GEOTECHNICAL DESIGN MANUAL

CHAPTER 3

GEOLOGY OF NEW YORK STATE

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Table of Contents

Table of Contents

Table of Contents

3.1 DEFINITIONS

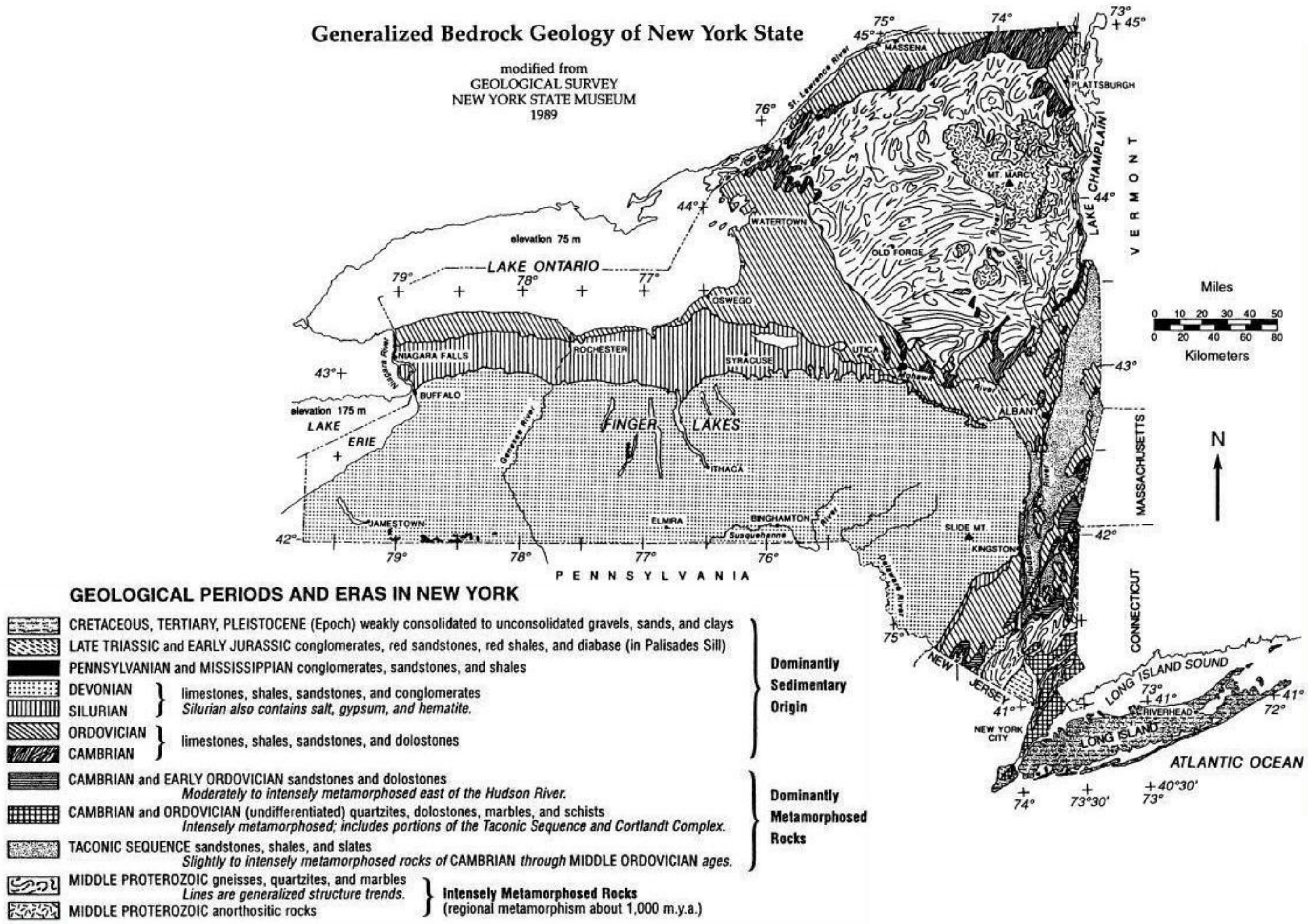


Figure 3-1 Generalized Bedrock Geology of New York (New York State Geological Survey)

Figure 3-2 1872 Relief Map of New York
(Florida Center for Instructional Technology)

CHAPTER 3
Geology of New York State

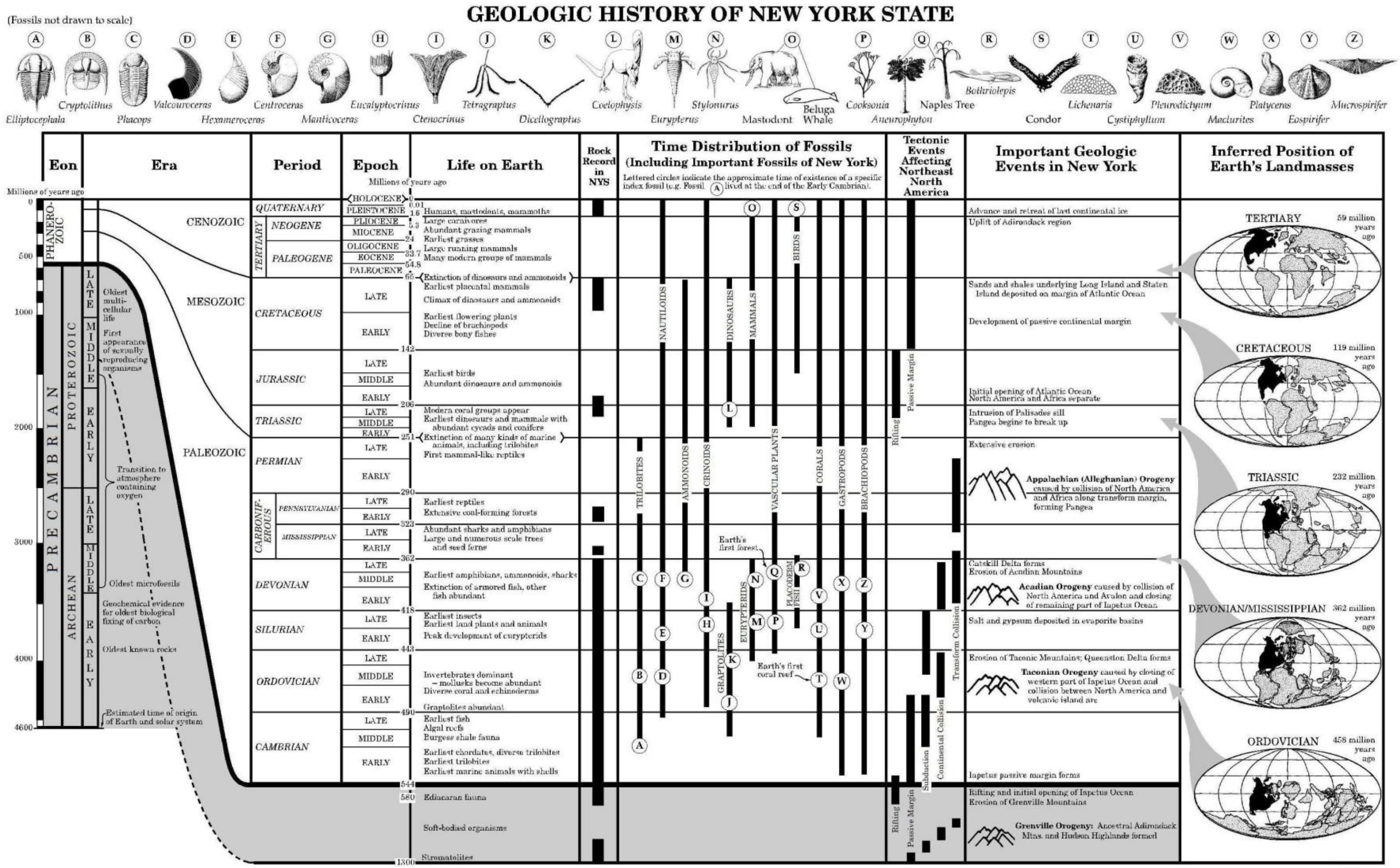


Figure 3-3 Geologic History of New York State (New York State Education Department)

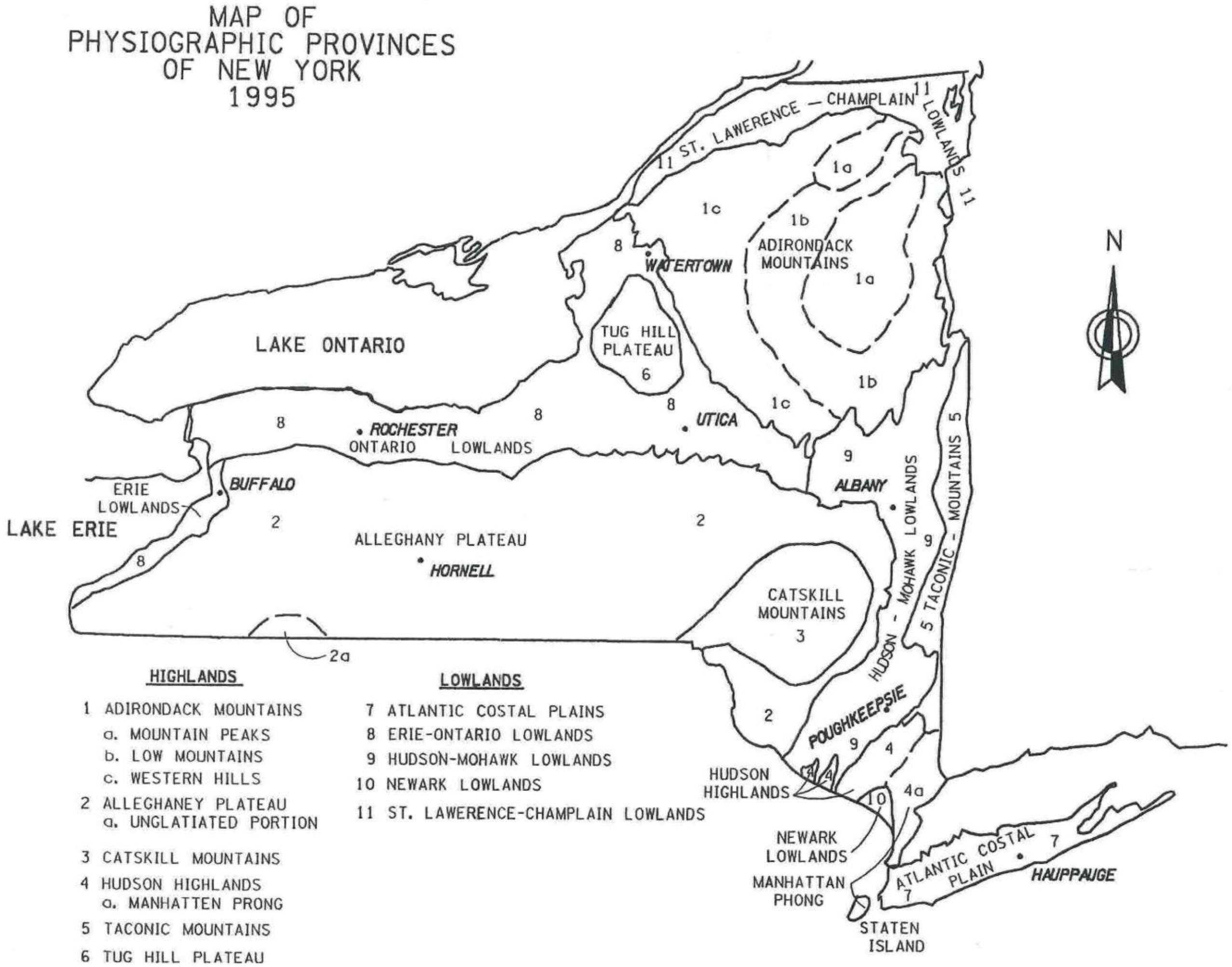


Figure 3-4 Map of Physiographic Provinces of New York (1995)

Ablation – the decrease in size and extent of a glacier by melting and evaporation.

Alluvium - clay, silt, sand, gravel, or other rock material transported by flowing water and deposited in riverbeds, estuaries, and floodplains, on lakes, shores, and in fans at the base of mountain slopes.

Alluvial Fan - a sloping mass of sediment, often granular, deposited at a point along a river or stream where there is a decrease in gradient, e.g. from a mountain to a plain.

Delta – a fan-shaped, low-lying area formed by sediments deposited at the mouth of a river or stream. In New York, often modified by glacier action (sometimes beyond recognition).

Drift or Diluvium - any rock material transported by a glacier and deposited by or from the ice or by water from melting ice.

Drumlin – a long, low, cigar-shaped hill made of glacial till lined up along the direction of ice flow. May have a rock core. Usually in groups (drumlin fields).

Dune – a hill or ridge of sand piled up by the wind. Irregularly cross-bedded with uniform grain size. Found on outwash plains and beaches.

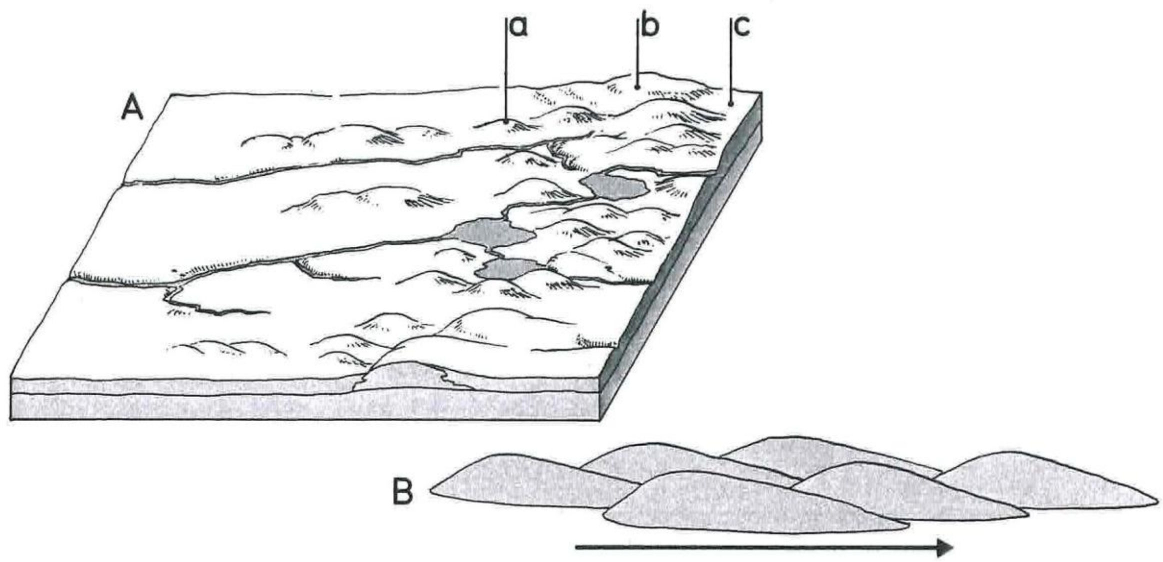
End or Terminal Moraine – usually a smooth undulating ridge-like accumulation along the terminal margin of a glacier. Formed only when ice flowage exactly equals ice melting (stationary front). Some moraines are built up by the glacier acting as a bulldozer.

Erratic – a boulder transported from its place of origin by a glacier and left when the ice melts.

Esker – narrow, steep-sided sinuous ridge made up of deposits from a meltwater stream flowing beneath (sub-glacial) or within (englacial) a glacier. Can be up to 100 ft. high and 150 miles long. Aligned generally parallel to path of glacier.

Esker Delta – formed when an esker ends in a glacial lake. Built up against ice and will slump when ice melts, destroying characteristic delta structure.

Glacial Lake Deposits – four types:
- deltas - see previously provided definition,
- bottom deposits - clay and silt separated in thin layers,
- rafter erratic - formed when an iceberg floating on a lake melts and dumps its load (boulders or till-like deposits, and
- shore features - varve-cut cliffs, beach ridges, spits, and bars. Usually formed in large glacial lakes where the water level remained constant for a long time.



Glacial deposits
A The block diagram (above) shows a landscape largely formed by drift
a Drumlins
b Terminal moraine
c Outwash sands
B A swarm of drumlins aligned with ice flow (arrow)

Figure 3-5 Debris Dumped by Glaciers and Ice Sheets (Lambert, 1988)

Glacial Marine Deposits – principal difference from glacial lake deposits is the absence of varves. Electrolytic action flocculates clay and causes it to settle out with the silt.

Glacial Stream or Glaciofluvial Deposits – all drift deposited by flowing water during glacial time. Includes eskers, kames, kame terraces, ice-contact deposits, outwash, many end or terminal moraines, etc.

Ground Moraine - formed by accumulation beneath the glacier. Usually composed of till. Has low relief and is devoid of transverse linear elements.

Ice Contact Deposits – stratified drift deposited by flowing water in contact with stagnant ice. Three characteristics: frequent and abrupt changes in grain size; intimate association with lenses and masses of till; deformation features such as faulting and folding. Includes: kames, kame terraces, kettles and eskers.

Inwash - glacial outwash mixed with recent alluvium.

Kame – low, steep-sided hill of stratified glacial drift with knoll-like short, ridge like, or mesa-like form. Origin – 1) accumulation of stream assorted material in openings in stagnant ice. 2) Deltas or cones against ice front by glacial streams. Both collapsed into mound like forms when ice melted. Sometimes kames are part of an end moraine. Usually kames are associated with kettles.

Kame Field – area or zone along margin of stagnant glacier occupied by deposit of granular material.

Kame Moraine – end moraines deposited by and beneath water. These features are composed of stratified sands and gravels with hummocky kame and kettle topography, but more subdued and with flatter slopes. Not uncommon in the Catskills and other parts of New York.

Kame Terrace – a deposit of stratified sand and gravel laid down by stream flow between a wasting glacier and adjacent valley wall. The surface, especially the inner face, is often marked by kettles and kame-like mounds.

Kame and Kettle Topography – mounds with intervening depressions many of which are closed and may contain lakes or ponds. Sure indication of granular material.

Kettle – closed depression, usually in stratified drift, but sometimes in till, made by melting out of buried mass of ice. Kettle with regular form – almost sure indication of granular material.

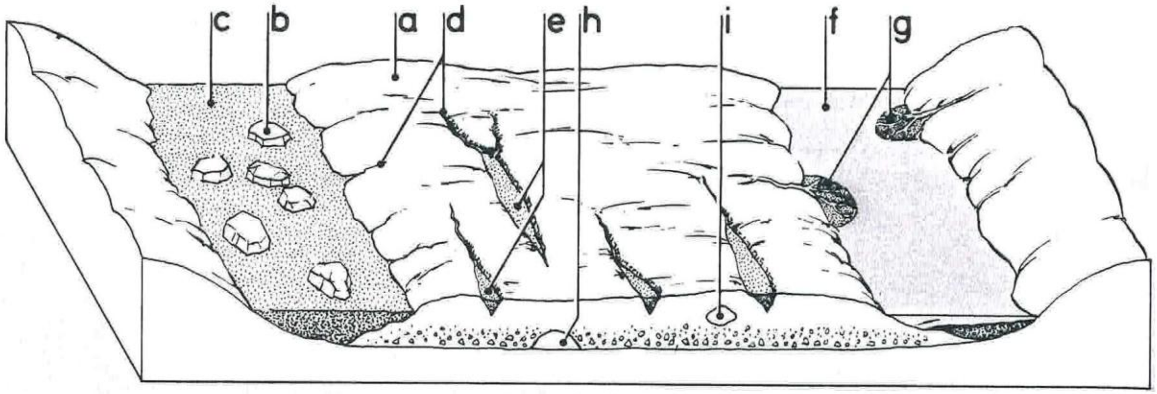
Lateral Moraine – ridge-like deposit of drift, usually till, along the side(s) of an actively flowing glacier confined in a valley. Ice contact counterpart is kame terrace.

Modified Drift – also modified, stratified, assorted or reworked drift. Glacially transported material deposited by water and therefore stratified and size sorted.

Moraine – Unsorted glacial drift deposited along the margin(s) of a glacier.

Mountain Glacier – in mountain valley as opposed to continental glacier. Occupied some higher valleys in the Catskills.

Moulin - a nearly vertical, cylindrical shaft in a glacier - often filled with gravel which forms a kame.



Glacial valley (above)
a Glacier
b Blocks of melting ice
c Lake filled by sediment
d Surface streams
e Crevasses containing sediment shed by streams
f Ice-margin lake
g Deltas
h Subglacial stream
i Englacial stream

Postglacial valley (below)
a Exposed valley floor
b Kettles (ex ice-filled hollows)
c Kame terrace (old lake bed)
d Streams
e Kames (ex crevasse deposits)
f Kame terrace (old lake bed)
g Kame-deltas
h Esker from subglacial stream
i Esker from englacial stream

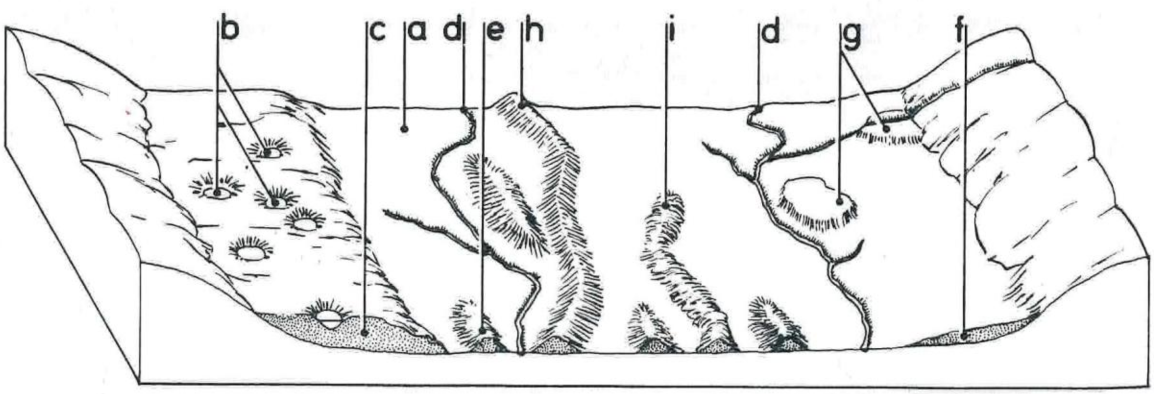


Figure 3-6 Debris Dumped by Glaciers and Ice Sheets (Lambert, 1988)

Outwash – glacial stream deposit laid down beyond margin of glacier. Wide variation in grain-size within short distance but not as marked as in ice-contact deposits. Valley trains – long narrow bodies of outwash confined in valleys. Outwash plain – series of outwash fans deposited by aggrading, braided streams. Post-glacial streams have been degrading and removing outwash from many valleys. In such valleys the remaining portion is characteristically terraced.

Proglacial Stratified Drift – outwash, glacial lake deposits and glacial marine deposits.

Rafted Boulder - see erratic.

Roches Moutonnée – rounded hummocks of ice-polished, smooth, striated bedrock. Commonly occur in "swarms", often with like alignment. Much smaller than “rock drumlins” and not covered with till: a.k.a. smoothed rocks, sheepbacks, & whalebacks.

Till – unsorted drift deposited directly by ice. Composition of till reflects underlying rock. 50% of till has been transported less than 10 miles; 90% less than 20 miles.

Run-of-Bank – deposits of granular materials ranging in size from sand to boulders.

Travertine – Calcium Carbonate ($CaCO_3$) incrustations around mouths of hot or cold calcareous springs. Also forms stalactites, stalagmites, and other deposits in limestone caves.

