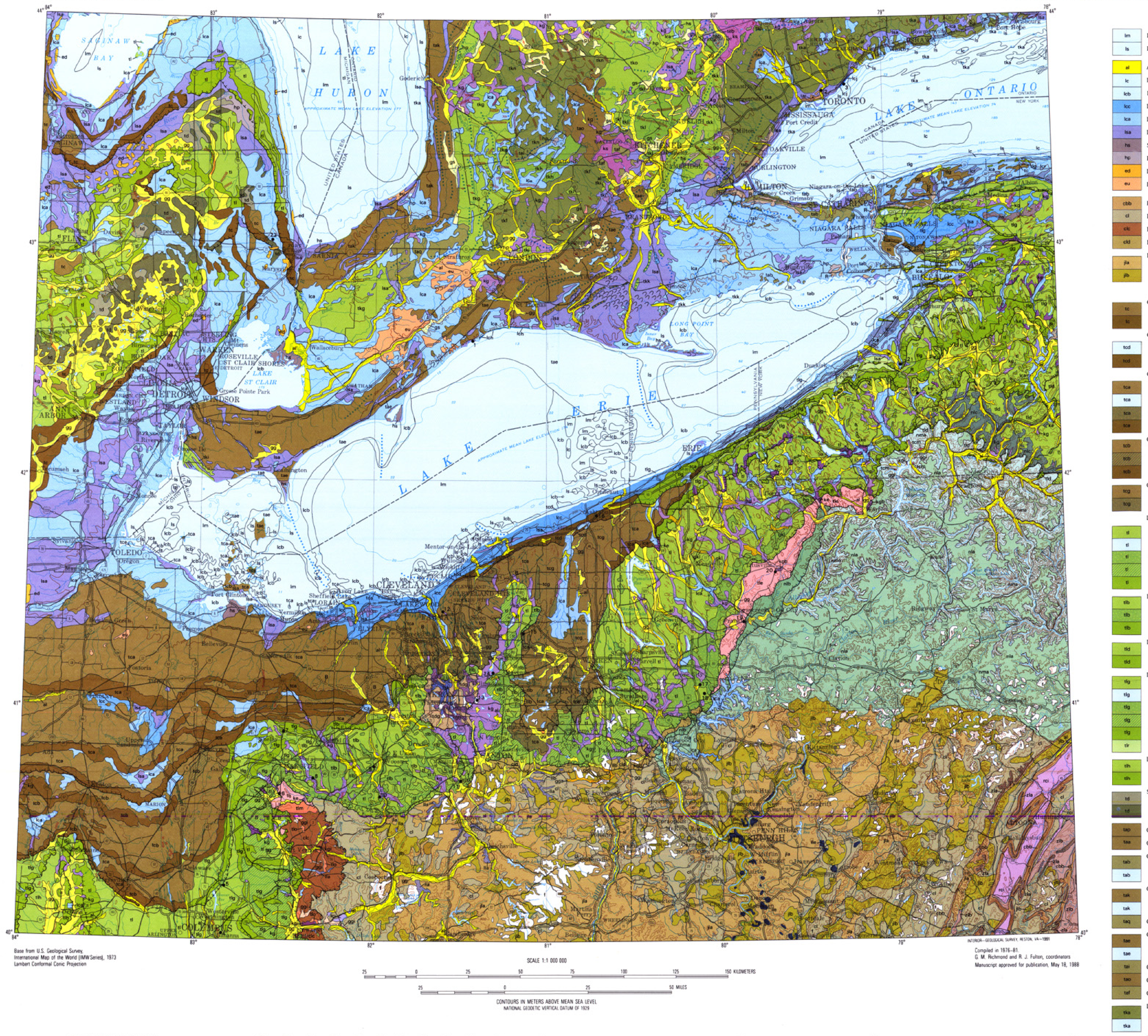
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

ONTARIO GEOLOGICAL SURVEY
PENNSYLVANIA BUREAU OF TOPOGRAPHIC AND GEOLOGIC SURVEY
DEPARTMENT OF GEOLOGY AND MINERALOGY, OHIO STATE UNIVERSITY
DEPARTMENT OF GEOLOGICAL SCIENCES, UNIVERSITY OF MICHIGAN
DEPARTMENT OF GEOLOGY, SYRACUSE UNIVERSITY AND
DEPARTMENT OF GEOLOGY AND GEOGRAPHY, WEST VIRGINIA UNIVERSITY

QUATERNARY GEOLOGIC ATLAS OF THE UNITED STATES
LAKE ERIE 4° × 6° QUADRANGLE
MISCELLANEOUS INVESTIGATIONS SERIES
MAP I–1420 (NK–17)
Explanatory pamphlet accompanies map



Base from U.S. Geological Survey, International Map of the World (IMW Series), 1973
Lambert Conformal Conic Projection

SCALE 1:1 000 000

25 0 25 50 75 100 125 150 KILOMETERS

25 0 25 50 MILES

CONTOURS IN METERS ABOVE MEAN SEA LEVEL
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Compiled in 1976–81.
G. M. Richmond and R. J. Fulton, coordinators
Manuscript approved for publication, May 18, 1988

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA—1991

LIST OF MAP UNITS

HOLOCENE

- lm LAKE CLAY AND SILT (under Lakes Huron, Erie, and Ontario)
- ls LAKE SAND AND GRAVEL (under Lakes Huron, Erie, and Ontario)

HOLOCENE AND LATE WISCONSIN

- al ALLUVIUM
- lc LAKE SILT AND CLAY (under Lakes Huron, Erie, and Ontario)
- lcb LAKE CLAY, SILT, SAND, AND GRAVEL (under Lakes St Clair and Erie)
- lcc LAKE CLAY, SILT, SAND, AND GRAVEL
- lca LAKE SILT AND CLAY
- lsa LAKE SAND AND GRAVEL
- hs SWAMP DEPOSIT
- hp PEAT
- ed DUNE SAND
- eu EOLIAN SAND AND SILT

HOLOCENE AND WISCONSIN

- cbb BOULDERY COLLUVIUM AND ROCK WASTE
- cl LOAMY COLLUVIUM
- clc LOAMY COLLUVIUM
- cld LOAMY COLLUVIUM
- LOAMY COLLUVIUM AND LANDSLIDE DEPOSITS
  - jla Areas with abundant or widely distributed landslide deposits
  - jlb Areas with scattered or localized landslide deposits

LATE WISCONSIN

Tills in Michigan, Ohio, Pennsylvania, and New York

- CLAYEY TILL
  - tc Ground moraine
  - tc End moraine
- CLAYEY TILL (Ashtabula Till and part of Lavery Till in northeastern Ohio)
  - tcd Ground moraine under Lake Erie
  - tcd End moraine
- CLAYEY TILL (part of Lavery Till in Ohio and part of Hiram Till in Ohio and Pennsylvania)
  - tca Ground moraine
  - tca Ground moraine under Lake Erie
  - tca Ground moraine veneer over nonoriented hummocky topography of older till or ice-contact sand and gravel
  - tca End moraine
- CLAYEY TILL
  - tcb Ground moraine
  - tcb Stagnation moraine
  - tcb End moraine
- CLAYEY TILL (part of Hiram Till in Ohio)
  - tcg Ground moraine
  - tcg Ground moraine veneer over nonoriented hummocky topography of older till or ice-contact sand and gravel
- LOAMY TILL (part of Darby Till, part of Navarre Till, and part of Hayesville Till in Ohio; Kent Till in Ohio, Pennsylvania, and New York)
  - tl Ground moraine
  - tl Ground moraine under Lake Huron
  - tl Ground moraine veneer over nonoriented hummocky topography of older till or ice-contact sand and gravel
  - tl Stagnation moraine
  - tl End moraine
- LOAMY TILL (part of Hayesville Till and part of Lavery Till in Ohio)
  - tlb Ground moraine
  - tlb Ground moraine veneer over nonoriented hummocky topography of older till or ice-contact sand and gravel
  - tlb End moraine
- LOAMY TILL (Olean Till in New York and Pennsylvania)
  - tld Ground moraine
  - tld End moraine
- LOAMY TILL
  - tlg Ground moraine
  - tlg Ground moraine under Lakes Erie and Ontario
  - tlg Ground moraine veneer over nonoriented hummocky topography of older till or ice-contact sand and gravel
  - tlg Stagnation moraine
  - tlg End moraine
  - tlr Attenuated drift
- LOAMY TILL
  - tlh Ground moraine
  - tlh End moraine
- SANDY LOAMY TILL
  - td Ground moraine
  - td End moraine

Tills in Ontario

- tap CLAYEY TILL (Kettleby Till)
- taa CLAYEY TILL (Wildfield Till)
- CLAYEY TILL (part of Halton Till)
  - tab Ground moraine and end moraine
  - tab Ground moraine and end moraine under Lakes Erie and Ontario
- CLAYEY TILL (St. Joseph Till)
  - tak Ground moraine and end moraine
  - tak Ground moraine under Lake Huron
- taq CLAYEY TILL (unnamed till)
- CLAYEY TILL (part of Port Stanley Till)
  - tae Ground moraine and end moraine
  - tae Ground moraine and end moraine under Lake Erie
- tai CLAYEY TILL (Wartburg Till)
- tao CLAYEY TILL (Mornington Till)
- taf CLAYEY TILL (Maryhill Till)
- LOAMY TILL (part of Halton Till)
  - tka Ground moraine and end moraine
  - tka Ground moraine and end moraine under Lake Ontario
- LOAMY TILL (Wentworth Till)
  - tkk Ground moraine and end moraine
  - tkk Ground moraine and end moraine under Lake Erie
- tkl LOAMY TILL (part of Port Stanley Till)
- tkg LOAMY TILL (Rannoch Till)
- tkn LOAMY TILL (Elma Till)
- tkh LOAMY TILL (Stratford Till)
- tko LOAMY TILL (part of Tavistock Till)
- tkf LOAMY TILL (part of Tavistock Till)
- tki LOAMY TILL (Catfish Creek Till)
- teb SANDY LOAMY TILL (Newmarket Till)
- kg ICE-CONTACT SAND AND GRAVEL
- ks ICE-CONTACT SAND
- ke KAME END MORAINE
- gg OUTWASH SAND AND GRAVEL
- gs OUTWASH SAND
- gkl OUTWASH SAND AND GRAVEL
- lcr ATTENUATED LAKE SILT AND CLAY
- lla SLACKWATER LAKE SILT AND SAND
- nlc LOAMY SOLIFLUCTION DEPOSITS

LATE WISCONSIN AND MIDDLE WISCONSIN

- lch LAKE SAND, SILT, AND CLAY

WISCONSIN

- lcj LAKE SAND, SILT, AND CLAY
- lgk LAKE GRAVEL, SAND, SILT, AND CLAY

EARLY WISCONSIN

- tar CLAYEY TILL (Sunnybrook Till in Ontario)
- tlj LOAMY TILL (Millbrook Till in Ohio)
- tle LOAMY TILL (Titusville Till in Pennsylvania)
- tdg SANDY LOAMY TILL (Mogadore Till in Ohio)
- kgb ICE-CONTACT SAND AND GRAVEL

WISCONSIN AND ILLINOIAN

- nma CLAYEY TO SANDY SOLIFLUCTION DEPOSITS
- nla LOAMY SOLIFLUCTION DEPOSITS
- nlb LOAMY SOLIFLUCTION DEPOSITS

EARLY WISCONSIN AND ILLINOIAN

- gga OUTWASH SAND AND GRAVEL
- llb SLACKWATER LAKE SILT AND SAND

ILLINOIAN

- CLAYEY TILL
  - tcm Ground moraine
  - tcm End moraine
- tlm LOAMY TILL (Butler Till in Ohio)
- tlo LOAMY TILL
- kgi ICE-CONTACT SAND AND GRAVEL
- ggi OUTWASH SAND AND GRAVEL
- lci LAKE CLAY AND SILT

ILLINOIAN AND PRE-ILLINOIAN

- lle LAKE SAND, SILT, AND CLAY (Carmichaels Formation in Pennsylvania)

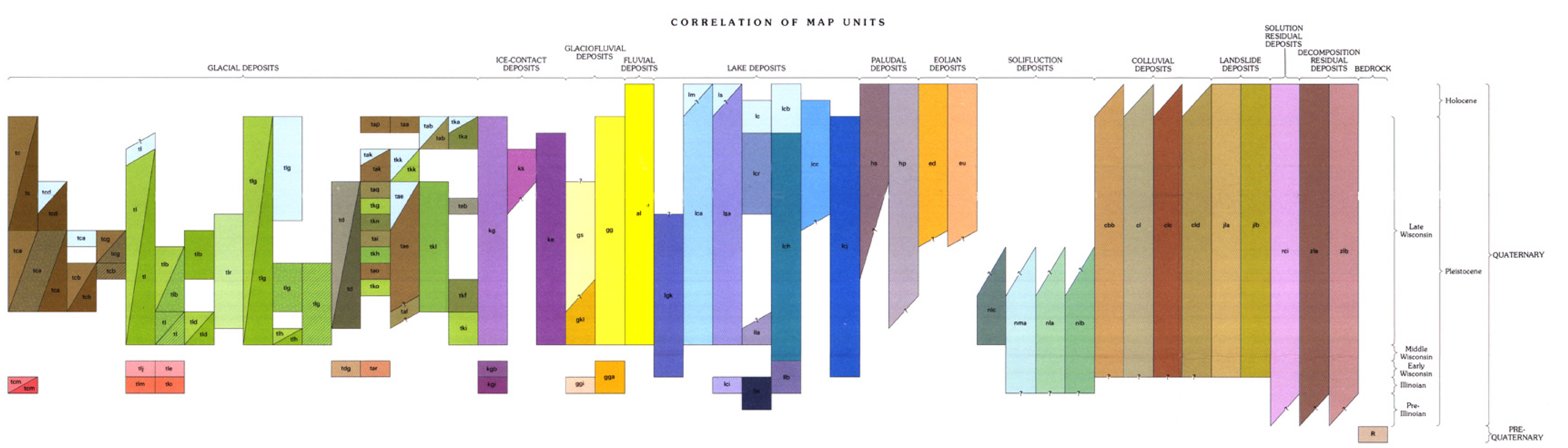
QUATERNARY

- rci LOAMY TO CLAYEY SOLUTION RESIDUUM
- zla LOAMY DECOMPOSITION RESIDUUM
- zlb LOAMY DECOMPOSITION RESIDUUM

PRE-QUATERNARY

- R BEDROCK

CORRELATION OF MAP UNITS



EXPLANATION OF UNITS

NOTE 1: This map is a product of collaboration of state and province geological surveys, universities, 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 of the parts of states and provinces included in the quadrangle were prepared by the compilers. Second, those maps were combined, integrated, locally supplemented, and related to a uniform map symbol classification. The map unit symbols and descriptions are consistent with those of other maps of this series.

