

## NEW OBSERVATIONS ON THE GLACIAL GEOMORPHOLOGY OF LONG ISLAND FROM A DIGITAL ELEVATION MODEL (DEM)

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### Abstract

A new topographic model based on digital elevation data (DEM) provides a high-resolution view of the glacial geomorphology of Long Island, New York. Features such as moraines, kames, kame deltas, kettles, tunnel valleys, and outwash channels are revealed with unprecedented clarity, allowing for the identity and relative chronology of these features to be re-examined. The geomorphic features revealed by the DEM strongly suggest that Long Island is defined by three distinct moraines, the Harbor Hill Moraine, the Roanoke Point Moraine, and the Ronkonkoma Moraine (terminology from Sirkin, 1996). The Harbor Hill Moraine is a linear ridge trending SW to NE from Brooklyn to Port Jefferson. The Roanoke Point Moraine is a discontinuous kame moraine, trending W to E from Port Jefferson to Orient Point, that defines the North Fork of the island. The Ronkonkoma Moraine is also a kame moraine with a W to E trend, extending from Roslyn Heights in Nassau County across central Long Island to the South Fork and Montauk Point. The Harbor Hill Moraine is a terminal moraine clearly defined by a terminal ridge and subjacent elevated outwash plain. It truncates the E to W trending Ronkonkoma Moraine and associated kame deltas in the Woodbury-Jericho area of western Long Island. The Harbor Hill Moraine is also associated with the necks of western Long Island, which are dissected by tunnel valleys. Outwash channels from tunnel valleys that disgorged along the front of the Harbor Hill Moraine extend southward and cross-cut the Ronkonkoma Moraine. Therefore, the Harbor Hill Moraine cannot be the western extension of the Ronkonkoma Moraine, but must instead be the product of a more recent glacial advance. Likewise, the Roanoke Point Moraine does not appear to be an eastward extension of the Harbor Hill Moraine, but is more likely a separate moraine also cross-cut by the Harbor Hill Moraine. The Roanoke Point Moraine is not associated with necks or tunnel valleys and is similar in morphology and geographic orientation to the Ronkonkoma Moraine, but different in orientation and morphology from the Harbor Hill Moraine. The overall morphology and cross-cutting relationships of Long Island's three major moraines strongly suggest that the Ronkonkoma and Roanoke Point Moraines are related features arising from the advance and retreat of one ice sheet and that the Harbor Hill Moraine is a separate feature developed during the advance of a second, younger ice sheet.

### Introduction

There is a long history of contention over the number and timing of glacial advances preserved in the Pleistocene deposits of Long Island (see summary and references in Sanders and Merguerian, 1998.) Much of this debate has focused on the dating and correlation of the deposits within the subsurface of Long Island, but all models for the history of glacial deposition of Long Island have also attempted to explain the origin of its glacial landforms and topography. Fuller (1914) interpreted the stratigraphy of Long Island to be the product of four distinct glacial

advances extending back through six stages of the Pleistocene. To explain the present topography of Long Island, Fuller (1914) postulated two separate advances of glacial ice in the Wisconsin stage, the first depositing the Ronkonkoma terminal moraine and a second major re-advance depositing the combined Harbor Hill and Roanoke Point terminal moraine (Fig. 1). Subsequent workers through the early and mid-twentieth century rejected Fuller's interpretation in favor of a more simple view that Long Island is primarily the product of the advance

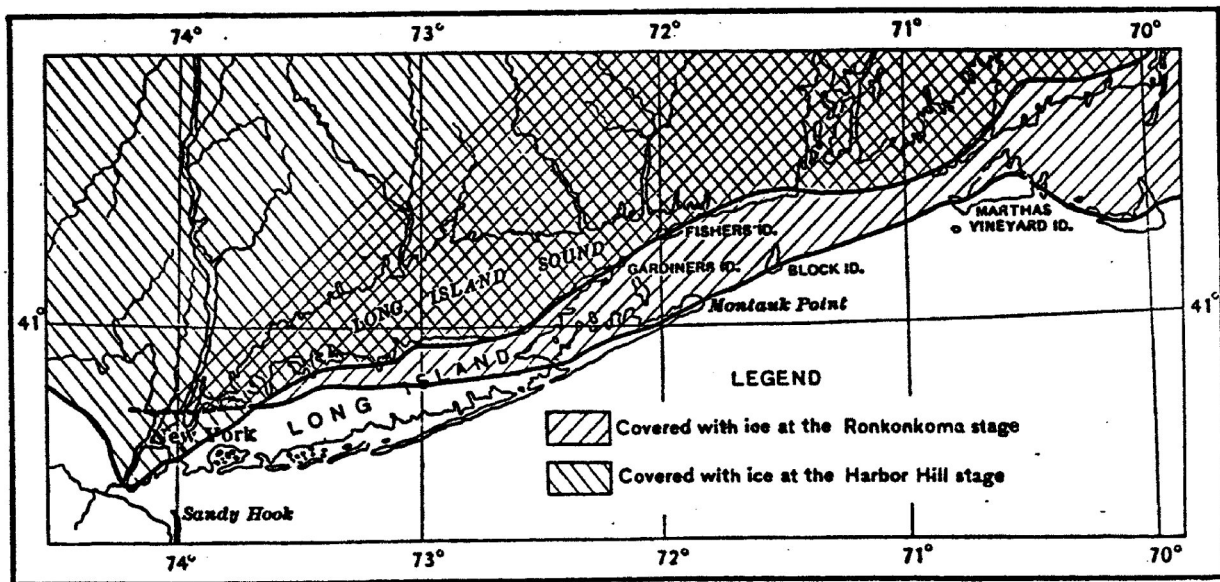


Figure 1. Diagram from Fuller (1914, Fig. 3) showing position of ice margin and formation of two terminal moraines during two separate advances of glacial ice.

