"The Stratigraphy of Hither Hills State Park"

Kevin Hatton, Taylor Grandfield, and Rondi Davies

Stony Brook University

Saturday, April 13, 2024 - 11:00 am - 3:00 pm

Hither Hills State Park in Montauk is on the Ronkonkoma Moraine. The exposed bluffs on the park's northern edge have archived the area's glacial history. The beach has many large boulders previously deposited by the Laurentide Ice Sheet. Pleistocene sediment beneath the Ronkonkoma Moraine exhibits deformation, creating a unique opportunity to think about glacial dynamics. Although the timing of glacial advance, retreat, and subsequent glacial deposition has yet to be well constrained, recent studies are in progress to solve this.

During this field trip, we will:

- Hike along the bluffs at Hither Hills
- Discuss Long Island's glacial history
- Characterize the stratigraphy, source material, and depositional history of Hither Hills

Directions

Continue on Montauk Highway (NY-27E) until you reach Second House RD

Turn left onto Second House RD and continue for 1.2 miles.

At the Intersection with Navy RD, turn left and continue for .8 miles to Navy Beach Pier

We will meet at 11:00 am at the Navy Beach Pier parking lot in Montauk. Traffic can be significant, so plan accordingly. We will walk from the parking lot, along the beach, around Rocky Point, for ~3 mi to the outcrops. The beach is predominantly cobbles and boulders, with some sand/gravel beds. The boulders can be slippery, so proper footwear is suggested. Low tide will be at ~10:00 and high tide at ~4:00 pm.

We will have some snacks at the cars but pack a lunch because we will eat at the outcrop. ***We will go rain or shine!***

"The Stratigraphy of Hither Hills State Park"

Kevin Hatton, Taylor Grandfield, and Rondi Davies

Stony Brook University

Overview

This field trip will walk through exposures of glacial sediment along the bluffs on the northern edge of Hither Hills State Park. The Manhasset formation is partly exposed and contains Pleistocene sediments exhibiting intensely folded sand and gravel layers (Fuller, 1914) and a thick interlayered sand and clay unit. The glacial stratigraphic sequence represents the final glacial advance on the southern fork of Long Island, NY, and records its subsequent retreat. Our understanding of the timing of when these sediments were deposited, glacial dynamics, and the provenance of the material have been the subjects of recent investigations.

Figure 1. Map illustrating outcrop location within Hither Hills State Park, white box. The Navy Beach Pier parking lot is highlighted in blue. The track of the hike is illustrated with a yellow

dashed line. Another unique geologic feature to the east, within Hither Hills State Park, the Walking Dunes fields, is outlined with a red box.

Trip Logistics

We will begin at the Navy Beach Pier parking lot in Montauk. We will walk from the parking lot along the beach, around Rocky Point, for ~3 mi to the outcrops. The beach is predominantly cobbles and boulders, with some sand/gravel beds. The boulders can be slippery, so proper footwear is highly recommended.

Long Island's Recent Glacial History

The upper portion of Long Island's, NY (LI) geological layers formed during the Wisconsin Glacial Episode (from~95,000 to 11,000 years ago) as the Laurentide Ice Sheet retreated (Figure 2) (Balco and Schaefer 2006, Balco et al. 2009). Across the island are two moraines: The Ronkonkoma and Harbor Hills. The Ronkonkoma moraine lies at the south shore of LI and is thought to have been the terminus of the ice sheet and deposited ~20,000 years ago (Sirkin, 1982). Cosmogenic nuclide dating of boulders suggests that the Harbor Hills moraine was deposited after 18 ka (Das, 2007; McCabe, 2006). However, based on measurements of till directions and bedrock orientation (Sanders & Merguerian, 1994b), it is possible that the Harbor Hills moraine was deposited as early as 20,000 years ago (McCabe, 2006). While regional glacial history is a subject of current research, subregional work on the glacial history of Long Island is lacking. Long Island hosts the longest Laurentide glacial exposure across the entire East Coast. A large amount of previous work has been done to describe the geology of Long Island (e.g., Fuller, 1914; Srikin, 1982). Yet, little work has been done to constrain further the timing of de-glaciation and subsequent formation of Long Island.

