Long Island Subglacial Drainage Patterns Reveal the Direction of Glacial Flow

Waldemar Pacholik

Introduction:

The debate regarding the chronology of the development of Long Island's (LI's) topography is now over a century old (see summary and references in Sanders and Merguerian, 1998 or introduction in Bennington, 2003). The discussion is still not conclusive. In 1914 Fuller proposed two advances of the Wisconsin glacier. After decades of working on this topic, Sirkin, 1996 concluded that LI topography is a product of a single advance and retreat. This concept was quickly contradicted by Sanders and Merquerian, 1998. In their interpretation, there were two separate advances, and they furthermore suggested the location of a terminal moraine south of LI. This point of view is also shared by Bennington, 2003.

The consensus that all researchers share is that beside the Harbor Hill moraine west (W) from Huntington all the LI moraines have a recessional character. Unfortunately, this fact cannot be used as a decisive argument because the recessional or transgressional character of the moraine depends mostly on the mass balance of the glacial edge.

Pacholik, 2014 suggested that if the Long Island Sound moraines were taken into consideration, then the positions of the LI moraines fit into a transgressional pattern of the Connecticut Lobe (CL), which is found all the way up north to the Canadian border. In that study, the Harbor Hill Moraine, W of Huntington, is a result of the push of the Hudson Lobe (HL) on the weaker stream of the CL. In this concept, a higher discharge through HL caused the formation of the Harbor Hill Moraine W of Huntington, and Long Island's moraine pattern could be explained by a single advance.

The understanding of the ice flow pattern inside the Laurenitide Ice Sheet in the region of study can shine some light on the morphological development of LI topography. For these reasons, valleys of subglacial drainage were used to establish the directions of ice flow and the sequence of chronological order of the formation of LI features.

The subglacial origin of LI drainage valleys was inferred from their alignment with glacial till, therefore in this study, LI valleys are classified as tunnel valleys. The earlier studies proposed that the valleys south of the Ronkonkoma Moraine are post-glacial formations developed on the permafrost (Das, 2007).

The principle of cross cutting was used to establish glacial events in chronological order.

The assumption that the main stream of secondary valleys, which carried water straight to the glacial terminus, were formed from the same distance to the edge of the glacier was used to map the glacial terminus south of LI.

This study also provides an explanation for the steeper slopes of the western banks of the South Shore valleys.

Subglacial versus post glacial models of South Shore valleys development

This study of the South Shore valleys is based on the subglacial model of their development. The surface runoff on a permafrost model (Sen, and Hanson, 2007) in which the valleys should have an irregular dendritic drainage pattern, gently sloping perpendicular profiles, and a circular watershed (Bogaart et al., 2003), was not considered. The runoff model, which has a highly irregular nature, does not explain the formation of the features listed below. On the other hand, the listed characteristic can be explained by their formation, in the subglacial environment which is in close proximity to the glacial terminus.

The characteristics of the South Shore valleys which speak of their glacial origin:

1. The valleys align with a till

2. There are observed regularities, which require a sideways pushing force (the mechanism of formation of this features is described further in this study)

    a. Steeper western than eastern slopes of the banks

    b. Presence of parallel drainage pattern

3. Common presence of beaded kettles on the South Shore streams, which are congruent with the features described on the North Shore streams as a result of seasonal freezing and thawing of subglacial meltwater channels (Tvelia, 2014)

4. The valleys which transverse Ronkonkoma Moraine and move down S required pressurized water in order to move up the slope of the moraine.

Long Island's Drainage Patterns

The alignment of Long Island's drainage valleys by glacial till points to their subglacial origin. In this study this evidence was used to reconstruct the sequence of the glacial history of LI.

On LI, there are three different drainage systems (Figure 1):

1. The primary drainage system (Fig. 1, nr. 1 valleys) includes valleys which run in an N-S direction through LI. They originate by the Harbor Hill Roanoke Point Moraine, transect the Ronkonkoma Moraine and extend up to the glacial terminus. The valley of the Nissequogue and Connetquot rivers system (Fig. 1, valley nr. 1c) originates in the LIS and served as a drainage canal for subglacial waters of this basin. Successively, with the glacial transgression, these valleys where extended S. Using this concept, topographic features cross cut by these valleys are successively younger as we move south.

