Long Island Subglacial Drainage Patterns Reveal the Direction of Glacial Flow

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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.

Long Island's Drainage Patterns

The alignment of Long Island's drainage valleys by glacial till points to the subglacial origin of these morphological features. Because of their tunnel valley nature, these valleys carry a potential to reconstruct the direction of the ice movement at the terminus of the Laurentide glacier.

On LI, there are three different drainage systems which developed in different phases of glacial history (Figure 1):

1. The oldest, primary drainage system includes valleys which drained water from the subglacial Long Island Sound region (Fig. 1, nr. 1 valley systems). These types of valleys were extended successively with a southward transgression of the glacier. These were active through all stages of glacial transgression (Roanoke Point Moraine stage, Harbor Hill E of Huntington Moraine stage, Ronkonkoma Moraine stage and Terminal Moraine stage). Using this concept, topographic features cross cut by these valleys are successively younger as we move south. The Nissequogue and Connetquot rivers system (Fig. 1, valley nr. 1c) demonstrate an unchanged example of this type of drainage. Later, the rest of these valleys were covered, south of Harbor Hill Roanoke Point Moraine, by outwash which came out from the subglacial LI Sound basin, after LI was cleared from ice.
2. The secondary drainage system is located on the South Shore (Fig. 1, nr. 2 valley systems). 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 after the formation of the Ronkonkoma Moraine and during the most southern expansion of the glacier.

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

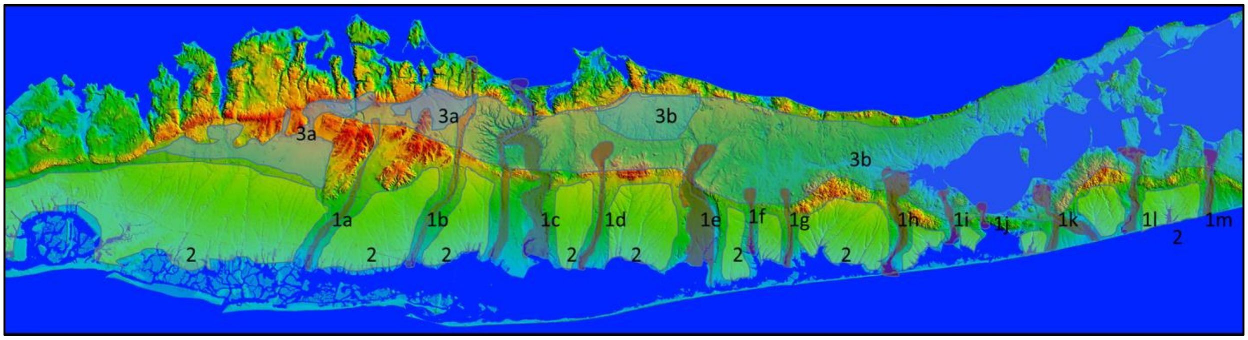

Fig. 1. Two systems of Long Island's drainage patterns, which indicate the sequence of glacial changes: primary valleys (nr. 1), which were continuously extended following a glacial transgression; secondary valleys (nr. 2), which formed during the terminal stage of the glacier; and outwash: 3a – formed 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 older primary valleys are located only east of Huntington. This line of division suggests that the topographic features east of this line are older.

The succession of development of LI topographical feature was established using the following: a sequence of development of subglacial valleys; the location of areas with exposed outwash; and the location of areas covered by exposed till. The chronology observed by the given outlines puts the events for the formation of the topographical features of LI in this order:

1. Formation of Harbor Hill Roanoke Point Moraine section E of Huntington - The primary valleys, which passed this line of moraines later on, were covered by outwash. In the section W of the Nissequogue River (Fig. 1, valley nr. 1c), outwash partially covered the northern sections of these valleys (Fig. 1, valleys 1a and 1b). Northern sections of primary valleys east of this river are completely covered by outwash.
2. Formation of Ronkonkoma Moraine – All of the primary valleys cross cut this moraine.
3. Formation of Harbor Hill Roanoke Point Moraine W of Huntington – There is coverage of the primary valleys with the outwash, possibly existing south of this moraine. Outwash fens cover northern sections of two primary valleys (Fig. 1, valleys 1a and 1b) E of the Nissequogue River (Fig. 1, valley 1c).
4. Glacial transgression S of LI –There is the formation of a secondary drainage pattern on the South Shore of LI, and an anastomosing tunnel valley's system N of the Harbor Hill

Moraine. (This kind of pattern formed when water pressure conditions ware more isotropic – conditions further away from the glacial terminus).