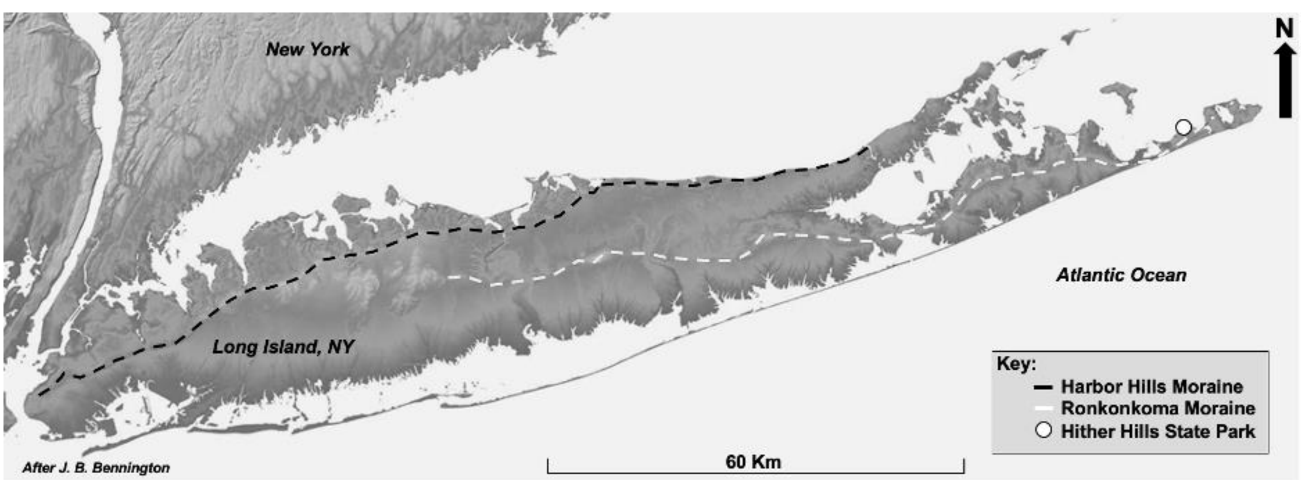


Figure 2. Topographic Map of Long Island, New York. Higher elevations are illustrated with lighter shading, and lower elevations are illustrated with darker shading. Long Island's two main glacial

moraines are highlighted: the Harbor Hills moraine (black dashes) and the Ronkonkoma moraine (white dashes). Hither Hills State Park (Ronkonkoma moraine) is indicated with a white circle, modified after J. Bret Bennington.

Hither Hills State Park

The topography of Hither Hills is a series of parallel, low-elevation hills, ~10m in height. The hills trend SW-NE and are regularly spaced (Figure 3; Goetz, 2005). Previous geophysical studies by Goetz (2005) within Hither Hills used ground penetrating radar (GPR; Neal, 2004) to develop a model to explain the structure and formation of the hills. They suggest that the hill represent a modern set of pro-glacial hills formed at the front of a glacier. Yet, there are number of hills in the series cannot be explained by a singular glacial advance. Based on their model, Goetz (2005) hypothesizes that the series of hills is a classic example of push-hills formed by the episodic glacial re-advance in a time of overall glacial retreat. An additional sedimentological study by Klein and Davis 2001 showed that the adjacent hills are stratigraphically different (e.g., the intermittent appearance of clays) and could be described by variable formation conditions..

