Trip B-5

WISCONSINAN GLACIAL STRATIGRAPHY AND STRUCTURE OF NORTHWESTERN LONG ISLAND

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Introduction

The most detailed report on the geology of Long Island is that of Fuller (1914). In this work, Fuller developed a detailed stratigraphy which incorporated the Pleistocene sediments of Long Island into the classical stratigraphy of 4 glacials and interglacials recognized in the midwest. Fuller's work, built on such preceding studies as Woodworth (1901) and others, contains many excellent stratigraphic sections, but it is restricted to the "state of the art" for that time. More recent contributions such as Fleming (1935), MacClintock and Richards (1936), deLaguna and Perlmutter (1949), Swarzinski (1963), Donner (1964), and Sirkin (1967, 1968, 1971, 1972, and 1975, and Sirkin and Stuckenrath, 1975) began to revise the stratigraphic interpretations, mainly in limiting the number of glaciations to mapable drift sheets. With the aid of palynology and radiometric dating, recent authors have been able to place the rock units into a more refined time scale.

Pollen analysis has shown that at least two cold episodes, corresponding to glacials, and possibly three warm intervals, an interglacial (?), and interstadial, and the postglacial, have taken place here (Sirkin, 1967, 1971, 1968, 1972, and 1975, and Sirkin and Stuckenrath, 1975). Additional information about glacial deformation has provided a better understanding of the complications observed in the stratigraphy (Mills and Wells, 1974). The recent discovery of interstadial deposits has also brought about a change in the interpretation of the stratigraphy of only a few years ago in which the trend seemed to be toward monoglaciation (Sirkin, 1968, and Connally and Sirkin, 1973). Prior to this discovery much of the confusion was centered around the incorporation of morainal terminology with stratigraphic units. This fostered a sort of morphostratigraphy in which drifts were named and associated with moraines. The observation that the moraines were constructed of superposed drifts (Sirkin, 1968) and the introduction of the new data (Sirkin, 1975, and Sirkin and Stuckenrath, 1975) has made it possible to distinguish between geomorphology and stratigraphy.

Stratigraphy

Pre-Pleistocene. Metamorphic rock of early Paleozoic age forms the basement on which this portion of the Atlantic Coastal Plain-Continental Shelf is constructed. The metamorphics are probably part of the Cambro-Ordovician eugeosynclinal facies known as the Hartland Gneiss (Hall, 1968, Pellegrini, 1974) or the Hutchinson River Group (Seyfert and Leveson, 1969). The basement is overlain by a sequence of deltaic and marine clay, sand, and gravel of Cretaceous age. Pollen analysis has shown that much of the nearly 603m (2000') of sediments beneath the south shore of Long Island is upper Cretaceous including the Raritan, Magothy, and Magothy-Matawan (undifferentiated) Formations (Sirkin, 1974a). The older, Raritan Formation (lower, upper Cretaceous) comprises a smaller segment of the record than previously believed, and the lower Cretaceous does not appear in the Long Island section. Sediments containing Monmouth age (youngest Cretaceous) foraminifera were also obtained in a south shore well by Perlmutter and Todd (1965). The main water bearing stratum, the Lloyd Sand, may include thick sands deposited during both Raritan and Magothy time and separated occasionally by thin clay lenses.

As yet, Tertiary sediments have not been identified in Long Island, although the sediments filling the deep buried valleys in central and eastern Long Island (Jensen and Soren, 1974) may be pre-Pleistocene. In the north shore of the Island, the Cretaceous sections exposed in the bluffs and sand pits have been identified as Raritan in age (Sirkin,1974a). Most of these outcrops are believed to be ice shoved, but whether they have been stacked over Magothy sediments has not yet been determined. The "stacked" Raritan is characterized by tan and orange colored sand, red and gray clay, white sand and gravel with a clay binder, and occasional lenses of lignite. There are also abundant concretions, ranging from iron oxide nodules surrounding lignite or plant debris, pipes and paint pots of probable ground water origin, and marcasite and pyrite nodules.

According to most authors, Pleistocene deposits may exceed 60m (200') in thickness. The glacial deposits consist mainly of till and outwash, in some areas occurring as local coarse gravels, and at least two estuarine or maine clay units. Many authors from Fuller on, believed that the presence of two moraines signified two glaciations late in the Pleistocene, and that sediments of earlier glaciations occurred beneath the surface or were exposed as surficial gravels. The contacts between these units were thought to be erosion surfaces and therefore evidence of interglacials. Alternatively,as late as 1973, Connally and Sirkin tied the moraines and encompassing drift to one major glaciation and minor readvances.

An equally simplistic model for the stratigraphy and geomorphology of Long Island, proposed by Sirkin and Stuckenrath (1975) is based first on the presence of two superposed drift sheets both with separable and mapable characteristics,and an interstadial, estuarine sequence defined by radiocarbon ages and pollen analysis. Secondly, the model is based on the concept of a lobate glacial margin in which ice flow and deposition was controlled by regional land forms such as the Hudson Valley, central Connecticut, and the Narragansett Bay regions (Connally and Sirkin, 1973, Sirkin 1975). Thus, a model emerges in which two drift sheets were deposited by different lobes of glaciers related to two separate glaciations.

In western Long Island the drifts are superposed and consist mainly of tills separated by outwash. Till fabrics on the lower till (the Montauk Till equivalent) show a preferred northeasterly orientation (Sirkin, 1975), while the upper till (the Roslyn Till of Sirkin, 1971) has a northwesterly orientation. In central Long Island, the lower drift has not as yet been observed south of the Harbor Hill Moraine, and the upper drift of outwash, till, and lacustrine sediments often directly overlies the Cretaceous in north shore cliffs. The upper drift also occurs as the kame-like deposits of the Ronkonkoma Moraine which overlie a thick outwash section. The lower drift emerges again in the south fluke of the Island and is best observed in the type section at Montauk Point (Newman and others, 1968). There, till fabrics and clast provenance point to a northeasterly source area in Rhode Island and eastern Massachusetts, and the drift represents deposition by the Narragansett Lobe of the early Wisconsinan glacier (Sirkin, 1975).

The long arc of the Harbor Hill Moraine in central and eastern Long Island consists mainly of till and outwash of the upper drift sheet, and outlines the shape of the late Pleistocene, Connecticut Lobe. Interlobate moraines are probably located where the north-south trending hills appear to separate or break up the east-west linear trend of the moraines. This occurs most noticably in the Dix Hills-Manetto Hills-Half Hollow Hills areas. Manetto Hills is the type locality of the Manetto Gravel which Fuller (1914) placed in an early Pleistocene glaciation. Rather than an early Pleistocene outwash, this gravel is probably a head of outwash, well weathered due to superglacial exposure, of late Wisconsinan age. Other probable interlobate moraines may exist in the Eatons Neck and Shelter Island areas.

Thus, the massive Harbor Hill Moraine in western Long Island is composed of two superposed drift sheets. The older drift in northwestern Long Island was derived from a Connecticut Lobe of the early Wisconsinan glacier (Fig. 1). The younger drift is an overlapping deposit from the Hudson Valley Lobe (Connally and Sirkin, 1973) that deposited the Ronkonkoma and Harbor Hill end moraines. In western and central Long Island, the Ronkonkoma Moraine, once believed to be a linear correlative of the Vineyard and Nantucket Moraines of the offshore islands of Massachusetts, is an end moraine composed of late Wisconsinan drift deposited mainly by the Connecticut Lobe of the late Wisconsinan glacier. This ice advanced over the Cretaceous cuesta and the older drift. To the west the Ronkonkoma is an end moraine of the Hudson Valley Lobe separated from its eastern portion by interlobate moraines located in the Dix Hills-Manetto Hills-Half Hollow Hills areas. Perhaps the lack of continuity of the older drift across Long Island may be attributed to the cutting of through valleys by meltwater from the Connecticut Lobe, which may not have reached Long Island in early Wisconsinan time.

