THE LATE QUATERNARY GEOLOGY OF THE MONTAUK PENINSULA: MONTAUK POINT TO SOUTHAMPTON, LONG ISLAND, NEW YORK

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ABSTRACT

The Montauk Peninsula is composed of several glacial, periglacial and interglacial units including the Gardiners Clay(?), Montauk Till Member of Manhasset Formation, late Wisconsin drift, and loess. The stratigraphy of these units is complicated by large-scale glacial tectonic structures. The occurrence of two or more drifts in several localities suggests that this area underwent multiple glaciations and that the morainal features may, in part, be diachronous. The surface of much of the late Wisconsin drift is mantled by aeolian sediments that closely resemble loess. Accumulation of the loess is believed to have occurred under true periglacial conditions which created thermokarst features such as the Scuttlehole depression.

INTRODUCTION

Long Island is long and narrow, reaching east-northeastward from New York City to form a fishlike eastward extension of New York State. The island lies south of and is approximately parallel to the Connecticut shore and is separated from it by Long Island Sound. Long Island also forms a north shore of that ocean reentrant known as the "New York Bight".

Although part of the Atlantic Coastal Plain physiographic province, Long Island features a topography almost completely modified by glacial, proglacial, and periglacial processes. Two conspicuous terminal moraines extend almost continuously along the length of the island. The Harbor Hill Drift traverses the northern length of the island. The Ronkonkoma Drift traverses the central length and constitutes a major part of the south fork. The island abounds in other glacial and proglacial features, such as the coalescing outwash fans and aprons that form much of the southern part of the island.

THE MONTAUK PENINSULA

The Montauk Peninsula, as here defined, extends east from the Shinnecock Canal to Montauk Point (figure 1). All trip stops and geographic localities mentioned in the text are located on figures 2 and 3. The Shinnecock Hills, just east of the Shinnecock Canal, are part of the morainal complex of the Ronkonkoma Drift and are the west end of a ridge of coalescing hills traversing the area from west to east. The knob and kettle topography of the

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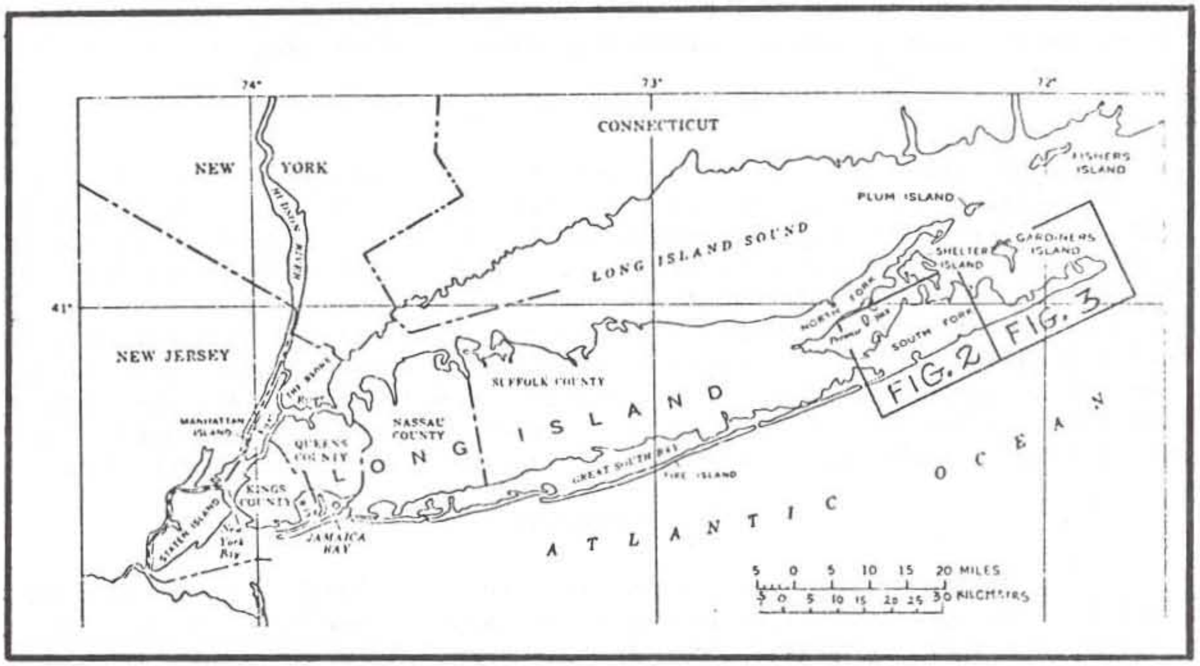

Figure 1. Location of study area and general geographic features of Long Island, N. Y. (Modified after Franke and McClymonds, 1972.)

Ronkonkoma Drift strikes northeast from a point north of the village of Southampton, arcs toward the east, north of Bridgehampton village, and finally strikes southeast, north and northeast of the village of Easthampton. This morainal segment abruptly terminates at the Bluff Road sea cliff. The terminal moraine reappears once again 4 miles east-northeast of Beach Hampton, at Hither Hills, where it strikes northeast and terminates once again at Fort Pond Bay. Another segment of knob and kettle morainal topography occurs between Fort Pond Bay and Lake Montauk. A final segment of morainal topography is found around Prospect Hill, northeast of Lake Montauk. East of Montauk Village and generally south of Route 27 (figure 4) the topography is relatively subdued. The south coast is fronted by bluffs up to 80 feet high, and the south-southwest trend of the south shore of Long Island is lost. Distinct kettles are relatively rare, although bogs are not uncommon.

The Ronkonkoma Drift forms the "backbone" of the Montauk Peninsula. It is as much as 3 miles (4.8 km) in width and achieves a local relief of more than 100 ft (30.5 m) in some places. A maximum elevation of more than 280 ft (85.3 m) is reached about 3 miles (4.8 km) northwest of Bridgehampton.

