

**QUATERNARY GEOLOGIC ATLAS OF THE UNITED STATES
MISCELLANEOUS INVESTIGATIONS SERIES MAP I-1420 (NL-17)
SUDBURY 4° x 6° QUADRANGLE**

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The Quaternary Geologic Map of the Sudbury 4° x 6° Quadrangle was mapped as part of the Quaternary Geologic Atlas of the United States. The atlas was begun as an effort to depict the areal distribution of surficial geologic deposits and other materials that accumulated or formed during the past 2+ million years, the period that includes all activities of the human species. These materials are at the surface of the earth. They make up the "ground" on which we walk, the "dirt" in which we dig foundations, and the "soil" in which we grow crops. Most of our human activity is related in one way or another to these surface materials that are referred to collectively by many geologists as regolith, the mantle of fragmental and generally unconsolidated material that overlies the bedrock foundation of the continent. The maps were compiled at 1:1,000,000 scale.

This map is a product of collaboration of the Ontario Geological Survey, the University of Michigan, 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 map unit descriptions were prepared by the editor from information received from the compilers and from additional sources. 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 descriptions of map units. Deposits of some constructional geomorphic features, such as end moraines, are distinguished as map units. Deposits of erosional landforms, such as stream terraces, are not distinguished, although alluvial 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 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 and 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.

A major regional glacial readvance in the Lake Superior basin west of the northwest quarter of this quadrangle (the Marquette advance) culminated approximately 10,000 yr B.P., synchronous with the arbitrarily defined Pleistocene-Holocene boundary of Hopkins (1975). Deposits of the advance in northern Michigan, in the adjacent Lake Superior 4° x 6° quadrangle (Farrand and others, 1984), were not distinguished as map units or by a glacial readvance symbol. Deposits of the Marquette advance in Michigan, represented by an advance limit and two recessional ice margin positions, subsequently were traced eastward to Whitefish Bay in the southeastern end of Lake Superior (Drexler and others, 1983; Farrand and Drexler, 1985). Three east-west trending belts of kame moraine deposits between lat 46°30' and 47° N. in this quadrangle, traced from Whitefish Bay to Capreol, Ont., by Boissonneau (1965, 1968), are aligned with the trends of the three Marquette ice margin positions in Michigan. It is possible that those belts of kame moraine deposits are products of the Marquette glacial readvance. If so, all till and other sediments deposited prior to formation of the southernmost belt of kame moraine are Pleistocene (late Wisconsin) in age and all till and other sediments that were deposited during and after recession of the ice margin from the readvance limit are Holocene in age.

Boissonneau, A.N., 1965, Surficial geology, Algoma, Sudbury, Timiskaming, and Nipissing: Ontario Department of Lands and Forests Map S465, scale 1:506,880.

Boissonneau, A.N., 1968, Glacial history of northeastern Ontario, II; The Timiskaming-Algoma area: Canadian Journal of Earth Sciences, v. 5, p. 97-109.

Drexler, C.W., Farrand, W.R., and Hughes, J.D., 1983, Correlation of glacial lakes in the Superior basin with eastward discharge events from Lake Agassiz, *in* Teller, J.T., and Clayton, Lee, eds., Glacial Lake Agassiz: Geological Association of Canada Special Paper 26, p. 309-329.

Farrand, W.R., and Drexler, C.W., 1985, Late Wisconsinan and Holocene history of the Lake Superior basin, *in* Karrow, P.F., and Calkin, P.E. eds., Quaternary evolution of the Great Lakes: Geological Association of Canada Special Paper 30, p. 17-32.

Farrand, W.R., Mickelson, D.M., Cowan, W.R., and Goebel, J.E., compilers, 1984, Quaternary geologic map of the Lake Superior 4° 6° quadrangle, United States and Canada: U.S. Geological Survey Miscellaneous Investigations Series Map I-1420 (NL-16), scale 1:1,000,000.

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

The map includes illustrations for:

- 1) INDEX MAP TO INTERNATIONAL MAP OF THE WORLD 1:1,000,000 TOPOGRAPHIC SERIES
- 2) AREAS OF RESPONSIBILITY FOR STATE AND PROVINCE COMPILATIONS
- 3) CORRELATION OF MAP UNITS

