Port Jefferson Geomorphology

By Danielle Mulch, Gilbert N. Hanson

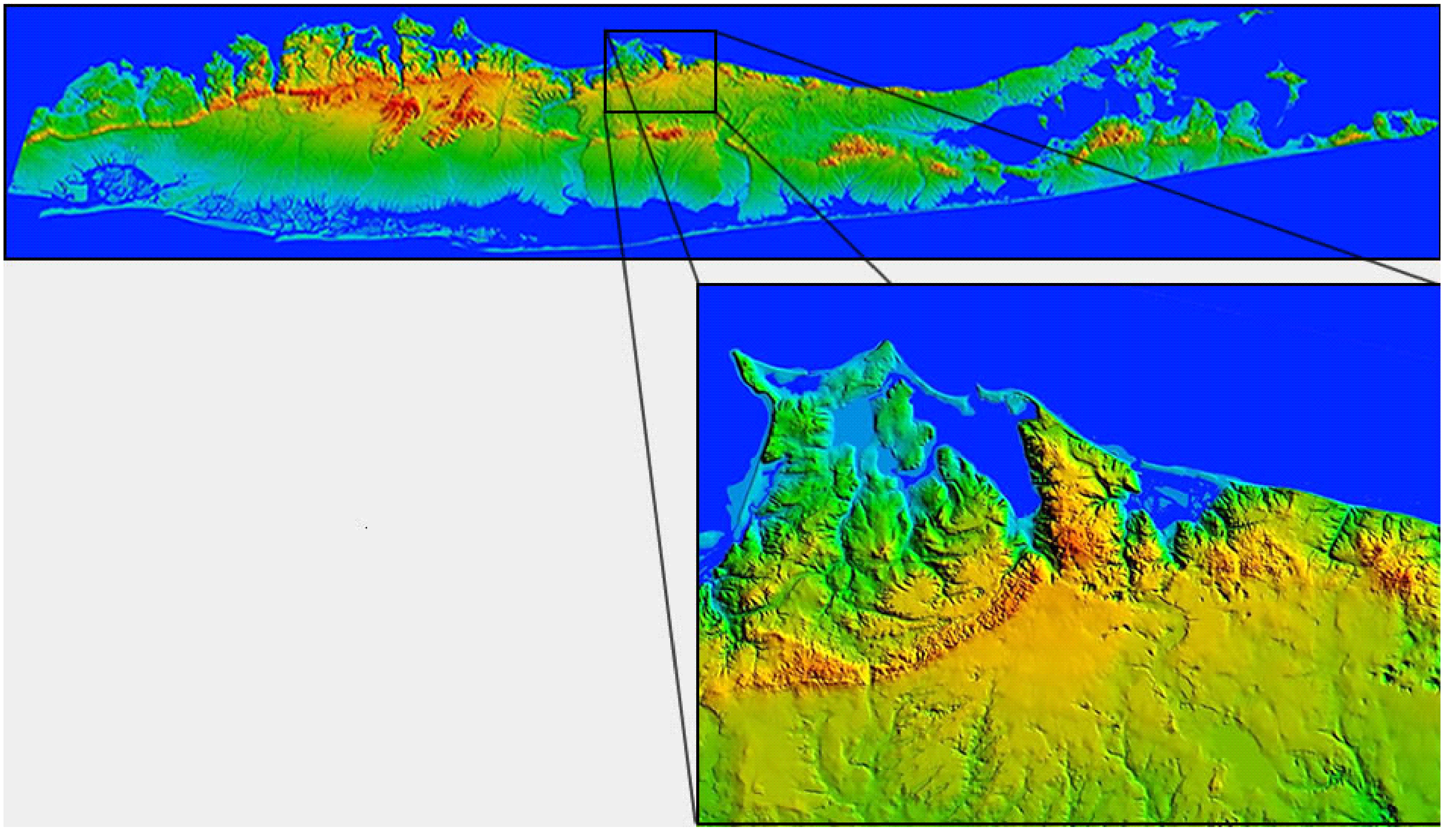


Figure 1 (Above)A DEM of Long Island with a close-up of the Port Jefferson Valley and Outwash Plain. Adapted from Gilbert Hanson's DEM.

Abstract

Research was conducted in the Port Jefferson region to determine the origin of the harbor itself as well as the gentle sloping plain that begins in Port Jefferson Station and slopes southward past the LIE. Surficial analysis and corroborating evidence (including past research, mapping projects and well logs) strongly indicate that Port Jefferson was formed during the late Wisconsinan, specifically, that the Port Jefferson valley, including the harbor, is the remnant of a tunnel valley fed by a subglacial lake and that Port Jefferson Station and south is the resulting outwash fan from a catastrophic subglacial discharge. The research strongly supports the initial hypothesis that the origin of Port Jefferson Harbor was incisement by a tunnel valley into the Harbor Hill moraine. Research also strongly supports the catastrophic deposition of the outwash fan. However, the research does raise significant questions that require further study. Two important questions are: *What is the stratigraphy and depositional history within the harbor, which is a buried tunnel valley?* and *What is the nature of Grim's Trench (if it exists) just north of the harbor and how does it interact with the buried tunnel valley?*

Introduction

In this paper, we propose that Port Jefferson valley is a tunnel valley created during the Wisconsinan. This valley cuts the Harbor Hill moraine. We also propose that the fan shaped feature immediately south of the valley is in fact a related alluvial fan that was deposited catastrophically when the sediment-rich water left the tunnel valley and lost energy abruptly. First we assured that the area of study was constrained by other identifiable Wisconsinan formations. Second we explored the details surrounding the catastrophic event and attempted to identify which geological features contributed to the event.

An extensive study of the Long Island area was conducted by Fuller, 1914. He identified several kettle holes in the Port Jefferson region and asserted that the alluvial fan rested on glacial ice. Since that period, seismic studies including Grim, et al, 1970, Lewis and Stone, 1991, geological studies including Sirkin, 1982, Hanson, 2000, Pacholik and Hanson, 2001, and Kundic and Hanson, 2004 and well logs have become available to help define the details of the event and to connect the event to other local geological features.

Methods

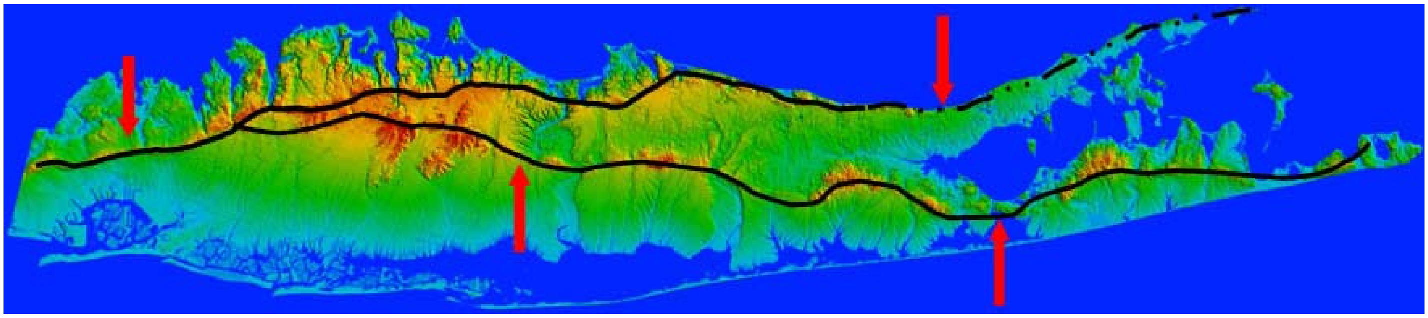
Geomorphic analysis was conducted using USGS topographic maps and a DEM of Long Island compiled by G. Hanson (personal communication.

Second, historical evidence was sought to: assure that surficial features were in fact of geological origin and not significantly altered by anthropogenic events or actions, and confirm the glacial origin of the area.

Next, corroborating geological evidence was sought to test the tunnel valley hypothesis. Geological evidence includes the study of well logs and a geological investigation of the Port Jefferson area including boulder analysis and a search for glaciotectonically thrusted Cretaceous sediment.