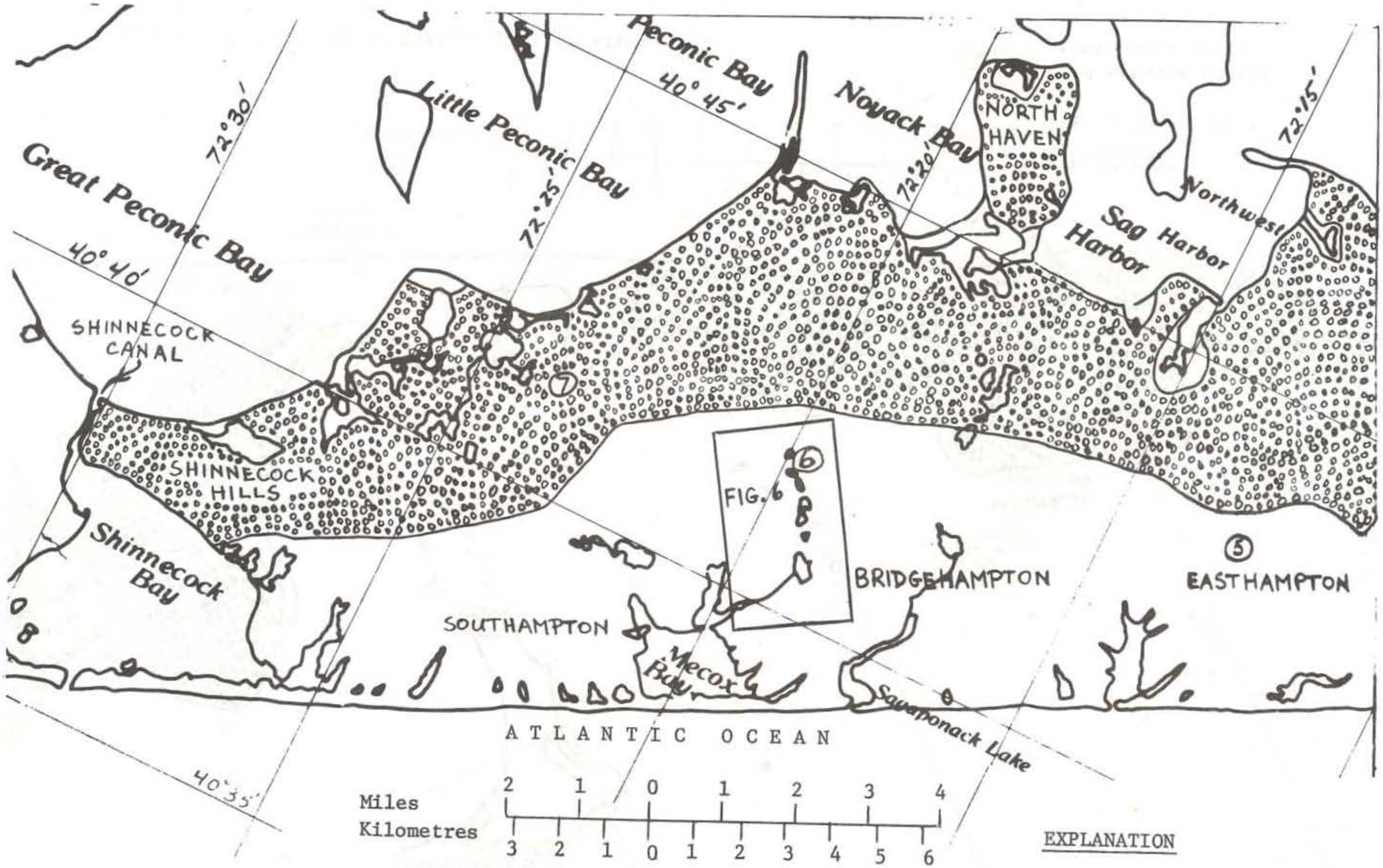

Figure 2. Outline map of western part of study area.

EXPLANATION

6 Field Trip Stop

End moraine of the Ronkonkoma Drift

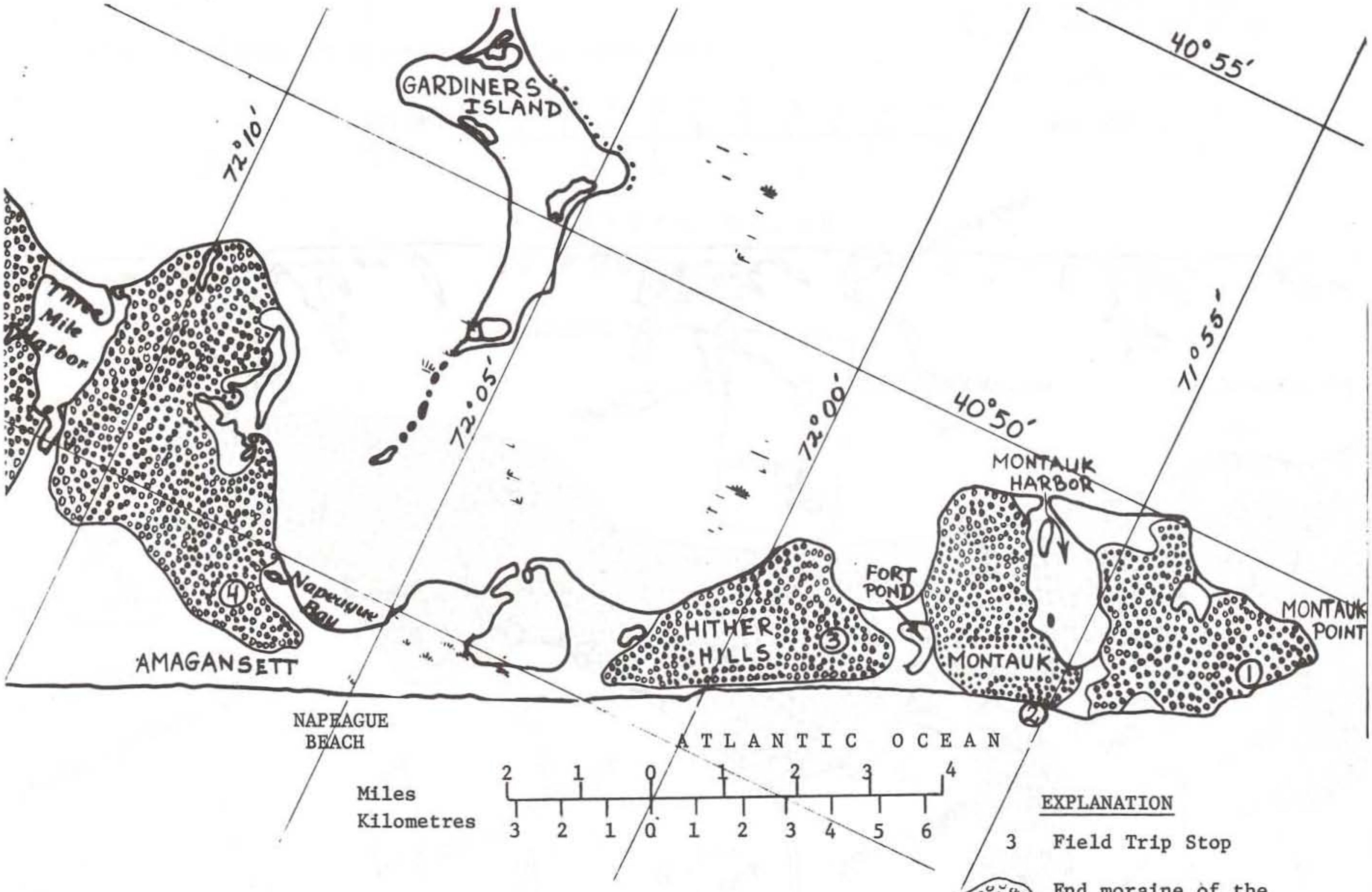

Figure 3. Outline map of eastern part of study area.

