Evidence of Glaciotectonic Phenomena in a North Shore Coastal Bluff at Nissequogue, Long Island, New York

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Summary

During the past century, numerous geologists have noticed structural features in Long Island's glacial moraines that indicate that glaciotectonic phenomena occurred during the Pleistocene. Prior to the wave of development that has exposed glacial sediments in quarries, recharge basins, and excavations for buildings, nearly all of these observations were made along coastal bluffs along the North Shore and Peconic Bay. The purpose of this study was to examine and interpret folds, faults, cross-bedding, other structures, and the sedimentary material exposed in bluffs along Long Island Sound in the Village of Nissequogue, and to determine 1) whether glaciotectonic activity was responsible for these features, and 2) whether the clay present was glaciolacustrine in origin. To facilitate this interpretation, a stratigraphic column was developed and photographs were taken that documented the character of the sediments and the structures that were encountered.

The research was conducted from May to August, 1998, on the bluffs at the David Weld Sanctuary. This preserve, owned by The Nature Conservancy, is located north of the Harbor Hill moraine in Nissequogue, New York. It is a protected area, therefore, in order to conduct the survey, special permission was required from The Nature Conservancy's regional office in Cold Spring Harbor. Funding was provided through the Summer Educational Interns program of the Earth Science Educational Resource Center, which is administered by the Center for High Pressure Research, a National Science Foundation Science and Technology Center. During this study, any disruption of the natural environment was kept to a minimum.

Geological Context

Evidence that glaciation occurred on Long Island during the Pleistocene is widespread and well-known, having been studied by numerous geologists for over a century, and in many studies, it has been noted that folding and faulting occurs in the deposits that represent this phenomenon (Bernard, Davis, and Holt, 1998; Black, Hanson, Meyers, and Welch, 1998; Davis, Haq, and Mutter, 1997; Fuller, 1914; Keller and Meyers, 1997; Mills and Wells, 1974; Sirkin, 1995, 1996; Sirkin and Stuckenrath, 1980). At numerous locations along the Long Island Sound shoreline, including the David Weld Sanctuary, large glacial erratics that represent samples of New England bedrock are scattered offshore. Many of these are over 100 meters offshore, marking the edge of where the bluffs once stood. This is a good indicator of the amount of erosion occurring on the bluffs. Hematite-cemented conglomerates of the Cretaceous period and arkose pebbles and boulders can be found all along the shoreline. Ventifacts indicative of aeolian activity and rocks containing chattermarks and striations due to transport by ice, are further evidence of glacial activity. Most of the sediment responsible for the formation of the bluffs in Nissequogue does not resemble the glacial till generally associated with moraines, and in fact, on Long Island the moraines are composed chiefly of glaciofluvial sediment. The Nissequogue bluffs contain an abundant amount of clay and silt material common in glacioacustrine deposits. Krulikas and Koszalka (1982) described the Smithtown Clay, a glaciolacustrine unit, as ranging up to 171 feet thick in Nissequogue.

Methods

Initially, several locations along the bluffs were chosen randomly and excavated in order to expose the material beneath the talus that tends to cover the bluffs. This revealed sand with parallel laminations. In one area, vertical veins of orange-brown material were present in the sand. Although these had a root-like appearance, they contained clay which seems to have seeped into a previous fracture that occurred when the sand was frozen. This initial exploratory excavation revealed a section of the bluffs where clay is prominent, and this area was chosen for more intensive study.

Due to strong erosional forces that occur on these steep bluffs, any sediment that is removed by excavation can quickly become covered by one heavy rain or gradual talus development during dry periods. Therefore, a large erratic boulder that lies 59 meters east of the footpath, which leads to the beach, was used as a reference point for the study area. The first excavation (DWI) that was chosen for intensive study was located 52 meters east of this reference point. Two more excavations were created, DWII, located 50 meters to the east of DWI, and DWIII, 50 meters west of DWI. These three stratigraphic columns revealed that the underlying beds were extensive enough laterally to be correlated through all three sections.