3.2 PHYSIOGRAPHIC PROVINCES OF NEW YORK STATE

Physiography is the study of the origin and evolution of landforms. A physiographic province is a region in which the shape of the land surface is fairly constant, and is different from the surrounding regions. The provinces of New York State are either uplands or lowlands, each of reasonably similar features, considerable extent and geographic continuity. There are 11 provinces in the State which are shown on Figure 3-4. They are:

UPLANDS
Adirondack Mountains
Allegheny Plateau – Glaciated and Unglaciated
Catskill Mountains
Hudson Highlands
Taconic Mountains
Tug Hill Plateau

LOWLANDS
Atlantic Coastal Plain
Erie and Ontario Lowlands
Hudson-Mohawk Lowlands
Newark Lowlands
St. Lawrence - Champlain Lowlands

On a broad basis, the bedrock, topography, and many of the soils in any province exhibit similarities. Repetitive units occur within a physiographic province. That is, soils formed on similar landforms throughout a province will exhibit similar generalized engineering characteristics. However, a soil formed on the same landform in another physiographic province may display different engineering properties because of different source bedrock type, etc. Any evaluation of the engineering significance of New York soils should start with a characterization of the various physiographic provinces.

As mentioned in NYSDOT GDM Chapter 2, agricultural soil surveys in the United States have been conducted by the Department of Agriculture (USDA) in conjunction with State agencies since the early 1900's. The maps show the extent and derivation of the various soil deposits. This and more information on soil surveys is available from United States Department of Agriculture, Natural Resources Conservation Service (NRCS):
http://www.ny.nrcs.usda.gov/.

3.2.1 Adirondack Mountains

3.2.1.1 Description

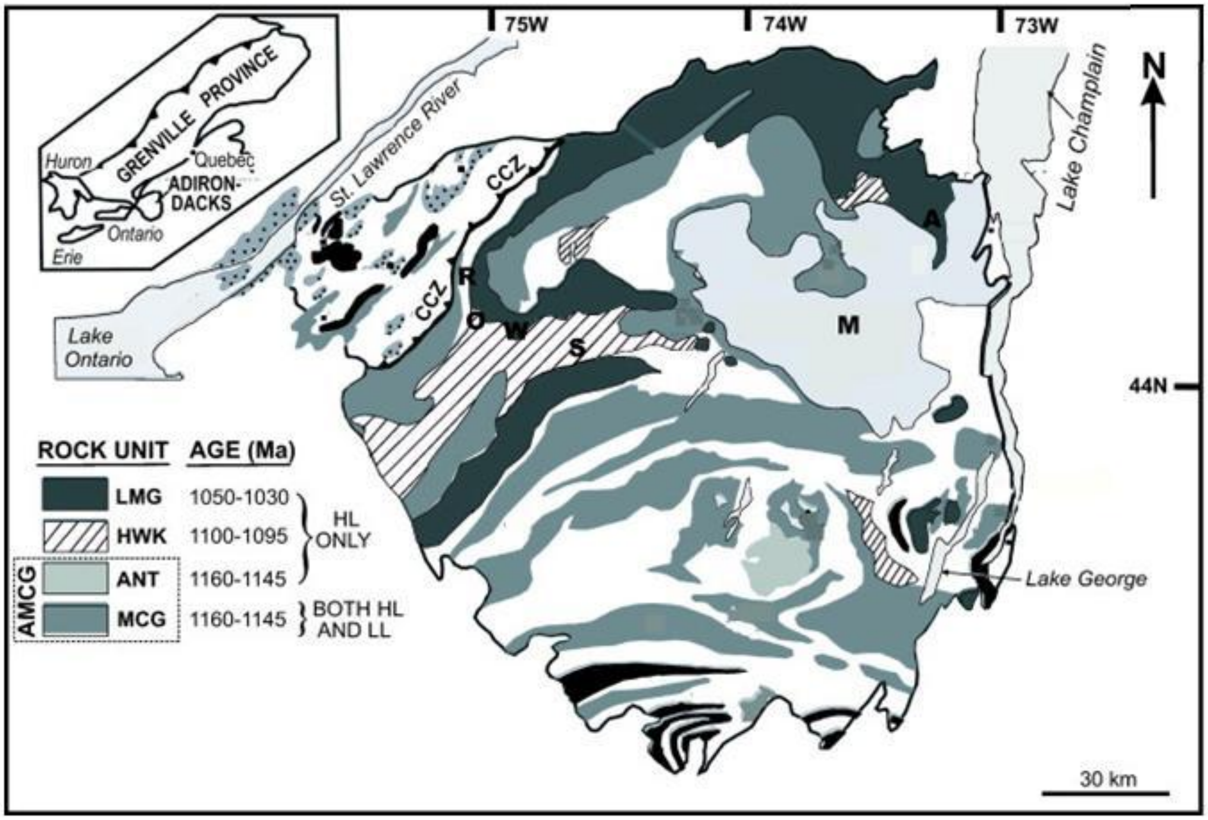
An extensive upland in northern New York, nearly circular mass (about 17,000 square miles) and surrounded by lowlands, the Adirondack Mountains occupy about one-fourth the area of the State. The boundaries of the province are where the large intrusions of igneous rock (anorthosites, granites, syenites, gabbros), have forced their way up through old sedimentary rocks .

In a broad sense, three subdivisions of the mountains are evident.

a. Mountain Peaks
   This region includes the highest and most rugged mountain peaks, with summit elevations over 5,000 ft. above sea level, and general relief in excess of 2,000 ft. Mt. Marcy (elev. 5,344 ft.) and Whiteface Mountain (elev. 4,872 ft.) are located in this sub-region.

b. Low Mountains
   This is an area of slightly lower relief surrounding (a) Mountain Peaks. Elevations exceed 1500 ft. with many summits over 2000 ft. This sub-region includes numerous glacial lakes, especially in the west; Upper and Lower Saranac Lakes, Tupper Lake, Raquette Lake and the Fulton Chain of Lakes are examples of glacial lakes. Included in this subregion are plateau-like areas such as the Saranac Intermontane Plateau.

c. Western Hills
   This is an area in the western Adirondacks with generally less relief than the Low Mountain sub-region. It is a broad zone of "foothills", crossed by numerous streams which make a radial pattern as they flow from the higher parts of the mountains. Many areas of sand deposited in and around former glacial lakes.



Rock Units:
LMG = Lyons Mountain Granite HWK = Hawk Mountain Gneiss ANT = anorthosite rocks
MCG = Mangerite–Charnockite–Granite rocks CCZ = Carthage-Colton Mylonite Zone
HL = Highlands LL = Lowlands
Sampling locations:
A=Au Sable Forks M=Marcy anorthosite O=Oswegatchie region (OSW) R=Russell area
S=Sabattis area W=Wanakena granite.

Figure 3-7 Generalized Geologic Map of Adirondack Mountains (Brown & McEnroe 2012, adapted from McLelland et al. 2004)

3.2.1.2 Bedrock

The bedrock of the Adirondacks consists mainly of hard, crystalline, igneous rock. Metamorphosed or recrystallized sedimentary rock is found in some of the major valleys. Because of the erosion-resistant nature of the rocks, the Adirondacks have remained an upland.

3.2.1.3 Landforms and Soil Deposits

The topography is controlled by the bedrock configuration. Valleys within the province are produced by bedrock structures such as folds, faults and joints. Minor topographic landforms are glacial depositional features.

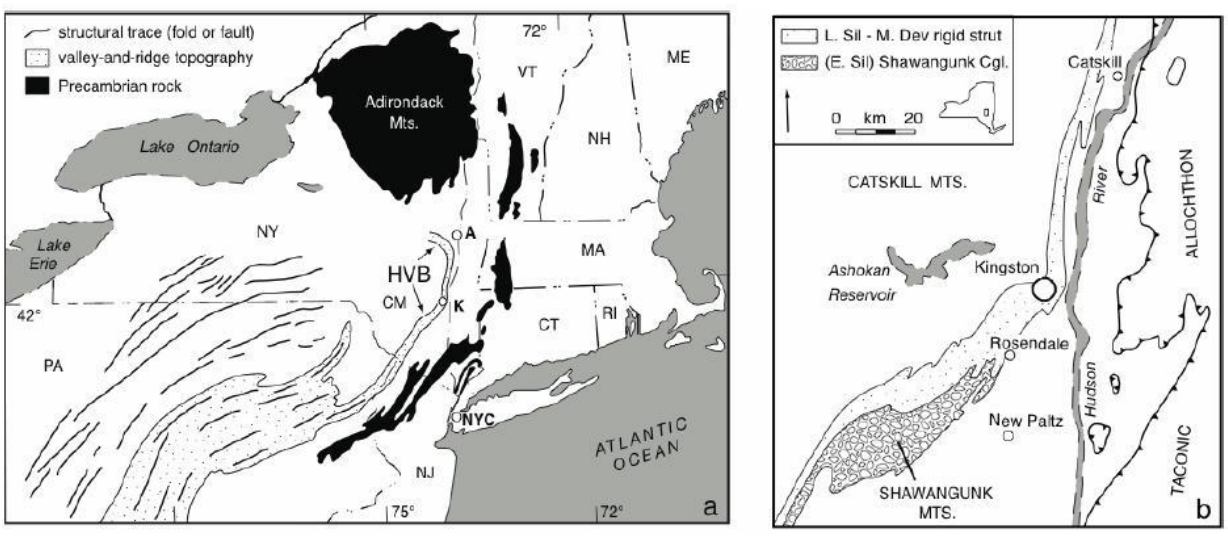
Most soils are derived from the crystalline rocks and are high in quartz, feldspar and mica. Almost all soils are granular glacial tills which are generally loose, bouldery sands and gravels. Outwash and delta deposits occur in most major valleys; many lower valley sides are covered with morainic material; and kames and kame terraces are numerous. In some locations, eskers are prominent. Swamps with peat and muck occur where drainage has been blocked, as well as in kettle holes.

3.2.2 Catskill Mountains

3.2.2.1 Description

The Catskills rise considerably higher than the neighboring parts of the upland. Summit elevations exceed 2000 ft. and some peaks are over 4000 ft. The mountainous character of the Catskills is due to the action of glaciation and streams carving deep valleys in the flat-lying rocks.

The eastern boundary of the province is very evident with its high scarp facing the Hudson River.



HVB = Hudson Valley fold-thrust belt; K = Kingston; A = Albany

Figure 3-8 Map of New York State Showing the Distribution of Fold-Thrust Belt Structures (Marshal et al., 2009)

3.2.2.2 Bedrock

Stratified sandstones and shales capped in the high areas with a resistant conglomerate are the bedrocks of the Catskills. Except for a slight westward inclination, these rocks are mostly arranged in practically horizontal layers.

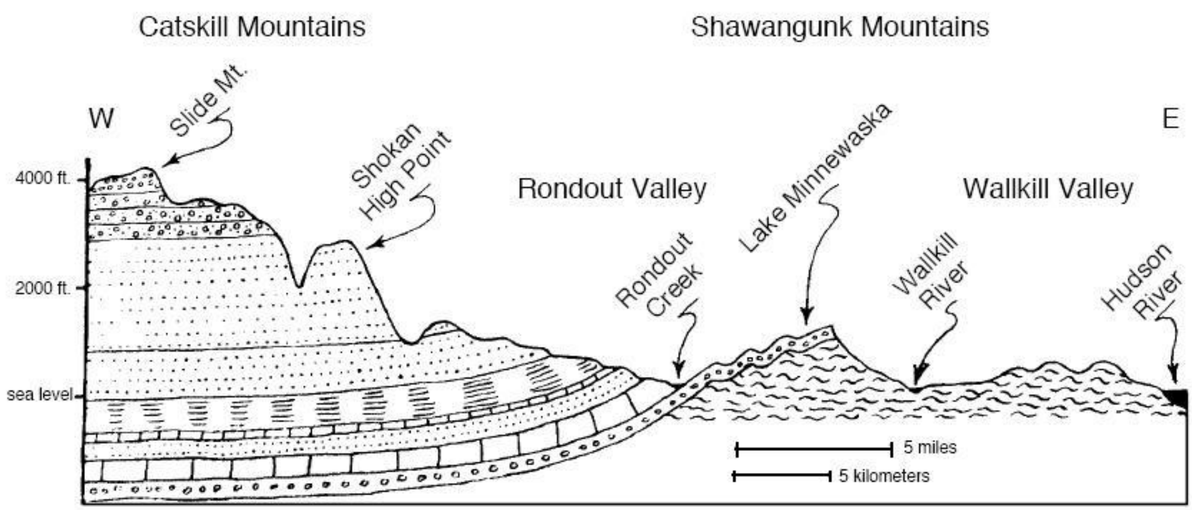


Figure 3-9 Cross Section Showing Orientation of Strata from Hudson River West to the Catskill Mountains (Bennington)

3.2.2.3 Landforms and Soil Deposits

The topography is controlled by the bedrock with steep valley sides being a normal occurrence. Minor landforms in the valleys are outwash, kames, kame moraines, deltas, alluvial flats and lacustrine plains. Upland deposits are dominantly glacial tills that are stony or contain flagstones. The only extensive lacustrine area is near Gilboa in Schoharie County. Soils on the other minor landforms are mostly water-laid deposits of granular material.

3.2.3 Allegheny Plateau- Glaciated

3.2.3.1 Description

The glaciated Allegheny Plateau, which includes about one-third of the State, is the most extensive province in the State. On the east, the plateau is separated from the Hudson-Mohawk lowlands by the Helderberg escarpment and, to the south, grades into the Catskill Mountains. A series of escarpments form the boundary between the plateau and the lowlands to the north. The province continues beyond the southern boundary of the State with the exception of the small unglaciated portion of the plateau in the southwest. It is the northeastern part of the great Appalachian Plateau which lies along the western side of the Appalachian Mountains and extends southward into Tennessee. This upland is underlain by great thicknesses of sedimentary rocks which lie almost horizontal, except for a slight dip to the southwest and a kind of sagging in the middle of the Finger Lakes District. Severe dissection by both water and ice erosion has given the upland a somewhat rugged relief. It varies in elevation from 500 to 600 ft. in the north to more than 2,000 ft. in the south. The plateau is thought to represent ancient erosion surfaces and gives a rather flat-topped appearance when viewed from a distance.

Numerous "through" valleys and troughs are found in this province. Some contain large lakes, such as the Finger Lakes, others only small ponds or streams. The valley walls are rather steep.

The sub-divisions are somewhat more similar than those of the categories discussed in the other major regions; there are, however, certain distinctive features briefly outlined below:

1. Delaware Hills
   Hilly terrain south and east of the Catskills, associated with the East Branch of the Delaware River and its upper tributaries.

2. Helderberg Hills
   Hills and ridges with an average height of 1800 – 2000 ft., capped by a very resistant limestone. From just west of Albany, the Helderberg's present a sharp plateau front, one of the outstanding scenic features of this section of the State.

3. Susquehanna Hills
   Hilly terrain associated with the Upper Susquehanna River and its tributaries; these streams spread fan-like north and northeastward; the divides rise to heights of 1700 – 2100 ft. above sea level, and are like giant loaves of bread set NE-SW between the rolling, relatively narrow valleys.

4. Finger Lane Hills
   Occupy the central "sagged" part of the Plateau; characterized by deeply glaciated valleys, some containing the famous Finger Lakes.

5. Cattaraugus Hills
   High southwestern section of the Plateau; fairly flat-topped divides separated by broad glacial valleys. Contains triple divide; drainage north to the St. Lawrence via the Genesee River; southeast via the Canisteo to the Susquehanna River and the Atlantic; southwest via the Allegheny to the Gulf of Mexico.

6. Allegheny Hills
   Small, unglaciated section of the southwestern uplands.

3.2.3.2 Bedrock

Except for the limestones that form the northern province boundaries, and a few small patches of conglomerate in the southwest corner of the State, the entire plateau is underlain by great thicknesses of interbedded shales, siltstones and mostly weak and soft sandstones. The rocks dip mainly to the southwest at a low angle.

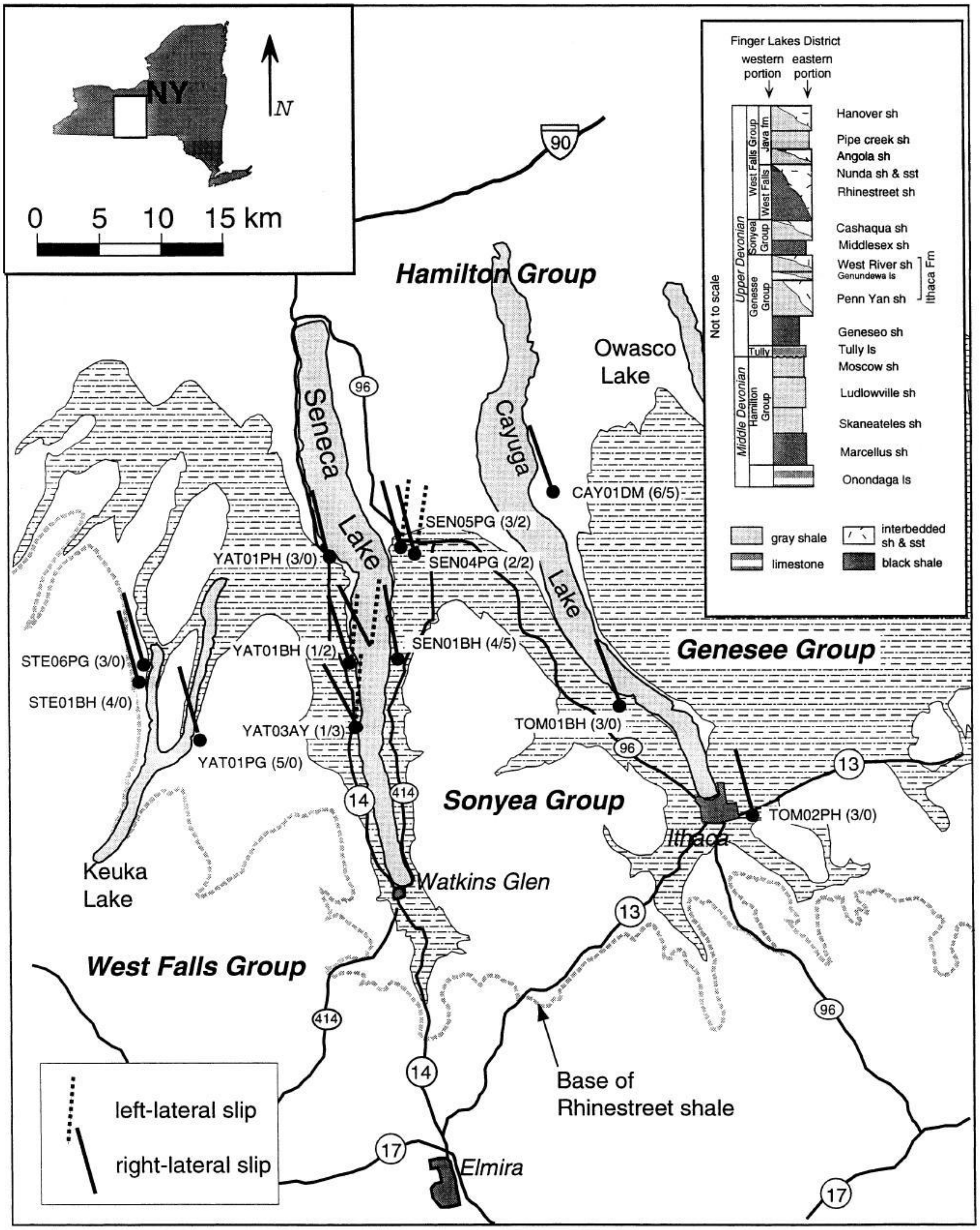


Figure 3-10 Geological Map of the Finger Lakes District Showing the Outcrop Distribution of the Hamilton, Genesee, Sonyea, and West Falls Groups (Engelder et al., 2001)

3.2.3.3 Landforms and Soil Deposits

The major topographic features are the bedrock-controlled uplands and the valleys entrenched into the rock. Glacial till deposits cover most valley sides and on the uplands. These till soils are dominantly stony silts and sand with varying amounts of clay. The mixture of these components is highly variable. In the Finger Lakes region lacustrine silts and clays may be found along with other lake associated deposits high on the valley walls.

The minor topographic features or landforms, found mostly in the valleys, are either depositional glacial or alluvial features. In the eastern plateau section, most valleys contain granular deposits. The Finger Lakes region has both granular and fine-grained soils in the valleys. Western Plateau areas have many fine-grained deposits with lesser amounts of granular materials in the valleys.

Morainic tills and ice-contact deposits are widespread and in some areas moraines are conspicuous features. Delta and outwash granular deposits are frequent. Valley bottoms often have alluvial veneers underlain by lacustrine sediments, because temporary glacial lakes occupied many of the valleys during periods of glacial activity. Swamps occur in kettle holes, in depression in alluvium, and on other low-lying areas with feeble or poor drainage outlets.

3.2.4 Allegheny Plateau- Unglaciated

3.2.4.1 Description

This small segment of the plateau, between the arc of the Allegheny River and the southern border of the State, is a rugged area with steep-sided valleys and high upland areas. Maximum relief is about 1,000 ft. The central mass of the province displays the normal erosion of water-cut features rather than the ice erosion features of the rest of the plateau in New York State. The fringes of the province on the east, north, and west do display features of glaciation and glacial deposition.

3.2.4.2 Bedrock

The bedrock is mostly weak, soft sandstone, shale and siltstone. Conglomerate caps the most southerly uplands extending into Pennsylvania.

3.2.4.3 Landforms and Soil Deposits

Major landforms are bedrock controlled. Minor landforms, occurring on the fringe areas, are water-laid glacial deposits. Since glaciation did not reach most of this area, the soils developed are mostly thin, residual types; and considerable colluvium exists. In the lower valley sides along the northern fringe some glaciation did occur; and deposits of strongly weathered glacial till, some old kame terraces, and moraine remnants are visible.

3.2.5 Tug Hill Plateau

3.2.5.1 Description

A wild bleak upland which is truly plateau-like in the “text book” sense. It is an outlier of the Appalachians, entirely separated from this and other provinces. The plateau drops off from flat swampy heights of 1800 – 2000 ft. to the Hudson Mohawk Lowland on the south and to the Erie and Ontario Lowland and the Lower Black River on the west and north. On the east the boundary is a steep scarp face but the steepness disappears on the other side. Relief on the plateau surface is gentle except where easterly-flowing streams have cut “gulfs” in the scarp resulting in a series of distinct terraces as it descends 100 ft. (as down a staircase) to the Black River Valley.

3.2.5.2 Bedrock

Tug Hill results from a resistant cap rock of sandstone resting on shales and limestone. The rocks are stratified, tilting slightly to the westward and are essentially flatlying.