and retreat of the most recent Wisconsin ice sheet. This scenario modified Fuller's explanation of the Harbor Hill Moraine, attributing it to a minor re-advance of ice over older deposits of the Ronkonkoma Moraine in western Long Island, and reinterpreted the Roanoke Point Moraine as a recessional moraine (Sirkin, 1968).

More recently, the recognition of two distinct tills in stratigraphic sequence in deposits of the north shore of Long Island and in New England shifted the majority opinion in favor of Long Island containing evidence for two distinct glacial advances (Sirkin, 1982). However, the expansion of Long Island's subsurface chronology to include two episodes of glaciation was not extended to the surface topography. Rather, publications by Sirkin and coworkers (e.g. Sirkin, 1982) began describing the eastern segments of the Harbor Hill Moraine, from Huntington to Port Jefferson, as separate recessional moraines deposited by different lobes of retreating ice. In this model the Roanoke Point Moraine along the north shore of eastern Long Island was correlated to the moraine deposits of the northern necks in western Long Island to mark the northernmost recessional position of the glacier (Fig. 2). Only the western reach of the Harbor Hill Moraine was seen as marking any significant re-advance of ice. The trend of trying to encompass all of Long Island's topography into a single advance and retreat of the last ice sheet

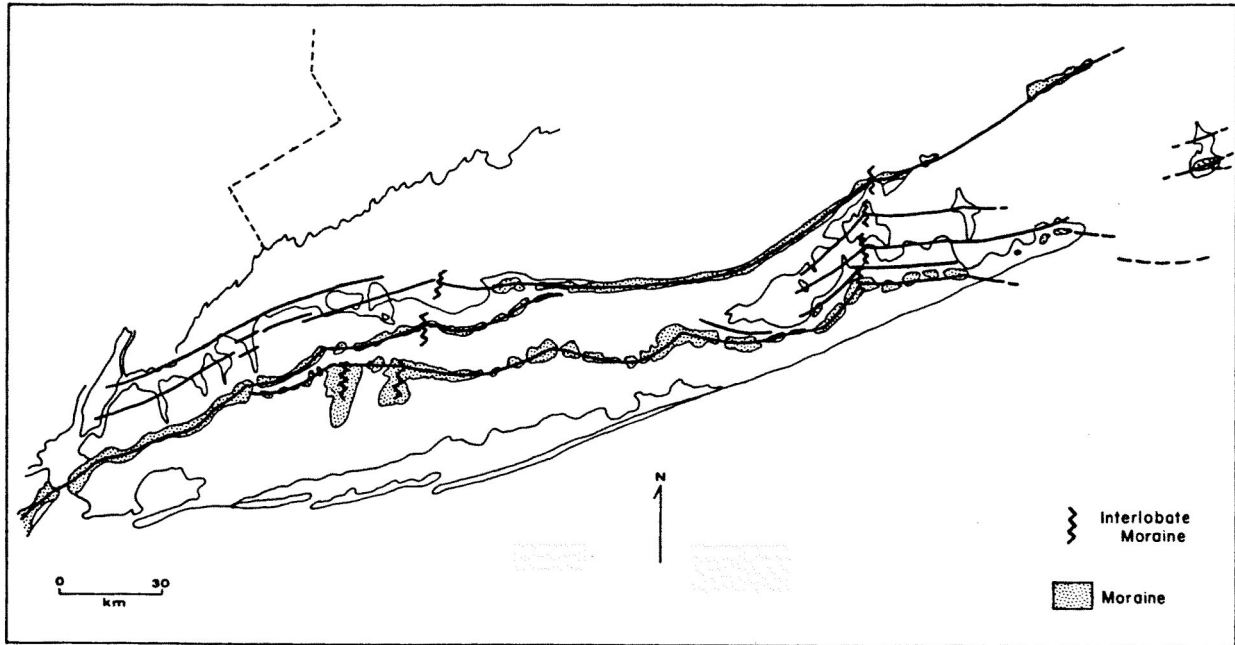


Figure 2. Diagram from Sirkin (1982, Fig. 2) showing terminal moraine and correlation of recessional moraine segments across Long Island.

