EXPLANATION

CENOZOIC

HOLOCENE

Has — Alluvial sand and silt

Medium to coarse sand with subordinate intercalated silt and gravel; loosely packed and permeable; generally oxidized and noncalcareous; mellow, but commonly with high water table.

Floodplain deposits of streams in mature reaches. Overbank deposition by streams flowing on low gradients and in open valleys.

Hag — Alluvial gravel

Pebble to cobble gravel with subordinate medium to coarse sand; loosely packed and permeable; generally oxidized and noncalcareous; locally bouldery.

Alluvial fan and channel deposits of streams flowing on steep gradients or emanating from narrow valleys into rapidly aggrading reaches.

Hls — Beach sand and gravel

Coarse sand with subordinate medium sand and gravel lenses; cross-bedded; highly permeable generally well sorted, without significant silt or clay.

Strand and nearshore deposits of large lakes in basins possessing closure independent of the former receding glacier margin, hence persisting after deglaciation. Notable are shore deposits of Lakes Erie and Ontario and former Lake Tonawanda.

Hlc — Lake silt, sand and clay

Silt, fine to medium sand and clay; thin-bedded to massive; in part very regularly bedded with cyclic alternation of clay and silt laminae; moderately permeable along along bedding surfaces.

Offshore deposits of lakes in basins which did not require an impounding ice margin for closure, hence persisted after deglaciation. Notable among filled basins is that of former Lake Tonawanda.

Hws — Wind deposited sand

Fine to medium sand; well sorted; oxidized and noncalcareous; cross-bedded; highly permeable. Closely associated with strand and nearshore deposits of postglacial lakes.

Wind-reworked littoral and beach sand initially deposited in postglacial lake basins.

Hpm — Peat, marl and muck

Bog deposits, dominantly peat and muck with subordinate gyttja; marl is a major component except in the southern tier of counties. Silt and clay are intercalated at base of organic section.

Deposition during late stages of in-filling of pond and lake basins, including numerous kettles and other shallow depressions on glacial drift; also parts of former Lake Tonawanda such as the Oak Orchard and Bergen Swamps.

PLEISTOCENE — WISCONSINAN — Woodfordian

Wls — Beach sand and gravel of ice-dammed lakes

Coarse sand with subordinate meduim sand and gravel lenses; cross-bedded; well-sorted and without significant silt or clay; highly permeable.

Strand and nearshore deposits in proglacial Lakes Whittlesey and Warren in the Erie Basin and Lake Iroquois in the Ontario Basin.

Includes suitable material for generally small scale sand and gravel production.

Wlc — Lake silt, sand and clay

Silt, fine to medium sand and clay; thin-bedded to massive; regularly bedded, in part with cyclic alternation of clay and silt laminae; moderate bedding plane permeability.

Offshore deposits in basins which required ice marginal impondment for closure; includes primitive lakes in northward-draining troughs as well as ancestral Lakes Whittlesey and Warren in the Erie Basin and Lake Iroquois in the Ontario Basin.

Wem — End moraine

Includes both ablation and lodgment till; till generally rather stony with limited admixture of poorly sorted gravel; carbonate and crystalline clasts generally exceed 20%; thickness and permeability variable but generally greater than in associated ground moraine.

Deposited by melting of ice at edge of ice sheet either at end of an advance or during stillstand at a stable ice-border position.

See figure 2 for names of principal moraines and schematic representation of chronology of glacial advance and retreat.

Wgm — Ground moraine

Dominantly lodgment till; silty clay till and sandy till; sparsely to moderately stony; carbonate and crystalline clasts generally exceed 20%; compact and generally very impermeable.

Variably comminuted rock material, transported by and lodged beneath actively flowing ice of the continental ice sheet.

Wkg — Ice-contact stratified drift

Coarse gravel and sand; sorting, poor and variable; ranges from sand to boulder gravel; in some areas with subordinate lenses of unsorted flow till; attitude of beds variable; moderately to highly permeable; carbonate and crystalline clasts comprise more than 20% and commonly dominate coarse fraction; locally indurated by secondary calcium carbonate.

Deposition as ablation moraine, mudflow and by meltwater streams distributing drift on stagnant ice to be deposited finally as the buried ice melted. Steep slopes commonly mark former ice-contact surfaces.

Comprises a major gravel source, but requires washing and crushing for many purposes.

Wog — Outwash, terrace and delta gravel

Pebble and cobble gravel with subordinate sand; well sorted; extremely permeable; carbonate and crystalline clasts generally exceed 30% of the coarse fraction; locally cemented by secondary calcium carbonate.

Deposition by strongly aggrading streams flowing from former ice sheets. Coarse alluvium deposited in coalescent aprons near the ice sheet, or as valley trains where streams drained freely from the glacier margin. Commonly persist as stream terraces or terrace remnants. Includes minor lenses of very coarse torrent (hlaup) deposits.