The model may be tested more realistically with the available stratigraphic data (Fig. 2). The lower or early Wisconsinan drift is overlain by the late Wisconsinan drift which may be correlated with the Woodfordian of the midwest (Frye and others, 1968). The early Wisconsinan drift is also older than 43,800 years B.P., the greatest age of interstadial beds in western Long Island (Sirkin and Stuckenrath, 1975). Both drifts are composed of till and outwash. The early Wisconsinan till is known as the Montauk Till at Montauk Point and the Montauk equivalent (or Montauk ?) in western Long Island. Lack of deep weathering on the lower drift, in fact weathering on the Montauk Till is rarely observed in the field, limits placing this drift in pre-Wisconsinan time. The composition of the Montauk Till and its presumed equivalents to the west varies from the darker gray colors derived from the dark metamorphic parent rock of Rhode Island and eastern Massachusetts, as seen in the mid gray color of the Montauk Till at Montauk Point, to a light gray or brown on western Long Island. The till on western Long Island owes its color to lighter colored granite and metamorphic rock of southern New England and New York. Other facies of the Montauk Till include the threefold sequence in Block Island, described by Kaye (1960) and

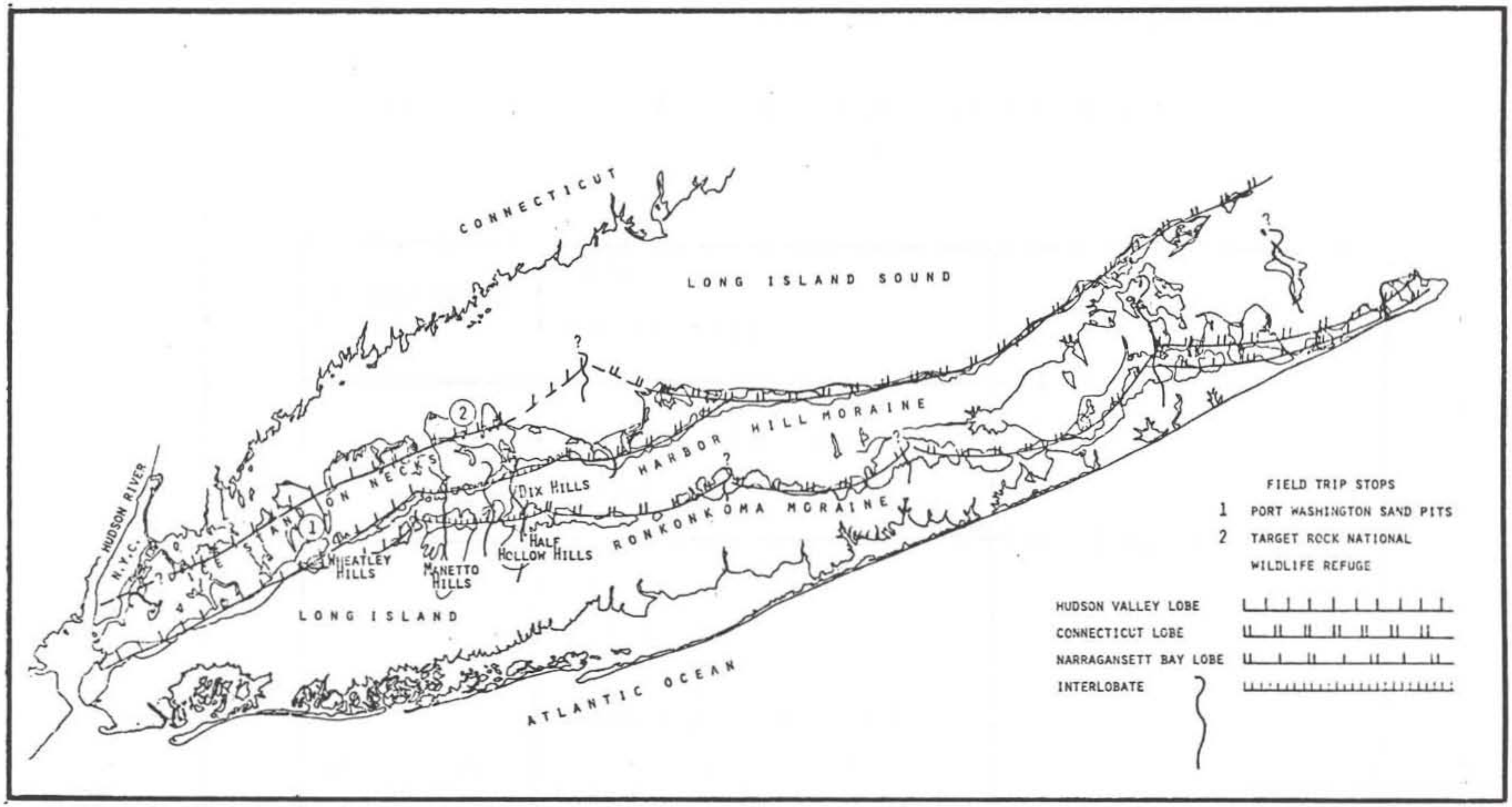

Fig. 1 Terminal moraines and lobate model of Wisconsinan glacial margins on Long Island. Narragansett Bay lobe is early-Wisconsinan; all others represent late-Wisconsinan ice stands. Probable and possible interlobate positions are also shown. (Harbor Hill and Ronkonkoma moraines after Fuller, 1914).

Stage	Substage	Stratigraphic Units	Ages
Wisconsinan	Late Wisconsinan	Surface deposits, Kames, etc. Proglacial lake beds, gravel Roslyn Till Outwash	18,000 yrs. B.P.
			ca 24,000 yrs. B.P.
	Mid Wisconsinan	Oyster Reefs, Clay Fresh and salt marsh peat	
			>43,800 yrs. B.P.
	Early Wisconsinan	Montauk Till Outwash	

Figure 2. Glacial stratigraphy - Long Island

Sirkin (1975a), and the thin bedded flow till-gravel sequence at Port Washington. Characteristic of the Montauk (?) Till in the superposed sequences at Port Washington is its tendency to erode in deep gullies and hoodoo structures (Fig. 3B & 3D).

If a Pleistocene unit older that the early Wisconsinan drift exists, it would be the Gardiners Clay and associated Jacob Sand. These units, known from the type section in Gardiners Island, contain marine invertebrate fossils comparable to warmer latitudes according to MacClintock and Richards (1936) and Gustavson (1974, personal communication), and pollen representative of temperate forests bounded by pollen of boreal forests (Donner, 1964). Many believe the Gardiners to be Sangamonian in age and to represent an interglacial unit deposited prior to the early Wisconsinan glaciation and deposition of the Montauk Drift. Alternatively, the Gardiners may be part of the mid-Wisconsinan interstadial and mark the high stand of the sea at that time rather than during the Sangamonian. The major difficulties in accurately locating the Gardiners in time are the absence of radiometric ages for this unit, some confusion as to what is Gardiners in other places than Gardiners Island (Upson, 1964), discrepancies in the faunas in the Gardiners Island section and elsewhere (Gustavson, 1974, personal communication), and the existence of other Pleistocene clays or Holocene clays found in drill cores and cliff sections in Long Island. Certain clays exposed in cliffs are now proven to be interstadial clays, deposited during the high stand of the sea in mid-Wisconsinan time. For example, organic-rich clay found in cores off Fire Island contains pollen indicative of temperate vegetation. This unit has been dated at 28,000 years B.P. (Dietrich, 1974, personal communication). Thus, the Gardiners remains an unsolved problem awaiting radiometric dating and faunal analysis, which was proposed by Gustavson (personal communication, 1974).