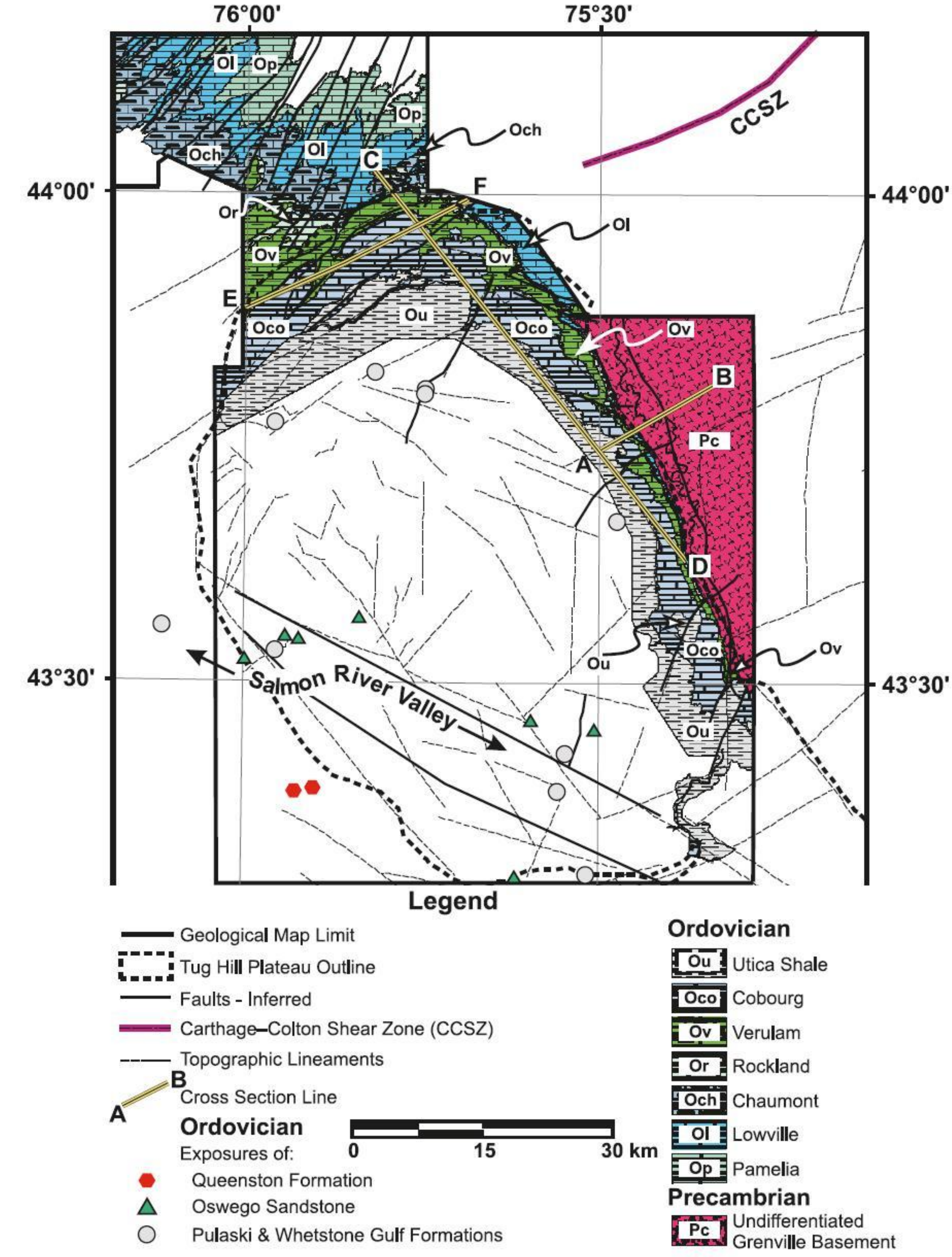


Figure 3-11 Geologic Map of Part of the Tug Hill Plateau (Wallach and Rheault, 2010)

3.2.5.3 Landforms and Soil Deposits

The landforms on the plateau surface are a glacial till plain and swamps. The glacial tills, derived mostly from the native sandstone and shale, contain numerous boulders. Drainage on the plateau is generally poor.

3.2.6 Hudson Highlands

3.2.6.1 Description

This province, extending across the Hudson River in a northeast-southwest direction, covers southern Orange and northern Rockland Counties and the area from southern Dutchess County southward across Putnam County and into Westchester County. It is a rugged, mountainous upland. Maximum relief is about 1,600 ft. where the Hudson River estuary dissects the province (Mt. Beacon, Storm King Mountain, Bear Mountain).

- Hudson Hills

Know commonly as "The Highlands of the Hudson." Composed of crystalline rocks, similar to those of the Adirondacks, which have been eroded to form very rugged terrain with summit levels reaching 1000 ft. above the sea. The Highlands trend northeast-southwest and through them the Hudson River flows in a steep-sided gorge from Storm King, past West Point, to a point just a little north of Peekskill.

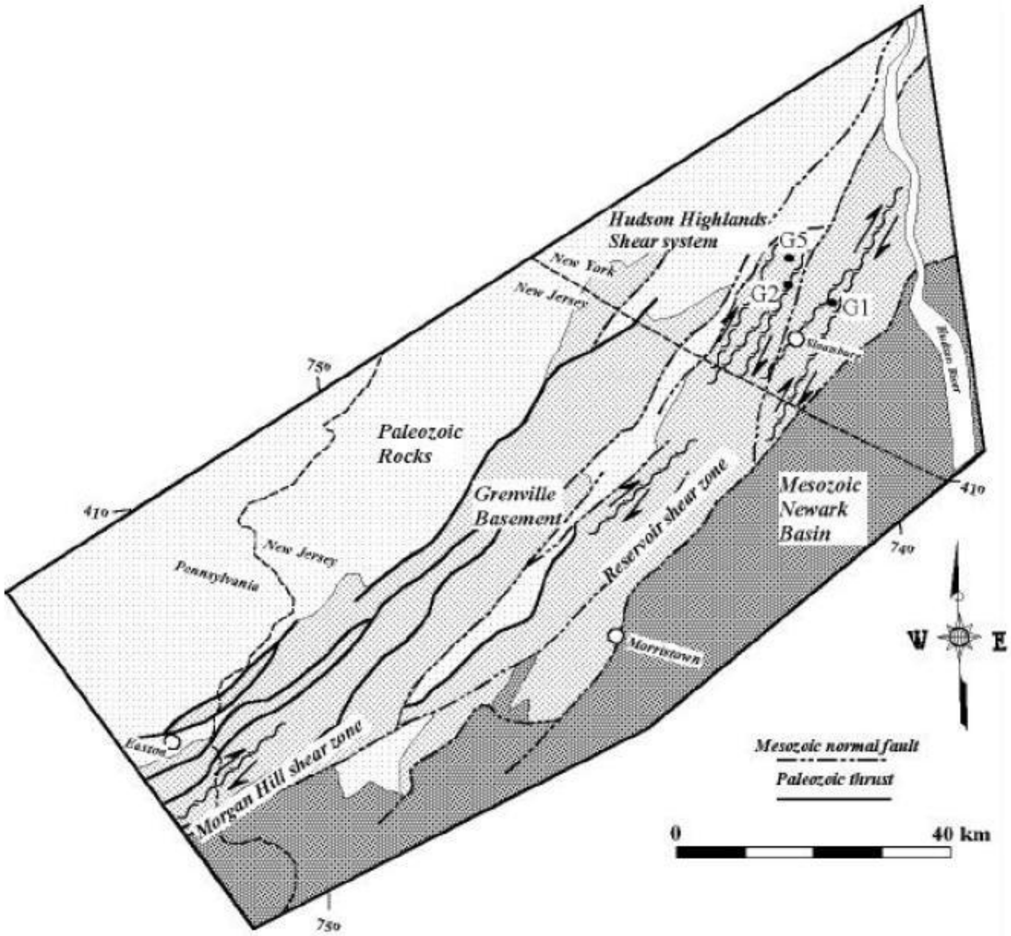


Figure 3-12 General Geologic Map of the Reading Prong and Hudson Highlands (Gates et al.)

3.2.6.2 Bedrock

Bedrock is dominantly crystalline and has been metamorphosed. The ridges and valleys generally follow the northeast-south-west linearity.

3.2.6.3 Landforms and Soil Deposits

Topography is relatively rugged with bedrock-controlled landforms being prevalent. The dominant condition is that of a rocky upland with little or no soil cover. Minor landforms, found in the major valleys and especially in Putnam County, are kames, kame terraces, outwash, deltas, alluvial fans and flood plains. The glacial till and water-sorted deposits, derived from the crystalline bedrock, are mostly stony and bouldery sands with some silt and little or no clay.

The minor topographic features or landforms, found mostly in the valleys, are either depositional glacial or alluvial features. In the eastern plateau section, most valleys contain granular deposits. The Finger Lakes region has both granular and fine-grained soils in the valleys. Western Plateau areas have many fine-grained deposits with lesser amounts of granular materials in the valleys.

Morainic tills and ice-contact deposits are widespread and in some areas moraines are conspicuous features. Delta and outwash granular deposits are frequent. Valley bottoms often have alluvial veneers underlain by lacustrine sediments, because temporary glacial lakes occupied many of the valleys during periods of glacial activity. Swamps occur in kettle holes, in depressions in alluvium, and on other low-lying areas with feeble or poor drainage outlets.

3.2.7 Manhattan Prong

3.2.7.1 Description

The Piedmont in New York State is a belt of worn-down complex mountains now almost reduced to a plain and lying between the coastal plain and the Highlands. It includes a portion of Staten Island, all of Manhattan Island, a small portion of western Long Island and most of Westchester County. The entire Piedmont area north of New York City is a peneplain comprising a series of nearly parallel ridges and valleys. The ridges and valleys trend north-north-east and south-southwest, giving the entire area a gently fluted surface of moderate relief. The maximum relief is 800 ft. in the north, while in New York City the relief is moderately low.

- Manhattan Hills

Low hilly terrain of gently relief, developed upon extremely complex geology, described by one authority as: "…intensely metamorphosed, heavily injected, re-crystallized and thoroughly re-organized ancient sediments…" Numerous lakes and reservoirs that supply the Metropolitan area dot the surface of central and western Westchester County.

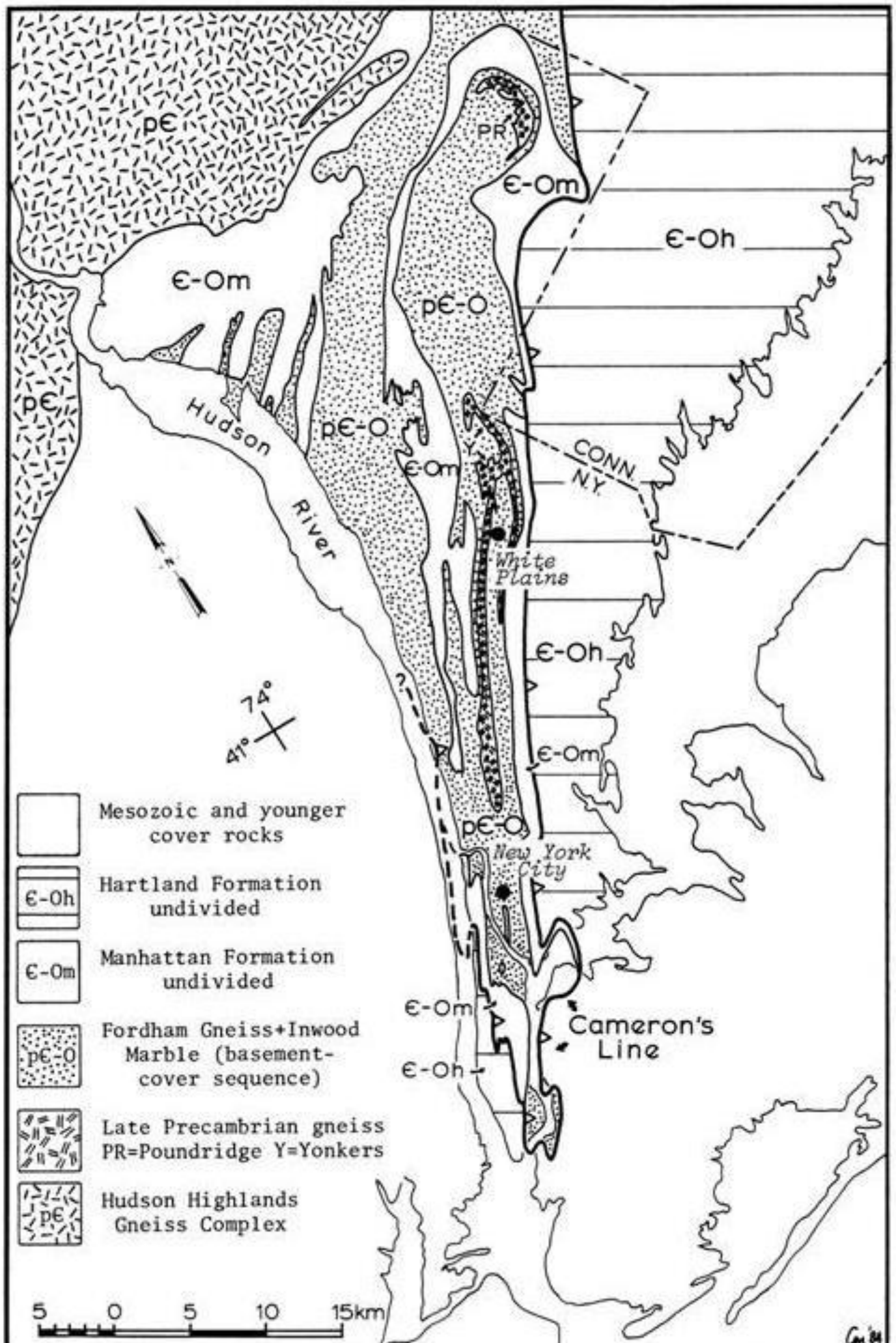


Figure 3-13 Simplified Geologic Map of Manhattan Prong
(Sanders & Merguerian 1991, adapted from Mose & Merguerian 1985)

3.2.7.2 Bedrock

The region is underlain by a series of intensely metamorphosed sediments. The rocks extend in parallel ridges; and folding has steeply upturned them so that differential erosion has developed the ridges. Resistant rocks of schist, gneiss and granodiorite form the ridges while less resistant marble is the valley maker.

3.2.7.3 Landforms and Soil Deposits

The topography is predominantly controlled by the bedrock with superimposed glacial deposits, alluvial deposits and swamps being the minor features. Glacial till, which is mostly sandy, lies over a highly irregular bedrock surface. Some kames occur in northern Westchester County, while outwash terraces are found along the Hudson River. Many swamps occur either in the poorly drained water-laid deposits or in pockets in the bedrock surface.

3.2.8 Taconic Mountains

3.2.8.1 Description

The uplands of western New England (Green Mountains, Taconics, Berkshires) have an extension southwesterly into New York State. East of the Hudson River along the State line is an upland area trending in a generally north-south direction with but few valleys. Elevations in the mountainous area range from 600 to 2,800 ft. A striking component of this province is the Rensselaer Plateau. Roughly 9 miles wide and 20 miles long, this relatively flat surface has elevation of 1,500 to 1,800 ft. It is not entirely flat but relief is expressed in rather broad swells and long slopes.

A series of rugged and rocky ridges which trend generally north-northeast; summit levels 1000 – 2000 ft. above sea, and 500 – 1500 ft. above the narrow valleys separating them. Rocks include limestones, sandstones and slates, altered and broken by the folding and faulting which have characterized the long geologic history of these mountain stumps. There are numerous small lakes and picturesque stream valleys in the Taconics. On the west, these mountains merge into flat or gently rolling plateaus which drop off toward the inner lowland of the Hudson.

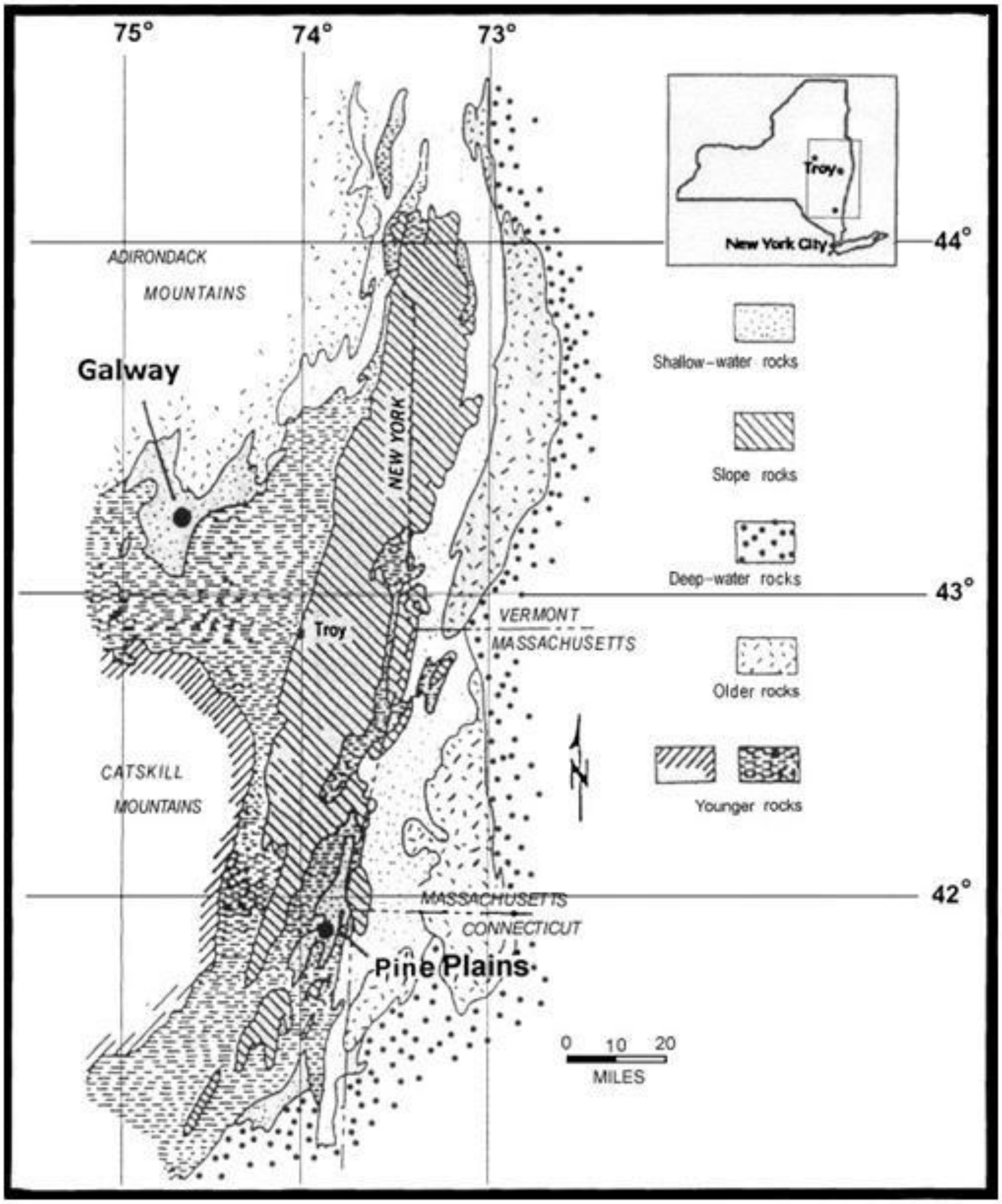


Figure 3-14 Generalized Geologic Map of the Taconic Area (Friedman 2002)

3.2.8.2 Bedrock

The original bedrocks were dominantly shale and sandstone which have been non-uniformly metamorphosed by severe compression. The source of energy was in the east so the degree of change is greatest in the eastern past of the province. Near the Hudson-Champlain Lowlands, the rocks are shales with slatey cleavage, farther east altered to slates, phyllites and schists. The Rensselaer Plateau is upheld by a metamorphosed grit or quartzite called "graywacke".

3.2.8.3 Landforms and Soil Deposits

This is essentially a mountainous area with few valleys. In two major valleys, the Battenkill and Hoosic, outwash and alluvial deposits occur in places, underlain by lacustrine bottom sediments. Glacial till is the dominant soil of the uplands and contains abundant chips and fragments of shale and slate. On the lower valley walls, kame terraces and small deltas may be found.

3.2.9 Hudson-Mohawk Lowlands

3.2.9.1 Description

This lowland is bounded everywhere by uplands, except for two small portions. It extends almost the entire north-south length of eastern New York. In general, except for the three ridges in the south, the low relief is caused by the glacial deposits. In the south, the lowland contains three ridges surrounded by lowland; these are Schunemunk, Shawangunk and Marlboro Mountains. West of the Hudson, the valleys of the Wallkill River and Roundout Creek form most of the lowlands, while east of the Hudson, the Fishkill and Wappinger’s Creek valleys form the rest of the lowlands.

A central lowland portion consists of a valley on both sides of the Hudson River extending to near Whitehall.

The northern portion is narrow and intermittent along the shore of Lake Champlain and then widens westward south of Plattsburgh. The western boundary with the St. Lawrence Lowland in the north is the drainage divide where waters flow to the St. Lawrence River instead of to Lake Champlain.

1. Hudson Valley
   The Hudson River begins in the southeastern Adirondacks and flows first southeast, then east, and finally southward through a wide (15-20 miles) lowland underlain by weak sedimentary rocks. Its outer boundaries are the Helderberg Plateau and Catskills on the west and the Taconics on the east; between these are several distinctive terrains which give the Hudson Valley much diversity.

   North of Albany, in the vicinity of the Mohawk, is a broad sandy area, the glacial Lake Albany Plain. Farther south, and to the east, is the Rensselaer Grit Plateau and the Slate Hills. In the neighborhood of the Catskills is a tightly folded series of rocks known as "The Little Mountains of the Catskills". From Newburgh northward, the river has a narrow inner valley with a conspicuous terrace, some 100 – 200 ft. high; the country bordering it is generally low and rolling, here and there interrupted by low hills or ridges. South of Newburgh, the river passes through the Highlands in a gorge; below Peekskill, the valley is considered in connection with adjacent regions, the Manhattan Hills and Triassic Lowland.

2. The Wallkill Valley
   A broad open valley, heavily covered with glacial drift and drained by the Wallkill River. The latter is a major tributary of the Hudson River; beginning in the Pochuck Mountains on the NY-NJ border, it flows northwestward for 70 miles to join the Hudson at Kingston; Roundout Creek enters the Wallkill below Rosendale.

3. The Shawangunk Mountains
   A steep-sided mountain ridge rising about 1000 ft. above the surrounding country and extending northeastward from the NY-NJ State line in Orange County, to the central part of Ulster County. The main body of the Shawangunk consists of a great thickness of folded shales and sandstones capped by a very resistant layer of conglomerate which "holds up" the mountain and causes it to stand out boldly. Westward, the Shawangunk drops off into the deep narrow Rondout Valley; eastward, it overlooks the Wallkill Valley.

4. Mohawk Valley
   Major west-east lowland between the Adirondacks and the Appalachian uplands. Drained eastward by the Mohawk River which rises 1800 ft. above sea level on Mohawk Hill, southern Lewis County. From here it flows generally south to Rome where it turns east to the Hudson, nine miles above Albany. The Mohawk is about 150 miles long. The river itself flows in a rather narrow inner valley; the lowland, however, eroded in soft shales between the hard rocks of the Adirondacks and the Appalachians, is 10-30 miles wide and about 1000 ft. deep. At Little Falls, the valley narrows to a deep gorge where the river has cut its way through a pre-glacial divide; above and below this "narrows", the lowland has a broad, open and slightly rolling aspect.

3.2.10 Mohawk Lowlands

3.2.10.1 Description

The Mohawk Lowland includes the river valleys of the Mohawk and Black Rivers and also the broad band between the crystalline rocks of the Adirondack Mountains and the resistant escarpments of the Tug Hill and Glaciated Allegheny Plateau uplands. The Mohawk River rises at an altitude of about 1,800 ft. and flows west, south and then east to join the Hudson only a few feet above sea level. The Mohawk and Black River valleys are separated by a divide of unconsolidated glacial moraine.

3.2.10.2 Bedrock

Bedrock is mostly soft shales which are easily eroded. Some limestone occurs near Amsterdam and much limestone is found north of Utica and on the west side of the Black River. Crystalline outlines occur at Little Falls and Yosts (Montgomery County) in the Mohawk River valley bottom.

