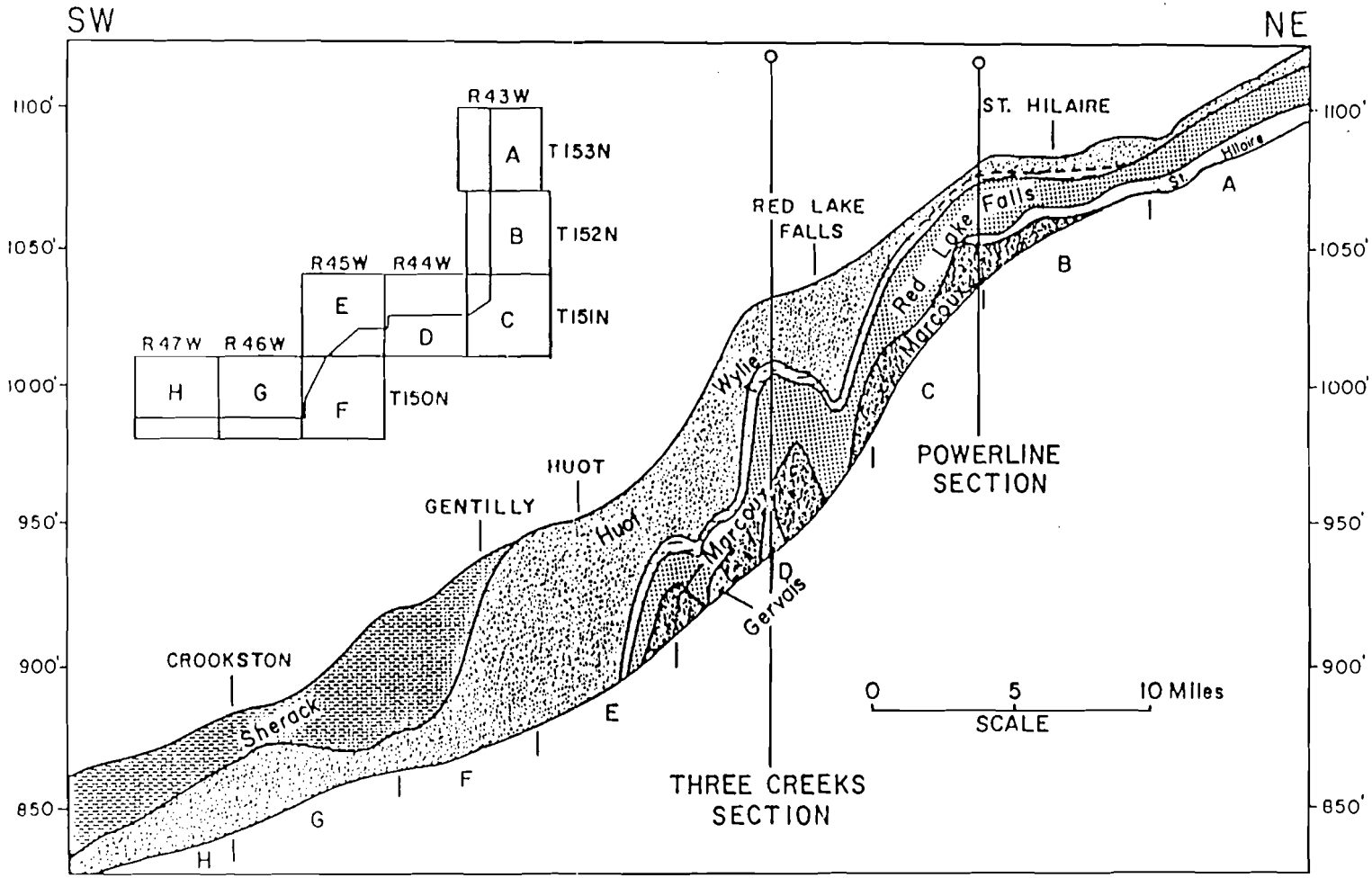


Figure 6. Generalized cross section along the Red Lake River in the Red Lake Falls, Minnesota, area. (Modified from: Harris, Moran, and Clayton, 1974.)

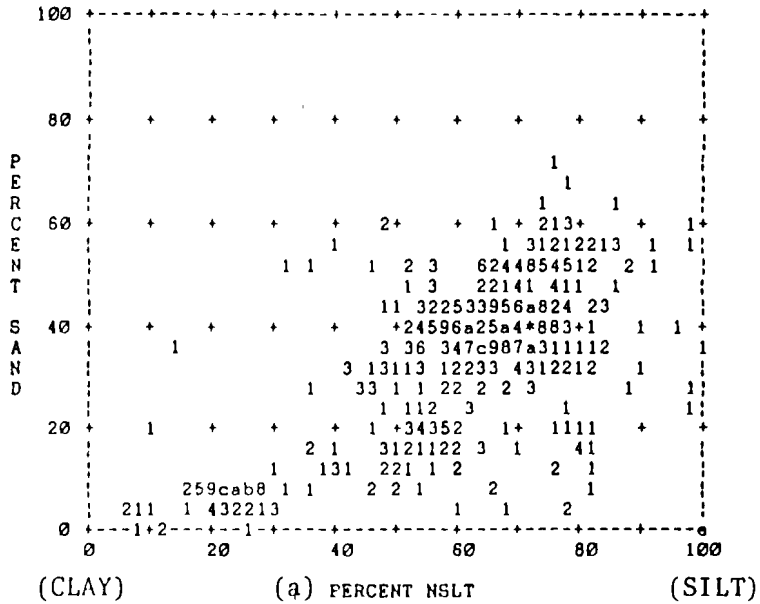
we will visit is shown on Figure 6. Powerline section is located near the southern limit (in the Red Lake River Valley) of the St. Hilaire Formation. The Three Creeks section is one of two known exposures of the Gervais Formation.

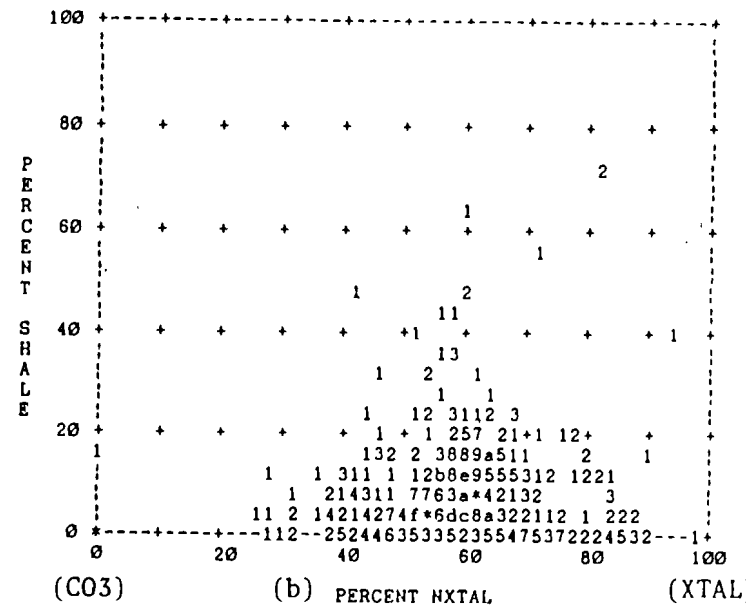
Description of the Stratigraphic Units

The stratigraphic framework used here was developed by Harris (1973) and Harris, Moran, and Clayton (1974). They used field identifiable characteristics, textural analysis, and calcite-dolomite content of the finer than 200 mesh fraction to characterize these stratigraphic units.

This summary uses textural and coarse-sand lithology data to characterize the units. About 600 samples (fig. 7) were used in this analysis. The samples were collected principally by S. R. Moran, Lee Clayton, Howard Hobbs, and K. L. Harris during the late 60s and early 70s. These data are stored in the North Dakota Geological Survey's near-surface stratigraphic data base (N-FILE). Computer software being developed by the NDGS to aid in till correlations was used in this analysis (Harris, in preparation).

The stratigraphic units we will see are described, from youngest to oldest, in the following pages. The information presented for each unit consists of a formal description (Harris, Moran, and Clayton, 1974) and a summary of the textural and coarse-sand, lithologic characteristics.





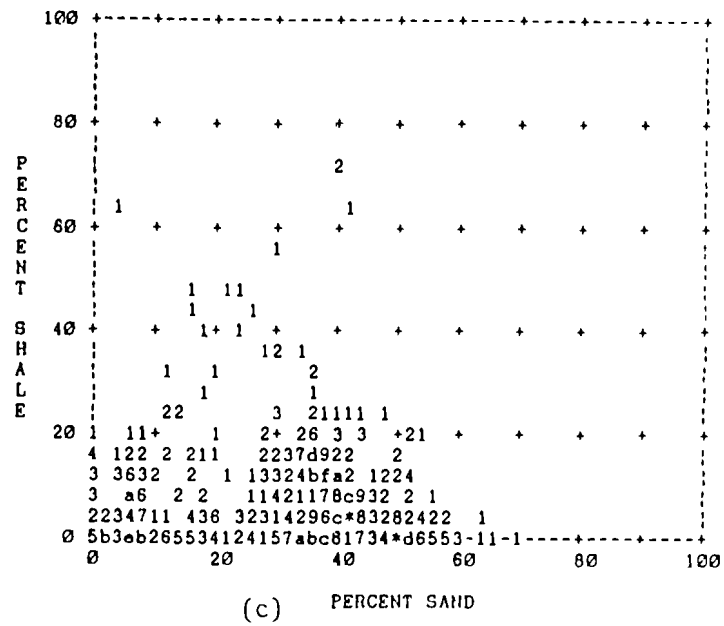


Figure 7. There were 599 samples used in this analysis. Crossplots of textural, coarse-sand lithology, and sand-shale characteristics are shown here.

(a) A crossplot showing textural variation in the data set.

(b) A crossplot showing lithologic variation of the coarse-sand fraction in the data set.

(c) A crossplot showing % sand vs % shale; this is a useful correlation relationship here.

HUOT FORMATION

Source of name: The hamlet of Huot, Red Lake County, Minnesota, located on the Red Lake Falls 15-minute quadrangle.

Type section: Clearwater Section, NE¼NW¼ sec. 22, T. 151 N., R. 44 W. (section 3, fig. 3).

Reference section: Snake Curve Section, NW¼SW¼ sec. 18, T. 151 N., R. 44 W. (section 9, fig. 3); Schist Cliff Section, SW¼SE¼ sec. 22, T. 151 N., R. 45 W. (section 10, fig. 3).

Description of unit: The Huot Formation is unbedded slightly pebbly clay. It is gray (5Y 5/1) when dry and very dark grayish brown (2.5Y 3/2) when wet. The formation is very hard and blocky when dry and very plastic when moist. The high clay content of the Huot Formation causes it to slump in outcrop, so most exposures are poor. Slickensides typically occur on shear faces in the Huot Formation.