The discovery of mid-Wisconsinan sediments stacked in the drift north of the Harbor Hill Moraine at Port Washington has provided the key to the age of the drift sheets and to the Pleistocene history of Long Island (Sirkin, 1975). The interstadial sediments consist of several layers of peat, clay, and oyster (Crassostrea virginica) reefs which were picked up by the advancing late Wisconsinan glacier as it crossed what is now the westernmost part of Long Island Sound. These beds were recumbently folded, thrusted, and emplaced in the late Wisconsinan outwash (Figs. 3,4). The beds range in age from greater than 43,800 to about 23,000 years B.P. (Sirkin and Stuckenrath, 1975). The older, fresh and salt water peats contain pollen of boreal vegetation, and tundra herbs, as well as spruce wood. Warming began around 31,000 years

B.P. and was accompanied by the high stand of the sea and the development of the oyster reefs. Foraminifera in the reef sediments are similar to those found in Long Island Sound today. The pollen record points to a temperate, deciduous forest in this region during the interstadial. The opening of this part of the Sound to the ocean may have been through deep channels cutting across Long Island southward into the Hudson estuary, south of its present mouth, and perhaps not eastward through a sound as it is today, although eastward drainage may have occupied a less imposing river valley. The warm episode lasted until around 29,000 years B.P. Pollen of much colder types of vegetation, mainly plants associated with the northern needleleaf forest, enter the record after this. Thus, a maximum age as well as environments, are established for this region just prior to the advance of the late Wisconsinan glacier.

This advance which probably began well before 24,000 years B.P. in more northerly regions was accompanied in the Long Island region by the deterioration of climate prior to glacial deposition. By the time the ice reached Long Island, the shoreline was near the margin of the continental shelf and vegetation had receded well to the south of the island. Radiocarbon dated sediments from the Delmarva Peninsula contain pollen of spruce forests and some tundra herbs during this time (Sirkin, 1974b). The ice advancing toward Long Island deposited outwash over Cretaceous hills and early Wisconsinan drift. This ice was capable of folding and thrusting large blocks of Cretaceous, outwash, and Montauk Till and forming overthickened sections of these sediments according to Mills and Wells (1974). The interstadial deposits were also involved in this deformation (see Deformation section and Fig. 4).

The Roslyn Till which caps this sequence has the appearance of lodgement till in most sections. In its upper portions it contains thrust planes which may mark its deposition at the ice margin as ablation till, or north of the terminus as ground moraine of the waning glacier. Facies of the late Wisconsinan till include the Roslyn (a clay till), thin flow tills seen in some outwash sections, a very sandy till capping the Ronkonkoma Moraine in western and central Long Island, and a clay till facies capping the early Wisconsinan drift in eastern Long Island and Block Island. During the late Wisconsinan, tundra vegetation persisted south of the glacial margin and boreal forests generally to the south of the tundra as seen in the pollen record in sections from near Sandy Hook, New Jersey, the Delaware River Valley, and the Delmarva Peninsula (Sirkin and others, 1970, Sirkin, 1974b).

Deformation

Over the years, several investigators (Fuller, 1914; Sirkin, 1968; Mills and Wells, 1974; and others) have described various structures in unconsolidated sediments resulting from ice-shove deformation on Long Island. These vary from minor overturned folds in near-surface outwash sands and gravels to major (up to 50m (150') thick by 300m (1000') long) thrust blocks of Cretaceous sediments.

Through detailed investigations of many of these structures on western Long Island (Manhasset Neck) it has been shown that the major deformational event occurred in the late-Wisconsinan, prior to the deposition of the Roslyn Till. In this region all units older than this till, including the Cretaceous, early-Wisconsinan drift, mid-Wisconsinan interstadial beds, and late-Wisconsinan outwash have been deformed rather extensively at one site or another. In contrast, the Roslyn Till at the surface maintains a relatively horizontal attitude truncating the structures in the underlying deformed beds. There is no evidence that the early Wisconsinan glaciation was a major deforming force. The advance outwash of this ice generally has an undeformed contact with the overlying Montauk (?) Till. Furthermore, no older Cretaceous sediments are found incorporated in this drift. During resession this ice produced no major deposits.

Sirkin and Stuckenrath (1975) have identified mid-Wisconsinan marine and fresh water deposits stacked in a deformed cliff section in Port Washington (see Interstadial and Part 1, Stop 3, sections). These sediments formed north of the Cretaceous cuesta in northern Long Island and indicate a significant ice front retreat and warming during the mid-Wisconsinan interstadial.

A model for the deformational sequence is suggested. As the ice front advanced in late Wisconsinan time it entered Long Island Sound and the north shore bay valleys depositing thick advance outwash and building up the Necks areas (MacClintock and Richards, 1936). The development of deep permafrost in this outwash and in the interstadial beds, early Wisconsinan drift, and Cretaceous sediment occurred at this time. The build up of ice in the lowland north of the cuesta pushed the glacial margin further south. Advancing ice picked up the interstadial beds, and meeting resistance at the northerly facing Cretaceous cuesta, sheared off long wedges of frozen sediment. These intact clasts were carried a mile or more to the south (Mills and Wells, 1974).

Movement of the ice with these massive blocks deformed the late-Wisconsinan advance outwash and underlying early-Wisconsinan drift. The mid-Wisconsinan beds were recumbently folded into the outwash. North of this section, larger Cretaceous blocks were stacked one behind the other with blunt northerly ends and long tapering tips pointing south (Fig. 4). As the ice continued to advance, it overrode and beveled all of the deformed sediments and deposited lodgement till (Roslyn Till) on the surface. Some minor structures related to later ice stands and fluctuations during deglaciation have also been observed and can be seen on this field trip at Target Rock (see Part 2, Field Excursions).

Deglaciation

The surface of the Harbor Hill Moraine in western Long Island includes numerous kames and possible lineations of surface deposits denoting minor glacial stillstands during glacial recession (Sirkin, 1967, 1968, 1971, and 1975; Newman and Pike, 1975). The retreat of the ice from Long Island was not uniform and surficial deposition, lineation of deposits, and erosional features supply some of the details of the glacial recession. Sirkin (1968) and Connally and Sirkin (1973) describe an ice stand across the northernmost parts of western Long Island necks (Fig. 1). This stand may be the Hudson Valley Lobe equivalent of the Connecticut Lobe, Harbor Hill Moraine on northeastern Long Island. The retreat of the ice was sequential with stillstands somewhat as marked in Fig.1. It has been suggested that minor readvances of the ice from its "Necks" stillstand partially excavated the bays. These valleys are U-shaped and are (or once were) occupied by north flowing streams that head in the proximal slope of the Harbor Hill Moraine. A few of the valleys may have occupied older through channels of pre-Wisconsinan drainage. The readvance in the valleys is marked by kames deposited against the valley walls on the proximal slopes but well up the valleys. As the ice receded to the "Necks" position, meltwater cut east- west channels at different elevations across the necks or incised channels from the bays into the necks. At this time drainage was probably blocked by ice masses and numerous proglacial lakes developed. Fine sediments, including cross-bedded deltaic sands, and varved lake clays and silts, attest to this event. Glacial recession probably began well before 18,000 years B.P., and the island was ice free about that time. The rate of deglaciation curve described in Connally and Sirkin (1973) gives an idea of the extensive downwasting of the ice that must have occurred before more accelerated northward glacial recession began around 15,000 years B.P. Much of the Long Island Sound Valley was probably excavated by meltwater in this 2,000 to 3,000 year interval.