Differences in mapping or interpretation in different areas were resolved by correspondence to the extent possible. Most differences on the map simply reflect differences in available information or differences in the mapping philosophies of the compilers and may encourage further investigations.

Surficial deposits have been mapped and described in less than forty percent of the conterminous United States. Traditionally, mapping of surficial deposits has been focused on glacial, alluvial, eolian, lacustrine, marine, and landslide deposits. Slope and upland deposits have been mapped in detail only in restricted areas. However, an enormous amount of engineering construction and many important problems of land use and land management are associated with regions that have extensive slope and upland deposits (colluvium, residuum, and solifluction deposits, for example). These materials have many different physical characteristics. Therefore, an effort has been made to classify, map, and describe these deposits, based in large part on interpretations of the compilers, published and unpublished subsoil and substratum data, and the distribution of bedrock parent materials. The classification is crude, but it represents a first step toward systematic mapping of slope and upland deposits.

For scientific purposes, the map differentiates Quaternary surficial deposits on the basis of a combination of criteria, such as lithology or composition, texture or particle size, structure, genesis, stratigraphic relationships, and age, as shown on the correlation diagram and indicated in the map unit descriptions. Some constructional geomorphic features, such as end moraines, are distinguished as map units. Erosional landforms, such as stream terraces, are not distinguished as map units, and differentiation of sequences of alluvial deposits of different ages in most regions is not possible at the scale of the map. Most landslide deposits are too small to be shown at this scale, but areas in which landslides are present are distinguished as map units in some regions. As a Quaternary geologic map it serves as a base from which a wide variety of derivative maps relating aspects of geologic history can be compiled.

For practical purposes, the map is a surficial materials map, with distinction of materials based on lithology or composition, texture or particle size, and local specific engineering characteristics such as plasticity and matrix carbonate content. It is not a map of soils as soils 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 and agronomic soils are formed. As a materials map it serves as a base from which a wide variety of derivative maps for use in planning engineering, land use, or land management projects can be compiled.

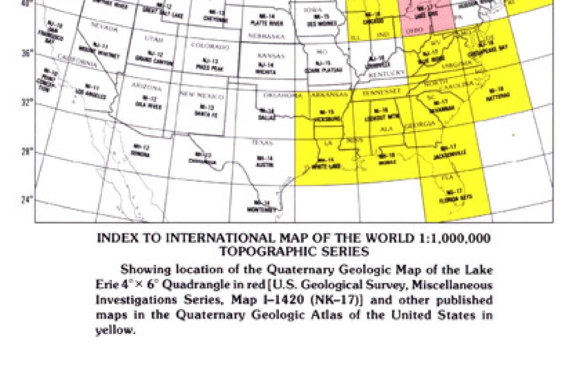
NOTE 2: The Pliocene-Pleistocene boundary defined by joint resolution of the International Union for Quaternary Research (INQUA) Subcommission 1–d on the Pliocene/Pleistocene Boundary (the International Commission on Stratigraphy (ICS) Working Group on the Pliocene/Pleistocene Boundary) and the Working Group of the International Geological Correlation Program (IGCP) Project No. 41 (Neogene/Quaternary Boundary) is that at the Vrica section in southern Italy. The age of that boundary currently is inferred to be 1.64 Ma (Aguirre and Pasini, 1985).

Time boundaries between the early Pleistocene and middle Pleistocene and between the middle Pleistocene and late Pleistocene are being proposed by the INQUA Working Group on Major Subdivision of the Pleistocene (in preparation). The boundary between the early Pleistocene and middle Pleistocene is placed tentatively at the Matuyama-Brunhes magnetic polarity reversal. That reversal has not been dated directly by radiometric methods. It is significantly older than the Bishop Tuff (revised K-Ar age 738 ka; Izett, 1982), and the estimated K-Ar age of 730 ka assigned to the reversal by Mankinen and Dalrymple (1979) is too young. In Utah, the Matuyama-Brunhes polarity reversal is recorded in lake sediments. The Bishop volcanic ash bed (K-Ar age 738 ka) overlies a major paleosol developed in normal-polarity lake sediments above the reversal horizon (Eardley and others, 1973). The terrestrial geologic record is compatible with the astronomical age of 788 ka assigned to the reversal by Johnson (1982); however, on the basis of terrestrial chronometric and stratigraphic data, the reversal may have occurred approximately 770 ka ago (Richmond and Fullerton, 1986).

The boundary between the middle Pleistocene and late Pleistocene is placed arbitrarily at the beginning of marine oxygen isotope substage 5e (at Termination II or the stage 6/5 transition). That boundary also is not dated directly. It was assigned provisional ages of 127 ka by CLIMAP Project members (CLIMAP Project Members, 1984) and by Imbrie and others (1984), and 128 ka by SPECMAP Project members (Ruddiman and McIntyre, 1984), based in part on uranium-series ages of deposits of the marine oxygen isotope substage 5e high eustatic sea-level stand. A provisional sidereal age of 132 ka (Richmond and Fullerton, 1986) is derived by projection of the boundary onto the astronomical time scale of Johnson (1982).

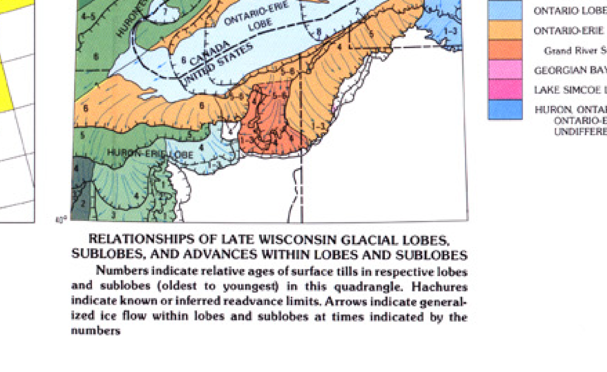
The Pleistocene-Holocene boundary is being proposed by the INQUA Subcommission on the Holocene. Currently in the United States it is placed arbitrarily at 10,000 B.P. (Hopkins, 1975).

Aguirre, Emiliano, and Pasini, Giancarlo, 1985, The Pliocene-Pleistocene boundary: Episodes, v. 8, p. 116–120.
CLIMAP Project Members, 1984, The last interglacial ocean: Quaternary Research, v. 21, p. 123–224.
Eardley, A. J., Shuey, R. T., Gvosdetsky, Vasyl, Nash, W. P., Picard, M. D., Grey, D. C., and Kukla, G. J., 1973, Lake cycles in the Bonneville Basin, Utah: Geological Society of America Bulletin, v. 84, p. 211–215.
Hopkins, D. M., 1975, Time stratigraphic nomenclature for the Holocene Epoch: Geology, v. 3, p. 10.
Imbrie, John, Hays, J. D., Martinson, D. G., McIntyre, Andrew, Mix, A. C., Morley, J. J., Pisias, N. G., Prell, W. L., and Shackleton, N. J., 1984, The orbital theory of Pleistocene climate—Support from a revised chronology of the marine $\delta^{18}O$ record, *in* A. Berger, J. Imbrie, J. Hayes, G. Kukla, and B. Saltzman, editors, Milankovitch and climate, part 1: Boston, D. Reidel Publishing Company, p. 269–305.
Izett, G. A., 1982, The Bishop ash bed and some older, compositionally similar, ash beds in California, Nevada, and Utah: U.S. Geological Survey Open-File Report 82–582, 44 p.
Johnson, R. G., 1982, Brunhes-Matuyama magnetic reversal dated at 790,000 yr B.P. by marine-astronomical correlations: Quaternary Research, v. 17, p. 135–147.
Mankinen, E. A., and Dalrymple, G. B., 1979, Revised geomagnetic polarity time scale for the interval 0–5 Ma B.P.: Journal of Geophysical Research, v. 84, no. B2, p. 615–626.
Richmond, G. M., and Fullerton, D. S., 1986, Introduction to Quaternary glaciations in the United States of America, *in* Richmond, G. M., and Fullerton, D. S., editors, Quaternary glaciations in the United States of America: Quaternary Science Reviews, v. 5, p. 3–10.
Ruddiman, W. F., and McIntyre, Andrew, 1984, Ice-age thermal response and climatic role of the surface Atlantic Ocean, 40° N to 63° N: Geological Society of America Bulletin, v. 95, p. 381–396.



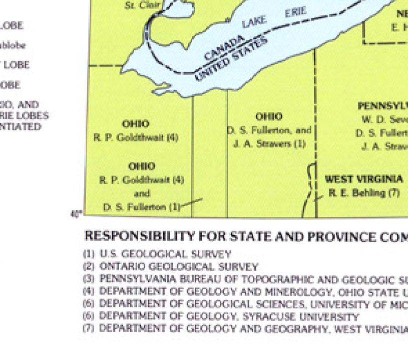
INDEX TO INTERNATIONAL MAP OF THE WORLD 1:1,000,000 TOPOGRAPHIC SERIES

Showing location of the Quaternary Geologic Map of the Lake Erie 4° × 6° Quadrangle in red [U.S. Geological Survey, Miscellaneous Investigations Series, Map I–1420 (NK–17)] and other published maps in the Quaternary Geologic Atlas of the United States in yellow.



RELATIONSHIPS OF LATE WISCONSIN GLACIAL LOBES, SUBLOBES, AND ADVANCES WITHIN LOBES AND SUBLOBES

Numbers indicate relative ages of surface tills in respective lobes and sublobes (oldest to youngest) in this quadrangle. Hachures indicate known or inferred readvance limits. Arrows indicate generalized ice flow within lobes and sublobes at times indicated by the numbers



RESPONSIBILITY FOR STATE AND PROVINCE COMPILATIONS

(1) U.S. GEOLOGICAL SURVEY
(2) ONTARIO GEOLOGICAL SURVEY
(3) PENNSYLVANIA BUREAU OF TOPOGRAPHIC AND GEOLOGIC SURVEY
(4) DEPARTMENT OF GEOLOGY AND MINEROLOGY, OHIO STATE UNIVERSITY
(5) DEPARTMENT OF GEOLOGICAL SCIENCES, UNIVERSITY OF MICHIGAN
(6) DEPARTMENT OF GEOLOGY, SYRACUSE UNIVERSITY
(7) DEPARTMENT OF GEOLOGY AND GEOGRAPHY, WEST VIRGINIA UNIVERSITY

CONTACT
DUNE FIELD—Mapped only where areas of dunes are too small to be shown as dune sand (ed)
GLACIAL LAKE SPILLWAY OR MELTWATER CHANNEL
ESKER
DIRECTION OF ICE MOVEMENT—Direction indicated by striated or grooved bedrock
DRUMLIN
ICE-MOLDED LANDFORM—Rock drumlin, drumlin, flute, or groove
OUTER LIMIT OF GLACIAL ADVANCE—Hachured line solid where known, dashed where inferred; ticks on side of advance
CREST OF END MORAINE—Mapped only in Ontario and under Lake Erie
B BURIED END MORAINE—Ground moraine veneer of clayey till (tca, tcg) over an older end moraine. Topographic form of buried end moraine is preserved
f MANMADE LAND—Chiefly filled land, open pit coal mines, mine waste, and chemical ponds. Larger areas in unglaciated Ohio and Pennsylvania represent many small areas of manmade land; materials not disturbed by man are the same as the surrounding map units

LOCATION OF IMPORTANT STRATIGRAPHIC SECTION

•1 Port Talbot, Plum Point, and "Bradtville" sections, Ontario—Type sections for Bradtville Till, Tyrconnell Formation, and Malahide Formation. Stratigraphic sequence from oldest to youngest: subsurface early Wisconsin Bradtville Till (lower unit from Georgian Bay ice lobe, upper unit from Ontario-Erie ice lobe); early Wisconsin and middle Wisconsin Tyrconnell Formation, including organic horizons with twelve ^{14}C ages from 47,700±1200 B.P. (GSC-217) to 36,530±300 B.P. (TO-232); late Wisconsin Catfish Creek Till (several units, including lithofacies diamictons formerly designated the Dunwich Till and the Southwold Till by Dreimanis and others, 1966) with five ^{14}C ages of wood in till from 28,200±1500 B.P. (L-185-B) to 24,600±1600 B.P. (L-217-B); Malahide Formation; Port Stanley Till (2–6 till units); deglacial and postglacial lake sediment (Dreimanis, 1958, 1980, 1982, 1987; Dreimanis and others, 1966; Terasmae and others, 1972; Karrow and others, 1978; Karrow, 1984)

•2 Don Valley Brickyard (Toronto Brick Company) section, Ontario—Holostratotype for York Till. Stratigraphic sequence, from oldest to youngest: Illinoian York Till; Sangamon Don Formation; early Wisconsin Scarborough Formation and Pottery Road Formation; at least three units of early Wisconsin Sunnybrook Till, separated by varved clay and silt; early and middle Wisconsin Thorncliffe Formation; late Wisconsin Halton Till (Karrow, 1969, 1984; Karrow and Morgan, 1975)