3.2.10.3 Landforms and Soil Deposits

The major landforms are bedrock-controlled erosion features. These are the inner valleys of the Mohawk and Black Rivers. The lowlands beyond the inner valleys are covered mainly by glacial till which contains considerable amounts of shale chips and fragments.

Most of the inner valleys were at one time occupied by glacial lakes. Therefore, lacustrine sediments dominate. The valley sides are covered by silts and clays in many places. Lake-associated delta deposits are found by both sides of the river valley. Farther from the valleys, water-sorted outwash and kame terrace deposits exist.

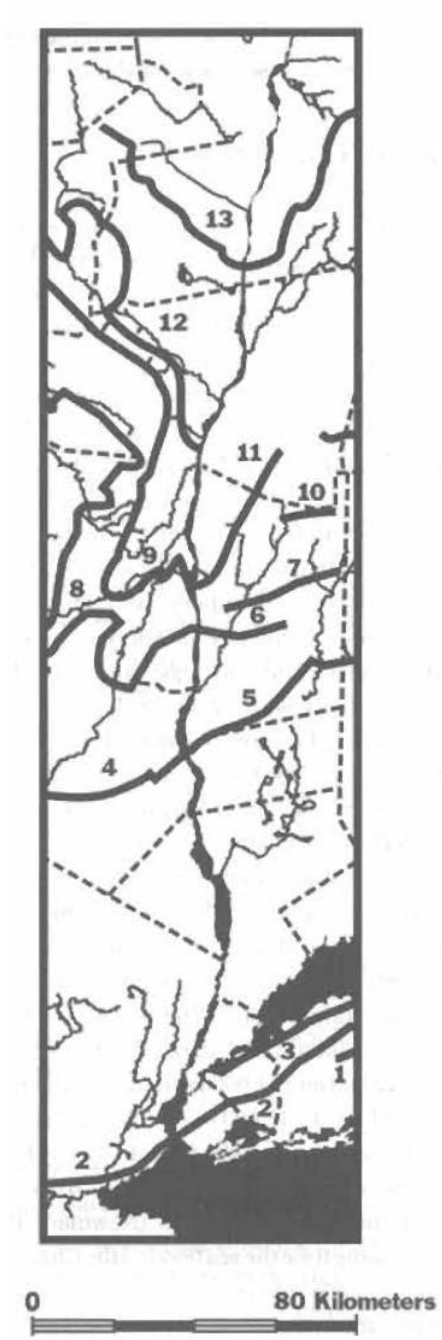
Bedrock

The bedrock is all sedimentary rock, mostly of shale and sandstone. Some limestone occurs in the southern portion and north of Whitehall along the lake to the Vermont border. Resistant sandstone or conglomerates cap the ridges in the southern portion.

Landforms and Soil Deposits

As a generalization, the lowland may be characterized as a relatively level lacustrine terrace flanked by undulating ice-contact and water-sorted deposits and then by glacial till borders.

In the south, the Rondout and Wallkill valleys contain lacustrine silt and clay soils with related water-sorted deposits. The Orange County muckland represents the last trace of a pro-glacial lake. The Hudson or central portion from Newburgh north is a lacustrine silt and clay terrace flanking the river trough with ice-contact terraces and deltas of water-sorted granular material farther from the river. These occur north of the Dutchess-Columbia County line east of the Hudson and on the proglacial Mohawk and Hudson deltas west of the river. In this area, some of the finer sands have been reworked by wind action to form dunes. The northern portion is covered with mostly silt and clay soils of lacustrine, estuarine or marine origin. Some granular materials occur in association with the silts and clays. As the adjoining uplands are approached, glacial till becomes the dominant soil material.



1 – Manetto Hills	2 – Harbor Hill Moraine	3 – Sands Point	4 – Pellets Island
5 – Shenandoah	6 – Poughkeepsie	7 – Hyde Park	8 – Wallkill
9 – Rosendale	10 – White Plains	11 – Red Hook	12 – Middleburgh
13 – Delmar			

Figure 3-15 Major Recessional Ice Margins
(Sirkin and Bokuniewicz, 2006: after Cadwell, 1986 and Connally & Sirkin, 1986)

3.2.11 St. Lawrence – Champlain Lowland

3.2.11.1 Description

The St. Lawrence Lowland is a smooth plain that borders the Adirondack Mountains and extends northerly beyond the Canadian border. On the south, the border is defined as the line where the crystalline rocks of the mountains are overlapped by the younger sedimentary rocks. The eastern boundary is the drainage divide where water begins to flow to Lake Champlain. The western edge may be arbitrarily taken as where the geologic age of the surface sedimentary rocks change from Cambrian to Ordovician north of Watertown.

The entire area is a low plain. Much of the area near the St. Lawrence River is a flat to billowy lake plain that has been smoothed by proglacial lake or marine waters. Local relief rarely exceeds 75 ft. In a few places, rock ridges occur. Numerous drumlins or drumlin-like hills furnish much of the local relief.

1. St. Lawrence Marine Plain
   Narrow (about 3-8 miles) strip of inner lowland adjacent to the St. Lawrence River; underlain by post-glacial marine clays; flat to gently rolling.

2. St. Lawrence Hills
   Area between the Marine Plain and the Adirondacks. A gently rolling country underlain by sandstones and limestones, covered with glacial drift and crossed by the Oswegachie, Grass, Raquette and St. Regis Rivers which roughly tend to parallel the St. Lawrence in this section.

3. Champlain Lake Plain
   Low, relatively flat area underlain with marine clays and limestone which outcrops occasionally along the lake shore. Drift deposits and peat bogs are common in the northeastern part.

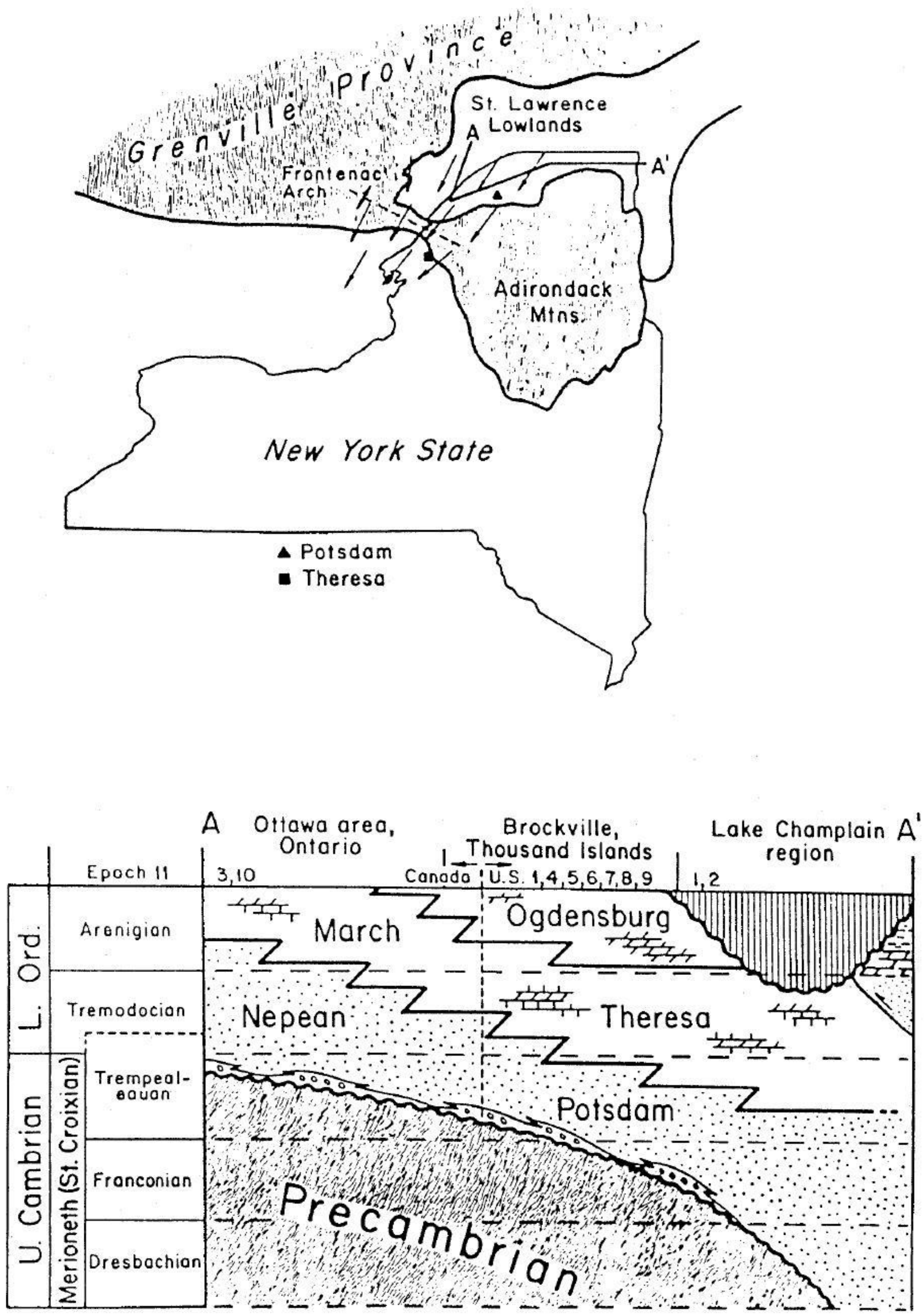


Figure 3-16 Canada/United States Schematic General Geology Section and Map (Billman, 1999)

3.2.11.2 Bedrock

The entire province is underlain by sedimentary rock. These are dolostone, limestone and sandstone. They are layered and dip northward away from the Adirondacks.

3.2.11.3 Landforms and Soil Deposits

This is a complex pattern of glacial till drumlins and drumlin-like hills surrounded by lacustrine silts and clays or related sands and gravels of beaches, bars and deltas. Toward the Adirondack Mountains, outwash and ice-contact deposits are found. The ice-laid glacial tills are often extremely stony or bouldery and in places are very compact. The fine sand soils found on some of the large deltas have been moved by wind to form the so-called "blow sand" areas. It is likely that some of the silt and clay deposits in the eastern portion are marine in origin, resulting from a Pleistocene Atlantic invasion up the St. Lawrence Valley.

3.2.12 Erie and Ontario Lowlands

3.2.12.1 Description

These are the plains which border the Great Lakes. They abut the Glaciated Allegheny Plateau to the south, and to their greatest extent, Tug Hill on the east. The Ontario lowlands are an area of generally subdued topography, except for the Niagara escarpment and the swarms of drumlins south of Lake Ontario. The Erie portion slopes rather uniformly from the Portage escarpment northwestward to the shore of Lake Erie. The generally low relief is provided by a series of proglacial lake beach ridges.

1. The Erie Lake Plain
   A strip of very low relief, a few miles wide, which slopes from 800 – 900 ft. to the level of Lake Erie (573 ft.) and borders the latter along the western extremity of New York State.

2. Ontario Lake Plain
   A sandy lake plain with east-west ridges which represent old shorelines of a former glacial lake.

3. Southern Ontario Hills
   Low hilly terrain, slightly rolling. Extends south of the Lake Plain sub-divisions as far as the plateau front.

4. Ontario Drumlins
   Region dominated by low "Whale-back" shaped glacial deposits known as drumlins. There are literally hundreds of these landforms scattered over this part of the Lake Plain.

5. Ontario Ridge and Swampland
   Area characterized by a fluted ground moraine and many swamps. Extends from the northern shore of Oneida Lake, northwest to Lake Ontario; though much lower in elevation, it has something of the desolate aspect of the Tug Hill Upland.

6. Oneida Lake Plain
   Low area lying south and east of Oneida Lake; characterized by broad swampy lands, e.g., Cicero Swamp, the Mucklands near Canastota, etc.

7. Eastern Ontario Hills
   Low hills of glacial drift adjacent to the eastern side of Lake Ontario.

8. Black River Valley
   North trending valley drained by the Black River. It is the most important north-south lowland, between the Adirondacks on the east and the Tug Hill upland on the west; provides access between the Mohawk Corridor and the St. Lawrence River Valley.

3.2.12.2 Bedrock

The bedrock is stratified beds of shale, sandstone, limestone and dolostone. They are gently tilted to the southwest. Except for the Niagara escarpment, exposures of bedrock are generally limited to river gorges and stream beds.

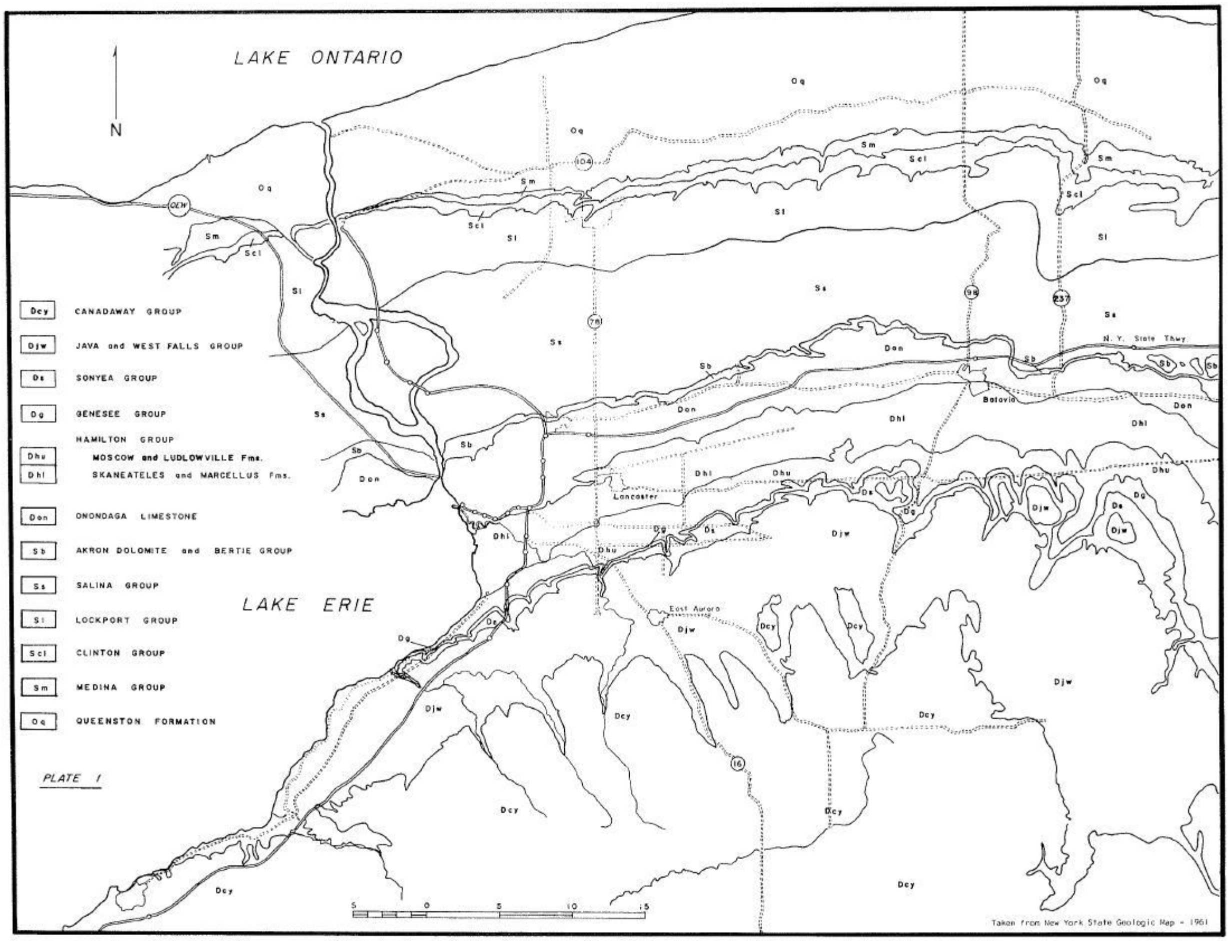


Figure 3-17 Bedrock of Northwestern New York (Buehler 1966)

3.2.12.3 Landforms and Soil Deposits

Glacial till plains and proglacial lacustrine plains are the dominant features. Drumlins clutter the central portion of the Ontario plain. Associated with the lacustrine silt and clay deposits are the related coarse-grained lacustrine soils found on beach ridges and deltas. Several large swamps occur which are vestiges of the proglacial lakes. These are the Oak Orchard Swamp, the Montezuma Swamp and the swamps south and east of Oneida Lake.

The glacial till deposits range from loose to exceptionally dense in consistency. In the northern section of the Ontario plain, the soil cover is usually thin. Also occurring across the lowlands are subdued morainic topography and, in places, ice-contact deposits.

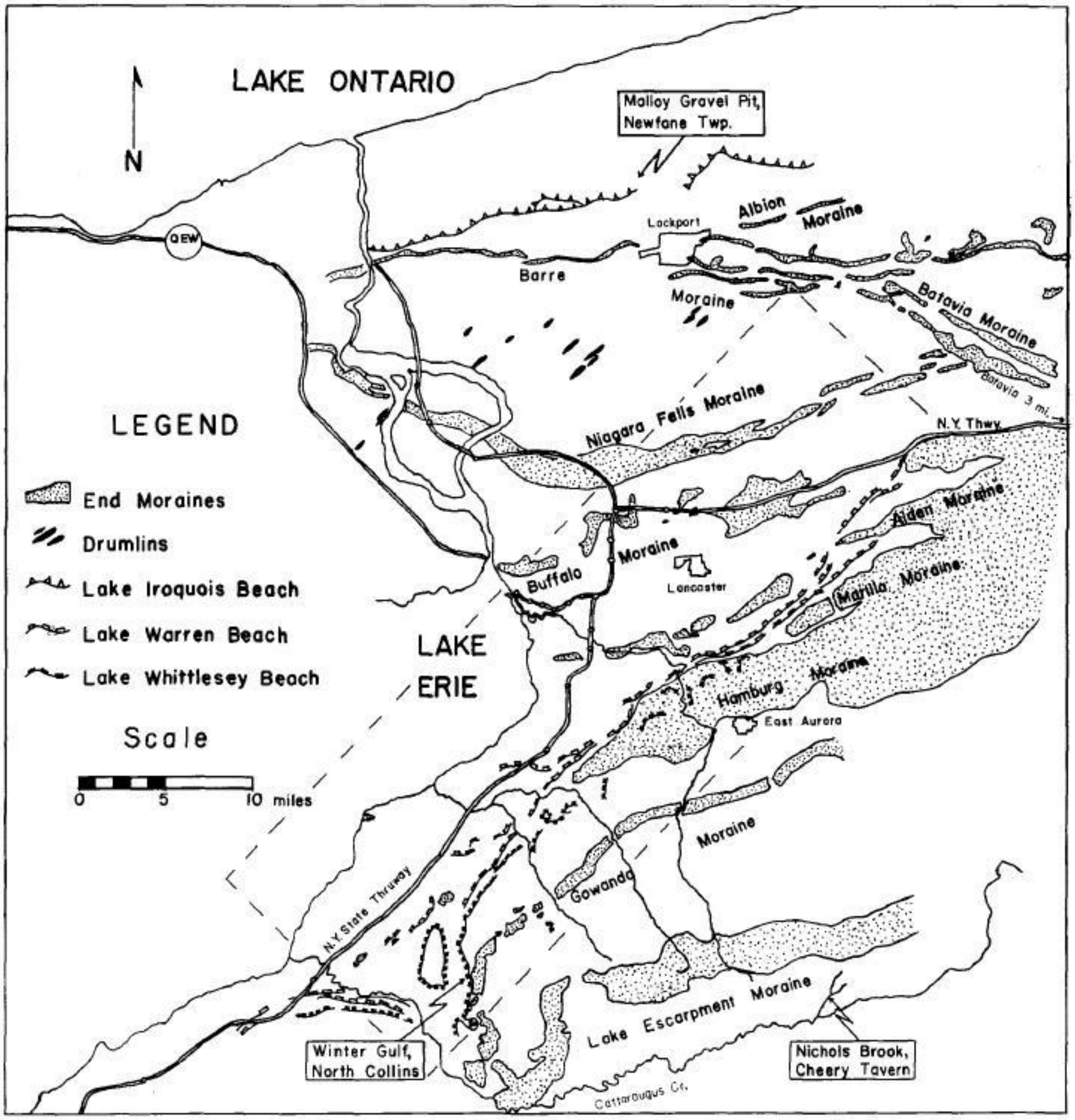


Figure 3-18 End Moraines and Major Strand Lines of Northwestern New York (Calkin, 1970)

3.2.13 Atlantic Coastal Plain

3.2.13.1 Description

This province is confined to the very southern portion of Staten Island and all of Long Island, except for the northwestern corner in Brooklyn. It represents the end or terminal moraines of a glacier and the associated outwash aprons beyond the moraine. The entire province has extremely low relief. On Long Island, the highest elevations are a little more than 400 ft., the lowest at sea level. On Staten Island, the highest elevation is just under 400 ft.

1. Harbor Hill - Ronkonkoma Moraines
   Long Island and Staten Island are crossed from southwest to northeast by the terminal moraine of the Great Ice Sheet. The surface of the northern parts of these islands is, therefore, low undulating terrain of glacial drift, usually under 75 ft. elevation. The moraine itself is a conspicuous surface feature on Long Island; a little more than a mile wide, with hummocks 100 – 125 ft. high, it makes a bold front when viewed from the south. It consists of irregular deposits of sand, compact till and stratified drift, with scattered large boulders.

2. Long Island Outwash Plain
   A broad low sandy plain extending southward from the moraine, with a very gradual slope to the sea.

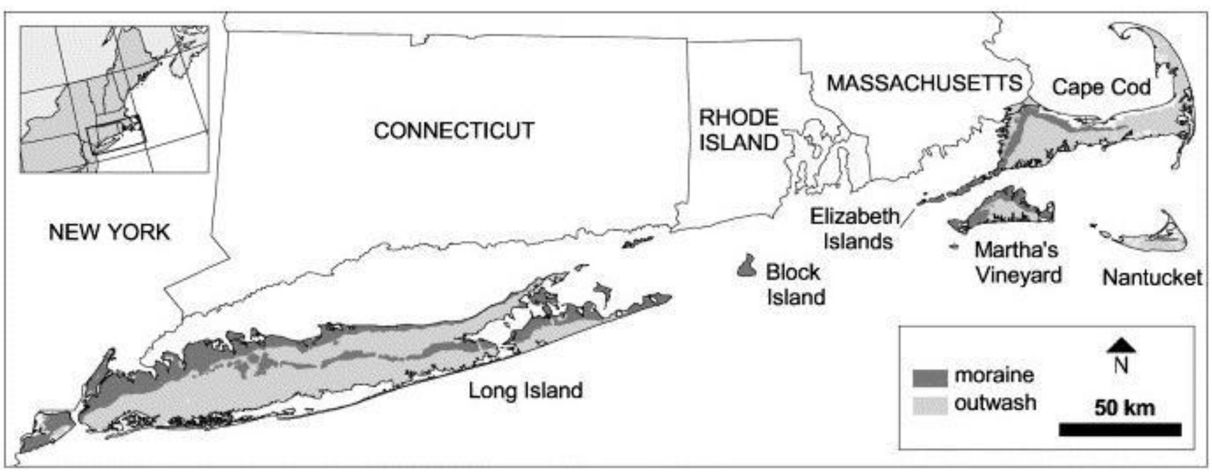


Figure 3-19 Surficial Geology of New England and Long Island (Foster & Motzkin 2003)

3.2.13.2 Bedrock

Bedrock, generally absent from Long Island and only slightly evident on Staten Island, is buried under glacial deposits. Data from wells indicate that bedrock is unconsolidated sand, gravel and clay of Cretaceous age.