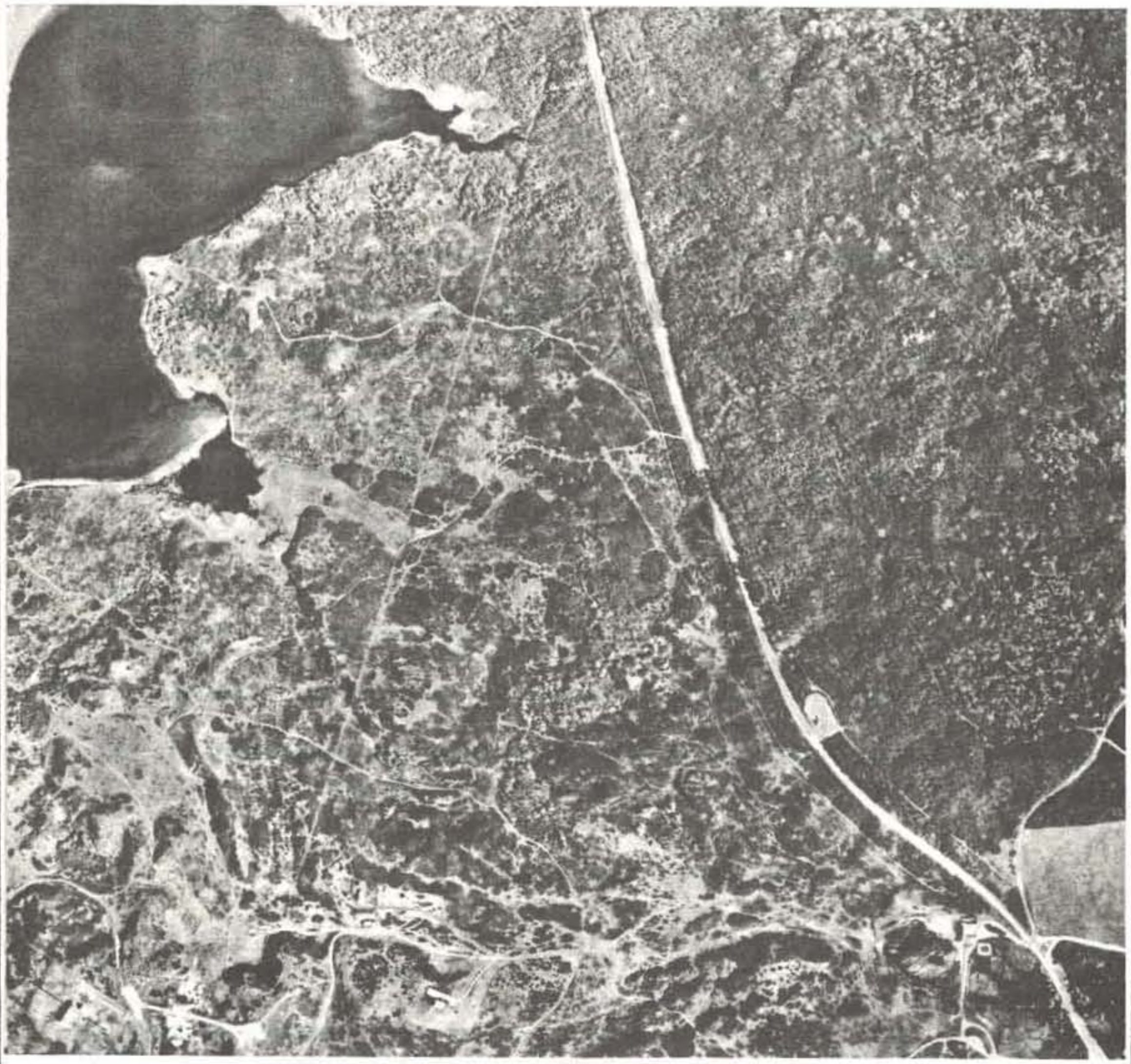

Figure 4. Aerial photograph illustrating changes in morainal topography along route 27, east of Montauk Village. Note conspicuous and relatively fresh ice contact deposits north of Route 27 which contrasts with the more subdued topography mantled by loess to the south.

Although traceable across the study area, the moraine should not be thought of as a stratigraphic unit. At several of our field stops, the moraine seems to be a composite feature that is composed of many different materials, often possessing a wide variety of structural relationships and probably originating at different times.

An outwash plain, generally consisting of coalescing alluvial fans, abuts the south edge of the Ronkonkoma Drift. The plain is nearly 5 miles (8.1 km) wide in the vicinity of Bridgehampton and narrows to a feather-edge both to the west-southwest and east-northeast of that village. In the vicinity of Bridgehampton, the outwash plain appears to be a large alluvial fan whose head is located at the lake-studded defile through the terminal moraine south of Sag Harbor. The maximum sill elevation of this defile is about 30 ft (9.1 m) above mean sea level. The village of Easthampton is located on a smaller alluvial fan, which heads in a defile south of Threemile Harbor. The maximum sill elevation here is also about 30 ft (9.1 m). The west end of the outwash plain terminates at Shinnecock Bay; the east end is cut off abruptly at Bluff Road in Beach Hampton. Farther east, there is no feature equivalent to the outwash plain.

The glacial drift that constitutes most of the Montauk Peninsula has been extensively modified by littoral and aeolian processes. East of Montauk Village, steep wave-cut bluffs rise abruptly from 30 to 80 ft (9.1 to 24.4 m) above the narrow boulder-strewn beaches. Fronting the ocean, from the village westward, are increasingly wide sandy beaches; from Montauk Village west to Easthampton, a wide beach is backed by a dune field, which has, in places, covered a fossil wave-cut cliff (see Bluff Road) onto the outwash plain to the north. From Easthampton west, the shoreline consists of fringing beaches at the distal edge of the outwash plain and several baymouth beaches. Along the north shore, littoral spits, baymouth beaches, and tombolos are common. Coastal sand dunes, which have migrated inland to distances up to 1.5 miles (2.4 km) cover much of the area directly behind the south-shore beaches from Hither Hills west to Southampton.

QUATERNARY STRATIGRAPHY

Fuller's (1914) mapping and description of eastern Long Island's Quaternary terrane is largely unassailable, although his interpretation of the areal geologic history requires extensive revision. Fuller recognized and described the deformation of Pleistocene and older strata in many exposures on Long Island. However, it remained for Mills and Wells (1974) to document the profound role that glacial tectonics has played in complicating the island's stratigraphy. Mills and Wells found that glacial movement onto Long Island caused large-scale thrust faulting and folding of Cretaceous and Pleistocene strata; for example, the transport of detached blocks of Cretaceous sediment over Pleistocene deposits in northwestern Nassau County (see trip B5).

Indeed, klippe and imbricate stacking of strata appear pervasive in much of the Montauk Peninsula (stops 1, 2 and 3) (figure 5). Glacial tectonics were responsible for most of the Pleistocene stratigraphic disagreements encountered in the geological literature concerning Long Island. With the recognition of the stratigraphic confusion caused by glacial tectonics, the stratigraphic sequences encountered in the field become more explicable, permitting some simplification of Long Island's Pleistocene stratigraphy.

The Gardiners Clay Problem

"The Gardiners Clay derives its name from Gardiners Island... on which several clay beds with included sands are well exposed at a number of points" (Fuller, 1914, p. 92). Fuller specifically restricted the term to interglacial clays. In western Long Island, the Gardiners Clay is consistently encountered under the south coast at depths of 50 or more ft (15.2 m) below sea level. It yields marine and brackish-water fossils similar to forms presently living along the Long Island littoral. According to Fuller (1914, p. 105-106), two localities on Gardiners Island contained fossils: (1) a locality just east of Cherry Hill Point, and (2) another unspecified locality. MacClintock and Richards (1936) visited the Cherry Hill Point locality and confirmed the presence of an interglacial fauna. However, de Laguna, in Suter and others (1949), although confirming the previous findings by MacClintock and Richards, found that the Gardiners Clay on Gardiners Island is, in large part, varved and therefore is probably lacustrine rather than marine in origin. Upson (1966) reported that many of the silt and clay exposures along the eastern part of the north shore of Long Island are lacustrine rather than marine in origin and believes they are glacial rather than interglacial. Further compounding the "Gardiners Clay Problem", was the discovery of another fossiliferous marine deposit of greenish-gray silt and clay above the Gardiners Clay under the southwestern shore of Long Island. Called the "20-foot" clay by Perlmutter, Geraghty and Upson (1959), this unit appears interbedded with outwash of Wisconsin age, is 5 to 20 ft (1.5 m) thick in most places, and its top is generally at about 20 ft (6.1 m) below mean sea level. Its fauna is similar to that of the Gardiners Clay.

Upson (1970) while mapping the Mattituck Quadrangle northeast of Riverhead, Long Island, recognized the three-fold nature of the problem.

> "As seen by this writer (Upson, 1970, p. B158), the typical Gardiners is tough clay in massive beds 10 or more feet thick and is nearly always deformed, with distortions ranging from broad folds to minute contortions. The clay is nearly always overlain by the Jacob Sand through a transitional phase; that is, where the sequence is well exposed, the Gardiners Clay becomes less tough in the upper part and is laminated with seams of fine sand and silt. Upward these seams become thicker and coarser, and the clay laminae become thinner and farther apart until the whole inter-laminated zone gives way to massive, or finely bedded fine to medium sand. This is the Jacob Sand."