•3 Scarborough Bluffs (Cathedral, Cudia Park, Dutch Church, Hi, Seminary, and Sunnypoint Bluffs), Ontario—Stratotype sections for Scarborough Formation, Seminary Till, and Meadowcliffe Till; holostratotype section for Sunnybrook Till; neostratotype section for Thorncliffe Formation. Stratigraphic sequence, from oldest to youngest: early Wisconsin Scarborough Formation, Pottery Road Formation, and Sunnybrook Till; early and middle Wisconsin lower member of Thorncliffe Formation, with ^{14}C age older than 53,000 B.P. (GSC-1228) in lower part; middle Wisconsin Seminary Till; middle Wisconsin middle member of Thorncliffe Formation; middle Wisconsin Meadowcliffe Till; middle and late Wisconsin upper member of Thorncliffe Formation, with thermoluminescence ages of 36,000±5,000 yr and 32,700±5500 yr and ^{14}C ages of 32,000±690 B.P. (GSC-1221) and 28,300±600 B.P. (GSC-1082); late Wisconsin Halton Till (Karrow, 1967, 1969, 1984; Karrow and Morgan, 1975; Berger, 1984; Lamothe and others, 1984)

•4 Rocky Fork (Gahanna) section, Ohio—Stratigraphic sequence, from oldest to youngest: Rocky Fork Till (formerly called Gahanna Till), probably Illinoian in age; bouldery alluvium, probably Sangamon and early Wisconsin in age; a complex unit of outwash and alluvium with ^{14}C ages older than 46,600±2200 B.P. (GrN-3219) and older than 50,000 B.P. (ISGS-40); three unnamed till units, probably early Wisconsin in age; alluvium and colluvium with a paleosol; late Wisconsin Boston Till; late Wisconsin Darby Till (Forsyth and Goldthwait, 1962; Goldthwait, 1958a; Fullerton, 1986; R. P. Goldthwait and D. S. Fullerton, unpub. data, 1972–74)

•5 Galena Shale Tile and Brick Company section, Ohio—Stratigraphic sequence, from oldest to youngest: two units of Rocky Fork Till (formerly called Gahanna Till), probably Illinoian in age; shale colluvium and bouldery alluvium, probably late Illinoian, Sangamon, and early Wisconsin in age; complex unit of outwash (and alluvium?), probably early Wisconsin in age; three unnamed till units of probable early Wisconsin age; outwash with interbedded till and flow till; bouldery and channery alluvium with paleosol; two till units of probable early Wisconsin age with paleosol; alluvium and loess with very well developed paleosol; late Wisconsin Darby Till (Fullerton, 1974, 1986; D. S. Fullerton, unpub. data, 1972–74)

•6 Derwacter Sand and Gravel Company section, Ohio—Stratigraphic sequence, from oldest to youngest: pre-Illinoian(?) outwash and till; two unnamed Illinoian till units; Illinoian Butler Till; early Wisconsin Millbrook Till; late Wisconsin Navarre Till (Totten, 1973)

•7 Shenandoah section, Ohio—Stratigraphic sequence, from oldest to youngest: six till units of Illinoian and (or) pre-Illinoian age; till of Illinoian or early Wisconsin age; early Wisconsin Millbrook Till; late Wisconsin Navarre Till; late Wisconsin Hayesville Till (Totten, 1965)

•8 Lucas section, Ohio—Stratigraphic sequence, from oldest to youngest: Illinoian or pre-Illinoian till; Illinoian Butler Till; early Wisconsin Millbrook Till; late Wisconsin Navarre Till; late Wisconsin Hayesville Till (Totten, 1973)

•9 Millbrook section, Ohio—Type section for early Wisconsin Millbrook Till (White, 1961)

•10 Oldtown Run section, Ohio—Type section for late Wisconsin Hayesville Till (White, 1961)

•11 Navarre section, Ohio—Type section for late Wisconsin Navarre Till (White, 1961, 1963)

•12 Garfield Heights sections, Ohio—Stratigraphic sequence, from oldest to youngest: pre-Illinoian (possibly early Pleistocene) ice-contact sand and gravel; "Sangamon soil" of White (1953c, 1968), possibly early Pleistocene and middle Pleistocene in age; two unnamed, thoroughly decomposed, pre-Illinoian tills; unnamed Illinoian "red" till; Illinoian Garfield Heights Till with paleosol; sheetwash alluvium with paleosol; accretion gley, probably Sangamon and early Wisconsin in age; early Wisconsin Titusville Till; "lower" loess with involutions and paleosol and with ^{14}C age of 28,195±535 B.P. (K-361-3); late Wisconsin ice-thrust deposits (folded, sheared, and stacked masses of loess, Titusville Till, and older deposits); undeformed "upper" loess; proglacial lake clay and silt with six ^{14}C ages from 24,600±800 B.P. (W-71) to 22,210 ±120 B.P. (DIC-32); two units of late Wisconsin Kent Till; late Wisconsin Lavery Till; late Wisconsin Hiram Till (White, 1953c, 1968; de Heinzelin, 1957; Fullerton and Groenewold, 1974; Fullerton, 1986; D. S. Fullerton, G. H. Groenewold, and Aleksis Dreimanis, unpub. data, 1973–74)

•13 Universal Clay Products section, Ohio—Type section for early Wisconsin Mogadore Till (White, 1960)

•14 Brady Lake section, Ohio—Type section for late Wisconsin Kent Till (White, 1960)

•15 Silver Creek section, Ohio—Type section for late Wisconsin Hiram Till (White, 1960)

•16 Ashtabula River section, Ohio—Type section for late Wisconsin Ashtabula Till (White, 1960)

•17 Valcourt strip mine section, Pennsylvania—Stratigraphic sequence, from oldest to youngest: pre-Illinoian Slippery Rock Till with paleosol; Illinoian Mapledale Till with paleosol; two units of early Wisconsin Titusville Till; late Wisconsin Kent Till (White and others, 1969)

•18 Vanport Stone Company section, Pennsylvania—Type section for pre-Illinoian Slippery Rock Till. Stratigraphic sequence, from oldest to youngest: pre-Illinoian Slippery Rock Till; two units of Illinoian Mapledale Till; early Wisconsin Titusville Till; late Wisconsin Kent Till (White and others, 1969)

•19 Mapledale section, Pennsylvania—Type section for Illinoian Mapledale Till (White and others, 1969)

•20 Titusville section, Pennsylvania—Type section for early Wisconsin Titusville Till (White and others, 1969)

•21 Gowanda Hospital section, New York—Stratigraphic sequence, from oldest to youngest: till of possible Illinoian age; organic silt and clay, some of which is sheared into overlying till, with ^{14}C ages older than 38,000 B.P. (W-866) and older than 48,400 B.P. (GrN-5486); "brown" till of possible early Wisconsin age; four units of late Wisconsin till (Muller, 1960, 1964, 1977; Calkin and others, 1982; Fullerton, 1986)

•22 Otto section, New York—Stratigraphic sequence, from oldest to youngest: till of probable Illinoian age; cobble gravel; flood-plain silt, muck and peat; boulder gravel; organic silt, sand, muck, and peat with ^{14}C ages older than 52,000 B.P. (GrN-2633, GrN-2634) and 63,900±1700 B.P. (GrN-3213); gravel and organic silt with ^{14}C ages older than 52,000 B.P. (GrN-2565, GrN-2632); two tills of late Wisconsin age (MacClintock and Apfel, 1944; Muller, 1960, 1964, 1977; Fullerton, 1986)

•23 Mill Creek section, Michigan—Stratigraphic sequence, from oldest to youngest: lake silt and clay; organic beds in lake sand, with ^{14}C ages of older than 37,000 (Gx-4975) and 48,300±800 (QL-1215); sand and gravel; middle Wisconsin Mill Creek Till; sand and gravel; lower member of late Wisconsin Fisher Road Till; lake sand, silt, and clay; upper member of Fisher Road Till (Avoca Till of Eschman, 1978) (Eschman, 1978, 1980)

QUATERNARY GEOLOGIC MAP OF THE LAKE ERIE 4° × 6° QUADRANGLE, UNITED STATES AND CANADA

State and Province compilations by
David S. Fullerton, William R. Cowan, William D. Sevon, Richard P. Goldthwait, William R. Farrand, Ernest H. Muller, Robert E. Behling, and Jay A. Stravers
Edited and integrated by
David S. Fullerton and Gerald M. Richmond

1991

QUATERNARY GEOLOGIC ATLAS OF THE UNITED STATES

EXPLANATION OF MAP UNITS

HOLOCENE

lm LAKE CLAY AND SILT (under Lakes Huron, Erie, and Ontario)—Brownish-gray, gray, or grayish-black calcareous clay, silty clay, and silt. Generally clay and silty clay in centers of basins and silt at basin margins. Soft, fluid, compressible; may contain gas bubbles. Faintly laminated to massive. Locally contains mollusc tests, wood chips, and disseminated plant debris. Deep-water facies of modern lake deposits. Commonly overlain by lake sand (ls) 1–6 cm thick. Thickness generally 2–6 m near margins and 8–20 m in centers of basins. Maximum thickness under Lake Huron 15 m and under Lake Erie more than 40 m

ls LAKE SAND AND GRAVEL (under Lakes Huron, Erie, and Ontario)—Brown to gray, calcareous, well-sorted to poorly sorted, fine to coarse sand with minor gravel. Locally stratified; mollusc tests and fragments common. Shore and nearshore facies of modern lake deposits. Generally overlies lake silt and clay (lc), till, or bedrock. Includes local boulder accumulations under Lake Erie. Where less than 15 km from shore, includes areas of thin till over bedrock and extensive areas of bedrock outcrop. Thickness generally 1–5 m, rarely 10 m

HOLOCENE AND LATE WISCONSIN

al ALLUVIUM—Yellowish-brown, brown, or reddish-brown to gray silt, sand, and gravel. Generally calcareous; very weakly calcareous or noncalcareous where derived from weakly calcareous or noncalcareous sandstone, siltstone, and shale in southwestern New York and Pennsylvania. Stratified; bedding generally horizontal; moderately to well sorted. Textures vary laterally and vertically; contrasting textures may be interbedded. Upper part commonly silt and fine sand with minor lenses of clay and organic material; lower part generally sand and rounded gravel, locally cobble or boulder gravel. Clast lithologies vary, reflecting compositions of local bedrock and other surface materials. Overbank and stream channel deposit; underlies flood plains, low stream terraces, and alluvial fans. In northwestern Pennsylvania and southwestern New York, includes alluvial-fan deposits of nonstratified rubble or bouldery, cobbly, or pebbly medium to coarse sand. In Michigan, alluvium is included in other units. Areas of till, outwash and ice-contact sand and gravel (gg, gs, kg, ks), lake clay, silt, sand, and gravel (lca, lcc, lsa), and bedrock outcrop included locally. Overlain by peat (hp) or swamp deposits (hs) in places. Thickness of overbank and channel alluvium generally 1–4 m, rarely more than 6 m; thickness in alluvial fans may exceed 25 m

lc LAKE SILT AND CLAY (under Lakes Huron, Erie, and Ontario)—Light-brown, reddish-brown, reddish-gray, or brownish-gray to gray or dark-gray, very calcareous silty clay and clayey silt. Generally soft, fluid, massive to laminated; locally varved. Much more compact than unit lm. Locally contains ice-rafted clasts; organic detritus absent. Offshore and deep-water facies of deposits of former glacial and postglacial lakes. Commonly overlain by well-sorted silt or sand 2–28 cm thick. Thickness generally 1–5 m, locally 10–15 m

lcb LAKE CLAY, SILT, SAND, AND GRAVEL (under Lakes St. Clair and Erie)—A complex deposit of lake clay and silt (lm, lc) and lake sand and gravel (ls). Textures vary laterally and vertically. Thickness generally 1–5 m, rarely more than 15 m

lcc LAKE CLAY, SILT, SAND, AND GRAVEL—A complex deposit of silt and clay (lca) and sand and gravel (lsa). Where chiefly silt and clay, thinly laminated to massive with occasional ice-rafted clasts; where chiefly sand, well sorted to poorly sorted, horizontally bedded or crossbedded, fine to medium sand with minor gravel. Thin and discontinuous in some areas; includes areas of wave-washed or current-scoured till. Deposits of beach ridges, offshore bars, and spits of former glacial and postglacial lakes included; some outwash and ice-contact sand and gravel (gg, gs, kg, ks) and alluvium (al) also included. Locally overlain by eolian sand and silt (ed, eu), peat (hp), or swamp deposits (hs). Thickness generally 1–10 m, locally more than 15 m

lca LAKE SILT AND CLAY—Yellowish-brown, reddish-brown, or brown to gray or bluish-gray calcareous clay and silt. Well bedded to massive, commonly laminated, locally varved; locally interbedded with sand and fine gravel. Ice-rafted pebbles, cobbles, and boulders common in lower part. Gullies common adjacent to major streams. Chiefly on extensive flat, low-lying areas formerly occupied by large glacial and postglacial lakes, but also in small separate lake basins. Included in clayey till (tca) in much of northwestern Ohio, where lake silt and clay is a thin veneer over till. Includes some lake sand and gravel (lsa), slackwater lake silt and sand (lla), wave-modified and current-modified outwash and ice-contact sand and gravel (gg, kg), extensive areas of wave-washed and current-scoured clayey till (tca), alluvium (al), small delta deposits, and areas of bedrock outcrop. Commonly overlain by eolian sand and silt (ed, eu), peat (hp), or swamp deposits (hs). Thickness generally 1–3 m; locally more than 15 m in Ontario

lsa LAKE SAND AND GRAVEL—Yellowish-brown or pale-brown to gray, calcareous fine to coarse sand with local lenses of rounded medium gravel or pebble layers. Commonly crossbedded; lenticular bedding or tabular foreset bedding locally. Generally well sorted, without significant silt or clay. Clast composition varies, reflecting compositions of materials transported by waves and currents. Nearshore, strand, and deltaic deposits of former glacial and postglacial lakes and present Great Lakes. Includes deposits of beach ridges, offshore bars, and spits; also includes small areas of lake silt and clay (lca), complex lake deposits (lcc), and bedrock outcrop. Locally overlain by eolian sand and silt (ed, eu), alluvium (al), peat (hp), or swamp deposits (hs). Mapped only where extensive. Thickness generally 1–10 m, locally more than 30 m