For each excavation, a garden hoe was used to remove the overburden of material from the surface to expose the original bedding, beginning from the top of the bluffs. A depth of approximately six centimeters of material was removed from the upper two meters of the columns. Because material tends to settle toward the base of the bluffs and new material is being added from what is scraped away, it was necessary to dig deeper and on an angle toward the east in order to expose the beds in the lower parts of the sections. Where the overburden was thick, a flat head shovel was used to remove the bulk of the material and a hoe was used to clean the surface.

Photographs and videos were taken each time a new bed or feature was exposed and samples of the sediment were extracted from each bed. The folds and faults found within the units are localized and if excessive digging is done, they tend to fade out. Starting from the base of the bluff, a Jacob's staff and clinometer were used to measure off one-meter sections on the

The David Weld Sanctuary

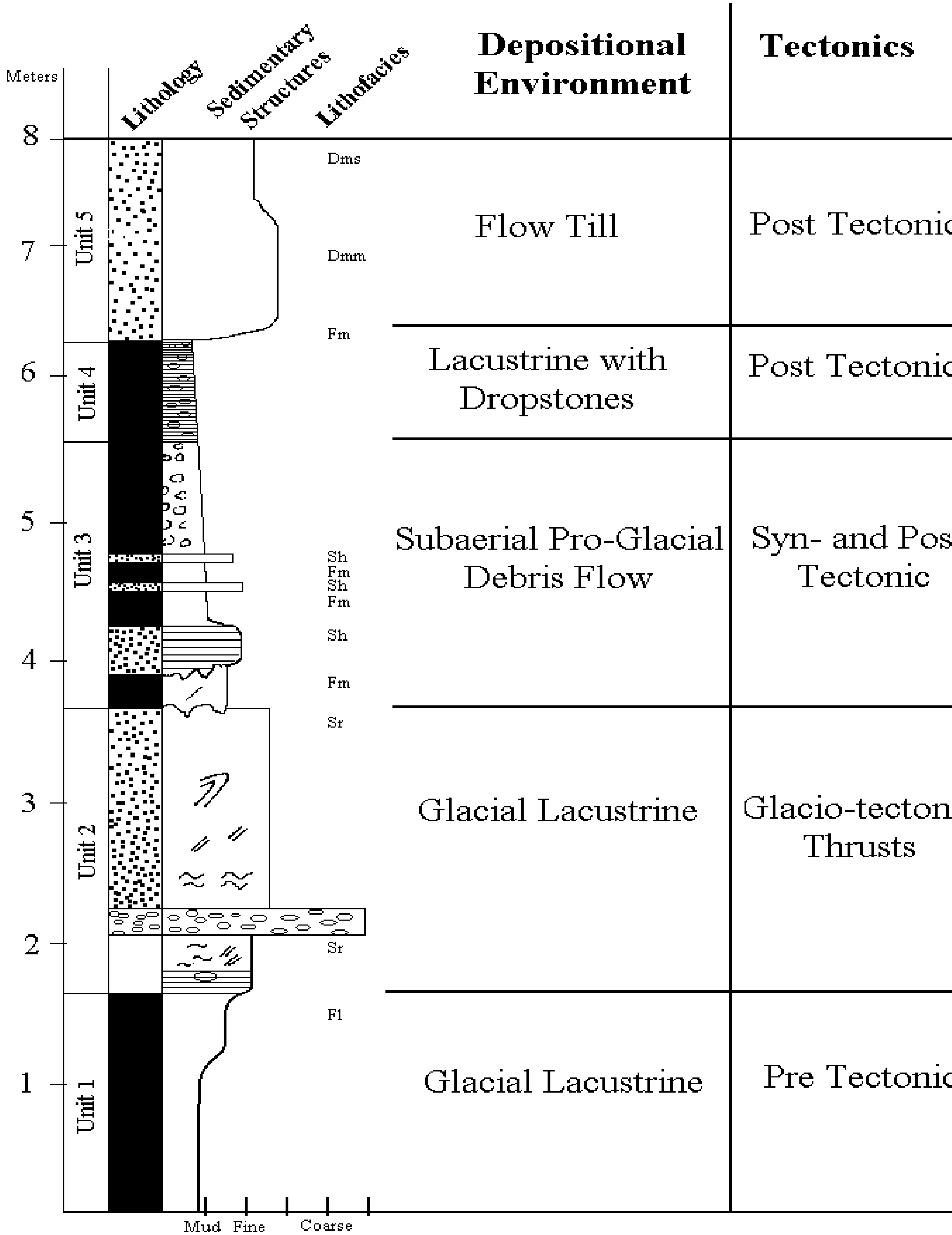


Figure 1. Statigraphic column for coastal bluffs at the David Weld Preserve, Nissequogue, Long Island