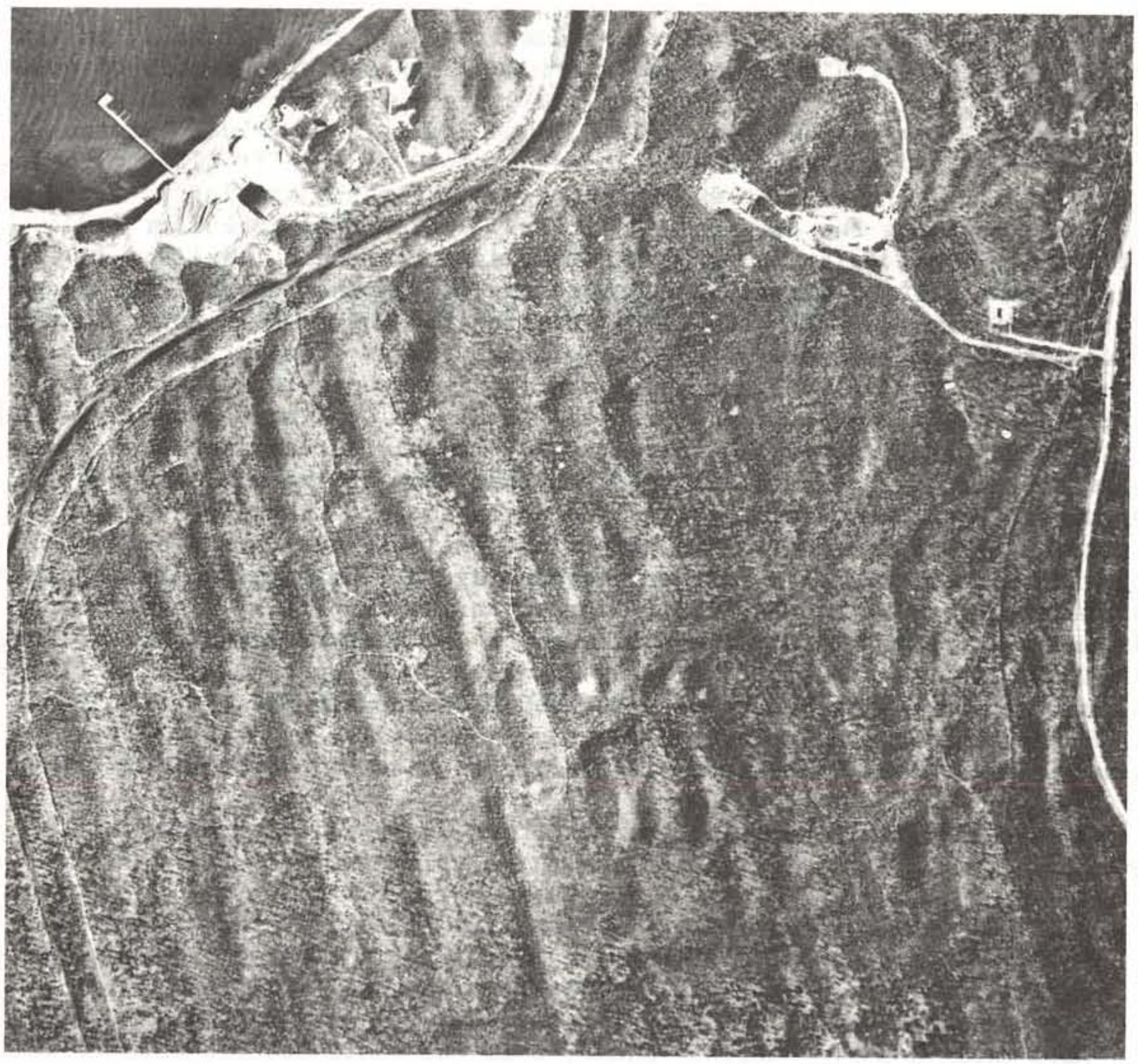

Figure 5. Aerial photograph illustrating the push moraine topography in the area of the Montauk sanitary landfill site.

Upson (op. cit.) further observes:

> "The overall stratigraphic sequence exposed in the cliffs of the Mattituck quadrangle and the eastern part of the adjoining Riverhead quadrangle consists from bottom to top of (1) dark, ordinarily red clay, ordinarily near the bottom of the exposures and visible only in places, (2) fine to medium, massive to faintly stratified sand and silt, gray or faintly yellowish, to faintly stratified sand and silt, gray to faintly yellowish, and characterized by more or less abundant white mica in tiny flakes, (3) thick and rather uniform coarse sand and pebble gravel, light gray to yellowish, and (4) compact gray till. The clay grades upward through interlamination with the fine sand and silt, these two representing the Gardiners Clay and Jacob Sand. Bedding of both these units is distorted to a greater or lesser degree. Except where strongly distorted the sand and silt pass upward through a gradual transition into the coarse sand and gravel. This unit is most conspicuous in the higher cliffs, where it is several tens of feet thick, and represents the Herod Gravel of Fuller. The overlying till is the Montauk Till of Fuller (1914, pl. I). The contact is sharp at some places and gradational at others. Some still younger deposits, present locally, are thought to represent the Harbor Hill Moraine and post-Harbor Hill outwash, but these are not discussed here."

Upson's Mattituck-Quadrangle stratigraphic sequence is remarkably similar to the sequence encountered in the southshore cliffs of the Montauk Peninsula east of Montauk village (stop 1). Upson (op. cit.) believes that:

> "In the Mattituck quadrangle the sequence indicates glacial conditions. The few pebbles of appreciable size occurring randomly in both the clay and the fine sand suggest ice rafting. The overall sequence is clearly a transitional one culminating in till, and in general the grain size increases upward...In the large cliff about a quarter of a mile from the northern edge of the quadrangle, the clay clearly interfingers with the sand and gravel that lies beneath the Montauk Till."

Although the laminated silts and clays exposed in the south shore bluffs of the Montauk Peninsula are clearly proglacial lacustrine deposits, at least one exposure of fossiliferous marine Gardiners Clay has been found in the area. Fuller (op. cit.) found a large block of allochthonous fossiliferous Gardiners Clay in the Ronkonkoma Drift north of Bridgehampton. The fauna was analyzed in detail by Gustavson (1972). He reported the occurrence of two foraminifers, one coelenterate, three bryozoans, and twenty-five molluscan species, five of which mollusks are restricted to more southerly waters. Gustavson (1972) concluded that the presence of a warm-water fauna suggests that deposition of the Gardiners Clay took place probably during the Sangamon Interglaciation, and that the climate at that time was slightly warmer than at present.

The authors sampled the "Gardiners Clay" at Montauk Point and examined it for microfossils. Although most samples were devoid of microfossils, several samples did contain lean assemblages of cool Pleistocene flora including Pinus (pine), Picea (spruce), and Betula (birch) as well as reworked Cretaceous and Tertiary spores and pollen. The small number of pollen grains suggest that they were transported into the depositional site by wind and glacial meltwaters. The contrast between Gustavson's locality at Bridgehampton and the Montauk site suggests that the "Gardiners Clay" represents a diachronous diversity of depositional environments.

The Problem of the Montauk Till Member of the Manhasset Formation

In his attempt to fit Long Island stratigraphy into the classical fourfold divisions of the American mid-west, Fuller (1914) assigned the Montauk Till Member of the Manhasset Formation to be Illinoian in age. Fuller's assignment has long since been corrected by MacClintock and Richards (1936). Nevertheless, the distinctive banding and lamination of compactness of the Montauk Till Member in its type area near Montauk Point (stop 1) led both Woodworth and Wigglesworth (1934) and Kaye (1964) to correlate tills of similar aspect, which they encountered on Martha's Vineyard with the Montauk Till Member of Long Island. The distinctive fabric of the Montauk Member is exposed in the coastal bluffs of the south shore east of Montauk Village and at one locality in the Port Washington sand pits of northwestern Long Island. Newman and others (1968) erroneously assigned the Montauk Member to the Ronkonkoma Stade of Wisconsin age. It is clear at stop 1 that a younger till overlies the type Montauk Till Member since a radiocarbon dated log found between these tills indicates that the Montauk Member is pre-Woodfordian in age.