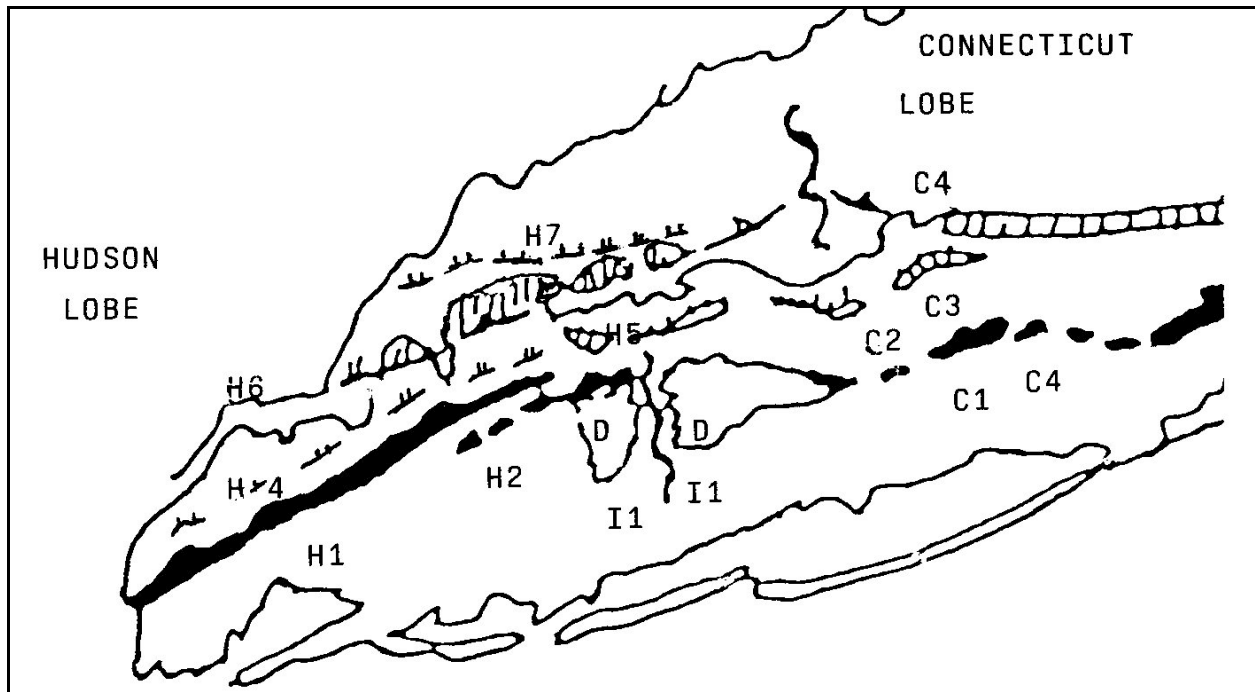


Figure 3. Diagram from Sirkin (1996, Fig. 10a) showing combined Harbor Hill and Ronkonkoma terminal moraine (dark shading, H1, H2, C1, C4) and recessional moraine segments (H4, H5, C2, C3, C4, H7) in western Long Island and central Long Island.

culminated in the most recent work of Sirkin (1996) in which he joined the western half of the Harbor Hill Moraine to the western end of the Ronkonkoma Moraine to form a continuous terminal moraine stretching from Brooklyn to Montauk Point (Fig. 3). In this model, no significant re-advance of ice is postulated and Long Island's geomorphic features are ascribed to a single terminal moraine deposited during the last glacial maximum and a series of discontinuous recessional moraines deposited during subsequent ice retreat.

Sirkin's model has been called into question by Sanders and Merguerian (1995, 1998) who argue for the validity of Fuller's original model, citing a variety of flow-direction and provenance evidence in favor of separate glacial advances producing an older Ronkonkoma terminal moraine and younger Harbor Hill-Roanoke Point terminal moraine. Furthermore, Sanders and Merguerian (1998) suggest that lake clays preserved within the Ronkonkoma Moraine imply the former existence of a true terminal moraine south of Long Island's present southern shore, relegating the Ronkonkoma Moraine to the status of a recessional moraine produced during a minor re-advance of the older ice sheet.

## Methods

Previously published models describing the development of Long Island's glacial topography were evaluated by comparing the relationships between topographic features described in the models to the features shown on a high resolution digital elevation model (DEM) of Long Island. The DEM was assembled from data files made available by the New York State Department of Environmental Conservation and downloaded from the Cornell University Geospatial Data Information Repository (CUGIR – <http://cugir.mannlib.cornell.edu>). The data files representing all USGS topographic quadrangles for Long Island, New York were processed into color-coded topographic models at 2X vertical exaggeration and joined using a freeware DEM application for the Macintosh OS called MacDEM (download at: <http://www.treeswallow.com/macdem/>). The full-size topographic model was then exported as a tiff image file for import into Photoshop. The completed, full-size DEM has a horizontal resolution of 10 meters and a vertical resolution of 0.1 meter (CUGIR, 2002).

## Results and Discussion

### *The Harbor Hill Moraine*

Examination of western Long Island on the DEM reveals the Harbor Hill Moraine to be a single, laterally continuous feature from Brooklyn east to Port Jefferson (Fig. 4). In Brooklyn, Queens, western Nassau County and between Stony Brook and Port Jefferson the moraine ridge is sharply linear and shows evidence of glaciotectonic deformation. Along the entire extent of the Harbor Hill Moraine the adjacent outwash plain forms a prominent, elevated surface sloping southward from the moraine ridge (Fig. 5). The average elevation of the landscape north of the moraine ridge is markedly lower than the outwash plain south of the ridge (see profiles in Fig. 5 and Fig. 6) due to the deposition of outwash sediments at the front of a stationary ice sheet. North of the moraine the landscape is dissected by deep, anastomosing tunnel valleys carved by subglacial melt water (Hanson, 2001). Although gently arcuate, the moraine ridge and outwash

plain show no evidence of discontinuities resulting from deposition by different major glacial lobes, as postulated by Sirkin (1996). The ridge is breached by tunnel valley mouths, which tend to be located at the intersections of moraine arcs (Fig. 5). Shallow, widening melt water channels are often found incised into the outwash plain south of tunnel valley breaches. In one case southeast of Northport, outwash material disgorged by one channel can be seen to partially infill an older outwash channel (Fig. 5).