The proglacial lake stages have not been dated and pollen has not been recovered from the sediments. Presumably pollen would include the tundra herbs and shrubs, as it does in the lake beds (varves?) in Block Island. That minor readvances occurred during recession is also seen in the Target Rock section where a gravel, which in some exposures is till-like, is thrust over a basal till (Fig. 5). Fluvial or glacio-fluvial sands overlying the till are deformed with thrusts and convolutions. A kame caps similar deposits on Eatons Neck eastward across the bay from Target Rock. The recession of the ice across the Sound area left remanents of small moraines that trend northeastward into Connecticut (Flint, 1974, Newman and Pike, 1975). There is also some indication of recession in the pollen record in western Long Island. The Flower Hill Bog near the proximal slope of the Harbor Hill Moraine contained a much longer pre-forest record than that in the bog at Kings Point Park which is located very near the "Necks" stand (Sirkin, 1967). In central Long Island bogs on the Harbor Hill and Ronkonkoma Moraines and on the Manetto Gravel surfaces all record late and postglacial vegetation and environments; none of these records extend into the interstadial (Sirkin, 1971). The pollen record for this region is summarized in Sirkin,(1968 and 1971).

The field trips accompanying this brief review of more recent concepts of the geology of Long Island are designed to present the evidence supporting the models of glaciation, stratigraphy, deformation, and deglaciation. The stops will allow participants to consider the evidence and the models, and test the inferences.

Field Excursions Part 1

Port Washington Sand Pits

Road Log Trip B-5 (Sunday, Nov. 2)

A.M. trip - Port Washington Sand Pits

From Hofstra take Hempstead Turnpike west to Clinton Rd. (Approx. 1.5 mi.). Turn right (north) (Clinton becomes Glen Cove Rd.) and follow (approx. 6 mi.) to Rt. 25A (Northern Blvd.) intersection. Turn left and proceed west across Roslyn viaduct to light at top of hill (2 mi.). Turn left at this light then left again at next light (100 ft.) (Old Northern Blvd.). Proceed down hill to triangle in road, come to stop sign (do not bear right) and make left hand turn onto West Shore Rd. Proceed north about 1 mile; stop 1 is opposite prominent partially excavated sand hill. (Total mileage approx. 10.5).

The large sand mines that extend for two and one-half miles from Roslyn to the Beacon Hill area of Port Washington along the west shore of Hempstead Harbor provide the best opportunity for observing glacial stratigraphy and ice-shove deformation on Long Island. The stops described for this field trip log were chosen as illustrative of the magnitude and variety of Wisconsinan events on western Long Island.

Stop 1-A. Remanent area, known as Billy Goat Hill (Fig. 3A). This location has an apparently undisturbed 2 till - 2 outwash sequence (outwash-till-outwash-till). There is a 5-6m layer of tan gravelly sand at the base of the cliff, which rests on clayey Cretaceous sands not far below the surface. A compact gray-brown till of fairly uniform thickness (about 2m) overlies the outwash. Abundant cobble and small boulder sized erratics can be seen in this till, and at one point a prominent boulder lag occurs at the top of the till. If this lower outwash and till are attributed to the early Wisconsinan glaciation, the till would be the Montauk Till equivalent on western Long Island. Above this till is another thick (8-10m) outwash similar to the lower outwash, except with more prominent oxidization zones due probably to ground water movement. A second till, well cemented and of variable thickness (2-4m) overlies the upper outwash. The upper outwash and till represent late-Wisconsinan drift commonly observed in western Long Island.

In both cycles outwash and lodgement till were deposited. The lag boulder zone on the Montauk (?) Till may represent a mid-Wisconsinan erosion interval. Large boulders resting on the Roslyn Till (Sirkin, 1971) and numerous kames and minor kame-like moraines on the Necks north of the Harbor Hill terminal moraine are products of late Wisconsinan deglaciation.

It might be noted that Fuller (1914) placed the top of his Manhasset Formation (of Illinoian age in his time scale) above the upper outwash (his Hempstead Gravel). As will be seen at later stops, an angular unconformity often occurs at this horizon due to late-Wisconsinan deformation. No significant depositional hiatus can be justified between the upper till and outwash.

Proceeding to Stop 1-B notice the persistent thickness and elevation of Montauk (?) Till. The late-Wisconsinan drift has been largely removed at several points by the sand mining. Other features of note are the well formed and sorted talus cones, mud cracks, and quicksand (BEWARE) if conditions are right.

Stop 1-B. 1/4 mile west of Stop 1-A (Fig. 3B). The Montauk (?) Till is dramatically thicker at this location due to ice-shove deformation associated with the late-Wisconsinan advance. A light reddish iron stain marks a folded thrust plane indicating that the relatively, thin, undisturbed lower till of Stop 1-A has been increased in thickness due to folding, faulting and probable flow. Dramatic changes in the thickness and position of the Montauk (?) Till have been described by Mills and Wells (1974) and can be seen at Stop 2 of this trip.

The thick till at Stop 1-B is well cemented, contains many cobble and boulder-sized erratics,and exhibits the sharp ridge and pinnacle "hoodoos" also seen in the Montauk Till at Montauk Point. A till fabric in this till revealed a northeasterly source direction. When traced along the outcrop to the west, this till again thins and assumes an apparently undisturbed horizontal altitude. Above the disturbed section of Montauk (?) Till, there is an unusually thin deposit of late-Wisconsinan drift capped by about 2 meters of loess. A gravelly zone in the Roslyn Till may indicate a local flow till or outwash. To the west, the upper outwash thickens and the section looks much as it does at Stop 1-A. Across the landfill site, a lighter area in the cliffs marks the site of an ice transported clay lens of probably mid-Wisconsinan age. This localized deformation is typical of the glacial stratigraphy north of the terminal moraine.