The northern sections of these valleys are covered by outwash. The outwash not covered by till is located on eastern LI in regions like Port Jefferson Fen or the Pine Barrens. This observation suggests that ice on western LI receded at a faster rate than ice on its eastern side. In that time, the recessional moraine, the ice of eastern LI, formed on LI's North Shore, the previous location of the transgressional moraine (Pacholik, 20014).

2. The secondary drainage system is located S of the Ronkonkoma Moraine on the South Shore (Fig. 1, nr. 2 valley). These valleys have their subglacial water shades located between the primary drainage system valleys. Occasionally they formed tributaries of valleys from primary drainage systems like tributaries of the Forge River Valley in Moriches (Fig. 1, valley nr. 1f). These are the younger generation of valleys, which formed during the most southern expansion of the glacier.

3. The anastomosing pattern of tunnel valleys north of Harbor Hill Roanoke Point Moraine, which formed in a significant distance from the glacial terminus (approximately 20 – 30 miles) where the water pressure distribution had more of an isotropic character.

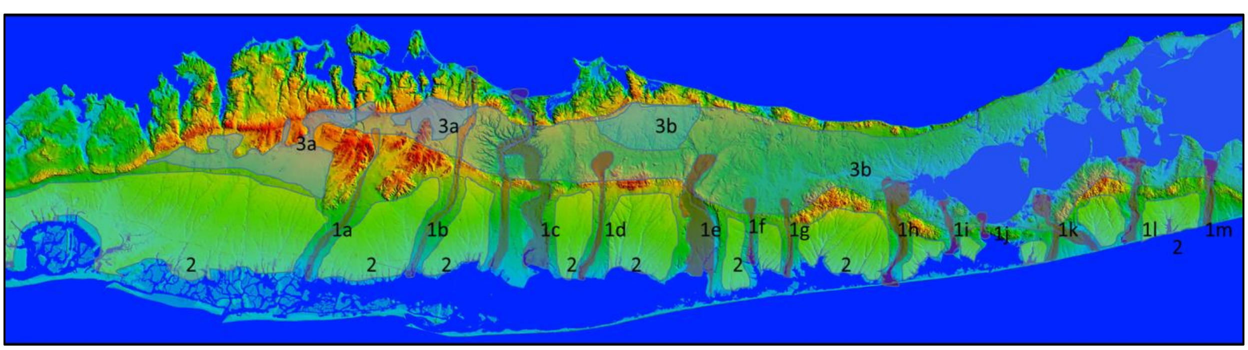

Fig. 1. Two systems of Long Island's drainage patterns, which indicate the sequence of glacial changes: primary valleys (nr. 1), which were continuously extended following a glacial

transgression; secondary valleys (nr. 2), which formed during the terminal stage of the glacier; and outwash: 3a – formed during the formation of the Harbor Hill moraine W of Huntington and later covered by till, 3b – outwash left by the glacier retreating from LI, which covered the northern part or primary valleys.

The chronological succession of LI's topographical feature was established using the following: a sequence of development of subglacial valleys; the location of areas with exposed outwash versus areas of outwash covered by till, and moraine's patterns (Pacholik, 20014).

This outlines put the events for the formation of the topographical features of LI in the following order:

1. Formation of Harbor Hill Roanoke Point Moraine section E of Huntington

2. Formation of Ronkonkoma Moraine – the primary valleys cross cut this moraine.

3. Formation of Harbor Hill Roanoke Point Moraine W of Huntington – Fig. 1, valleys 1a and 1b originated from this moraine are covered by outwash topped with a till in their northern sections.

4. Glacial transgression to its terminus S of LI, a formation of a secondary drainage pattern of the South Shore, and an anastomosing tunnel valley's system N of the Harbor Hill Moraine. (Anastomosing pattern forms further away from the glacial terminus, where pressure conditions are more isotropic).

5. Glacier from eastern LI retreats back to the North Shore (Roanoke Point Moraine line) – deposition of outwash of Pine Barrens and Port Jefferson Fen. The ice of western LI retreats N of the island leaving this region of LI covered by till.

