QUATERNARY GEOLOGIC MAP OF THE LAKE OF THE WOODS 4° X 6° QUADRANGLE, UNITED STATES AND CANADA

State and Province compilations by
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1995

This map is a product of collaboration of the Ontario Geological Survey, the Minnesota Geological Survey, the Manitoba Department of Energy and Mines, and the U.S. Geological Survey, and is designed for both scientific and practical purposes. It was prepared in two stages. First, separate maps and map explanations were prepared by the compilers. Second, the maps were combined, integrated, and supplemented by the editor. Map unit symbols were revised to a uniform system of classification and the map unit descriptions were prepared by the editor from information received from the compilers and from additional sources listed under Sources of Information. Diagrams accompanying the map were prepared by the editor.

For scientific purposes, the map differentiates Quaternary surficial deposits on the basis of lithology or composition, texture or particle size, structure, genesis, stratigraphic relationships, engineering geologic properties, and relative age, as shown on the correlation diagram and indicated in the description of map units. Deposits of some constructional landforms, such as kame moraine deposits, are distinguished as map units. Deposits of erosional landforms, such as outwash terraces, are not distinguished, although glaciofluvial, ice-contact, and lacustrine deposits that are mapped may be terraced. As a Quaternary geologic map, it serves as a base from which a variety of maps relating Quaternary geologic history can be derived.

For practical purposes, the map is a surficial materials map. Materials are distinguished on the basis of lithology or composition, texture or particle size, and other physical, chemical, and engineering characteristics. It is not a map of soils that are recognized and classified in pedology or agronomy. Rather, it is a generalized map of soils as recognized in engineering geology, or of substrata or parent materials in which pedologic or agronomic soils are formed. As a materials map, it serves as a base from which a variety of maps for use in planning engineering, land-use, or land-management projects can be derived.

REFERENCES FOR RELATIVE AGES OF GLACIAL PHASES

Hopkins, D.M., 1975, Time-stratigraphic nomenclature for the Holocene Epoch: Geology, v. 3, p. 10.

Sado, E.V., Fullerton, D.S., and Farrand, W.R., 1994, Quaternary geologic map of the Lake Nipigon 4° x 6° quadrangle, United States and Canada: U.S. Geological Survey Miscellaneous Investigations Series Map I–1420 (NM-16), scale 1:1,000,000.

The map layout includes:

- An index to the location of the Quaternary geologic map of the Lake of the Woods 4° x 6° quadrangle and other published maps in the Quaternary Geologic Atlas of the United States
- An illustration and table showing the relative ages of glacial phases in the Koochiching and Rainy lobe areas
- An illustration showing the areas of responsibility for compilation of the map with names and organizations of the compilers
- A diagram showing the correlation of map units

DESCRIPTION OF MAP SYMBOLS ON PRINTED MAP

CONTACT

LIMIT OF GLACIAL ADVANCE OR MAJOR STILLSTAND OF ICE MARGIN

CREST OF UNMAPPED TILL END MORAINE, KAME END MORAINE, OR INTERLOBATE MORAINE RIDGE

WASHBOARD MORAINES OR MINOR MORAINES

DIRECTION OF ICE MOVEMENT INDICATED BY STRIATED OR GROOVED BEDROCK

ICE-MOLDED LANDFORM—Drumlin, rock drumlin, flute, or groove

BOULDER TRAIN OR DISPERSAL FAN

ESKER

GLACIAL LAKE SPILLWAY OR MELTWATER CHANNEL

DUNE FIELD

LOCATION OF IMPORTANT STRATIGRAPHIC SECTION-Stratigraphic units are listed from youngest to oldest; rank terms of informal stratigraphic units are not capitalized

Borehole FW 99 (Fenton, 1974), sec. 16, T. 9, R. 12 E., Man.—Designated as reference section for Whiteshell Formation by Teller and Fenton (1980). Holocene, 1.5 m artificial fill; late Wisconsin Marchand(?) Formation, 1.2 m till; late Wisconsin Senkiw Formation, 8.5 m till, 5.5 m sand, 5.2 m till. Formal stratigraphic reassessment of this section is required if it is to serve as a reference section because the Whiteshell Formation was not recognized by Fenton (1974)