hs SWAMP DEPOSIT—Dark-brown to black muck, mucky peat, and organic residues mixed with fine-grained mineral sediment. Locally underlain by gray or white marl, a very calcareous, soft, crumbly clay that contains mollusc tests and fragments, or by gyttja, an anaerobic, pulpy, freshwater mud containing abundant organic material. Includes peat (hp) where peat and swamp deposits have not been distinguished. Commonly overlies lake silt, clay, sand, or gravel (lca, lcc, lsa) on former lake beds, or outwash sand and gravel (gg, gs) in abandoned glacial meltwater channels, ice-block depressions, and other shallow depressions and poorly drained areas. Mapped only where extensive. Thickness generally 1–5 m, rarely 15 m

hp PEAT—Black or dark-brown fibrous peat and decomposed organic residues or fibrous peat and clay and silt containing comminuted plant material and organic residues. Commonly underlain by gray or white marl, a very calcareous, soft, crumbly clay that contains mollusc tests and fragments. Commonly overlies lake deposits in low, poorly drained areas or occurs as bogs in ice-block depressions. Mapped only where extensive. Thickness generally 1–10 m

ed DUNE SAND—Pale-brown, crossbedded, well-sorted, weakly calcareous to very calcareous medium to fine sand. In Michigan, sand chiefly quartz grains with some heavy minerals; in Ontario, sand chiefly limestone and dolomite grains. Occurs as massive dune ridges parallel to present shores of Lake Huron and as parabolic dunes on former lake beds. Dunes generally stabilized; locally active where vegetation has been removed. Small isolated areas of dunes in Ontario shown by symbols. Thickness generally 1–30 m

eu EOLIAN SAND AND SILT—Pale-brown or yellowish-brown, well sorted to moderately well sorted, weakly calcareous, medium to fine sand and silt. Bedding thin, laminar, and horizontal to crossbedded in sand; silt (loess) has weakly developed horizontal bedding or is massive. Occurs as undifferentiated dune sand, sheet sand, and silt (loess) on former lake beds. Generally stabilized; blowouts and small parabolic dunes active where vegetation has been removed. Mapped only in Ontario and Ohio, where extensive. Thickness generally 1–10 m

HOLOCENE AND WISCONSIN

cbb BOULDERY COLLUVIUM[1] AND ROCK WASTE—Deposits of colluvium and rock waste that accumulated below cliffs or steeply sloping bedrock outcrops by rockfall and creep. Clasts generally angular to subangular quartzitic sandstone, quartzitic siltstone, or conglomerate. On upper part of slopes, generally rock waste (an accumulation of blocks, boulders, and cobbles with no interstitial matrix); sandy or loamy matrix may be present at depth. Rock waste generally coarsely sorted vertically and laterally; average diameters of clasts increase downslope and increase upward within deposit. Clasts generally randomly oriented; crude imbrication, with long axes dipping upslope, apparent where materials moved by secondary creep. Boulders and blocks in rock waste in point contact; individual boulders may be unstable. Size of largest blocks or boulders dependent on joint spacing and bedding thickness in parent rock upslope; maximum diameters of blocks locally more than 6 m. Forms talus and debris cones on steep slopes; locally forms block fields and block streams more than 850 m long. Rock waste generally grades downslope into bouldery colluvium with sandy or loamy matrix. On lower parts of slopes, chiefly yellowish brown, pale reddish brown, brown, brownish gray, and gray loamy to clayey colluvium with scattered boulders. Colors and textures reflect those of bedrock higher on slopes. Boulders in matrix-rich colluvium downslope from rock waste lack point contacts. Where rock waste is absent, entire slope covered by bouldery colluvium with sandy or loamy matrix. Bouldery colluvium occurs as talus cones and aprons and as continuous slope mantle. Deposits generally more extensive on south-facing than on north-facing slopes. Most deposits inactive; inferred to have accumulated in a periglacial environment, contemporaneous with glaciation farther north. Includes rockfall deposits and debris avalanche deposits locally superposed on periglacial deposits, colluvium of pre-Wisconsin age, and bedrock outcrops on ridge crests; bedrock seldom exposed on slopes. Thickness on upper parts of slopes generally less than 3 m; thickness on lower parts of slopes commonly less than 15 m, but may exceed 30 m

cl LOAMY COLLUVIUM[1]—Pale-yellow, yellowish-brown, or brown to gray or black sandy loam, loam, silt loam, silty clay loam, clay loam, and silty clay. Textures and colors vary, reflecting composition of bedrock higher on slopes. Generally noncalcareous or weakly calcareous; locally very calcareous where derived from limestone. Clasts dominantly angular and subangular sandstone, quartzitic sandstone, siltstone, and shale; limestone or conglomerate common locally. Most material on slopes is colluvium, although included solifluction deposits are widespread in northern part of area mapped as unit cl. Materials on flat upland surfaces or very gentle slopes commonly are undifferentiated solifluction deposits and residuum. Colluvium generally pale brown or dark brown to gray, poorly sorted to massive, pebbly to bouldery debris transported and deposited chiefly by creep. Included solifluction deposits yellowish brown or brown to gray, similar to those described in unit nma. Included residuum pale yellow or brown to gray or black and stony to pebble free, similar to that described in unit nla. Where derived from limestone, residuum is tough, plastic, silty clay loam or silty clay. Also included are small areas of sheetwash alluvium, stream alluvium (al), rock waste, bedrock outcrop, and isolated landslide deposits. Units mapped as landslide deposits (jla, jlb) consist of same materials but are distinguished on the basis of a greater abundance of landslide deposits. Thickness of colluvium 1–2 m on gentle slopes, 2–4 m on foot slopes, locally more than 10 m at toes of colluvial fans and aprons. Thickness of solifluction deposits generally 1–3 m. Thickness of residuum generally 1–2 m thick on flat surfaces, less than 1 m on gentle slopes

clc LOAMY COLLUVIUM[1]—Same as loamy colluvium (cl), but contains scattered erratic clasts of limestone, granite, granitic gneiss, and quartzite and includes areas of discontinuous loamy till of Illinoian age (tlo) less than 2 m thick. Mapped only in east-central Ohio

cld LOAMY COLLUVIUM[1]—Same as loamy colluvium (cl), but contains scattered erratic clasts of granite, gneiss, greenstone, and quartzite and includes areas of discontinuous sandy loamy or loamy till of early Wisconsin and Illinoian age less than 1 m thick. Till generally yellowish brown or brown and intensely weathered and dissected. Throughout much of area mapped as unit cld, glaciation recorded only by scattered erratic pebbles and occasional erratic cobbles and boulders on land surface; boulders as large as 2 m. Includes many extensive areas of bedrock outcrop. Mapped only in northeastern Ohio and Pennsylvania

LOAMY COLLUVIUM AND LANDSLIDE DEPOSITS—Same as loamy colluvium (cl), but distinguished on the basis of greater abundance of landslide deposits. Landslide deposits are products of downslope movement of colluvium, solifluction deposits, residuum, and bedrock as a result of earthflow or slump. Earthflow deposits typically are heterogeneous mixtures of clay, silt, and sand with scattered angular clasts of bedrock that were transported and deposited as a result of slow flow of wet, but not necessarily saturated, unconsolidated materials. Areal extent of earthflow deposits commonly less than 0.405 hm² (1 acre), although some deposits are tens of meters to a few hundred meters wide and 15–30 m long. Slump deposits typically are masses of unconsolidated materials and bedrock that have rotated and slid downslope as a unit, with little or no flow; physical properties of transported materials are not altered greatly and textures, stratification, and bedding of slumped colluvium, solifluction deposits, residuum, and bedrock are retained; slump deposits typically less than 120 m wide, with upslope lengths of 10–45 m and vertical crown scarp displacements of 1–5 m. Colluvium thickness commonly 1–2 m on gentle slopes, 2–4 m on foot slopes, locally more than 10 m at toes of colluvial fans and aprons. Thickness of solifluction deposits generally 1–3 m. Thickness of residuum generally 1–2 m on flat surfaces and less than 1 m on very gentle slopes. Earthflow deposits generally less than 5 m thick; slump deposits generally 2–30 m thick

- **jla** Areas with abundant or widely distributed landslide deposits—Landslide deposits generally present in 10–30 percent of area
- **jlb** Areas with scattered or localized landslide deposits—Landslide deposits generally present in 2–10 percent of area

LATE WISCONSIN

Tills in Michigan, Ohio, Pennsylvania, and New York

CLAYEY TILL—Yellowish-brown, pale-brown, or brown to light- or dark-gray, calcareous clay loam, silty clay loam, and clay. Nonsorted to very poorly stratified. Pebbles infrequent; very few cobbles and boulders. Clasts chiefly sandstone, limestone, and shale in Michigan and limestone, dolomite, and shale in New York. Cobbles and boulders of erratic igneous and metamorphic lithologies conspicuous locally. Includes small areas of outwash and ice-contact sand and gravel (gg, kg), lake clay, silt, sand, and gravel (lca, lcc, lsa), and alluvium (al). In places overlain by eolian sand and silt (ed, eu), peat (hp), or swamp deposits (hs)

- **tc** Ground moraine—Thickness generally 2–20 m
- **tc** End moraine—Broad, low ridges, locally with hummocky topography. Thickness generally 10–30 m

CLAYEY TILL (Ashtabula Till and part of Lavery Till in northeastern Ohio)—Brown or dark-brown to bluish-gray or gray, calcareous clay loam, silty clay loam, and silty clay; locally reddish brown where composed primarily of red shale. Nonsorted to very poorly sorted. More pebbly than units tca and tcg; shale granules and pebbles common to abundant. Cobbles and boulders chiefly limestone, dolomite, granite, gneiss, and quartzite. Includes small areas of ice-contact sand and gravel (kg), lake clay, silt, sand, and gravel (lca, lcc, lsa), older clayey or loamy till, alluvium (al), and bedrock outcrop. Locally overlain by eolian sand and silt (ed, eu), peat (hp), or swamp deposits (hs)

- **tcd** Ground moraine under Lake Erie—Includes areas of bedrock outcrop and local accumulations of boulders. Thickness generally 1–3 m
- **tcd** End moraine—Broad, low, till ridges, generally with well-developed constructional topography. In places, ridge segments are superposed end moraines of clayey till that overlie end moraine ridges of older clayey or loamy till. Thickness locally more than 20 m

CLAYEY TILL (part of Lavery Till in northeastern Ohio and part of Hiram Till in northeastern Ohio and Pennsylvania; not formally named elsewhere)—Dark-yellowish-brown, reddish-brown, or brown to bluish-gray or dark-gray, very calcareous clay loam, silty clay, clay, and silty clay loam. Nonsorted to very poorly sorted; locally with faint pseudo-stratification or streaks of interstratified clay. Pebbles infrequent; very few cobbles and boulders. Locally composed entirely of incorporated lake clay and silt with no clasts. Pebbles chiefly limestone or dolomite; rare large boulders chiefly granite, gneiss, or quartzite. Matrix smooth and tacky where moist; generally blocky structure where dry, forming 1–2 cm cubes or prisms or with horizontal parting. Undrained shallow depressions common locally on surface. In parts of northeastern Ohio and northwestern Pennsylvania, till is thin and discontinuous and areas of older clayey or loamy till or bedrock outcrop are included. In northwestern Ohio, includes large areas of clayey till overlain by lake clay, silt, sand, and gravel (lca, lcc, lsa). Throughout mapped area, includes small areas of ice-contact and outwash sand and gravel (gg, kg), lake clay, silt, sand, and gravel (lca, lcc, lsa), and alluvium (al). Locally overlain by eolian sand and silt (ed, eu), peat (hp), or swamp deposits (hs)

- **tca** Ground moraine—Thickness generally 1–10 m
- **tca** Ground moraine under Lake Erie—Includes areas of bedrock outcrop and local accumulations of boulders. Thickness generally 1–3 m
- **tca** Ground moraine veneer over nonoriented hummocky topography of older till or ice-contact sand and gravel—Mapped previously as end moraine, but constructional topography is inherited from underlying deposits. Thickness generally 1–3 m
- **tca** End moraine—Broad, low ridges with undulating surfaces and local subdued hummocks. Ice-block depressions common locally. Thickness generally 3–25 m

CLAYEY TILL—Yellowish-brown, pale-brown, brown, or grayish-brown to gray, calcareous silty clay loam and clay loam. Similar to unit tca, but less clayey and more pebbly. Includes areas of outwash and ice-contact sand and gravel (gg, kg), lake clay, silt, sand, and gravel (lca, lsa), and alluvium (al). Locally overlain by peat (hp) or swamp deposits (hs)

- **tcb** Ground moraine—Thickness generally 2–10 m
- **tcb** Stagnation moraine—Broad, irregular area of hummocky collapsed topography, locally with ice-disintegration features and ice-block depressions. Thickness generally 3–15 m
- **tcb** End moraine—Broad, low ridges, locally with hummocky topography. Ice-block depressions common locally. Thickness generally 3–25 m

CLAYEY TILL (part of Hiram Till in northeastern Ohio)—Dark-yellowish-brown or brown to bluish-gray or dark-gray, calcareous silty clay loam, clay loam, and silt loam; locally reddish brown where composed primarily of red shale. Nonsorted to very poorly sorted. Sparingly to moderately pebbly; cobbles and boulders rare. Similar to unit tca, but less clayey and locally more pebbly. Thin and discontinuous locally; includes areas of older clayey or loamy till. Includes small areas of outwash and ice-contact sand and gravel (gg, kg), lake clay, silt, sand, and gravel (lca, lsa), and alluvium (al). Locally overlain by peat (hp) or swamp deposits (hs)

- **tcg** Ground moraine—Thickness generally 2–4 m, rarely 6 m
- **tcg** Ground moraine veneer over nonoriented hummocky topography of older till or ice-contact sand and gravel—Mapped previously as end moraine, but constructional topography is inherited from underlying deposits. Thickness generally 1–3 m