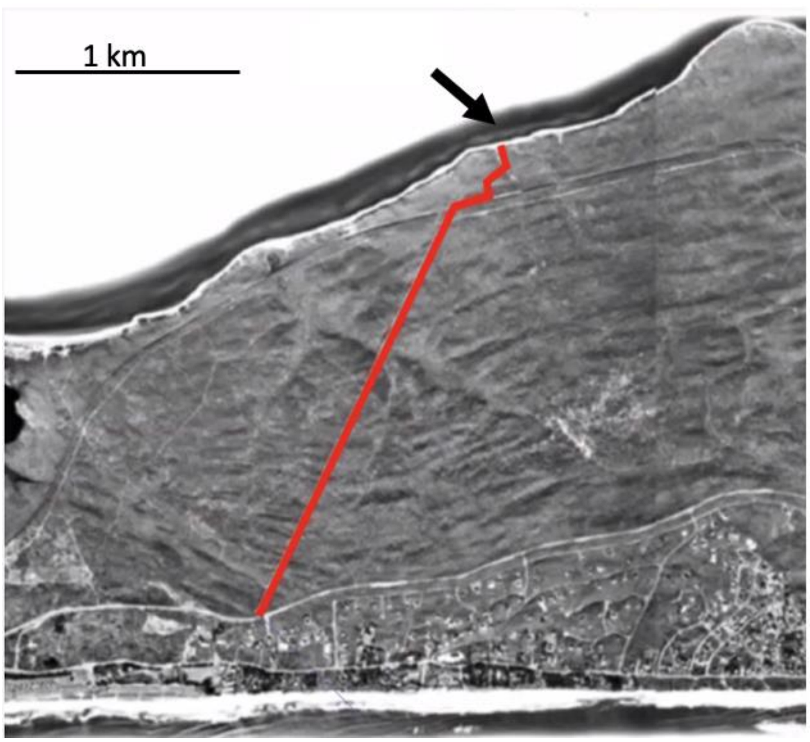


Figure 3. Modified scanned United States Geological Survey (USGS) Aerial Image of Hither Hills State Park. Track analyzed with GPR in Goetz (2005) indicated by the red line. Bluff exposure of glacial deposits and Ronkonkoma till indicated with the black arrow.

Goetz's (2005) study concluded that the hills found at Hither Hills State Park likely formed subglacially but adjacent to the front of the glacial margin. Additionally, the hills resulted from minor episodic readvances of the glacier during a time of overall retreat. Due to the presence of numerous cobbles and boulders it is difficult to image the stratigraphy below a nearly horizontal till that extends from near Montauk Highway to the Northern Shore of the park using GPR. However, erosion of the bluffs on the edge of Napeague Bay exposes over 15 meters of stratigraphy.

The topographic hills of Hither Hills are composed of glacial till, which consists of all grain sizes from clay to boulders. In particular, primary ridge of the Ronkonkoma moraine is composed of stratified sands, gravels, cobbles, silt, and clay and is referred to as the Ronkonkoma till(Williams 1976). At the eroded bluffs, the thickness of the till can be difficult to assess because of the modern erosional process and varying thickness across the bluffs. However, it is the uppermost unit in the stratigraphic section. The Ronkonkoma till is ~3 m for most outcrops, including the transition of unconsolidated sands and gravels to a thick clay unit. An angular, unconformable contact is just below this clay. The unit below this contact can vary from stratified sands with identifying red iron oxide staining between layers to gravel and cobble beds. This is most likely the Herod Gravel, which is a lower member of the Manhasset Formation. A greater than ~15 cm thick layer of iron oxide cemented sands with gravel is also interlayered. Above these sands are grey clay beds with interlayered and alternating sands, which could be varves of a proglacial lake, as explained in the following section *Proglacial lake*. The change in lithology is not the only indicator of a new stratigraphic unit. The units beneath the unconformity are variably dipping, as extensive deformation exists within these units.

Field Trip Exposures

This field trip focuses on an exposure that extends ~300 m along the beach. We break the exposure down into three main sections: 1) The plunging syncline, 2) Proglacial Lake, and 3) Ronkonkoma Till

Plunging Syncline

The Herod Gravel is exposed here, and the abundance of sands and gravel layers suggests it is a plunging syncline with one limb vertical to partly overturned (Figure 4). The layer which is best used to identify the folding of this unit is a thick Iron oxide cemented conglomerate with unconsolidated cobbles and sub rounded gravels. This iron oxide can be used as a tracer bed to more easily trace the deformed layer across the beach. Beneath the gravels are sands of alternating colors, tan, and iron oxide-stained red. Within the sands, deformation can be seen on the centimeter scale. These sediments were likely deformed by the advance of the glaciers based on the orientation, vergence, of the most intense folding which is consistent with a North to South movement (Fig. 4).

These folded layers are then unconformably cut near the top of the exposure. The contact is not well exposed, though it is likely to be an erosional contact caused by the last glacial advance.