Comprises a major source of relatively clean and uniform gravel.

PLEISTOCENE — WISCONSINAN — Altonian

Aem — End moraine

Includes both ablation and lodgment till; silty clay till to sandy till; moderately to abundantly stony with admixture of poorly sorted gravel; sandstone and siltstone channers generally comprise more than 80% of coarse fraction; permeability and thickness variable but generally greater than for associated ground moraine.

Deposited by melting of ice at edge of ice sheet either at end of an advance or during stillstand at a stable ice-border position.

Agm — Ground moraine

Dominatly lodgment till but locally with a veneer of variably washed ablation drift; clay till, silty clay till and sandy till; moderately to abundantly stony; siltstone and sandstone channers comprise more than 80% of coarse fraction; deeply oxidized and essentially noncalcareous; compact and generally impermeable.

Variably comminuted rock material, transported by and lodged beneath actively flowing ice of the continental ice sheet.

Akg — Ice-contact stratified drift

Coarse gravel and sand; sorting poor and variable; ranges from sand to boulder gravel, in some areas with subordinate lenses of unsorted flow till; attitude of beds variable; moderately to highly permeable; siltstone and sandstone generally more than 80% of coarse fraction; generally uncemented.

Deposition as ablation moraine, mudflow and by meltwater streams distributing drift on stagnant ice to be deposited finally as the buried ice melted. Steep slopes commonly mark former ice-contact surfaces.

Comprises a major gravel source but requires washing and crushing for many purposes.

Aog — Outwash, terrace and delta gravel

Pebble and cobble gravel with subordinate sand; well sorted; extremely permeable; carbonate and crystalline clasts generally less than 30% of the coarse fraction; generally uncemented.

Deposition by strongly aggrading streams flowing from former ice sheets. Coarse alluvium deposited in coalescent aprons near the ice sheet, or as valley trains where streams drained freely from the glacier margin. Commonly persist as stream terraces or terrace remnants.

Comprises a major source of relatively clean and uniform gravel.

PLEISTOCENE — ILLINOIAN

Iem — End moraine

Includes both ablation and lodgment till; silty clay till; moderately to abundantly stony with admixture of poorly sorted gravel; sandstone and siltstone channers dominate coarse fraction; permeability and thickness variable but generally greater than for associated ground moraine.

Deposited by melting of ice at edge of ice sheet either at the end of an advance or during stillstand at a stable ice-border position.

Igm — Ground moraine

Dominantly lodgment till but with local veneer of variably washed ablation drift; clay till to silty clay till; moderately to abundantly stony; siltstone and sandstone channers dominate coarse fraction; deeply oxidized and essentially noncalcareous; compact and generally impermeable.

Variably comminuted rock material, transported by and lodged beneath actively flowing ice of the continental ice sheet.

Ikg — Ice-contact stratified drift

Coarse gravel with subordinate pebbly sand; well stratified but laterally variable, ranging from sand to coarse gravel and subordinate lenses of unsorted flow till; attitude of beds variable; moderately to highly permeable; siltstone and sandstone dominate coarse fraction; oxidized and essentially noncalcareous; uncemented.

Deposition as ablation moraine, mudflow and by meltwater streams distributing drift on stagnant ice to be deposited finally as the buried ice melted. Steep slopes commonly mark former ice-contact surfaces.

Of minor extent near limit of glaciation where it is an important gravel source.

Iog — Outwash and terrace gravel

Pebble and cobble gravel with subordinate sand; well-sorted; extremely permeable; carbonate and crystalline clasts generally less than 30% of the coarse fraction; generally uncemented; contains lower proportion of shale than in associated materials; oxidized and noncalcareous in general.

Deposition by strongly aggrading streams flowing from ice sheets. Coarse alluvium deposited as valley trains and preserved as limited terrace remnants beyond the glaciated region.

Comprises a potential source of gravel.

PALEOZOIC*

Psh — Shale

Fine-grained clastic rocks; fissile, thin bedded; generally frost-brecciated and softened by surface weathering.

Mapped in areas where regolith is less than 5 feet thick or comprises less than 50% cover over dominantly shaly bedrock. Areas of non-deposition of glacial drift, or of thin and patchy cover, or of subsequent erosion exposing shale.

Pss — Siltstone and sandstone with minor conglomerate units

Medium to coarse-grained clastic rocks; well stratified; ranging from thin-bedded to thick-bedded.

Mapped in areas where regolith is less than 5 feet thick or comprises less than 50% cover over dominantly clastic bedrock. Areas of non-deposition of glacial drift, or of thin and patchy cover, or of subsequent erosion exposing siltstone and sandstone.