5. The fast retreat of the glacier from LI – The entire Island got covered by a veneer of till, with the exception of areas south of Roanoke Point Moraine.
6. The retreating glacier stops around the Roanoke Point Moraine line. The glacial front receded NW from the point somewhere between the mouth of the Nissequogue River and Crain Neck because the mouth of the Nissequogue River was not covered by outwash, but the outwash covered the northern section of the island E of this location. (starting with the Port Jefferson Fen (Hanson, 2005) and further going E, including the LI Pine Barrens)

The main streams of both the primary and secondary drainage systems generally are parallel to each other. Their orientation suggests that these valleys were positioned perpendicularly to the glacial terminus which insured the fastest way of releasing water pressure.

South Shore Tunnel Valleys – Striation System

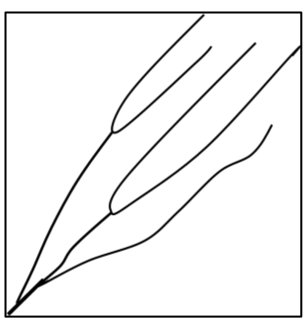

Fig. 2. Example of parallel drainage pattern.

The South Shore drainage system (Fig. 1, nr. 2 drainage system) has a predominantly parallel pattern (Fig. 3, 4). The existence in this region of this type of drainage formation is out of place because the parallel drainage system usually forms on steep uniformly sloping surfaces, or in regions of an outcropping of resistant parallel rock bands, or in an area with a parallel fault system. But these geological predispositions for this kind of formation do not exist on LI.

To produce this kind of pattern, the direction of the moving ice had to follow along the elongation of the parallel valleys. Most likely, the ice forced the water to flow in the same direction as its own. For that reason, the parallel valleys should be interpreted as striation valleys (Fig. 3, 4, and 5).

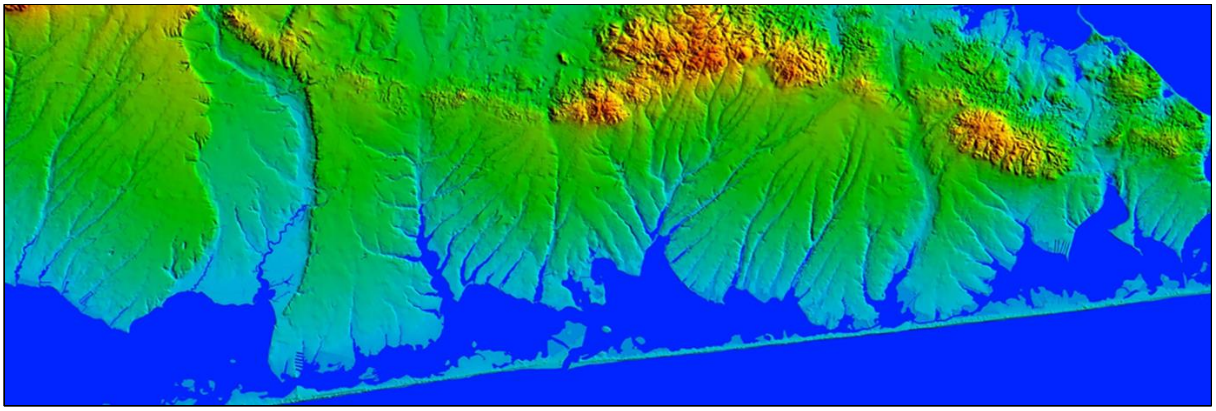

Fig. 3. Drainage pattern of the South Shore of Long Island. Eastern tributaries of the main streams (vent valleys) have parallel drainage patterns, while western side tributaries of these streams have dendritic patterns.

The parallel striation valleys exist as tributaries of the eastern side of the main valleys. The 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).