Borehole EV (Keatinge, 1975), sec. 24, T. 9, R. 12 E., Man.—Holocene and (or) late Wisconsin, 2.4 m sand, silt, and clay; Holocene and (or) late Wisconsin Steinbach Member of Hazel Formation, 4.6 m till; late Wisconsin Marchand Formation, 2.4 m till; late Wisconsin, 4.0 m sand and gravel; late Wisconsin Sprague Formation, 8.5 m till; late Wisconsin Whiteshell Formation, 0.6 m till

Borehole ER (Keatinge, 1975), sec. 3, T. 10, R. 13 E., Man.—Type section for Whiteshell Formation designated by Keatinge (1975). A different borehole in the adjacent Winnipeg 4° x 6° quadrangle (IA of Keatinge, 1975) was designated as the type section for the same formation by Teller and Fenton (1980). Late Wisconsin, 3.4 m clay; late Wisconsin Whiteshell Formation, 1.5 m till

Borehole EZ (Keatinge, 1975), sec. 4, T. 5, R. 14 E., Man.—Reference section for Roseau Formation (Teller and Fenton, 1980). Late Wisconsin, 3.9 m sand, silt, and clay; late Wisconsin Roseau Formation, 2.4 m till; late Wisconsin or older, 40.1 m sand, silt and clay

Borehole EAA (Keatinge, 1975), sec. 4, T. 5, R. 14 E., Man.—Reference section for Whiteshell Formation (Teller and Fenton, 1980). Late Wisconsin, 3.0 m sand; late Wisconsin Sprague Formation (Keatinge, 1975) or Roseau Formation J.T. Teller, annotation of Keatinge, 1975), 1.8 m till; late Wisconsin Whiteshell Formation, 4.6 m till

Borehole EI (Keatinge, 1975), sec. 21, T. 1, R. 14 E., Man.—Type section for Sprague Formation. Holocene and (or) late Wisconsin Steinbach Member of Hazel Formation, 1.5 m till; late Wisconsin Marchand Formation, 1.8 m till; late Wisconsin, 0.9 m sand and gravel, 4.0 m silt; late Wisconsin Sprague Formation, 9.1 m till: late Wisconsin, 6.1 m silt, 4.3 m gravel; late Wisconsin Whiteshell Formation, 0.6 m till

DESCRIPTION OF MAP UNITS

(Map unit thicknesses are typical thickness ranges; in some areas units may by thinner than given range)

HOLOCENE

al ALLUVIUM—Yellowish-brown, brown, yellowish-gray, brownish-gray, gray, or mottled flood-plain silt and sand, commonly overlying channel sand and gravel. Calcareous; partly to completely oxidized. Moderately to well sorted; moderately to well stratified. Textures may vary abruptly laterally and vertically; may be interbedded with clay and silt. Locally contains mollusc and gastropod tests or detrital wood and plant debris. Clasts chiefly subangular to well rounded pebbles, cobbles, and boulders of limestone, dolomite, granite, schist, gabbro, and mafic volcanic and metavolcanic rocks; minor shale. Includes alluvium in low terraces. Mapped only in Minnesota. Alluvium of different composition is included in other map units in Ontario and Manitoba. Thickness 1–4 m

hp PEAT AND MUCK—Dark-brown or black, fibrous, undecomposed, woody, reedsedge or sphagnum peat overlying partly to well decomposed peat or clay and silt containing organic residues and comminuted plant material. Strongly acid where deposit overlies noncalcareous till or stratified materials. Occurs as muskeg or swamp fens on former lake beds, as blanket deposits in former drainageways, and as bogs in depressions and other poorly drained areas. Mapped only where very extensive; unmapped deposits are abundant in many areas. Thickness 1–4 m, locally more than 5 m