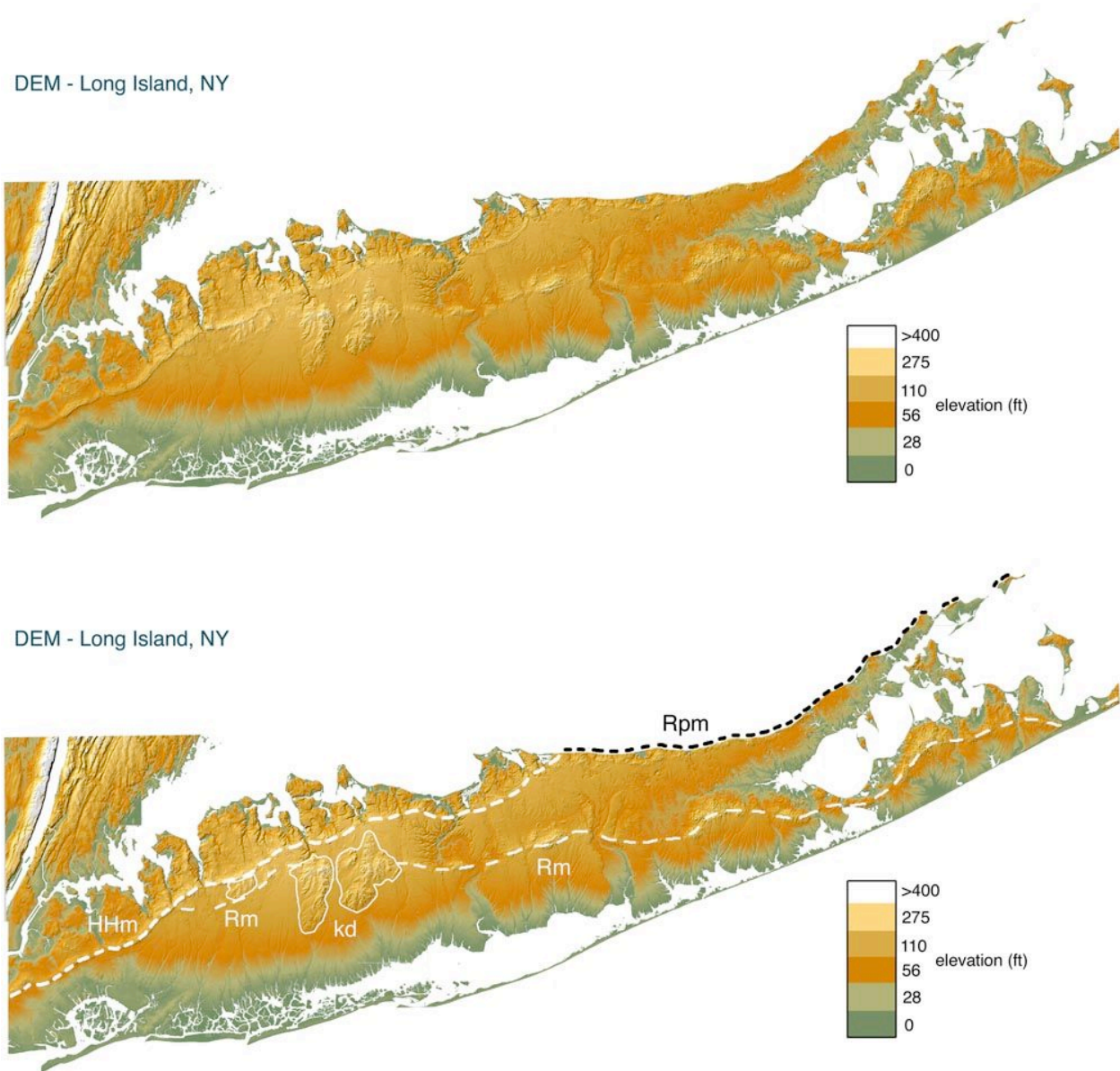


Figure 4. Digital elevation model (DEM), Long Island, New York. Glacial features: Ronkonkoma Moraine (Rm), Roanoke Point Moraine (Rpm), Harbor Hill Moraine (HHm), kame deltas (kd).