Finally we sought to compare geological evidence found in the field to both our geomorphic analysis as well as the current scientific understandings of tunnel valley formation and current scientific observations of the area.

Figure 2 (Below) A DEM showing the moraines. Arrows pointing down show the Harbor Hill Moraine. Arrows pointing up show the Ronkonkoma Moraine.



Results: Surficial Analysis

Surficial analysis of the Port Jefferson valley helped to place many constraints on the glacial event that created Port Jefferson. First, Port Jefferson lies on the northern edge of the Harbor Hill Moraine indicating that its formation can be constrained to the time period associated with the formation of the Harbor Hill Moraine during the last glacial maximum. **Figure 2**

Second, the Port Jefferson valley actually cuts the Harbor Hill Moraine indicating that the valley was formed after the development of the moraine. **Figure 3**

Third, the walls of the harbor and valley are incredibly steep and have the shape of a nozzle pointed south.

Fourth, a close inspection of the Harbor Hill Moraine in the Port Jefferson area indicates that the area is composed of three moraine sections: a gently arcing section running west through Stony Brook called the Stony Brook Moraine by Sirkin,1982, (black dashed arrow) a relatively straight section extending east toward Riverhead called the Roanoke Point Moraine by Sirkin,1982 (black outlined arrow) and a small north-south interlobate moraine (red arrow) on the east side of the village and including Mount Misery.**Figure 4**

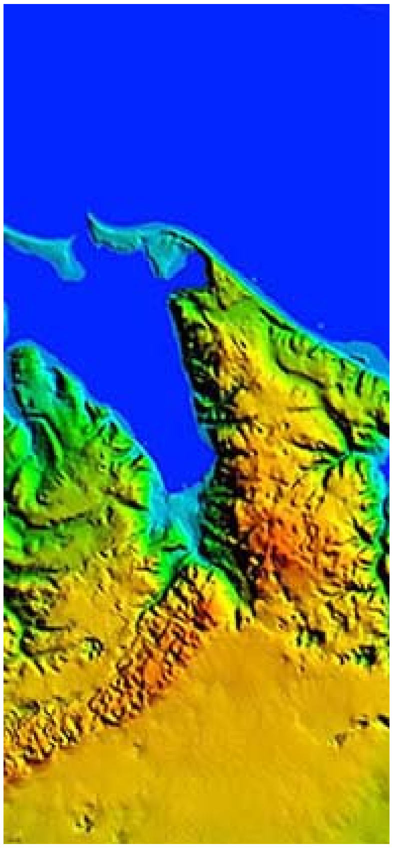
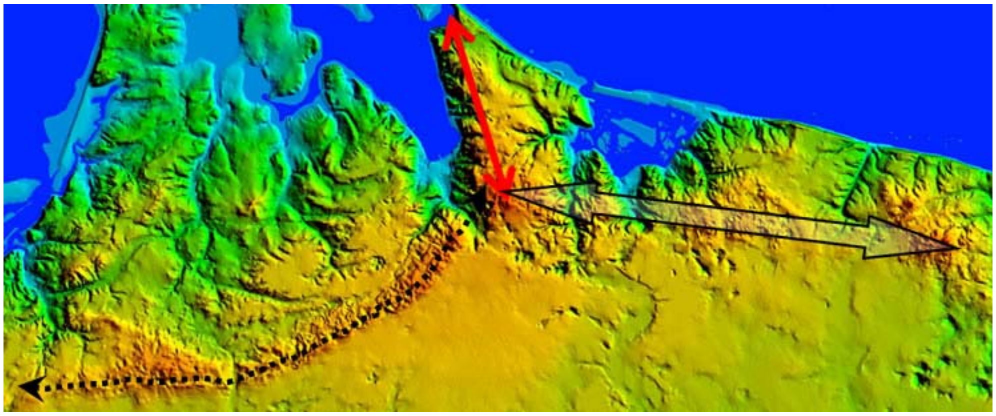


Figure 3 (Left) showing the tunnel valley cutting through the moraine

Figure 4 (Below) Showing the three distinct parts of the Harbor Hill Moraine that define the Port Jefferson Area. The interlobate moraine is incredibly small and may represent a local environmental change rather than an ice sheet lobe.(*e.g.* The ice sheet is like to have made contact with the Long Island Sound basin at different speeds causing a localized separation of a larger lobe). The interlobate moraine may have previously extended to the north and may have been eroded by Lake Connecticut or erosion could be associated with eventual sea level rise.



Sirkin, 1982, asserts that the Harbor Hill Moraine is west of the Stony Brook, that the arcuate moraine between Port Jefferson and Stony Brook is the Stony Brook Moraine and the moraine east of Port Jefferson is the Roanoke Point Moraine. His reasoning is based on comparison of tills and glacial formations within sections of the North shore highland. Others accept that the Harbor Hill moraine is the entire northern moraine on Long Island

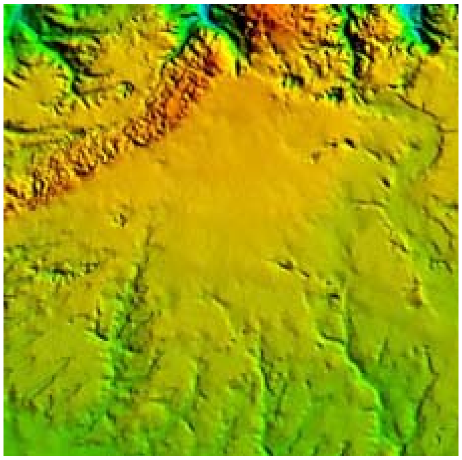


Figure 5 (Above) note that on the east side the outwash plain is distinct from the moraine and thins in a fan shape to the south east.

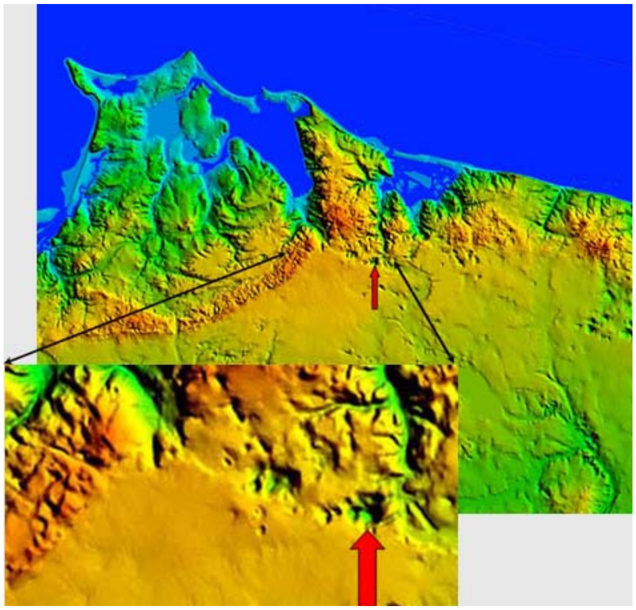
Figure 6 (Below) Note the large kettle hole- the event had to be completed before the ice chunk melted.

Geomorphic analysis of the outwash fan constrains the relative timing of the tunnel valley and alluvial fan event as well as the nature of the discharge.

The timing of the event is first constrained by the cross-cutting relationships between the outwash fan and the Harbor Hill Moraine. The western edge laps onto the Stony Brook moraine indicating that the moraine was there prior to the event. On the eastern edge, the fan/moraine contact is marked by several kettle holes and is the same height as or higher than the top of the Roanoke Point moraine. This indicates that the outwash fan was deposited against the ice or the Roanoke Point moraine. In fact, Fuller, 1914, asserts that the alluvial fan lapped up against the ice and overlies the moraine. **Figure 5**

The timing of the event is further constrained by a significant kettle hole located on the eastern side of the outwash plain. The kettle hole is 30m. deep indicating that a large chunk of ice was surrounded by at least 30m. of sediment and could have been buried altogether by outwash (Kundic et al., 2003). As the kettle hole is beyond the Harbor Hill Moraine the ice chunk had to be ripped from the glacier and deposited beyond the moraine. Both the amount of sediment and the size of the ice chunk indicate a large-scale event. **Figure 6**

Thus, the outwash fan was created after the development of the moraine sections and while the glacial ice was still present.