3.2.13.3 Landforms and Soil Deposits

Topography on Long Island is the result of two moraines and their associated outwash aprons. The moraines are hilly areas and the outwash areas are flat and slope south to the sea. The soils are sandy with varying amounts of gravel. In the glacial tills on the moraines, the granular soils are somewhat more compact and less stratified than on the outwash. Wind has worked some areas on the outwash into dunes, while much of eastern Long Island has a thick silt blanket over the sand and gravel. Clay is exposed on the northern fluke of the Island near Greenport. On Staten Island, there is only a single moraine where the till is quite bouldery. The outwash apron is thin. In many places the underlying Cretaceous sediments are found. Many tidal marsh areas are found along the shores of both islands behind barrier beaches.

3.3 THE GEOLOGIC ORIGIN OF NEW YORK SOILS

3.3.1 Discussion

A knowledge of regional soil behavior and engineering practices is a valuable asset in a geotechnical engineer. The concept of a regional approach to soils engineering stems from an understanding of the geologic history: the manner in which the soil was deposited, the material from which it was derived, and weathering processes to which it has been subjected. The geologic context provides the basis for planning more detailed studies and adds to the information available in interpreting subsurface conditions.

Historically, the soils of New York originated during three different times. They are:

1. Pre-glacial period
2. Glacial periods
3. Post-glacial period

The deposits are named and described and some engineering characteristics are indicated in the following pages.

As a consequence of different geological origins, the various deposits can be grouped so that each group has some specific engineering significance. This grouping will prove to be one of the most useful tools for planners, soils engineers and builders. It has been used by some and entirely neglected by too many. Planners, in particular, have stressed demography and neglected the economics of soil capability, particularly on planning for future development of many parts of the State.

3.3.2 The Pre-Glacial Deposits

In New York State, a very large portion of the unconsolidated soils owe their origin to the action of the Wisconsin glacial period. Some, however, are residual soils developed on areas that were not glaciated or on areas not greatly affected by glacial ice. There are also remnants of outwash and morainic deposits of Illinoian age on parts of the Allegheny River Valley. On Long Island, unconsolidated sediments of Cretaceous and other ages occur. They are mostly overlain by glacial period soil. In addition, some exposed bedrock was always being subjected to weathering forces during much of geologic time. Coastal plain sediments of various ages may be encountered on parts of Long Island and Staten Island and sporadically some residual soils will occur where glacial action overrode the previously existing deposits without eroding them. On steep locations, these materials are generally thin veneers over bedrock; on flat areas, they may be thick where they were not exposed to glacial ice action.

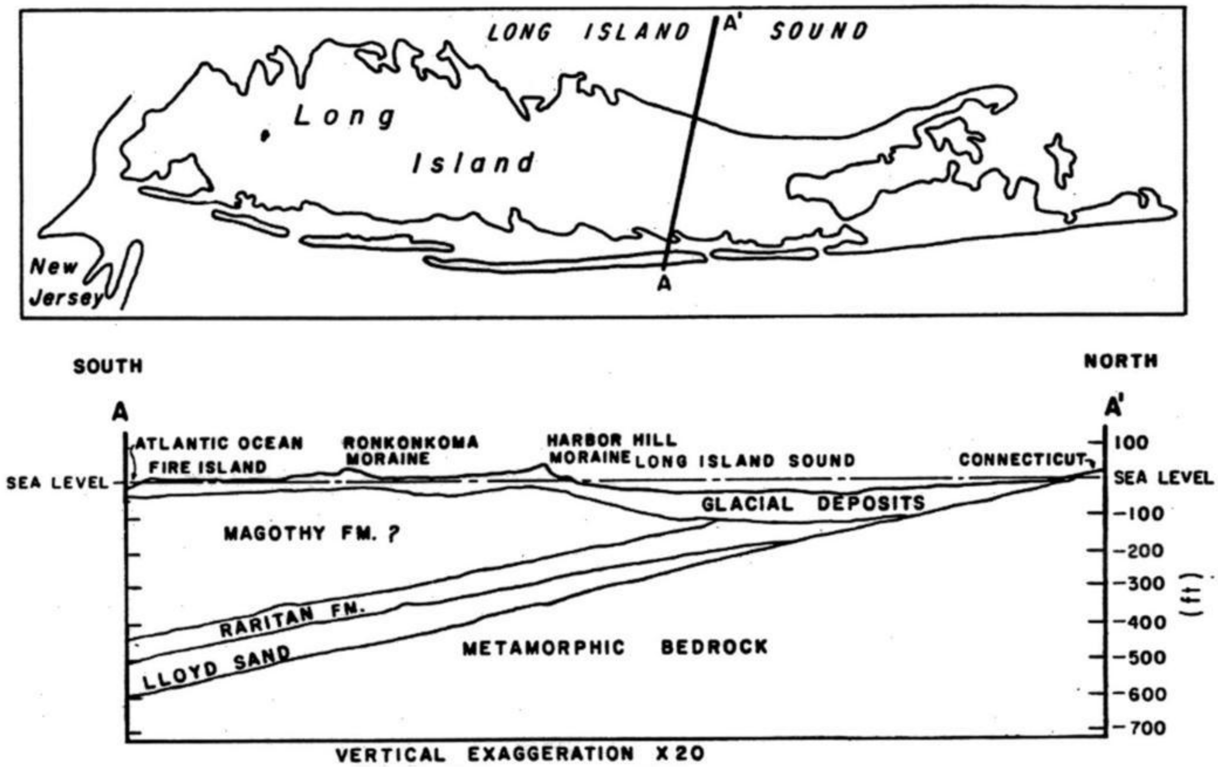
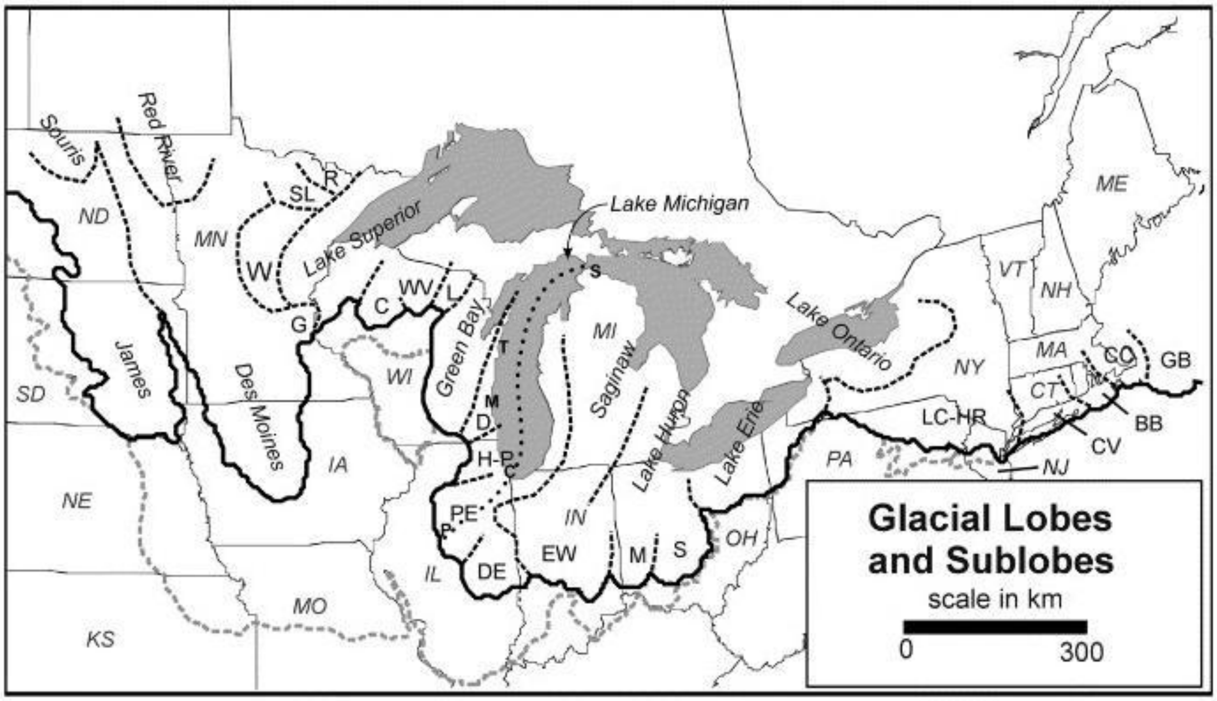


Figure 3-20 Geologic Cross Section from the South Shore of Long Island North to the Connecticut Mainland (Williams 1981)

3.3.3 Glacial Period Action and Deposits

At the present time, it is common knowledge that glaciers exist and it is an accepted fact that glaciers covered most of New York a few thousands years ago. Mountain glaciation occurred on high places and a thick ice sheet covered nearly all of New York. The latter sheet was called the continental ice sheet.

Glacial ice occurred where there was a source of precipitation and the temperature was low enough to permit the accumulation of the precipitated moisture. Wherever ice built up high masses, the front of the mass would move in a manner similar to what we now call plastic flow. The glacier that covered the State extended out from Canada.



(sublobes) LC – Lake Champlain, HR – Hudson River

Figure 3-21 Glacial Lobes and Sublobes of the Southern Laurentide Ice Sheet during the Late Wisconsin Glaciation (Mickelson & Colgan 2003)

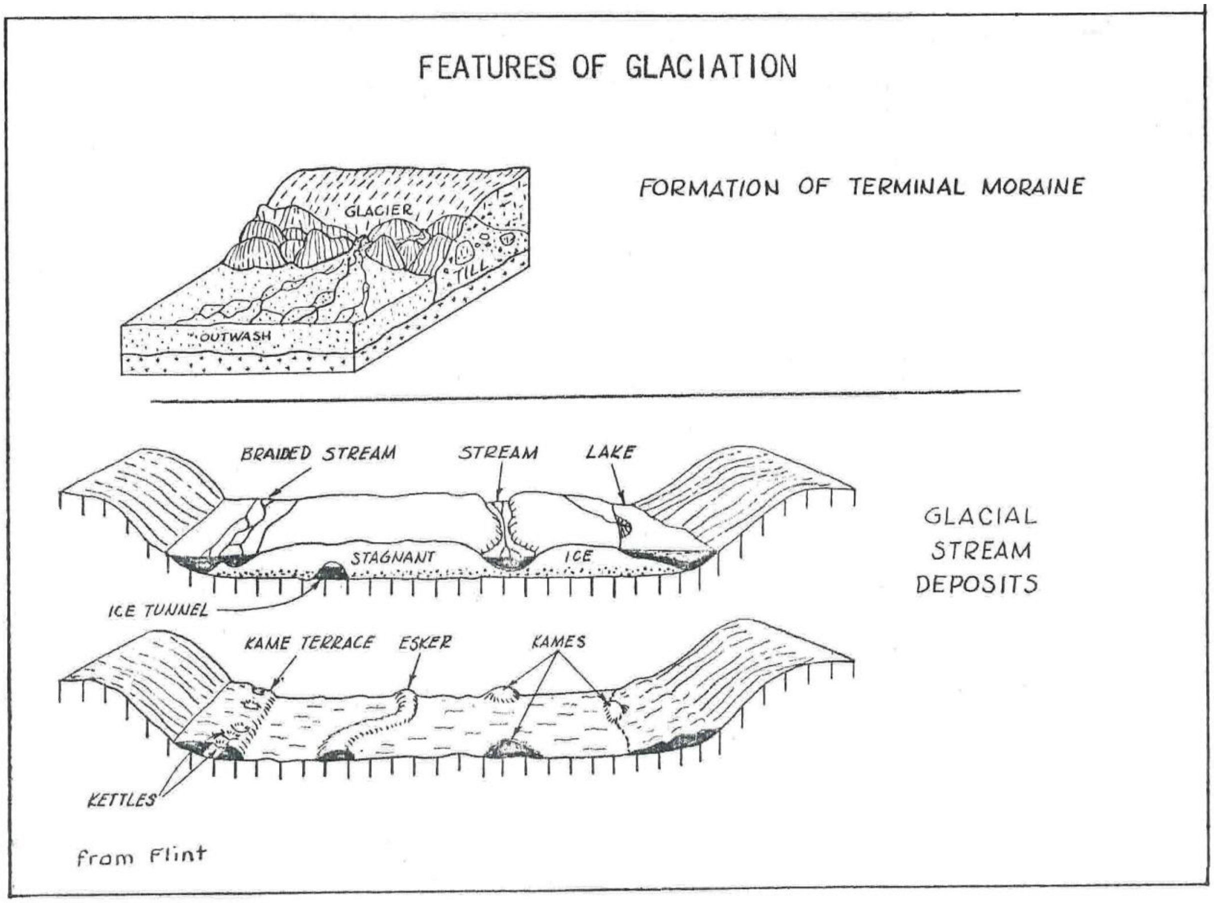


Figure 3-22 Features of Glaciation

On its dominantly southern course (except where impediments to straight flow prevented it) it eroded the pre-existing soils and shattered some of the underlying bedrock. In effect, it sandpapered the landscape and incorporated the plucked material in its mass. When the plucked materials exceeded the transporting power of the ice, deposition took place. Where this occurred, the resultant deposits are glacial tills. But deposition by other processes took place when meltwater streams were active during the ablation stages and when bare dry land was exposed to wind action. Still another type of deposition took place where glacial ice or glacial deposits formed dams and streams carried sediment to the sometimes ephemeral lakes. Post-glacially, seas invaded some lowlands. Streams emptying into these seas carried clays and silts that settled out on the now exposed sea bottom.

On a broad basis, the deposits of the glacial period can be placed into five broad categories. They are:

1. Glacial ice deposits of glacial till which are dominantly unsorted and unstratified but in places layered and containing some intercalary material.
   A. Basal till - Compact glacial till.
   B. Morainic till - includes ice shove material - a generally less compact material than is the basal till.

2. Glacio-fluvial deposits which are mostly sorted and stratified material of sand and gravel.
   A. Ice-contact deposits of materials often poorly sorted.
      1. Kame-type deposits
      2. Esker deposits
      3. Outwash fan deposits
      4. Water sorted portions of moraines - sands and gravels
   B. Generally well-sorted stratified deposits.
      1. Outwash train, outwash terrace, and valley train deposits
      2. Delta and esker delta deposits
      3. Some alluvial fan deposits
      4. Overflow and spillway channel deposits
3. Glacio-lacustrine deposits of sorted materials with various textures.
   A. Bottom sediments of pro-glacial lakes and some ponded areas associated with ice-contact deposits - mostly varved silts and clays.
   B. Shore and near-shore deposits including current deposition and thin delta material - mostly laminated silts and fine sands.
   C. Bars and Beaches - sorted materials - sands and gravels.
   D. Wave washed tills - sorted but unstratified deposits of glacial till.
4. Marine bottom sediments of mostly fat, very sensitive clays and silty clays. Actually these deposits are later than the glacial deposits, but glacial ice caused subsidence which permitted marine invasion.
5. Eolian deposits of sorted sands and silts.

3.3.3.1 Glacial Ice Deposits

3.3.3.1.1 Glacial Till – Basal

- Description

Glacial till is the unsorted, generally unstratified but often layered, usually long-graded material carried by and deposited directly from the ice. It is basal till when overridden and compacted; and it is englacial or morainic till when not overridden.

- Occurrence

Till deposits cover a major portion of the State. They may be shallow over bedrock or very thick. They cover wide expanses of some till plains, fill many valleys, cover valley sides, and often mask plateau and mountain bedrock. On some low areas, the tills may be covered with lacustrine, outwash, or other water- or wind-laid material.

- Basal and Morainic Till

On a geologic basis, till deposits are either basal or morainic. The basal tills are compact. The morainic tills are generally less compact and will contain some sorted water-laid material and, when derived from the same parent materials, are generally more permeable. Morainic till deposits occur on smooth landforms. They are often difficult to separate from the water-sorted portions of moraines. Complex slopes are common.

- Soil Textures

Till deposits are highly variable mixtures. The matrix may be dominantly one texture or two textures or any combination of sand, silt, and clay. Stones, boulders, and ledgy pieces will comprise the coarse portions. Till from sandstones will generally be stony and dominantly sandy. Tills from interbedded sandstone, siltstone, and shale will be stony mixtures of sand, silt, and clay. Soils from shales will be silts and clays. Soils from crystalline areas will be stony, and bouldery and contain sand, some silt and little, if any, clay.

- Inclusions in Till

The term glacial till includes the original ice-laid deposits, locally sorted inclusions, ice fractured material, and some residuum. Since these materials may have undergone post-depositional movements, the term will include intercalary deposits, colluvium, sloughed till, and the deposits caused by solifluction.

- Thick and Thin Till

For engineering purposes, all glacial till deposits can be placed in two broad categories. They are thick and thin tills. No precise thickness figure is offered. Thin tills are those on which light grading operations will encounter bedrock in cuts. Some of the newer soil surveys give precise depths to bedrock. This can be misleading; indicated depths should not be used as a substitute for an on-site., evaluation where precise depth to bedrock would be critical for the proposed engineering feature. Thick tills are those till deposits in which bedrock would not be encountered in light grading operations. However, rock might occur in deep cuts.

Thick Glacial Till

- Engineering Significance

Thick till deposits are usually good sources of common fill material. The poorly drained portions may require drying before use, and trafficability problems may occur. Some till deposits may contain large boulders or ledge fragments. These may interfere with placement of fills in thin lifts. Generally, the basal tills have adequate bearing power to support high fills. Since some areas mapped as tills may be sloughed material, it is generally good practice to evaluate sites for heavy fills, particularly on sites where valley sides adjoin the bottom lands. Morainic tills may occur as deposits that have been shoved over bottom sediments or old alluvium. Here again, the sites for heavy fills should be evaluated.

Basal tills are generally more slowly permeable than the morainic tills of similar texture.

Till deposits generally form hill and dale landscapes where flat road profiles are impractical.

Where tills occur on sloping landforms, both longitudinal and transverse cuts and fills will be necessary on highway alignments. On a small but significant portion of till deposits, cut slopes will slough to some degree - principally during the frost withdrawal period. Some slopes will be slide-prone, either because of excessive steepness, excessive wetness or a high clay content. Seepage into cuts does so under a considerable hydraulic gradient. Often, intercepting ditches above the top of cut slopes are warranted in order to prevent slope saturation. All soils are erodible. However, some are more readily eroded than others. A vegetative cover or a slope protection blanket will be necessary on all slopes. Fill slopes from dominantly sandy materials will require positive runoff control.

The location of unstable areas, intercalary material, colluvium and sloughed till is not always easily discernible. On-site evaluation, air photo analyses, seismic interpretations, test pitting, and cased borings are the tools available for assessment. Their use is imperative on many sites.

- Frost Effects

In the colder parts of the State, boulder heave is a common occurrence. In general, this phenomenon is associated with morainic tills and may occur in the very compact basal tills. Two treatments are possible. The first is the processing of the till subgrades; the second is an elevated grade with a boulder-free material.

"Uniform" heave occurs on many till landscapes. It is not as severe as on granular and lacustrine areas.

On a comparative basis, basal till deposits are the densest soils of the State. They are generally not exceptionally wet, with low permeability.

Thin Glacial Till

- Engineering Significance

Thin glacial tills are shallow to bedrock. They have textures similar to the thick glacial tills. In general, they will be set in the spring and, except on seep areas, are generally dry in summer. Except on steeply sloping areas, these soils will support very high embankments. Fill sites on steeply sloping landscapes may require keying. Cuts in thin till areas will generally encounter bedrock. High rock slopes may require special design. On extensive flat areas, an elevated grade line may eliminate the need for blasting bedrock for drainage ditches. Thin tills are poor sources of borrow because they will yield low soil volumes. However, in metropolitan areas, they may be a valuable source.

- Ablation Till

Any till deposits overridden by ice are called basal till. All till deposits in a loose state are called ablation or morainic till. The ablation tills are not always easily discernible, but, in general, the morainic areas have smoother landforms and the slopes may be complex; that is they have multi-directional slopes and often they grade into stratified associated kames and kame terraces. The ablation tills have a lower in-place density and greater permeability than do the basal tills in the same geographic region.

Very often glacial fronts readvanced after a retreat period. These readvances may be the sites where the morainic till may have been shoved over less suitable and weaker materials such as bottom sediments. One such location is east of Rochester in Monroe County and many others will be encountered particularly between the lakes and the Allegheny Front (The Glaciated Plateau).

- Engineering Significance

Ablation till may be thick or thin. In general, it can be expected that these deposits will have a little lower bearing capacity than the basal tills. Sorted intercalary materials may occur. Very often, at any one place, a profile may show tills and interbedded granular or other materials; and extrapolation beyond sampled sites is purely guess work. The ablation tills are good sources of common borrow and, when steeped with good gravels, may be a source of select borrows.

In places, ablation tills may overlie poorer materials. Where such adverse soil conditions might influence engineering, these sites should be thoroughly investigated.

Areas of thick deposits and also areas of thin deposits can occur. On shallow deposits, bedrock can be expected to be encountered in light grading operations. In thick ablation till, rock may occur in deep cuts. Some ablation tills will be prone to differential heaving where a replenishable water supply exists. In the Adirondacks and the St. Lawrence province, these soils are often very bouldery.

3.3.3.1.2 Glacio-Fluvial Deposits

- Origin

Streams flowing on, within, and beyond the glacier transported and ultimately deposited the material they carried. Deposits of this origin are called glacio-fluvial deposits. They occur on a confusing array of landforms and have a wide range of engineering properties. The sites of deposition may be on firm bedrock, compact glacial till, or on weak deposits of old lake beds and elsewhere. They are generally, but not exclusively, stratified sands and gravels and some silts.

- Kame-Type Deposits

Kames are rounded hills or hummocks generally, but not exclusively, composed of well to poorly stratified cobbles, gravels and sands. Some deposits may be comprised entirely of silts. Some dominantly sandy and gravelly deposits have interbedded silt strata. Often, contiguous strata show a wide range in texture. Stratification is not always horizontal. A collection of kames is called a kame field and, where these deposits occupy extensive mostly valley side positions, they may be called kame terraces. For terraces, ice lay in the valleys and deposition was along the valley sides. Water-sorted portions of moraines are materials laid down at the wasting front and sides of a glacier. Here, sorted and unsorted material usually exists in extremely variable and fortuitous combinations. The water-sorted portion would be a granular stratified deposit called a kame moraine and the unsorted material would be a loose morainic till. These areas have complex slopes and the entire landscape is smooth. Contiguous knobs may contain entirely different textured material. Some deposits will often have morainic till and stratified sands and gravels in the same profile. These deposits have an easily recognized landform but the ultimate evaluation of the deposits generally requires subsurface investigation. Cased borings and test pitting are the most positive methods.

- Associated Deposits

Kame delta deposits, lacustrine bottom sediments laid down in ephemeral lakes, and kettle deposits can occur. These areas may not be shown on soil maps. Usually, this is because the map scale used is inadequate to show minor occurrences. On a few locations, moulin kames will occur. They were formed by deposits falling through ice crevasses.

- Engineering Significance

These soils will support light embankments and most locations will probably support high embankments. The problem of what underlies the granular materials constantly arises and so, where the subsurface conditions would be significant to the engineering work, the profile should be evaluated.

For the most part, these deposits are pervious. But surficial infiltration may eventually be impeded by less pervious underlying materials and consequently a seasonal water table will occur. Excavations made during dry periods of the year may not show this condition.

These deposits are potential sources of sand and gravel. Throughout the State, there will be a wide variation in soundness and gradation and not all deposits will furnish material acceptable for all the uses applicable to sands and gravels.