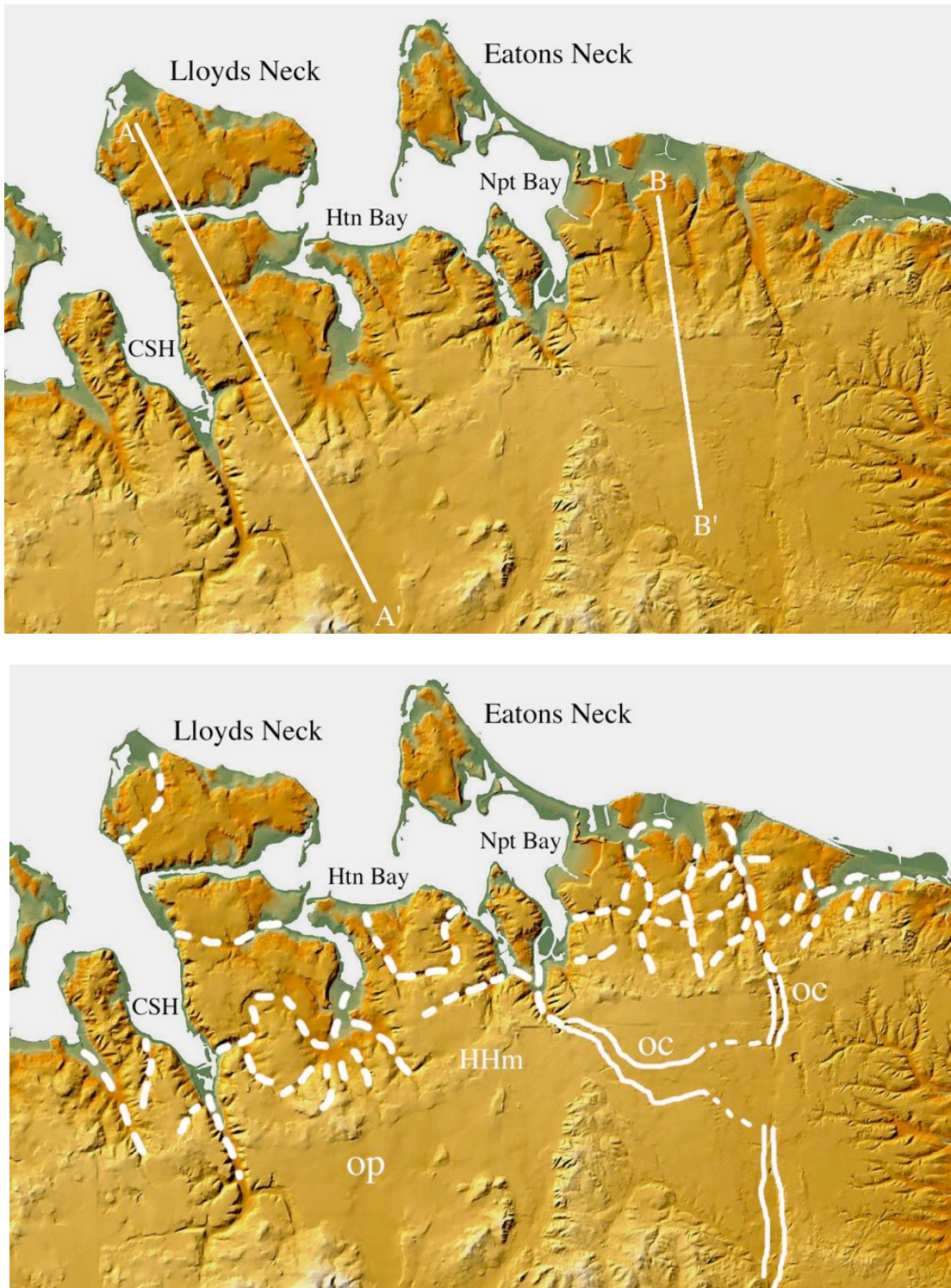


Figure 5. Harbor Hill Moraine (HHm) in Huntington-Northport area. Glacial features: Tunnel valleys (dashed lines), outwash channels (oc), outwash plain (op). Cold Spring Harbor (CSH). See Fig. 6 for profiles A-A' and B-B'.

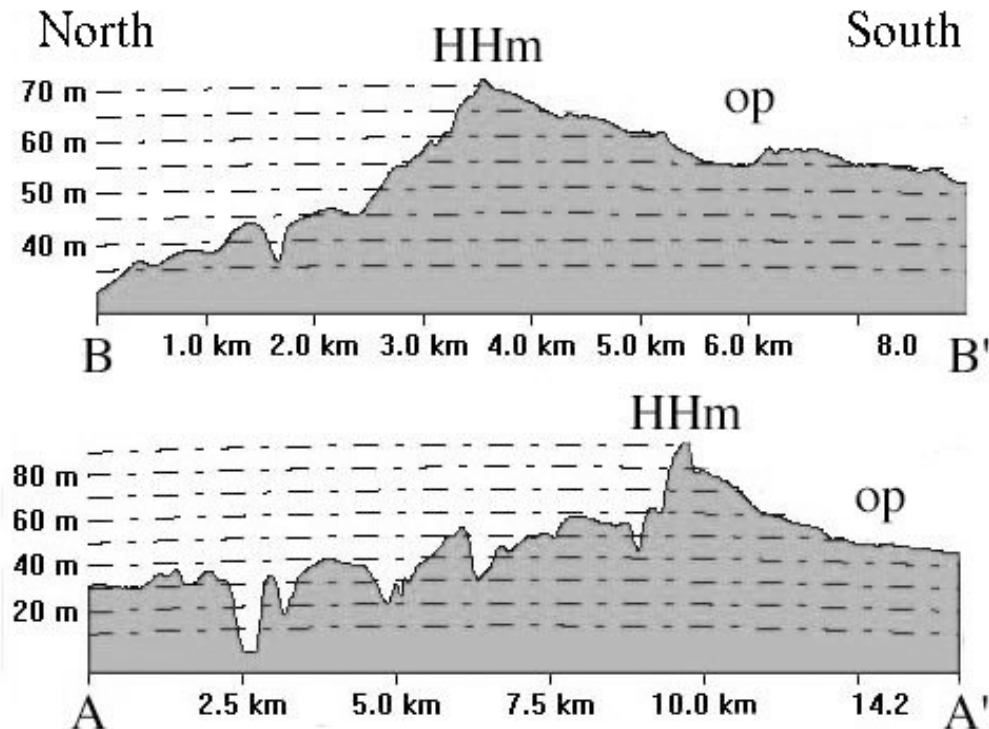


Figure 6. Topographic profiles across the Harbor Hill Moraine (HHm) and outwash plain (op). See Fig. 5 for location of profiles.