Many other tunnel valleys are found on Long Island north of the front of the Harbor Hill Moraine. Generally, these valleys extend onto the outwash plain as meandering valleys south of the moraine. This would indicate that the sediment load carried in the Port Jefferson event was significantly greater than the sediment load associated with other tunnel valley events. **Figure 7**

Tunnel valleys that travel englacially act to only drain water stored above or within the glacier and will have a much smaller sediment load than a tunnel valley that has a water source at the base of the glacier. Till and sediment at or near the base of the glacier will carried through the tunnel valley along with the water.

While Port Jefferson tunnel valley is different from other tunnel valleys on Long Island in that it has an alluvial fan at its mouth, it remains a prime example of a tunnel valley according to this description from Benn and Evans, 1998: "Further evidence for a subglacial origin is the tendency for tunnel valleys to terminate abruptly at major moraines, where they may grade into large subaerial ice-contact fans (p.333)".

The extensive outwash Fan implies a sediment-rich sub-glacial stream

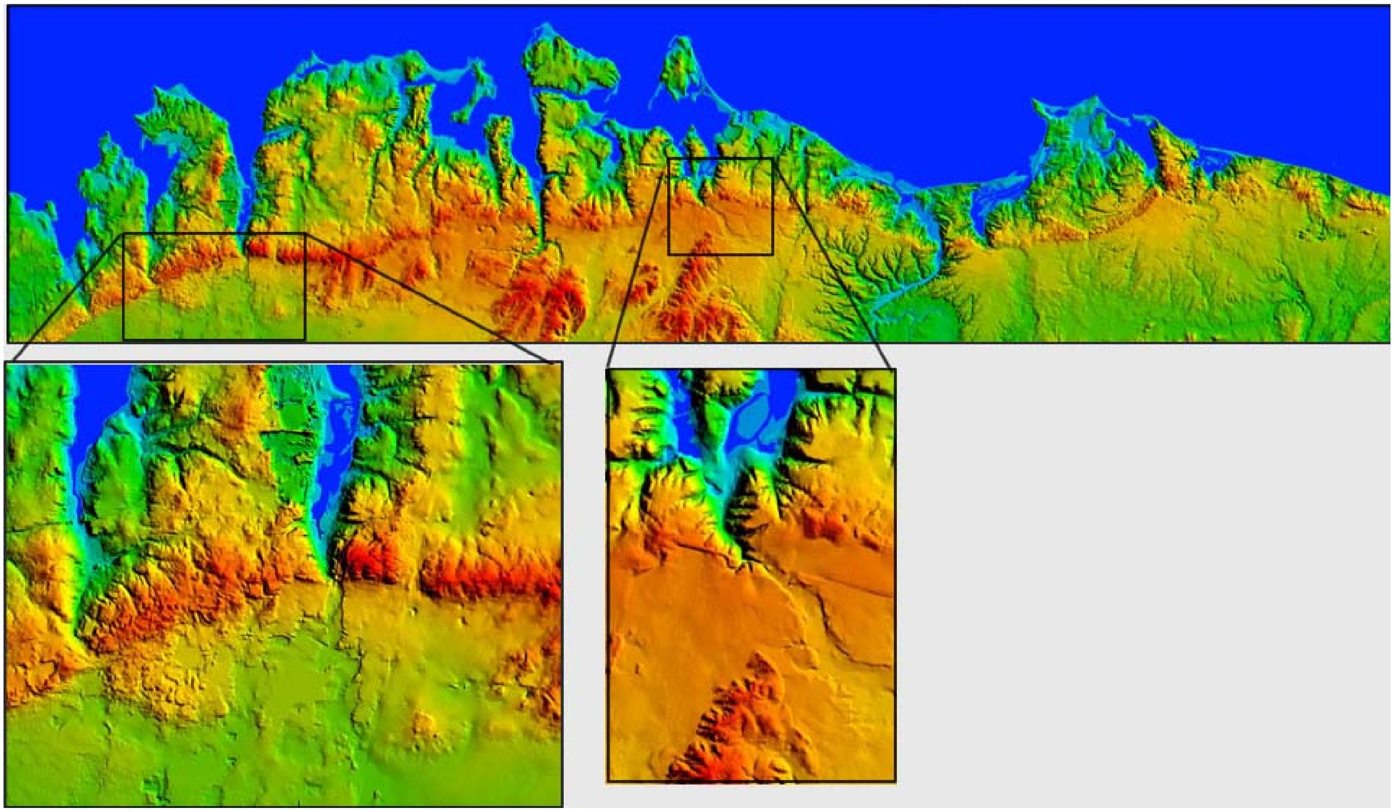


Figure 7 (Above) A close up inspection of other tunnel valleys on Long Island shows that many of them exhibit an eroded channel in the outwash plain south of the moraine.

Results Historical Evidence

Based on information available at the Mather House, the home of the Port Jefferson Historical Society, all anthropogenic alterations to the area are surficial and small scale. A possible kettle hole within the valley was filled in, the harbor has been dredged several times, the southern most tip of the harbor was filled and continues to be built up, there was a small sand mine at the northern tip of Mt. Misery and there were small brick making operations on the north west side of the valley. While there are alterations associated with development, the general shape of the valley and fan has not been disturbed. Most importantly, the kettle holes observed on the DEM are in fact kettle holes and not mine pits or some other anthropogenic artifact.

Results Corroborating Evidence

Based on the surficial analysis, there are several questions that need to be answered and a great deal of evidence that needs to be corroborated. First, there should be evidence within the Port Jefferson valley that a rapid expulsion of water occurred. As it is just as likely that the kettle hole was formed over an extended period from minor flood events since an ice chunk of this size is capable of existing in the permafrost region just beyond the ice sheet for a long time. Kundic et al's, 2003, hypothesis is that the ice remained in this kettle hole well beyond the draining of Lake Connecticut (15,500 calendar years ago, Kundic et al, 2003)and until permafrost left the region (14,000 calendar years ago, Kundic and Hanson, 2004) as it did not trap a large amount of loess and had to still contain ice through the time period that loess was deposited on Long Island.

The well logs in Fig. 8 were recorded respectively in 1947 (#2) and 1955 (#3). Both well logs are from the central harbor area just north of West Broadway at the Suffolk County Water Authority office . Respectively, they are 100 feet and 90 feet deep and the ground elevations are near sea level. The coarse sediments described in these well logs are filling in the tunnel valley. Diagonal hash layers represent clay. The topmost clay layer in #2 is actually an organic rich bog material and the topmost layer in #3 is cinder fill and sand/gravel. The shapes show the relative size of the largest material pulled from the bore hole. The largest material is 9 inch cobbles and the smallest material is 1 inch pebbles. The matrix is coarse sand and gravel. The bottom-most section up to and including the lowest clay layer (lowest green line) a thickness of 60 to 64 ft. consists of poorly sorted coarse gravel, fining upward. The first clay layer at the to (some 30 feet below sea level, lowest green line) was probably deposited in standing water.