Perlmutter and DeLuca (1963) investigated the Pleistocene stratigraphy of the Montauk Air Force Station (stop 1). Borings in the area disclosed a lower unit of stratified drift composed of nonmarine grayish-brown medium to coarse sand and gravel and some thin lenses of clay and silt. Perlmutter and DeLuca (op. cit., p. B11) found:

> "Immediately above the lower unit of stratified drift is an undifferentiated unit of varied lithology composed of interbedded deposits of till and stratified drift about 30 to 100 feet thick...the lower 20 to 40 feet of the undifferentiated deposits consists of interbedded gray and brown clay, laminated green and gray silt and clay, and some lenses of fine brown sand."

The latter sequence resembles the proglacial Gardiners Clay-Jacob Sand sequence of Upson (1970). Perlmutter and DeLuca (op. cit., p. B11-B12) continue:

> "The middle part of the undifferentiated deposits is probably composed largely of gray and brown compact clay and gravelly till, which grades laterally into fine-grained stratified drift in some places. Immediately above the compact till (read "Montauk Till Member") is generally stratified drift, which ranges in thickness from a featheredge to about 30 feet and is composed chiefly of beds and lenses of brown and gray silt, fine to medium sand, and clayey sand. The upper-

most part of the undifferentiated unit is generally a loose brown clayey till, about 5 to 20 feet thick, which contains some boulders. In some outcrops the intervening stratified drift is missing, and the upper till apparently rests directly on the lower till."

Robert Matarese, then an undergraduate geology student at Queens College, discovered a one-foot thick peaty silt lense between the two tills at stop 1. The lens contained wood, which yielded a C-14 date of 38,800 + 5600/-3200 years B.P. (sample no. RL-318). Mary Whiting Goldberg, currently a graduate student at Queens College, found a boreal pollen spectrum in the silt adhering to the wood, whereas silt above and below the wood showed largely N.A.P. spectra. The lens appears to represent a mid-Wisconsin interstade and suggests the Montauk Till Member to be pre-late Wisconsin. If this is a correct evaluation, earlier Wisconsin Glaciation was as extensive as in the late Wisconsin Glaciation along this segment of the Laurentian ice front.

The Montauk Till Member is commonly exposed in the sea bluffs along the south shore east of Montauk Village. Although the Montauk Member is usually mantled by younger drift, the latter sediment is mostly thin, and the morainal topography south of Route 27 east of Montauk Village appears distinctly more mature, as compared to the relatively fresh appearance of the late Wisconsin Drift north of Route 27.

Late Wisconsin Drift

As noted earlier, the Ronkonkoma Drift extends as a terminal moraine ridge almost completely across the area. The moraine is best described as a series of coalescing kames composed of foreset beds of sand and some gravel. Surficial till is relatively inconspicuous, although, occasionally, massive lenses and layers of till are encountered in the moraine at depth. Some of the till appears to resemble flowtill (stop 4). Exposures in the moraine frequently reveal folds and faults due to some combination of glacial tectonics and slumping. Although we, as yet, have no absolute date, the undissected terrain suggests to us that most of the Ronkonkoma Drift in the area is late Wisconsin in age.

The outwash plain between Southampton and Amagansett slopes gently south-southeast at approximately 20 ft/mi. (6.1 m/km). Near the Atlantic shore, the outwash plain is truncated by wave erosion and the prevailing westerly longshore drift. In its northern reaches the outwash plain grades into the moraine of the Ronkonkoma Drift, neither feature being dissected to any great degree. The moraine and outwash plain appear to be intimately linked and probably coeval in origin. Large parts of the outwash plain in this area are covered by loess.

The problem of loess

Late-glacial aeolian activity has been reported from the New England-Long Island area (de Laguna 1963, Schafer and Hartshorn 1965, Hartshorn 1967). A late-glacial loess was first reported from the eastern Montauk Peninsula by Newman and others (1968). Further field work and laboratory analysis by Nieter (1975) confirmed the occurrence of loess, and its distribution and thickness in the western Montauk Peninsula (Shinnecock Canal to Amagansett) was mapped. Scanning electron microscopy of the silt and sand components and grain-size analyses of the samples showed marked similarities between the deposits on eastern Long Island with the classic loess of Europe and the midwestern United States.

The loess on the Montauk Peninsula is best developed south of the terminal moraine of the Ronkonkoma Drift on the outwash plain between Southampton and Easthampton, where it extends from the moraine to the Atlantic shore. Discontinuous patches of similar loess are known from the eastern Montauk Peninsula but their relationships to the western loess are unclear. The deposits are similar in appearance over widely separated areas and cover the last glacial outwash in blanketlike fashion. Thickness of the loess ranges from about 7 ft (2.1 m) near Easthampton to less than 2 ft (.6 m) near Southampton. Light colors predominate, most commonly beige and white where it is thicker and olive green where it is thinner. Texturally, the deposits are coarse silt with minor admixtures of fine sand and fine silt. The contact between the loess and the glacial outwash below is interpreted by the authors as being erosional. A lag-gravel concentrate is usually found at the contact and seems to represent a very widespread episode of deflation prior to the deposition of the loess. Gravel clasts in this layer commonly show evidence of strong aeolian abrasion. Many of the clasts are highly polished and etched ventifacts, but true dreikanter forms are only rarely developed.

Over large areas on the Montauk Peninsula the loess and the soils developed on them are the youngest significant geologic deposits and form the surficial materials for approximately 40 mi^2 (103.6 km^2). However, in the Easthampton area parts of the loess have been buried by a later aeolian deposit of dune sand (stop 5). The dune sand is discontinuous but can be traced on the surface and also on topographic maps and aerial photographs into the dunes that are now developing behind the fringing beaches on the south shore. To the west of Easthampton, the dune forms have been blown inland some 2 miles (3.2 km) and are now stabilized by mature forests and thin soil.

The authors tentatively conclude that, after a period of aeolian deflation, the loess was deposited on the outwash plain in blanketlike fashion. The deposition occurred shortly after the last glacial retreat from the area, possibly under a true periglacial regime, but certainly before the area was stabilized by vegetation. Although not conclusive, changes in the grain size and thickness of the deposit indicate a northerly or easterly source area.

The Scuttlehole depression - evidence of former periglacial activity?

The Scuttlehole depression is a large topographic feature on the outwash plain in the central part of the Sag Harbor Quadrangle (see figure 6). The depression is actually a series of semi-isolated basins approximately 2 mi (3.2 km) in total length and has a marked linearity trending N25°W, almost