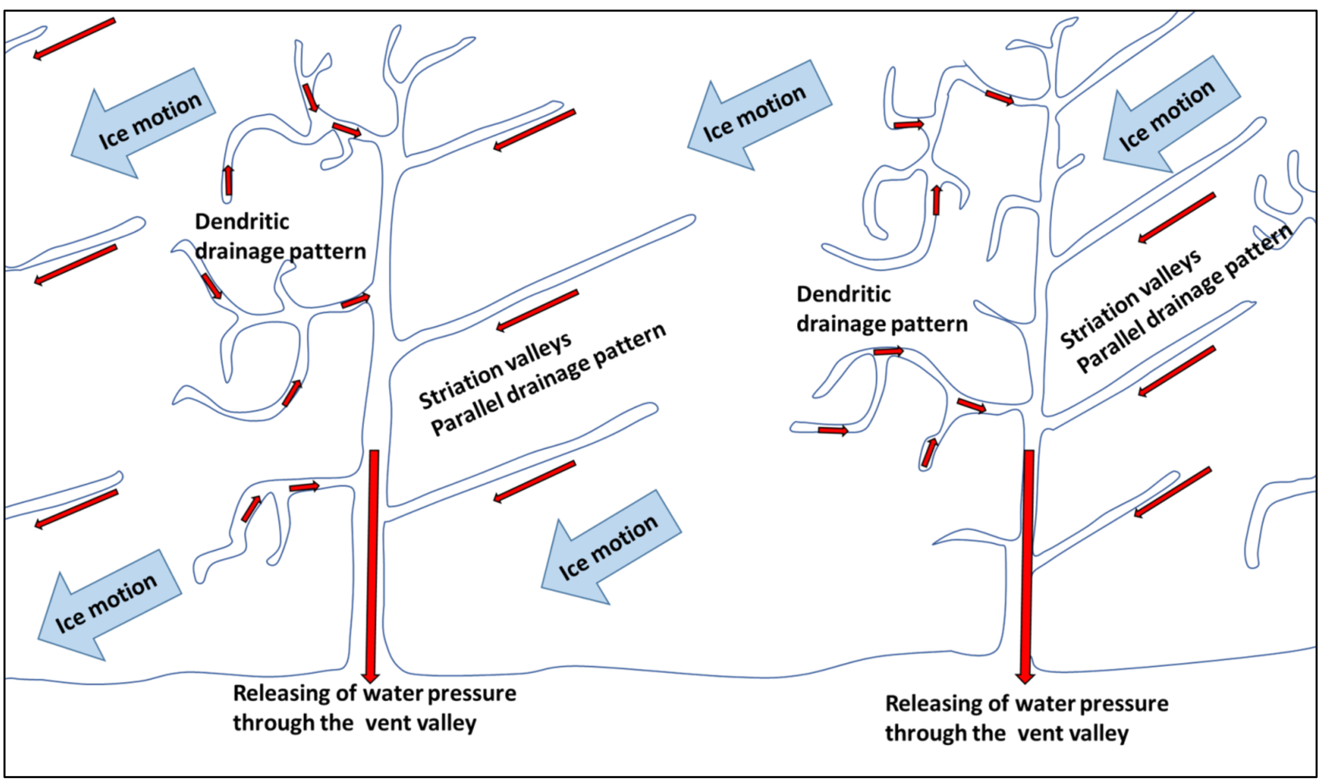

Fig. 4 Schematic illustration which explains the parallel drainage pattern formation on the eastern side of the vent valleys and the dendritic pattern on their western side.

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).