DESCRIPTION OF MAP UNITS

HOLOCENE

- lm LAKE CLAY AND SILT UNDER LAKE HURON—Brownish-gray, gray, or grayish-black calcareous clay, silty clay, and silt. Typically clay and silty clay in deeper parts of basins, silt closer to basin margins. Soft, fluid, compressible. Locally porous; may contain gas bubbles. Faintly laminated to massive. In places contains mollusc tests, wood chips, and plant debris. Deep-water facies of modern lake deposits. Commonly overlain by lake sand (ls) 1-6 cm thick. Thickness 1-6 m, locally more than 15 m
- ls LAKE SAND AND GRAVEL UNDER LAKE HURON—Brown, brownish-gray, or gray, calcareous silty fine sand, fine to coarse sand, and gravel. Poorly to well sorted; locally stratified. Mollusc tests and fragments common. Shore and nearshore facies of modern lake deposits. Includes local accumulations of boulders and cobbles or coarse lag gravel. Also includes areas of bedrock and thin till over bedrock. Thickness 1-5 m, rarely 10 m
- ed DUNE SAND—Pale-yellow, yellowish-brown, and pale-brown, calcareous or noncalcareous, well-sorted, finely laminated or crossbedded, fine to medium sand and local coarse silt. Mapped only in Michigan, where sand occurs as massive dune ridges parallel to present shore of Lake Huron and as longitudinal and parabolic dunes on former lake beds, on outwash plains, and on till downwind from outwash plain; included in other map units (**gs**, **gg**, **ks**, **kg**, **gkl**, **lsa**, and till) in Ontario and Quebec. Includes some windblown sheet sand and loess. Dunes generally stable; locally active where vegetation has been removed. Some isolated areas of dunes in Ontario are shown by symbol. Thickness 1-30 m

HOLOCENE AND LATE WISCONSIN

SANDY TILL—Brownish-yellow, grayish-yellow, yellowish-brown, reddish-brown, olive-brown, grayish-brown, brown, olive, reddish-gray, yellowish-gray, brownish-gray, olive-gray, bluish-gray, gray, or mottled sand, loamy sand, and sandy loam; locally loam, silt loam, sandy clay loam, or silty clay. Colors and textures reflect composition of local igneous and metamorphic bedrock. Generally noncalcareous or very weakly calcareous. Typically weathered throughout because of coarse texture, thinness of deposit, and low permeability of underlying bedrock. Nonsorted or very poorly sorted; nonstratified or very poorly stratified. Stringers, lenses, interbeds, and clasts of contorted silt, sand, and gravel common, particularly near base. In many areas, upper 1-2 m of map unit is reworked till comprising subaqueous and subaerial debris-flow deposits, sediment-flow deposits, and flowtill. Upper 1-2 m of till typically is very sandy; loose to moderately compact; gritty, stony; crudely stratified; thin sorted and deformed silt beds common; friable; platy structure common; clasts dominantly cobbles and boulders; boulder and cobble litters common on surface. Till below is nonstratified, commonly with subhorizontal parting; typically either weakly cohesive and slightly fissile till or massive, dense, hard, and jointed till with iron oxide stains on joint surfaces; generally pebbly; locally gravelly, stony, or rubbly; cobbles and boulders common to very abundant. Clasts in most areas are almost exclusively igneous and metamorphic rocks; erratic limestone pebbles and small cobbles present locally. In

- places resembles outwash or ice-contact sand and gravel (**gg, kg**), but lacks pronounced stratification. Occurs chiefly as ground moraine, locally as drumlins, end moraine, or hummocky stagnation moraine. Includes areas of outwash and ice-contact sand and gravel (**gg, kg**), lake clay, silt, sand, and gravel (**lca, lsa, lu**), alluvium (**al**), and bedrock. Locally overlain by dune sand (**ed**), peat (**hp**), or swamp deposits (**hs**)
- ts Ground moraine and end moraine—Some segments of end moraine shown by symbol. Thickness 1-5 m, locally 30 m
- tsr Discontinuous sandy till—Thin, discontinuous deposits of till separated by numerous or extensive bedrock outcrops on which are scattered clasts 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**) and lake clay, silt, sand, and gravel (**lca, lsa, lu**). Thickness less than 2 m
- ts Ground moraine under Lake Huron (late Wisconsin only)•—Includes areas of bedrock and local accumulations of cobbles and boulders or lag gravel. Thickness 1-3 m
- ke KAME MORaine DEPOSIT—Pale-yellow, yellowish-brown, reddish-brown, brown, brownish-gray, gray, or mottled, noncalcareous or weakly calcareous ice-contact sand and gravel similar to unit **kg**, occurring as aligned, massive, linear or arcuate ridges or as aligned belts of undulating or hummocky topography with local ridges. In places interbedded with or contains lenses of till or flowtill; locally overlies or is intertongued with lake clay, silt, sand, and gravel (**lca, lsa, lu**). Sorting, stratification, and textures vary vertically and laterally. Faults, folds, and slump and collapse structures common. Clasts subangular to rounded pebbles, cobbles, and boulder of igneous and metamorphic rocks. Northernmost deposits in northwest quarter of quadrangle were overridden by ice during a minor glacial readvance; discontinuous till and flowtill locally is draped over those deposits. Locally overlain by peat (**hp**). Thickness 3-30 m
- kg ICE-CONTACT SAND AND GRAVEL—Pale-yellow, yellowish-brown, reddish-brown, olive-brown, grayish-brown, brown, brownish-gray, or mottled 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. Calcareous or noncalcareous, reflecting composition of source materials. Poorly to well sorted; poorly to well stratified. Crudely bedded to well bedded; beds discontinuous laterally. Locally interbedded with or contains masses of clay, silt, flowtill, or till; in places, mantled by a thin veneer of till or flowtill. Gravel locally cemented by secondary calcium carbonate where clasts include limestone or dolomite. Faults, folds, slump, and collapse structures common. Clasts subangular to rounded pebbles, cobbles, boulders, and blocks. Clast composition similar to that of other stratified materials and till in same area. Surfaces hummocky to knobby; commonly pitted with ice-block depressions; surface litter of cobbles and boulders common. In some areas, deposits subsequently were modified and reworked by waves and currents in lakes and upper part of map unit is lake sand and gravel (**lsa**). Occurs in kames, kame terraces, eskers, and ice-fracture fillings; some eskers are indicated by symbol. Includes ice-contact sand (**ks**) where units **kg** and **ks** have not been distinguished and some kame moraine deposits (**ke**), kame delta deposits, lake delta deposits, and subaqueous fan deposits. Also includes areas of outwash sand and gravel (**gs, gg**), lake clay, silt, sand, and gravel (**lca, lsa, lu**), alluvium (**al**), till, and bedrock. Locally overlain by dune sand (**ed**), peat (**hp**), or swamp deposits (**hs**). Thickness 1-30 m, locally more than 60 m