Figure 4. (Top) The plunging syncline in full view, it is unconformably cut at the top. Overall sense of Southwest movement. (Bottom Left) The marker oxidized layer with cobbles beneath and then sand. (Bottom Right) Deformation can be seen in small scale faulting within the sands.

Proglacial lake

There is a large clay exposure approximately 100 m long and up to 4m depth into the exposed section. These gray clays have interlayered, heavily oxidized sands. The clays are unconformably on top of the Herod Gravel and these sediments do not appear to be draping along their unconformable contact. Instead, these sediments appear to be stratified and the interlayering of sands and clays are similar in appearance varves (Figure 5). Varves are annual layers of sediments. Clays settle to the lake bottom during the low energy winter and during the higher energy spring, melt waters bring in coarser grained sediments. The combination of layers represents a year. The lack of draping seen at the unconformable surface could be due to an underflow circulation, which would make the proglacial lake an ice-contact lake (Carrivick and Tweed, 2013). This would mean that the oxidized sediments are caused by the precipitation of insoluble Fe^{3+} during periods of efficient water mixing (Zolitschka et al., 2015). Different paleolakes can record the same weathering conditions, allowing for a relative chronology to be built across an area. Varves have been recognized within the Long Island sound but studies of varved sediments on LI have not been conducted (Lewis and Stone 1991).

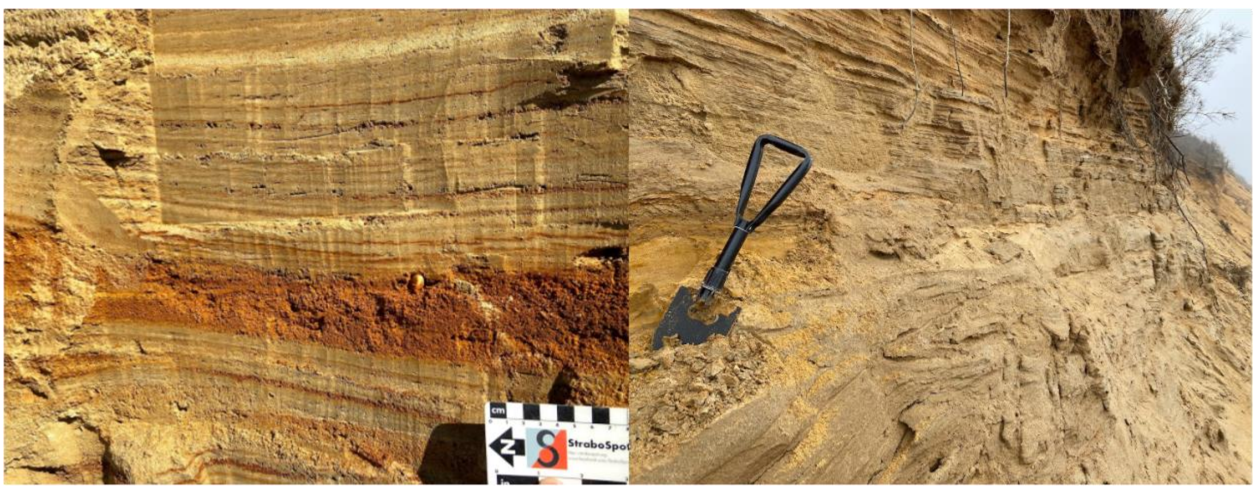


Figure 5. (Left) alternating bands of clay and oxidized sands, varved sediments. (Right) The sands become thicker and noncontinuous bands at the top of the section.

Luminescence dating efforts of the Ronkonkoma Moraine at Hither Hills State Park

The Luminescence dating research laboratory at Stony Brook University has developed a project to directly date glacial sediment deposits using Optically Stimulated Luminescence (OSL) dating and provide the first comprehensive chronology of the glacial deposition on LI, NY. Previous geophysical surveys done by D. Davis et al, of the area imaged a thin pebble layer interpreted as a till (Figure 6; Davis and Cangelosi, 2005). In April 2021, a team went to Hither Hills to assess the till layer imaged by the survey.