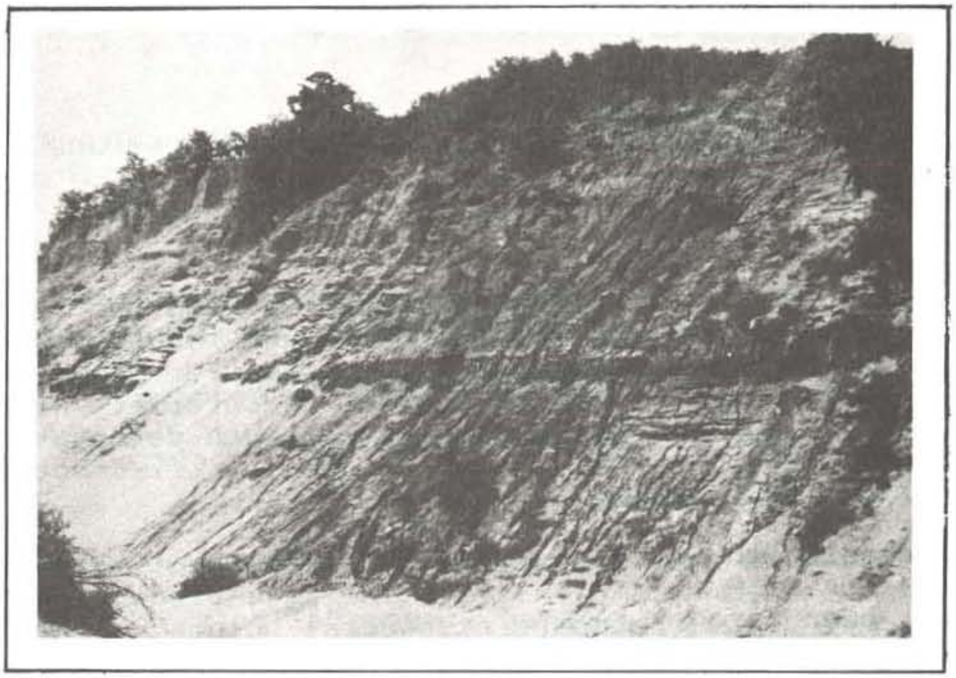

Figure 3A. Port Washington, Stop 1A - Early Wisconsinan outwash at cliff base is covered by Montauk (?) Till (dark band) with lag boulder zone at right. Late-Wisconsinan outwash with Roslyn Till at the surface complete this section.

Figure 3B. P.W., Stop 1B - Montauk (?) Till overthickened by ice-shove deformation. Note fault plane dipping from left to right near center of picture, also "hoo-doo" erosion of till.

<u>Stop 2-A</u>. North end of sand pits (Fig. 3C). This section described by Sirkin (1968) and redefined by Mills and Wells (1974) exhibits several meters of gravelly outwash at the base, a large thrust block of ice-shoved Cretaceous sands, clays and gravels, and unusually thick, bouldery layer of Roslyn till. The Cretaceous thrust block, one of several (Fig. 4), is about 15 meters thick with a gravelly zone of rotted quartz pebbles near the top. The basal thrust plane is marked by a thin purplish clay and occasional small folds. There is also a less obvious thrust plane within the Cretaceous which is noticed by an offset in the gravel zone. The brown silt that covers the cliffs just south of Stop 2-A is sediment from an old settling pond that was placed on the cliff to slow the erosion.

Proceeding to Stop 2-B, note another section similar to 2-A except with an incredible number of large boulders eroding from the Roslyn Till.

<u>Stop 2-B</u>. about 500 meters south of 2-A (Fig. 3 D). A prominent erosion pinnacle of thick Montauk (?) Till with ice-shoved Cretaceous draped over the top is the highlight of this stop. The till dips steeply and pinches out less than 100m to the north. To the south, it dips below thick talus and reappears at a lower elevation in the bluffs. The till then enters a large, almost 50m high fold, swelling in thickness in the synclines and pinching out over the crest of the anticline (Fig. 4). Rising at a steep angle on the south limb of the fold, the till is truncated by the flat lying Roslyn Till at the surface.

The Cretaceous thrust block draped over the till pinnacle thickens rapidly just to the south and then tapers to a long wedge and pinches out above the large fold. The northerly, butt end of another Cretaceous thrust block is in contact with the steeply rising Montauk (?) till on the south limb of the fold. Thick, deformed outwash units (early-Wisconsinan below and late-Wisconsinan above the Montauk (?) Till) complete the deposits seen in this section, except that presumably in place Cretaceous beds are exposed in the lower elevations of the mining pits.

Other features of note in this vicinity include: a spectacular boulder field with erratics collected from source areas as far away as the southern Adirondacks; numerous Cretaceous iron-oxide and pyrite concretions; a deformed Cretaceous clay and lignite, containing pollen of Raritan age (Sirkin, 1974a);many crystalline quartz ventifact cobbles located on the Cretaceous surface suggesting strong periglacial winds (Mills and Wells, 1974); and a cobble filled stream channel cut into the Cretaceous thrust block beneath the Roslyn Till, just to the left of the Montauk (?) Till pinnacle.

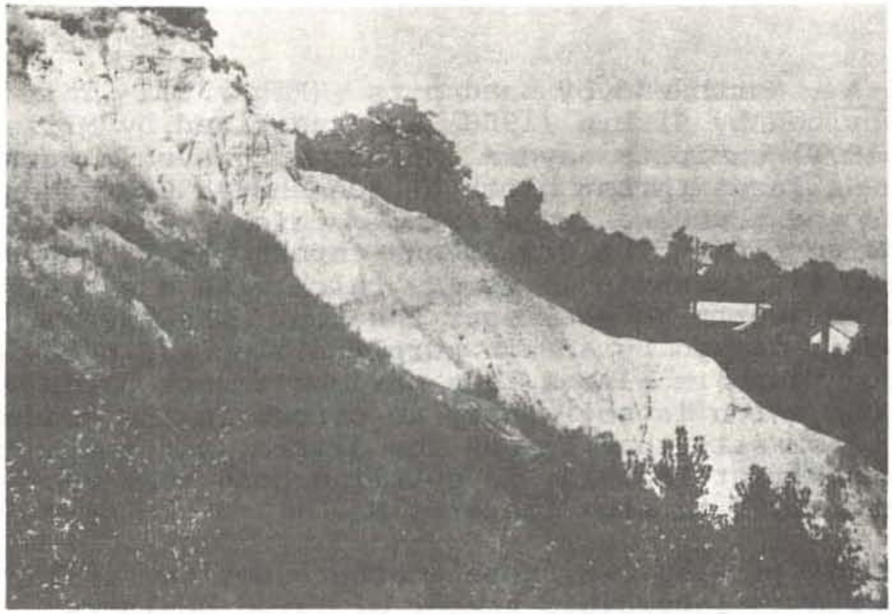

Figure 3C. P.W., Stop 2A - Late-Wisconsinan outwash at lower right corner is covered by about 15 meters of ice-shoved Cretaceous sand, clay, and pebbles. Thick (7-9m), bouldery Roslyn Till forms the resistant surface layer (upper left corner).

Figure 3D. P.W., Stop 2B - Large, eroded pinnacle of resistant Montauk (?) Till at right is partially covered by ice-shoved Cretaceous sediments seen as light area in cliff (center & left). Horizontal Roslyn Till (5m) caps the section.

Stop 3. Approximate mid-point of the sand pits, along the west wall, northwest of Stop 1. The section of peat, clay and oyster reef stacked in the late Wisconsinan drift has provided important new information on the late Pleistocene stratigraphy of Long Island. The dark layers in the cliff (Fig. 3E) are peat and clay layers. The structure of the section is similar to those already observed to the north. The beds have been recumbently folded and somewhat thrusted. The axes of the folds are nearly horizontal, and the peat and clay beds are often overthickened (doubled) or telescoped into greater thicknesses. The two main shell bearing horizons on the north side of the section represent the same unit with the underlying sequence overturned. Both have been folded into small synclines and are overthickened along the axes of the fold. They consist mainly of peat, marine clay, oyster reef, and thin interbedded till and outwash. A series of over 20 radiocarbon ages have been determined by Bob Stuckenrath of the Smithsonian Radiation Biology Laboratory. The dates represent a sampling of all of the units and of different materials from each layer including peat, shell and wood. The ages range from > 43,800 to 23,000 years B.P. and with the pollen data have made it possible to reconstruct the sequence of environments and vegetation during the mid-Wisconsinan interstadial and high stand of the sea. The brown peats lower in the section represent fresh and salt marsh deposits formed over 35,000 years ago in the western end of what is now Long Island Sound. These peats contain pollen of pine, spruce, birch, alder and nonarboreal pollen (NAP). These pollen spectra suggest boreal vegetation, like the northern needleleaf forest or taiga in northern Canada, and cold climatic conditions at the end of the early Wisconsinan glaciation. The shell beds, dated around 31,000 years B.P., contain pollen of pine, hickory, black gum, oak, birch, and minor hemlock and NAP. This assemblage indicates a much warmer climatic regime and a regional forest composed of pine, oak, and hickory. The black gum suggests a coastal setting. These sediments also contain foraminifera similar to those of the Sound today. Overall, the climate and vegetation are similar to the modern climate and vegetation in this area. Evidence of cooling is seen in the pollen from the peats and clays dated at 28,150 years B.P., found above the shell zones. These sediments contain pine, alder, birch, hemlock, oak, and NAP; the indicators of warm temperate conditions have dropped out of the record or are only minor elements. Within the next few hundred years rather cold climate developed in this region as seen in the pollen record. Pollen of pine, birch, spruce, and alder suggest a return to boreal forests and cold, moist conditions by 27,900 years B.P. This evidence heralds the onset of the late Wisconsinan glaciation. The last radiocarbon date in this sequence, an age of about 23,000 on spruce wood may be the maximum age for the arrival of the late Wisconsinan glacier on Long Island, and for the deformation of the interstadial and subsequent deposits.