The Huot Formation contains limestone pebbles and cobbles and numerous tan, chalky inclusions that range in size from less than 2 mm to more than 1 cm. A few pebbles of igneous rock are also present. Locally, boulder-size inclusions of a highly calcareous, pale-yellow glacial sediment are present.

The Huot Formation is composed of 4% to 9% sand, 14% to 26% silt, and 62% to 84% clay. The very coarse sand (1-2 mm) contains 40% to 45% igneous and metamorphic rock types, 50% to 55% limestone, and dolomite calcareous material makes up 25% of the minus 200 mesh fraction of the sediment.

Nature of contacts: The lower contact of the Huot Formation with the Wylie Formation is gradually interbedded to diffuse and locally is highly contorted. Boulder-size silt inclusions are associated with the areas of local disturbance.

The upper contact, where the Huot is overlain by the Poplar River or Sherack is sharp and erosional. The contact with the Brenna has not been seen but is believed to be gradational.

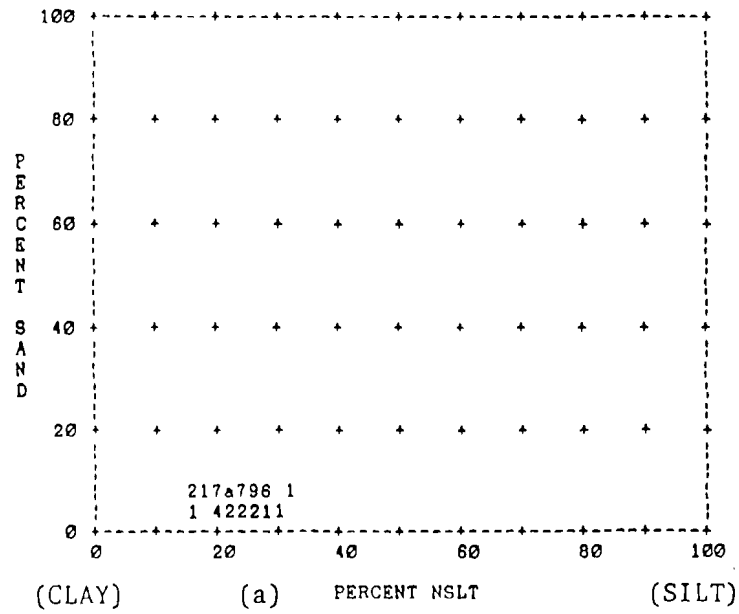
Regional extent and thickness: The Huot Formation is present in the Red Lake River valley from Red Lake Falls to west of Crookston, where it is overlapped by the Sherack Formation (fig. 5). It is at the surface in the area north and west of Red Lake Falls and in an arcuate belt a few miles wide across the Red River Valley (fig. 6). Because the Huot Formation is the surface unit in exposures west of Red Lake Falls and generally is prone to slumping, its exposed thickness is variable. From 3 to 15 feet (0.9 to 4.6 m) of the formation are exposed in most outcrops. However, as much as 70 feet (21.4 m) of the Huot Formation is exposed in the Schist Cliff Section. As much as 100 feet (30.6 m) of the Huot Formation is present in the central part of the Red River Valley.

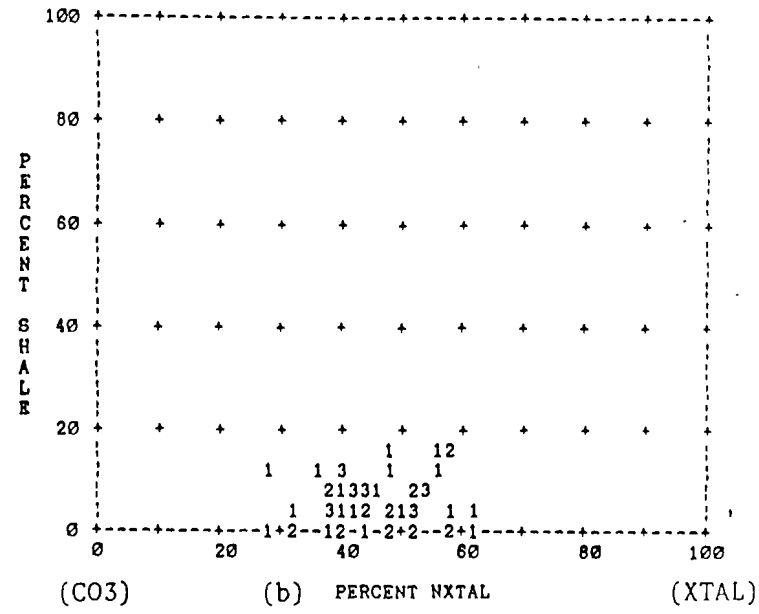
Differentiation from other units: The Huot Formation can be easily distinguished from other formations in the region by its texture, pebble content, unbedded, blocky structure, and color. The Brenna is the only formation resembling the Huot. They may be distinguished by the higher sand and pebble content of the Huot and the presence of obscure laminations in the Brenna.

Origin: The Huot Formation is glacial sediment deposited by ice moving southward down the Red River Valley.

Correlation: The Huot Formation is laterally and chronologically equivalent to the Falconer Formation in the central and western part of the Red River Valley.

Age: No radiocarbon dates are available to unambiguously date the Huot Formation. Two dates that can be related to the time of deposition of the Edinburg Moraine which lies along the outer margin of the Falconer Formation suggest a minimum age of 13,500 or 12,800 B.P. for deposition of the formation (Moran and Clayton, in preparation).





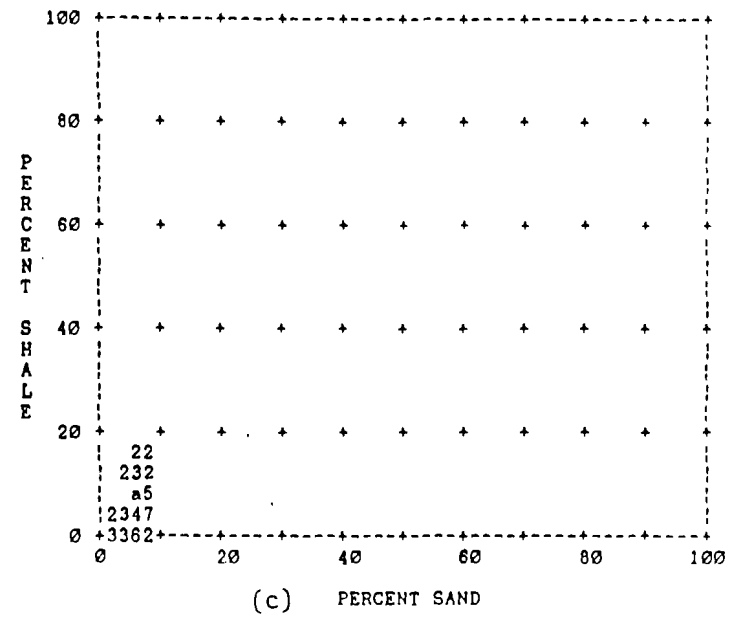


Figure 8. Crossplots summarizing the textural (a), coarse-sand lithologic (b), and sand-shale (c) characteristics of the Huot Formation in this area.

N = 56
Mean = 7-24-46-6 (7-22-71; 43-51-6)
S. Dev. = 2-4-8-5

WYLIE FORMATION

Source of name: The village of Wylie, Red Lake County, Minnesota, located on the Red Lake Falls 15-minute quadrangle.

Type section: Clearwater Section, NE¼NW¼ sec. 22, T. 151 N., R. 44 W. (section 3, fig. 3).

Reference section: Old Dam Section, SE¼NW¼ sec. 14, T. 151 N., R. 44 W. (section 8, fig. 3).

Description of unit: The Wylie Formation contains clay and silt that are generally thinly laminated. The clay is olive gray (5Y 5/2) when dry and dark gray (5Y 4/1) when wet. The silt is light brownish gray (2.5Y 6/2) when dry and olive brown (2.5Y 4/4) when wet. In outcrop, the formation is friable when dry and tough and plastic when moist. The silt laminae become thinner and the clay laminae become thicker upward. In most outcrops, the laminae range in thickness from a few millimeters to a centimeter.

Nature of contacts: The lower contact of the Wylie Formation with the Red Lake Falls Formation is gradual and interbedded. This contact is locally highly contorted.

The upper contact with the overlying Huot Formation is gradually interbedded or diffuse. Locally the contact is highly contorted, and boulder-sized masses of glacial sediment are present.

The upper contact of the Wylie Formation with the Falconer Formation has not been observed. It is believed to be similar in nature to the contact with the Huot Formation.

Regional extent and thickness: On the Red Lake River the Wylie Formation is exposed from the Needles Eye Section (SW¼NE¼SE¼ sec. 22, T. 151 N., R. 43 W.) downstream to the area of the Schist Cliff Section (SE¼SE¼ sec. 22, T. 151 N., R. 45 W.). It is exposed at the surface north of Red Lake Falls beyond the eastern limit of the Huot Formation. The Wylie Formation is discontinuously present beneath the Huot or Falconer Formations throughout the central part of the Red River Valley in Traill, Grand Forks, and southern Walsh Counties, North Dakota, and in Norman and Polk Counties, Minnesota (fig. 5).

The Wylie Formation ranges in thickness from less than 2 feet (0.6 m) to more than 7 feet (2.1 m). Average thickness of exposures is about 5 feet (1.5 m).

Differentiation from other units: The Wylie Formation, by its distinct laminations, can be distinguished from all other named formations in the Grand Forks area except the Sherack Formation. The Sherack Formation is separated stratigraphically from the Wylie Formation by the Brenna and Falconer or Huot Formations. Where these formations are present the distinction can be readily made.

Origin: The Wylie Formation is lacustrine sediment. Deposition occurred in an ice-marginal lake during the retreat of the ice sheet that deposited the Red Lake Falls Formation and the advance of the ice sheet that deposited the Huot Formation and Falconer Formation.

Age: The Wylie Formation is Late Wisconsinan in age. It was deposited during an early phase of Lake Agassiz.

RED LAKE FALLS FORMATION

Source of name: The city of Red Lake Falls, Red Lake County, Minnesota, located on the Red Lake Falls, Minnesota, 15-minute quadrangle.

Type section: Clearwater Section, NE¼NW¼ sec. 22, T. 151 N., R. 44 W. (section 3, fig. 3).

Reference sections: Needles Eye Section, SW¼NE¼SE¼ sec. 18, T. 151 N., R. 43 W. (section 4, fig. 3); Damned House Section, SW¼NE¼SE¼ sec. 15, T. 151 N., R. 44 W. (section 7, fig. 3).