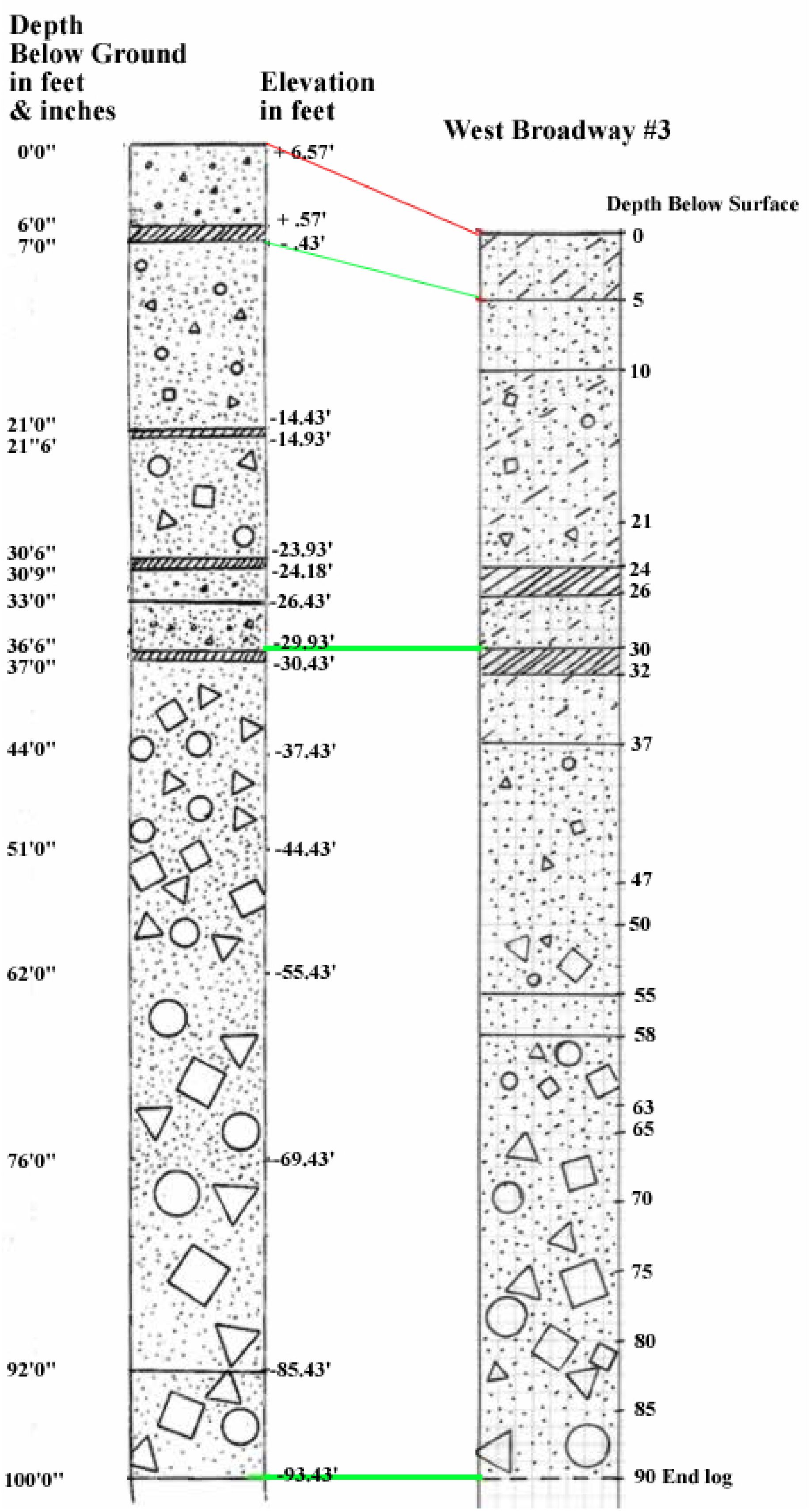


Figure 8 SCWA Logs of Broadway #2 Well on left and #3 Well on right

One scenario is that as the flow of the sub-glacial stream abated, more than 60 feet of coarse gravel was deposited rapidly. Between the lowest clay layer and the upper bog layer are a series of unknown events. These layers could represent later flow events, basal/lodgment till or thrust sheets of related or unrelated material. Most likely, the mid layers represent reworking of glacial material through a series of colluvial and alluvial events. The bog layer (red line) represents modern deposition. When the first settlers came to Port Jefferson, the area where these wells were drilled was a tidally controlled wetland. **Figure 8**

It should be noted that these deposits have the possibility of being time transgressive. Benn and Evans, 1998, submit that tunnel valleys forming over sediment may have a much smaller conduit than the size of the valley and that this conduit moves across the surface of the valley excavating and possibly infilling as it moves (p.335). The well logs may represent a specific period of infilling of the conduit and not the infilling of the entire valley.

To determine the origin of the sediment load the size of the outwash fan and the amount of sediment needs to be ascertained and compared to the valley itself. If the fan is merely the reorganization of moraine material from the Port Jefferson valley then the fan does not necessarily express a catastrophic event. From a previous study by G.N. Hanson, the outwash fan is measured from the DEM information:

"The elevation of the Port Jefferson Fan at the mouth of the fan is about 200 feet. The elevation on the outwash fan is about 100 feet. The radius of the fan is about 5 miles and consists of about 1/3 (120 degrees) of a cone. In the metric system this is 1/3 of a cone 30 meters high with a radius of 8000 meters and has a volume of about 640 million cubic meters. Port Jefferson Harbor is a trapezohedron about 750 meters wide on the south end, 1,600 meters wide on the north end and has a length of about 3,000 meters. This trapezohedron has an area of about one million square meters. The elevation of the surrounding area north and west of the moraine assuming that it does not include much of the moraine has an elevation of about 50 meters or less. The present depth of the harbor is mainly less than 10 meters, but probably contains significant post glacial fill. The volume of material removed from the harbor area is thus about 60 meters times one million square meters or 60 million cubic meters. This volume of material removed to produce the present Port Jefferson Harbor is about one-tenth that of the Port Jefferson Fan. Thus, it should be expected that the harbor was excavated to a greater depth and that the tunnel valley extends into Long Island Sound (Hanson, 2000)."

Hanson's DEM derived estimate makes two important points. First, the valley incision as we see it today, represents one tenth of the material found on the outwash fan. Second, that we should expect that the filled tunnel valley extends out into the sound.

Tunnel valley evidence is generally evidence of incisement of lower material which is then covered in a blanket of till. The blanket of till being the evidence that the incisement occurred prior to recession of the glacier. In the case of Long Island Sound, Cretaceous sediment should be incised and covered with till and then by other glacially related deposits. A good example of Cretaceous incisement is shown the tunnel valleys from Little Neck Harbor to Hempstead Harbor. **Figure 9**

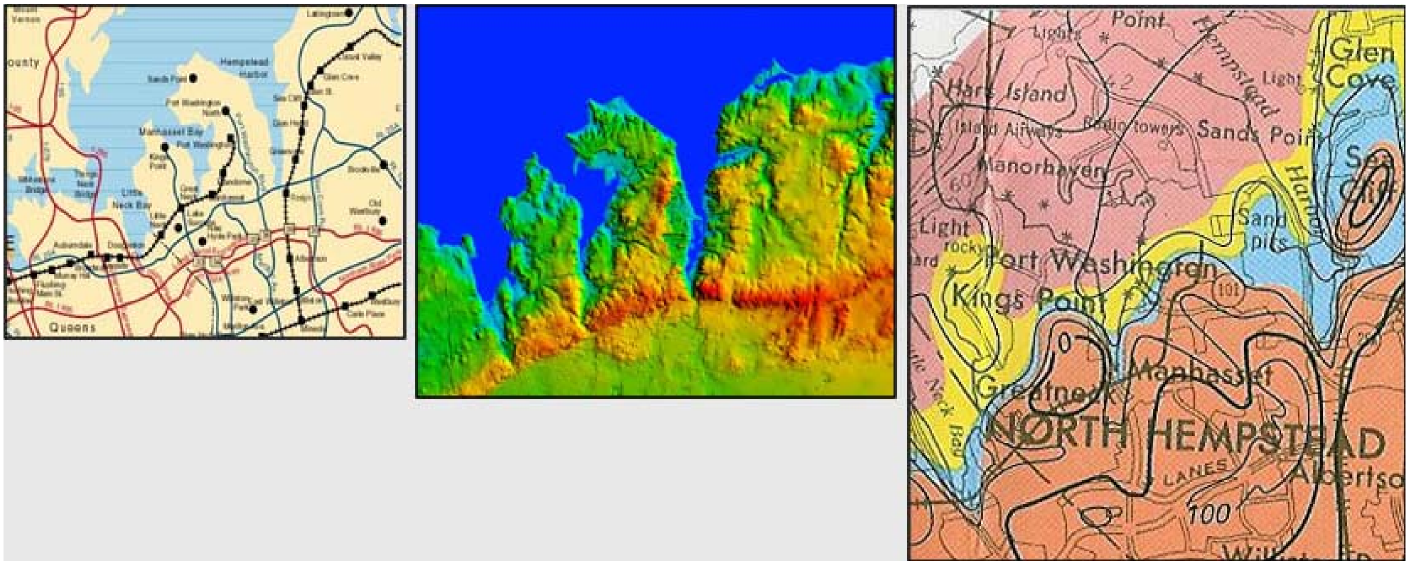


Figure 9 (Above Left, Middle and Right) The three images all depict Little Neck Harbor, Manhasset Bay and Hempstead Harbor.