- gg **OUTWASH SAND AND GRAVEL**—Pale-yellow, yellowish-brown, reddish-brown, brown, gray, or mottled sand and gravel. Calcareous or noncalcareous, reflecting composition of source materials. In Michigan, typically fine to coarse sand alternating with beds of granule to cobble gravel; in Ontario south of north shore of Lake Simcoe, generally pebble or cobble gravel with lenses and interbeds of clay, silt, and sand; farther north in Ontario and Quebec, generally sand and pebble, cobble, or boulder gravel. Textures generally coarsen with depth and vary laterally. Poorly to well sorted; crudely to well stratified. Bedding varies from (1) horizontal beds of well sorted sand, (2) pebbly sand with ripple-drift, planar, or trough crossbeds, or (3) interbedded pebbly sand and cobble or boulder gravel to (4) pebble, cobble, or boulder gravel. Cobbles and boulders abundant where outwash deposits head near end moraine, kame moraine, or ice-contact deposits. Clasts subrounded to very well rounded; size of largest clasts typically decreases downstream in valley train deposits. Clasts lithology varies with lithologies of local bedrock and till; chiefly dolomite, limestone, sandstone, and shale in Michigan and in Ontario south of north shore of Lake Simcoe and chiefly igneous and metamorphic rocks farther north in Ontario and Quebec. Clasts locally intensely stained by iron oxides; gravel locally cemented by secondary calcium carbonate where clasts include limestone or dolomite. In many areas, deposits were modified and reworked by waves and currents in lakes and outwash sand and gravel is overlain by unmapped lake sand and gravel (**lsa**). Occurs in valley trains, outwash plains, fans and aprons, terrace remnants, and delta topset beds and as fills in meltwater channels. Surfaces typically smooth to undulating; locally pitted with ice-block depressions. Includes outwash sand (**gs**) where units **gs** and **gg** have not been distinguished. Includes areas of till, ice-contact sand and gravel (**ks**, **kg**), kame moraine deposits (**ke**), lake delta deposits, lake clay, silt, sand, and gravel (**lca**, **lsa**, **lu**), alluvium (**al**), and bedrock. Locally overlain by dune sand (**ed**), peat (**hp**), swamp deposits (**hs**), subaqueous or subaerial debris-flow deposits, sediment-flow deposits, or flowtill. Thickness 1-30 m, locally more than 60 m
- al **ALLUVIUM**—Yellowish-brown, brown, brownish-gray, gray, or mottled calcareous silt, sand, and gravel. Moderately to well sorted. Poorly to well stratified; bedding generally horizontal; cut-and-fill crossbeds common. Textures vary laterally and vertically; contrasting textures may be intertongued or interbedded. Upper part typically silt and fine sand with scattered pebbles and stringers and lenses of clay and organic material; lower part typically pebbly sand or gravel and sand; local cobble or boulder gravel. Clast lithologies reflect compositions of bedrock and other surface materials in same area. Overbank, stream channel, and fan deposit; underlies flood plains, low stream terraces, and alluvial fans. Mapped only in part of southern Ontario; included in other map units elsewhere. Includes areas of till, outwash and ice-contact sand and gravel (**gs**, **gg**, **ks**, **kg**), lake clay, silt, sand, and gravel (**lca**, **lsa**, **lu**), and bedrock. Locally overlain by dune sand (**ed**), peat (**hp**), or swamp deposits (**hs**). Thickness of overbank and channel alluvium 1-4 m, rarely more than 6 m; thickness of fan alluvium locally more than 10 m
- lc **LAKE SILT AND CLAY UNDER LAKE HURON**—Pale-brown, reddish-brown, reddish-gray, brownish-gray, or gray, very calcareous silty clay and clay. Generally well sorted; poorly to well stratified. Massive to laminated; locally varved. Ice-rafted clasts common; organic detritus absent. Much more compact than unit lm. Offshore and deep-