### *The Ronkonkoma Moraine*

The Ronkonkoma Moraine forms a low, discontinuous ridge of kame hills extending from Jericho in Nassau County east to Montauk Point at the end of the South Fork (Fig. 4). The overall form of the moraine is gently lobate, with kame hills concentrated at lobe intersections. A Ronkonkoma outwash plain is present to the south of the moraine and is moderately elevated relative to the north side of the moraine, particularly along the South Fork. To the west the Ronkonkoma Moraine is cross cut by three sets of N-S trending hills (Fig. 7). Each group of hills has an elongate branching structure resembling the distributary lobes of a delta and previous authors have described these features as kame deltas (e.g. Sirkin, 1996). The westernmost group of hills in Old Westbury appears to be truncated to the north by the Harbor Hill Moraine (Fig. 7). To the east the Ronkonkoma Moraine is cross cut by two wide, shallow channels, which form broadly sinuous valleys that begin north of the moraine and extend south to the modern shoreline (Fig. 8). These valleys host three of Long Island's four modern rivers (the Nissequogue, the Connetquot, and the Carmans) that probably were initially eroded by the drainage of proglacial lake water impounded behind the Ronkonkoma Moraine during ice retreat. The northern reach of both valleys is located in the center of the island, north of the Ronkonkoma Moraine and south of the Harbor Hill outwash fans, the deposits of which are seen to overlap the valley heads (Fig. 8). The drainage of the Nissequogue River flows northward, and has cut a narrow valley across the Harbor Hill Moraine. However, this narrow valley is likely post-glacial in origin and not an extension of the original outflow channel.