Primary valleys and main streams of secondary drainage system valleys generally are parallel to each other. These valleys were positioned perpendicularly to the glacial terminus because they followed the direction of a decreasing hydraulic gradient.

South Shore Tunnel Valleys – Striation System

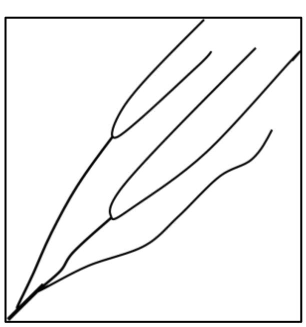

Fig. 2. Example of parallel drainage pattern.

The South Shore drainage system (Fig. 1, nr. 2 drainage system) has a predominantly parallel pattern (Fig. 3, 4).

In this region the existence of this type of drainage formation is out of place because the parallel drainage system forms on steep uniformly sloping surfaces, in regions of an outcropping of resistant parallel rock bands, or in an area with a parallel fault system.

To produce this kind of pattern in a glacial environment, the direction of the moving ice and water had to agree with each other. For that reason, the parallel valleys where interpreted as striation valleys (Fig. 3, 4, and 5).

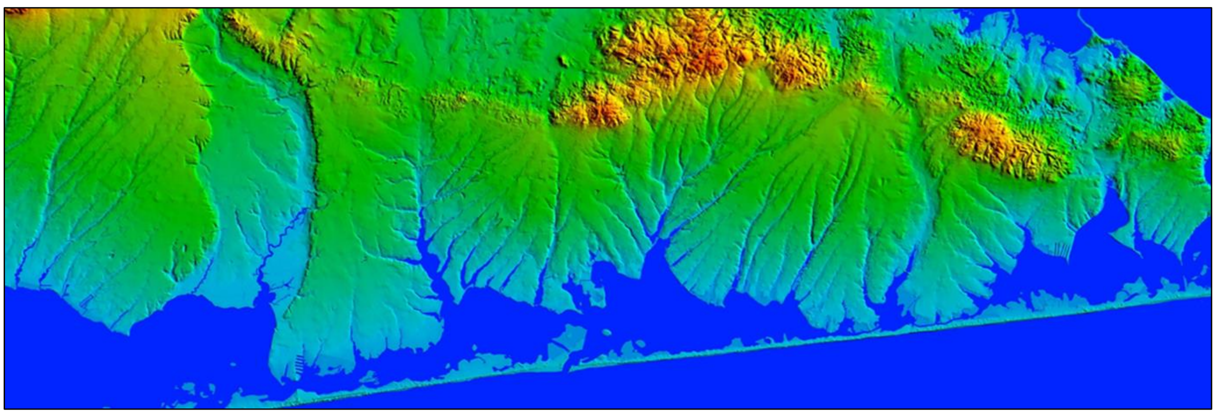

Fig. 3. Drainage pattern of the South Shore of Long Island. Eastern tributaries of the main streams (vent valleys) have parallel drainage patterns, while western side tributaries of these streams have dendritic patterns.

The parallel striation valleys form eastern tributaries of the southward elongated main valleys. These main valleys carried water southward out of the glacier, following a decreasing pressure gradient. Because of their decompressing function, the term vent valley was used. The tributaries of the western sides of the vent valleys formed dendritic rather than parallel patterns. This kind of pattern formed most likely because the direction of the water flow on the western side of the vent valleys did not agree with direction of the moving ice (Fig. 3, 4 and 5).