The image on the right depicts the upper surface of subcrops of Cretaceous deposits and bedrock. The red on the south is the Magothy aquifer. The blue is the Raritan clay. The yellow is the Lloyd aquifer. The pink to the north is the pre-Cretaceous bedrock. The U-shaped intrusions into each of the bays represents incisement. Map adapted from Smolensky, Buxton and Shernoff, 1989.

Road map: http://www.island-metro.com/lodging/nassau.html

Oddly, they show no incisement related to the Port Jefferson tunnel valley. **Figure 10**

In **Figure 10** there are no U-shaped incisements running up to the valley. If there is no buried tunnel valley extending into Long Island Sound, what is the source of the sediment that formed the outwash fan?

It must be noted that the West Broadway wells (**Figure 8**) indicate an incisement of at least 93 feet below the surface (at the southern harbor shoreline) and that there are no deeper wells in the area or any seismic studies in Port Jefferson Harbor or north of the harbor into Long Island Sound Further. So while Smolensky et al, 1989, do not show any incisement, more data are needed to verify the extent of incisement in the Port Jefferson area.

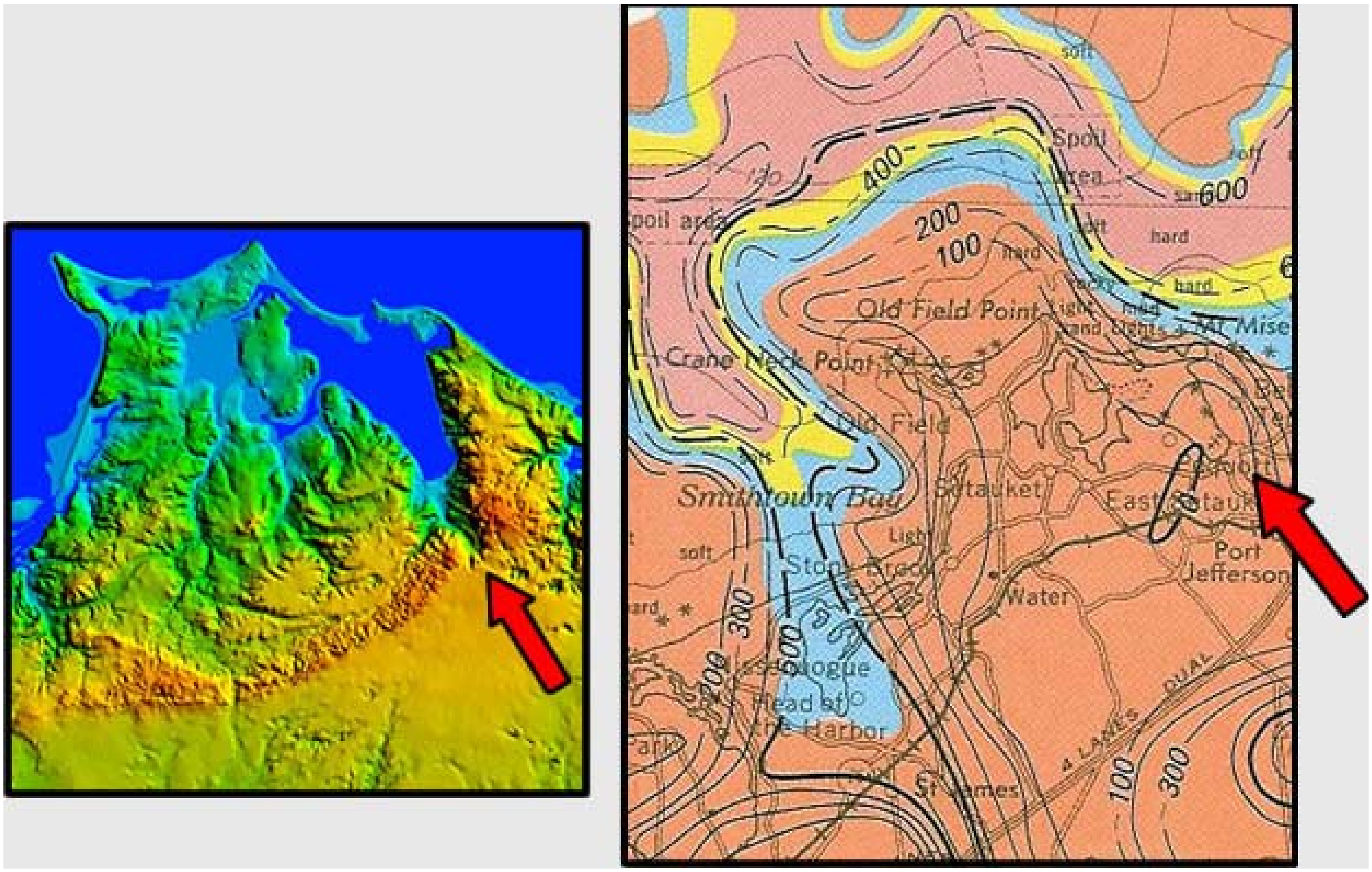


Figure 10 (Above Left and Right) DEM and The image on the right depicts the upper surface of subcrops of Cretaceous deposits and bedrock. The red to the south is the Magothy aquifer. The blue is the Raritan clay. The yellow is the Lloyd Sand. The pink to the north is the pre-Cretaceous bedrock. The U-shaped patterns into Stony Brook Harbor and Smithtown Bay shows comparative incisement. Port Jefferson Harbor does not show incisement. Map adapted from Smolensky, et al, 1989. Arrows mark the southern tip of the Port Jefferson valley. The pink band running generally East-west is "Grim's trench" and is more than 600 ft deep and a mile wide north of Port Jefferson.

Smolensky, et al, 1989 provide a cross section of the Port Jefferson area based on well logs. **Figure 11**

The cross section shows a trench in Long Island Sound filled with glacial sediments (UG) and cuts through the Cretaceous sediments (M: Magothy Formation, Rc: Raritan clay, L: Lloyd Sand) to the basement rocks (Br) There is also a glacial sediment filled trench south of Port Jefferson. Both trenches approach -600 feet below sea level and each trench lies just north of either the Harbor Hill or Ronkonkoma moraines.

The trench in Long Island Sound was first noted by Grim et al, 1970 based on a seismic survey of Long Island Sound. The trench does not appear in either the maps or the text of Lewis and Stone, 1991. This would indicate that there are some lingering questions about the existence of or the nature of Grim's trench.

Grim et al, 1970, made the following observations.

"The Channel is easily followed (west until 72degrees 40 minutes W., quotes mine) from 73 degrees 20 minutes W., where depths of over 700 ft are attained. It is generally more than 600 ft deep and reaches maximum depths of more than -800ft. The channel parallels the north shore of Long Island and is found very close to it. It has the characteristics of a glacial channel, steep sides, a U-shaped cross section, and a series of steps and basins along its profile.

Unlike the area west of 73 degrees 20 minutes W., and with the exception of two large channels corresponding to the Nissequogue River and Stony Brook Harbor, the steep southern wall of the buried channel in this area is conspicuously lacking in large indentations. This area has, at present, a straight unindented shoreline (p. 660-662)."