Description of unit: The Red Lake Falls Formation is unbedded pebble-loam. It is brownish gray (2.5Y 6/2) when dry and olive brown (2.5Y 4/4) when wet. Vertical joints result in a strong columnar structure in dry, weathered outcrops, and oxidation along the joints produces a reddish yellow (7.5YR 6/6) stain. The Red Lake Falls Formation is hard and resistant to erosion in dry outcrops and is friable when moist.

Sand and gravel inclusions are common; these include thin beds a few millimeters thick, channel fills, and contorted masses. Thin beds of laminated silt and clay as much as a few inches thick may be laterally persistent for tens of feet.

In some outcrops two slightly different lithologies occur in the Red Lake Falls Formation. The differences are subtle enough that in most cases consistent field separation of the two units is not yet possible. The upper unit is generally more conspicuously jointed than the lower, more massive unit. The upper unit contains less sand, 32% to 42%, more silt, 36% to 46%, and about as much clay, 17% to 27%, as the lower unit; 39% to 49% sand, 34% to 40% silt, and 15% to 25% clay. The very coarse sand (1-2 mm) of the upper unit contains more shale, 10% to 15%, and less limestone and dolomite, 33% to 35%, than the lower unit, 0% to 4% shale and 38% to 52% limestone and dolomite. Both units contain about 50% igneous and metamorphic rock types. Calcareous material makes up a greater percentage of the minus 200 mesh fraction of the lower unit, 36%, than the upper unit, 28%. Pebbles, cobbles, and boulders are abundant in both units. The pebbles in the lower unit consist of about 2/3 limestone and dolomite; about 1/3 igneous and metamorphic rock types, and minor amounts of shale. The pebbles of the upper unit are similar but with a greater percentage of shale. The contact between the two units is commonly marked in some places by a cobble concentration similar to the solid, striated boulder pavement at the base of the formation. The cobbles making up this concentration are much smaller than in the basal pavement.

Nature of contacts: North of the Powerline Section the Red Lake Falls Formation overlies the St. Hilaire Formation. The contact between these formations is sharp to diffusely graded. The Marcoux Formation underlies the Red Lake Falls Formation south of the Powerline Section. The contact between these formations is sharp, with sand and gravel commonly present. The sand and gravel ranges from a few inches to 17 feet (5.2 m) thick. A boulder pavement is present at the contact in some outcrops. The upper contact of the Red Lake Falls Formation is a gradual interbedding with the overlying Wylie Formation. The Red Lake Falls Formation commonly becomes less sandy and more clayey near its upper contact. Where the Wylie Formation is absent, there is a diffuse contact with a contorted silty, pebbly clay containing silt inclusions. This is probably a subaqueous mud flow deposit made up of material derived from the Red Lake Falls and Wylie Formations. At several locations the upper contact of the Red Lake Falls Formation is an erosional surface overlain by Holocene fluvial sediment.

Regional extent and thickness: The Red Lake Falls Formation is exposed along the Red Lake River trench from Thief River Falls to near Huot. It is present in surface exposures in northwestern Minnesota from the Canadian border to the Wild Rice River. It is present in the subsurface throughout the Red River Valley and is believed to extend westward into North Dakota.

The Red Lake Falls Formation ranges in thickness from at least 70 feet (21.5 m) at Knife's Edge Section (NW¼NW¼SE¼ sec. 19, T. 151 N., R. 43 W.) to 7 feet (2.15 m) at the Stony Bench Section (NE¼NE¼NW¼ sec. 17, T. 152 N., R. 43 W.). The normal range of thickness is from 15 to 30 feet (4.6 to 9.2 m).

Differentation from other units: The Red Lake Falls Formation can be distinguished from similar units on the basis of texture, pebble lithology, and color. It is sandier than either the silty Gervais or Falconer Formations or the clayey Huot Formation. It is lighter in color than both the Gervais and Huot Formations. Pebble lithology distinguishes the Red Lake Falls from the Marcoux Formation, and color distinguishes it from the St. Hilaire Formation which is much darker.

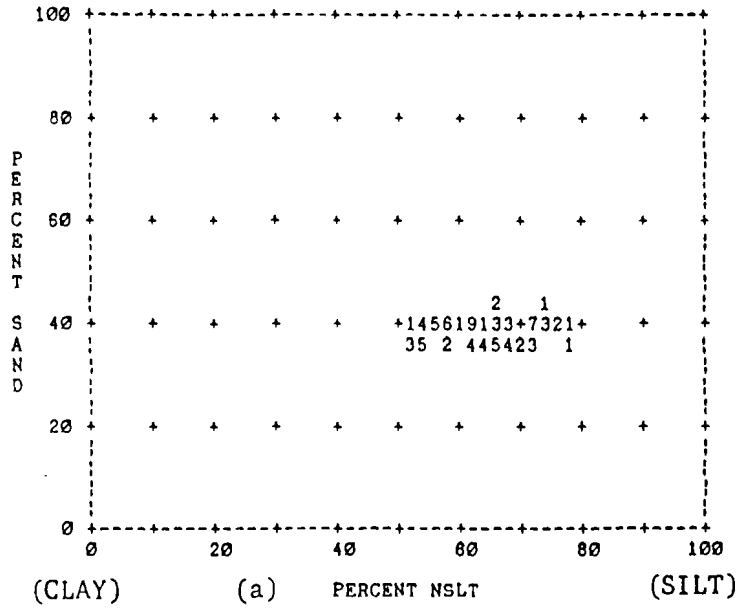
Origin: The Red Lake Falls Formation is composed predominantly of glacial sediment. In the Red Lake Falls area, minor amounts of lake and stream sediment are included in the formation. In the central part of the Red River Valley, in eastern Grand Forks County, as much as 20 feet (6.1 m) of laminated lacustrine clay lies between the 2 pebble-loam units of the formation in an area of several 10's of square miles. In some places, several 10's of feet of fluvial sand and gravel occur in the formation.

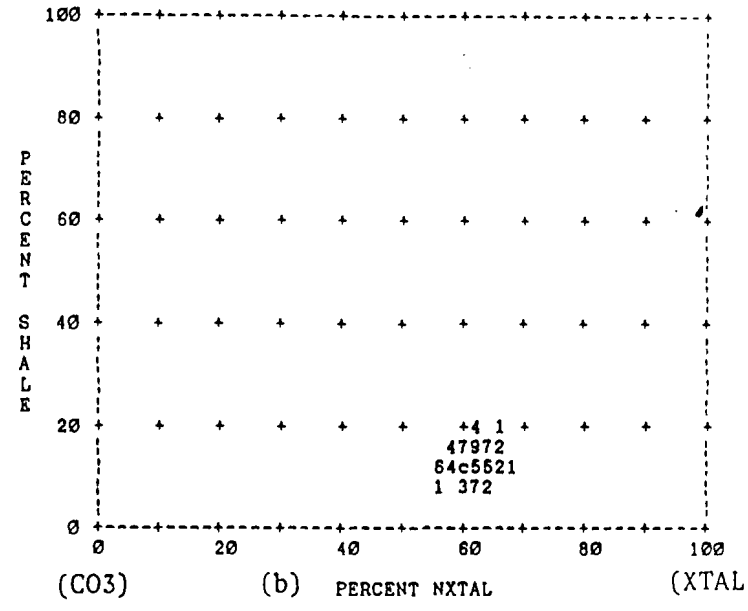
On the basis of pebble and sand-grain lithology we believe that the lower pebble-loam unit of the Red Lake Falls Formation was deposited by a glacier that advanced from the north. On the same basis we believe that the upper pebble-loam unit of the formation was deposited by a glacier that advanced from the northwest.

Correlation: The lower unit of the Red Lake Falls Formation correlates with the Granite Falls Formation of southwestern Minnesota (Matsch, 1971). The very similar appearance, texture, and pebble lithology of these two formations strongly suggests that they are correlative. Correlation of the lower unit of the Red Lake Falls Formation to the west into North Dakota is much less certain. Salomon (1973, in press) correlated the lower part of the formation with a very shaley till that is widespread in northeastern North Dakota. Although this correlation seems reasonable on the basis of available information on stratigraphic position and lateral continuity of the two units, the very abrupt change in lithology, from nearly no shale in the Red Lake Falls to 70% shale to the west, needs to be explored further before this correlation can be considered certain.

The upper unit of the Red Lake Falls Formation correlates with the New Ulm till of southwestern Minnesota (Matsch, 1971). The stratigraphic position and lithology of the two formations argues strongly for this correlation. Salomon (1973, in press) has correlated the upper unit of the Red Lake Falls with the surface till in northeastern North Dakota. Her correlation is based on stratigraphic position and pebble lithology.

Age: The age of the Red Lake Falls Formation is believed to be Wisconsinan. No evidence to support this assignment has been found in the Grand Forks area. Matsch (1971, p. 63-64) considers the Granite Falls Till to be Wisconsinan in age. Three radiocarbon dates from the New Ulm area were greater than 39,000 B.P. The upper part of the Red Lake Falls Formation can be dated with greater certainty. On the basis of radiocarbon dates below and above the formation in southwestern Minnesota and northwestern Iowa, the New Ulm Till can be dated as Late Wisconsinan. Ruhe (1969, p. 106, 201, 212) reported 2 dates of about 20,000 B.P. beneath till that Matsch (1972, p. 335) considered to be part of the New Ulm Till. Numerous radiocarbon dates from above the New Ulm Formation in southwestern Minnesota and Iowa indicate that deposition ceased about 14,000 B.P. (Matsch, 1971, p. 63). Dates in North Dakota are several thousand years younger, suggesting that the top of the formation is younger farther toward the north (Clayton, 1966).