columns, which were marked with flagging tape. A series of three photographs were taken of the entire 100-meter section of the bluffs being studied. These photos were juxtaposed to create a panoramic view of the area and enable the beds from each column to be connected as a unit.

The outcrop was divided into five distinct units (Figure 1). From top to bottom, the units are as follows:

Unit 5. Diamict

Unit 4. Clay

Unit 3. Clay and sand

Unit 2. Sand

Unit 1. Clay

Each unit was further broken down into individual beds. A stratigraphic column was drawn up for each of the three columns excavated so a comparison could be made. Lithology, grain size, textures, and special sedimentary and structural features were recorded.

Descriptions and Interpretations of Units

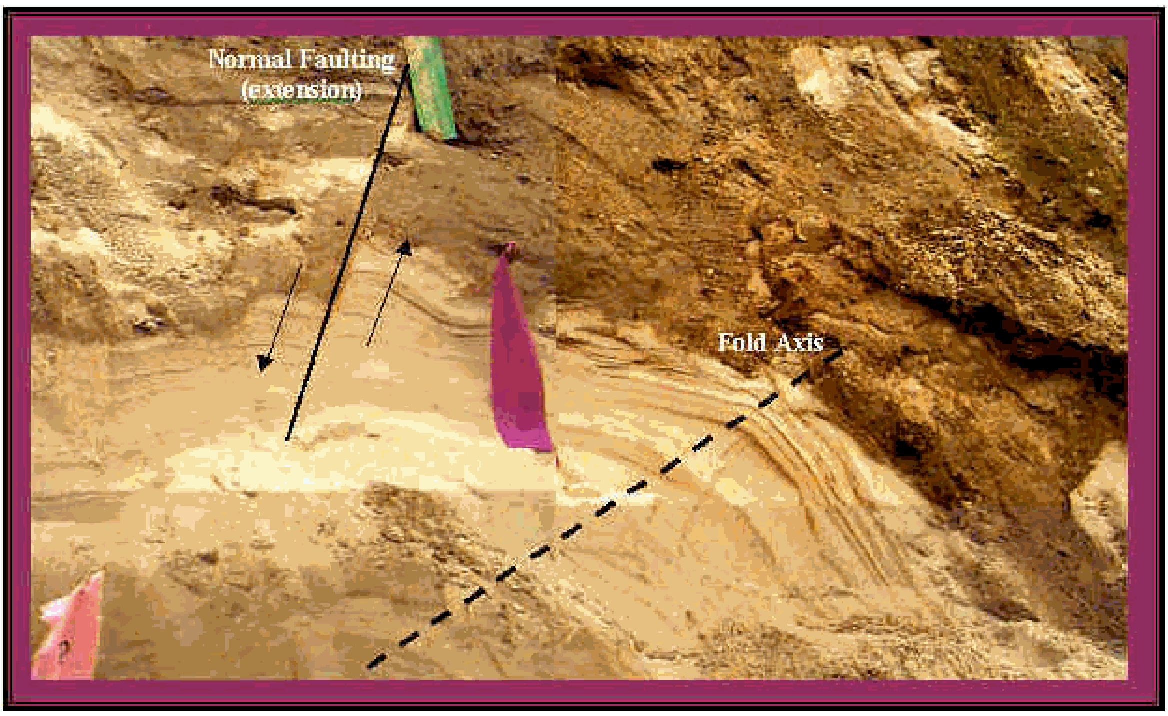
Detailed descriptions of the units were written, based on the DWI excavation, starting from the base of the column and working up toward the top of the bluff. The three columns were then compared to each other revealing that although the thicknesses varied, they all contained similar beds and features. This verified that the depositional environments and tectonic activities noted below were extensive enough to span the entire study area.