- water facies of deposits of former glacial and postglacial lakes. Commonly overlain by well-sorted silt or sand (**ls**) 2-28 cm thick. Thickness 1-5 m, locally 10-15 m
- lca LAKE SILT AND CLAY—Pink, red, pale-yellow, yellowish-brown, reddish-brown, grayish-brown, brown, grayish-green, pinkish-gray, reddish-gray, brownish-gray, bluish-gray, gray, or mottled silt and clay; locally silt, silty sand, and very fine sand. Calcareous or noncalcareous, reflecting composition of source materials. Well sorted; stratified. Well bedded to massive; soft to very firm. Sticky and plastic where damp; weak to strong blocky structure where dry; locally jointed or fractured. Commonly laminated; locally varved. Ice-rafted clasts common in lower part in some regions. In places, strongly contorted with load structures; locally folded and faulted. In some areas, interbedded with sand or fine gravel or with till or flowtill. Mollusc and gastropod tests and secondary calcium carbonate concretions common locally. Sinkholes common where deposit is thin over limestone or dolomite. Gullies common adjacent to major streams. Offshore deposit of former lakes. Includes areas of collapsed or terraced lake silt and clay. Also includes areas of outwash and ice-contact sand and gravel (**gs**, **gg**, **ks**, **kg**), kame moraine deposits (**ke**), lake sand and gravel (**lsa**), alluvium (**al**), till, and bedrock. Locally overlain by dune sand (**ed**), peat (**hp**), or swamp deposits (**hs**). Thickness 1-10 m, locally more than 30 m
- lcr DISCONTINUOUS LAKE SILT AND CLAY—Thin, discontinuous clay and silt (**lca**) over bedrock. Most of area is wave- or current-washed bedrock or wave- or current-washed till with isolated patches of silt and clay. Thickness generally less than 1m
- lsa LAKE SAND AND GRAVEL—Pale-yellow, brownish-yellow, reddish-brown, yellowish-brown, grayish-brown, brown, yellowish-gray, brownish-gray, gray, or mottled fine-to-coarse sand and silty sand with layers of medium gravel or lenses of silt and pebble gravel; locally pebble or cobble gravel. Calcareous or noncalcareous, reflecting composition of source materials. Generally well sorted; well stratified. Commonly crossbedded or parallel bedded; local lenticular or tabular foreset beds. In places, chiefly rhythmically laminated sand and silt locally massive. Grain size typically coarsens upward in thick deposits. In places, interbedded or intercalated with lake silt and clay (**lca**), till, or flowtill. Locally deformed; load and dewatering structures common. Friable; very weakly developed coarse blocky structure common. Locally contains wood fragments, plant debris, and tests of molluscs and gastropods. Clasts generally well rounded; clast composition reflects composition of other surficial materials that were transported by waves and currents. Sinkholes common locally where deposit is thin over limestone or dolomite. Nearshore, strand, deltaic, and shallow-water deposits of former lakes, including deposits of beach ridges, offshore bars, spits, and local delta or subaqueous underflow fan deposits. Includes areas of outwash and ice-contact sand and gravel (**gs**, **gg**, **ks**, **kg**), kame moraine deposits (**ke**), lake silt and clay (**lca**), alluvium (**al**), till, and bedrock. Locally overlain by dune sand (**ed**), peat (**hp**), or swamp deposits (**hs**). Thickness 1-10 m, locally 30 m
- lsr DISCONTINUOUS LAKE SAND AND GRAVEL—Thin, discontinuous lake sand and gravel (**lsa**) over bedrock. Includes areas of thin, discontinuous lake silt and clay (**lca**). Most of mapped area is wave-or current-washed bedrock or wave-or current-washed till with isolated patches of sand and gravel. Thickness generally less than 1 m

- lu LAKE CLAY, SILT, SAND, AND GRAVEL—Complex deposit of undifferentiated lake silt and clay (**lca**) and lake sand and gravel (**lca, lsa**). Thickness 1-10 m, locally more than 30 m
- lur DISCONTINUOUS LAKE CLAY, SILT, SAND, AND GRAVEL—Thin discontinuous, undifferentiated lake clay, silt, sand, and gravel (**lu**) over bedrock. Most of mapped area is wave- or current-washed bedrock or wave- or current-washed till with isolated patches of clay, silt, sand, and gravel. Thickness generally less than 1 m
- hp PEAT AND MUCK—Black or dark-brown fibrous undecomposed peat overlying partly to well decomposed fibrous peat and organic clay and silt containing comminuted plant material and organic residues. Occurs on former lake beds, as bogs in ice-block depressions, and in other shallow depressions and poorly drained areas. Mapped only where extensive. Included in swamp deposits (**hs**) where peat and swamp deposits have not been distinguished. Thickness 1-3 m, locally 10 m
- hs SWAMP DEPOSIT—Dark-brown or black muck, mucky peat, and organic residues mixed with fine-grained mineral sediment. Occurs on former lake beds, as bogs in ice-block depressions, and in other shallow depressions and poorly drained areas. Includes peat (**hp**) where peat and swamp deposits have not been distinguished. Mapped only where extensive. Thickness 1-5 m, rarely 15 m