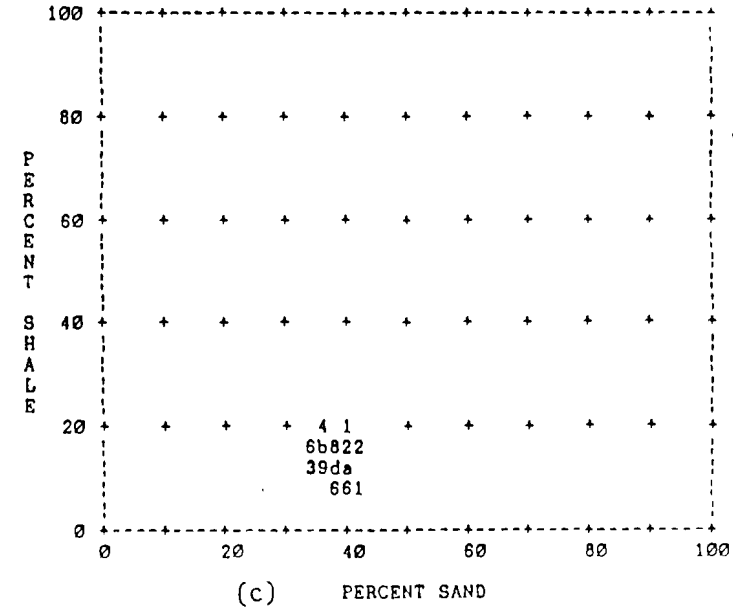
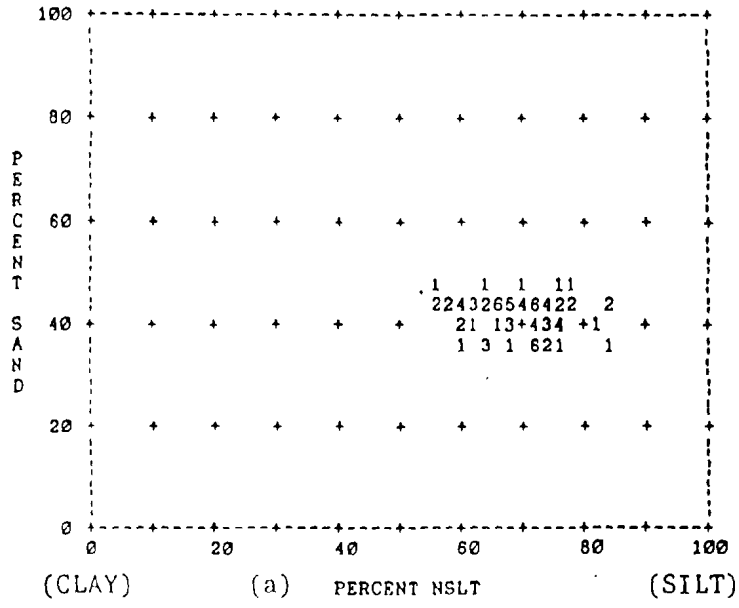
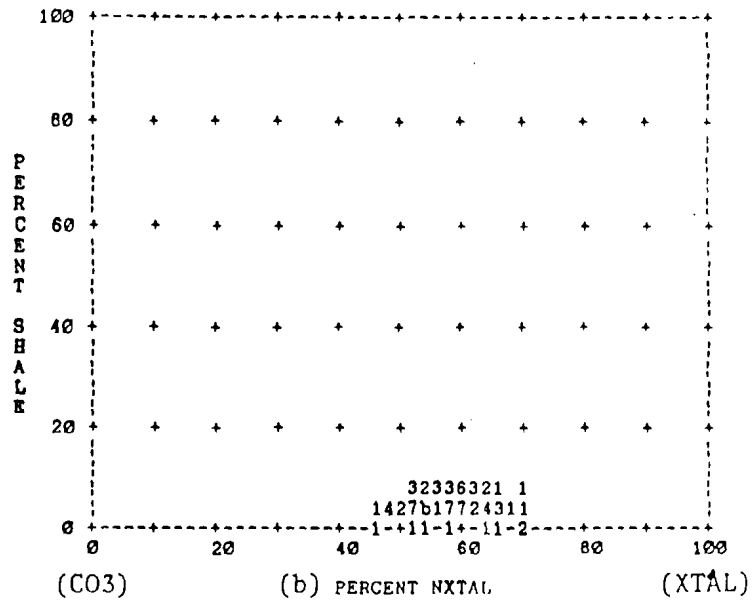


Figure 9. Crossplots summarizing the textural (a), coarse-sand lithologic (b), and sand-shale (c) characteristics of the upper member of the Red Lake Falls Formation in this area.

N = 82
Mean = 38-64-62-13 (38-40-22; 54-33-13)
S. Dev. = 2-7-3-3





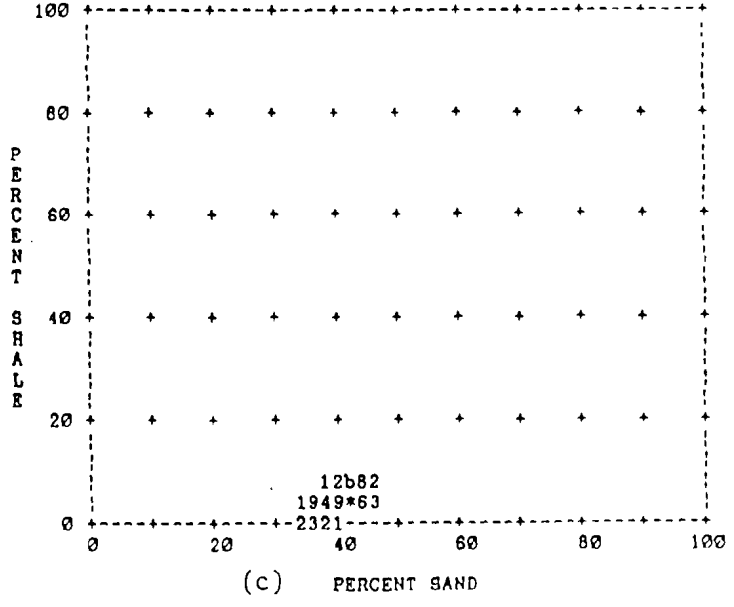


Figure 10. Crossplots summarizing the textural (a), coarse-sand lithologic (b), and sand-shale (c) characteristics of the lower member of the Red Lake Falls Formation in this area.

N = 83
Mean = 41-70-58-4 (41-41-18; 56-40-4)
S. Dev. = 3-7-6-2

ST. HILAIRE FORMATION

Source of name: The village of St. Hilaire in Pennington County, Minnesota, located on the Thief River Falls 7.5-minute quadrangle.

Type section: Powerline Section, SE¼SE¼NE¼ sec. 5, T. 151 N., R. 43 W. (section 5, fig. 3).

Reference sections: Opernockity Section, SE¼NE¼SE¼ sec. 32, T. 152 N., R. 43 W. (section 6, fig. 3); Small Creek Section, SE¼SW¼SE¼ sec. 17, T. 152 N., R. 43 W.

Description of unit: The St. Hilaire Formation is unbedded pebble-loam. It is gray (5Y 5/1) when dry and very dark gray (10Y 3/2) when wet. Weak vertical joints are common and result in a moderately columnar structure. The pebble loam of the formation consists of 30% to 40% sand, 38% to 46% silt, and 15% to 29% clay. Pebbles and cobbles are abundant. Two groups of pebbles, igneous and metamorphic rock types, and limestone and dolomite, occur in equal numbers and constitute most of the pebbles. Shale pebbles, which are conspicuously present, are about half as abundant as either of these groups. Lignite pebbles are commonly present in amounts as great as 5% of the total pebble fraction. The very coarse sand (1-2 mm) contains 37% to 44% igneous and metamorphic rock types, 27% to 36% dolomite and limestone, 20% to 35% shale, and 1% to 3% miscellaneous rock types. Calcareous material makes up about 25% of the sediment finer than 200 mesh.

Nature of contacts: The St. Hilaire overlies the Marcoux Formation in the Red Lake Falls area. The contact between them is sharp, and typically there is a cobble concentration or boulder pavement present. In some places as much as 18 inches (0.46 m) of fine sand is present at the contact. The upper contact with the overlying Red Lake Falls Formation is sharp to gradational. Discontinuous and contorted sand beds are commonly present.

Regional extent and thickness: In the Red Lake River valley the St. Hilaire Formation is exposed only from Thief River Falls, south to the Powerline Section. In this area the unit is from 1 to 4 feet thick. Its characteristic dark color makes it a useful stratigraphic marker.

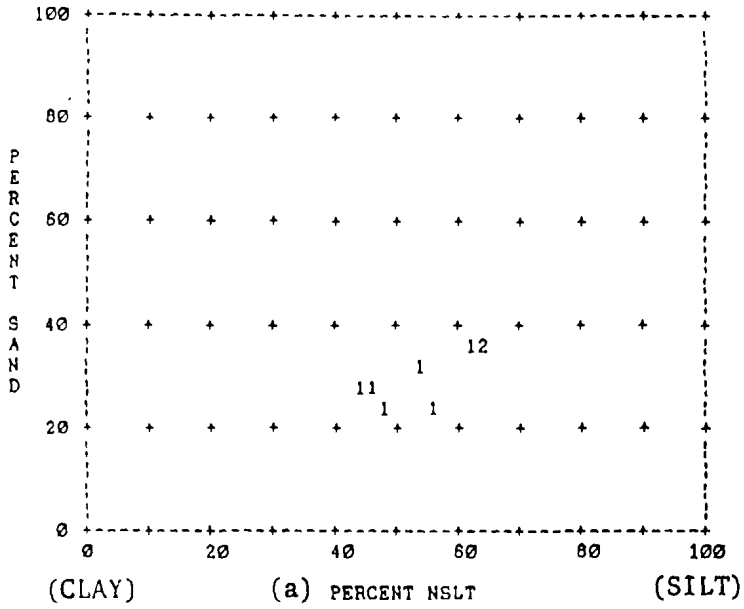
The St. Hilaire Formation thickens to the south. At the Twin Valley Section on the Wild Rice River near Heiberg, Minnesota, 20 feet (6.11 m) of the formation is exposed. The St. Hilaire Formation is thought to extend throughout northeastern North Dakota, southern Manitoba, and northwestern Minnesota.

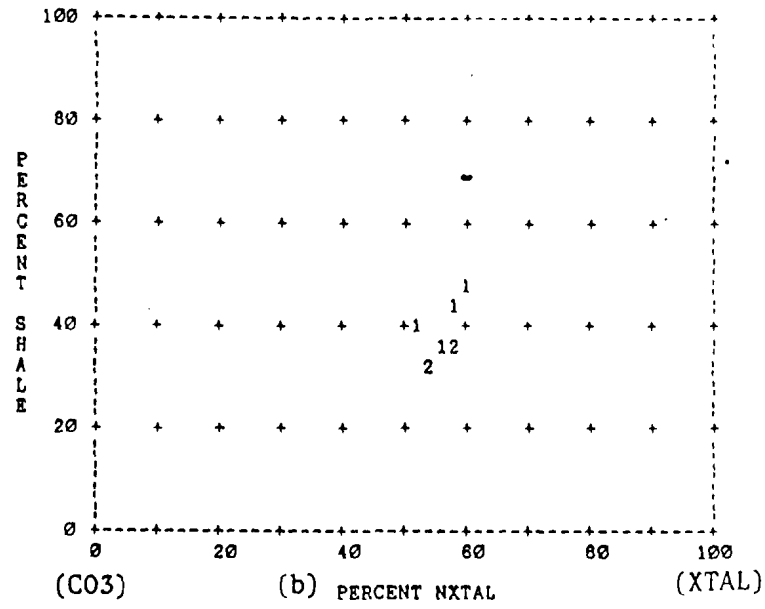
Differentation from other units: The St. Hilaire Formation is easily distinguished from the Marcoux and Red Lake Falls Formation by pebble lithology and color. The Marcoux Formation contains predominantly igneous and metamorphic pebbles and the Red Lake Falls Formation contains largely limestone and dolomite pebbles. Neither of these formations contains appreciable shale or lignite and both are lighter in color than the dark gray St. Hilaire. The Huot and Gervais Formations contain significantly less sand than the St. Hilaire Formation.