Stop 4. Northerly facing bluffs at south end of pits (Fig. 3F). Although only 1 mile south of Stop 1, the section here appears markedly different. Instead of the two distinct tills of Billy Goat Hill, the Montauk (?) Till is represented by a series of thin tills interbedded with thin layers of orange, oxidized outwash. The Roslyn Till at the surface is much less pronounced here and in places may be absent completely. Fuller (1914) noted lateral changes in the Montauk (?) Till, and Mills and Wells (1974) found an orange outwash phase of this till at the north end of the sand pits. Facing the main section of slopes and looking eastward, the Montauk (?) shows a facies change from the thin interbedded till and outwash to a single thicker till with outwash above and below. Since this outcrop is located at the foot of the proximal slope of the Harbor Hill terminal moraine, we may be observing lateral facies changes associated with glacial deposition.

At the low outcrop near West Shore Road, a thin bedded deposit probably of lacustrine origin covers the Montauk (?) Till. The late-Wisconsinan drift is very thin with no till, and the section is capped with loess.

Part 2

Late Pleistocene Geology of Long Island

Evidence for deglaciation in the coastal bluffs at Target Rock National Wildlife Refuge, Lloyd Neck, N.Y.

Road Log Trip B-5 (Sunday, Nov. 2)

Optional P.M. trip - Target Rock National Wildlife Refuge

Drive south from last stop on West Shore Rd. pass under Roslyn viaduct and make first right turn onto Mott St. Drive up hill and bear around to right onto 25A eastbound. Stay on 25A for about 14 miles passing through the Village of Cold Spring Harbor. About 1 mile beyond the shopping district turn left onto West Neck Road.

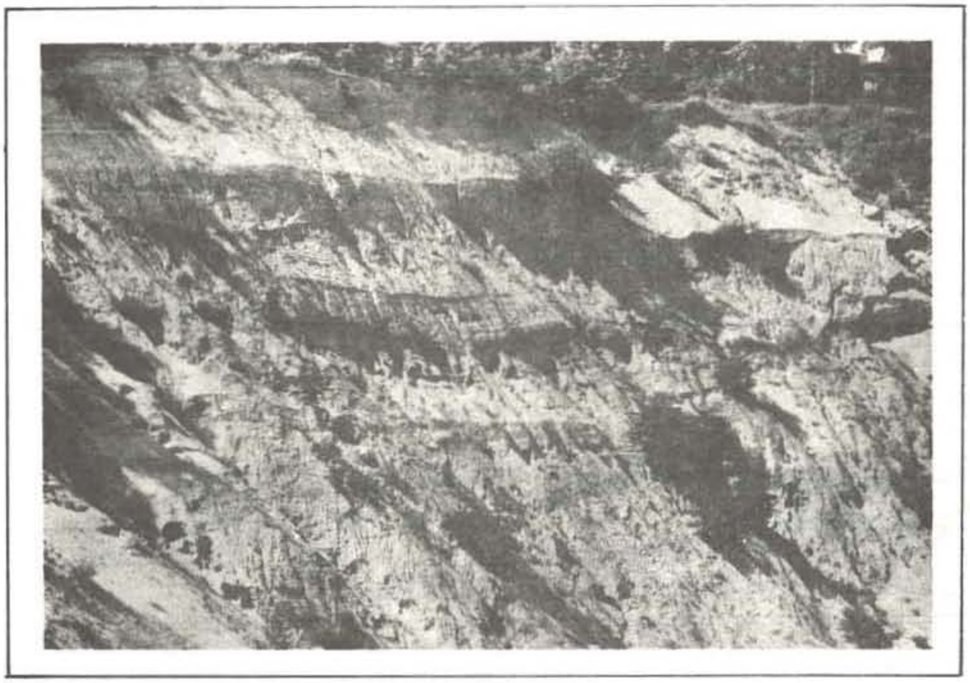

Figure 3E. P.W., Stop 3 - Three darker bands in cliff are recumbently folded, ice-thrusted layers of mid-Wisconsinan (interstadial) peat and clay. Middle layer is overturned, and folded outwash is noticeable above this layer. Oyster reef shells (indistinguishable) occur in middle and upper bands at extreme right of photo.

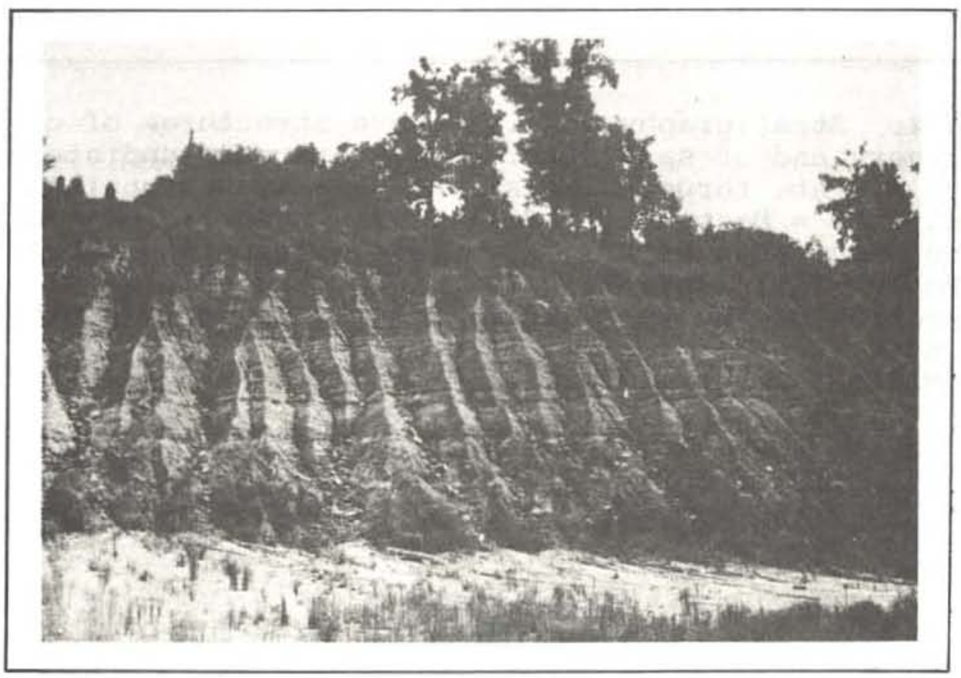

Figure 3F. P.W., Stop 4 - Eroded cliff on proximal slope of Harbor Hill terminal moraine showing the sequence of thin interbedded tills and outwash believed to be a facies of the Montauk (?) Till.