LATE WISCONSIN

Tills in Michigan

- CLAYEY TILL—Yellowish-brown, reddish-brown, brownish-gray, or mottled calcareous clay, silty clay, silty clay loam, and clay loam. Nonstratified. Locally interbedded with sand and gravel. Pebbles infrequent; very few cobbles and boulders. Pebbles and cobbles chiefly subangular to well rounded sandstone, limestone, dolomite, and shale; large boulders dominantly erratic igneous and metamorphic rocks. Includes areas of loamy till (**tl**), sandy loamy till (**td**), outwash and ice-contact sand and gravel (**gg, kg**), lake clay, silt, sand, and gravel (**lca, lsa**), and alluvium (**al**). In places overlain by dune sand (**ed**), peat (**hp**), or swamp deposits (**hs**)
- tc Ground moraine—Thickness 2-20 m, locally 30 m
- tc End moraine—Broad, low ridges or linear belts of hummocky till with undrained ice-block depressions. Thickness 10-30 m
- LOAMY TILL—Yellowish-brown, reddish-brown, brown, brownish-gray, bluish-gray, gray or mottled calcareous loam and silt loam; minor silty clay loam and clay loam. Nonstratified or poorly sorted; nonstratified. Compact; horizontal platy structure common. Generally moderately pebbly; locally cobbly or bouldery. Gravel lenses or interbeds common locally, particularly in end moraine. Pebbles and cobbles chiefly subangular to well rounded sandstone, limestone, dolomite, and shale; large boulders dominantly erratic igneous and metamorphic rocks. Includes areas of clayey till (**tc**), sandy loamy till (**td**), outwash and ice-contact sand and gravel (**gg, kg**), lake clay, silt, sand, and gravel (**lca, lsa**), and alluvium (**al**). Locally overlain by dune sand (**ed**); peat (**hp**), or swamp deposits (**hs**)
- tl Ground moraine—Thickness 2-20 m, rarely 30 m
- tl Ground moraine under Lake Huron—Includes areas of bedrock and local accumulations of cobbles and boulders or lag gravel. Thickness 1-2 m

- tl End moraine—Broad, low ridges or linear belts of hummocky till with undrained ice-block depressions. Thickness 8-30 m
- SANDY LOAMY TILL—Yellowish-brown, reddish-brown, brown, gray, or mottled calcareous sandy clay loam, sandy loam, and loamy sand. Nonsorted to poorly sorted; nonstratified. Commonly contains lenses of clay or silt. Pebbly to bouldery. Pebbles and cobbles dominantly subangular to well rounded limestone, dolomite, shale, and sandstone; large boulders chiefly erratic igneous and metamorphic rocks. Locally resembles outwash sand and gravel (**gg**) owing to abundance of well rounded clasts. Deposits are nonstratified, however, and commonly include lenses of clayey or silty till and flowtill. Includes areas of clayey till (**tc**), loamy till (**tl**), outwash and ice-contact sand and gravel (**gg, kg**), lake clay, silt, sand, and gravel (**lca, lsa**), and alluvium (**al**). Locally overlain by dune sand (**ed**), peat (**hp**), or swamp deposits (**hs**)
- td Ground moraine—Thickness 2-20 m, locally 30 m
- td Ground moraine under Lake Huron—includes areas of bedrock and local accumulations of boulders and cobbles or lag gravel. Thickness 1-2 m
- td End moraine—Broad, low ridges or linear belts of hummocky till with undrained ice-block depressions. Thickness 10-30 m, locally more than 40 m
- tdr Discontinuous sandy loam till—Thin, discontinuous deposits of till separated by numerous or extensive bedrock outcrops on which are scattered clasts or litters of clasts. In many areas bedrock knobs and hills were stripped of surficial cover by waves and currents in lakes; map unit is almost entirely bedrock with isolated remnants of sandy loamy till (**td**) and lake clay, silt, sand, and gravel (**lca, lsa**). Thickness less than 2 m