Origin: The St. Hilaire is glacial sediment. The occurrence of appreciable quantities of shale in the pebble fraction suggests a western or northwestern source. The shale appears to be derived from the Pierre and Riding Mountain Formations in eastern North Dakota and southern Manitoba.

Correlation: It has not been possible to correlate the St. Hilaire Formation outside the Red River Valley.

Age: The age of the St. Hilaire Formation is unknown, but stratigraphic position suggests that it is Wisconsinan or pre-Wisconsinan in age.





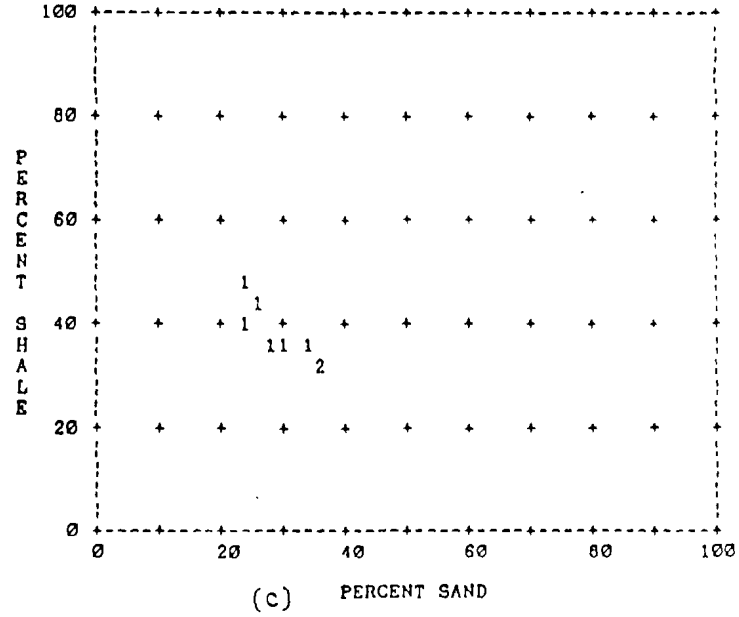


Figure 11. Crossplots summarizing the textural (a), coarse-sand lithologic (b), and sand-shale characteristics of the St. Hilaire Formation in this area.

N = 8
Mean = 30-55-57-37 (30-39-32; 36-27-37)
S. Dev. = 5-7-2-5

MARCOUX FORMATION

Source of name: Marcoux Corners, Red Lake County, Minnesota, located on the Red Lake Falls 15-minute quadrangle.

Type area: Red Lake Falls area, Minnesota.

Type section: Clearwater Section, NE¼NE¼ sec. 22, T. 151 N., R. 44 W. (section 3, fig. 3).

Reference section: Needles Eye Section, SW¼NE¼SE¼ sec. 18, T. 151 N., R. 43 W. (section 4, fig. 3) and Damned House Section, SW¼NE¼SE¼ sec. 15, T. 151 N., R. 44 W. (section 7, fig. 3).

Description of unit: The Marcoux Formation is unbedded, very sandy pebble-loam. The formation is light gray (5Y 6/1) when dry and grayish brown (2.5Y 5/2) when wet. In weathered outcrops it is *extremely hard* and stands in nearly vertical slopes. It is weakly jointed. Pebbles, cobbles, and boulders are abundant in this formation. Rapids along the Red Lake River are generally associated with outcrops of the Marcoux Formation. The pebble loam of the Marcoux consists of 48% to 58% sand, 30% to 40% silt, and 8% to 18% clay. The abundant pebbles consist of roughly 2/3 igneous and metamorphic rock types and 1/3 limestone and dolomite. Shale pebbles occur only very rarely. The very coarse sand (1-2 mm) contains from 73% to 85% igneous and metamorphic rock types, from 12% to 26% limestone and dolomite, from 0% to 8% shale, and 1% to 2% miscellaneous rock types. Calcareous material makes up about 28% of the less than 200 mesh fraction of the sediment.

Nature of contacts: The lower contact of the formation has been seen only at the Three Creeks Section, where the Marcoux Formation overlies the Gervais Formation. Here the contact is sharp. Cobbles are concentrated at the contact.

North of the Powerline Section (SE¼SE¼NE¼ sec. 5, T. 151 N., R. 43 W.), the Marcoux is overlain by the St. Hilaire Formation (fig. 4). The contact between these formations is sharp and generally marked by a boulder pavement. Where the boulder pavement is absent, a bed of sand as much as 18 inches thick is commonly present.

South and west of the Powerline Section, the Marcoux is overlain by the Red Lake Falls Formation (fig. 4). The contact between these formations is sharp and marked by a bed of sand or sand and gravel ranging in thickness from a few inches to 17 feet (5.2 m). A boulder pavement is present in some outcrops but is not common.

Regional extent and thickness: The Marcoux Formation is exposed in the Red Lake River trench for a distance of about 20 miles (32 km), from south of Thief River Falls to west of Red Lake Falls (fig. 4). It has been seen in outcrop from Florian, in Marshall County, Minnesota, to Ulen, in Clay County, Minnesota, a distance of about 100 miles (160 km). A sandy, pebble-loam believed to be the Marcoux Formation occurs throughout the Red River Valley (L. Froelich, personal communication; R. W. Schmid, personal communication; J. P. Bluemle, personal communication). The Marcoux Formation is thought to extend from north of the Canadian border throughout northwestern Minnesota and eastern North Dakota.

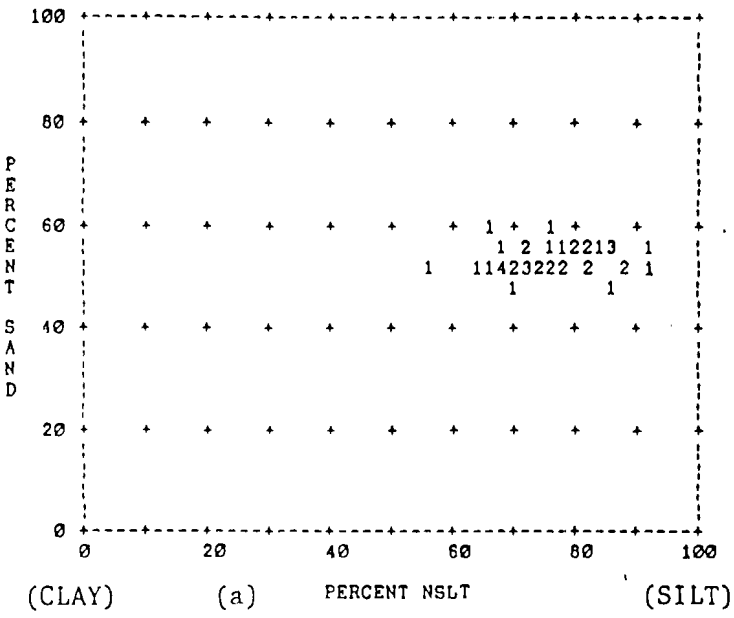
Exposed thicknesses of the Marcoux Formation range from 6 inches to 27 feet (0.15 to 8.25 m). Attempts to penetrate the Marcoux with a truck-mounted power auger have been frustrated by the large number of boulders and extreme hardness of the formation. Borings in the Grand Forks area penetrated as much as 64 feet (19.57 m) of the Marcoux Formation.

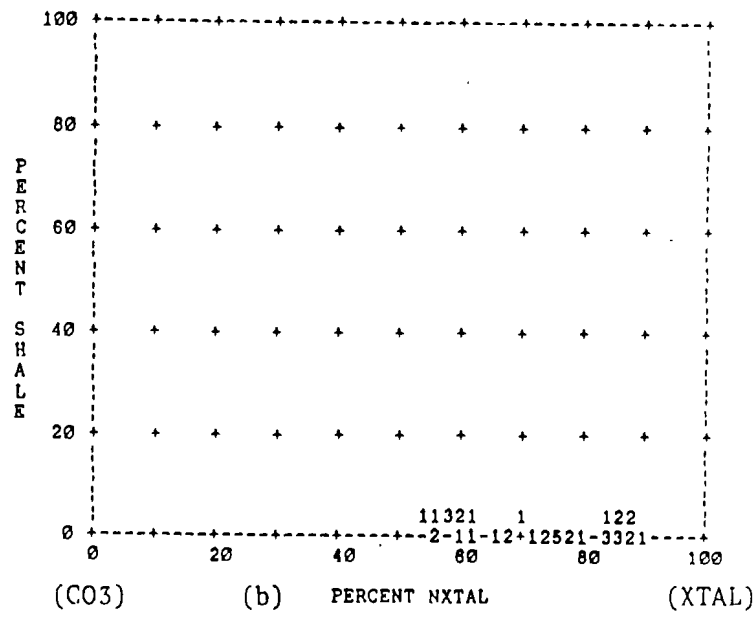
Differentation from other units: The most useful characteristic for distinguishing the Marcoux Formation from other late Quaternary formations is its texture. No other formation contains as much sand and as little clay as the Marcoux. The abundance of stones, predominance of igneous and metamorphic pebbles, hardness, and weak jointing are all characteristic of the Marcoux.

Origin: The Marcoux Formation is glacial sediment. The predominance of granitic and metamorphic rock types suggests that the glacier that deposited the Marcoux Formation advanced from the northeast across the Canadian Shield.

Correlation: Formation probably correlates with the Hawk Creek Till in the Minnesota River valley (Matsch, 1971). Both formations are very sandy, contain a mineral assemblage characteristic of areas to the northeast, and occur in the same stratigraphic position.

Age: The age of the Marcoux Formation is unknown, but stratigraphic position suggests that it is Early Wisconsinan or pre-Wisconsinan in age.