Generally, these areas are excellent sources of common borrow. Select borrow may also occur. Where the materials are dominantly sandy, they will readily erode on fills. Here, positive runoff control will be necessary. Water must generally be added for proper compaction.

Subgrades will be good above the water table - if any. In cold regions, these materials will be prone to differential, frost heaving. Processing to produce uniformity will be necessary. It can be expected that standard compaction efforts will generally be inadequate. These deposits are subject to densification by very heavy and vibratory loads.

Slope stability depends on several elements. First, the materials are mostly non-cohesive. Second, interbedded silts will retard run-in. Third, run-in may accumulate at the contact between the granular water-laid materials and any less pervious underlying material. Fourth, the deposition may have occurred over steeply sloping till or bedrock. Fifth, the underlying deposits may in some instances be soft bottom sediments or clayey tills which will be unstable when wet.

These deposits are potential sites for recharge basins and leaching fields.

Moulin kames will exhibit varying degrees of gradation but they are usually granular. Their engineering significance will be similar to that of Kames.

Eskers

- Origin

Eskers were formed by the deposition of poorly- to well-sorted material laid down by streams flowing in channels and under the glacial ice. They occur mostly in valley positions. Eskers are generally low sinuous ridges usually less than 50 ft. high and they have a landform that resembles a railroad embankment. They often terminate in deltas or in kame-like deposits on till and outwash plains.

- Description

Esker deposits are stratified sands and gravels. Some deposits have a high cobble and boulder content. This is particularly true in regions of crystalline rocks such as are found in the Adirondack province.

- Engineering Significance

These deposits have adequate strength to support moderately high embankments. They may very well support high embankments, but generally these deposits are higher than adjacent lands and cuts are often necessary.

Cut slopes will generally be stable. On very coarse deposits, cobbles and boulders may lose their embedment. These materials generally lack fines and are consequently droughty. Establishment of a vegetative cover for erosion control may require addition of silty and clayey material and the use of drought tolerant vegetation.

Esker materials are good sources of common borrow. In places, they may lack adequate fines for compaction. Some deposits may be dominantly cobbles and boulders. Granular material suitability will vary with the lithology of the parent material. Very often, processing will be necessary because of oversize material content.

Esker deltas are granular deposits formed by streams under ice. Their engineering significance is similar to that of other delta deposits.

Outwash Fan Deposits

- Origin

An outwash fan is a fan-shaped deposit put down by a stream where an abrupt decrease in gradient occurs. The stream emerges from steep uplands, encounters flatter land in the valley where the carrying power of the stream is reduced, and the stream unloads and makes the typical fan shaped deposit. During the ablation stage of glaciation, many fast flowing, debris-laden, upland streams built outwash fans on their lower courses. Some streams are still forming fans.

- Occurrence

Fan deposits are widespread, particularly in mountain and plateau valleys. They vary in size. In places, entire villages have been built on them. In most places, the deposits may cover many acres, but some are smaller.

- Textures

The deposits are mostly stratified materials. Stratification is often crude and often contiguous strata vary greatly in particle size. Cobbles, gravels, sand, and some interbedded silts generally occur. The lithology of the deposits is the same as that of the country rock over which the stream coursed. Generally, very few erratics will be found in the deposits.

- Drainage

Seepage is a common occurrence. As is true of many other deposits, excavations made during the dryer periods of the year may not show the drainage condition.

- Engineering Significance

These deposits will generally support moderately high embankments. Where the fan materials overlie lowland deposits subsurface investigations, strength and settlement evaluations are necessary.

Granular materials occur. Particle shape and soundness will vary.

Cut slopes will generally be stable.

Subgrade will be prone to differential heaving in cold climates.

Water-Sorted Portions of Moraines

- Origin and Description

During the glacial melt period, a large amount of englacial materials were let down in place as the ice wasted. Concurrently, some portions of the englacial material were sorted by meltwater. Often, unsorted and sorted deposits were laid down on the same location; and bedded materials may overlie or underlie unstratified material. Both types have the same landform, so discrimination must be done by subsurface methods, usually borings.

- Engineering Significance

These deposits are sources of good borrow and may contain enough stratified material to justify their exploitation for sands and gravel. In cold climates, processing will be necessary on subgrades to prevent differential frost heave.

Outwash Plains, Trains, and Terraces

- Origin

These deposits are generally distributed downstream from glaciers. Outwash is the result of redistribution of glacial erosion products occurring where these products were deposited beyond the glacier. On the plains, they form broad flat surfaces of accumulation with gentle slopes originating at end moraines. In mountain regions, the deposits have similar appearances, but here the lateral extent of the deposits is limited by the width of the valleys into which the erosion products were carried. Terraces probably had similar origins but owe their terrace landform to post-deposition stream dissection or to, in some instances, deposition adjacent to standing ice. At many locations, these deposits continue amazingly far beyond the farthest advance of the glacial ice.

- Description

Outwash plains are usually very gently sloping, extensive plains of mostly well-drained granular deposits. They are stratified. Near the former retreating ice front, the deposits are gravelly. Particle size reduces with increased distance from the glacial front. In places, minor depressions occur. These are where ice blocks occurred and eventually melted with no subsequent deposition. These areas may contain organic matter.

The water-laid material may overlie both good and poor dissimilar deposits. It would be similar to the deposits of recent alluvium to the extent that each was a water-laid material laid over any previously existing material.

All other outwash deposits are similar except they have generally less lateral extent.

With depth, a water table, often fairly shallow, will generally occur.

- Engineering Significance

Outwash deposits are generally good locations for highways. The well-drained areas can be considered to be the best deposits; and any other geologic deposit has a lesser degree of suitability. In other words, all other terrains can be evaluated using outwash as a standard of comparison.

These deposits generally have adequate strength to support moderately high embankments. Sites for high fills should be evaluated because poor materials may underlie the granular deposits. Generally, stable cut slopes can be constructed on these granular materials. If the deposits are dominantly sandy, they will be highly erodible.

Subgrades will be good above a water table. In cold regions, the stratified material is prone to differential frost heaving. Processing to produce uniformity is usually indicated.

Grade line can be anywhere above the water table.

These deposits are potential sources of sand and gravel. Gradation and soundness will vary.

There is a good possibility that many outwash deposits are potential sites for leaching basins.

Delta Deposits

- Origin

Delta deposits are mostly granular materials carried by glacial period streams and deposited in glacial period lakes or immediately post-glacial seas. They are like many other types of outwash, differing only in the site of deposition. This is a very significant difference, because it implies that most delta deposits are underlain by lacustrine bottom sediments with which many soils engineering problems are associated. To the uninitiated, it is often difficult to conceive that sometimes soupy silts and clays are hidden by sands and gravels.

- Description

Delta deposits are mostly stratified sands and gravels. Ideally, foreset, topset, and bottom-set beds can occur. The foreset beds should slope outward from the mouth of the contributing stream. But aggradation generally was not a simple depositional process so the strata may slope in many directions. Braided streams were common occurrences causing deposition and erosion alternately or simultaneously on different portions of the delta.

- Engineering Significance

Delta deposits will generally support moderately high embankments. Sites for very heavy fill should be evaluated for strength and settlement characteristics, because, more often than not, the behavior of engineering works can be influenced by the adverse properties of the silts and clays which will usually occur below the deltas.

Cuts in the true delta materials should be stable above the water table. Deep cuts may encounter bottom sediments. If so, cuts in these materials will require measures to ensure stability.

Subgrades will be good, except when cuts are made below the water table or when the underlying wet silts and clays are encountered.

These deposits are good sources of common borrow and are potential sources of granular materials. Some locations may be suitable for leaching basins.

Overflow and Spillway Channel Deposits

- Origin

Very often, glacial lakes filled entire basins and, when outlets were finally acquired, either because elevations became sufficiently high to flow through low cols or because impoundments were breached, torrential streams carried debris and spread it along the outlet path. These deposits are either well-sorted granular materials or they may be cobbles sometimes containing huge boulders. The Palmyra Channel is an example of the former and Iroquois Channel near Jamesville is an example of the latter. Generally, the deposits are mapped as outwash.

- Engineering Significance

These deposits are granular or very coarsely granular. Some can be treated like outwash, others will require evaluation. Each location proposed for use should be individually evaluated.

Glacio-Lacustrine Bottom Sediments

- Origin

As the glacier advanced over the State, it formed ice dams. In some valleys, glacial till and ice blocks did the same thing. When climatic conditions were favorable, torrents of meltwater running off the glacier or from streams of meltwater from the rapidly melting ice in the hills and higher valleys formed glacial lakes. A series of these lakes, at one time or another, covered large lowland areas in central, western, and northern New York. Another lake was formed in the Hudson Valley. Here presumably ice blocks or till deposits held up Lake Albany, which was supplied by meltwater streams such as the Mohawk and Hudson Rivers. The lakes were the settling basins for the deposits of the meltwater streams. Near shore, deltas were built. In the deep portions of the lake, the fine-grained silts and clays were deposited. During ice-free periods of the year, the silt would settle. Then, when the lakes were frozen over, the clays would settle. This type of alternating deposition was seasonably periodic, so the laminated sediments have a "varved" structure. These varved sediments are called lacustrine bottom sediments.

On the disappearance of the lakes, newly emergent lake plains and valleys appeared. Many former lake areas have been changed by post-glacial events, some eroded and dissected, some covered by alluvial and eolian deposits. Present day streams have cut through the former continuous deposits that filled entire valleys to leave many unstable dissected remnants. Parts of the cities of Albany and Troy are on remnants of lake deposits which once filled the entire Hudson River Valley.

- Description

These fine-grained soils are varved silts and clays. A single varve is two strata composed of a clay and a silt pair. These deposits may by very thick or they may be thin veneers. The general condition is that of deep deposits in valleys and lake basics and thin deposits near the shores of the former glacial lakes. In places, there were many different lake elevations, so sand and silt deposits may occur interbedded with the varved silts and clays. These deposits have been subject to no compactive effort other than their own weight. As they were deposited under water and in a loose state, it follows that they should be wet and compressible. While this is the general condition, on some terrace positions oxidation and drying have changed the original materials from a grey soupy material to a brown oxidized, blocky structured material that is hard when dry. But even these areas are usually underlain by soft, wet, weak, highly compressible material. Varying degrees of wetness occur. A high water table is characteristic. Very often, these deposits have greater permeability in a horizontal direction than in a vertical direction, but in either case it is slow to very slow.

- Engineering Significance

The characteristics of these materials make them undesirable from an engineering point of view, causing severe design, construction, and maintenance problems. On many locations, these areas are very flat and, where they are extensive, effecting proper drainage is difficult. While elevated grades are generally indicated, there is generally a concomitant need for satisfactory borrow. Very often, good sources of borrow may be remote and require extensive hauling. Where the bottom sediments are used, it can be expected that they will have moisture contents considerably above optimum, which can be reduced only by spreading the material in thin layers exposed to warm sun, for a long period of time. Contractors encountering difficulty in excavating, transporting, placing, and properly compacting these materials, often find it more economical to waste the wet material.

Post-depositional erosion and dissection have produced very unstable slopes on terrace edges and on other erosion remnants. The flatter slopes required for stability require more extensive right-of-way. On many slopes, an erosion protection blanket will be necessary.

As these deposits are often wet, soft, and weak, shear strength may be minimal, so long-time settlements are characteristic. It follows that no heavy loads should be imposed on these materials until a proper evaluation of each proposed site has been made. This implies subsurface investigation, laboratory testing and engineering analysis. Very often, alternate locations for highway alignments may be available. Unfortunately or otherwise, much urban and other development has taken place on bottom sediments and so transportation facilities will be necessary. All that has been said about these deposits warrants a very careful evaluation in the planning and design stages of proposed locations and careful engineering supervision of the projects during construction.

Shore and Near Shore Deposits - Lacustrine Sands and Silts

- Origin

These materials owe their origin to streams which deposited their coarse materials as deltas; the intermediate sized particles as interbedded, often laminated silts and fine sands near not always static shores; and the finer silts and clays farther into the lake.

- Description

The lacustrine sands and silts are stratified materials. Each stratum may be comprised of sand under silt. These deposits are extensive in the Ontario Lake Plain and on parts of the plain formed by the now extinct Lake Albany. These fine sands and silts may be interbedded with silty and clayey lacustrine bottom sediments. The deposits may be shallow or very deep. In places, shore currents may have horizontally redistributed the original deposits.

- Engineering Significance

These deposits generally have a shallow water table. In general, an elevated grade is preferable. On many sites, drainage outlets are not available.

These deposits will generally support low embankments. Sites for high fills should be evaluated, because many of the deposits are underlain by soft wet, weak bottom sediments which may require special engineering design.

Fill materials, as a general rule, will be fair to poor. They will generally require excavation from wet areas and sandy fills from these deposits are very readily erodible by wind and water. Positive runoff control will be necessary.

Cut slopes will rapidly erode. Severe seepage and sloughing will occur.

The subgrades will generally be wet. The feasibility of cuts should be demonstrated prior to design. The laminated materials are extremely prone to severe differential frost heave.

Bars and Beaches

- Origin

The gently sloping shore of a body of water which is washed by waves or tides is a beach. The billowy mounds in old lake beds and seas are bars. These deposits occurred on many water-covered areas. They have formed by the transportation of existing bottom materials and by reworking shore deposits.

- Description

These deposits may be sands or silts or may be clean gravels. They are underlain by a wide variety of materials.

- Engineering Significance

An on-site evaluation is necessary because these deposits are underlain by different kinds of deposits which have a wide range of textures and drainage.

Beach Ridges

- Origin

A beach ridge is a ridge of mostly sand and gravel, but in places cobbles, representing an old shore line of a lake or ocean. A shore line of former glacial Lake Iroquois is now occupied by parts of Route 104 south of Lake Ontario. It is locally known as the Ridge Road. Part of U.S. Route 20 in Chautauqua County is on a glacial lake beach. There are some remnants of beaches north of the Adirondacks and elsewhere. The ridges were built where wave action carried off-shore materials and deposited them in one or more shore ridges.

- Description

The deposits are usually sands or gravels. However, cobbles and some boulders are dominant on some portions. For example, Lake Iroquois Beach south of Watertown is mostly a small boulder deposit. The topographic form of these deposits is a ridge and, where observed in New York State, it may be up to 50 ft. higher than the adjacent lacustrine deposits. On some locations more than one ridge occurs; and the deposits may be several hundred yards wide. Lagoons with lacustrine deposits may occur behind the ridges.

The deposits are stratified, but often irregularly. The materials show a wide range of grain size.

- Engineering Significance

These deposits are good highway locations. At the present time, they are particularly occupied by roads, residential developments, orchards, and vineyards. Limited acreage is being exploited as sand and gravel sources.

A water table may occur at the contact of the ridge and underlying deposits.

Cut slopes will usually be stable on "normal" gradients.

Subgrades will be good above the water table. In cold regions, the subgrades will be subject to differential frost heave.

Wave Washed Till

- Origin

On many old shore lines of former glacial lakes and portions of the marine waters, particularly in northern New York, the glacial till deposits were wave-washed. The till fines were winnowed out and the coarse materials remained. These areas, as test pitted, have been found to be up to 10 ft. high. Otherwise, undisturbed till underlies them.

- Description

These areas are not extensive. They are gravelly, sometimes bouldery, and are unstratified. Till underlies them.

- Engineering Significance

For the most part, these materials can be treated like the glacial tills in which they occur. However, subgrades encountering these sorted materials will be subject to differential frost heave and, particularly in morainic deposits, to boulder heave. It may be possible to adjust highway grades to avoid these locations.

Marine Bottom Sediments

- Origin

After the retreat of the glacial ice, the elevations of the oceans were raised by contributions from glacial meltwaters. On many areas, the land had been depressed by the great weight of the ice that covered it. The increase in the ocean level flooded some areas of New York State so that the seas invaded parts of the present St. Lawrence and Champlain Lowlands. Streams deposited sediments into these seas and, when the seas retreated, the marine bottom sediments were exposed.

- Description

Marine bottom sediments are stratified, loose, very sensitive, clays and silts. They may overlie lacustrine bottom sediments, if the latter were not removed prior to deposition of marine sediments. In some locations, particularly in some parts of the Champlain Lowlands, the bottom sediments filled the lowlands from mountain to mountain. Now, many of these areas are severely dissected because of the streams that now cut these deposits acquired a low base level when the seas gradually disappeared. Hence, the present topography has two aspects; in some places, low flat plains; in other places, severely dissected remnants of higher plains. The deposits are mostly very fat, silty clays. Deposited in a saline or brackish environment, they are in a very flocculent state. The deposits are weak, soft, sticky, wet, sensitive and are very easily erodible. All that has been said about lacustrine bottom sediments applies to marine bottom sediments, except in the latter case, the emphasis should be greater on their very poor engineering properties. If these deposits occurred in areas undergoing intensive development, the soils engineering aspects would be more severe than those involved in lacustrine bottom sediments.

Eolian Deposits

- Origin

Wherever loose silt and sand, in such deposits as delta sands, lacustrine silts and sands, sandy kames, sandy and silty coastal plain sediments, and beach and bar deposits, were exposed to wind action, the deposits were removed and piled on top of anything downwind. Many of the above-mentioned deposits were not covered with protective vegetation immediately after deposition so they were subject to erosion and redeposition. Some wind-deposited materials are still undergoing movement.

- Occurrence

Wind-worked materials occur on many locations throughout the State. Often, they are only veneer thick; sometimes they are very thick. At the present time, sands are being actively worked on Long Island and Staten Island. Parts of old lacustrine materials are being wind eroded from the perimeter of Lakes Erie and Ontario. Wherever earth moving operations such as highway grading, site development operations, and even farm-plowing encounter sands, there may be wind erosion. Surprisingly, many areas in the Adirondacks have a sandy, or sometimes silty, veneer which is mostly wind-laid. On parts of the south side of Long Island, silts up to 8 ft. in thickness cover extensive areas.

- Description

Wind-blown deposits are most prominent as dunes. Elsewhere, on extensive acreages, the material is a veneer from a trace up to 8 ft. in thickness. Wind-blown sand, like wind-blown snow, covers anything onto which it was blown, so the underlying deposits may be muck, alluvium, bottom sediments or good materials. Blown sands and silts may or may not be stratified. In a very loose state, they would be highly erodible by wind and water.

- Engineering Significance

These materials are non-cohesive, loose, and mostly sands. They are fair sources of dry fill material, but water must be added for proper compaction. These materials are very susceptible to densification by vibratory loads, but other compaction effort is generally inadequate. Erosion control must be instated as soon as fills are completed. Fills should have positive runoff control, even during construction. An unexpected heavy rain can move tons of sand and it can happen overnight. Since vegetation is difficult to establish, consideration should be given to a mechanical cover, such as a mulch.

Subgrades may be subject to differential frost heave. Parts of Route 20 on dunes near Albany have been observed to be heave-prone.

These areas will generally support moderately high embankments. But, since dunes may obscure poorer materials, even mucks, an on-site evaluation is indicated. Wherever sand dunes lie over bottom sediments, the bottom sediments will be wetter than they might be when exposed as surface material.

3.3.4 Post-Glacial Deposits

While the dominant acreage of the deposits of the State were put down during and immediately following glacial action, some materials are still being laid down. These would be alluvium, windblown silts and sands, man-made fills, and some organic deposits. In addition, frost effects and other types of weathering are producing residual material and gravity is producing colluvium.

Residual deposits were a pre-glacial as well as a post-glacial phenomenon. Principally, residual soils will be found in the unglaciated regions and soil formation is currently occurring on some exposed rock throughout the State.

Soil creep is a common geologic occurrence and colluvium is being produced by natural slides, in places being induced and intensified by man-made cuts and fills.

Only alluvial deposits are given separate treatment as post-glacial deposits. Other deposits are described in association with other time periods. Man-made fills include well-constructed fills, poorly made fills, sanitary landfills, quarry wastes, manufacturing wastes, hydraulic fills, tunnel spoil, and construction spoil banks.

It should be evident that no definite characterization of these variable materials can be made and, for engineering purposes, an on-site evaluation is imperative.

3.3.4.1 Alluvium

- Origin

Alluvium is the soil material deposited by streams, usually on flood plains. It may be termed recent or old. Recent alluvium is generally subject to periodic overflow. It has been on-site for such a short period of geologic time that there is very little soil profile development and horizonation may be indistinct. The deposits may range from boulders to clay and are stratified. The materials are usually loose and may be compressible. A water table will occur with the same elevation as the surface of the adjacent stream. Old alluvium is material deposited by earlier streams which may have had a greater volume than at present. The older deposits are often on one or more terraces having an elevation higher than that of the present first bottom flood plain. The old alluvium water table, unless perched, will be at the same elevation as the adjacent stream. Alluvial deposits may overlie bottom sediments, glacial till, muck, outwash and delta deposits, and man-made fills. The old alluvium is not generally subject to periodic overflow, but, on some locations, may be subject to sporadic flooding.

In one sense, alluvium could be applied to any deposit transported and deposited by streams. This would then include delta or fan deposits, outwash, kame, esker, bar, beach, and some lacustrine and marine material. As used here, alluvium is construed to mean only post-glacial stream deposits put down on flood plains.

Most areas of recent alluvial deposits are subject to overflow, have a shallow water table, are loose, variable textured, and are underlain by both good and poor engineering materials including, in some places, muck.

- Engineering Significance

As has been previously indicated, the alluvial deposits have a fluctuating, but generally shallow water table; and they are subject to annual or sometimes more frequent periods of overflow.

In places, these areas are underlain by soft, wet, compressible bottom sediments, mucks or other equally poor materials.

Even a shallow cut can encounter a water table. Hence, cuts are generally not practical. Since the areas are subject to overflow, the gradeline should be above highest flood elevation.

Foundation conditions are generally poor in alluvial areas. Thorough investigation, and certainly on some locations, special analysis and design, are required before foundations for bridges and high embankments are constructed on these soils. A long lead time of investigation may be necessary prior to final design.

Alluvial deposits subject to flooding hazards should be avoided as building sites. The possibility of flooding and the elevation of the water table must be carefully evaluated before these areas are considered for any building purposes.

Some alluvial deposits may be potential sources of good topsoil.

Foundation conditions are generally better on the second or high bottom phases of alluvium. Wherever a doubt exists, a subsurface investigation is indicated. The depth of cut will be dictated by a water table generally at the same elevation as the surface of the adjacent stream.

3.3.4.2 Organic Deposits

- Discussion

Organic deposits are occasionally encountered on highways and other engineering features that have considerable longitudinal extent. In early years in New York, organic terrains were generally avoided because alternate alignments were usually available. Now, very often, sites for roadways, particularly around urban areas, are limited. About the only open areas remaining are swamps. To further complicate matters, such wetland areas have become valued for the ecological and environmental benefits they may offer and numerous agencies strive to limit their alteration.

- Origin

Organic matter will generally accumulate on some low, wet locations. These would be depressions with poor or no drainage outlets, such as between rock ridges, depressions in soil deposits, kettle holes, old meander channels on flood plains, and, most extensively, on glacial lake basins where drainage is impeded by bedrock or glacial deposits.

Conditions in these locations provide a highly favorable environment for .aquatic plants such as pondweed, cattails, reeds, and sedges. When build-up of organic matter approaches the water surface, the partially filled areas will be growth sites for grasses, mosses, shrubs, and trees. All these plants in numberless generations grow, die, and are covered by the water in which they grew. Here the aqueous environment minimizes or precludes aerobic decomposition and at least partially preserves the portions of the plant that are the most difficult to destroy. Whatever decay occurs is principally through the agency of anaerobic bacteria, algae, fungi, and certain aquatic animals.