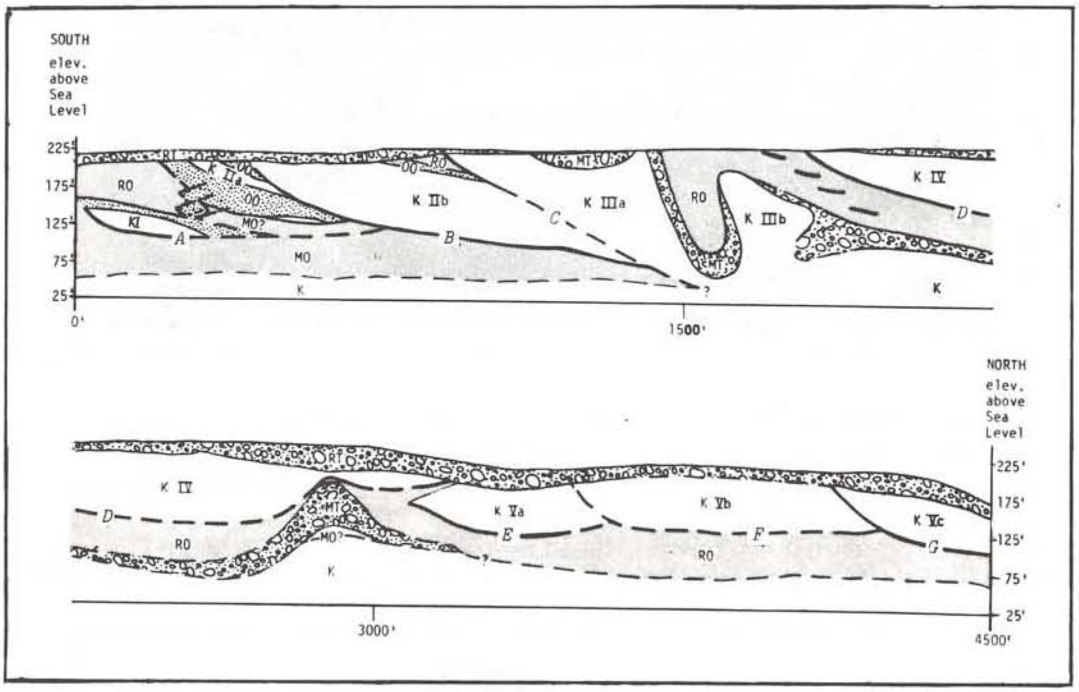

Figure 4. Stratigraphy and ice-shove structures of cliffs at northern end of sand pits. K = Cretaceous undisturbed; KI etc. = Cret. thrust blocks; MO = early-Wisconsinan outwash; MT = Montauk (?) Till (early Wisc.); OO = oxidized outwash phase of MT; RO = late-Wisconsinan outwash; RT = Roslyn Till (late-Wisc.). Field trip stop 2A at intersection of faults F and G; Stop 2B to left (south) of 3000' mark.
(From Mills & Wells, 1974).

(at St. Patrick's Church). Stay on West Neck Rd. to dead end on Lloyd's Neck (about 6 mi.). Entrance to Target Rock National Wildlife Refuge is at end of road. (total mileage approx. 20).

An interesting sequence of glacial and proglacial deposits may be observed in the one-half mile of northeasterly facing bluffs exposed along the eastern shore of Lloyd Neck.

The Neck itself seems to be separated from the mainland by a pronounced east-west channel, Lloyd Harbor. This channel probably formed as a drainage channel marginal to the ice during the "Ice stand on the Necks" (Sirkin, 1968, Connally and Sirkin, 1973).

Smaller east-west topographic lows may be drainage channels while topographic highs may represent ice marginal positions, both contributing to a sort of washboard effect. This is a prime location to study depositional and erosional features associated with the final sequence in the deglaciation of Long Island. This part of the excursion begins at the stairway to the beach and proceeds northwesterly along the shoreline of Huntington Bay.

Stop 1. About 100m northwest of the stairway. The cliff section reveals a sequence of outwash, till, outwash, and loess. At the base, from the level of the beach upward are approximately 5m of glacial outwash composed of stratified sand and gravel. A compact, brown till (a sandy loam with abundant cobbles and boulders) about 1m thick overlies the outwash. Above the till another unit of stratified sand and gravel (outwash?) forms a lens pinching out to the southeast and thickening to about 2m to the northwest. The height of the cliff diminishes southward as this unit pinches out. The section is capped by about 1m of loess. On the beach there is an abundance of cobbles and boulders. Diabase and purple-red puddingstone conglomerate erratics, along with till fabrics and other rock compositions suggest a northwesterly source area for the till. The diabase may be derived from the Palisades and the puddingstone from lower or middle Paleozoic conglomerates such as the Green Pond Conglomerate found near the New York-New Jersey border northwest of the Palisades.

Between Stops 1 and 2, cobbles begin to appear in the loess and the stratified unit above the till thickens and then thins until the loess is nearly resting on the till.

Stop 2. (Fig. 5A). At the actively slumped section in the topographic high in the bluffs. The increased elevation of the bluffs in due to the thickening to about 8m of the fine grained bedded sediments above the till. These stratified layers exhibit small scale cross bedding and bedding rippled by translational waves overturned to the southeast. This unit is characterized by clay, silt, and fine sand at the base which is somewhat obscured by slumping. It coarsens upward into fine and medium sized sand. Overall this unit probably represents sedimentation in a proglacial lake that formed between the ice just to the north and the upland to the south. Eastward across the bay in Eatons Neck, a well defined, horizontal band is visible in the bluffs. This dark layer also consists of proglacial lake sediment that overlies Cretaceous sand, but at a somewhat higher elevation than the lake beds at Lloyd Neck. The proglacial lake deposits are seen as evidence of the "Necks" stillstand during the recession of the late Wisconsinan glacier. A marked increase in cobbles in the loess layer and a thin stone layer on the stratified sands also appears in this section. Between Stops 2 and 3 the elevation of the bluffs decreases and the lake sequence becomes thinner. Also, the dark silty base of the lake deposits becomes visible and minor deformational features begin to appear in the overlying sediments. The surface unit has coarsened and also shows evidence of deformation, mainly small thrusts displaced southward. At one point a sizable granitic boulder in this unit has been rotated to the southeast. This evidence suggests southeastward movement of ice that overrode and deformed this section. On the beach a number of predominantly dark colored erratics of mafic composition have been eroded from the till. Some of these rocks resemble the Harrison Gneiss found to the north and northwest in southern Westchester and Connecticut.

Stop 3. This stop is separated into two parts, 3A and 3B. Stop 3A (Fig. 5B) is in the low cliff where well exposed lake silts may be observed. Here the basal unit of interbedded, fine grained silts and sands are well exposed. These beds are somewhat disturbed and have small folds that are overturned to the southeast, and represent additional evidence of minor glacial deformation due to overriding by the ice.