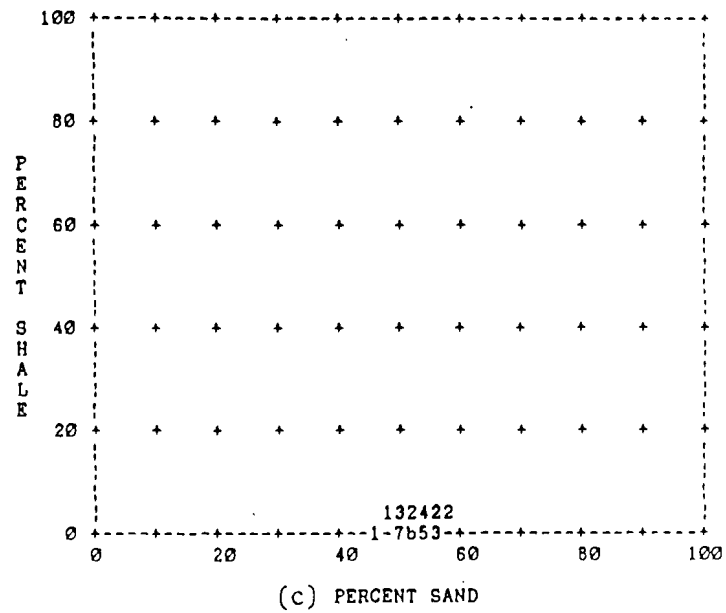


Figure 12. Crossplots summarizing the textural (a), coarse-sand lithologic (b), and sand-shale (c) characteristics of the Marcoux Formation in this area.

N = 41
Mean = 53-77-74-1 (53-36-11; 73-26-1)
S. Dev. = 3-8-11-1

GERVAIS FORMATION

Source of name: Gervais Township, Red Lake County, Minnesota.

Type area: The Red Lake Falls area of Minnesota (figs. 1 and 3).

Type section: Three Creeks Section*, NE¼NE¼NW¼ sec. 21, T. 151 N., R. 44 W. (section 1, fig. 3).

Reference section: Moo Point Section, NE¼NE¼NW¼ sec. 19, T. 151 N., R. 44 W. (section 2, fig. 3).

Description of unit: The Gervais Formation is unbedded, silty, very slightly pebbly clay-loam. It is light olive gray (5Y 6/2)** when dry and very dark gray (5Y 3/1) when moist. In outcrop, it tends to part or flake along joints that are oxidized to dark brown (7.5YR 3/2), giving the outcrop a brownish cast. Abundant wood chips, twigs, and logs up to 6 inches (150 mm) across occur in the Gervais Formation. Fragments of mollusk shells, insects, carbon flakes, and green moss are also present. Abundance of all organic material decreases upward, and the abundance of pebbles increases upward. A few cobbles are present near the upper contact. Though not abundant, sand lenses a few millimeters thick are present with increasing abundance upward.

The Gervais Formation contains 15% to 21% sand, 45% to 51% silt, and 32% to 36% clay***. Calcareous material makes up about 15% of the minus 200 mesh fraction of the sediment.

Nature of contacts: At the Three Creeks Section, the contact of the Gervais Formation with the overlying Marcoux Formation is sharp, and cobbles are concentrated along the contact. At the Moo Point Section, the Marcoux Formation is absent and the Gervais Formation is in sharp to gradational contact with the Red Lake Falls Formation. Cobbles are concentrated at the contact here also. The lower contact of the formation has not been observed, and its nature is unknown.

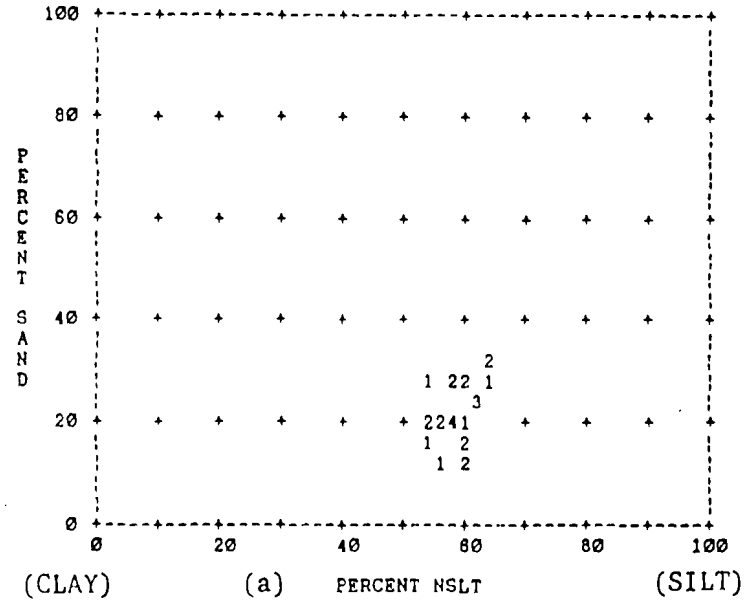
Regional extent and thickness: The Gervais Formation is exposed at only two known outcrops in the Red Lake River valley (fig. 4). It is at least 40 feet (12.25 m) thick at the Three Creeks Section.

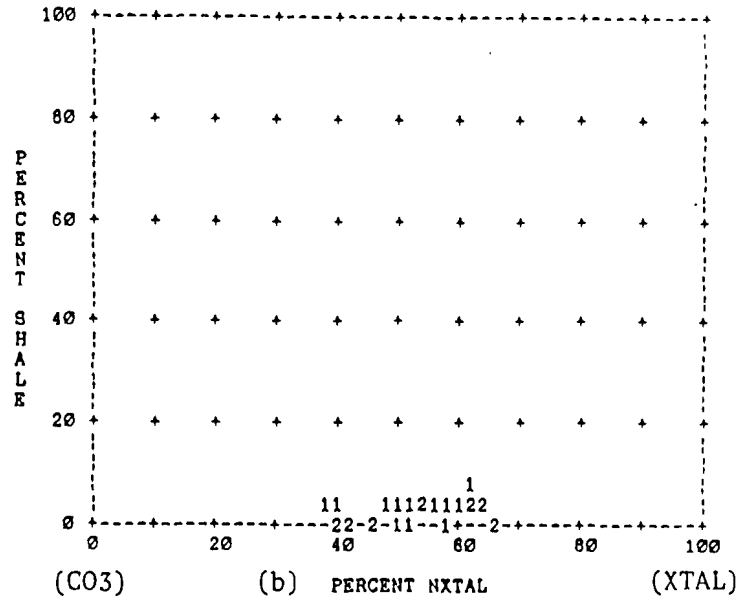
Differentiation from other units: The Gervais Formation is overlain by the Marcoux Formation at the Three Creeks Section and by the Red Lake Falls Formation at the Moo Point Section. It may be differentiated from both of these formations on the basis of its finer texture, darker color, and the presence of organic debris.

Origin: The Gervais Formation probably consists of glacially modified fluvial or lacustrine sediment. The sediment of the formation becomes progressively more homogeneous upward. The silt and clay was probably originally derived locally.

Correlation: The Gervais Formation may be correlative with a silt and sand unit found in well borings in the Lake Bronson, Minnesota, area. These borings ranged in depth from 90 to 140 feet (27.5 to 44.0 m) and produced abundant organic material. Radiocarbon dates on the organic debris recovered are: greater than 19,000 B.P. (C-496), greater than 36,000 B.P. (W-102), greater than 36,000 (W-498), and greater than 38,000 (W-1028).

Age: The Gervais Formation is Early Wisconsinan or pre-Wisconsinan in age. A radiocarbon date obtained from a log near the base of the Three Creeks Section is greater than 39,900 B.P. (I-5317).





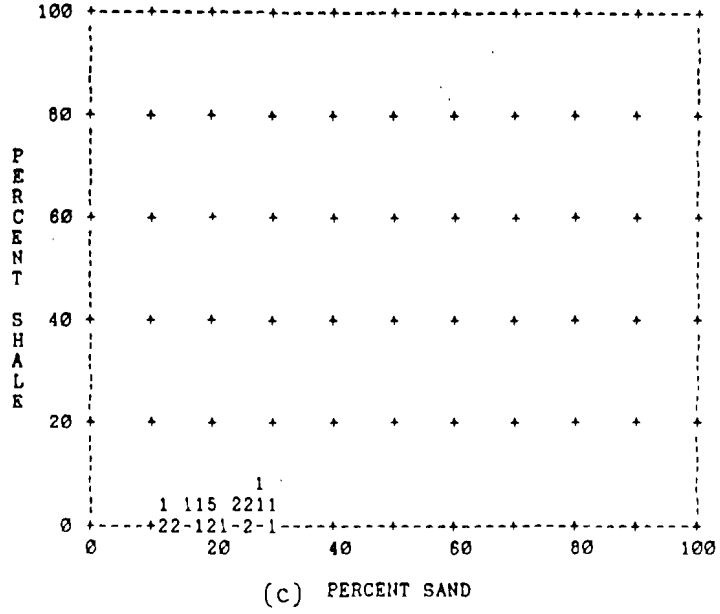


Figure 13. Crossplots that summarize the textural (a) coarse-sand lithologic (b), and sand-shale (c) characteristics of the Gervais Formation in this area.

N = 26
Mean = 21-59-53-2 (21-47-32; 52-46-2)
S. Dev. = 5-3-9-2

Surface Exposure of the Stratigraphic Units

Plate II shows the areas where these stratigraphic units are exposed at the surface. A legend for Plate II is provided in Figure 14.

Three lithostratigraphic units with distinctly different textural and coarse-sand lithologic characteristics are exposed at the surface in the Red Lake Falls area. The Huot Formation is exposed in a band extending from the Red River of the North, near Shelly, northeastwardly through the Huot-Red Lake Falls area. The upper member of the Red Lake Falls Formation is exposed north and east of Red Lake Falls, and the lower member of the Red Lake Falls Formation is at the surface southeast of Red Lake Falls and in the adjacent glaciated uplands.

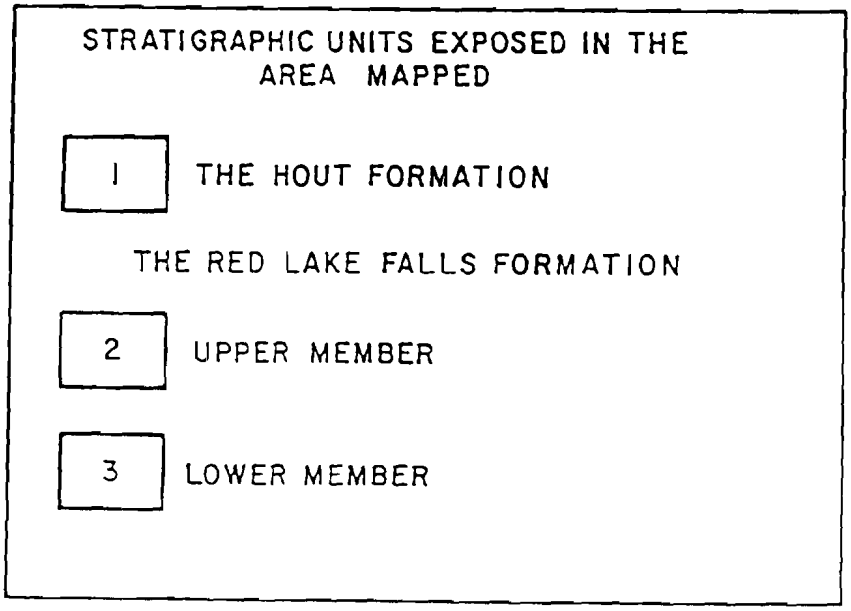


Figure 14. Legend for Plate II, areas of surface exposure of stratigraphic units.