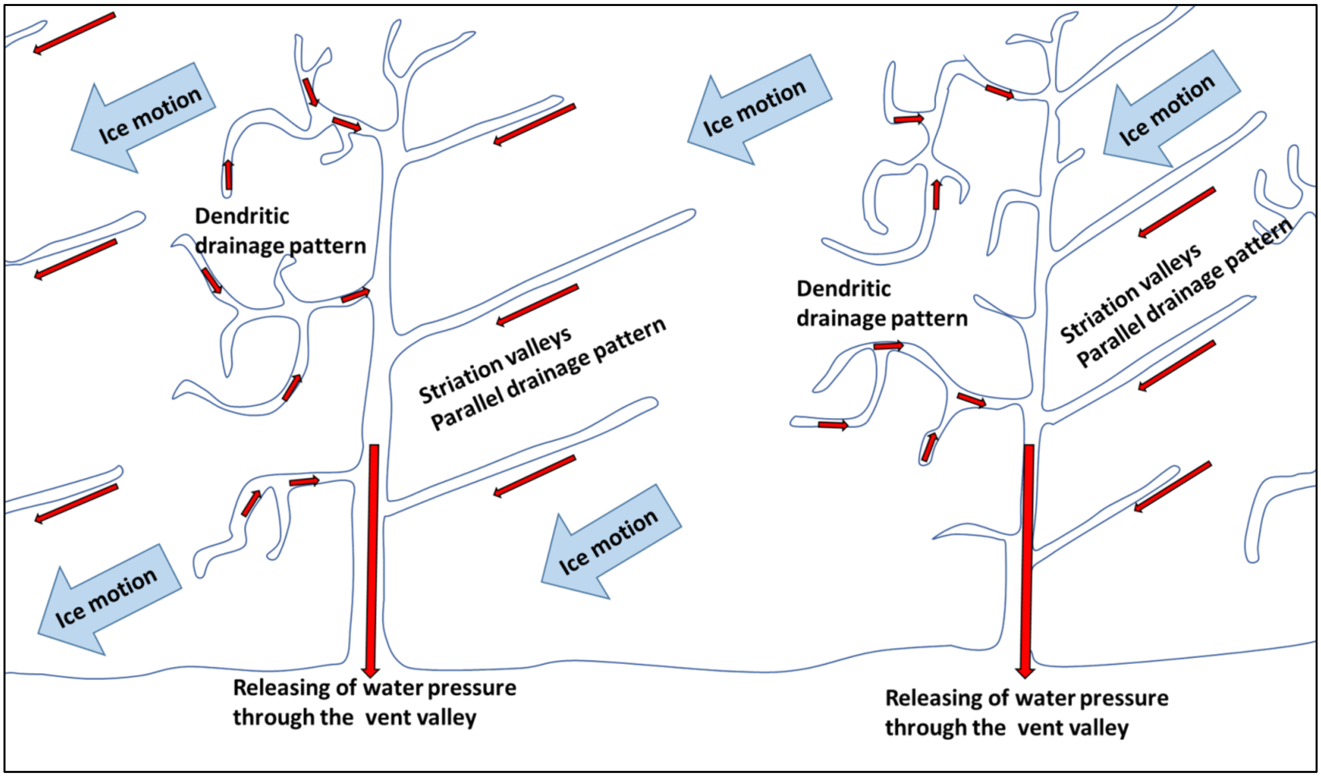

Fig. 4 Schematic illustration which explains the parallel drainage pattern formation on the eastern side of the vent valleys and the dendritic pattern on their western side.

When striation valleys are plotted on the LI map, they show the direction of the glacial ice motion through the South Shore of LI (Fig. 5).

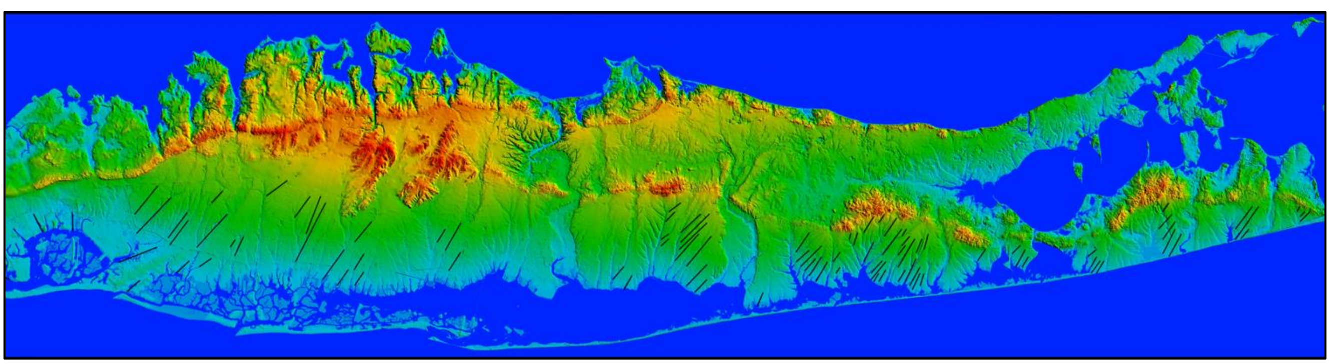

Fig. 5. Digital elevation map of Long Island with black lines indicating striation valleys. The striation valleys show the direction of ice flow through the South Shore of LI.