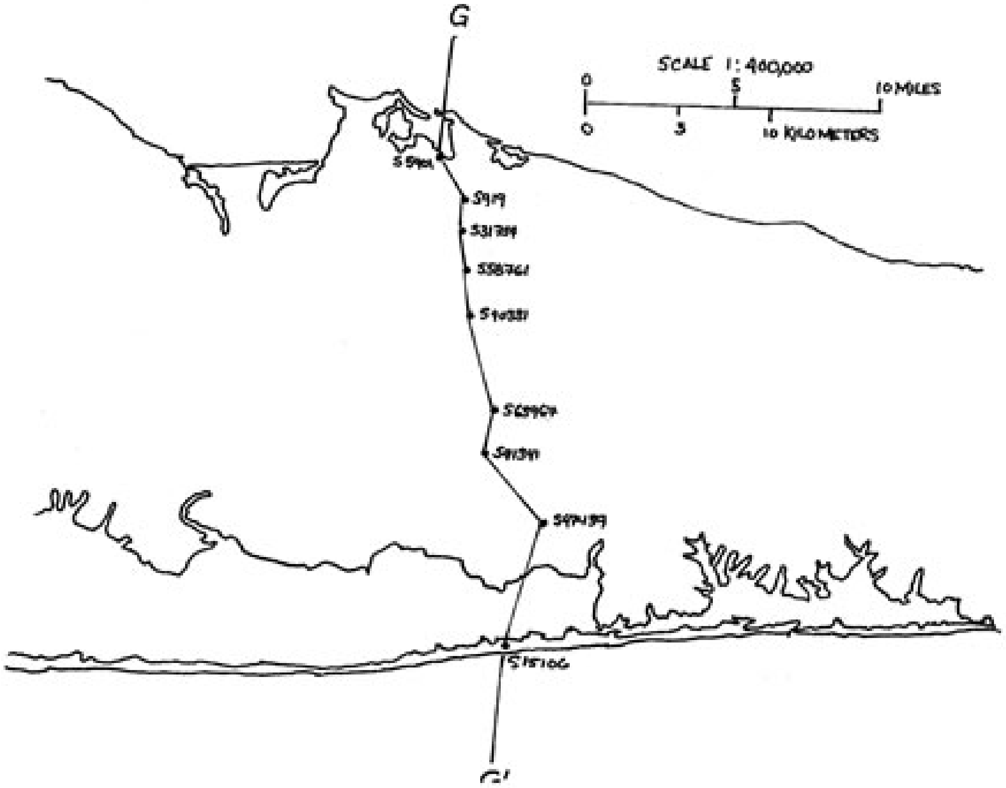
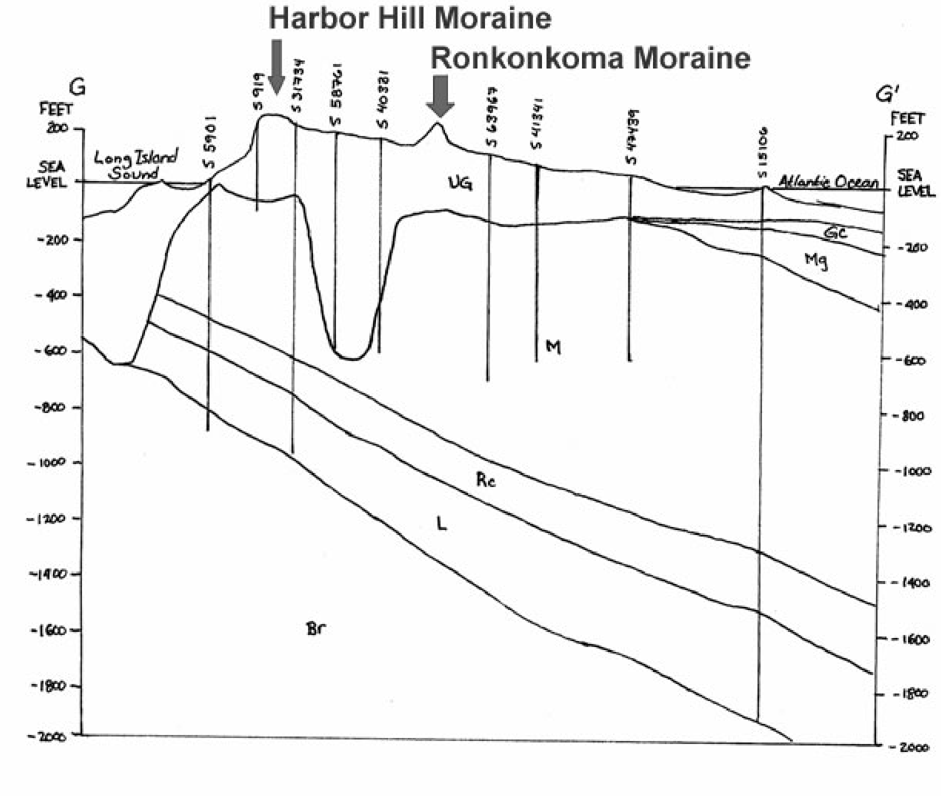


Figure 11(Above and Below) G-G' represents a cross section from Port Jefferson (G) to the Atlantic Ocean(G') using well logs. Map adapted from Smolensky, et al, 1989. Vertical Exaggeration in Cross Section



There is some supporting evidence within Port Jefferson for the glaciotectonic excavation of the trench described by Grim et al, 1970. The trench is supported by both boulders and well logs.

According to the research done by Waldemar Patcholik, 2001, locally quarried boulders need to be large and have angular shapes. Therefore, a search was conducted in Port Jefferson valley for the largest boulders still partially sunk into the ground (implying that they are where the glacier left them). Three boulders match Pacholik's description. **(See Figures 12, 13, 14)** Surprisingly, all three boulders were pegmatitic granitic gneisses where the pegmatites were of potassium and plagioclase feldspars. They fit well Pacholik's 2001 description of rocks in the Avalonian terrane.

Figure 12 (Left) The largest boulder found in the Port Jefferson valley. Larger than a 15 passenger van, this boulder exhibits Avalonian characteristics. Roundness could not be measured as the boulder was cut on all faces. Close up of K-spar pegmatite.

Figure 13 (Right) Located in the next lot over from Figure 12, this boulder showed potassium feldspar pegmatites and was elongate into the photograph. The boulder from Figure 12 can be seen in the background.

Figure 14 (Below) The boulder is obviously elongate into the photo and on the x-axis. Fractures are very evident. The vertical fracture is located streetside on the back fifth of the boulder and is partially visible in the original photograph. Close up on K-spar pegmatite with a fine grained matrix.

Edwards et al, 2004, determined a cosmogenic age for the boulder in ***Figure 12*** *(710 Main Street, Port Jefferson, LI) to be 16.9 ± 2.2 kyr (calendar years). The cosmogenic age based on the interaction between cosmic rays and the atoms at the surface of the boulder gives the time that the boulder was exposed to cosmic rays. This age suggests that the boulder was covered for several thousands of years after the glaciers retreated from Long Island some 22,000 calendar years ago (Kundic and Hanson, 2004).*

Grim's trench may also explain the tremendous boulders in the Port Jefferson area and probably, along the entire mid-section of the north shore. Many of the boulders are too large to have traveled far within the basal region of the glacier. Grim's trench provides ample plucking grounds close to the eventual resting place for each boulder. The north edge of the trench would have acted as a trailing edge of a *roches moutonees* allowing the glacier's differential stresses to cleave and pluck the boulders.

Evidence for the southern side of the trench comes from surficial observation and well logs. Glaciotectonics may have moved the sediment from the trench then deposited these sediments in the moraine at Port Jefferson. Erosion by the tunnel valley event has left some evidence at or near the surface. Steve Englebright reports seeing folded sediments in an excavation at Port Jefferson (personal communication). Our observations of surface sediments found on a new construction site within the valley showed a thick layer of Cretaceous sand above a section of till. **Figure 15** shows two well logs taken from northeastern portion of Port Jefferson valley. The exact location is not given. The well logs both had a base elevation of five feet above sea level. **Figure 15**

Both well logs show an irregular repetition. In S-113, "dirty yellow sand, hard black clay and sticky clay all come up twice in a non-rhythmic order. This is what we would expect from a well log from the folding and thrusting of the same layers. S-113 has a total thickness of 334 feet, Jensen and Soren, 1974, describe the Smithtown clay as being up to 150 feet thick and the Raritan Clay member as being up to 250 feet thick. Krulikas and Koszalka, 1983, infer that the Smithtown Clay ends just south of the Harbor Hill Moraine in the Port Jefferson area. Smolensky, et al, 1989, show the Raritan Clay at -400 feet or greater. Based on location and thickness, this well log does not fit either definition and is best explained as evidence of glaciotectonics.