Pld — Limestone and dolomite

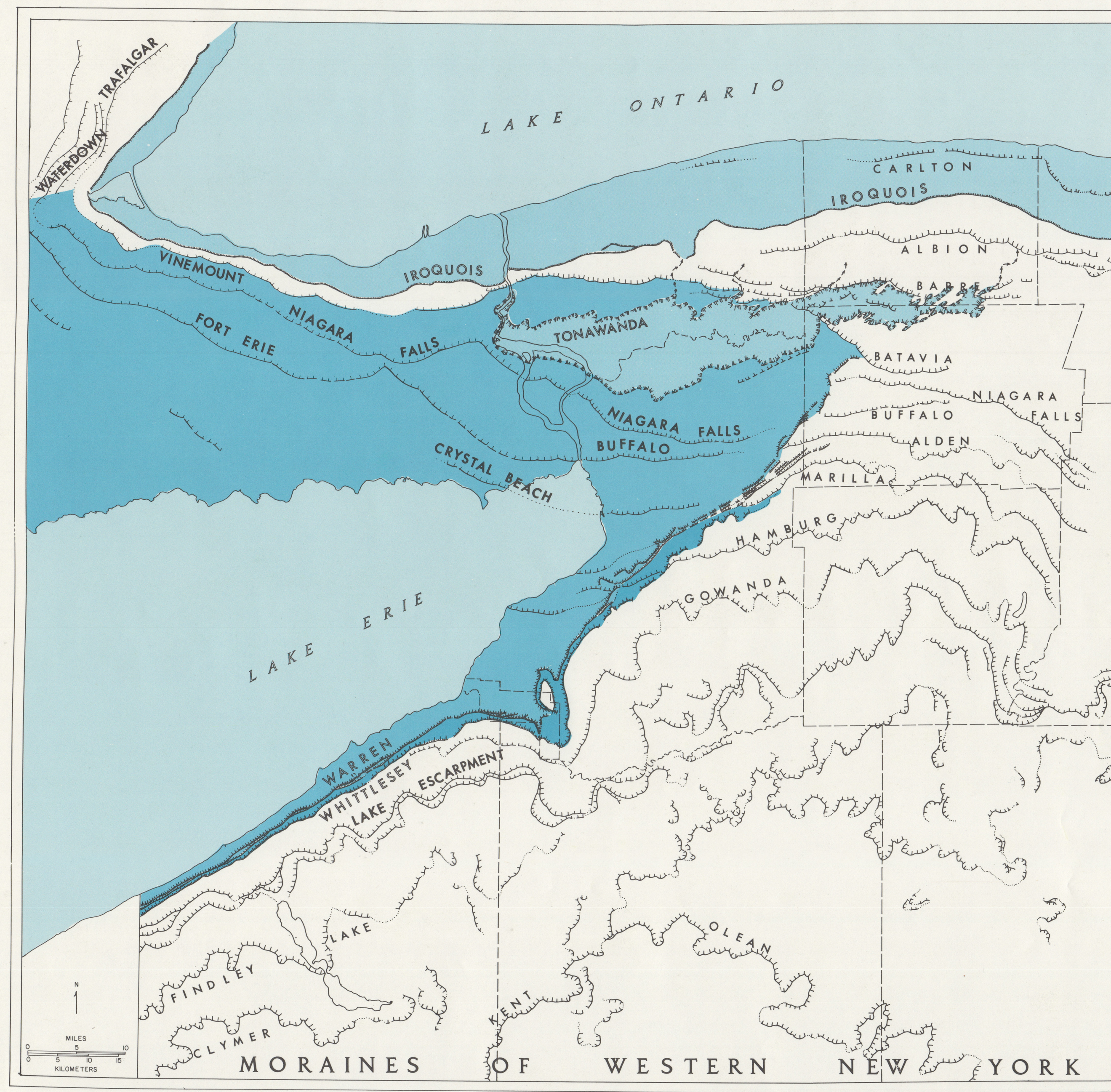
Marine carbonate rocks; well stratified; ranging from thin-bedded to medium-bedded.

Mapped in areas where regolith is less than 5 feet thick or comprises less than 50% cover over dominantly carbonate bedrock. Areas of non-deposition of glacial drift or of thin and patchy cover, or of subsequent erosion exposing siltstone and sandstone.

Map Symbols

- Contact; dashed where uncertain
- Glacier marginal positions; dashed, position uncertain; dotted, position inferred; hachures toward glacier.
- Direction of flow of glacial lake outlet
- Strandline
- Wave-cut cliff; dashed, weakly developed; hachures toward lake.
- Beach or bar; hachures toward lake.
- Inferred pre-glacial drainage divide.
- Striae: sense of flow indicated; undetermined sense of flow
- Type and reference section.
- Esker
- Glacial meltwater channels, col elevation in feet.
- Approximate position of drift-filled bedrock valley.
- 19. Dated radiocarbon locality

*Paleozoic rocks are not differentiated with respect to age. For information on classification, distribution, origin, and stratigraphic relationships refer to Niagara Sheet, Geologic Map of New York, New York State Museum & Science Service, Map and Chart No. 15



RADIOCARBON DATING

A small fraction of a percent of the Carbon atoms in all living matter is made up of the radioactive isotope $_{14}C$ (Radiocarbon) which disintegrates spontaneously with a half life of 5570±130 years. In fossil organic material the ratio of remaining Radiocarbon atoms to atoms of the stable isotopes of Carbon affords a basis for estimating the duration of time since the organism died.