Vent Valleys and the Estimated Location of the Glacial Terminus of the Laurentide glacier

The South Shore of LI has a uniform geological makeup (sand and gravel). Taking this into consideration, the assumption can be made that vent valleys should form at approximately the same distance from the glacial terminus. The average extension of vent valleys can be measured by calculating the length of vent valleys down to Jamaica Bay, the only location on LI which was free of ice during the last glaciation (Pacholik, 2014). Because the average length of vent valleys was estimated to be 11 miles, the extension of vent valleys 11 miles down into the Great South Bay and the Ocean should yield the approximated location of the glacial terminus (Fig. 6).

Southwest of Long Beach the location of the glacial terminus was established on the basis of the presence of coarse ocean floor sediments (Pacholik, 2014).

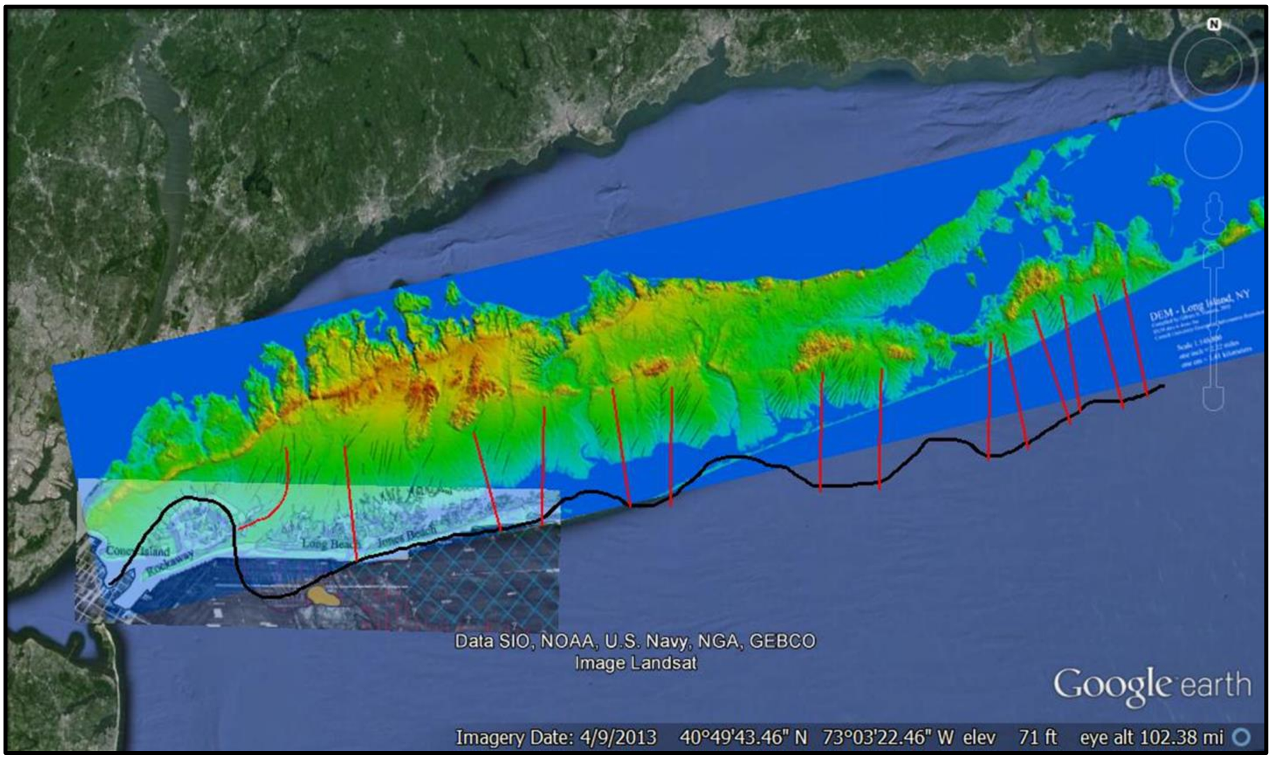

Fig. 6. Approximated position of the terminal moraine from the Laurentide Ice Sheet (black line) estimated on a basis of extended vent valleys (red lines), and SW from Long Beach on the basis of coarse ocean sediment. The map also indicates the striation valleys