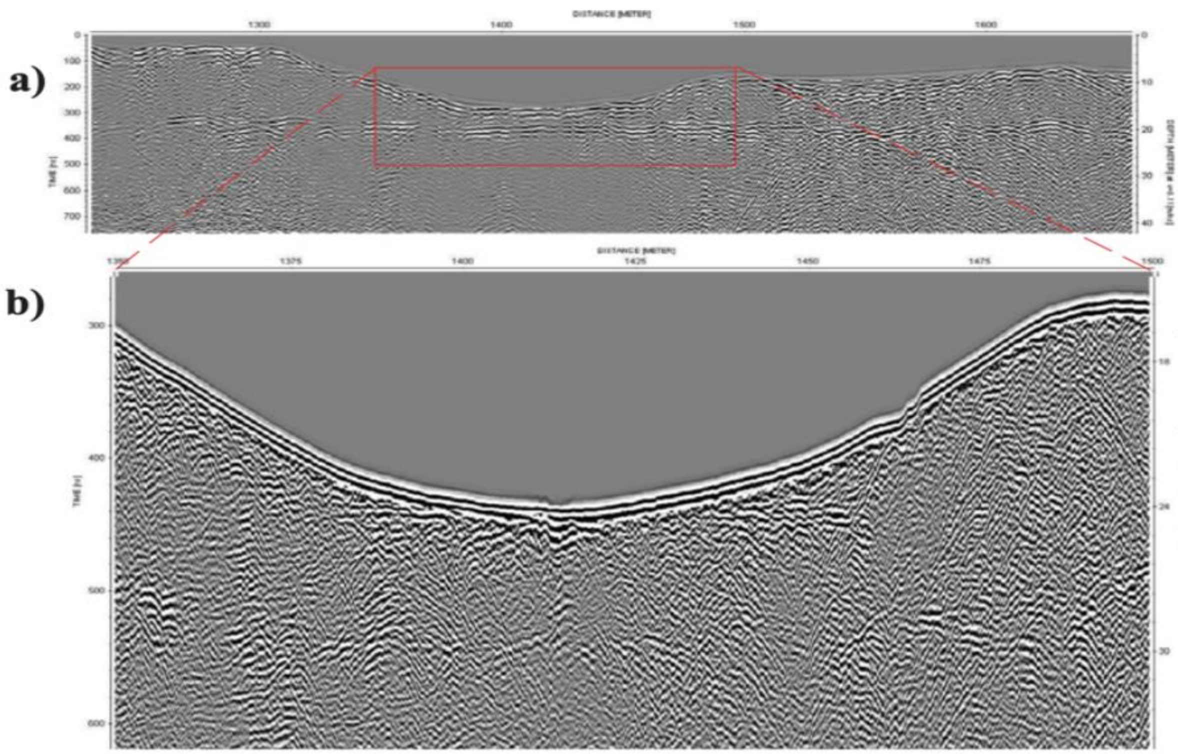
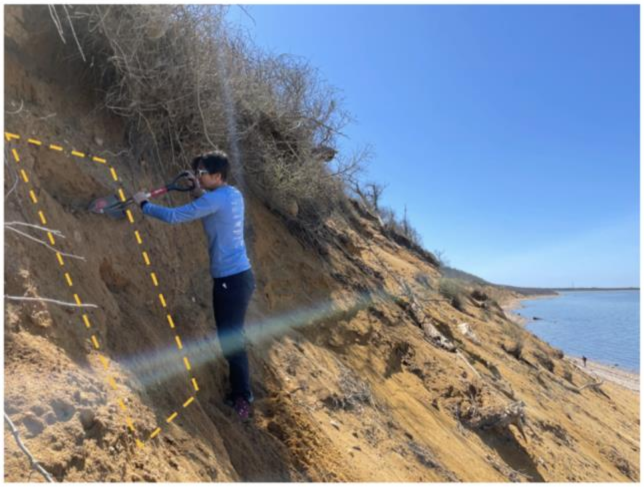


Figure 6. GPR Radargrams, from D. Davis' Hither Hills Field Guide (2005), image a relatively horizontal layer. A) displays a low-frequency (50 MHz) antenna with a sharp reflector, whereas B) displays a high-frequency (250 MHz) antenna with a weaker reflector. This indicates a reflector that contains cobbles and is interpreted as basal till, in our case, the 'upper till' layer.