HOLOCENE AND LATE WISCONSIN

SANDY TILL—Pale-reddish-brown, yellowish-brown, grayish-brown, brown, reddish-gray, brownish-gray, gray, or mottled noncalcareous or weakly calcareous sand, loamy sand, and sandy loam; locally loam, silt loam, sandy clay loam, or silty clay. Typically oxidized throughout because of coarse texture, low carbonate content of matrix, and thinness of deposit and also because of low permeability of underlying bedrock. Nonsorted or very poorly sorted; nonstratified or very poorly stratified. Stringers, lenses, interbeds, and clasts of silt, sand, and gravel common, particularly near base. In many areas, upper 1–2 m is reworked till comprising subaqueous and subaerial debris-flow deposits, sediment-flow deposits, and flowtill, all of which are included in unit. Upper 0.5–2 m of till typically is loamy sand and sand; loose or compact; friable; gritty and stony; crude stratification or platy structure common. Litter of boulders and cobbles common on surface. Till below is nonstratified, commonly with subhorizontal parting. Typically either weakly cohesive and slightly fissile or very compact, massive, hard, and jointed, with iron oxide stains on joint surfaces. Shear planes and extension fractures common. Generally pebbly; locally gravelly, stony, or rubbly; cobbles and boulders common to very abundant. In most areas, clasts are almost exclusively angular to subrounded, locally derived, granitic rocks, syenite, and migmatite; basalt, andesite, dacite, rhyolite, breccia, metaigneous, metavolcanic, and metasedimentary rocks common locally. In places, till resembles outwash or ice-contact sand and gravel (**gg**, **kg**) but it lacks pronounced stratification. Boundary between discontinuous sandy till (**tsr**) and discontinuous sandy loamy till (**tdr**) is arbitrary. Includes areas of outwash and ice-contact sand and gravel (**gg**, **kg**), kame moraine deposits (**ke**), lake clay, silt, sand, and gravel (**lca, lsa, lu**), lake delta deposits, alluvium (**al**), and bedrock. In some areas, till is overlain by unmapped eolian silt (loess) less than 30 cm thick or by peat and muck (**hp**)

ts Ground moraine—Includes areas of unmapped hummocky stagnation moraine. Thickness of ground moraine 2–5 in; thickness of stagnation moraine locally 45 m

tsr Discontinuous sandy till—Thin, discontinuous deposits of till separated by numerous or extensive bedrock outcrops on which are scattered pebbles, cobbles, and boulders or litters of clasts. In many areas bedrock knobs and hills were stripped of surficial cover by waves and currents in lakes and map unit is almost entirely bedrock with isolated remnants of till (**ts**), lake clay, silt, sand, and gravel (**lca**, **lsa**, **lu**), and peat and muck (**hp**). Thickness of till less than 3 m ke KAME MORAINE DEPOSIT—Complex deposit of ice-contact, outwash, and lake sand and gravel (**kg**, **gg**, **lsa**), kame delta deposits, density underflow fan deposits, and till comprising end moraines and interlobate moraines. End moraine and interlobate moraine deposits locally were fluted or furrowed by overriding ice and in places are overlain by thin, discontinuous till, flowtill, or debris-flow deposits. Beaches and wave-cut terraces, composed of or mantled by lake sand and gravel (**lsa**), present on distal slopes of some kame moraines; lake clay and silt (**lca**) locally veneers moraines. End moraine and interlobate moraine deposits differ in three aspects: (1) End moraines commonly are asymmetrical in profile, with steep, collapsed, proximal ice-contact slopes and gentle distal slopes: collapsed ice-contact slopes are present on both sides of interlobate moraines. (2) Ridge crests, aligned parallel to the moraine trends, are common on some end moraine deposits that were not modified by waves and currents, but are rare or absent on most interlobate moraines. (3) Eskers typically are aligned perpendicular to proximal margins of end moraine deposits but may be present on crests, aligned parallel to trends, of interlobate deposits