which show the direction of ice flow through the LI South Shore. Overlay maps: DEM map of Long Island, NY, and the map of ocean sediments SW from Long Beach from Seafloor Characterization Offshore of the New York-New Jersey Metropolitan Area using Sidescan-Sonar, USGS.

Steeper Western Slopes of Vent Valleys

Generally, the western sides of the vent valleys have a steeper slope than their eastern side. This topographical pattern was described by Fuller, 1914.

This geomorphology can be explained by the subglacial erosional and depositional action of ice and water. The drift coming diagonally toward the vent valleys (direction of striation valleys) was getting partially eroded by the stream of water in the vent valley. This action caused the eastern side to be less elevated and gently sloped. On the other hand, the western sides of the valleys were bulldozed by ice, which created a steeper slope (Fig. 7).

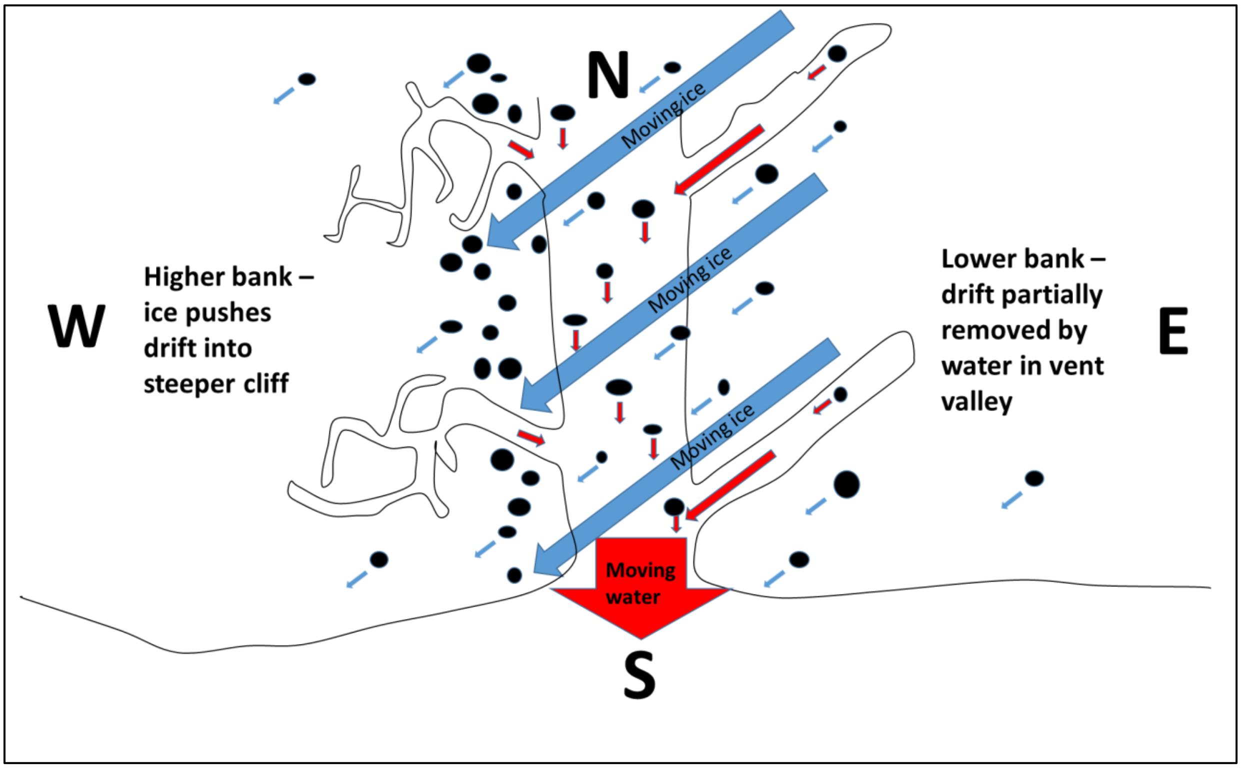

Fig. 7. Schematic illustration of the formation of the steeper western slope of the vent valleys as an effect of the simultaneous action of diagonal bulldozing by ice and the removal of glacial drift on the eastern side of the valley by the stream of water.