In S-114, the base layer is considered to be in the Magothy which is consistent with **Figure 11**. Just above the Magothy are 3 layers that could be the glacial deposits. Above these are irregular repetitive layers. Like S-113, this is what we would expect from the folding and thrusting of sedimentary layers.

McEachern, 2002, suggested that Grim's trench was an optimal site for subglacial water storage. The depth of the trench encourages meltwater to flow into the area but does not provide an easy exit allowing a substantial amount of water to pond. If the front of the glacier were frozen to the underlying sediment as a result of permafrost, the water pressure would increase until the increasing hydraulic pressure, as a result of melting ice, became great enough to force a massive discharge event (Piotrowski, 1997)

USGS S-113 (1930)		
	THICKNESS *FEET*	DEPTH *FEET*
DIRTY YELLOW SAND	85	85
CLAY	2	87
SANDY CLAY	49	136
WHITE CLAY	1	137
SANDY CLAY	9	146
HARD BLACK CLAY	7	153
SANDY CLAY	16	169
STICKY WHITE CLAY	6	175
HARD BLACK CLAY	7	182
SOFT WHITE CLAY	5	187
SOFT GREY CLAY	22	209
SANDY CLAY	13	222
DIRTY YELLOW SAND	3	225
SANDY CLAY	1	226
STICKY CLAY	46	272
SANDY CLAY	35	307
WATER BEARING SAND	27	334
USGS S-114 (1945)		
	THICKNESS *FEET*	DEPTH *FEET*
SAND & GRAVEL	11	11
SANDY CLAY	21	32
QUICK SAND	20	52
SANDY CLAY	11	63
FINE SAND	21	84
SANDY CLAY	51	135
CLAY	98	233
QUICK SAND	9	242
SANDY CLAY	27	269
TOUGH CLAY	8	277
DIRTY SAND & GRAVEL	11	288
CLAY	18	306
DIRTY SAND	10	316
CLEAN COARSE WHITE SAND	17	333

Figure 15 (Table Above) Well Logs Obtained from the USGS office in Coram, New York.

Discussion

While Grim et al.'s, 1970, description of the trench (across from **Figure 11**) leaves little doubt that the tunnel valley does not appear to cut the Cretaceous sediments north of Port Jefferson Harbor, Grim's seismic paths do not actually travel into the harbor and in fact the survey remains well away from the harbor area. It is entirely possible that any incisement or indentation may not be seen so far from the harbor. In a more detailed seismic study Lewis and Stone, 1991, show a valley filled with glacial sediments deepening to the north extending out of Port Jefferson Harbor which cuts the Cretaceous sediments (Fig. 6 in Lewis and Stone, 1991). Unfortunately, they do not provide enough information about the dimensions of the valley to evaluate if the valley could be large enough to supply the sediments in the alluvial fan.

Lewis and Stone, 1991, also show another valley deepening to the north extending out from Mt. Sinai which correlates well with DEM imaging showing tunnel valley coming out of Mount Sinai harbor and the front of the moraine extending to the south as a subaerial stream that cuts the Port Jefferson Station alluvial fan. **Figure 4, 5** (See tunnel valley labeled Crystal Brook Hollow and the Channel at this link)

Based on **Figure 11**, if water entered Grim's trench and exited through the Port Jefferson valley, it should have cut easily through the Cretaceous sediments on the south side of the trench and left a very noticeable mark which Lewis and Stone, 1991, note. Without further information about the valley it is hard to determine whether it comes from the base of the trench (if there is a trench) or if the valley intersects the trench well above the base which would indicate that there had been englacial flow to the north.

If Grim's trench exists then it can have two origins. The trench could have formed from subglacial excavation/ erosion or it could have formed as a meltwater channel. Based on the existence of a similar trench with a similar spacial relationship to a moraine in **Figure 11**, the trench most likely has its genesis from a subglacial relationship to moraine building.

Assuming Grim's trench exists then it is structurally complex. The north side, being based in bedrock (**see Figure 11**) should behave like an overdeepening. Benn and Evans, 1998, describe an overdeepening as an area where there is effective quarrying and abrasion causing a basin to form. The authors associate overdeepenings with temperate glaciers and fluctuating water pressures. Crevasses form up glacier from the overdeepening which allows surface water to penetrate the glacier. Once the water makes its way to the base it aids in the plucking, quarrying and abrasion of the bedrock (Benn and Evans, 1998, p 349).

The south side of the trench will behave more like an excavational deformation zone or a partially constructed Hill-Hole Pair: A sediment-basin equivalent of an overdeepening (**see Figure 11**). Benn and Evans, 1998, state that erosional basins form from one of or a combination of glaciotectonic thrusting, excavational deformation and plucking of rigid sediment beds (p. 349). They also state that glaciotectonics are associated with glacier margins (p.349) while excavational deformation is associated with the area just below the transition between the accumulation zone and ablation zone (p. 340).

The excavation of Grim's trench is most likely associated with glaciotectonics. This is hard to imagine using the cross section of Smolensky, et al (1989). The vertical exaggeration makes the trench look extremely deep. More importantly, the cross section makes it appear that the moraine is incredibly close to the trench. In a cross section without exaggeration, the topography appears more like a hill-hole pair and the peak of the moraine shows its true distance from the trench. **Figure 16**

Figure 16 represents a cross section across Mount Misery, which is just east of the Port Jefferson valley. In the case of the Port Jefferson valley, the trench is at a greater distance to the moraine and at a more oblique angle. The trench also has a northern fork that travels a great distance into the Sound. **See Figure 10**. This Northern fork would also be a good area for subglacial water storage.

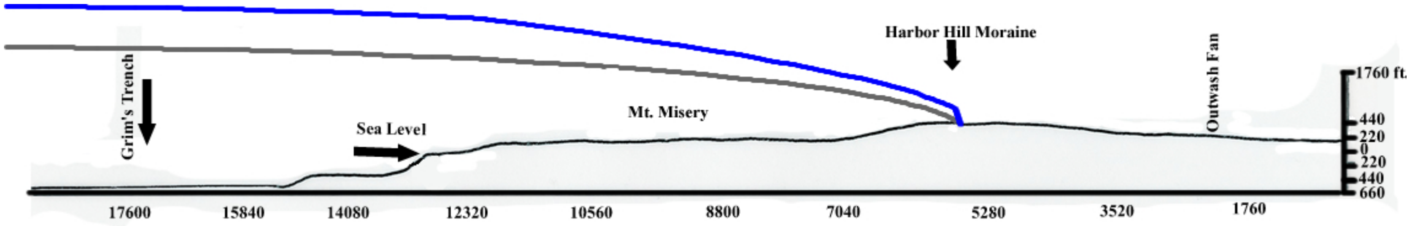


Figure 16 North-South Cross from Grim's trench across Mount Misery to the Harbor Hill Moraine and the outwash fan in front of the glacier. Information based on topographical data from USGS 24k topographical quadrangle of Port Jefferson and upper surface subcrops (Figure 10) from Smolensky, et al, 1989. The black line represents topography. The blue line represents the possible top of the glacier. The gray line represents the possible height of the potentiometric surface. From left to right text reads: Grim's trench, Sea Level, Mt. Misery, Harbor Hill Moraine, and Outwash Fan , which indicate the features that are visible. Sea Level is the approximate location of where Long Island Sound touches Mt. Misery.

We must consider several variables when attempting to reconstruct the flow of water that created the Port Jefferson tunnel valley. First is the behavior of the trench both wholly and in parts. Second is the location(s) of meltwater storage. Third is the role of subglacial water including pore pressure, hydraulic gradient, and flow patterns.

Flow of water at the base of the glacier is required for efficient plucking and quarrying of the basement rock which produced the large boulders found in Port Jefferson. Yet too high of a water pressure over the sediment could have tendency to cause decoupling between the basal ice and the underlying sediment. Benn and Evans, 1998, point out that very high pore water pressures would lead to the development of a distributed drainage system which would cause decoupling and allow the base of the glacier to reduce strain through slipping (p. 156). To efficiently excavate Grim's Trench we need a porewater pressure over the sediment which is generally high enough to "encourage deformation" while not high enough to cause decoupling (Benn and Evans, 1998,p. 156) after the sediment is removed the conditions have to be appropriate for excavating the boulders.