LOAMY TILL (part of Darby Till in south-central Ohio; part of Navarre Till and part of Hayesville Till in northeast-central Ohio; Kent Till in northeastern Ohio, Pennsylvania, and part of western New York; not formally named elsewhere)—Yellowish-brown to olive-gray, bluish-gray, gray, or dark-gray, calcareous loam and silt loam. Locally sandy loam in northeastern Ohio and Pennsylvania, near southern limit of Kent Till. Nonsorted to poorly sorted. Typically has horizontal platy structure, breaking into irregular pieces 1.5–4 cm thick. Generally moderately pebbly, locally cobbly or bouldery. In New York, locally very stony with gritty matrix and abundant angular granules of shale and siltstone. Gravel lenses or interbeds common in northeastern Ohio. In Michigan and central Ohio, pebbles, cobbles, and small boulders chiefly dolomite and limestone; large boulders chiefly erratic igneous and metamorphic lithologies and quartzite. On uplands in eastern Ohio, Pennsylvania, and New York, till is thin and discontinuous; clasts dominantly sandstone, siltstone, and shale. Includes areas of pre-late Wisconsin loamy till and bedrock outcrop. Locally includes small areas of ice-contact sand and gravel (gg, kg), lake clay, silt, sand, and gravel (lca, lcc, lsa), and alluvium (al). Locally overlain by eolian sand and silt (ed, eu), peat (hp), or swamp deposits (hs)

- **tl** Ground moraine—Thickness generally 1–3 m, rarely 6 m
- **tl** Ground moraine under Lake Huron—Includes areas of bedrock outcrop and local accumulations of boulders. Thickness generally 1–2 m
- **tl** Ground moraine veneer over nonoriented hummocky topography of older till or ice-contact sand and gravel—Mapped previously as end moraine in Pennsylvania and northeastern Ohio (Shepps and others, 1959; Goldthwait and others, 1961). More recent investigations indicate surface morphology is largely inherited from hummocky topography on early Wisconsin till and ice-contact deposits, and the late Wisconsin till is a fairly continuous veneer over the buried topography (White and others, 1969; White, 1969, 1982; White and Totten, 1985; G. W. Totten and S. M. White, unpub. mapping). Thickness generally 1–3 m
- **tl** Stagnation moraine—Broad irregular areas of hummocky collapsed topography, locally with ice-disintegration features and ice-block depressions. Thickness generally 4–10 m
- **tl** End moraine—Broad, low ridges or complex areas of narrow, concentric or overlapping ridges with knob-and-kettle topography and undrained depressions. Thickness generally 8–30 m

LOAMY TILL (part of Hayesville Till in northeast-central Ohio and part of Lavery Till in northeastern Ohio)—Brown or dark-brown to dark-gray or dark-bluish-gray, calcareous clay loam, loam, and silty clay loam. Nonsorted to poorly sorted. Generally oxidized throughout, with horizontal parting, breaking into 1- to 3-cm cubes or prisms; unoxidized till massive and compact. Pebbles infrequent; cobbles or boulders rare. Clasts chiefly dolomite, limestone, sandstone, and shale. Generally thin and discontinuous; in southern part of area mapped as unit tlb, includes older loamy till and areas of bedrock outcrop. Locally includes small areas of outwash and ice-contact sand and gravel (gg, kg), lake clay, silt, sand, and gravel (lca, lsa), and alluvium (al). Locally overlain by eolian sand and silt (ed, eu), peat (hp), or swamp deposits (hs)

- **tlb** Ground moraine—Thickness 1–2 m, rarely more than 3 m
- **tlb** Ground moraine veneer over nonoriented hummocky topography of older till or ice-contact sand and gravel—Mapped previously as end moraine, but constructional topography is inherited from underlying deposits. Thickness generally 1–2 m
- **tlb** End moraine—Broad, low ridges or complex areas of narrow, concentric, or overlapping ridges with knob-and-kettle topography or irregular hummocks and undrained depressions. Thickness generally 3–6 m

LOAMY TILL (Olean Till in New York and Pennsylvania)—Yellowish-brown or grayish-brown to gray, calcareous or noncalcareous loam, silt loam, and sandy loam; locally mottled brown and gray silty clay loam or silty clay where derived chiefly from shale. Texture reflects composition of bedrock. Generally nonsorted; lenses and interbeds of silt, sand, and gravel uncommon. Upper 0.5–1 m loose; firm to compact below 1 m. Moderately developed platy structure where clayey; hard where dry and tacky to moderately plastic where moist. Pebbly to bouldery; rubbly where derived from jointed sandstone or conglomerate; commonly very stony in end moraine. Clasts dominantly local bedrock lithologies: 80 to 90 percent sandstone and siltstone with minor shale, limestone, and conglomerate; erratic igneous and metamorphic lithologies commonly comprise less than 1 percent of clasts. Thin and discontinuous on hill summits and uplands; thick till generally only on lower slopes and in valleys. Includes areas of solifluction deposits (nlc), outwash and ice-contact sand and gravel (gg, kg), lake silt and clay (lca), alluvium (al), and bedrock outcrop. Locally overlain by peat (hp) or swamp deposits (hs)

The Olean Till (tld) has been assigned a late Wisconsin age (Crowl and Sevon, 1980), a middle Wisconsin age (Calkin and others, 1982), and an early Wisconsin age (Muller, 1977). Stratigraphic data in New York (LaFleur, 1979, 1980; Braun and others, 1985) indicate the till is the same age as the late Wisconsin Kent Till (tl) in northeastern Ohio and northwestern Pennsylvania (Fullerton, 1986)

- **tld** Ground moraine—Thickness generally less than 1.5 m on uplands, 3–6 m in valleys
- **tld** End moraine—Low ridges, generally with subdued constructional topography. Thickness generally 5–10 m, locally more than 15 m

LOAMY TILL—Pale-yellow, yellowish-brown, pale-brown, brown, or dark-brown to light-gray, gray, or bluish-gray calcareous loam, silt loam, clay loam, and silty clay loam. Nonsorted to poorly sorted. Typically has irregular horizontal platy structure; moist till tacky where clayey. Jointed, with light-gray calcium carbonate joint fillings. Sparingly pebbly to pebbly; generally less pebbly than units tl and tlh and more pebbly than units tca and tcb. Nearly pebble free where derived chiefly from incorporated lake sediments. Cobbles and boulders common locally, particularly in end moraine. Pebbles, cobbles, and small boulders chiefly limestone, dolomite, siltstone, and sandstone in Ohio and New York and shale, siltstone, and sandstone in Pennsylvania; large boulders chiefly erratic crystalline igneous and metamorphic rocks and quartzite. Thin and discontinuous on uplands; includes areas of older till and bedrock outcrop. Includes small areas of outwash and ice-contact sand and gravel (gg, kg), lake clay, silt, sand, and gravel (lca, lcc, lsa), and alluvium (al). In Ohio, commonly overlain by windblown silt (loess) 15–45 cm thick; loess cover generally absent elsewhere. Throughout mapped area, locally overlain by peat (hp) or swamp deposits (hs)

- **tlg** Ground moraine—Thickness generally 1–3 m, rarely 6 m
- **tlg** Ground moraine under Lakes Erie and Ontario—Includes areas of bedrock outcrop and local accumulations of boulders. Thickness generally 1–2 m
- **tlg** Ground moraine veneer over nonoriented hummocky topography of older till or ice-contact sand and gravel—Mapped previously as end moraine, but constructional topography is inherited from underlying deposits. Thickness generally 1–3 m
- **tlg** Stagnation moraine—Broad, irregular areas of hummocky collapsed topography, locally with ice disintegration features and ice-block depressions. Thickness generally 3–10 m
- **tlg** End moraine—Broad low ridges, narrow sharply defined ridges, or complex areas of concentric or overlapping ridges with knob-and-kettle topography or irregular hummocks and undrained depressions. Till end moraine locally is replaced by kame and kame moraine deposits (ke) that are included in map unit. Thickness generally 4–15 m
- **tlr** Attenuated drift—Thin, discontinuous deposits of loamy till separated by numerous or extensive bedrock outcrops. Thickness generally less than 1 m

LOAMY TILL—Yellowish-brown, reddish-brown, grayish-brown, brownish-gray, gray, bluish-gray, or mottled calcareous loam, silt loam, and clay loam. Locally sandy loam or loamy sand. Nonsorted to poorly sorted. Friable; loosely compact to compact. Blocky structure; lenses and pods of sand and gravel common. Vertical joints typically 5–10 cm apart, filled with light-gray secondary carbonate. Moderately pebbly to pebbly; cobbles and boulders abundant locally. Clasts chiefly limestone and dolomite; some shale, sandstone, siltstone, chert, and erratic granite, gneiss, and quartzite. Generally more sandy and less clayey than unit tlg; matrix has much lower carbonate content and lower magnetic susceptibility; limestone clasts less abundant and chert clasts more abundant than in unit tlg. Includes areas of outwash and ice-contact sand and gravel (gg, kg), alluvium (al), and bedrock outcrop. Commonly covered by windblown silt (loess) 20–90 cm thick; locally overlain by peat (hp) or swamp deposits (hs)

- **tlh** Ground moraine—Thickness generally 2–3 m, rarely 6 m
- **tlh** End moraine—Broad low ridges, narrow sharply defined ridges, or complex areas of concentric or overlapping ridges with knob-and-kettle topography or irregular hummocks and undrained depressions. Thickness generally 4–15 m

SANDY LOAMY TILL—Reddish-brown to light- or dark-gray, calcareous sandy clay loam, sandy loam, and loamy sand. Nonsorted to poorly sorted. Commonly contains lenses of clay or silt. Pebbly to bouldery. Pebbles and cobbles dominantly limestone, dolomite, shale, and sandstone; boulders chiefly erratic igneous and metamorphic rocks. Deposits locally resemble outwash sand and gravel (gg), owing to abundance of well-rounded clasts. Deposits are nonstratified, however, and include lenses of clayey or silty till and flow till. Mapped only in Michigan. Includes areas of finer-textured till (tl, tc), outwash and ice-contact sand and gravel (gg, kg), lake silt and clay (lca), complex lake deposits, and alluvium (al). Locally overlain by eolian sand and silt (ed, eu), peat (hp), or swamp deposits (hs)

- **td** Ground moraine—Thickness generally 2–20 m, locally 30 m
- **td** End moraine—Belts of hummocky till ridges with ice-block depressions. Thickness generally 10–30 m, locally more than 40 m

Tills in Ontario

(Ground moraine and end moraine not distinguished)

tap CLAYEY TILL (Kettleby Till)—Brown to gray, very calcareous silty clay and silt loam. Nonsorted; locally interbedded with lake silt and clay. Clast free or with occasional pebbles; pebbles chiefly limestone, dolomite, and siltstone. Blocky structure; moderate plasticity. Secondary carbonate concretions common. Occurs as discontinuous ground moraine veneer. Includes areas of lake clay, silt, sand, and gravel (lca, lsa), alluvium (al), and older till. Thickness generally less than 2 m, locally 12 m

taa CLAYEY TILL (Wildfield Till)—Dark-gray, very calcareous silty clay loam, silty clay loam, silty clay, and clay. Nonsorted; nonstratified; low to intermediate plasticity. Matrix as much as 35 percent carbonate, primarily calcite. Occasional pebbles; clasts chiefly limestone, siltstone, shale, and erratic igneous and metamorphic rocks. Derived chiefly from incorporated lake silt and clay; commonly contains rip-up clasts of silt and clay. Occurs as low-relief ground moraine. Includes small areas of lake silt and clay (lca) and alluvium (al). Thickness generally 0.5–2 m, locally 5 m

CLAYEY TILL (part of Halton Till)—Reddish-brown or yellowish-brown to gray, very calcareous clay loam, silty clay loam, silty clay, and clay. Locally loamy, similar to unit tka. Nonsorted; nonstratified; may contain local flow till units near lower and upper contacts. Low plasticity. Matrix carbonate content variable, chiefly dolomite. Sparingly to moderately pebbly; clasts chiefly shale, dolomite, and limestone; some erratic igneous and metamorphic rocks. Includes small areas of ice-contact sand and gravel (kg), lake clay, silt, sand, and gravel (lca, lsa), alluvium (al), and bedrock outcrop. Locally overlain by peat (hp) or swamp deposits (hs)

- **tab** Ground moraine and end moraine—Thickness generally 2–6 m, locally 30 m
- **tab** Ground moraine and end moraine under Lakes Erie and Ontario—Includes areas of bedrock outcrop and local accumulations of boulders. Thickness generally 1–15 m

CLAYEY TILL (St. Joseph Till)—Yellowish-brown to gray or dark-gray, very calcareous silty clay loam and silt loam. Clay content increases southward; low plasticity. Matrix chiefly incorporated lake silt and clay; in places occurs primarily as deformation till. Nonsorted; nonstratified; locally intercalated with lake silt and clay. Matrix averages 45 percent carbonate, primarily dolomite. Pebbles infrequent; clasts dominantly limestone and dolomite; some sandstone, shale, chert, and erratic igneous and metamorphic rocks. Limestone increases southward relative to dolomite; tillite and jasper conglomerate erratics common locally. Pronounced columnar jointing; blocky structure; clay skins and secondary carbonate common on joint and fracture surfaces. 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 eolian sand and silt (ed, eu), peat (hp), or swamp deposits (hs)

- **tak** Ground moraine and end moraine—Thickness generally 2–25 m
- **tak** Ground moraine under Lake Huron—Includes areas of bedrock outcrop and local accumulations of boulders. Thickness generally 1–3 m

taq CLAYEY TILL (unnamed till)—Yellowish-brown to gray calcareous silty clay and silty clay loam. Nonsorted; contains lenses and inclusions of lake silt and clay. Low plasticity. Matrix carbonate averages 40 percent, dominantly calcite. Nearly stone free; rare pebbles chiefly limestone. Intensely jointed; secondary carbonate on joint surfaces. Distinguished from unit tak chiefly on basis of heavy-mineral composition. Occurs chiefly as ground moraine and as veneer on older 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 eolian sand and silt (ed, eu), peat (hp), or swamp deposits (hs). Considered by some geologists to be an upper member of Rannoch Till (tkg). Thickness generally 1–6 m