At the cliffs, several possible pebble and cobble layers were present. However, it was difficult to discern the one imaged by the survey. Towards the top of the bluff, a prominent cobble and pebble layer was interpreted to be the upper till associated with the Ronkonkoma Moraine. The primary focus for dating purposes was to sample two locations where the 'upper till' layer was prominent. A total of 7 OSL samples were collected for dating purposes. Samples were collected from above the till, within the till, and below the till for a full chronological assessment of glacial deposition. An example of sampling locations can be seen in Figure 7.

Preliminary luminescence dating of Potassium(K)-rich feldspars suggests that the sediment above the till was deposited ~15 ± 3 ka, within the till to be deposited ~36 ± 3 ka, and the sediment below the till to be deposited ~50 ±10 ka. However, glacial deposits can be tricky for dating purposes, and measurements at the single-grain level are necessary to assess the light history of the sediment. Additionally, more samples are needed from Hither Hills to further assess if the 'upper till' layer described is, in fact, the exposed and continuous deposits of the Ronkonkoma moraine.



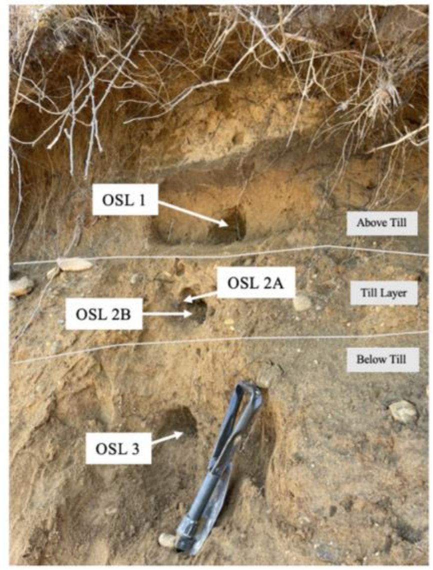


Figure 7. Example of OSL sample locations for Hither Hills bluffs. The figure on the left highlights the location of the sample spot on the cliff face. The figure on the right displays the locations of the OSL samples shovel for scale.

Detrital zircon data from Hither Hill's State Park

As part of a larger study that aims to determine the provenance of the rocks that make up the moraines of Long Island in order to constrain the travel history of the Laurentide ice sheet, glacial sands were sampled from the bluffs on the north side of Hither Hills. Samples were taken from above and below the till layer at locations adjacent to where samples were collected for the OSL study (discussed above).

Zircon grains between 250 and 125 microns were concentrated from the Hither Hills sands following sieving, washing with dilute HCl, magnetic, and density separation. 366 zircons were U-Pb age dated using LA-ICPMS at the Isotope Geology Laboratory at Boise State University. About 500 heavy mineral concentrates from three sand samples were also observed.

155 zircons from above the till layer produced a dominant age peak at 365 Ma, with smaller peaks at 189, 281, 606, 1046, and 103 Ma1. 212 zircons from below the till layer produced a dominant age peak at 379 Ma, with smaller peaks at 195, 260, 545, 603, 1012 and 1149 Ma (Figure 8).