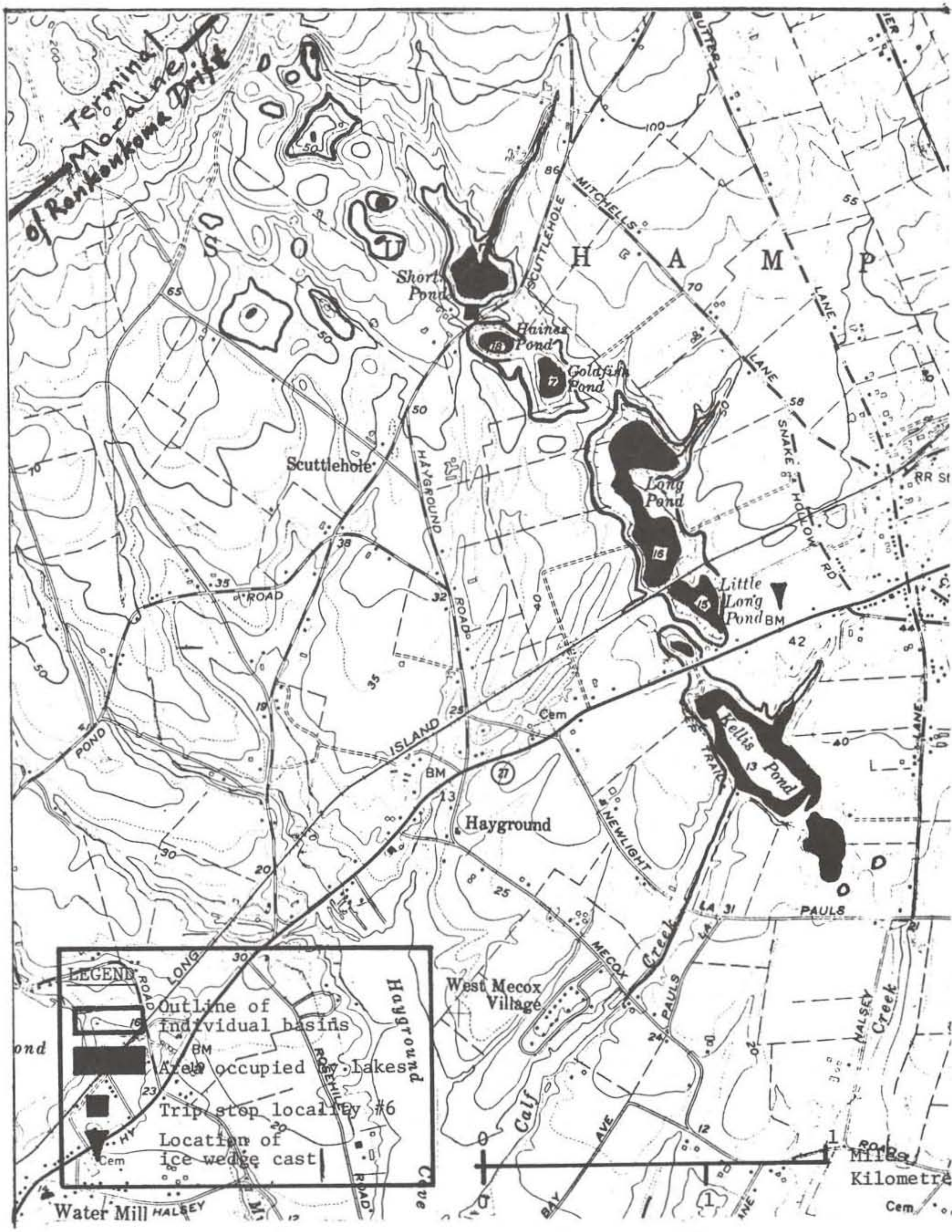

Figure 6. Detail of Sag Harbor quadrangle topographic map showing location of the Scuttlehole depression.

perpendicular to the terminal moraine of the Ronkonkoma Drift. The depression heads near the terminal moraine, where individual basins are small and elliptical in outline. As it extends to the southeast, the depression is larger, and the basins are irregular to elliptical in outline. The bottoms of many of the basins are flat, and several contain lakes, the largest being Kellis, Long, and Little Long Ponds. Although through-flowing drainage does not presently exist, a slight increase in the level of the water table would initiate a through-flowing drainage system from lake to lake; i.e. a beaded drainage course.

Fuller (1914, p. 42-43) discussed the Scuttlehole depression and its topographic expression and attributed its origin to the burial of stagnant glacial ice, which had filled a pre-existing valley. This hypothesis requires that glacial ice somehow moved past the Ronkonkoma Drift for at least 2.5 mi (4 km) onto the outwash plain. There is no obvious evidence of this event as, for example, erratics, ice-contact deposits, or ground moraine. On this basis alone, Fuller's hypothesis of origin appears doubtful. Fuller carefully noted, however (p. 43), that there exists on Long Island a large number of depressions for which glacial ice is obviously not the answer. In fact they were inexplicable at that time to quote (Fuller, 1914, p. 44). "and it may be that they (kettles of doubtful origin) have resulted from some unknown peculiarity of deposition."

In recent years research in the high latitudes has revealed an entire suite of features that would most certainly qualify as "peculiarities of deposition". A number of these features can be referred to by the term "thermokarst", which is applicable to topographic depressions that result from the formation and subsequent thawing of ground ice. Thermokarst features commonly range in size from small ice wedges up to several feet across, to collapsed pingos up to several tens of feet across, to thaw lakes and alas valleys in which collapse features are so numerous that they coalesce and dominate the topography. The large thermokarst features called alas valleys commonly range in size from 0.06 to 9 mi (.1 to 15 km) in length and are 10 to 130 ft (3 to 40 m) deep. They are characterized by beaded drainage systems of pools and channels that are straight or consist of series of straight segments separated by angular bends. Individual depressions are usually oval in outline and have flat floors and steep sides, and many of them contain lakes. Association with small-scale features such as ice wedges and polygons is common (Czudek and Demek 1970, Washburn 1973).

On the eastern rim of the Scuttlehole depression, about 330 ft (100 m) from the edge, a single relict ice-wedge cast was observed in an excavation during the summer of 1972. The wedge cast occurred in the uppermost glacial outwash and had been filled in with loess that had drifted in from above. The wedge itself was not a large feature, measuring 32 cm (13 in) in width and 90 cm (35 in) in depth. The presence of an ice-wedge cast marginal to the Scuttlehole depression implies that, for at least a short time, the area was subjected to a permafrost regime. Such structures in the present day periglacial regions are created in places where the mean annual air temperatures range from -6 to -8 C°, Pewe (1966).

In addition numerous "floating" pebbles, some highly polished by aeolian abrasion, are found in the loess that covers the depression. These pebbles are much too large to have been entrained and transported by wind action. They were probably lifted to their present location by frost heaving (cryoturbation) from the lag-gravel-concentrate layer below.

Although the evidence is not conclusive, the presence of the Scuttlehole depression on the outwash plain, its oriented nature, its straight beaded drainage course, the size and shape of the individual basins, and its close association with periglacial phenomena, suggest that this feature originated from the formation and degradation of ground ice (thermokarst).

HOLOCENE SHORELINE MODIFICATION

The shoreline-configuration of the Montauk Peninsula has undergone significant change in Holocene time. Krinsley and others (1964) and Newman and others (1968) noted that the headlands of the Montauk Peninsula have been eroded and truncated by wave and littoral processes, and the derived sediments have generally moved westward. As the littoral sand moved westward, a narrow beach formed, abutting the headlands for several miles to the south and east, and has been eroded back to its present location because of its exposure to the ocean.

The postglacial marine transgression drowned swales in the Ronkonkoma Drift moraine, separating parts of the peninsula into a series of islands in mid-Holocene time, some 2000 to 6000 years ago. Presumably, Orient Point, on Long Island's north Fork, is a modern analogue of the ancestral Montauk archipelago. The Hither Hills area and the region east of Montauk Village presumably were islands separated from the Easthampton area. An additional strait may have trended north at Ditch Plains. Bluff erosion and longshore drift converted the archipelago into a peninsula by means of single and double tombolo construction during later Holocene time.

The conspicuous gap in the terminal moraine of the Ronkonkoma Drift in the vicinity of Napeague Beach has been filled principally with sand derived from the high bluffs to the east (Taney, 1961; Krinsley and others, 1964). The area from Montauk Village west to Easthampton Village and including the Napeague Beach beach-dune tombolo complex is unique in that it seems to be the only part of Long Island's south shore that is currently prograding. Initially, the later Holocene dominant mode of shoreline modification was erosional, as witnessed by the prominent bluffs, now isolated from the south shore, at Hither Hills State Park and along Bluff Road. Debris, principally sand, derived from these bluffs was transported by long-shore drift, constructing a spit towards the northeast, marked by the Promised Land beach ridges, while another spit built from Hither Hills west toward Southampton.