CLAYEY TILL (part of Port Stanley Till)—Yellowish-brown or brown to gray, very calcareous silty clay loam, silty clay, and silt loam. Nonsorted; generally nonstratified; locally contains flow till units; locally interbedded with lake sediments. Blocky structure, with clay skins or secondary carbonate on fracture surfaces. High plasticity. Matrix carbonate averages 30–40 percent, dominantly calcite. Pebbles infrequent; clasts primarily dolomite or limestone, depending on composition of local bedrock; shale, sandstone, siltstone, chert, and erratic igneous and metamorphic rocks generally constitute less than 20 percent of clasts. 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 eolian sand and silt (ed, eu), peat (hp), or swamp deposits (hs)

- **tae** Ground moraine and end moraine—Thickness generally 2–15 m; maximum thickness 25 m
- **tae** Ground moraine and end moraine under Lake Erie—May include some end moraine of unit tkk under Lake Erie. Includes areas of bedrock outcrop and local accumulations of boulders. Thickness generally 2–15 m

tai CLAYEY TILL (Wartburg Till)—Brown to gray very calcareous silty clay and silty clay loam. Nonsorted; nonstratified. Low to moderate plasticity. Matrix carbonate averages 40–50 percent, chiefly calcite. Rare clasts chiefly limestone; some dolomite, sandstone, siltstone, shale, chert, and erratic igneous and metamorphic rocks. Exposed on land surface only as ground moraine. Thickness generally 2–10 m

tao CLAYEY TILL (Mornington Till)—Brown to gray or mottled, very calcareous silty clay loam, silty clay, and clay. Basal part locally is deformation till. Nonsorted; nonstratified; low to medium plasticity. Matrix carbonate averages 35–40 percent, generally chiefly calcite; dolomite increases northward. Almost pebble free; clasts chiefly limestone and dolomite; some sandstone, siltstone, shale, and erratic igneous and metamorphic rocks. Occurs as flat or weakly fluted 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 peat (hp) or swamp deposits (hs). Considered by some geologists to be an upper member of Tavistock Till (tkf, tko). Thickness generally 1–3 m

taf CLAYEY TILL (Maryhill Till)—Brown to gray, very calcareous silty clay, silty clay loam, clay, and minor loam. Nonsorted; locally intercalated with lake sediments. Blocky structure; low to moderate plasticity. Matrix carbonate averages 35 percent, generally dominantly calcite. Pebbles infrequent. Clasts primarily dolomite; some sandstone, siltstone, shale, chert, and erratic igneous and metamorphic rocks. Occurs chiefly as ground moraine; locally as thin veneer of ground moraine on older end moraine. Includes small areas of outwash and ice-contact sand and gravel (gs, gg, ks, kg), lake sand and gravel (lsa), and alluvium (al). Locally overlain by peat (hp) or swamp deposits (hs). Thickness generally 2–15 m

LOAMY TILL (part of Halton Till)—Yellowish-brown to gray, very calcareous loam, silt loam, sandy loam, and clay loam. Locally clayey, similar to unit tab. Nonsorted; nonstratified; may contain local flow till units near lower and upper contacts. Low plasticity. Matrix carbonate content variable, chiefly calcite. Occasional pebbles; clasts chiefly limestone and shale, with some erratic igneous and metamorphic rocks. Occurs chiefly as low-relief ground moraine. Includes areas of outwash and ice-contact sand and gravel (gg, kg), lake clay, silt, sand, and gravel (lca, lsa), and alluvium (al). Locally overlain by peat (hp) or swamp deposits (hs)

- **tka** Ground moraine and end moraine—Thickness generally 2–6 m, locally 30 m
- **tka** Ground moraine and end moraine under Lake Ontario—Includes areas of bedrock outcrop and local accumulations of boulders. Thickness generally less than 1 m

LOAMY TILL (Wentworth Till)—Yellowish-brown to gray, very calcareous loam and sandy loam; locally clay loam. Nonsorted; nonstratified. Low plasticity or nonplastic. Matrix 30–40 percent carbonate, dominantly dolomite. Fissile structure common. Moderately pebbly to pebbly; locally stony. Clasts chiefly dolomite; some limestone, siltstone, sandstone, chert, and erratic igneous and metamorphic rocks. Occurs as ground moraine and as drumlins. Includes areas of outwash and ice-contact sand and gravel (gs, gg, ks, kg), lake clay, silt, sand, and gravel (lca, lsa), alluvium (al), and bedrock outcrop. Locally overlain by eolian sand (ed), peat (hp), or swamp deposits (hs)

- **tkk** Ground moraine and end moraine—Thickness generally 1–15 m
- **tkk** Ground moraine and end moraine under Lake Erie—Some end moraine may be included in unit tae under Lake Erie. Includes areas of bedrock outcrop and local accumulations of boulders. Thickness generally 1–3 m

tkl LOAMY TILL (part of Port Stanley Till)—Pale-brown, yellowish-brown, or reddish-brown to gray, very calcareous silt loam or sandy loam. Nonsorted; nonstratified; locally contains lenses or inclusions of sand. Low plasticity or nonplastic; fissile structure common. Matrix carbonate averages 45 percent, mostly dolomite. Moderately pebbly to pebbly or stony; large dolomite boulders common. Clasts primarily dolomite; some limestone, siltstone, sandstone, and erratic igneous and metamorphic rocks. Occurs as ground moraine and as drumlins. Includes areas of outwash and ice-contact sand and gravel (gs, gg, ks, kg), lake sand and gravel (lsa), and alluvium (al). Locally overlain by peat (hp) or swamp deposits (hs). Thickness generally 2–15 m

tkg LOAMY TILL (Rannoch Till)—Gray to brown, very calcareous silt loam and silty clay loam. Texture becomes finer westward. Nonsorted; nonstratified. Low plasticity. Blocky structure common; secondary carbonate on fracture surfaces. Matrix carbonate averages 50–60 percent, dominantly calcite in south and dolomite in north. Pebbles infrequent, dominantly limestone; some dolomite, chert, sandstone, siltstone, shale, and erratic igneous and metamorphic rocks. Occurs in end moraines and 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 peat (hp) or swamp deposits (hs). Thickness generally 2–6 m; maximum thickness 70 m

tkn LOAMY TILL (Elma Till)—Yellowish-brown to gray, very calcareous silt loam, loam, and silty clay loam; generally more clayey in south and more sandy in north. Nonsorted; nonstratified; generally lacks inclusions of stratified drift. Fissile structure; low plasticity or nonplastic. Matrix carbonate averages 45–55 percent, chiefly dolomite in north and calcite in south. Sparingly pebbly to pebbly; clasts dominantly dolomite in north and limestone in south; some sandstone, siltstone, shale, chert, and erratic igneous and metamorphic rocks. Occurs as ground moraine or as drumlins. 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 veneer of younger till. Thickness generally 2–15 m

tkh LOAMY TILL (Stratford Till)—Pale-brown to yellowish-brown or gray, very calcareous loam and silt loam. Nonsorted; nonstratified. Low plasticity; soft. Matrix carbonate averages 50 percent, calcite and dolomite about equal. Moderately pebbly. Clasts dominantly limestone; some dolomite, sandstone, siltstone, shale, chert, and erratic igneous and metamorphic rocks. Occurs as thin ground moraine. Includes areas of outwash and ice-contact sand and gravel (gs, gg, ks, ke), lake clay, silt, sand, and gravel (lca, lsa), and alluvium (al). Locally overlain by peat (hp) or swamp deposits (hs). Thickness generally 1–3 m

tko LOAMY TILL (part of Tavistock Till)—Light-brown to brown or gray, very calcareous silty clay loam, silt loam, clay loam, and silty clay. Nonsorted; local lenses or thin interbeds of lake sediments. Massive to blocky structure; very stiff; low plasticity. Matrix carbonate averages 35–45 percent, dolomite dominant in north and calcite dominant in south. Pebbles rare. Clasts chiefly dolomite or limestone, depending on local bedrock lithology; some sandstone, siltstone, shale, and erratic igneous and metamorphic rocks. Occurs chiefly as low-relief ground moraine that locally is fluted, or as drumlins; locally as veneer of ground moraine on older end 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 peat (hp), swamp deposits (hs), or a thin veneer of younger till. Thickness generally 2–12 m

tkf LOAMY TILL (part of Tavistock Till)—Yellowish-brown to brown or gray, very calcareous clay loam, silt loam, and sandy loam; locally clayey and silty clay loam. Nonsorted; locally intercalated with stratified sediments. Fissile structure. Low plasticity or nonplastic. Matrix carbonate averages 41 percent; either calcite or dolomite may be dominant. Moderately pebbly. Clasts chiefly limestone; some sandstone, siltstone, shale, and erratic igneous and metamorphic rocks; tillite and jasper conglomerate erratics common locally. Red shale chips in matrix are a diagnostic feature of the till. Occurs as ground moraine and as drumlins. 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 veneer of younger till. Thickness generally 2–12 m

tki LOAMY TILL (Catfish Creek Till)—Yellowish-brown or brownish-gray to gray, very calcareous silt loam, loam, and sandy loam. Nonsorted, nonstratified. Massive, compact; low plasticity or nonplastic. Matrix carbonate averages 35–60 percent, dominantly dolomite. Moderately pebbly to pebbly; cobbles and boulders common. Clasts chiefly dolomite and limestone; some sandstone, siltstone, shale, chert, and 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 generally 2–15 m

teb SANDY LOAMY TILL (Newmarket Till)—Yellowish-brown or brown to light-gray, calcareous loam and sandy loam. Nonsorted; nonstratified; stiff. Matrix averages 30–40 percent carbonate; either calcite or dolomite dominant. Moderately pebbly to pebbly. Clasts chiefly limestone and siltstone, and sandstone, depending on composition of local bedrock; erratic igneous and metamorphic rocks common. Occurs as ground moraine or hummocky end moraine. Includes small areas of outwash and ice-contact sand and gravel (gs, gg, ks, ke), lake clay, silt, sand, and gravel (lca, lsa), and alluvium (al). Thickness generally less than 3 m, locally 12 m

kg ICE-CONTACT SAND AND GRAVEL—Yellowish-brown or pale-brown to gray, generally calcareous sand and gravel. Textures vary laterally and vertically, ranging from fine sand with minor silt and occasional pebbles to cobble and boulder gravel. Locally capped by, interbedded with, or contains lenses or masses of clay, silt, flow till, or till. Sorting variable. Poorly to well stratified; irregularly bedded to well bedded. Faults, folds, and slump and collapse structures common. Locally cemented with calcium carbonate. Clasts rounded to subangular; composition reflects that of local till. Larger clasts chiefly limestone, dolomite, and erratic igneous and metamorphic lithologies on till plains and in lowlands; chiefly sandstone and siltstone on uplands in Ohio, Pennsylvania, and New York. Surfaces generally hummocky to knobby or with isolated mounds; commonly pitted with ice-block depressions. Occurs in kames, kame terraces, kame deltas, kame end moraines, interlobate moraines, eskers, and ice-fracture fillings. Eskers indicated by symbol locally. Kame end moraine (ke) is distinguished only in New York and Pennsylvania. Includes some exhumed early Wisconsin and Illinoian kame and kame terrace deposits (kgb, kgi) in Ohio and Pennsylvania. Throughout mapped areas includes some outwash sand and gravel (gg, gs), lake clay, silt, sand, and gravel (lca, lcc, lsa), alluvium (al), and till. Locally overlain by eolian sand and silt (ed, eu), peat (hp), or swamp deposits (hs). Thickness generally 2–30 m, locally more than 60 m

ks ICE-CONTACT SAND—Yellowish-brown or pale-brown to gray, calcareous fine to coarse sand with minor silt. Poorly to moderately sorted; poorly to well stratified. Folds, faults, and slump and collapse structures common. May contain scattered pebbles. Clast lithology similar to that of outwash sand and gravel (gg) in same area. Surfaces generally hummocky, commonly with ice-block depressions. Occurs in kames, kame deltas, kame terraces, and eskers. Eskers indicated by symbol locally. Includes small areas of ice-contact sand and gravel (kg), outwash sand and gravel (gg, gs), lake clay, silt, sand and gravel (lca, lcc, lsa), and alluvium (al). Locally overlain by eolian sand and silt (ed, eu), peat (hp), or swamp deposits (hs). Mapped only in Ontario; included in ice-contact sand and gravel (kg) elsewhere. Thickness generally 2–30 m

ke KAME END MORAINE—Linear or arcuate end moraine ridges of ice-contact sand and gravel similar to unit kg. Sand and gravel locally capped by, interbedded with, or contains lenses or masses of silt, flow till, or till. In places sand and gravel is intertongued with till or is replaced laterally by till. Occurs as massive valley plugs, arcuate ridges, or systems of imbricated or overlapping ridges. Thickness generally 8–30 m, locally more than 60 m

gg OUTWASH SAND AND GRAVEL—Pale-yellowish-brown, yellowish-brown, pale-brown, or brown to gray sand and gravel. Generally calcareous in glaciated areas, weakly calcareous or noncalcareous in unglaciated areas. Generally pebble or cobble gravel with interbedded sand and local lenses of boulders in Michigan, New York, Ontario, and glaciated Pennsylvania; medium sand and coarse gravel with clay and silt lenses in glaciated Ohio; sand and fine gravel with scattered cobbles and interbedded silt and clay in unglaciated Ohio and Pennsylvania. Well stratified; bedding varies from horizontal beds of well-sorted sand and gravel with local cut-and-fill structures to irregular beds of very poorly sorted cobble or boulder gravel. In valley train deposits in unglaciated Ohio and Pennsylvania, gravel beds alternate with silt beds and are continuous for great distances. Textures generally vary laterally and vertically; textures become finer downstream in valley train deposits. Clast lithology varies with that of local bedrock and till in glaciated terrain. Cobbles and boulders abundant where outwash deposits head near end moraines or ice-contact deposits. Clasts generally rounded; size of largest clasts decreases downstream in valley train deposits. Clasts chiefly sandstone, limestone, dolomite, siltstone, sandy shale, and erratic igneous and metamorphic rocks in Michigan, Ontario, New York, and glaciated Ohio and Pennsylvania; chiefly quartzitic sandstone, cherty sandstone, siltstone, and sandy shale in unglaciated Ohio and Pennsylvania. Gravel locally cemented by calcium carbonate. Surfaces generally smooth; locally pitted with ice-block depressions. Occurs as terrace remnants, valley trains, outwash plains, delta topset beds, outwash fans and aprons, and fills in abandoned meltwater channels. Includes some till, ice-contact sand and gravel (kg, ks), lake silt, sand, and gravel (lca, lcc, lsa), and alluvium (al). In Pennsylvania, includes some early Wisconsin and Illinoian outwash (gga, ggi). Locally overlain by eolian sand and silt (ed, eu), peat (hp), or swamp deposits (hs). In northeastern Ohio and Pennsylvania, locally overlain by thin till. Thickness generally 1–15 m, locally more than 30 m