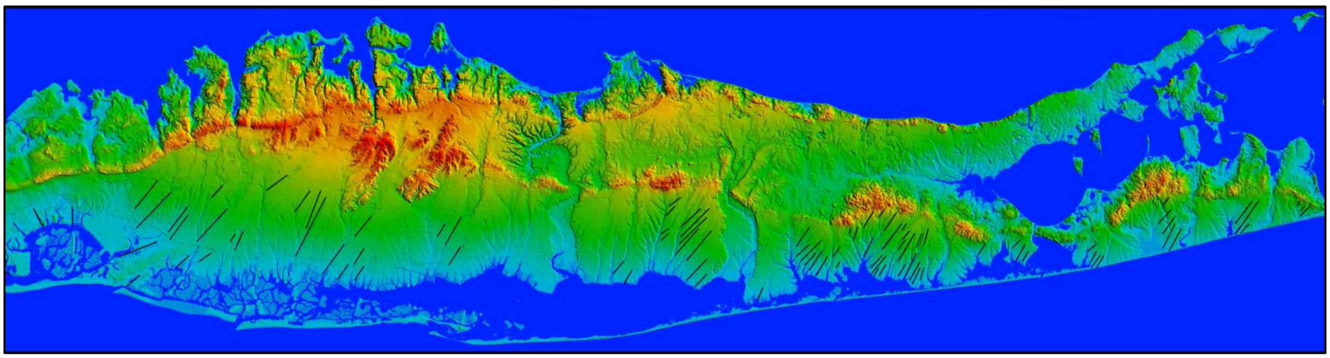

Fig. 5. Digital elevation map of Long Island with black lines indicating striation valleys. The striation valleys show the direction of ice flow through the South Shore of LI.

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).

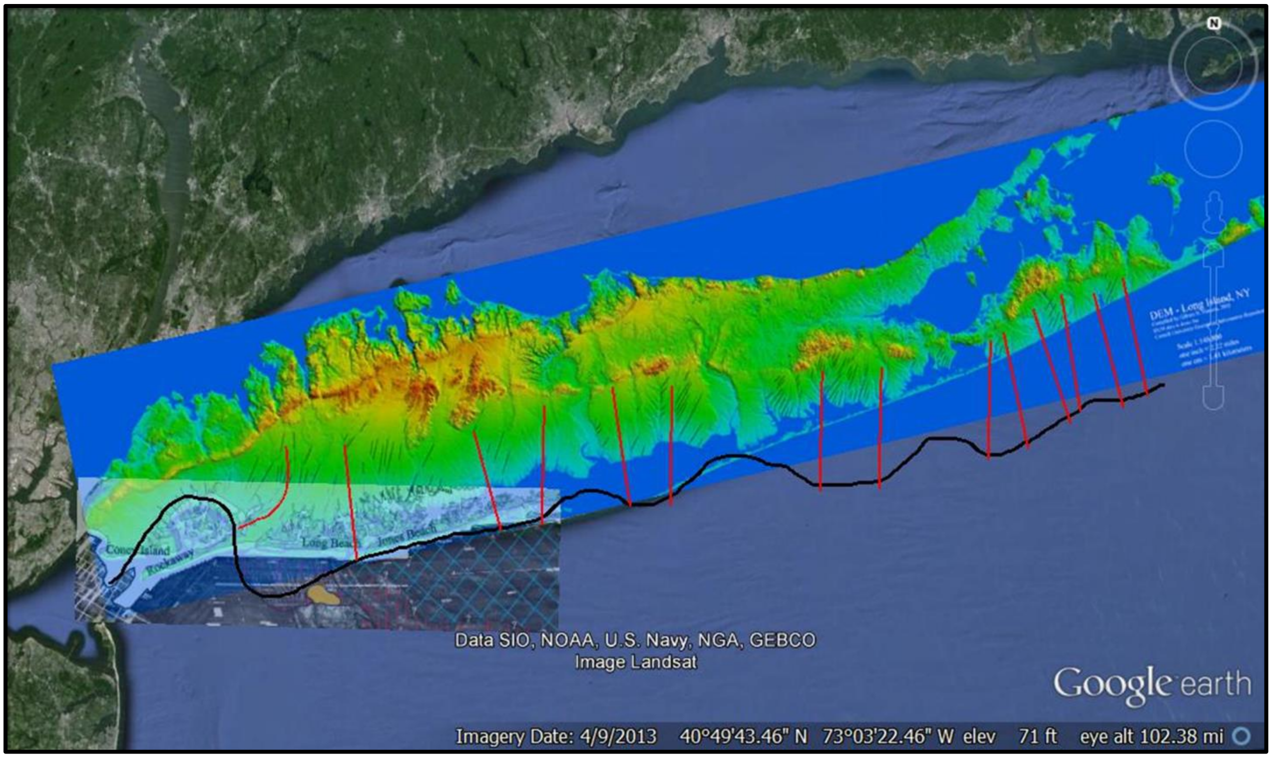

Fig. 6. Approximated position of the terminal moraine from the Laurentide Ice Sheet (black line) estimated on a basis of extended vent valleys (red lines), and SW from Long Beach on the basis of coarse ocean sediment. The map also indicates the striation valleys which show the direction of ice flow through 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 side of 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 system 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).