End moraine deposits—Some deposits are aligned, narrow, sharp-crested, pitted, single or multiple ridges composed of nonsorted or poorly sorted, stratified, slumped and faulted, bouldery and cobbly sand and gravel (**kg**): relief generally 20–38 m, locally more than 150 m. Where modified by waves and currents in lakes, similar deposits form broad flat-topped ridges, commonly with surface litter or rubble of cobbles and boulders. Other end moraine deposits are aligned, flat-topped, lobate ridge segments composed of massive or weakly stratified, clast-supported gravel overlain by or grading upward to trough crossbedded, planar bedded, rippled, and laminated sand deposited as subaqueous density-current fan deposits, debris-flow deposits, and sediment-flow deposits. Some flat-topped ridge segments may be subaerial lake delta deposits. Boulders as large as 5 m common on surfaces and distal sides of some lobate ridge segments but rare within the deposits. Some end moraine deposits occur as aligned, isolated, elongate hills and hummocks (kames) composed of nonsorted, bouldery, ice-contact sand and gravel (**kg**). The kames are separated by bedrock hills or margined by relatively flat areas of pitted ice-contact and outwash sand and gravel (**kg**, **gg**); relief of kame hills and hummocks commonly 15–30 m, locally only 23 m. Other end moraine deposits form aligned irregular hills or low hummocks with knob-and-kettle topography, composed of poorly sorted, gravelly or bouldery, sandy or sandy loamy till (**ts**), and ice-contact sand and gravel (**kg**). Those deposits are separated by bedrock hills with a discontinuous till cover or by areas of outwash sand and gravel (**gg**). Still other end moraine deposits form aligned ridges, hills, and hummocks composed of both till and stratified sand and gravel, commonly with relief of 20–35 m. In some areas, kame moraine deposits include blocks and rafts of glaciotectonically transported bedrock and surficial deposits. Thickness of end moraine deposits 10–30 m, locally more than 150 m

Interlobate moraine deposits—Belts of stratified ice-contact and outwash sand and gravel (**kg**, **gg**) deposited between confining ice lobes or sublobes. Deposits commonly form broad ridges with relatively flat tops, undulating or hummocky ridges with deep ice-block depressions, or aligned, low, rounded hills. Thickness 5–30 m, locally more than 45 m

kg ICE-CONTACT SAND AND GRAVEL—Pale-yellow, yellowish-brown, reddish-brown, olive-brown, grayish-brown, brown, brownish-gray, gray, or mottled noncalcareous sand and gravel with minor silt. Textures vary laterally and vertically, ranging from fine sand with minor silt and scattered pebbles to cobble and boulder gravel. Poorly to well sorted; poorly to well stratified. Crudely bedded to well bedded; beds discontinuous laterally. Stratification typically crossbedding, cut-and-fill, or horizontal bedding. Locally interbedded with or contains inclusions of clay, silt, flowtill, or till. In places mantled by a thin veneer of till or flowtill. Faults, folds, slumps, and collapse structures common. Clasts subangular to well-rounded pebbles, cobbles, and boulders. Clast composition similar to that of other stratified materials and till in same area. Surfaces hummocky to knobby; commonly pitted with ice-block depressions as deep as 50 m; relief generally 10–30 m. Litter of boulders and cobbles common on surface. In some areas, deposits were modified by waves and currents in lakes and ice-contact sediments are overlain by discontinuous lake sand and gravel (**lsa**). Forms kames, kame terraces, eskers, and ice-fracture fillings; some eskers indicated by symbol. In some areas, arbitrarily distinguished from kame moraine deposits (**ke**). Includes kame moraine deposits (**ke**), kame delta deposits, and subaqueous underflow fan deposits. Also includes areas of outwash sand and gravel (**gg**), lake clay, silt, sand, and gravel (**lca**, **lsa**, **lu**), inset alluvium (**al**), till, and bedrock. Locally overlain by peat and muck (**hp**) or thin eolian sand and silt. Thickness 5–10 m, locally more than 30 m

gg OUTWASH SAND AND GRAVEL—Pale-yellow, reddish-brown, yellowish-brown, olive-brown, brown, gray, or mottled sand, pebbly sand, and gravel. Calcareous or noncalcareous, depending on composition of source materials. Poorly to well-sorted; poorly to well stratified. Stratification typically is (1) horizontal beds of well sorted sand, (2) pebbly sand with ripple-drift, cut-and-fill, planar, or trough crossbeds, (3) interbedded pebbly sand and cobble or boulder gravel, or (4) crudely bedded to chaotic pebble, cobble, or boulder gravel. Textures generally coarsen with depth and vary laterally. Cobbles and boulders abundant where outwash deposits head near kame moraine or ice-contact sand and gravel deposits. Clasts subrounded to very well rounded; size of largest clasts typically decreases downstream in valley train deposits. Clast lithology varies with lithologies of local bedrock and till. Clasts locally intensely stained by iron oxides; gravel locally cemented by secondary calcium carbonate where clasts include limestone or dolomite. Forms valley trains, outwash plains, fans and aprons, terrace remnants, and delta topset beds; also mapped as fills in meltwater channels. Valley trains commonly terminate in unmapped deltas. Surfaces smooth to undulating; locally pitted with ice-block depressions, particularly adjacent to kame moraine deposits that were not modified by glacial lakes. Includes areas of till, ice-contact sand and gravel (**kg**), kame moraine deposits (**ke**), lake delta deposits, density underflow fan deposits, lake clay, silt, sand, and gravel (**lca**, **lsa**, **lu**), fan, channel, and flood-plain alluvium (**al**), and bedrock. In many areas deposits were modified and reworked by waves and currents in lakes and outwash sand and gravel is overlain by lake sand and gravel (**lsa**) or lake clay and silt (**lca**). In some areas, overlain by eolian sand and silt (dunes locally shown by symbol), peat and muck (**hp**), subaqueous or subaerial debris-flow deposits, sediment-flow deposits, or flowtill. Thickness 1–30 m