The chronology of Wisconsin glacial events in western New York is pegged to absolute ages by radiocarbon assays of material collected from less than a score of localities which are located on the Quaternary Geology Map, and listed below. Published reference to the dated materials and the localities where they were collected are listed.

SITE	NAME, TOWN	QUADRANGLE, COUNTY	YEARS B.P.	LAB.	REMARKS: MATERIAL, STRATIGRAPHY, LOCATION, SIGNIFICANCE	PUBLISHED REFERENCES
1	Otto, Otto	Cattaraugus, Cattaraugus	>35,000 >38,000	W-87 W-688	Peat near stream level, S. Br. Cattaraugus Creek, S edge of Otto. **Picea** and **Pinus** dominate pollen spectra.	24, 12
			>52,000	GrN-2565 GrN-2632	Carb. silt in gravel beneath lake clay, 2 tills left bank, S. Br. Cattaraugus Cr., S edge of Otto.	17, 16, 12
			63,900±17,000	GrN-2634	Peat beneath gravel, lake clay, 2 tills; left bank, S. Br. Cattaraugus Cr., S edge of Otto. Dates Otto Interstadial.	17, 16, 12
2	Clear Creek, Collins	Gowanda, Erie	>48,400	GrN-5486	Wood, probably **Picea**, in firm silty clay imbedded in 6.5m till beneath 4 tills; left bank Clear Ck. Rte 39 & 62 bridge. Minimum age of interstadial.	20, 16
3	Corry Bog, Corry	Corry, Erie (Pa.)	9,430±300	W-347	Base of 3m peat; bog contained in kettle just inside NW Corry Village limits.	5, 26, 19
			13,000±300	W-346	Top of .9m marl beneath 3m peat; bog in kettle just inside NW Corry Village limits.	5, 26, 19
			14,000±330	W-365	Base of .9m marl beneath 3m peat; bog contained in kettle just inside NW limits of Corry. Postdates Kent Glaciation.	5, 26, 19
4	Nichols Bk., Sardinia	Arcade, Erie	11,210±160	I-6023	Wood fragments in marly silt above gravel; Chaffee Outwash Plain; streambank 1.6km N of Yorkshire. Postdates Valley Heads maximum.	13
			12,020±300	W-507	Wood fragments in marly silt over gravel; Chaffee Outwash Plain; streambank 1.6km N of Yorkshire. Postdates Valley Heads maximum.	3, 13, 18
			12,800±200	I-5092	Wood fragments in marly silt above gravel; Chaffee Outwash Plain; streambank 1.6km N of Yorkshire. Postdates Valley Heads maximum.	13
			13,800±250	I-4043	Marly detritus 25cm above gravel, Chaffee Outwash Plain; streambank 1.6km N of Yorkshire. Because marl may contain recycled (inert) carbon, this date may be too old.	3, 13
			14,000±450	I-4216	Marly detritus, 2cm above basal contact over gravel; Chaffee Outwash Plain; streambank 1.6km N of Yorkshire. Because marl may contain recycled (inert) carbon, this date may be too old.	3, 13
5	Winter Gulf, N. Collins	N. Collins, Erie	12,610±200	I-8022	Spruce wood 1.78m below toe of shale shingle, 14m below maximum level of Lake Whittlesey at level of Warren I; 3km S of N. Collins.	3
			12,730±220	I-3665	Organic detritus in gray clay beneath 1.08m of shale, 14m below maximum level of Lake Whittlesey at level of Warren 1; 3km S of N. Collins. Postdates Gowanda Moraine.	3
6	Lewiston, Lewiston	Lewiston, Niagara	12,080±300 12,660±400	W-861 W-861	**Picea** twigs in gray silty clay over till, underlies brown silty clay; 340 ft. above sea level. Filled area, SE Lewiston.	17, 20, 21