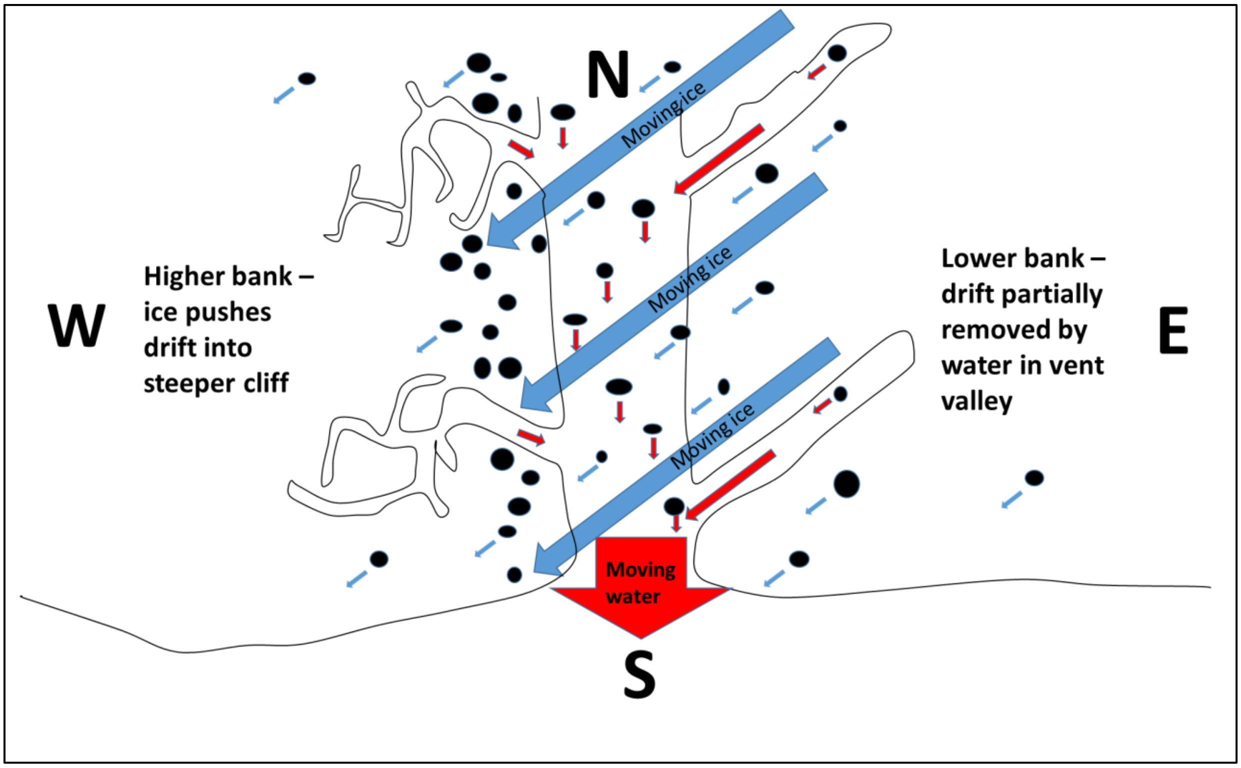

Fig. 7. Schematic illustration of the formation of the steeper western slope of the vent valleys as an effect of the simultaneous action of diagonal bulldozing by ice and the removal of glacial drift on the eastern side of the valley by the stream of water.

Conclusion:

1. The subglacial drainage patterns on LI provide evidence for the sequence of the chronological development of the island's topography.
2. The meltdown of ice on LI occurred at a fast rate.
3. The parallel valleys (striation valleys) of LI can be used to indicate the directions of ice flow through the South Shore of LI.
4. The position of the terminal moraine on LI can be estimated on the basis of the average length of the vent valleys.
5. 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.

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