FIELD EXAMPLES OF THE STRATIGRAPHIC UNITS

The Powerline Section

This exposure is a good example of the stratigraphy that is exposed in outcrops along the Red Lake River between Red Lake Falls and Thief River Falls.

A detailed outcrop description (Fig. 15) and an outcrop sketch showing formational boundaries and the results of sample analyses (fig. 16) are provided.

The Three Creeks Section

This section exposes all of the stratigraphic units present along the Red Lake River Valley except the St. Hilaire and Sherack Formations.

The Huot Formation is present here in the uplands, above the vertical slopes, but is too slump-prone to stand up well in outcrops.

The glacial sediment of the Marcoux Formation is almost gone here, eroded away and replaced by a 20-foot-thick sand bed.

The Gervais Formation is known to be present at only one other outcrop along the river. This is one of the most unusual and oldest glacial sediments exposed in the upper midwest. It contains abundant disseminated organic debris including wood and fossil beetle fragments. The wood, including some 6-inch diameter spruce logs, has been radiocarbon dated twice and found to be 39,900 yr. B.P. (I-5317; Harris, Moran, and Clayton, 1974; Ashworth, 1980) and 46,900 yr. B.P. (BIRM 522; Ashworth, 1980). This would indicate an early Wisconsinan or pre-Wisconsinan age for the Gervais Formation (Moran et al., 1976).

The fossil beetle assemblages present in the Gervais were studied by Allan Ashworth (1980). He suggests that the sedimentary environment indicated by the beetles was a small lake with open margins characterized by open areas and a spruce woodland. The climate was similar to that found today in the Lake Superior region or somewhat further north near the tundra-forest transition zone.

A detailed outcrop description (fig. 17) and an outcrop sketch showing formational boundaries and the results of sample analyses (fig. 18) are provided.

Powerline Section

SE¼SE¼NE¼ sec. 5, T. 151 N., R. 43 W.

Left bank of Red Lake River

Section 5 - Figure 3

Section described by K. L. Harris, S. R. Moran, Lee Clayton.

Depth in Feet	Elevation Above Sea Level	Description
Red Lake Falls Formation		
0-28	1082-1054	Pebble-loam; unbedded; friable; light gray (5Y 6/1 dry); abundant sand lenses present; lower contact gradational; cobble, sand, and gravel concentrations occur at contact.
St. Hilaire Formation		
28-30	1054-1052	Pebble-loam; clayey; unbedded; friable; gray (5Y 5/1 dry); sharp lower contact.
Marcoux Formation		
30-47	1052-1035	Pebble-loam; sandy; unbedded; hard; light gray (2.5Y 6/2 dry); lower contact not exposed.

Figure 15. Detailed section description of the Powerline Section, Red Lake County, Minnesota (From: Harris, Moran, and Clayton, 1974).

POWERLINE SECTION

SD	SLT	CLY	XTAL	CO3	SH	SD	NSLT	NXTAL	SH
30	46	24	50	35	15	30	66	59	15
38	40	22	0	100	0	38	65	0	0
34	43	23	51	35	14	34	65	59	14
44	39	17	0	100	0	44	70	0	0
45	40	15	0	100	0	45	73	0	0
46	38	16	60	37	3	46	70	62	3
41	43	16	0	100	0	41	73	0	0
36	46	18	58	38	4	36	72	60	4
38	45	17	0	100	0	38	73	0	0
31	53	16	0	100	0	31	77	0	0
47	37	16	0	100	0	47	70	0	0
43	43	14	0	100	0	43	75	0	0
46	38	16	0	100	0	46	70	0	0
43	41	16	58	39	3	43	72	60	3
50	33	17	56	41	3	50	66	58	3
51	32	17	0	100	0	51	65	0	0
30	38	32	38	28	34	30	54	58	34
37	37	26	44	36	20	37	59	55	20
45	45	10	60	31	9	45	82	66	9
40	39	21	59	32	9	40	65	65	9
58	32	10	85	12	3	58	76	88	3
52	22	26	78	15	7	52	46	84	7
52	35	13	77	15	8	52	73	84	8
57	17	26	79	14	7	57	40	85	7
51	40	9	85	15	0	51	82	85	0

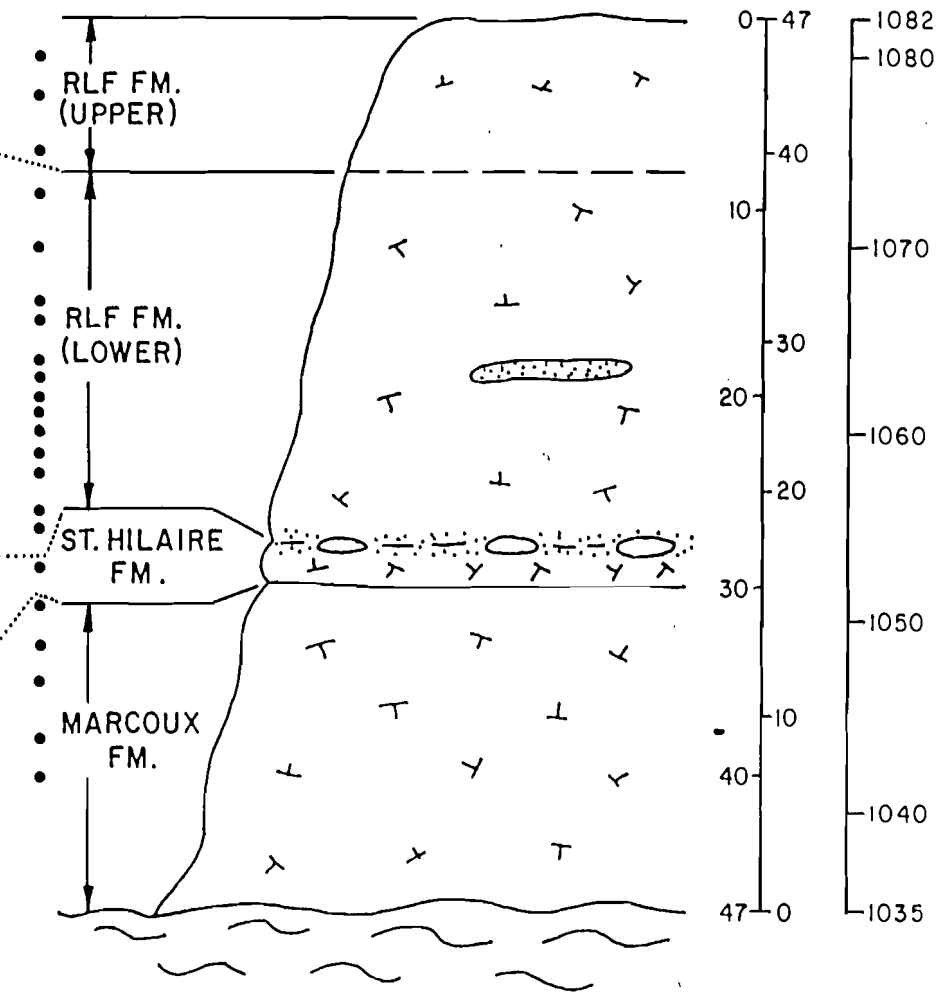


Figure 16. Outcrop sketch and data summary for the Powerline Section, Red Lake County, Minnesota.

Three Creeks Section*

NE¼NE¼NW¼ sec. 21, T. 151 N., R. 44 W.

Left bank of Red Lake River

Section 1 - Figure 3

Section described by K. L. Harris.

Depth in Feet	Elevation Above Sea Level	Description
Huot Formation		
0-15	1023-1008	Clay; very slightly pebbly; unbedded: gray (5Y 5/1 dry); contains tan, pebble-sized, calcareous inclusions; highly slumped: gradational contact with Wylie Formation.
Wylie Formation		
15-19	1008-1004	Clay and silt; thinly laminated; clay is olive gray (5Y 5/2 dry); silt is light brownish gray (2.5Y 6/2 dry); laminae thicken upward; gradational contact with Red Lake Falls Formation.
Red Lake Falls Formation		
19-25	1004-998	Pebble-loam; clayey; unbedded; friable; light brownish gray (2.5Y 6/2 dry); lower contact gradational; laminated clay at contact.
25-41	998-982	Pebble-loam; unbedded; friable; light brownish gray (2.5Y 6/2 dry); abundant sand inclusions; sharp contact with Marcoux Formation.
Marcoux Formation		
41-58½	982-964½	Sand, alternating fine and medium grained; flat bedded to ripple cross-bedded; jointed: limonitic stains: gradational lower contact.
58½-59	964½-964	Pebble-loam; sandy; unbedded; friable; light gray (5Y 6/1 dry); lower contact is sharp; cobbles are common at contact.
Gervais Formation		
59-85	964-938	Clay-loam; silty; very slightly pebbly; unbedded; friable; light olive-gray (5Y 6/2 dry); wood chips, twigs and logs abundant near base; pebbles and sand lens inclusions increase upward; mollusk fragments and charcoal flakes present; lower contact not exposed.

Figure 17. Detailed section description of the Three Creeks Section, Red Lake County, Minnesota (from: Harris, Moran, and Clayton, 1974).