7	Malloy, Newfane	Lockport, Niagara	12,100	I-838	**Picea** wood in lake silt overlain by gravel of low stage of Lake Iroquois; Malloy Gravel Pit, 7.5km N of Lockport. Postdates glaciation in W. New York.	2, 15
8	Houghton Bog, Springville	Concord, Erie	11,880±730	I-3290	Peat in kettle between ridges of Valley Heads Moraine complex; Nature Sanctuary Soc. of N.Y. Reserv., 3.7km N of Springville; dates of **Picea-Pinus**, Zone A.	14
9	Byron, Byron	Byron, Genesee	10,450±400	W-1038	Wood directly beneath mastodon pelvis; shallow basin at 620 ft. above sea level, 1.4km WNW of Byron; postdates Lake Dana.	7, 9
10	Sheridan, Forestville	Sheridan, Chautauqua	9,200±500	M-490	Mastodon rib in lake sand beneath 60cm muck in basin landward from Warren Beach; Dahlman Farm; postdates Lake Warren.	4, 6
11	Marilla, E. Aurora	Alden, Erie	9,640±250	W-199	Wood in lake clay exposed in pipeline ditch, 4km N of Marilla. Postdates Lake Warren.	1, 22
12	Protection, Arcade	Holland, Erie	4,390±110	I-3550	Peat in kettle associated with Valley Heads Moraine; Erie Cty Plantation #5, 2.3km NE of Protection; Dates abrupt decline in **Tsuga** (Hemlock) abundance.	14
			9,030±150	I-3550	Peat in kettle associated with Valley Heads Moraine; Erie Cty Plantation #5, 2.3km NE of Protection; Dates **Pinus** maximum in pollen profile.	14
13	Colden, Colden	Colden, Erie	9,745	SI-1328 SI-1329	Average of 2 analyses on twigs near base of lake silt which overlies drab till; gully, left bank tributary of W. Branch Cazenovia Cr. 2km SSE of Colden.	8
14	St. Davids, Stanford	Niagara E., Welland (Canada)	22,800	GSC-816	Wood in sand 46m below sfc; overlain by 2 tills and strat. sand, silt, clay in bore hole drilled in filled channel near St. Davids; pollen indicates boreal forest, probably predates Kent Glaciation.	10
15	Hamilton, Hamilton	Hamilton W., Wentworth (Canada)	11,510±240	Y-691	Wood, perhaps **Populus** in blue-gray silt beneath lake sand and gravel. Excavation for Hamilton City Hall, 11.5m below Iroquois bar; dates Lake Iroquois.	11, 23
16	Burlington Bar, Hamilton	Hamilton W., Wentworth (Canada)	10,150±450	I(GSC)-11	Plant material from 62.5m in test boring. Burlington Bar, mouth of Hamilton Harbor; 4.5m above till in thick succession of lake sediments.	11, 25
17	The Gulf, Lockport	Lockport, Niagara	10,920±160	I-5841	Wood (**Picea**) from base of organic deposits overlying gravel and waterbedded lake clay and silt in floor of The Gulf. Postdates L. Iroquois and major outflow from L. Tonawanda by the Gulf Spillway.	
18	Sonyea, Groveland	Sonyea, Livingston	8,050±135	I-7527	Woody flotsam in fine gray lacustrine clay, 15 ft. below top of laminated silts and clays, exposed in streambank, Canaseraga Cr. 2 mi. SSE of Hampton Corners at abandoned crossing south to Sonyea. Dates postglacial lake in Canaseraga Valley.	27
19	Macauley Site	Livingston	4,745±110	I-6804	Carbonized wood granules in silt overlying varved sediments. Earliest of 15 C-14 dates on similar materials in Paleo-Indian archeologic site, 1 mi. N of Hampton Corners.	27