Swift et al., 2002, state that "unusual or unseasonal events such as jokulups (or periods of intense rainfall may be solely or partly responsible for the development of a channelized glacial network". We may however need a distributed drainage system within the sound to supply the large volume of sediment in the outwash fan.

It is hard to account for such a complex requirement. It would appear that freezing the sub glacial water on the south side of the trench is a feasible option. Benn and Evans, 1998, state that any glacier can have "temperature mosaics", that a temperate glacier may in fact have "a few cold patches" and that such zones of freezing and melting can "migrate through time"(p.96). Benn and Evans, 1998, Mathews and Mackay, 1960, and Moran et al., 1980, postulated that the southern margin of the Laurentide ice sheet was cold-based near the edge due to thinning of glacial ice but was wet-based further away from the margin (p.192). It is possible that the excavation of Grim's trench resulted when the glacier approached this cold-based zone.

It is also possible that a glacial process "clogged" the meltwater in the region. A possible process is net freeze-on by glaciohydraulic cooling. Alley et al., 1998, explains it as the melting point rising more rapidly than the water temperature rising "from the heat generated by viscous dissipation of the flow" which could lead to "ice growth plugging subglacial conduits and eventually to englacial water flow". Swift et al., 2002, states that "basal waters rising from overdeepenings in the glacier bed may undergo supercooling, leading to ice growth plugging the subglacial channels and eventually leading to englacial water flow".

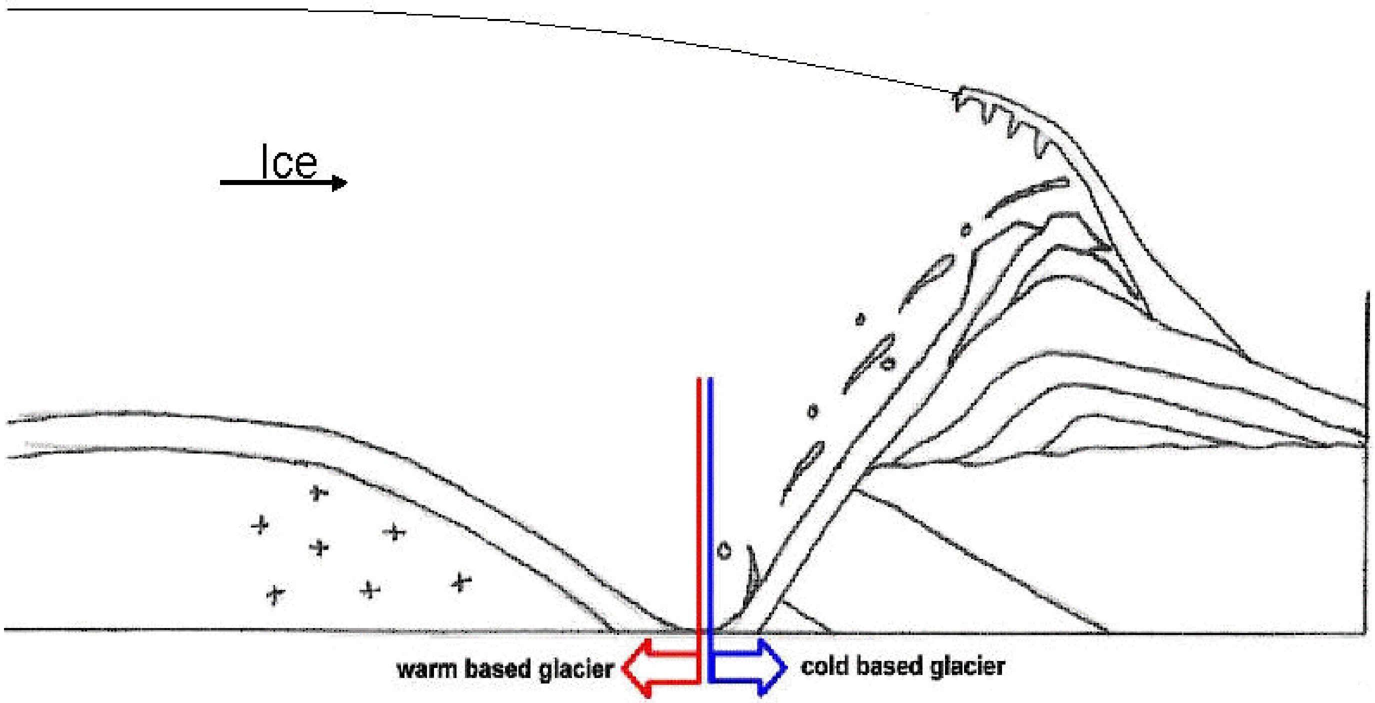


Figure 17 Exaggerated cross section of the glacier showing how the two sides of the trench must have different behaviors. North=Left

With meltwater being stored in a subglacial lake in Grim's trench or in the northern fork of Grim's trench, we have a water supply. Swift et al., 2002, state: "the extent of the channelized system is primarily dependent upon the availability, magnitude and distribution of surface meltwater inputs to the glacier bed", inputs being dependent on the organization of crevasses and moulins. The surface water storage would be located north of the harbor and above the Long Island Sound Basin. As the area moves from glaciation to permafrost to eventual permanent vegetative cover, much of the strong sediment topography should have been mediated by meltwater erosion and deposition and to a lesser extent by katabatic winds. The steep side of Mount Misery should have become well rounded and the hills should have slumped. Instead we see that Mount Misery was preserved, the harbor shows an infilling of at least 100 feet and the hills remained long enough to be cut by streams into their present position.

The trench provides a serious alternative and an answer to preservation. The ice within the trench may have prevented the front of the ice south of the trench to recede. Pietrowski, 1997, states that small groundwater discharge combined with high meltwater production can lead to rapid flow events and even initiate ice sheet collapse. Recession would have then occurred farther back in the sound north of Grim's trench as the stagnant entrenched ice became separated from the ice sheet.

Lewis and Stone, 1991, have some evidence to support the stagnant ice hypothesis. Glacial Lake Connecticut developed in the Long Island Sound basin as the glacier retreated from Long Island to the north. Small fans associated with glacial recession begin close to the middle of the sound and north of Grim's trench. This suggests that the ice may not have begun to retreat immediately to the north of the Harbor Hill Moraine, rather it may have started mid sound before receding northward (Lewis and Stones Fig. 7). However, varved lake-bottom deposits are found near the edge of the Cretaceous cuestas in the sound north of the current Port Jefferson Harbor. Lewis and Stone, 1991, state that Lake Connecticut had a maximum height of -10m below sea level. If the ice had retreated north from the Harbor Hill Moraine, varved deposits should be within a mile of the mouth of the habor and they are. This would indicate that any stagnant ice in the sound melted shortly after the development of the Glacial Lake Connecticut.

The stagnant ice could have lasted above lake level for a significant time after the glacier retreated because permafrost may have lasted until 14,000 years ago (calendar years, Kundic and Hanson, 2004). The walls of the Port Jefferson valley are draped with till which will prevent erosion of the walls. As the ice melted, a strong vegetation cover could have encroached on its fringe also helping to stabilize the topography of Port Jefferson valley. Since evidence indicates that the 100 foot deep kettle hole maintained ice until permafrost left the region (Kundic and Hanson, 2004), it seems likely that stagnant ice could have remained similarly as long.

Edwards et al's, 2004, Cosmogenic age of 16.9 kyr ± 2.2 kyr (calendar years) for the boulder in **Figure 12** also supports this hypothesis. This age places the ice leaving the upper Port Jefferson area between Kundic and Hanson's, 2004, dates of Lake Connecticut filling (~ 18,000 calendar years) and permafrost leaving Long Island (~14,000 calendar years). It supports the hypothesis that stagnant ice was still overlying Port Jefferson when glacier was actively retreating in the Long Island Sound

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