As indicated above, organic deposits are the residue of mostly plant remains. During the early stages of plant decomposition these are brown, and this stage is called peat. Generally, the individual components of peat are recognizable. When more complete decomposition has occurred, the identity of the contributing plants is obscured and the black residue is called muck. In the realm of soil science, three types of organic deposits exist: fibrous, sedimentary, and woody. Fibrous peats owe their origin to the decomposition of sedges, mosses such as sphagnum and hypnum, reeds and cattails. These peats have a high water-holding capacity and may exhibit varying degrees of decomposition. More often than not, the peats are overlain by mucks. Sedimentary peats, usually accumulated in comparatively deep water, would be found deep in the soil profile. The sedimentary peats apparently readily humify and exhibit rubbery colloidal properties. In their undisturbed state, the deposits are quite green, but on exposure to air, readily turn black. The colloidal parts of fibrous peat are usually irreversible, for when dried, they persistently remain in a hard lumpy condition. In their natural state, these material may hold water up to four or five times their dry weight. As a generalization, the woody peats are surface deposits since the source trees require dry periods because their roots cannot survive in a continuous water habitat. The aquatic regimen of any particular low area may change with climatic or stream conditions and then so would the vegetation. If more continuously wet conditions succeeded wet-dry conditions, reed and sedge types of vegetation would resume growth. Virgin deposits of woody peat are non-fibrous and noticeably granular. The water-holding capacity of sedge peats is lower than moss peats.

Organic deposits occurring in low areas occupy the same locations to which some eroded mineral soils are transported. As a consequence, organic deposits may be interbedded with mineral soils. A rarity, pure organic deposits have dry weights of 8 to 10 pounds per cubic foot, in contrast to mineral soils that will weight from around 100 to 145 pounds per cubic foot. Peat can be defined as the accumulation of organic material in various stages of decomposition which contains at least 65% organic matter, or less than 35% mineral content. On well-drained inorganic soils areas, the percentage of organic matter will rarely exceed 5%.

3.3.4.3 Marl

Many wet areas that are now the sites or organic deposits were formerly lakes and other ponded areas whose waters were alkaline. Here marl, which is calcium carbonate, is often found below mucks and peats and often interbedded with organic deposits but may occur alone. The calcium carbonate originated from the calcareous remains of the chara plant (chara marl), from mollusk shells (shell marl), or from simple precipitation from saturated alkaline waters. Marl, with wide range of grain sizes, may be sand size, more often silt size, and is frequently clay size. All three sizes do occur within the State. The Chara and Shell marls have organic origins; the precipitated marl is chemical in origin. The types have the same sites of deposition and are most often associated with mucks and peats. Their engineering properties will be discussed under organic deposits, even though they are actually mineral deposits.

- Engineering Significance

Peats and mucks are absolutely unsuitable as a foundation for any engineering structure. Soft, wet, and extremely compressible, there areas should be avoided. When encountered, muck must be replaced or displaced by suitable material. If placement is under water, the suitable material should be either granular material or broken rock. In some instances, dewatering may be possible, after which other soils may be used. This was done on the Thruway crossing the Montezume Marsh. In places, mucks may have a lower permeability than might be expected. In dewatered excavations, the stability of the excavated slopes must be evaluated.

Muck removal may be by excavation or by displacement. Excavation operations will usually be underwater. Then it becomes necessary to determine the thoroughness of completeness of the removal. Unless removal is complete post-construction subsidence may occur. Where muck is removed by excavation methods, it may be placed beyond the roadway prism. When dried and vegetated, it will generally support light grass mowing equipment, but when exposed it is subject to wind erosion.

When dried, organic deposits may be used to amend mineral soils. Mucks are infertile and require high fertilization rates to make them productive. When exposed, wind erosion will be commonplace.

The marls associated with organic deposits have a wide range of properties. When interbedded with organics, they would be removed with them. If they are the sole deposit or if muck is removed from above them, then marl texture range must be considered. Clay sizes when encountered can be treated similar to the way lacustrine clays are used. On former lake beds, lacustrine deposits may underlie the organic material.

Subsurface investigations are generally indicated. Accessibility to swamps is often a serious problem. Drilling in cattail swamps when the reeds are dry involves fire hazards. Estimates of volumes to be removed must be made and suitable replacements located. Swamp areas are expensive sites to work but of low land cost. Material volumes involved in removal and replacement mean double earthwork.

3.4 NEW YORK STATE SOILS

3.4.1 Discussion

The State of New York, with the exception of a small area roughly bounded by the loop of the Allegheny River north of the Pennsylvania State line, has been subject to multiple glaciations. These glaciations, particularly the last one, seemed to have been the extension of an ice cap that had its center west of Hudson Bay. As the ice flowed out from this center, it passed over vast areas of preexisting soil and bedrock, which it was able to pick up and carry on top of, within, ahead of, and beneath the advancing ice mass. When climatic conditions changed, the ice mass wasted away by melting, depositing this huge quantity of material, mantling the area formerly occupied by the ice. The generic term for this soil forming mantle is "till".

Till was deposited in many ways, but basically the two commonest forms are "moraines" and "till plains". A moraine was formed when the ice front was stationary for long periods, that is, the rate of melting was about the same as the rate of advance. With this thought in mind, one can picture the tremendous deposits that were left, and the rough, rugged topography that was bound to result. One can also see that a moraine would occur at the farthest advance of the glacier and also that moraines might occur at any time, when climatic conditions were right, during the retreat of the glacier. This was actually the case. For convenience, the moraine at the farthest advance is called the “end moraine”, the others “recessional end” or “terminal moraines”.

Till plains were formed when the glacier melted and retreated at a steady rate, depositing its load of debris in a fairly uniform manner. The thickness of the deposit varies greatly, from less than a foot to 50 ft. or more.

Sometimes as the ice advanced, its bottom load was too great to carry. When this occurred, “basal till” (called hardpan by old timers) was laid down. As the glacier retreated, it left ordinary till on top of the basal till. The ordinary till is much less dense than the basal till, the latter having been compressed by the over-riding ice.

Texturally, tills are completely heterogeneous, and may contain (but are not necessarily containing) all soil fractions from the finest clay to huge boulders, The stone fragments of till are usually angular to sub-rounded; very seldom are they as well rounded as a water-deposited gravel would be. There is no continuity or stratification in tills as a generalization, but pockets and lenses of pure sand, silt, clay gravel or boulders do occur. Quite frequently, the pockets of granular material are water bearing.

Another ice deposit, of great importance through the central part of the State, is the "drumlin". Drumlins are elongated, streamlined, cigar-shaped hills from a few to 100 ft., or more, high and from a few hundred feet to a mile, or more, in length. The mechanics of their deposition is obscure, but apparently they were a "bottom-of-the-ice" phenomenon, deposited while the ice was advancing. In any case, textually they are till, but much more compact than the tills of the moraines or till plains, indicating that some great weight has compressed them. Some of the drumlins have a rock core, but they are in the minority. Investigation by drilling is necessary to ascertain the presence of the rock core. Rock core drumlins are no different in appearance from the ordinary kind.

While the glacier was melting, great quantities of water were released. When the glacier had been building a moraine, this water was impounded behind the moraine, much as a lake is impounded behind a dam. The moraine, being a poorly constructed dam, could not retain the water when it reached a good depth, so that the dam would break, releasing great quantities of water in a trench. This water, as it passed through the moraine at high speed, would pick up the moraine material and transport it down stream. As the ground over which this great outwash of water was flowing leveled off, the velocity decreased and the water dropped part of its load. The coarser material - cobbles and boulders - settled out first, then gravel and sand, and finally, as the water became still or stagnant, the silt and clay. Such a deposit it called “outwash”; its topography is a smooth to pitted plain. Sometimes, when the outwash occurred in a valley, the outwash deposit is in the form of terraces along the valley walls. Texturally, outwash is sand and gravel, frequently stratified because of its water deposition. Gradation and quality, of course, varies with the deposit.

The deposition of great masses of glacial debris blocked drainage channels, in some cases completely reversing stream flow. Under these conditions, it was inevitable that lakes, some ephemeral and some of comparatively long duration, would be formed. If the melt water discharged directly into the lake, the coarser material formed "deltas". Wave action in the lakes formed "bars", "spits" and "beaches", exactly as these are formed in lakes today. Finally, the fine grained particles were carried out into the lakes where the water was still, allowing the fine material to settle out forming "bottom sediments", usually called "lacustrine bottom sediments" to distinguish them from the "marine bottom sediments". Since the speed of settlement of a particle in water is a function of its size, the coarser particles of silt and very fine sand settled most rapidly, this deposition apparently taking place during warm weather. During the cold seasons, material was not supplied to the lake as rapidly because the surface was frozen, inhibiting wave action; and the finer clay size particles settled out. As a result, "bottom sediments" are laminated or "varved", a "varve" being a double layer, the bottom being of silt, the top layer of clay-sized particles, each varve representing a year's accumulation. Generally speaking, the bottom sediments are rather soft and weak soils, no load except their own weight ever having been applied to them.

Marine bottom sediments are the salt water counterpart of the lacustrine bottom sediments. In general, they do not have the varved structure of the lacustrine sediments. Marine sediments usually have a honeycomb structure that makes them softer and weaker than the lacustrine soils, especially when disturbed. This makes them "sensitive".

There are two other landforms, products of the wasting ice that are of importance. These are the "kame" and the "esker". The kame is an ice front phenomenon, formed by a stream running off the ice front and carrying with it glacial debris of all kinds and piling it up, much like an alluvial fan, against the ice. As the ice melted, the “fan” collapsed, leaving a roughly cone shaped mound of poorly sorted, partially stratified, sand, gravel and cobbles. Other kames were formed by the melt water running into a hole in the ice and carrying the gravel and other material with it. Such holes are called “moulins” and the kames “moulin kames”. From an engineering viewpoint, there is no difference in the two types.

The esker on the other hand, is the trace of a stream running within or below the ice or in ice walled canyons cut in stagnant ice, also carrying debris which it deposited along its course as its velocity changed. The result, after the glacier left, was a serpentine ridge, roughly triangular in cross section, of sand, gravel and cobbles, with little or no evidence of sorting or stratification. Eskers in this State are comparatively small, but in some parts of the world they are up to 150 or more miles in length, counting the gaps which break their continuity.

The glacial melt-water deposits all have their characteristic landform. Outwash is a smooth to pitted plain, sloping gradually down valley, or valley wall terraces. Deltas also have a smooth to pitted top but the sides are steep. Bars and spits are gravelly ridge-like forms, while beaches are more gently sloping. Bottom sediments take the form of level to gently undulating plains, often eroded by post glacial streams. Marine bottom sediments are generally smooth and nearly level plains. The kame is a rounded hillock, while the esker is a serpentine ridge.

A few soils of the State are the result of post glacial processes or at least were little affected by glacial action. The residual soils of the unglaciated area were formed by the weathering in place of the underlying bedrock. These soils in New York State are usually shallow to bedrock, the transition from soil to rock being very gradual rather than a sharp contact line. The soil is a reflection of the type of bedrock, for instance, sandstones would leave a sandy soil and shales leave silts and clays. The topography of the residual areas is that of the bedrock.

In the hilly areas of the State, particularly in the Southwestern Plateau, there are areas of colluvial soils. These are soils derived from erosion products of adjacent hillsides and have very much the character of the soils above them in elevation. In general, they are quite stony. Their topography is usually a slope slightly concave upward, gentler than the hill above, but steeper than the valley floor.

The alluvial soils are the soils of the areas contiguous to present-day streams, laid down by the streams during flood stage. They are heterogeneous in texture both vertically and horizontally. Sometimes, they are excellent gravel sources, while at other times they are soft, plastic silts and clays with varying amounts of organic material.

Cumulose soils are the mucks, peats and marls. Muck is the remnants of plants, so decomposed as to retain little if any fibrous structure, the organic matter being more or less mixed with inorganic silt and clay. Peat is formed by dead plants falling into water where there is not enough air to support bacterial action. The result is only partial decay, and consequently, peat is very fibrous and retains most of the plant forms. In general, muck is black, very dark grey or dark brown, while peat is dark to light brown.

Marl, or "bog lime", is calcium carbonate precipitated from the hard water of ephemeral lakes and more or less mixed with silt, clay and shells. It is white to dark grey in color and usually occurs beneath peat deposits.

Of minor extent in this State, but of considerable local importance, are the "eolian" or windblown deposits, usually in the form of rounded to irregular hillocks called "dunes". Most of the dune areas of this State are characterized as "ancient dunes", the area between Albany and the Adirondacks being typical. It is thought that these dunes were formed at the close of the ice age in this area when much of the surface was covered with deposits washed from the wasting ice and vegetation had not as yet started to grow. Adiabatic winds coming off the glaciers were periodically high-velocity, scouring the outwash immediately in front of the glacier and piling it as dunes on the adjacent plain. The material of these dunes is fine sand with some silt-size grains. The gradation is very uniform, and the particles are much rounded.

The foregoing brief outline of the processes of soil deposition forms the framework of a broad grouping of New York State soils. It can be inferred, and field experience has proven that, on a broadly generalized basis, each of the landforms mentioned, no matter where found, has engineering characteristics in common. That is, thick tills in the eastern part of the State will be very similar to those in the west, and the bottom sediments of the Hudson Valley, in a general way, resemble those of the Erie-Ontario Plain.

The engineering characteristics of the soils found in the various landforms are outlined below, covering the following points:

1. Grade elevation
2. Foundation conditions
3. Unsuitable material
4. Slopes
5. Subgrade conditions
6. Under drainage
7. Foundation course
8. Source of construction materials
9. Equipment requirements
10. Sheeting and bracing or Cofferdams for temporary excavations
11. Topsoil

3.4.2 Thick Tills

1. Grade line for highways can be placed at almost any elevation. Wet silt pockets and variable quantities of boulders will be encountered, but it is very unlikely that rock excavation will be necessary except in very deep cuts.
2. Provides excellent foundation conditions for fills or other structures. Benching and transitions from cut to fill will be necessary.

   Investigation of foundations for large fills and heavy structures should be made by borings.

3. Ordinarily, not much unsuitable material to remove and waste. May be shallow muck in poorly drained areas. Wet silt pockets may require removal and waste.
4. Fill slopes are usually stable on a 1 on 1 ¾ or 1 on 2 slope. Cut slopes may be unstable because of wet pockets that will require drainage or special treatment.

   By the very nature of till, it is impossible to predict where, how large or how frequent such pockets will be, even with very elaborate subsurface investigation. It is best to make the cut and let the pockets reveal themselves. Many times they will drain and become stable before the job is complete. If they do not, the wet material should be excavated, the hole backfilled with gravel and drained by means of a gravel-filled trench down the slope to the ditch.
5. Provides generally good subgrade conditions. When wet silt pockets are encountered in subgrade, they should be removed and replaced with either well compacted suitable soil from the vicinity or with run-of-bank gravel. If gravel is used, special attention must be paid to drainage. These measures are to provide a uniform subgrade and prevent differential frost heave.
6. Because of the variable nature of till soils, it is impossible to predict the efficacy of an underdrain and, therefore, the amount needed. For estimate purposes, it can be assumed that at least one line of underdrain will be needed the full length of every cut in till.
7. Depth of foundation course is a function of the drainage characteristics of the soil. A minimum of 12 in. should be estimated for all cuts in till – with ample rounding to allow for greater depth where necessary.
8. Usually a good source of common borrow. In some cases, soil may be above optimum in moisture content and be difficult to dry. Particularly in the Southwestern Plateau, the stone content may be great enough to interfere with compaction.
9. Any kind of excavating and hauling equipment should work well although the high stone content of some tills may interfere with the operation of carry-all scrapers. On the compact basal tills and on drumlins, rooting may be necessary. Sheepsfoot rollers give best compaction results although, in very stony tills, the flat wheel roller may be best. When too wet for proper compaction, heavy disc harrows, rotary tills and graders will be necessary for proper aeration and drying.
10. Temporary excavations will stand on a slope of 3 vertical on 1 horizontal for considerable periods when the excavation does not exceed 12 to 15 ft. When the excavation is deeper, or is to be left open for more than about 2 weeks, temporary sheeting and bracing will usually be necessary, or the slopes must be flattened.

    Slope failures in tills are usually almost instantaneous. It is suggested that flatter slopes or sheeting and bracing be used where failure might endanger life, equipment or form work.
11. As a generality, tills do not furnish the best quality topsoil as they are usually stony and their natural fertility and organic matter content is apt to be low. Each source should be sampled and tested before use.

3.4.3 Thin Tills

1. Grade line should be kept high because of entrapment of water at the contact between earth and rock and the presence of a "hard pan" or "clay pan" layer at 6 to 18 in. in some thin tills, which inhibits downward movement of water.
   Excavations deeper than a few feet will almost certainly encounter rock.
2. Furnish excellent foundation conditions for fills and structures. Most structures can readily be founded on rock.
3. The quantity of unsuitable material is generally negligible.
4. Since cuts of any magnitude will encounter rock, the type and conditions of the rock will govern the rock slope. In the overburden, a slope of 1 vertical to 2 horizontal is generally stable.
5. Subgrade conditions are much the same as those for thick tills with the additional consideration of seepage at the contact plane between rock and earth, the “hard pan” and “clay pan” layers mentioned above, and the possibility of infiltration and entrapment of water along the rock surface beneath the pavement. Each of these considerations requires thought during design, and the provision of adequate quantities of foundation course and tile under drain. Transitions from cut to fill are of great importance in thin till soils.
6. Two lines of under drain should be estimated for the full length of all thin till cuts.
7. At least 12 in. of foundation course should be estimated, with ample rounding to take care of contingencies.
8. A poor source of borrow because of the thinness of the overburden. Granular material for select borrow or foundation course are seldom found in thin tills.
9. Equipment the same as for thick tills with the addition of power shovels, air compressors, drills and blasting equipment, where rock cuts are contemplated.
10. Sheeting and bracing will not ordinarily be necessary in temporary excavations because of the shallow depth to bedrock.
11. The topsoil in thin tills is usually of very poor quality.

3.4.4 Outwash

1. Grade can be placed at any elevation.
2. In general, supplies an excellent foundation for both structures and embankments. However, outwash may be relatively thin and over-lie soft silt and clay (lacustrine material) at shallow depth, in which case the characteristics of the lacustrine material may govern.
3. The "kettle holes" in pitted outwash may contain considerable depths of muck that must be removed and wasted before fill construction is begun.
4. Slopes for both cut and fill are stable at the angle of repose, that is 1 vertical on 1 ½ horizontal. They are subject to erosion, however, and should be mulched and vegetative growth established as soon after construction as possible.
5. Supplies excellent subgrade conditions.
6. Under drainage is very effective in lowering a high water table in outwash. The need for under drainage should be ascertained by suitable borings for estimate purposes.

7. Foundation course will not usually be needed in outwash if the subgrade in both cuts and fills is properly compacted. Otherwise, subsequent traffic vibration will compact the granular material beneath the pavement, leading to cracking of concrete pavement, and to roughness of flexible types. A 6 in. thickness of foundation course may be advisable to supply uniform subgrade conditions.
8. An excellent source of common and select borrow and usually of run-of-bank gravel for foundation course. Each deposit should be checked for gradation and type of rock making up the gravel. Some outwashes tend to be shaly.
9. Any type of excavating and hauling equipment will work well. If the outwash is cemented, as it occasionally is, rooters or blasting equipment may be necessary.

   Pneumatic tired rollers are best for compaction, with flat wheel rollers a second choice. Much addition of water may be necessary for compaction, particularly in the sandier and drier outwashes.
10. Outwash will usually stand to a height of 25 ft. or more on a nearly vertical face. However, in some of the more incoherent members, sheeting and bracing or flatter slopes will be necessary.

    Below the water table, very heavy seepage can be anticipated.
11. Topsoil is usually draughty, stony and lacking in organic material. The physical condition is usually excellent. Some members are highly fertile.

    The engineering characteristics of bars, spits, beaches, kames and eskers are very similar to those for outwash. However, the gravel in kames may be too dirty, too coarse or too poorly graded for foundation course.

    Old beaches are often the site of very intensive agriculture - either truck gardening or fruit growing. As a result, they are available for highway construction only at considerable cost for right of way, and their cost for borrow, select borrow and run-of-bank gravel is usually prohibitive.

3.4.5 Kame Fields

1. Grade may be placed at any elevation.
2. Foundation conditions are usually good.
3. Unsuitable material is usually absent. Some muck may be encountered in the bottoms of "kettle holes" that are deep enough to be below the groundwater table.
4. Slopes are stable at the angle of repose, that is, 1 vertical on 1 ½ horizontal. Large boulders may lose their embedment and roll down the slopes. The sandier kame materials are very erodible; vegetative growth should be encouraged.
5. Subgrade conditions are apt to be non-uniform because almost any grading operation will cut across several strata in a kame. These strata may be anything from silt or fine sand to cobbles and boulders; fine granular material can very easily be adjacent to coarse granular material. Efforts should be made to supply uniformity. Ordinarily, no water table will be encountered.
6. Under drainage will not be necessary as a generality. Kames are very well drained both internally and externally.

7. Foundation course will not ordinarily be necessary. However, a 6 in. layer of foundation course should be estimated to assist in achieving the subgrade uniformity mentioned in (5) above.
8. A good source of common borrow and possible sources of select borrow and run-of-bank gravel. However, gradation of individual deposits should be checked before use as either of the last two items.
9. Any kind of excavating or hauling equipment should work well, although stones may interfere with the use of carry all scrapers.

   Pneumatic tired rollers will give best results for compaction with flat wheel rollers a second choice. A flat-wheel may work best on some of the stonier materials.

   Large quantities of water will be necessary in compacting the sandier kame soils.
10. Sheeting and bracing or slopes no steeper than 1 on 1 are necessary in temporary excavations of any depth. Kame soils are usually completely non-cohesive.
11. The topsoil on kame fields is usually absent or of very poor quality.

3.4.6 Lacustrine Bottom Sediments

1. Grade should be kept high - about 3 or 4 ft. above terrain level - wherever possible. Cuts of more than a few feet will encounter ground water and soft soil conditions.
2. Foundation conditions are usually poor. Considerable settlement may take place under high embankments. Bridges and buildings will usually require pile foundations unless loads are very light.

   Thorough subsurface investigation is always necessary at the site of large fills to determine the settlement characteristics and strength of the soil so that the fill section and construction procedure can be regulated to prevent shear failures.
3. As a generalization, there will not be much surface unsuitable material to be removed and wasted. Poorly drained areas may have muck or highly organic topsoil of comparatively shallow depth that will require removal.

   However, cuts greater than a few feet in depth will encounter soft material, which, because of its high moisture content and slow drying characteristics, will not compact readily to an acceptable density. In many cases, it is more economical to waste this material than to try to use it for embankment purposes.

   To save borrow, these wet materials may sometimes be used outside the downward extension of the subgrade foundation prism, complete compaction being less important in this part of the cross section. Where future widening is contemplated, the wet material should not be used under the proposed future lane, unless it is certain that several years will elapse before the new pavement is placed, so that natural compaction can take place.

   If granular material is used for the core of the fill; that is, that part within and beneath the downward extension of the subgrade foundation prism; adequate drainage through the more impervious outside material must be provided. A suggested method is a layer of the granular material, at least 2 ft. thick, the full width of the embankment at the original ground surface. Where the embankment is high, additional layers of this type should be provided at about 5 ft. intervals.
4. Slopes are a function of the strength of the soil, so that, for major cuts or fills, these values should be determined and the rate of slope set that gives stability.