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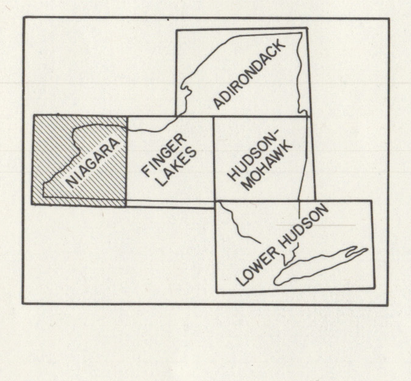
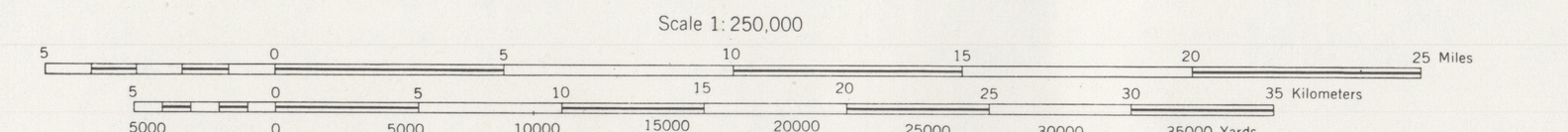
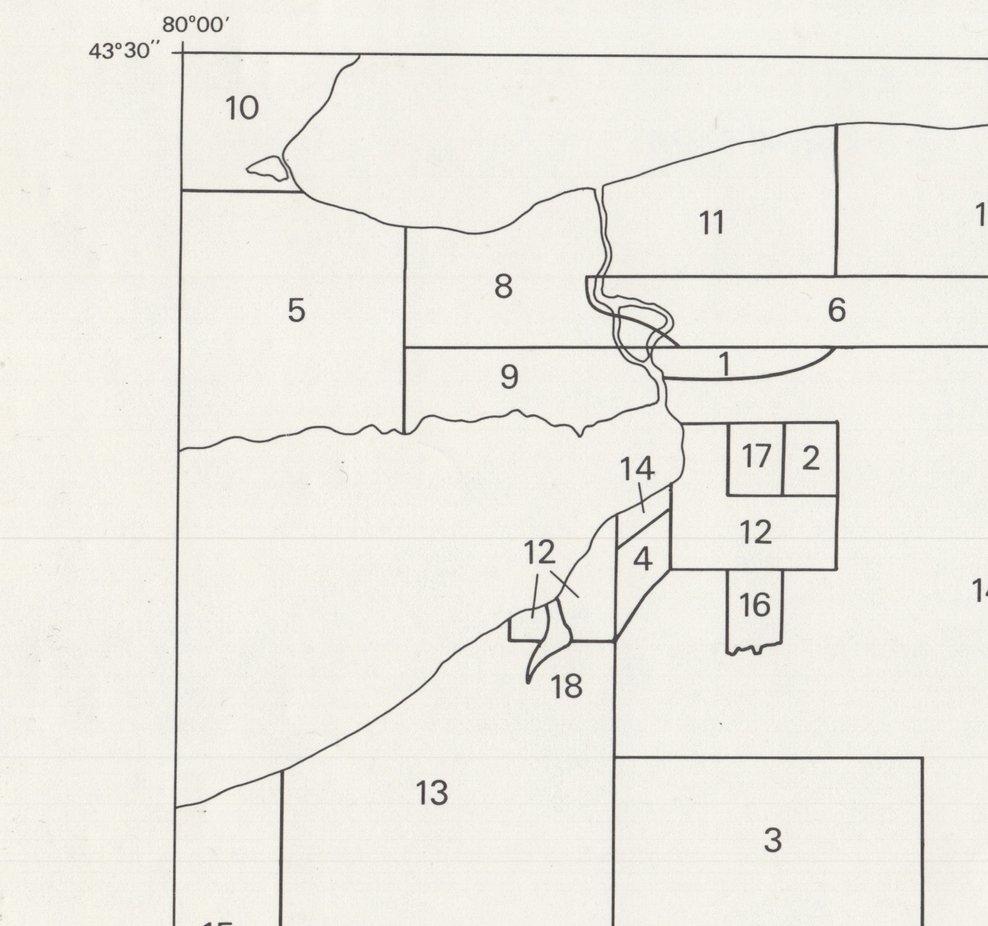