gs OUTWASH SAND—Pale-brown to gray, calcareous, fine to pebbly coarse sand. Well sorted; well stratified to poorly stratified; beds or lenses of granule or pebble gravel and lenses of silt locally. Clasts rounded. Clast lithology similar to that of outwash sand and gravel (gg) in same area; varies with that of bedrock and till in same region. Occurs principally as sheet deposits beneath terraces and outwash plains and as channel fills. Surfaces smooth or pitted with ice-block depressions. Includes some outwash and ice-contact sand and gravel (gg, kg, ks), lake clay, silt, sand, and gravel (lca, lcc, lsa), alluvium (al), and till. Locally overlain by eolian sand and silt (ed, eu), peat (hp), or swamp deposits (hs). Thickness generally 1–6 m

gkl OUTWASH SAND AND GRAVEL—A complex deposit consisting of outwash sand and gravel (gg), ice-contact sand and gravel (kg), lake silt and clay (lca), and lake sand and gravel (lsa). Includes alluvium (al) inset into older deposits. Locally overlain by eolian sand and silt (ed, eu), peat (hp), or swamp deposits (hs). Mapped only in Pennsylvania. Thickness generally 1–10 m, locally more than 30 m

lcr ATTENUATED LAKE SILT AND CLAY—Thin and discontinuous lake silt and clay (lca) over bedrock. Most of area is wave- or current-washed bedrock. Thickness of silt and clay generally less than 1 m

lla SLACKWATER LAKE SILT AND SAND—Pale-yellow, yellowish-brown, and brown to gray, calcareous to noncalcareous silt and fine sand. In some valleys, chiefly silt with local interbeds of plastic clay or fine sand; in other valleys, chiefly fine sand with interbedded silt. Clasts dominantly local bedrock. Includes extensive alluvium (al) in upper parts of valleys and narrow ribbons of alluvium (al) inset into terraced slackwater lake deposits in lower parts of valleys. Lake deposits commonly grade into or interfinger with alluvium (al) in upper parts of valleys and with outwash sand and gravel (gg) in lower parts of valleys. Deposited in shallow slackwater lakes that formed where an outwash fill in a trunk valley dammed a lake in a tributary valley. Locally overlain by windblown sand and silt. Thickness generally 1–4 m, locally more than 6 m

nlc LOAMY SOLIFLUCTION DEPOSITS[1]—Yellowish-brown, pale-brown, or brown to gray, generally noncalcareous or very weakly calcareous sandy loam, loam, silt loam, silty clay loam, and clay loam. Solifluction deposits comprise approximately half of area mapped as unit nlc; thin, discontinuous, loamy till (tld) on summits of small knolls and hills and in poorly drained bedrock; alluvium; and colluvium on steeper slopes comprise remainder of area. Solifluction and related periglacial deposits similar to those in unit nma; however, block fields, boulder rings, and boulder stripes are uncommon and solifluction deposits locally are composed of redeposited till. Colluvium similar to that in unit nla; locally consists of till redeposited by creep. Includes areas of bedrock outcrop, valley-bottom deposits of alluvium (al), and landslide deposits. Thickness of solifluction deposits generally less than 1–3 m on upper parts of slopes, 2–3 m on lower parts of slopes; occasionally more than 6 m at bases of slopes. Thickness of till generally less than 2 m. Thickness of colluvium generally 1–3 m

LATE WISCONSIN AND MIDDLE WISCONSIN

lch LAKE SAND, SILT, AND CLAY—A complex deposit in bluffs on north shore of Lake Erie, consisting of postglacial and deglacial lake sand, silt, and clay; 2–6 units of late Wisconsin clayey Port Stanley Till with interbedded lake deposits; several units of late Wisconsin loamy Catfish Creek Till with associated ice-contact sand and gravel and interbedded lake deposits; and middle Wisconsin and early Wisconsin lake silt and clay (stratigraphic section 1). Youngest lake deposits similar to units lsa and lca. Port Stanley Till (tae) purplish gray, very calcareous silty clay, silty clay loam, and silt loam; very few clasts. Catfish Creek Till (tki) generally gray, very calcareous sandy loam or loam; abundant clasts and interbedded sand and gravel. Total thickness generally 10–35 m

WISCONSIN

lcj LAKE SAND, SILT, AND CLAY—A complex deposit in bluffs on northwest shore of Lake Ontario in Ontario, consisting of deglacial and postglacial lake sand; late Wisconsin Halton Till; lake clay, silt, and sand of late Wisconsin and middle Wisconsin upper member of Thorncliffe Formation; middle Wisconsin Meadowcliffe Till; lake clay, silt, and sand of middle Wisconsin middle member of Thorncliffe Formation; middle Wisconsin Seminary Till; lake clay, silt, and sand of middle Wisconsin and early Wisconsin lower member of Thorncliffe Formation; early Wisconsin Sunnybrook Till; fluvial sand of early Wisconsin Pottery Road Formation; deltaic sand of early Wisconsin upper member of Scarborough Formation; and lake clay of early Wisconsin lower member of Scarborough Formation (stratigraphic section 3). Youngest lake deposits similar to unit lsa; Halton Till is unit tka. The three members of Thorncliffe Formation consist chiefly of well-stratified fine sand, locally with deltaic foreset beds, and subordinate massive silt and varved clay and silt. Meadowcliffe Till gray calcareous clayey till; clasts chiefly limestone, erratic igneous and metamorphic rocks, and shale, with minor dolomite. The Seminary Till gray, calcareous, moderately stony clay loam; clasts chiefly limestone and shale, with minor dolomite and igneous and metamorphic rocks. Sunnybrook Till (tar) dark-gray calcareous clay loam, clay, silty clay loam, and silty clay; clasts chiefly limestone and shale, with minor erratic igneous and metamorphic rocks, dolomite, and sandstone. Pottery Road Formation is channel sand. Upper member of Scarborough Formation is deltaic coarse sand with foreset beds and crossbeds; lower member is bedded clay, silt, and sand with disseminated plant detritus. Total thickness generally 30–50 m, locally more than 100 m

lgk LAKE GRAVEL, SAND, SILT, AND CLAY—A complex deposit of late Wisconsin, middle Wisconsin, and early Wisconsin stratified materials and till. Undifferentiated late Wisconsin lake silt and clay (lca) and sand and gravel (lsa) overlie late Wisconsin outwash sand and gravel (gg), middle Wisconsin alluvium (al), early Wisconsin sandy loamy till (tdg), outwash sand and gravel (gga), and ice-contact sand and gravel (kgb) in valleys and on gentle slopes. Till, outwash, and ice-contact sediments on hills and steeper slopes. Lake sediments in valleys dissected and interrupted by inset deposits of younger late Wisconsin outwash sand and gravel (gg) and alluvium (al), all of which are included in unit lgk. Stratified deposits locally overlain by windblown silt (loess). Mapped only in northeastern Ohio, in an area that projected as a nunatak during maximum late Wisconsin glaciation. Thickness of lake sediments generally 1–10 m

EARLY WISCONSIN

tar CLAYEY TILL (Sunnybrook Till in Ontario)—Dark-gray or gray, calcareous clay loam, clay, silty clay loam, and silty clay. Nonsorted; nonstratified. Low to moderate plasticity. Matrix carbonate ranges from 12 to 20 percent; calcite generally dominant. Nearly pebble free. Clasts chiefly limestone; minor dolomite, shale, sandstone, and erratic igneous and metamorphic rocks. Mapped only in vicinity of Toronto. Thickness generally 6–9 m, locally 30 m

tlj LOAMY TILL (Millbrook Till in northeast-central Ohio)—Olive-brown to dark-olive-gray, weakly calcareous loam and silt loam with abundant lenses of gravel, sand, and silt. Weathered; commonly leached throughout. Nonsorted to very poorly sorted; dense, hard, compact. Irregular blocky structure; breaks around pebbles and cobbles and breaks through sand grains. Intense manganese oxide and iron oxide stains on clasts and joint surfaces. Pebbly to stony; cobbles and boulders common. Pebbles, especially granite, commonly partly to completely rotted. Discontinuous. Smooth, rolling erosional surface topography; subdued constructional topography rare. Includes solifluction deposits (nma), colluvium (cl), and areas of bedrock outcrop; locally includes ice-contact sand and gravel (kgb) and alluvium (al). Locally overlain by windblown sand and silt (eu) or swamp deposits (hs). Thickness generally less than 3 m, locally more than 10 m

tle LOAMY TILL (Titusville Till in Pennsylvania)—Olive-brown to light-olive-gray, light-gray, or dark-gray, weakly calcareous loam, silt loam, and sandy loam with lenses of gravel, sand, and silt. Intensely weathered; generally leached throughout. Nonsorted to very poorly sorted. Upper part typically loose and stony, with horizontal parting; lower part generally compact, dense, hard. Intense manganese oxide and iron oxide stains on surfaces of joints and clasts. Moderately pebbly to stony; cobbles and boulders common. Pebbles and cobbles chiefly sandstone, siltstone, and sandy shale; boulders chiefly erratic igneous and metamorphic rocks and quartzite. Commonly discontinuous. Smooth, rolling, erosional surface topography; subdued constructional topography very rare. Dissection nearly identical to that in region to east, characterized by loamy solifluction deposits and very thin and discontinuous Illinoian till (nlb). Includes solifluction deposits (nma), colluvium (cl), and areas of bedrock outcrop; locally includes outwash sand and gravel (gg), ice-contact sand and gravel (kgb), and alluvium (al). Locally overlain by windblown sand and silt (eu), peat (hp), or swamp deposits (hs). Thickness generally 1.5–3 m, locally more than 10 m

tdg SANDY LOAMY TILL (Mogadore Till in northeastern Ohio)—Yellowish-brown to bluish-gray or dark-gray, weakly calcareous sandy loam and loam with abundant interbeds and lenses of gravel, sand, silt, and flow till. Nonsorted to very poorly sorted; dense, hard, compact. Intense manganese oxide and iron oxide stains on surfaces of joints and clasts. Pebbly; commonly cobbly or bouldery. Clasts chiefly sandstone, siltstone, limestone, dolomite, and shale. Consists of ground moraine and subdued hummocky stagnation moraine that cannot be distinguished at this scale. Depressions on hummocky surfaces generally filled with solifluction deposits (nma), alluvium (al), lake deposits (lca, lsa), peat (hp), or swamp deposits (hs). Includes some ice-contact sand and gravel (kgb), outwash sand and gravel (gg, gkl), lake clay, silt, sand, and gravel (lca, lsa), and areas of bedrock outcrop. Locally overlain by windblown sand and silt (eu), peat (hp), or swamp deposits (hs). Thickness generally 2–6 m, locally more than 10 m

kgb ICE-CONTACT SAND AND GRAVEL—Pale-brown or brown to gray, calcareous sand and gravel. Textures vary laterally and vertically, ranging from fine sand with minor silt and occasional pebbles to cobble and boulder gravel. Locally interbedded with or contains lenses or masses of clay, silt, flow till, or till. Sorting variable. Poorly to well stratified; irregularly bedded to well bedded. Faults, folds, and slump and collapse structures common. Locally cemented with calcium carbonate. Clasts rounded to subangular; clast composition reflects that of associated till (tle, tdg) in same area. Pebbles and cobbles chiefly sandstone, siltstone, limestone, and dolomite in Ohio; sandstone, siltstone, sandy shale, and quartzite in Pennsylvania. Boulders chiefly sandstone, limestone, dolomite, and erratic igneous and metamorphic rocks in Ohio; sandstone and erratic quartzite, granite, gneiss, and greenstone in Pennsylvania. Surface morphology generally subdued; depressions nearly filled with solifluction deposits (nma), alluvium (al), peat (hp), or swamp deposits (hs). Occurs in kames, kame terraces, and kame deltas. Includes some outwash sand and gravel (gg, gkl), lake clay, silt, sand, and gravel (lca, lcc, lsa), alluvium (al), and till (tle, tdg). Locally overlain by windblown sand and silt (eu). Thickness generally 2–30 m, locally more than 60 m