Unit 1:

Unit 1 consists of a finely laminated clay layer with a thickness of 152 centimeters. Within the lower 126 centimeters the clay exhibits fissility and the bedding planes are quite pronounced. Mica flakes are scattered throughout the clay, but are concentrated along the bedding planes. Fine laminations of either iron or organic matter appear every 15-30 centimeters within the unit. No analysis of this material was performed to determine its composition. Laminations in glacial lakes are often assumed to be varves, which are seasonal layers, but we decided to refer to these particular layers as cyclic laminations. The temperature in this area could have fluctuated markedly over the course of one year, or over periods of several years, which would mislead us if we used these laminations as time markers. There is a smooth, gradual upward transition into a sandy-clay, which makes up the top 26 centimeters of the unit. The clay that is found in this unit exhibits similar qualities to the Smithtown Clay, described by Krulikas and Koszalka (1983). The fine layers of clay suggest that deposition of this sediment occurred in quiet waters, indicative of a glaciolacustrine environment. There is no evidence that tectonic activity occurred during deposition of this unit.

Unit 2

There is a smooth transition from unit 1 to unit 2, indicating that the depositional environment was similar for the two units. Unit 2 consists of medium and coarse-grained laminated sand, 207 centimeters thick. Parallel laminations lead up to small cross bedding and climbing ripples within the lower 44 centimeters of a medium grained sand bed. The presence of these features is evidence that running water entered the lake from streams within the glacier. In this unit, a sharp upward transition occurs from the top of the sand to a 22-centimeter thick bed of gravel that dips 30 degrees east. An increase in velocity of the stream enabled larger sized particles to be deposited. This gravel bed extends east to DWII, but fades out at DWIII. The unit continues upward with a 141-centimeter bed of massive medium grained sand. Climbing ripples and small cross bedding found at the base of this bed grade into parallel lamination. A small structural fold occurs approximately 30 centimeters from the top of this bed, strongly suggesting that some glaciotectonic thrusting was occurring. After the sand was deposited, the ground became frozen. The overriding ice sheet shoved the sediment, causing the sand layer to fold, as shown in photograph 1. Although this unit contains glaciotectonic structures, the deformation occurred after deposition. The orientation of this fold indicates that the ice moved from NNE to SSW. Other folds found within the bluff have the same orientation. This thrusting created several synclines situated at the top of unit 2.



Photograph 1. Fold in unit 2 and normal fault in units 2 and 3.

Unit 3

Unit 3 contains alternating layers of deformed sand and clay with clasts of various sizes scattered throughout. The haphazard assortment of these clasts and layers in this unit indicates that the depositional environment was a subaerial proglacial debris flow. The sediment in this unit fills in the troughs of the synclines found in unit 2. Several soft mudstone clasts (approximately 10 centimeters long) were found near the base of unit 3. They all appear to be orientated in a similar nearly horizontal position. The clasts are oblong and contain parallel striation marks. The fact that these clasts are soft suggests that they were not transported a great distance by the ice. Cobble-sized schists were also found scattered throughout this unit. They are highly weathered and disintegrated when removed from the surrounding sediment. Laminations of clay and silt are found toward the top of the unit. Deposition of this sediment occurred during glacial thrusting, creating a "wavy" pattern in the laminations. Several small offsets occur in unit 3, which may have been caused by the slumping of material after ice became buried and subsequently melted. An extensional fault lies directly above the axis of the fold located in unit 2 that is pictured in photograph 1. As the sand was folded, the more competent clay layer lying above it resisted this deformation. In column DWIII, this unit contains a series of normal faults (photograph 2).

Photograph 2. Series of normal faults in unit 3, column DWIII.