Conclusion:

1. The subglacial drainage patterns on LI provide evidence for the sequence of the chronological development of the island's topography.

2. The parallel valleys (striation valleys) of LI can be used to indicate the directions of ice flow through the South Shore of LI.

3. The estimated position of the terminal moraine on LI can be estimated on the basis of the average length of the vent valleys.

4. The steeper western slopes of the vent valleys are the result of a sideways glacial push, while the gentler slopes of the eastern sides are the result of the removal of glacial drift by the water current of the vent valleys.

References

Bennington, J.B., 2003, New observations on the glacial geomorphology of Long Island from a digital elevation model DEM., 10th Conference - Geology of Long Island and Metropolitan New York, vol. 10, URL http://pbisotopes.ess.sunysb.edu.lig/conferences/abstracts/bennington/

Bogaart, P., Tucker, G. and De Vries, J., 2003, Channel network morphology and sediment dynamics under alternating periglacial and temperate regimes: a numerical simulation study, Geomorphology, vol. 54(3), pp. 257–277.

Fuller, M.L., 1914, The Geology of Long Island, New York, USG, Professional Paper 82

Hanson, G.N., 2005, Glacial Geology of the Stony Brook-Setauket-Port Jefferson Area, Report., Stony Brook University, http://pbisotopes.ess.sunysb.edu/reports/dem_2/references.htm

King C., Mion L., Pacholik W., Hanson G, H., Evidence of Till South of Ronkonkoma Moraine, 2003, 10th Conference - Geology of Long Island and Metropolitan New York, URL http://dspace.sunyconnect.suny.edu/bitstream/handle/1951/48074/kingindex.pdf?sequence=1

Pacholik W., Direction of the ice flow through Long Island during maximum extension of Laurentide Ice Sheet, 2014, 21st Conference - Geology of Long Island and Metropolitan New York, URL http://www.geo.sunysb.edu/lig/Conferences/abstracts14/Pacholik-edited.pdf

Pacholik W., Formation of Long Island's North Shore Coastline, 2013, 20th Conference - Geology of Long Island and Metropolitan New York, URL http://www.geo.sunysb.edu/lig/Conferences/abstracts13/4-13-program.htm

Sanders, J.E., and Merguerian, C. M., Evidence for pre-Woodfordian ages of Long Island's terminal moraines, 1995, 2nd Conference - Geology of Long Island and Metropolitan New York, URL https://dspace.sunyconnect.suny.edu/bitstream/handle/1951/48207/SANDER00-95.PDF?sequence=1&isAllowed=y

Sen, S., Hanson, G. N., 2007, Origin and Evolution of Dry Valleys South of Ronkonkoma Moraine, URL
http://www.geo.sunysb.edu/lig/Conferences/abstracts07/abstracts/soma-sen-cmprsd-5.pdf

Sirkin, L., 1996, Western Long Island Geology: History, Processes & Field Trips, Book & Tackle Shop.

Schmitt, K., 2006, More Evidence of Till South of the Ronkonkoma Moraine, 13th Conference - Geology of Long Island and Metropolitan New York, URL
http://pbisotopes.ess.sunysb.edu.lig/conferences/abstracts/

Schwab, W.C., Denny, J.F., Butman, B., Danforth, W.W.,Foster, D.S., Swift, B.A., Lotto, L.L., Allison, M.A., Thieler, E.R., Hill, J.C., 2000, Seafloor Characterization Offshore of the NewYork-New Jersey Metropolitan Area using Sidescan-Sonar, USGS,
http://pubs.usgs.gov/of/2000/of00-295/default.htm

Tvelia, S., 2014, Long Island's Kettle Chains and their Correlation to Ancient Meltwater Channels, URL http://www.geo.sunysb.edu/lig/Conferences/abstracts14/Tvelia.pdf