lca LAKE CLAY AND SILT—Pink, pale-red, pale-yellow, reddish-brown, yellowish-brown, grayish-brown, brown, grayish-green, pinkish-gray, reddish-gray, yellowish-gray, brownish-gray, greenish-gray, bluish-gray, gray, white, or mottled silt, clayey silt, silty clay, and clay. Calcareous or noncalcareous, reflecting composition of source materials. Well sorted; well bedded to massive. Commonly laminated or varved in lower part, massive in upper part. Ice-rafted clasts common in lower part; upper part typically stone free. In some areas, interbedded with sand and fine gravel or with till or flowtill. Locally strongly contorted, with load structures; may be folded and faulted. Soft to very firm. Sticky and plastic where damp; weak to strong blocky structure where dry. Locally gritty. Mollusc and gastropod tests and secondary calcium carbonate concretions common in upper part locally. Gullies common adjacent to major streams. Offshore and deepwater deposit of former lakes. Includes areas of unmapped density underflow fan deposits, subaerial and subaqueous debris-flow deposits, and lake delta sand and gravel; also includes areas of lake sand and gravel (**lsa**), kame moraine deposits (**ke**), outwash and ice-contact sand and gravel (**gg**, **kg**), till, alluvium (**al**), and bedrock. In many places, overlain by peat and muck (**hp**) or eolian sand and silt. Mapped only in southern part of quadrangle; included in unit **lu** elsewhere. Thickness 1–3 m, locally more than 25 m

lsa LAKE SAND AND GRAVEL—Pale-yellow, brownish-yellow, yellowish-brown, grayish-brown, brown, yellowish-gray, brownish-gray, or mottled sand and gravel. Calcareous or noncalcareous, reflecting composition of source materials. Moderately to well stratified; generally well sorted. Grain size coarsens upward in thicker deposits. Typically either (1) fine-to-coarse sand and silty sand with thin interbeds of pebbly sand and medium gravel or lenses of pebble gravel or silt and clay, (2) uniform crossbedded, horizontally bedded, or massive sand, or (3) pebble or cobble gravel. May be interbedded or intercalated with lake clay and silt (**lca**), till, flowtill, or debris flow deposits. Locally deformed; load and dewatering structures common. In places, contains wood fragments, plant debris, and tests of molluscs and gastropods. Clasts rare in many areas; cobbles and boulders present only locally. Clasts generally well rounded; composition reflects composition of other surficial materials that were reworked by waves and currents. Nearshore, strand, deltaic, and shallow-water deposits of former and modern lakes. Included in unit **lu** in much of Ontario and Manitoba, where lake sand and gravel (**lsa**) and lake clay and silt (**lca**) have not been mapped separately. Includes unmapped lake delta deposits. Subaqueous density underflow fan deposits, and sand and gravel of beaches, terraces, offshore bars, and spits. Also includes areas of kame moraine deposits (**ke**), outwash and ice-contact sand and gravel (**gg**, **kg**), lake clay and silt (**lca**), till, inset alluvium (**al**), and bedrock. Locally overlain by peat and muck (**hp**) or eolian sand and silt; dunes in places have relief as great as 12 m (some dune areas shown by symbol). Thickness 1–5 m, locally 15 m