QUATERNARY GEOLOGY OF NEW YORK, NIAGARA SHEET

by Ernest H. Muller

Compilation completed 1975





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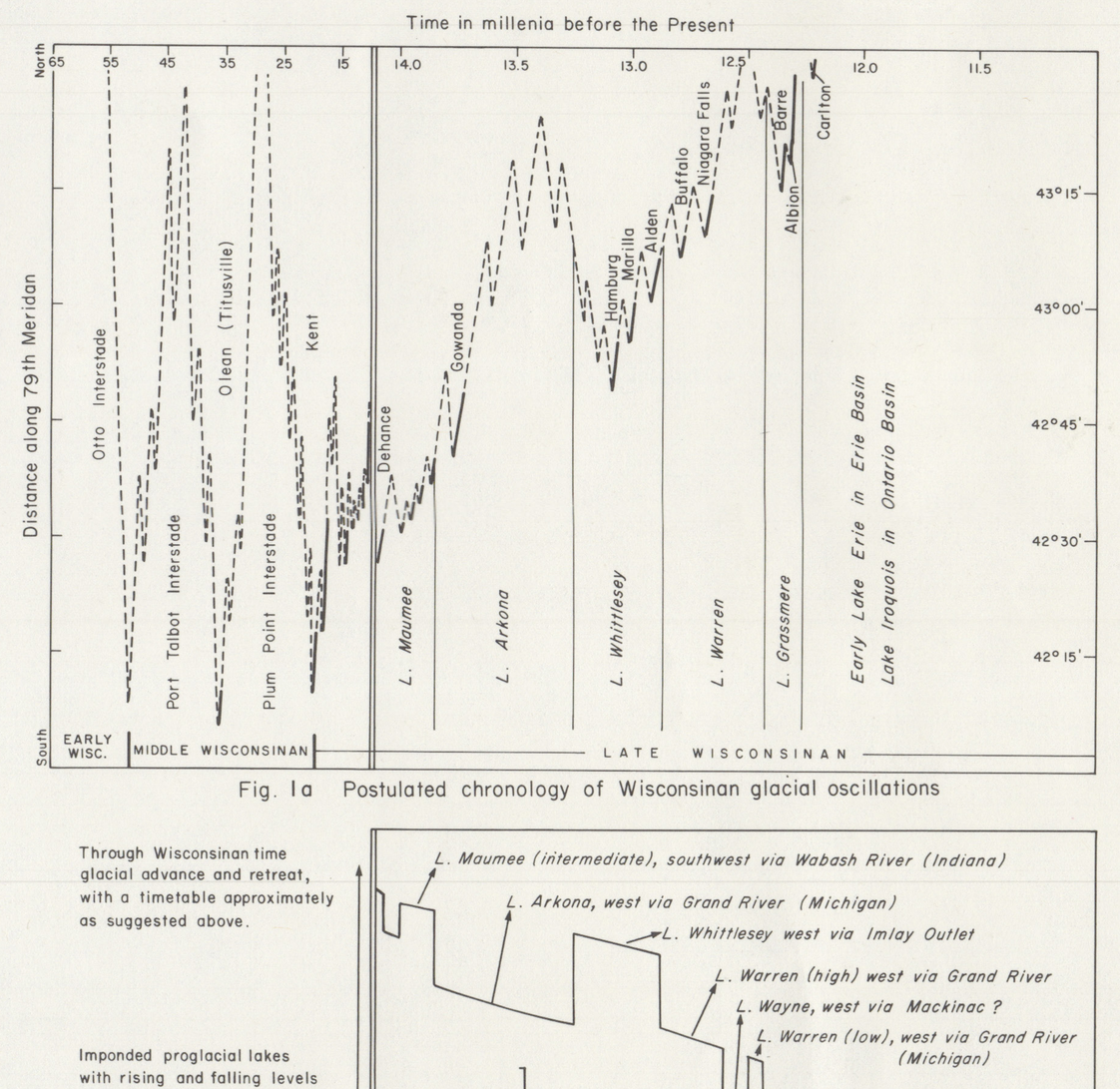

Fig. 1a Postulated chronology of Wisconsinan glacial oscillations

Through Wisconsinan time glacial advance and retreat, with a timetable approximately as suggested above.

Impounded proglacial lakes with rising and falling levels controlled by lowest available outlets, with chronology like like that for the Late Wisconsinan illustrated in the Erie Basin at right.

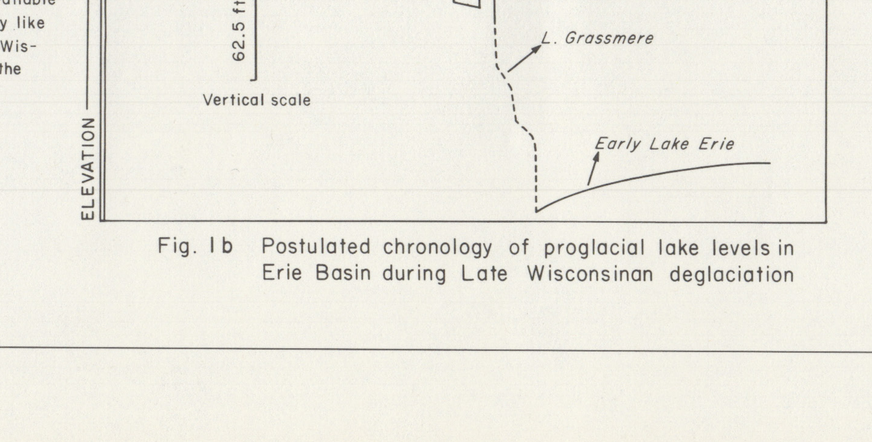

Fig. 1b Postulated chronology of proglacial lake levels in Erie Basin during Late Wisconsinan deglaciation

GEOMORPHIC HISTORY OF WESTERN NEW YORK

The face of the earth in western New York is like a slate upon which has been repeatedly inscribed and effaced the evidence of rapid environmental changes of the Quaternary Period.

Landscape evolution, though very slow, is an unending process. Precisely speaking, no landscape is older than the day it is viewed. Yet the imprint of past environments may be so gradually effaced that relict landforms dominate for a long time over features evolving by present processes. Because landscape modification by running water is slow relative to the frequency of climatic change during the Quaternary Period, present landscapes of western New York are dominated by relics of glaciation. On the other hand, glaciation rapidly effaces superficial landscape features, impressing its own imprint and destroying the prior record to the limit of glacial advance.

Of pre-glacial landscapes, only a suggestion of summit accordance, a few drift-filled valleys and vestiges of the drainage pattern can be traced from the unglaciated Salamanca Re-entrant south of the Allegheny River in Cattaraugus County northward into the glaciated area. Intensity of glacial modification increases northward, obliterating all pre-glacial topographic details within a few tens of miles.