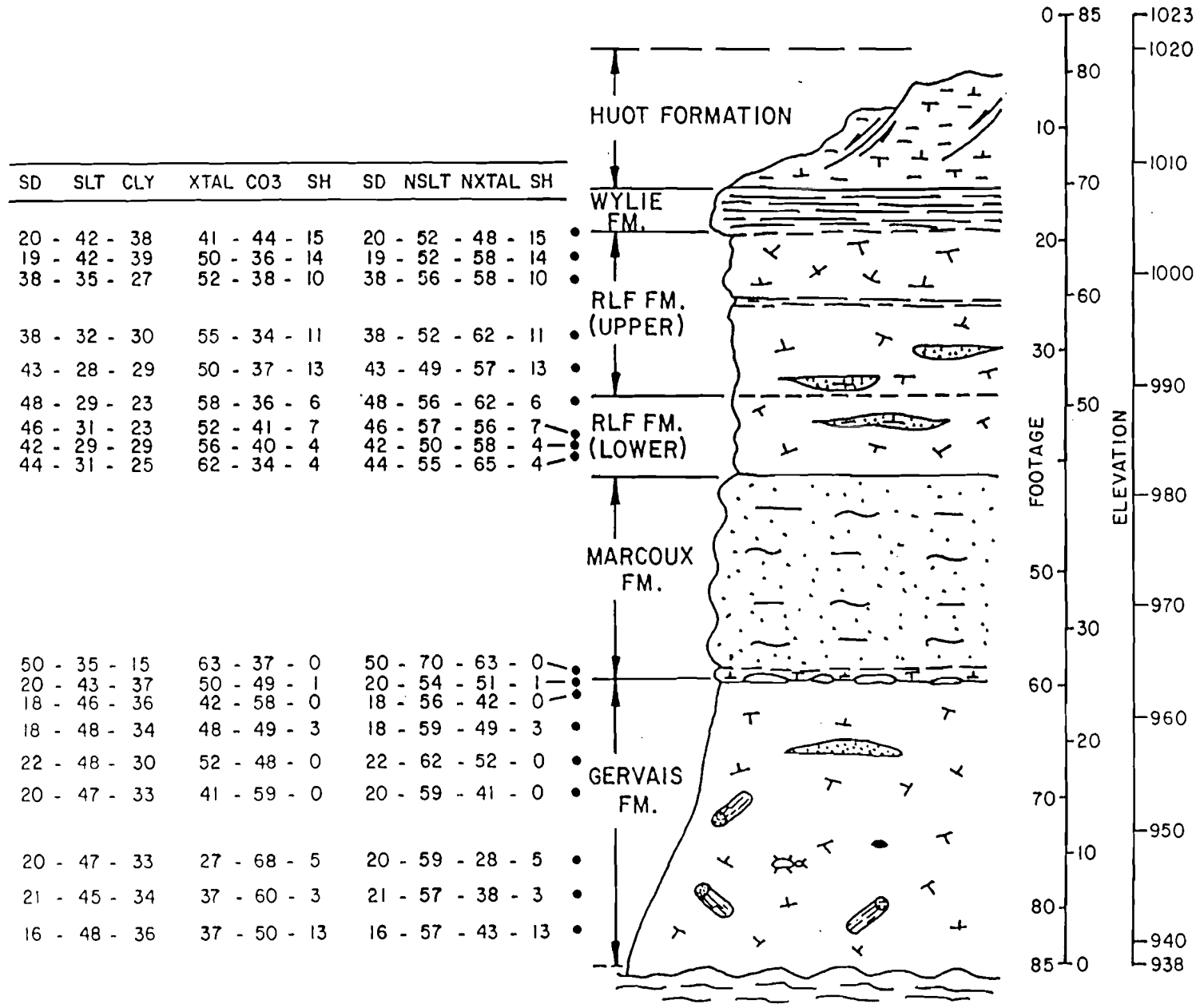


Figure 18. Outcrop sketch and data summary for the Three Creeks Section, Red Lake County, Minnesota.

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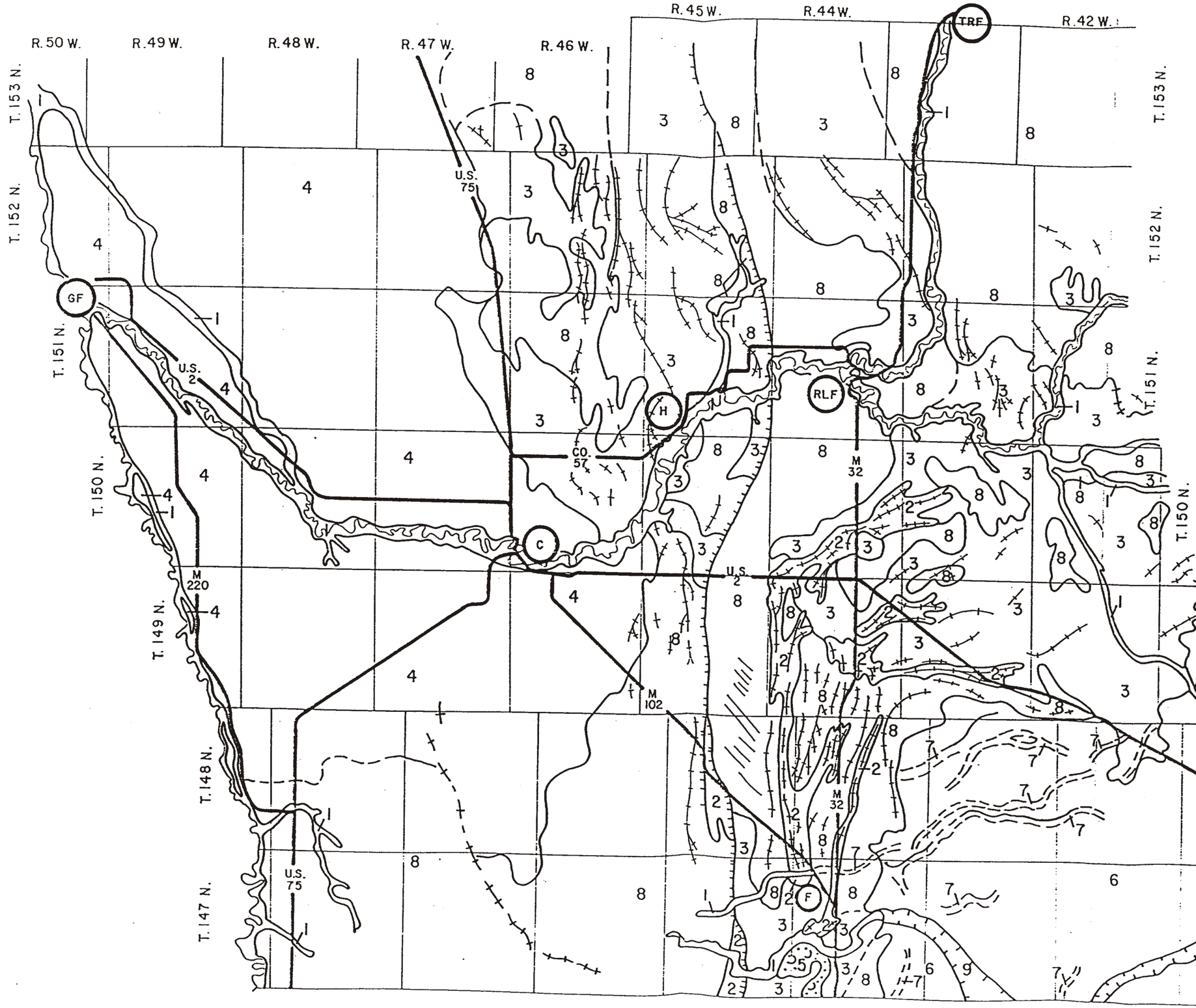

SURFACE GEOLOGY OF THE RED LAKE FALLS AREA, MINNESOTA

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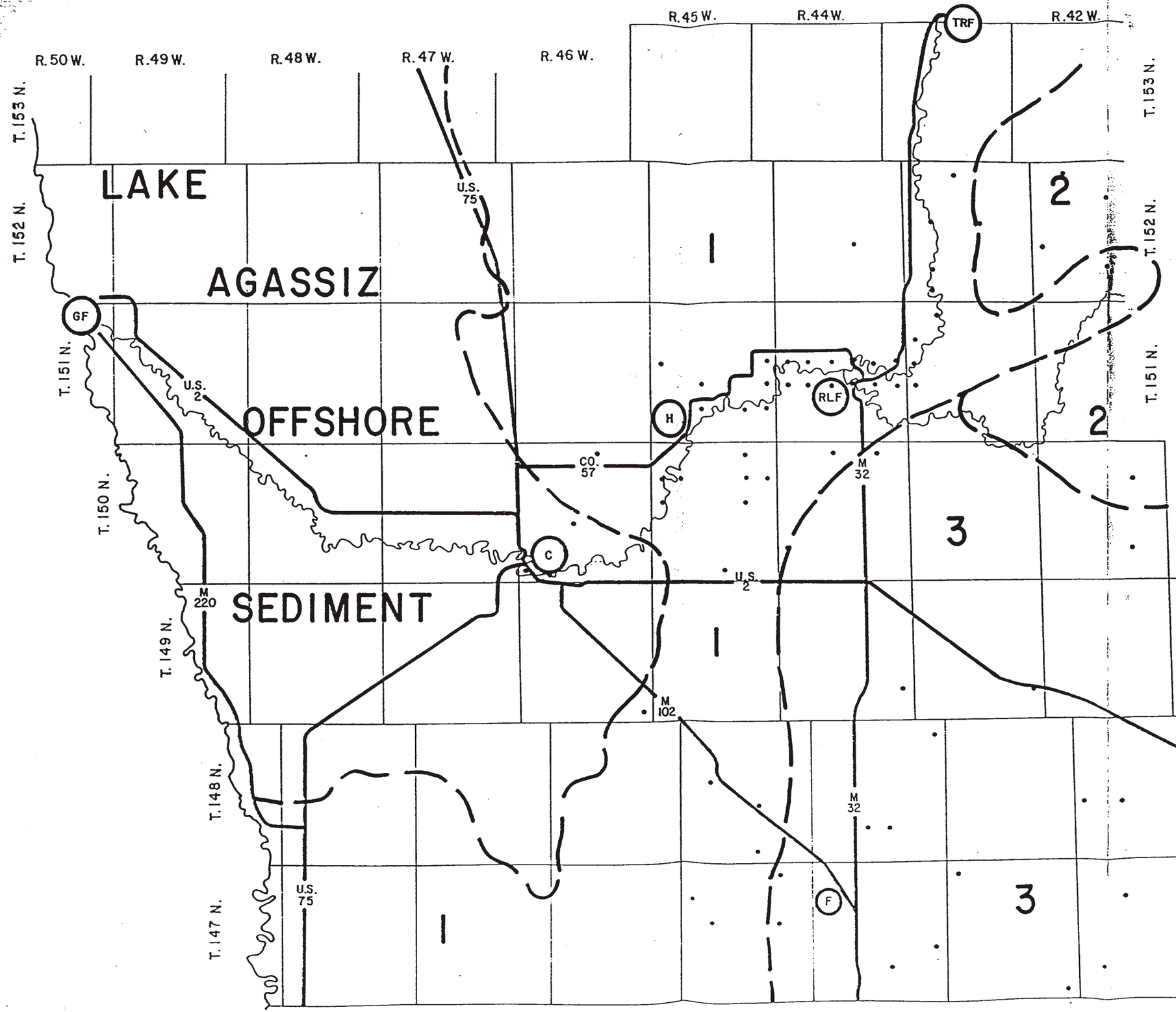
MILES

by
KENNETH L. HARRIS
1987

PLATE I



AREAS OF SURFACE EXPOSURE OF STRATIGRAPHIC UNITS

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PLATE 2

• = Control point