lu LAKE CLAY, SILT, SAND, AND GRAVEL—Undivided deposit of lake clay and silt (**lca**) and lake sand and gravel (**lsa**). In many areas, deposit is chiefly (1) ripple drift stratified fine sand and silt overlying laminated or varved clay and silt, (2) horizontally bedded alternations of sandy silt and clayey silt, or (3) massive to laminated clay, silt, and fine sand mantled by massive or horizontally bedded silt. Discontinuous in many areas. Includes unmapped, upward-coarsening deltaic and subaqueous density underflow fan deposits; topset beds in deltas typically fine to coarse sand. Includes areas of outwash and ice-contact sand and gravel (**gg**, **kg**), kame moraine deposits (**ke**), till (**ts**, **tlg**), inset alluvium (**al**), and bedrock. Locally overlain by peat and muck (**hp**) or eolian sand and silt; dunes in places have relief as great as 12 m (some dune areas shown by symbol). Thickness 1–4 m, locally more than 7 m

LATE WISCONSIN

tc CLAYEY TILL (Falconer Formation in Minnesota)—Olive-brown, grayish-brown, olive-gray, gray, or mottled very calcareous clay, silty clay, clay loam, and silty clay loam. More clayey in south, more silty in north. Fine matrix typically 25–30 percent limestone and dolomite. Nonstratified nonsorted; typically no apparent structure. Contorted beds of silt abundant locally as inclusions, particularly in upper part; in places contains chalky inclusions or inclusions of oxidized older till. Very local interbeds of sand and fine gravel. Slickensides common. Sparingly pebbly to pebbly; scattered cobbles; boulders very rare. Clasts chiefly limestone and dolomite; minor shale and erratic igneous and metamorphic rocks. Slumps in outcrops in many areas. Chiefly derived from offshore glacial lake sediment that was incorporated by ice. Commonly overlain by discontinuous lake clay, silt, sand, and gravel (**lca**, **lsa**), alluvium (**al**), or peat and muck (**hp**). Thickness 3–5 m, locally more than 10 m

tku LOAMY TILL—Grayish-brown, yellowish-gray, olive-gray, or mottled silt loam, loam, and clay loam; locally silty clay loam, silty clay, clay, sandy clay loam, or sandy loam. Very calcareous; fine matrix more than 50 percent carbonate. Nonstratified, nonsorted. Generally massive with closely spaced vertical and horizontal fractures that are stained by iron oxides. Lenses or pockets of clay, silt, sand, and gravel common. Locally interbedded or intertongued with lake clay, silt, sand, and gravel (**lca**, **lsa**). Local concentrations of cobbles and boulders. Sparingly pebbly to very pebbly. Pebbles dominantly dolomite and limestone; igneous and metamorphic erratic clasts minor or absent; shale clasts absent. Thin and discontinuous; absent in many boreholes. Boundary between clayey till (**tc**) and loamy till (**tku**) is arbitrary. Mapped in southwest part of quadrangle. Thickness 2–7 m; maximum thickness more than 18 m

LOAMY TILL—Yellowish-brown, olive-brown, grayish-brown, brown, olive, brownish-gray, olive-gray, bluish-gray, gray, or mottled very calcareous loam and silt loam; locally silty clay loam, silty clay, clay loam, or sandy loam. Fine matrix typically 20–25 percent carbonate. Nonstratified; nonsorted or poorly sorted. Compact; gritty, with weak columnar structure where matrix is derived chiefly from shale. Lenses or pockets of sand and gravel common; contorted beds of clay and silt present as inclusions. Locally intertongued or interbedded with lake clay and silt (**lca**). High content of expandable clay minerals (smectite). Shale typically very abundant, as clasts and in matrix. Generally pebbly in Minnesota, sparingly pebbly in Ontario. Pebbles and cobbles dominantly angular to subrounded shale, limestone, and dolomite; minor basalt, diabase, gabbro, mafic volcanic rocks, granite, schist, sandstone, and chert. Locally cobbly or bouldery; boulder concentrations common on surface; large boulders chiefly angular or subangular granite; local angular blocks of limestone and dolomite more than 3 m in diameter. Disintegration ridges common in some areas. Includes areas of kame moraine deposits (**ke**), outwash and ice-contact sand and gravel (**gg**, **kg**), lake clay, silt, sand, and gravel (**lca**, **lsa**), alluvium (**al**), and peat and muck (**hp**). Locally overlain by patchy eolian silt (loess). Mapped in southwest part of quadrangle.