WISCONSIN AND ILLINOIAN

nma CLAYEY TO SANDY SOLIFLUCTION DEPOSITS[1]—Yellowish-brown or brown to gray, generally noncalcareous or weakly calcareous clayey to sandy debris on moderate to steep slopes. Rock fragments may comprise less than 2 percent to nearly 100 percent of deposits. Matrix may vary from clay to sand, reflecting composition of bedrock higher on slopes. In north, solifluction deposits are chiefly either (1) heterogeneous, nonstratified, nonsorted rubble, consisting of angular or subangular flagstones or channers with voids and little or no matrix; or (2) imbricated subangular or angular flagstones or channers in a silty or sandy matrix. Farther south, solifluction deposits are chiefly either (1) faintly stratified silty clay loam with occasional fragments of sandstone, siltstone, and shale; or (2) massive silty clay with few or no rock fragments. Clasts chiefly sandstone, siltstone, and shale, locally limestone or conglomerate, derived from bedrock higher on slopes. Transportation and deposition inferred to have occurred contemporaneously with glaciation farther north. Small block fields, boulder stripes, colluvial fans, and other phenomena indicative of severe periglacial frost activity common locally. Deposits generally stable, with well-developed soil profiles; modified by creep and landslide activity locally. Included landslide deposits have hummocky topography and occur mainly in short, steeply sloping tributary valleys. Landslide deposits generally are 0.1–0.5 km wide and less than 0.5 km long. Landslide deposits generally comprise less than 5 percent of unit and are more abundant in north, near limit of glacial deposits. Includes small areas of colluvium, residuum, and bedrock outcrop. Thickness of solifluction deposits generally 1–3 m on gentle slopes, locally 6–10 m at bases of slopes; thickness of block-field deposits generally less than 10 m; thickness of landslide deposits generally less than 5 m, locally 10 m

nla LOAMY SOLIFLUCTION DEPOSITS[1]—Yellowish-brown, pale-brown, or dark-brown to gray or black, generally noncalcareous to very weakly calcareous sandy loam, loam, silt loam, silty clay loam, and clay loam on uplands. Solifluction deposits comprise 50–70 percent of area mapped as unit nla; remainder is undifferentiated colluvium and residuum. Solifluction deposits are chiefly either (1) faintly stratified sandy loam, loam, silt loam, silty clay loam, or clay loam with occasional clasts or fragments of sandstone, siltstone, shale, and limestone; or (2) massive silty clay loam or clay loam with few or no rock fragments. Small block fields, boulder rings, boulder stripes, areas of patterned ground, and other phenomena indicative of periglacial frost activity common in north, near limit of glacial deposits. Colluvium included generally is pale-brown or dark-brown to light- or dark-gray, poorly sorted to massive, pebbly to bouldery debris that was transported and deposited by creep on slopes. Residuum included is yellowish-brown, pale-brown, or brown, stony to pebble-free loamy material that is a product of in-place decomposition of sandstone, siltstone, shale, and limestone on flat or gentle slopes. Includes some areas of bedrock outcrop and landslide deposits. Thickness of solifluction deposits generally 1–3 m; thickness of block-field deposits generally less than 10 m. Thickness of colluvium generally 1–2 m on upper parts of slopes, 2–3 m on lower parts of slopes. Thickness of residuum generally less than 1 m on flat surfaces, 1–2 m on very gentle slopes

nlb LOAMY SOLIFLUCTION DEPOSITS[1]—Similar to loamy solifluction deposits (nla), but distinguished on the basis of presence of discontinuous sandy loamy till (Mapledale Till) of Illinoian age. Solifluction deposits locally consist of redeposited till. Till is dark-yellowish-brown, noncalcareous, moderately pebbly to stony sandy loam, loam, and clay loam. Till thin, intensively weathered, and very discontinuous. Cobbles and boulders chiefly sandstone, siltstone, and shale; erratic clasts dominantly quartzite. Boulders of quartzite, granite, gneiss, and greenstone, generally less than 0.4 m in diameter, scattered widely on land surface. Topography maturely to submaturely dissected and only slightly less eroded than adjacent unglaciated topography. Includes some sheetwash alluvium (al), stream alluvium (al), areas of bedrock outcrop, and landslide deposits. Included till and residuum locally overlain by less than 1 m of windblown silt (loess). Thickness of solifluction deposits generally 1–3 m. Thickness of colluvium generally 1–2 m on upper parts of slopes, 2–4 m on lower parts of slopes, locally more than 10 m at toes of colluvial fans and aprons. Thickness of residuum generally 1–2 m on flat surfaces, less than 1 m on very gentle slopes. Thickness of till generally less than 1 m

EARLY WISCONSIN AND ILLINOIAN

gga OUTWASH SAND AND GRAVEL—Yellowish-brown, pale-brown, or brown to gray sand and gravel. Generally pebble or cobble gravel with interbedded sand and lenses of boulders or silt. Calcareous where not leached. Well stratified; bedding varies from horizontal beds of well-sorted sand and gravel with local cut-and-fill structures to irregular beds of poorly sorted cobble or boulder gravel. Textures vary laterally and vertically. Clast lithology varies with that of associated till (included in unit cld). Clasts rounded, chiefly sandstone, siltstone, sandy shale, and erratic igneous and metamorphic rocks. Occurs in terrace remnants at multiple levels; higher remnants may be Illinoian in age and lower remnants may be early Wisconsin. Includes inset late Wisconsin outwash sand and gravel (gg) and alluvium (al). Locally overlain by windblown sand and silt. Mapped only in eastern Ohio. Thickness generally 1–3 m

llb SLACKWATER LAKE SILT AND SAND—Pale-yellow, yellowish-brown, or dark-brown to gray, weakly calcareous or noncalcareous silt and fine sand, locally with interbeds of plastic clay. Intensely weathered and dissected. Occurs in terrace remnants in valleys tributary to major outwash valley fills. Lake deposits grade into or intertongue with outwash in lower parts of valleys. Includes inset deposits of alluvium (al). Locally overlain by windblown sand and silt (eu). Thickness generally 1–4 m, locally more than 6 m

ILLINOIAN

CLAYEY TILL—Yellowish-brown, brown, or mottled brown and gray to bluish-gray, weakly calcareous clay and silty clay. Contains lenses of poorly sorted gravel. Nonsorted to very poorly sorted. Hard, compact, dense; sticky where moist. Moderately pebbly to stony; clasts dominantly sandstone and siltstone channers. Intensely weathered; leached throughout where less than 3 m thick. Mapped only in New York

- **tcm** Ground moraine—Thickness generally 2–4 m
- **tcm** End moraine—Subdued till ridges. Thickness locally more than 18 m

tlm LOAMY TILL (Butler Till in east-central Ohio)—Yellowish-brown, dark-yellowish-brown, dark-brown, or grayish-brown to dark-gray, weakly calcareous loam, clay loam, and silt loam. Nonsorted to very poorly sorted. Thick clay skins and intense iron oxide and manganese oxide stains on joint surfaces. Dense, hard, compact; oxidized till typically has platy horizontal parting. Pebbly; locally stony; boulders uncommon. Clasts chiefly sandstone fragments; limestone ghosts and rotted granite pebbles common in leached till. Intensely weathered; generally leached throughout where less than 3 m thick. Generally thin and discontinuous; thick till locally on lower slopes, where it is covered by colluvium and solifluction deposits. Smooth, rolling, erosional topography; subdued constructional topography (stagnation moraine) locally on lower slopes in major valleys. Includes areas of solifluction deposits, colluvium, bedrock outcrop, and landslide deposits. Commonly overlain by windblown sand and silt (eu) or alluvium (al). Thickness generally less than 3 m on uplands, 3–6 m on lower slopes

tlo LOAMY TILL—Light-orange-red, orange-yellow, brownish-yellow, yellowish-brown, pale-brown, brown, brownish-gray, gray, or mottled, moderately calcareous to noncalcareous silt loam, clay loam, and silty clay loam. Intensely weathered; leached and porous in upper 3 m. Thick clay skins and intense manganese oxide and iron oxide stains on joint surfaces. Sparingly pebbly to moderately stony; pebbles and cobbles common, boulders rare. Clasts dominantly local acid shale, sandstone, coal, flint, and chert; erratic clasts chiefly limestone, granite, granitic gneiss, and quartzite. Weak constructional topography retained locally. Mapped only where extensive and more than 2 m thick; till is included in unit clc where discontinuous. Commonly overlain by windblown silt (loess) 1–2 m thick. Mapped only in east-central Ohio. Thickness generally more than 6 m; maximum thickness more than 45 m in buried valleys

kgi ICE-CONTACT SAND AND GRAVEL—Yellow, red, reddish-brown, or brown to brownish-gray sand and gravel. Noncalcareous in New York, calcareous in Ohio where not leached. Textures vary laterally and vertically, ranging from fine sand with occasional pebbles to cobble gravel with lenses of flow till. Generally well stratified and moderately to poorly sorted. Sand commonly crossbedded. Gravel uncemented in New York; commonly cemented by secondary calcium carbonate in Ohio. Faults, folds, and slump and collapse structures common. Clasts rounded to subangular; clast composition reflects that of associated till (tcm, tlo). In New York, clasts dominantly sandstone and siltstone; in Ohio, chiefly limestone, sandstone, and sandy shale. Very subdued hummocky topography locally; ice-block depressions generally filled with alluvium (al), windblown deposits (eu), peat (hp), or swamp deposits (hs). Occurs in kames and dissected kame terrace remnants. Includes small deposits of outwash sand and gravel (ggi), till (tlo), and alluvium (al). Locally overlain by windblown silt, peat (hp), or swamp deposits (hs). Thickness generally 2–20 m, locally more than 30 m

ggi OUTWASH SAND AND GRAVEL—Pale-yellow, yellow, red, reddish-brown, or brown to dark-grayish-brown sand and gravel. Generally calcareous or weakly calcareous where not leached. In Ohio, generally horizontally bedded gravel underlain by plastic silt and clay; gravel locally cemented by secondary calcium carbonate. In New York, dominantly bedded, commonly crossbedded pebble and cobble gravel with subordinate sand. Intensely weathered, chiefly sheetflow or till-capped. Clasts rounded. Clasts chiefly quartzite, sandstone, sandy shale, cherty sandstone, concretions, and resistant erratic igneous and metamorphic rocks. Depressions filled with alluvium (al), windblown sand and silt (eu), peat (hp), or swamp deposits (hs). Includes small areas of late Wisconsin outwash sand and gravel (gg) and alluvium (al). Commonly overlain by windblown silt 0.5–3 m thick; locally overlain by peat (hp) or swamp deposits (hs). Thickness generally 3–6 m, locally more than 30 m

lci LAKE CLAY AND SILT—Yellow, yellowish-brown, grayish-brown, or mottled yellow and grayish-brown to gray or bluish-gray, calcareous to noncalcareous clay and silt, locally with minor fine sand. Well bedded to massive; commonly laminated or varved. Locally underlain by gravel and sand. Commonly dissected by deep gullies. Occurs in terrace remnants in valleys blocked by Illinoian ice. Includes some outwash and ice-contact sand and gravel (ggi, kgi) and alluvium (al). Locally overlain by windblown sand and silt. Thickness generally 2–10 m

ILLINOIAN AND PRE-ILLINOIAN

lle LAKE SAND, SILT, AND CLAY (Carmichaels Formation in Pennsylvania)—Pale-yellow, yellow, orange-red, red, reddish-brown, yellowish-brown, or brown, generally noncalcareous sand, silt, and clay. Stratified; moderately to well sorted. In many areas, intensely weathered coarse channel gravel is overlain by less weathered slackwater lake sediments consisting of upward-fining sand, irregularly bedded sand, interbedded sand and clay, or sand with lenses of silt and clay, similar to units lla and llb. Clasts local bedrock lithologies, dominantly resistant sandstone and sandy shale. Occurs in remnants of two terraces. Slackwater lake deposits in highest terrace remnants (as much as 90 m above present streams) have reversed remanent magnetic polarity, indicating early Pleistocene age; deposits in lower terrace remnants have normal polarity and are correlated with Illinoian till included in units nlb and cld (R. B. Jacobson, D. P. Elston, and J. W. Heaton, unpub. data, 1987). Locally overlain by colluvium, sheetwash alluvium, or windblown sand and silt. Thickness generally 1–30 m

QUATERNARY

rci LOAMY TO CLAYEY SOLUTION RESIDUUM[1]—Pale-yellow, yellowish-brown, yellowish-red, or reddish-brown, noncalcareous to weakly calcareous silt loam, silty clay loam, clay loam, silty clay, and clay. Chiefly solution residuum derived by in-place solution of limestone and dolomite that locally contain thin interbeds of shale and sandstone. Generally tough, moderately plastic to plastic, silt loam to clay. Contains fragments of chert where developed on siliceous carbonate rocks; fragments of chert, shale, and sandstone where developed on interbedded carbonate and clastic rocks. Includes colluvium on moderately steep slopes and foot slopes. Colluvium is poorly sorted, poorly stratified material with angular to subangular fragments of limestone, dolomite, and chert; fragments of shale and sandstone common locally. Colors generally darker in colluvium than in residuum. Outcrops of bedrock common locally. Sinkholes and underground caverns common. Thickness of solution residuum generally less than 1 m; thickness of colluvium generally 1–3 m, locally more than 10 m

zla LOAMY DECOMPOSITION RESIDUUM[1]—Pale yellow, yellowish-brown, brown, or dark-brown, noncalcareous to weakly calcareous sandy loam, loam, and silt loam on ridge crests. Chiefly residuum derived by in-place decomposition of sandstone and minor shale. Includes areas of heterogeneous, nonstratified, nonsorted rubble formed by frost shattering of sandstone and quartzitic sandstone. Bouldery where derived from quartzitic sandstone; channery where derived from bedded sandstone; small sandstone and shale fragments common elsewhere. Residuum commonly grades laterally into bouldery colluvium and rock waste (cbb) and colluvium on slopes. Includes extensive areas of bedrock outcrop. Thickness of residuum generally 1–2 m; thickness of frost-shattered rubble locally 3–5 m

zlb LOAMY DECOMPOSITION RESIDUUM[1]—Yellowish-brown, brown, reddish-brown, or purple, noncalcareous silt loam, loam, and clay loam with clasts of acid shale and sandstone on flat or gentle slopes. Includes channery colluvium on steeper foot slopes and scattered bedrock outcrops. Thickness of residuum generally less than 1 m; thickness of colluvium generally 2–4 m

PRE-QUATERNARY

R BEDROCK

[1]For purposes of this map, solifluction deposit is a general term for material transported and deposited by viscous flow of unconsolidated debris saturated with water. Colluvium is material transported and deposited by mass-wasting processes, chiefly creep. Sheetwash alluvium is material transported and deposited by unconfined running water, chiefly sheetflow or rill wash. Decomposition residuum is material derived by in-place decomposition of clastic bedrock, with no appreciable subsequent lateral transport. Solution residuum is insoluble residues derived chiefly by in-place solution of carbonate rocks, with no appreciable subsequent lateral transport.

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