The stratigraphy in the swale at Hither Hills Beach, where exposed, exhibits a sequence which, from the bottom upward, consists of the Montauk Till Member of the Manhasset Formation, thin beds of laminated silts with some pebbles, freshwater peat, and Holocene dune sand. Tree stumps are occasionally found rooted in the peat. One of the stumps was C-14 dated to be 5,450±115 years B.P. (sample no. I-5664). The date presumably indicates the time when the transgressing sea, and sand derived from its beach, began to influence the Ditch Plains area. Pollen extracted from the peat is principally pine and oak but with a conspicuous contribution of N.A.P., an assemblage similar to that found currently around Fresh Pond in Hither Hills State Park.

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ROAD LOG

Assembly Point: Hofstra University

Total Miles	Point to Point Milage	
0.0	0.0	Enter Montauk Peninsula and cross Shinnecock Canal connecting Great Peconic Bay (north) to Shinnecock Bay (south). Begin measured distances.
1.6	1.6	Divided highway ends, pass with care because of two-way traffic.
3.3	1.7	Southampton College to your immediate right (south).
4.0	0.7	From Southampton College to this point you are traveling through the rolling morainal knob and kettle topography of the Shinnecock Hills.
4.1	0.1	Outcrop on north side of road showing head of outwash. The moraine at this point bends sharply to the northeast.
6.2	2.1	Village of Southampton approximately 1 mile south of the road.
6.6	0.4	The trace of the Ronkonkoma Terminal Moraine can be seen to the north with the outwash plain abutting against it. The outwash is covered by thin loess in this area.
7.0	0.4	FULL STOP. Turn onto Montauk Highway, Route 27.
8.1	1.1	Entering head of Mecox Bay, Mill Creek on south.
9.4	1.3	One of the numerous Long Island duck farms can be seen on immediate left on north shore of Hayground Cove which enters directly into Mecox Bay. There is considerable controversy concerning periodic eutrophication of the water mass caused by nitrogeneous wastes from these farms entering the bay.
10.6	1.2	On north and south of road observe the southernmost extension of the Scuttlehole depression. Kellis Pond is to the south and occupies most of the depression. (See text and description of Stop 6 for details of origin.)
11.5	0.9	Village of Bridgehampton.

15.0	3.5	Active sand and gravel operation at north side of road. These pits have been dug deeply enough to intersect the water table, and present operations involve dredging methods.
17.8	2.8	Traffic light. Turn left into Village of Easthampton.
18.6	0.8	Main intersection in the center of Easthampton.
18.8	0.2	Bear to right of windmill.
20.0	1.2	Village of Amagansett.
21.8	1.8	Bluff Road entering Route 27 from south. Site of former wave cut cliff.
22.1	0.3	Leave glacial deposits and descend onto the Napeague beach complex. Note steep wave-cut bluff to immediate north. This is the central part of the Napeague tombolo. Napeague Harbor is to the north.
26.5	4.4	Observe wave-cut bluff in morainal deposits.
27.0	0.5	Observe dunes from north of the moraine. Dunes have been blown inland and over the moraine for approximately 1 mile.
27.1	0.1	Road divides. Bear left and ascend the moraine. The western boundary of Hither Hills State Park is crossed here.
31.1	4.0	Rapid descent from moraine, entering Montauk Village.
31.6	0.5	Traveling on beach deposits that have been drifted in by long-shore currents. Fort Pond to north has been isolated from the ocean by a double tombolo.
32.2	0.6	Reascend moraine. Several overlooks on the road provide beautiful ocean views on clear days.
35.2	3.0	Oyster Pond can be seen in the distance to the northeast.

36.2	1.0	Turn right into Air Force Base. Drive slowly and obey signs. In the next one mile follow these instructions: Proceed through gate; drive along winding road and go past radar tower; go straight past two right turns and through a second gate (unattended), and make sharp right turn onto a winding narrow road.
37.2	1.0	Road ends. Make right turn past sign for L.I. State Park Commission Park and dismount buses well away from the edge of the cliffs. Walk east descending to base of bluffs.
		STOP 1. Montauk Air Force Station. Here along the littoral bluffs on Long Island's southeast coast which includes the type section of the Montauk Till, we have the opportunity to examine the excruciating complexities of the island's Quaternary stratigraphy. The hoodoo topography developed on the Montauk Till provides a conspicuous marker bed which enables us to follow the till where it outcrops along the eroding bluff. However, the complicated glacial tectonics, immediately apparent in these exposures, has detached blocks of Montauk Till, and these blocks have been transported into anomalous stratigraphic positions. To our west, stratified drift beneath the Montauk Till is exposed in a large mile-wide antiform. Stratified drift including laminated silts and clay, frequently folded and in fault contact, also lie above the Montauk Till. The barely finite age obtained from a log in the lower portion of the upper stratified drift has been previously noted while a second date on disseminated wood from the upper stratified drift dates at 12,170 $\pm$ 180 years B.P. (QC-122). Discontinuous lenses of a younger till cap portions of the bluff. Also found in the upper part of the section are pockets of loess up to ten feet thick.
38.4	1.2	Return to buses and retrace way back to Route 27. Turn left and proceed westbound.
41.3	2.9	Look for sign on left reading, "Ditch Plains". Turn left onto Ditch Plains Road.

41.7 0.4 Leave paved road; travel on hard gravel road to parking area adjoining beach. Park buses and dismount. Walk west on beach to base of sea cliffs.

STOP 2. Ditch Plains.
The Montauk Till forms the base of the section exposed along the coastline. Close inspection of the till reveals pervasive deformation. The western end of our traverse displays well-developed hoodoo topography on the Montauk Till. The western portion of the section shows stratified drift and loess above the till. At the eastern end of the high bluff, thinly bedded fine sand dips towards the east and passes from view beneath the beach. This stratified deposit lies upon a persistent peat zone upon which rooted stumps are occasionally exposed. As noted previously, a radiocarbon date on one of these stumps shows it to be about 5500 years old. Excavation at the east end of our traverse (near where we enter upon the beach) discloses the following section:

Eolian sand
Peat
Laminated silt (lacustrine?)
Montauk Till

Since the peat appears to be mid-Holocene in age, the thinly bedded sand body appears to be the distal portion of a delta that was built into the Ditch Plains basin prior to the Holocene marine transgression of the area. We cannot explain why the late Holocene sand wedge was deposited. We suspect that it might have been deposited because the vegetation cover was temporarily destroyed allowing the mobilization of considerable amount of sand.

42.1 0.4 Remount buses. Return to Route 27 and turn left (westbound).

44.1 2.0 After passing through Montauk Village, Route 27 forks where Old Montauk Highway enters Route 27. Bear right and ascend moraine.

45.2	1.1	Turn right into sanitary-landfill disposal area.
45.6	0.4	Travel north on landfill access road and park buses. Dismount buses and walk to edge of largest open pit.

<u>STOP 3. Montauk Sanitary landfill</u>.
This section reveals at least 100 feet of stratified sand in the middle of the Ronkonkoma kame-moraine complex. The topographic maps of the area as well as air photos (figure 5) display a series of northeast striding ridges superimposed upon the moraine. These ridges appear to be push moraines. The deposit exhibits both folding and faulting, including several large thrust faults. The section is capped with a bouldery deposit that is probably till. The high percentage of boulders suggests the till has been washed and the boulders at least in part, represent a lag deposit. (Perhaps the term "flowtill" is appropriate here.)

46.0	0.4	Return to Route 27 and turn right (westbound).
48.0	2.0	Overlook on right side of road shows numerous beach and littoral features on north side of Montauk Peninsula. The Atlantic Ocean is to the immediate south.
49.5	1.5	Turn left onto side road and enter Hither Hills State Park.
49.7	0.2	Turn left onto Old Montauk Highway (eastbound).
49.9	0.2	Turn right into parking lot. LUNCH STOP AND REST ROOMS.
50.0	0.1	Return to Old Montauk Highway and turn left (westbound). A prominent wave cut bluff is directly to the north.
50.6	0.6	Intersection with Route 27. <u>Careful</u>; dangerous crossing. Travel west on Route 27. Magnificent dunes can be seen on both sides of the highway. They are presently stabilized by vegetation.