Tills in Ontario

- CLAYEY TILL (St. Joseph Till)•—Yellowish-brown, brown, brownish-gray, gray or mottled calcareous silty clay, clayey silt, silty clay loam, silt loam. Clay content generally increases southward. Nonsorted; nonstratified. Compact to very compact; massive to blocky structure. Pronounced columnar jointing; clay skins and secondary calcium carbonate common on joint and fracture surfaces. Low plasticity. Matrix chiefly incorporated lake silt and clay; locally intercalated or interbedded with silt and clay or contains clasts of lake silt and clay. In places occurs primarily as deformation till. Matrix averages 45 percent carbonate, dominantly dolomite. Locally gritty where derived from shale. Clasts infrequent. Pebbles dominantly limestone dolomite; some sandstone, shale, and erratic igneous and metamorphic rocks. Large boulders chiefly erratic metasedimentary and metavolcanic rocks. Tillite and jasper conglomerate erratics common locally. Includes some outwash and ice-contact sand and gravel (**gs, gg, ks, kg**), lake clay, silt, sand, and gravel (**lca, lsa**), and alluvium (**al**). Locally overlain by thin loess, dune sand (**ed**), peat (**hp**), or swamp deposits (**hs**)
- tak Ground moraine and end moraine—Some segments of end moraine shown by symbol. Thickness 2-5 m, locally more than 30 m
- tak Ground moraine under Lake Huron—Includes areas of bedrock local accumulations of boulders and cobbles or lag gravel. Thickness 1-3 m
- tap CLAYEY TILL (Kettleby Till and unnamed till)•—Pale-brown, brown, brownish-gray, gray, or mottled calcareous silty clay, clayey silt, silty clay loam, and silt loam.

Nonsorted; nonstratified. Commonly intercalated or interbedded with lake silt and clay or contains clasts of silt and clay. In places, composed entirely of incorporated lake silt and clay. Locally sheared or deformed. Moderately compact; massive to blocky structure. Secondary calcium carbonate concretions common locally. Clast free or with scattered pebbles. Pebbles dominantly limestone, dolomite, siltstone, shale, and sandstone; minor erratic igneous and metamorphic rocks. Cobbles and boulders rare; dominantly erratic igneous and metamorphic rocks. Occurs chiefly as discontinuous ground moraine veneer on older loamy or sandy loamy till. Includes areas of older till, outwash and ice-contact sandy and gravel (**gs**, **gg**, **ks**, **kg**), lake clay, silt, sand, and gravel (**lca**, **lsa**), and alluvium (**al**). Locally overlain by thin loess, dune sand (**ed**), peat (**hp**), or swamp deposits (**hs**). Thickness 0.5-5 m, locally 12 m

tkq LOAMY TILL—Yellowish-brown, brown, gray, or mottled calcareous silt loam, silt, and fine sandy silt. Nonsorted; nonstratified. Compact to very compact; blocky structure. Matrix chiefly incorporated lake sediment; locally gritty. Clast free or with scattered pebbles. Pebbles chiefly limestone, dolomite, siltstone, shale, and sandstone; minor erratic igneous and metamorphic rocks. Occurs chiefly as discontinuous ground moraine veneer on older loamy or sandy loamy till; in places forms end moraine, shown by symbol. Includes areas of outwash and ice-contact sand and gravel (**gs**, **gg**, **ks**, **kg**), lake clay, silt, sand, gravel (**lca**, **lsa**), alluvium (**al**), and older loamy or sandy loamy till. Locally overlain by peat (**hp**), swamp deposits (**hs**), dune sand (**ed**), or thin loess. Thickness 2-5 m, locally 30 m

tka LOAMY TILL (Halton Till)•—Yellowish-brown, light-olive-brown, grayish-brown, gray, or mottled calcareous loam, silt loam, sandy loam, and clay loam; locally silty clay. Nonsorted; nonstratified. Commonly intertongued or interbedded with lake silt and clay; may contain local flowtill units near lower and upper contacts. Low plasticity. Matrix carbonate content varies, chiefly calcite. Scattered pebbles; some cobbles and boulders. Clasts chiefly limestone and shale; minor erratic igneous and metamorphic rocks. Occurs chiefly as ground moraine. Includes areas of outwash and ice-contact sand and gravel (**gs**, **gg**, **ks**, **kg**), lake clay, silt, sand, and gravel (**lca**, **lsa**), and alluvium (**al**). Locally overlain by dune sand (**ed**), peat (**hp**), or swamp deposits (**hs**). Thickness 1-6 m, locally 30 m

tkg LOAMY TILL (Rannoch Till)•—Yellowish-brown, reddish-brown, brown, gray, or mottled calcareous silt loam and silty clay loam. Nonsorted; nonstratified. Low plasticity. Blocky structure common; secondary carbonate on fracture surfaces. Matrix carbonate dominantly dolomite. Clasts infrequent, dominantly pebbles of dolomite, limestone, chert, sandstone, siltstone, and shale; minor erratic igneous and metamorphic rocks. Occurs as ground moraine. Includes small areas of outwash and ice-contact sand and gravel (**gs**, **gg**, **ks**, **kg**), lake clay, silt, sand, and gravel (**lca**, **lsa**), and alluvium (**al**). Locally overlain by peat (**hp**) or swamp deposits (**hs**). Thickness 2-6 m

tkn LOAMY TILL (Elma Till)•—Yellowish-brown, reddish-,brown, brown, gray, or mottled very calcareous silt loam, loam, and silty clay loam. Nonsorted; nonstratified; generally lacks inclusions of clay, silt, sand, and gravel. Fissile; low plasticity or nonplastic. Matrix carbonate chiefly dolomite; matrix locally gritty. Sparingly pebbly to pebbly. Clasts dominantly dolomite and limestone; some sandstone, siltstone, shale, and chert; minor erratic igneous and metamorphic rocks. Locally very loose and bouldery, with