Stop 3B is just to the northwest of Stop 3A. The lake beds pinch out between these stops and the coarsened cobble unit rests directly on the compact (lodgement?) till. The rapidly changing nature of the upper unit is apparently the result of changing levels of energy of nearby ice and meltwater from the ice. It may have been emplaced as a till or ground moraine or as a head of outwash. Alternatively, this layer could be a colluvium or a lag deposit developed after the ice receded. Thus this unit seems to exhibit a combination of glacial, glacio-fluvial, or postglacial erosional characteristics. Clearly, deposition occurred near

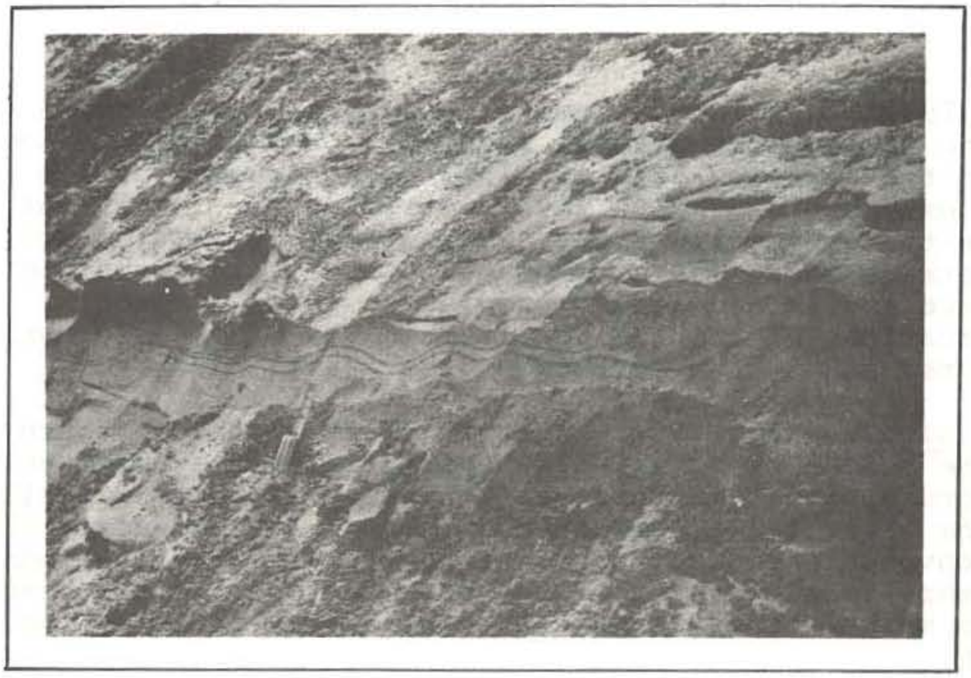

Figure 5A. Target Rock, Stop 2 - Small translational ripples, overturned to southeast, in fine proglacial lake sands.

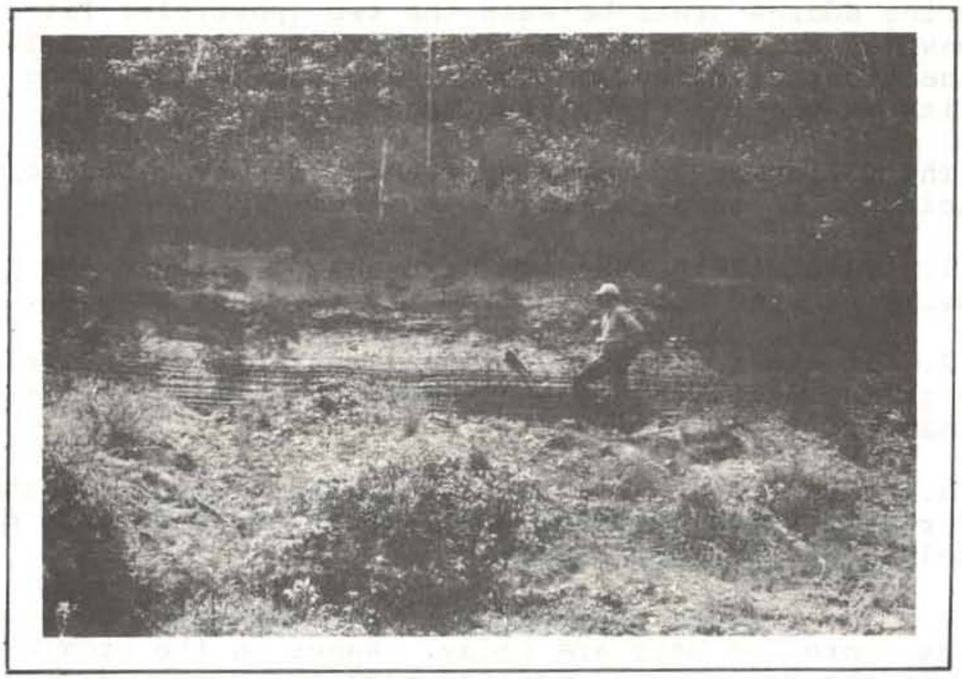

Figure 5B. T.R., Stop 3A - Thinly interbedded silts and fine sands form the basal unit of the proglaical lake deposit seen below the shovel. Slight disturbance of these beds (due to glacial overriding?) occurs at the contact with the cobbly upper unit (see text).

the glacial margin and some glacial overriding is indicated in the minor deformational features. When the ice stood along the northern edge of Lloyd Neck, tongues of ice may have extended southward into Huntington Bay. Till was deposited at the ice front, and outwash, colluvium and lacustrine sediments accumulated on the upland south of the ice and in and around proglacial lakes. Minor fluctuations of the ice resulted in the minor deformational features and in the sorting of the gravel layer.

Stop 4. (Fig. 5C). The low cliff at the northern point of the beach. The till-like character of the upper unit is more apparent in this section where it rests directly on the lower till. Pronounced thrusts and complex folds or convolutions occur along the contact between the beds. The more felsic nature of the erratics seen on the beach is in marked contrast to the rocks on the beach to the south.

This upper till is of limited extent and seems to grade southward into proglacial deposits. It was probably deposited during the "Necks" stillstand, with a different source area than the underlying till. While correlation with other local tills has not been resolved, the lower till at Lloyd Neck may be the equivalent of the upper or late Wisconsinan till (the Roslyn Till) in Port Washington. The differing source areas between the two (possible) late Wisconsinan tills may be due to their interlobate position and the stacking of Hudson Valley and Connecticut lobe deposits as the ice front fluctuated.

The following sequence of events is postulated for deglaciation in this region.

1. Late Wisconsinan ice downwasted, thinned and gradually receded northward from the terminal moraine.

2. As the ice receded minor lineations of surficial deposits and meltwater channels developed, marking ice marginal positions.

3. When the ice reached the northern margin of the necks, a major stillstand occurred. Meltwater cut east-west drainage channels such as Lloyd Harbor.

4. Ice tongues expanded into and excavated U-shaped valleys where the bays are today. Kames on the proximal slope of the Harbor Hill moraine mark the southward extent of this readvance.

5. As the ice receded, proglacial sediments, outwash and

Figure 5C. T.R., Stop 4 - Contact between upper and lower tills shows complex convoluations caused by the emplacement of the localized upper till during the "Ice stand on the Necks". Lower till is lighter in color but contains more dark erratics, it is also more indurated.

colluvium were deposited. Lacustrine sediments accumulated in proglacial lakes dammed between the ice and the upland. Minor fluctuation of the ice deformed these sediments but on a much smaller scale than the deformation observed at Port Washington which was related to the main advance of the Late Wisconsinan glacier.

6. Recession of the ice from the "Necks" position formed other minor lineations observed in the position of small islands of glacial deposits in the Sound and minor moraines in Westchester and Connecticut.

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