52.3	1.7	Make a 30° right turn off Route 27. Cross railroad tracks. Full Stop.
52.6	0.3	Napeague Harbor can been seen on the right. Beach ridges, dunes and lagoonal sediments typify this area.
53.6	1.0	FULL STOP. Turn left.
56.0	2.4	Warning - narrow bridge. Blow horn before crossing.
56.2	0.2	Return to Route 27 (westbound).
57.1	0.9	Make a 150° right turn and cross railroad tracks.
57.2	0.1	Road divides. Bear left onto Fresh Pond Road. The head of outwash is to your left (south) and the moraine is to your right (north).
58.2	1.0	Stop buses after passing rifle range. Dismount and walk into woods along dirt path.

STOP 4. Gravel pit at Amagansett.
Here is the last easternmost exposure of the Late Wisconsin drift to be seen before its termination at Bluff Road sea cliff and its reappearance 4 miles east-northeast at Hither Hills. The till at this stop has a sandier texture, fewer boulders, a lower clay content, and fewer glacial tectonic structures than the Montauk Till. The stratified drift underlying the till is postulated to be either an Early Wisconsin drift that was overridden and deformed by the Late Wisconsin advance or a Late Wisconsin proglacial outwash that was overridden by the advance. The lower stratified drift exhibits many glacial tectonic structures such as thrust faults and folds. This same unit also has preserved depositional structures such as cross bedding and graded bedding. A third unit of wind-blown sediments overlies the till.

58.4	0.2	Remount buses and proceed north. Make a left turn onto Cross Highway.
58.8	0.4	Turn left onto Abrahams Landing.
59.2	0.4	Turn left onto Alberts Landing Road.
59.6	0.4	Bear left.
60.2	0.6	Turn right and cross railroad tracks. Make a right turn onto Route 27 westbound.
63.4	3.2	Make right turn at traffic light in downtown Easthampton.
63.8	0.4	Bear left before the railroad tracks.
63.9	0.1	S-curve left.
64.0	0.1	S-curve right.
64.6	0.6	Make a right turn onto Co. Rd. 114 (Sag Harbor-Easthampton Turnpike).
64.8	0.2	Make a left turn into Easthampton Bus Co.

STOP 5. Easthampton Bus Company

This stop is included to illustrate the late-glacial loess deposit and the surficial sands that have blown in and partially covered the loess in the Easthampton area. The flat bull-dozed surface is near the top of the loess deposit. It is possible to dig down through some 62 inches of wind blown silt and enter coarse stratified sands and gravels below. The contact between the loess and the underlying glaciofluvial deposits is erosional and a lag-gravel concentrate has been developed with many wind-abraded clasts and ventifacts which were left behind during a period of aeolian deflation. Frost action (cryoturbation), probably in late glacial times, disturbed much of the section and introduced the erratic pebbles into the loess from below. After deposition of the loess and some soil formation on the loess, dune sand was blown in from the south shore and heaped into 10-foot dunes in this area. The sands are now stabilized by a soil profile and by a mature forest cover. A minor paleosoil can be seen within the dune sands. The dune sands have stripped much of the A soil horizon from the top of the loess but the B horizon is still present here.

The dune sands are traceable on topographic maps and aerial photographs to the south shore and have blown inland at least 2.2 miles (3.5 km).

The sequence of events determined from this and other similar outcrops in this area include: 1. deposition of the last glacial outwash sands and gravels 2. widespread aeolian deflation and the formation of lag-gravel concentrate and ventifacts 3. deposition of the loess on a cold barren surface devoid of vegetative cover and intense cryoturbation of the deposits. 4. indeterminant length of time during which a soil formed on top of the loess. 5. deposition of dune sand from the south shore, probably shortly after sea level reached near its present level. 6. stabilization of the dunes by soils and forest.

65.6	0.8	Exit from bus company. Turn left and go under railroad overpass. As you proceed north along Route 114 note dunal topography to the south and loess topography to the north.
66.0	0.4	Make left turn onto Stephen Hands Path. Pass a small water mill on immediate left.
67.4	1.4	Return to Route 27 and turn right (westbound).
71.3	3.9	Pass through Bridgehampton.
72.0	0.7	Slow down for blind left turn onto Snake Hollow Road just before shopping center.
72.2	0.2	Cross railroad tracks.
72.6	0.4	Make left turn onto Mitchells Lane which runs parallel to the Scuttlehole depression.
72.8	0.2	In this area, the outwash plain is blanketed with loess. The trace of the Ronkonkoma Terminal Moraine can be seen directly ahead.
73.5	0.7	Scuttlehole Road. Turn left.
73.8	0.3	Dip into the Scuttlehole depression.

74.0 | 0.2 | Pull to side of road by "Cattle Crossing" sign. Dismount buses. Watch for traffic in both directions. Cross to south side of road overlooking Haines Pond.

STOP 6. The Scuttlehole Depression.
The Scuttlehole depression is a large topographic feature some 2.5 miles (4 kilometres) in length. It is impossible to observe the entire structure from any one point on the ground. Therefore, reference to a topographic map (Sag Harbor quadrangle) is recommended.

Our bus stop is on Scuttlehole Road just south of Shorts Pd. and just north of Haines Pd. To the north and south you can observe a topography that is strange for Long Island, reminiscent of karst topography. The elevation of the outwash plain (out of view from this point) on both sides of the depression is approximately 70 feet and the plain is amazingly level considering the nearness of the Ronkonkoma Terminal Moraine which is about 1 mile to the northeast. In this area, only glaciofluvial deposits and aeolian loess are known on the outwash plain. No till or ice-contact deposits or erratics are found on the outwash plain so the presence of glacial ice far south of the Ronkonkoma front is doubtful. The Scuttlehole depression heads near the moraine and extends southeast about 2.5 miles (4 kilometres) and consists of more than a dozen semi-isolated basins identical in size and shape with the two that can be observed here. The basins are steep-sided and flat-bottomed and are isolated from one another by shallow divides.

Several characteristics have led us to conclude that this feature is a collapse structure of thermokarst origin:

1. linearity of trend approximately 2.5 miles (4 kilometres) N25W.
2. beaded drainage system, an often observed phenomena in present-day periglacial areas.
3. size and shape of the individual basins are almost identical to present-day regions of active thermokarst.

4. lack of evidence for the existence of glacial ice in the area of the outwash plain.
5. association with small scale periglacial features such as cryoturbated loess and a single ice wedge cast of the Scuttlehole depression.

Although not conclusive, we feel the evidence merits consideration and any discussion of the interpretation would be welcomed by the authors....

75.8	1.8	Remount buses and return to Route 27 via Scuttlehole road. Turn west (right) onto Route 27.
78.1	2.3	Turn right onto North Road.
79.6	1.5	Right turn onto County Road 38 and bear right immediately. Take Majors Path going north. Note here how outwash abruptly grades into the kame and kettle topography of the moraine.
83.2	3.6	Drive slowly because of the winding road. Stop buses at Southampton Sanitary Landfill.

STOP 7. Southampton Sanitary Landfill Site. At this stop one sees a contrast in morainal morphology between here and the previous sites. Here kame and kettle topography predominates as compared to the "push" topography seen earlier. At this site one sees mostly primary sedimentary structures, although secondary structures formed by glacial tectonic activity are present. Geophysical investigations have indicated a finer till-like material at a lower level of the pit, possible equivalent to the Late Wisconsin till.

83,4	0.2	Exit landfill and turn left. Return to Route 27 via same route.
83.9	0.5	Bear left at fork in road.
86.1	2.2	Turn right (west) onto Route 27.
89.4	3.3	Pass Southampton College on left.
92.7	3.3	Pass Shinnecock Canal. Leave Montauk Peninsula. Return to Hofstra University.

NOTES