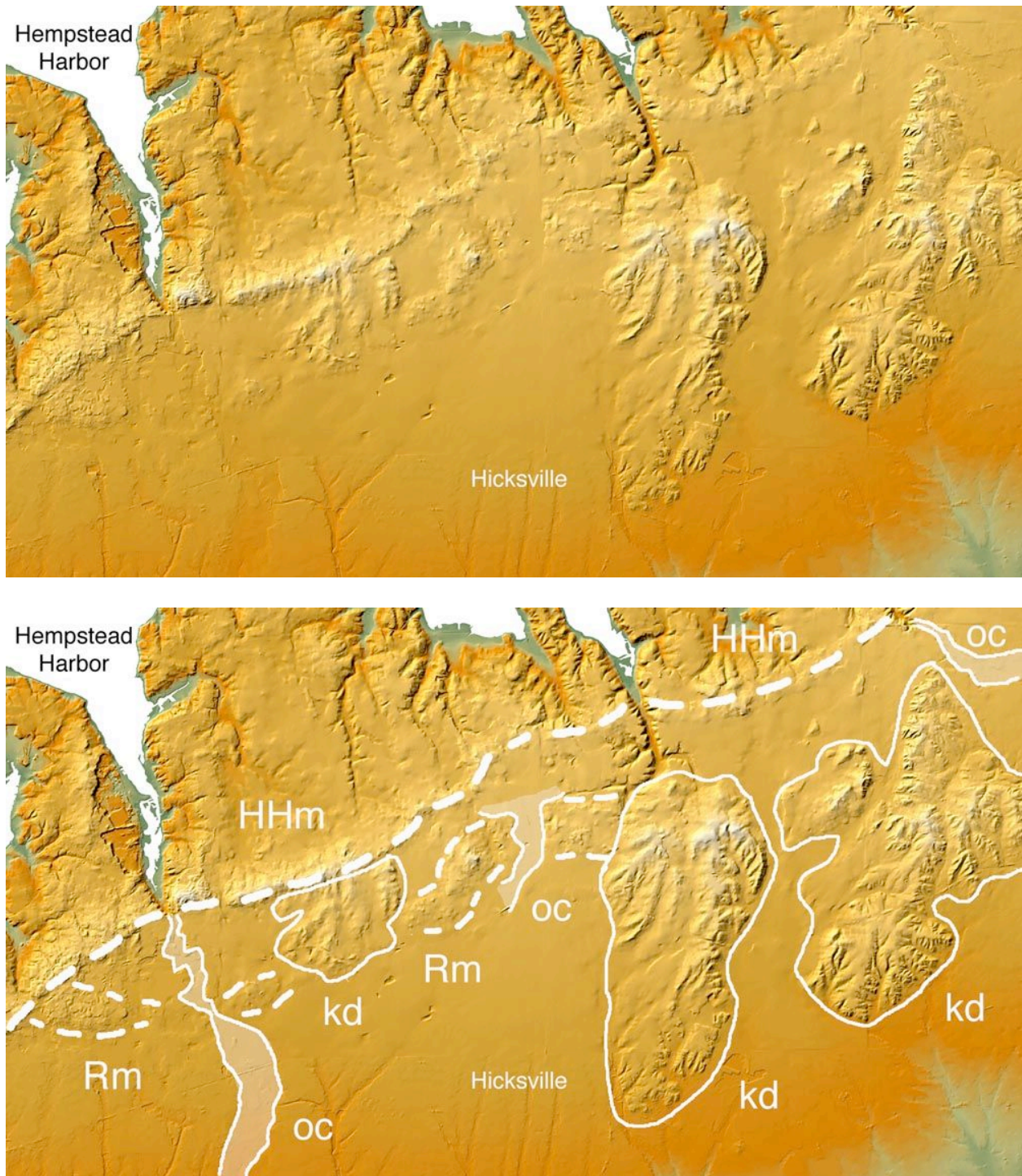


Figure 7. Intersection of Harbor Hill Moraine (HHm) and Ronkonkoma Moraine (Rm), Manhasset west to Dix Hills region. Other features: Harbor Hills outwash channels (oc) cross-cutting Ronkonkoma Moraine, kame deltas (kd) cross-cutting Ronkonkoma Moraine.

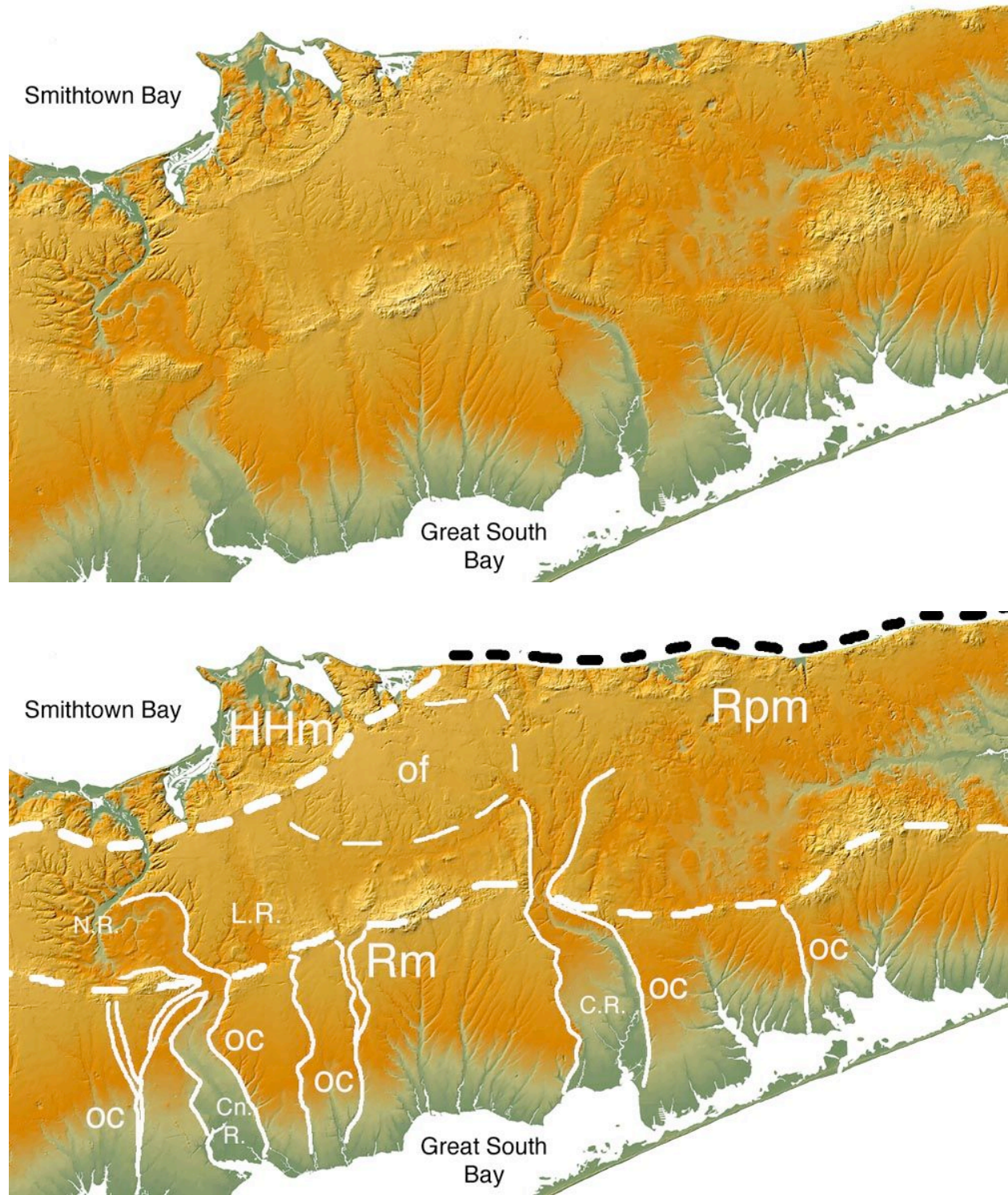


Figure 8. Intersection of Harbor Hill Moraine (HHm) and Roanoke Point Moraine (Rpm) in central Long Island. Other features: Ronkonkoma Moraine (Rm-thin dash), outwash channels (oc) through Ronkonkoma Moraine, outwash fan (of), Nissequogue River (N.R.), Connetquot River (Cn.R.), Carmans River (C.R.).