For ordinary grading operations, lacustrine soils will be stable on a 1 vertical on 2 horizontal slope, for fills, and a 1 vertical on 3 horizontal in cuts, depending on the moisture conditions.

Although generally not as erodible as some soils, a growth of vegetation should be established as soon as practicable.

5. Because of their uniformity and low permeability, lacustrine bottom sediments are not prone to excessive differential frost heaving. Frost heave does occur but it is usually uniform and does little damage.

   However, these soils lose strength rapidly with increased moisture and manipulation, and there is always pumping at the joints in pavement laid directly on the soil, so that a foundation course of granular material is always advisable. If the foundation course is slag or stone, a layer of sand or stone dust, 2 to 3 in. in thickness between the foundation course and soil, is recommended to prevent infiltration of the soil into the foundation course material, and the gradual movement of the stone or slag downward into the soil.

   The subgrade in bottom sediment soils is often very soft. These soft subgrades will be adequate to carry the pavement and traffic load if heavy equipment does not bog down and churn it up. In these areas, it is recommended that a "mat" of granular material, 12 to 18 in. or more in depth, depending on conditions, be placed as a working platform for the equipment. This will entail some additional excavation and also more foundation course.

   Do not consider this mat as part of the foundation course. The soft material beneath is almost certain to be mixed with the granular material in sufficient quantity to make the mat subject to frost heave.

   It is recommended that an additional quantity of foundation course be estimated in cuts for this purpose, the actual locations and depths of its use to be determined by the Engineer in the field.

6. Under-drainage does not usually work well in these soils. However, when the pavement grade is at or below terrain level, an underdrain at both pavement edges, connected with the foundation course to supply positive drainage to the latter, is always advisable.

   A special deep side ditch section is recommended wherever its use is practicable. The bottom of this ditch should be at least 6 in. below the bottom of the foundation course at the edge of pavement.

7. For reinforced concrete pavement 9 in. in thickness, a foundation course 12 in. in depth will usually prove sufficient for most modern highway loads. Where conditions are not uniform, for instance, where the subgrade cuts across the varves, this thickness should be increased as conditions demand.

   Due consideration should be given to the installation of a "filter layer" as mentioned in 5 above and to under drains at both edges of the pavement as mentioned in 6 above.

8. When well drained, these soils are a source of common borrow.

   Rigid control of density and moisture content are essential if a good embankment is desired.

9. Carryall scrapers work very efficiently in lacustrine soils above the water table. Rooting is seldom necessary. In cuts below the water table, shovels working on mats and comparatively light trucks may be necessary.

   The sheepsfoot roller is the most efficient compacting tool. Heavy disc harrows, rotary tillers and blade graders are necessary to work the soil for proper aeration and drying.

10. Sheeting and bracing will be necessary for all temporary excavations below the water table. When not below the water table, these soils will stand for a long time on slopes of 3 vertical to 1 horizontal on a height of about 15 ft.
11. These soils are a good to excellent source of topsoil. They are fine grained, essentially stone free, high in organic matter and have a reasonable natural fertility.

The engineering characteristics of marine bottom sediments are almost identical with those outlined for lacustrine bottom sediments. In general, they are weaker and much more sensitive to remolding. Settlements are usually greater, and danger of shear failure, under even fairly small embankments, is always present.

Residual soils and colluvial soils have engineering characteristics very similar to those of the tills. Colluvial soils are usually very stony.

3.4.7 Alluvial Soils

1. Grade line should be kept high, which is usually dictated by the possibility of flooding during high water. If flooding is not a problem, as in "second bottom lands", depth to ground water should govern. Where possible, grade should be kept at least 4 ft. above highest ground water.
2. Foundation conditions are generally poor in alluvial soils. Since alluvial soils are the general site of bridges and their approach embankments, thorough investigation is indicated. These investigations should extend to, and into, rock, where rock is at a reachable depth.
3. Alluvial soils very frequently have a covering of wet, mucky topsoil or even of actual muck from one to several feet in depth. The depth of these deposits should be determined and ample quantities should be estimated to allow for their removal and replacement with suitable borrow. Where replacement is underwater, granular material such as a course sand or run-of-bank gravel should be specified as the replacement material.
4. Slopes are not ordinarily a problem because cuts are seldom necessary and use of alluvial material as borrow is usually impossible. However, heavy fills across alluvium may require special flat slopes or counter-weighing berms to prevent shear failure of the under soil. When unusual conditions are encountered, undisturbed sampling, structural testing and soil mechanics analyses of the situation are required.
5. Subgrade conditions are not generally a problem on alluvial soils because they are generally crossed on fills. Where necessity dictates their use as subgrade, subgrade conditions are usually very poor, and ample quantities of foundation course should be estimated.
6. Under-drainage is usually not necessary on the alluvial soils because of the height of grade required to prevent flooding. In the instances where employment of alluvial soil as subgrade is necessary, underdrain should be provided at each edge of the pavement.
7. Extra depth of foundation course will be necessary whenever alluvial soils are used as subgrade.
8. Construction materials, except for topsoil, are not usually obtainable from alluvial soils. Some swift - flowing streams deposit sands and gravels as alluvium that may be useable as foundation course.

9. Bulldozers, clam shell buckets, and drag lines may be necessary for removal of unsuitable material.
10. Sheeting and bracing or cofferdams will be necessary in temporary excavations of any size. Pumps of high capacity will usually be necessary.
11. Topsoil from alluvial soils will generally be of very high quality, in good physical condition with plenty of organic matter and a reasonably high natural fertility.

3.4.8 Muck, Peat and Marl

The only engineering characteristic of these soils is their complete uselessness for any engineering purposes. Their shear strength is almost zero, and because of their high water content, often 500% and occasionally as high as 1000% of the dry weight of material, they are very compressible, so that anything built on them soon settles out of shape.

When possible, extensive areas of these materials should be avoided by realignment. If it is imperative that such material be crossed, they should be excavated down to solid bottom, disposed of and replaced with suitable borrow. When such replacement is in water, the replacing material should be coarse sand or run-of-bank gravel to at least 2 ft. above the water surface because of the impossibility of compacting fine grained materials under these conditions.

In some instances, it may be very costly to remove the muck by complete excavation and it is necessary to consider other means. Fundamentally, these means consist of displacing the muck by the weight of the fill, assisted by excavation of side and front relief trenches, by underfill blasting and by jetting with high pressure water streams, or a combination of these methods. Great care must be taken with these methods because pockets of the objectionable material are frequently trapped under the fill and the result is differential settlement.

1. Grade elevation should be at least 5 ft. above high water.
2. Foundation conditions are nearly always bad. Thorough investigation is imperative. Structures will nearly always require pile foundations.
3. These soils are always unsuitable and should be treated as outlined in the introductory paragraph.

4, 5, 6, 7 and 8. Not applicable.

9. Bulldozers, clam shell buckets, and drag lines will be necessary for removal. Blasting equipment may be necessary for underfill shooting.
10. Sheeting, bracing, cofferdams and pumping will nearly always be necessary.
11. Mucks and peats are not good topsoils in themselves, but will serve as an amendment to topsoil to give a higher organic matter content and to promote better physical condition and soil aeration. Marl can be used as an alkalizing agent on acid soils in the same manner as lime or limestone dust.

3.4.9 Dune Sands

1. Grade can be at any elevation.
2. Foundations should be thoroughly investigated. Dune sands are frequently underlain at comparatively shallow depths by soft, weak bottom sediments.
3. Unsuitable material is almost completely absent in dune areas.
4. Slopes in cut and fill are stable on slopes of 1 vertical on 1 ½ horizontal or 1 vertical on 2 horizontal. However, these sands are extremely erodible both by wind and water. They should be given a mulch cover at once and vegetative growth started as soon as possible.
5. Subgrades must be compacted to high density before pavement is placed. Otherwise, traffic vibration will cause compaction beneath the pavement, resulting in cracked concrete slabs and uneven surfaces on flexible pavements.
6. Under drainage ordinarily will not be necessary in sand dune areas, their natural tendency being toward excessive internal drainage.
7. Foundation course at least 6 in. in depth should be provided to prevent, so far as possible, compaction from traffic vibrations, and movement of the sands from beneath the slab.
8. Where dunes occur, they are frequently the only convenient source of common borrow. They are not a source of select borrow, or run-of-bank gravel.
9. Almost any type of digging and hauling equipment can be used successfully. Heavy equipment may bog down in loose sand on new embankments.
   Pneumatic-tired rollers are the best compacting agent. It will be necessary to add a great deal of water to secure proper compaction of the dry, uniform grain-sized sand.
10. Sand will stand to considerable heights in temporary excavations so long as it is damp. As soon as it dries however, it will slough. Therefore, it is necessary to utilize sheeting and bracing, or slopes of 1 vertical on 1 ½ horizontal or flatter, for support.
11. Dunes are not a source of topsoil.

3.5 SESIMICITY OF NEW YORK STATE

3.5.1 Discussion

The northeast United States (NEUS) lies within the relatively tectonically stable and geologically old North American plate, where a great deal of the tectonic action took place over two hundred million years ago when the Atlantic basin began to form due to the separation of Africa from North America. However, based on instrumental seismic records, earth scientists believe that the tectonic activity in the Northeast is still going on (Barosh, 1984; Ebel, 1987; Zoback, 1987) and that earthquakes with a magnitude equal to the October 17, 1989, Loma Prieta earthquake could also strike, but less frequently, any location in the NEUS. Such an occurrence would affect a much wider area and create more damage than in the western United States. This is because the Earth's crust in the eastern States is probably harder, older and colder. It tends to transmit seismic energy more efficiently, at a very low rate of attenuation.

See NYSDOT GDM Chapter 9 *Appendix A* for a discussion on the background information for performing a site-specific seismic analysis.

3.6 VARVED CLAYS

The landforms and deposits of New York State described earlier in this Chapter were created during the Pleistocene Epoch and have been recognized worldwide as an exemplary legacy of the most recent glaciations. Evidence has suggested that New York has likely experienced at least 20 major glaciations. Glacial deposits are wide spread in New York to varying degrees, with some locations absent of deposits and bedrock exposed at the surface while other locations have deposits greater than 1000 ft. in thickness.

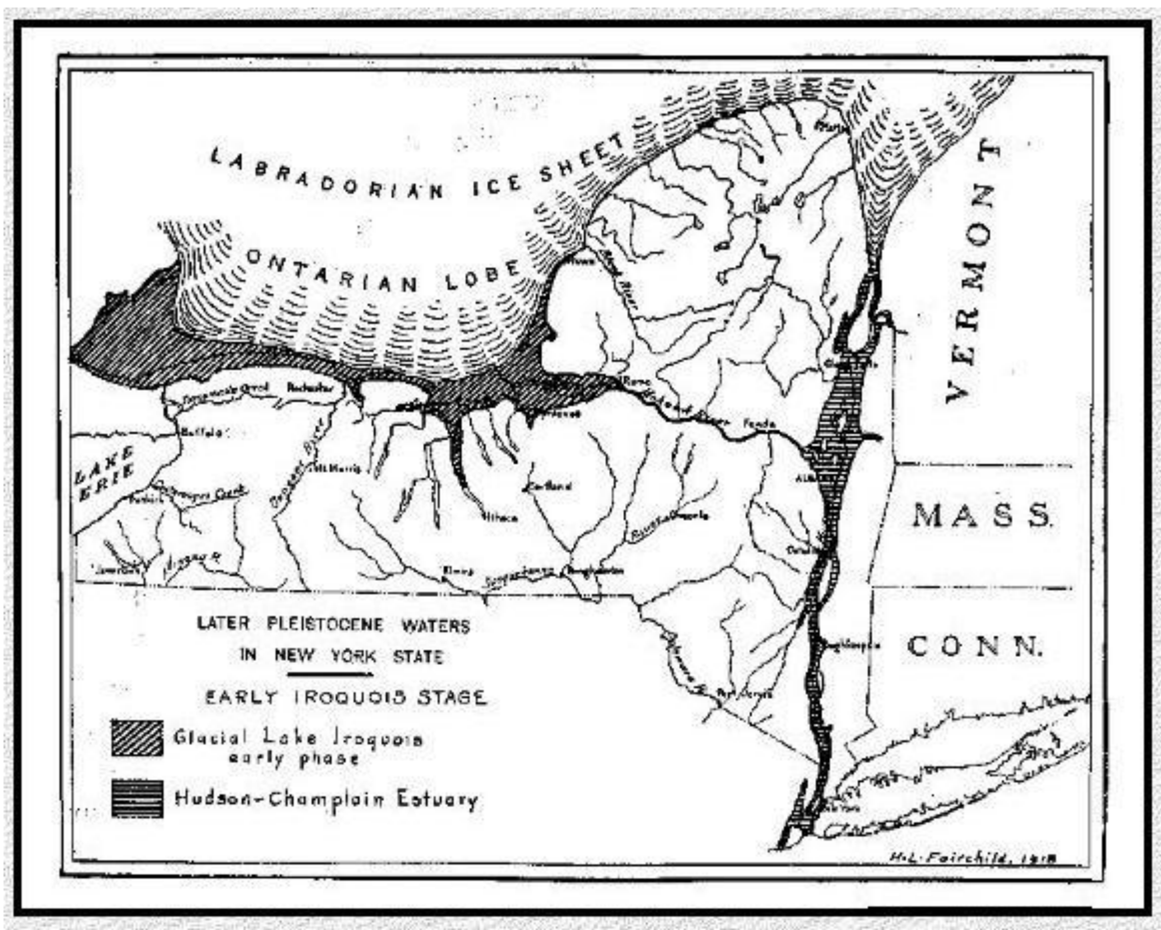


Figure 3-23 Later Pleistocene Waters in New York State (Vintageveiws.org)

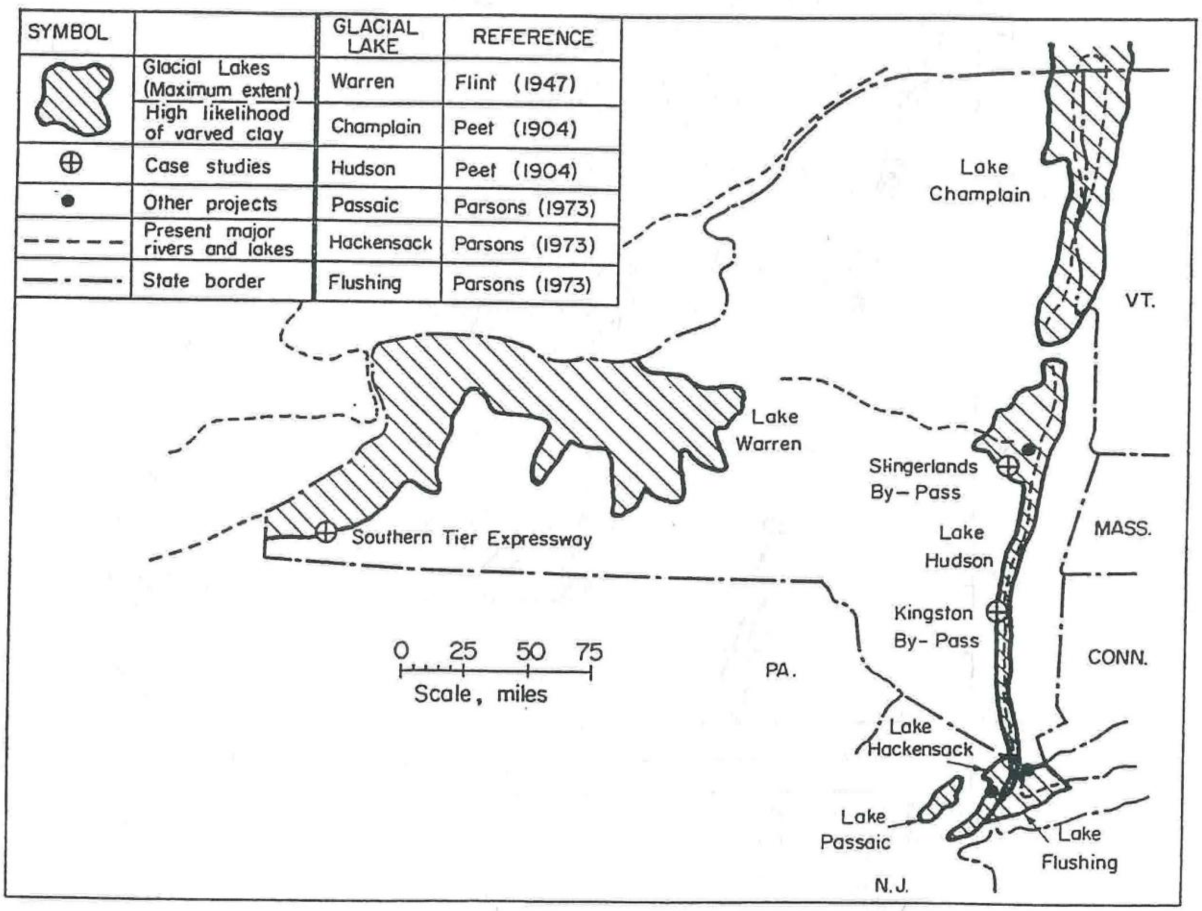


Figure 3-24 Glacial Lakes of New York State

Clays are fine-grained, cohesive soil deposits that contain varying amounts of types of clay minerals. Clay minerals are typically formed over long periods of time by the gradual chemical weathering of rocks by low concentrations of diluted solvents or through hydrothermal activity. Clay deposits may be formed in place as a residual deposit, but thick deposits are usually formed as the result of a secondary sedimentary deposition process after they have been eroded and transported from their original location of formation.

The bulk of clay deposits in New York date from the late Pleistocene Epoch. These deposits are from very low-energy depositional environments.

- Lake clays were formed on the bottom of pro-glacial lakes that existed across the State;
- Marine clays were formed within the coastline bays of the sea that occupied portions of the St. Lawrence and Champlain valleys.

The physical characteristics of a particular clay deposit are defined by factors such as the source of the mineral particle being deposited, depositional and post-depositional environment and the present conditions and factors affecting the deposit.

- Varved clay is a clay with visible annual layers, formed by seasonal differences in erosion and organic content. These layers were derived from the glacial lakes low energy depositional environment yielding to eroded soils cyclically settling on the lake bed.

Lake and marine clays in New York (and elsewhere around the world) have a history of slope instability resulting in foundation problems, settlement, downhill soil creep, and minor to catastrophic landsliding. Glacial lake deposits, particularly clays, are generally highly susceptible to landsliding. The generally low shear strength of clay facilitates sliding on even moderate slopes. The sensitivity of clays (i.e. the ratio of peak to remolded strength) is an important characteristic factor influencing the behavior of glacial clays. High pore water pressure reduces shear strength and is a major environmental mechanism responsible for triggering landslides.

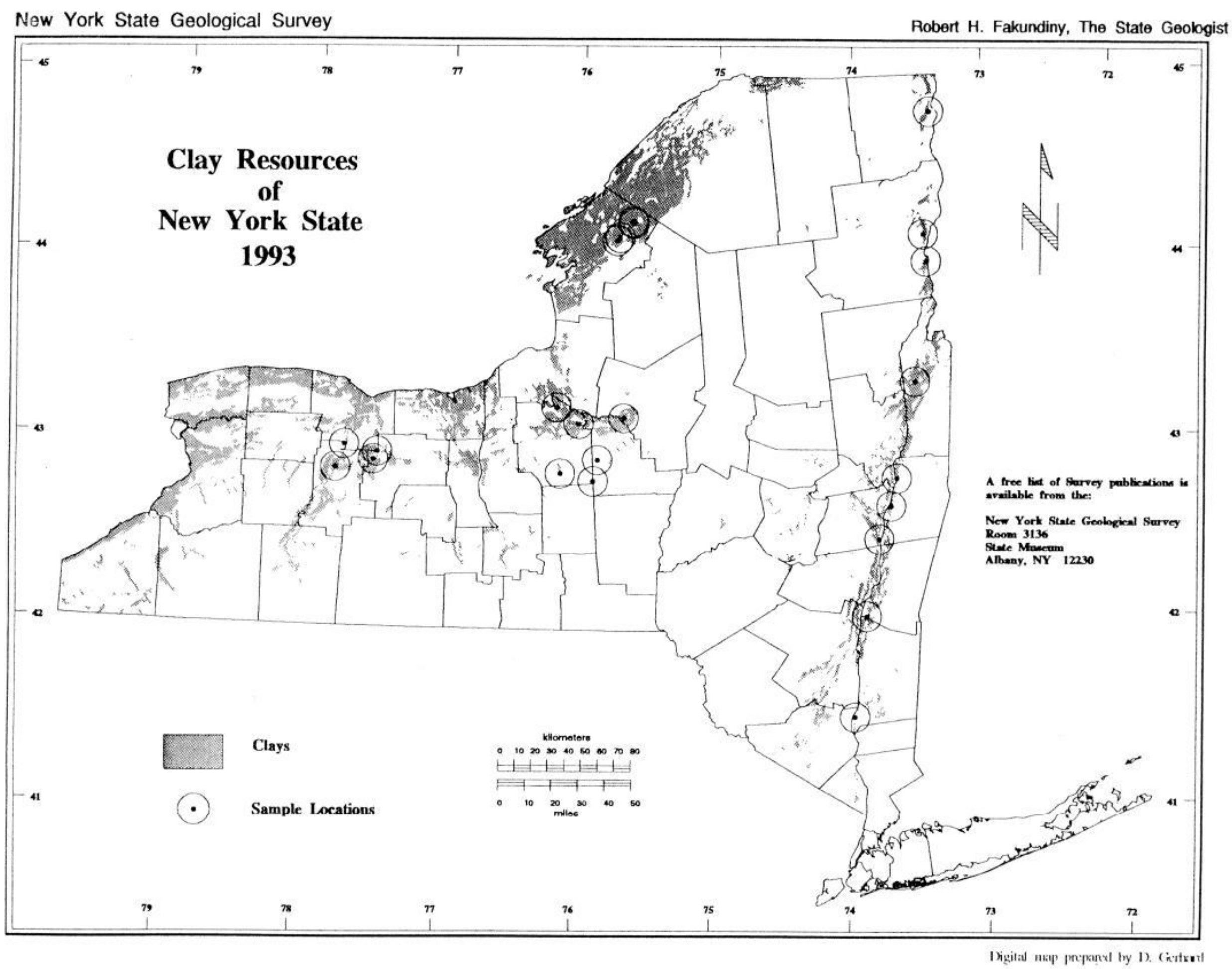


Figure 3-25 Clay Resources of New York State (Fickies, 1994)

3.7 DEPOSITIONAL GROUPING OF NEW YORK STATE SOILS

Geologic Period	Mode of Deposition	Depositional Unit	Typical Landform
Pre-Glacial	Variable	Bedrock	Gross topographic forms
Pleistocene (Glacial)	Ice	Thick Till Thin Till Morainic Till	Plains, drumlins Landform underlying bedrock determines Hummocks across valleys, complex slopes along valley wall footslopes
	Stream	Ice-contact Deposit Outwash	Hummocks, conical hills Plains, terraces
	Lake	Lacustrine Shore Deposit	Delta, beach or bar
		Lacustrine Bottom Sediment	Plains, dissected terraces
	Sea	Marine Bottom Sediment	Plains
Holocene (Post-glacial or Recent)	Wind	Eolian Deposit	Dunes
	Stream	Recent Alluvial Deposit Alluvial Terrace Deposit Alluvial Fan Deposit	Flood plains Flood plain terrace Fan at valley wall footslope
	Sea	Tidal Marsh Deposit	Along coastline, Hudson River estuary
	Cumulose	Organic Deposit Residuum and Colluvium	Depressions Hillsides and Hilltops

Table 3-1 Depositional Grouping of New York State Soils

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