Penultimate glaciation is recorded in a few favored locations where accidents of topography preserved earlier deposits from erosion during subsequent glaciation. Such are the reference sections at Otto and Gowanda (Radiocarbon localities 1, 2. See Quaternary map and Radiocarbon Dating.) At these two localities, organic remains indicative of boreal forest conditions and dated from 52,000 to 64,000 years ago are preserved between underlying and overlying evidence of glaciation. They document the Otto Interstade, an interval of diminished interglacial extent, which may be correlated with the St. Pierre Interstade of the St. Lawrence Lowlands. At the Clear Creek site near Gowanda, the radiocarbon-dated organic material was disturbed and partially assimilated in till with a pinkish cast and containing weathered soil material.

The common picture of Wisconsinan glaciation in New York State has been one of simple advance at the beginning and retreat at the end of a prolonged interval at the end of the Pleistocene Epoch. By contrast, Fig. 1a at the left illustrates a conjectured history of repeated, oscillatory southward advance and northward retreat of the ice margin across western New York. Though schematic, the diagram represents a north-south section along the 79th Meridian, west of Buffalo and lying approximately through Gowanda and Randolph.

In the absence of adequate stratigraphic data in New York, heavy reliance is placed upon interpretation of the record where it is better preserved nearer to the glacial limits in Pennsylvania and western Ontario. Particularly along the north shore of Lake Erie the chronology of the Port Talbot and Plum Point Interstades has been established on firm stratigraphic basis. Although details of oscillatory retreat and advance of the ice margin are conjectural, limits on the major oscillations are inferred from drainage and lake level conditions implicit in the western Ontario stratigraphy.

Terrace remnants and isolated patches of till in the Allegheny Valley southwest of Salamanca are of probable pre-Wisconsinan age, but the earliest extensively preserved till sheet is the drab, stony Olean Till. As shown, the Olean Till is considered to represent a glaciation between the Port Talbot and Plum Point deglacial intervals. This correlation is based upon the apparent relationship of Olean Till to a glaciation slightly younger than radiocarbon dated peat near Titusville, Pennsylvania about 85 miles south of the New York State Line. The possibility that Olean Till represents glaciation prior to Port Talbot time as well cannot be ruled out.

Glacial readvance following the Plum Point Interstade has been documented in Ohio and western Ontario. By about 27,500 years ago glacial impounding had begun to raise the level of Lake Erie. Shortly after 24,000 years ago the ice margin had spread beyond Cleveland, Ohio and, by inference was expanding towards its limits on the plateaulands of western New York. As late as 19,000 to 20,000 years ago the ice sheet may have been still near the limits marked by the Kent Moraine. Though interrupted by stabilization, or minor readvance marked by the Clymer and Findley Lake Moraines, the retreat at the end of the Kent Glaciation was apparently rapid and extensive, though without evidence that the ice sheet withdrew entirely from the Erie Basin.

Glacial oscillations represented by the Lavery, Hiram and subsequent moraines can be directly related to the succession of proglacial lakes recorded by strand features in the Erie Basin (Fig. 1b). Lake Maumee, with its outflow primarily by the Wabash River southwest across Indiana persisted through most of the interval represented by the Lake Escarpment Moraines, though its strand features are nowhere recognized in New York.

Lake Whittlesey which came into existence 13,000 years ago is represented by a well-marked and fairly continuous strandline which transects all moraines earlier than the Marilla, and apparently persisted while the Marilla Moraine was being deposited. Evidence of the glacial withdrawal marked by lowering to the Arkona level is well marked in Michigan, but not independently established in New York. Based on its relationship to the Whittlesey Strand, the Hamburg Moraine is tentatively correlated with the Port Huron Moraine of Michigan.

Retreat of the Huron Lobe of the ice sheet made the threshold at the head of the Grand River in Michigan the control on level of proglacial meltwaters in the Erie Basin. The resulting Lake Warren Strand is strongly developed in eastern Erie County by multiple beach ridges. The higher beach ridges cut across the truncated end of the Alden Moraine, but only the lower beach ridges are developed across and modify the Buffalo and Niagara Falls Moraines. The subsequent Batavia Moraine angles obliquely across the alignment of earlier moraines in manner that suggests a surging readvance of the glacier margin. Withdrawal from the Batavia Moraine opened eastward drainage for waters in the Erie Basin, permitting rapid lowering of lake level through a series of stages represented in western New York by Lake Grassmere. Above (south of) the Lockport Escarpment, Lake Tonawanda persisted in an enclosed basin after glacial withdrawal. Its level floor is the site of extensive swamps even today.

In the Ontario Basin Lake Iroquois came into existence with uncovering of the eastern threshold at the head of the Mohawk River near Rome and persisted until deglaciation of the northern flank of the Adirondack Mountains.

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(Numbers correspond to "Published References" in table of radiocarbon dates)

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