Map unit **tlg** in this quadrangle includes till deposited during the Sugar Hills and Erskine glacial phases of J.E. Goebel (1978, unpub. mapping). The physical and compositional properties of the tills deposited during the two phases are similar. On the basis of overlapping relationships of tills and regional directions of ice movement, the Vermillion phase till in this quadrangle (**tdb**, glacial phase 1) is correlated temporally with the Alborn phase till in the adjacent Minneapolis 4° x 6° quadrangle (Goebel and others, 1983), and the Sugar Hills phase till in this quadrangle (**tlg**, glacial phase 2) is correlated with the Big Stone phase till in the Minneapolis quadrangle (*see* Relative ages of glacial phases in the Koochiching and Rainy lobe areas). In the Minneapolis quadrangle, the Vermillion phase till was inferred to be older than the Alborn phase till, the Sugar Hills and Alborn phase tills were inferred to be equivalent in age, and the Big Stone phase till was inferred to be younger than the Sugar Hills phase till. In the Minneapolis quadrangle, loamy till of the Alborn phase in the St. Louis sublobe area was indicated as map unit **tlf**, a symbol assigned to till of Lake Superior lobe provenance elsewhere in that quadrangle. The loamy till (**tlf**) in the St. Louis sublobe area in the Minneapolis 4° x 6° quadrangle (Goebel and others, 1983) should have been designated as **tlg**

tlg Ground moraine—Thickness 2–6 m, locally more than 30 m

tlg Stagnation moraine—Areas of hummocky collapsed topography lacking distinct morainal ridges. Nonintegrated drainage. Mapped only in southwest part of quadrangle, south and southeast of Upper Red Lake. Thickness less than 15 m tlr Discontinuous loamy till—Thin, discontinuous deposits of till separated by numerous or extensive bedrock outcrops on which are scattered clasts or litters of clasts. In areas where bedrock knobs and hills were stripped of surficial cover by waves and currents in lakes, map unit is bedrock with isolated remnants of till (**tlg** or **ts**) and lake clay, silt, sand, and gravel (**lca**, **lsa**). Contact between discontinuous loamy till (**tlr**) and discontinuous sandy till (**tsr**) is inferred northern limit of calcareous till. Thickness less than 2 m

SANDY LOAMY TILL—Grayish-brown, brown, brownish-gray, gray, or mottled noncalcareous sandy loam, loamy sand, and loam. Nonsorted or poorly sorted; nonstratified. Clasts chiefly angular to well-rounded pebbles, cobbles, and boulders of resistant mafic volcanic and metavolcanic rocks, granite, schist, and gabbro; shale clasts absent. Surface litters of large boulders common. Mapped only in Minnesota. Includes areas of kame moraine deposits (**ke**), outwash and ice-contact sand and gravel (**gg**, **kg**), lake clay, silt, sand, and gravel (**lca**, **lsa**), alluvium (**al**), and bedrock. Locally overlain by peat and muck (**hp**)

tdb Ground moraine—Thickness 2–15 m

tdb End moraine—Broad ridges of bouldery till. Segments east of long 92° W. have hummocky surface topography and deep ice-block depressions. End moraine crossed by the southern boundary of the quadrangle at long 93° W. was formed by ice that moved south-southwestward during glacial phase 1. It was overridden during a later glacial advance from the northwest (glacial phase 2) and loamy till (**tlg**) was deposited on the end moraine. Subsequently, most of the loamy till was removed by waves and currents in glacial lakes. In some areas the partly exhumed moraine, composed of sandy loamy till, is mantled by lag boulders; in other areas it is veneered by beach and terrace deposits, chiefly lake sand and gravel (**lsa**). Thickness more than 15 m

tdr Discontinuous sandy loamy till—Thin, discontinuous deposits of till separated by numerous or extensive bedrock outcrops on which are scattered clasts or litters of clasts. In areas where bedrock knobs and hills were stripped of surficial cover by waves and currents in lakes, map unit is bedrock with isolated remnants of till and lake clay, silt, sand, and gravel (**lca**, **lsa**). Contact between discontinuous sandy loamy till (**tdr**) and discontinuous sandy till (**tsr**) is arbitrary. Thickness less than 2 m

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