### *The Roanoke Point Moraine*

The Roanoke Point Moraine is a very broadly lobate line of kame hills, the crest of which defines the shoreline of the North Fork of Long Island from Mount Sinai east to Orient Point (Fig. 4). The landscape north of the moraine has been eroded away. To the south of the moraine is a low outwash plain defined by a series of partially coalesced outwash fans and pitted with numerous kettles (Fig. 8).

### *The Relationship Between the Ronkonkoma and Harbor Hill Moraines*

The interpretation of the Harbor Hill Moraine as a western extension of the Ronkonkoma terminal moraine (Fig. 3) is not supported by the DEM. The Harbor Hill Moraine ridge can be clearly seen to truncate the western end of the Ronkonkoma Moraine in the vicinity of Roslyn Heights in Nassau County (Fig. 7). The Harbor Hill Moraine also appears to substantially truncate the westernmost of three kame delta complexes near Old Westbury. Furthermore, southward flowing outwash channels originating in the Harbor Hill Moraine and outwash plain cross-cut the Ronkonkoma Moraine, demonstrating that the Harbor Hill Moraine is a younger feature (Fig. 7).

### *The Relationship Between the Harbor Hill and Roanoke Point Moraines*

The interpretation of the Roanoke Point Moraine as the eastern extension of the Harbor Hill Moraine can be challenged, but is not unambiguously resolved by the DEM. There is no clear overlap or cross-cutting of one moraine by the other where they meet east of Mount Sinai (Fig. 4, Fig. 8 for detail). The intersection of the two moraines appears to be buried beneath outwash fan deposits from the Port Jefferson and Mt. Sinai harbor tunnel valleys (Fig. 8). However, there are substantial differences between the two moraines that argue that they are separate features. The Roanoke Point Moraine trends W-E and parallels the orientation of the Ronkonkoma Moraine, whereas the Harbor Hill Moraine trends SW-NE and intersects the Ronkonkoma Moraine. The Harbor Hill Moraine is associated along its entire extent with broad necks and narrow tunnel valley harbors north of a well-defined moraine ridge, which in many areas appears to be glaciotectonic in origin. The Roanoke Point Moraine has no associated necks or harbors and has a more discontinuous ridge composed of kame hills. The Harbor Hill Moraine has a continuous, elevated outwash plain south of the moraine ridge with relatively few kettle depressions. This outwash plain was built up from the coalescing of large outwash fans disgorged from major tunnel valleys. The Roanoke Point Moraine has a much lower outwash plain composed of smaller outwash fans and pitted with numerous kettles. Overall, the Roanoke Point Moraine appears to have the characteristics of a recessional moraine, developed during the wasting of the ice sheet, whereas the Harbor Hill Moraine shows features associated with the actively advancing terminal margin of an ice sheet.

## Conclusions

### *A New Model for the Formation of Long Island*

Based on the geomorphic features described from the DEM of Long Island and their cross-cutting relationships, the following sequence of events is proposed to account for the major glacial features of Long Island. No particular dates for the events are implied, only the relative order of the events in time.

The Ronkonkoma Moraine is clearly the oldest glacio-geomorphic surface feature preserved on Long Island. Deposition of the Ronkonkoma Moraine and outwash plain was followed by recession of the ice sheet to the position of the Roanoke Point Moraine. Deposition of the kame deltas seen in western Long Island must have occurred during this recession, as the kame deltas originate at a position midway between the two moraines but cross-cut the Ronkonkoma Moraine. The presence of kame deltas projecting south of the Ronkonkoma Moraine also implies the impounding of a body of standing lake water south of the Ronkonkoma Moraine, which itself implies the existence of a moraine south of the present shoreline of Long Island to function as a dam. Sanders and Merguerian (1994) also have proposed that the Ronkonkoma Moraine is a recessional moraine and that a true terminal moraine existed farther south to account for the presence of lake clays in the till sequence at Montauk Point.

Recession and stabilization of the ice margin at a position coincident with the north shore of Long Island produced the Roanoke Point recessional moraine and pitted outwash plain north of the Ronkonkoma Moraine. A second advance of glacial ice from the northwest cross-cut both the Roanoke Point Moraine and Ronkonkoma Moraine in western Long Island and deposited the drift underlying the northern necks, the Harbor Hill terminal moraine and the elevated outwash plain.

The presence of two drift sequences in stratigraphic succession, separated by an interval of interglacial marine sediments has been described from the Port Washington area of northwestern Long Island (Sirkin, 1996) and beneath New York Bay (Merguerian, this volume). If the lower till can be correlated with the Ronkonkoma Moraine and the upper till with the Harbor Hill Moraine, then the interglacial interval and associated sea level rise would separate the formation of the Roanoke Point Moraine from the Harbor Hill Moraine. Sea level rise and flooding of the Long Island Sound valley would have allowed substantial erosion of the coastline associated with the Roanoke Point Moraine in eastern Long Island, truncating the moraine south to its crest. During the subsequent Harbor Hill glaciation, new deposits of drift and ice-thrusted sediments were emplaced along the coast of western Long Island, rejuvenating the coastline and forming the necks and bays associated with the Harbor Hill Moraine.

## Acknowledgements

I would like to thank Gil Hanson for introducing me to the joys of digital elevation data and for encouraging me use DEMs to investigate the glacial geology of Long Island. Likewise, I owe most of my knowledge of the issues and controversies surrounding Long Island's glacial

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