blocks of angular dolomite. Occurs chiefly as ground moraine, locally as drumlins; some segments of end moraine shown by symbol. Includes areas of outwash and ice-contact sand and gravel (**gs, gg, ks, kg**), lake clay, silt, sand, and gravel (**lca, lsa**), and alluvium (**al**). Locally overlain by peat (**hp**), swamp deposits (**hs**), or a thin, discontinuous veneer of younger till. Thickness 1-6 m, locally 15 m

tko LOAMY TILL (Tavistock Till)•—Reddish-brown, light-brown, brown, gray, or mottled very calcareous silty clay loam, silt loam, clay loam, and silty clay. Nonsorted; nonstratified. Local lenses or thin interbeds of lake silt and clay. Massive to blocky structure; very stiff, low plasticity. Matrix carbonate chiefly dolomite. Locally gritty. Clasts rare, chiefly dolomite pebbles; some limestone, sandstone, siltstone, shale; minor erratic igneous and metamorphic rocks. Occurs chiefly as low-relief ground moraine that locally is fluted, or as drumlins; locally occurs as veneer of ground moraine on older end moraine; some segments of end moraine shown by symbol. Includes areas of outwash and ice contact sand and gravel (**gs, gg, ks, kg**), lake clay, silt, sand, and gravel (**lca, lsa**), and alluvium (**al**). Locally overlain by peat (**hp**), swamp deposits (**hs**), or a thin, discontinuous veneer of younger till. Thickness 2-12 m

tki LOAMY TILL (Catfish Creek Till)•—Yellowish-brown, brown, brownish-gray, gray, or mottled very calcareous loam, silt loam, and sandy loam. Nonsorted; nonstratified. Massive, compact; low plasticity or nonplastic. Matrix carbonate dominantly dolomite. Moderately pebbly to pebbly; cobbles and boulders common. Clasts chiefly, dolomite; some limestone, sandstone, siltstone, shale, chert; minor erratic igneous and metamorphic rocks. Occurs as ground moraine and end moraine, Includes small areas of outwash and ice-contact sand and gravel (**gs, gg, ks, kg**), lake clay, silt, sand and gravel (**lca, lsa**), and alluvium (**al**). Locally overlain by peat (**hp**) or swamp deposits (**hs**). Thickness 2-15 m

SANDY LOAMY TILL (Newmarket Till and unnamed till)•—Yellowish-brown, brown, brownish-gray, gray, or mottled calcareous sandy loam and loam; some silt loam, silty clay loam, and clay loam. Grades northward into sandy till (**ts**). Nonsorted; nonstratified or poorly stratified. Commonly contains abundant lenses of sand and gravel. Friable; fissile where dry. Locally gritty. Nonplastic, soft to very stiff; typically very compact. Blocky structure where more clayey. Either calcite or dolomite dominant in matrix. Typically moderately pebbly or pebbly. Pebbles and cobbles chiefly limestone and siltstone or dolomite and siltstone, reflecting composition of local bedrock; erratic igneous and metamorphic rocks common. Large boulders chiefly erratic igneous and metamorphic rocks. Occurs chiefly as ground moraine, locally as drumlins or drumlinoid hills. In areas where surface was modified by waves and currents in lakes, includes discontinuous patches of lake clay, silt, sand, and gravel (**lca, lsa**) over till. Also includes areas of older till, outwash and ice-contact sand and gravel (**gs, gg, ks, kg**), kame moraine deposits (**ke**), and alluvium (**al**). Locally overlain by dune sand (**ed**), peat (**hp**), or swamp deposits (**hs**)

teb Ground moraine and end moraine—End moraine shown by symbol. Thickness 0.5-6 m, locally 12 m

teb Ground moraine under Lake Huron—Includes areas of bedrock and local accumulations of cobbles and boulders or lag gravel. Thickness 1-3 m