Unit 4

Resting above unit 3 is 62 centimeters of finely laminated clay that represent unit 4. Small pebbles are scattered throughout the unit, and they appear to be dropstones, as evidenced by the presence of laminations around them. The dropstones do not seem to exhibit a preferred orientation. No folds or faults appear in this unit, therefore it was determined that the sediment was deposited after the glaciotectonic activity had occurred. A distinct transition zone is clearly visible between units 4 and unit 5.

Unit 5

This upper unit contains 152 centimeters of diamict. The lower 1 meter of the unit consists of a graded bed of tan colored sand. The top 52 centimeters consist of orange-brown, unstratified sand, silt and clay. This poorly sorted clay and silt layer may represent loess. Small rootlets intrude the unit from the vegetation at the top of the bluff. The top layer of the bluffs represents a post-tectonic flow till.

Conclusion

The evidence uncovered during this study strongly suggests that the environment in this area was glaciolacustrine in nature during the early portion of the time period represented by the sediments present. There is an abundant amount of clay and silt seen in this outcrop. The pro-glacial lake that formed was situated between the front of the ice sheet and the Ronkonkoma moraine. Extensive layers of clay settled to the bottom of the lake. The lack of fossils in the various beds is due to the cold permafrost conditions that existed at the time of deposition. It is possible that microorganisms thrived, but further investigations of the material would be needed to confirm that. As the ice sheet began its advance, glaciotectonic thrusting created the folds and faults visible in units 2 and 3. Unit 4, which contains another clay unit, was deposited after the ice sheet ceased its advance. A general coarsening up sequence is evident in the bluffs, further indicating that this was originally a low-energy glaciolacustrine environment that later became overwhelmed by a large influx of sediment.

Acknowledgments

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References Cited

Bernard, M., Davis, D., and Holt, W. (1998). Shallow Seismic Reflection in Glaciotectonic Hither Hills, Long Island. *Geology of Long Island and Metropolitan New York: Long Island Geologists Program with Abstracts*, April 18, 1998

Black, J., Hanson, G.N., Meyers, W.J., and Welch, R.S. (1998) Glacio-tectonic Features at Bald Hill Ronkonkoma Moraine. *Geology of Long Island and Metropolitan New York: Long Island Geologists Program with Abstracts*, April 18, 1998

Bernard, M., Davis, D., Haq, S., and Mutter, D. (1997) Glacio-tectonic Origin of Terrain, Hither Hills, Long Island: A Preliminary Study. *Geology of Long Island and Metropolitan New York: Long Island Geologists Program with Abstracts*, April 19, 1997

Fuller, M. L. (1914) The Geology of Long Island, New York. *U.S.G.S. Professional Paper*: 82

Keller, J.A. and Meyers, W.J. (1997) Glaciofluvial and Glaciotectonic Structures in Manorville, Long Island. *Geology of Long Island and Metropolitan New York: Long Island Geologists Program with Abstracts*, April 19, 1997

Krulikas, R.K. and Kosalka, E.J. (1983) Geologic Reconnaissance of an Extensive Clay Unit in North-Central Suffolk County, Long Island, New York. *U.S.G.S. Water Resources Investigation*: 82-4075

Mills, H.C. and Wells, P.D. (1974) Ice-shove Deformation and Glacial Stratigraphy of Port Washington, Long Island, New York. *Geological Society of America Bulletin*: 85, pp. 357-364

Niebling, J.L. and Richard, G.A. (1999) Summer Educational Interns: Training Future Teachers to Utilize the Natural Environment as a Laboratory for Student Research

Projects. *Geology of Long Island and Metropolitan New York: Long Island Geologists Program with Abstracts*, April 24, 1999

Sirkin, L.A. (1995) *Eastern Long Island Geology With Field Trips*. Book and Tackle Shop, Watch Hill, RI

Sirkin, L.A. (1996) *Western Long Island Geology With Field Trips*. Book and Tackle Shop, Watch Hill, RI

Sirkin, L.A. and Stuckenrath, R. (1980) The Port Washingtonian Warm Interval in the Northern Atlantic Coastal Plain. *Geological Society of America Bulletin*: 91, pp. 332-336