- ter 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 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 (**teb**) and lake clay, silt, sand, and gravel (**lca**, **lsa**). Thickness less than 2 m
- tsa SANDY TILL—Brownish-yellow, yellowish-brown, brownish-gray, gray, or mottled calcareous coarse sand, loamy sand, or sandy loam; locally reddish brown or reddish gray silty clay where derived from red shale and siltstone. Poorly sorted; nonstratified. In places intertongued or interbedded with poorly sorted gravel. Typically compact; locally loose. Extremely stony and bouldery; clasts chiefly angular and subangular pebbles, cobbles, boulders, and blocks of limestone. Commonly fewer than 2 percent of clasts are igneous and metamorphic rocks from Canadian Shield to north; crystalline boulders conspicuous locally. Typically very hummocky; relief of irregular mounds generally less than 6 m, locally 15 m. Includes some outwash and ice-contact sand and gravel (**gg**, **kg**) and alluvium (**al**). Locally overlain by peat (**hp**) or swamp deposits (**hs**). Map unit is "Dummer moraine" of Deane (1950), Gravenor (1957), and Chapman and Putnam (1973, 1984); however, deposit was not formed as an end moraine (Shulmelster, 1989). Thickness 1-4 m, locally 30 m
- ks ICE-CONTACT SAND—Pale-yellow, yellowish-brown, reddish-brown, brown, grayish-brown, gray, or mottled calcareous fine to coarse sand with minor silt and scattered pebbles. Poorly to moderately sorted; poorly to well stratified. Folds, faults, and slump and collapse structures common. Clast lithology similar to that of outwash sand and gravel (**gg**) and till in same area. Surfaces generally hummocky, commonly with ice-block depressions. Occurs in kames, kame deltas, kame terraces, and eskers; some eskers indicated by symbol. Includes areas of ice-contact sand and gravel (**kg**), outwash sand and gravel (**gg**, **gs**), lake clay, silt, sand, and gravel (**lca**, **lsa**), subaqueous fan deposits, and alluvium (**al**). Included in ice-contact sand and gravel (**kg**) where units **ks** and **kg** have not been distinguished. Locally overlain by dune sand (**ed**), peat (**hp**), or swamp deposits (**hs**). Thickness 2-30 m
- gs OUTWASH SAND—Pale-yellow, yellowish-brown, reddish-brown, brown, gray, or mottled calcareous fine to coarse pebbly sand and minor silt. Well sorted; crudely to well stratified. Typically horizontally bedded; local beds or lenses of granule or pebble gravel and lenses of silt. Clasts well rounded; clast composition reflects lithology of bedrock and composition of till in same area. Occurs chiefly as sheet deposits beneath terraces and outwash plains and as channel fills. Surfaces smooth or pitted with ice-block depressions. In some areas, outwash sand subsequently was modified and reworked by waves and currents in lakes and upper part of map unit is discontinuous lake sand and gravel (**lsa**). Distinguished from outwash sand and gravel (**gg**) only in Ontario south of north shore of Lake Simcoe; included in unit **gg** elsewhere. Includes some outwash and ice-contact sand and gravel (**gg**, **ks**, **kg**), lake clay, silt, sand, and gravel (**lca**, **lsa**), alluvium (**al**), and bedrock. Locally overlain by dune sand (**ed**), peat (**hp**), or swamp deposits (**hs**). Thickness 1-6 m
- gkl OUTWASH SAND AND GRAVEL—Complex deposit of undifferentiated outwash and ice-contact sand and gravel (**gs**, **gg**, **ks**, **kg**), lake clay, silt, sand, and gravel (**lca**, **lsa**),

and till (**tka, teb**) in southeast corner of quadrangle. Core of deposit typically is outwash sand and gravel (**gs, gg**) with clasts as large as 20 cm in diameter, upper part typically is sand and coarse silt, ice-contact deposits (**ks, kg**), on north and south flanks of area mapped, typically are partly or entirely buried by outwash deposits (**gs, gg**) and lake deposits (**lca, lsa**). Lake silt and varved clay and silt as thick as 6 m are common on north flank of area mapped; thinner lake sediments locally on crest. Topography on crest typically hummocky; ice-block depressions common locally. Topography on flanks typically rolling, with isolated hummocks or mounds. Outwash, ice-contact, and lake deposits were overridden by readvancing ice margins on north and south flanks of area mapped; till on flanks is more clayey than typical textures of those units (**tka, teb**) elsewhere, owing to incorporation of proglacial lake clay and silt. Map unit is "Oak Ridges moraine" of older literature; however it is not an end moraine (Gwyn and Cowan, 1978; Duckworth, 1979; Chapman, 1985). Sediments were deposited on a topographic high, in an interlobate position, during separation of late Wisconsin ice lobe margins in southern Ontario. Includes inset alluvium (**al**). Commonly overlain by dune sand (**ed**) in fields of lunate dunes, eolian sheet sand and loess 1-3 m thick, and local peat (**hp**) and swamp deposits (**hs**). Thickness 10-30 m, locally more than 90 m

EXPLANATION OF MAP SYMBOLS

CONTACT

DUNE FIELD

GLACIAL LAKE SPILLWAY

GLACIAL LAKE DELTA

ESKER—Direction of transport indicated by chevrons

DIRECTION OF ICE MOVEMENT INDICATED BY STRIATED OR GROOVED
BEDROCK

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

LIMIT OF GLACIAL ADVANCE OR STILLSTAND OF ICE MARGIN—Solid where known, dashed where inferred; ticks on side of advance. Limit of Port Huron phase advance in Michigan; limits of younger late Wisconsin and Holocene advances and stillstands in Ontario in west half of quadrangle

CREST OF UNMAPPED TILL END MORaine OR KAME MORaine
DEPOSIT—Mapped only in Ontario and Quebec

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