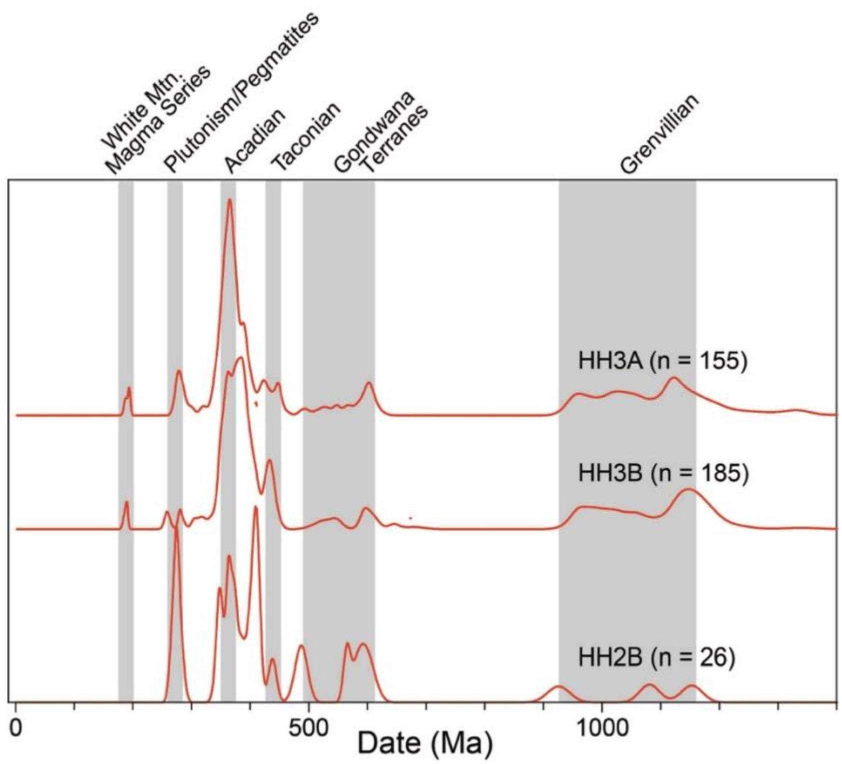


Figure 8. U-Pb ages for zircons from above (HH2A) and below (HH2B & HH3B) the till layer in the bluffs at Hither Hills. Ages are compared to ages of the Gondwana derived terranes, the Grenvillian, Taconic, and Acadian orogenies, and magmatic events of New England and New York.

For both layers (above (A) and below (B) the till), the dominant age peak at ~380 Ma corresponds to metamorphic events related to the Acadian and Neoacadian orogenies and suggests an origin from the Avalonia terrane in southern New England to the north. Smaller populations of zircons are interpreted to be from the Laurentian (>1000 Ma) margin to the northwest (Jaret et al., 2021), Gondwanan terranes to the north and northeast (500-600 Ma), the Taconic orogeny (~440 Ma) to the north and northwest. Peaks at ~275 Ma may correspond to plutonism and pegmatite emplacement throughout New England, while a small peak at ~190 Ma may be derived from igneous rocks of the White Mountain batholith in New Hampshire (Kinney et al., 2022), about 215 miles to the north-northeast of Long Island. This data suggests the majority of rocks making up the glacial sands of Hither Hills are derived from terranes and igneous and metamorphic events to the north.

Summary

The sediments at Hither Hills display the advance and the proximal and distal retreat of the Laurentide ice sheet. The deformation of the Manhasset formation displays the degree of plasticity these sediments had while the glacier was advancing. The push-hills formed during the initial glacial retreat which comprise the park, are complemented by the proglacial lake varves exposed on the bluffs. The glacial history of Long Island is rich and long, but studies investigating and determining the details are infrequently conducted. Hither Hills is an excellent candidate for continued investigation.

References

Balco, G., Schaefer, J., 2006. Cosmogenic-nuclide and varve chronologies for the deglaciation of southern New England. Quaternary Geochronology 1, pp. 15-28.

Balco G., Briner J., Finkel R.C., Rayburn J., Ridge J.C., Schaefer J.M., 2009. Regional beryllium-10 production rate calibration for late-glacial northeastern North America. Quaternary Geochronology 4, pp. 93-107.

Carrivick,JL and Tweed,FS (2013) Proglacial Lakes: character, behaviour and geological importance. Quaternary Science Reviews, 78. 34 - 52. ISSN 0277-3791

Das, S., Origin and Evolution of Dry Valleys South of Ronkonkoma Moraine, M.S. Thesis, Stony Brook University, 2007.

Davis, D.M., and Cangelosi, M., Glacial Tectonics and Walking Dunes Hither Hills State Park, Long Island Geologist Field Trip, 2005.

Fuller, M.L., Geology of long Island, New York, Professional Paper 82, United States Geological Survey, Washington, D.C., 1914.

Goetz, K., Glacial Tectonism at Hither Hills, Long Island, Revealed by Ground-Penetrating Radar Investigations. M.S. Thesis, Stony Brook University, 2005.

Klein, E., and Davis, D.M., Long Island Clast Orientations and What They Till Us. *Annual Conference on Geology of Long Island and Metropolitan New York (LIG), 2001*

Lewis, R.S. and Stone, J.R., 1991. Late Quaternary stratigraphy and depositional history of the Long Island Sound Basin: Connecticut and New York. Journal of Coastal Research, SI #11, 1-23. Fort Lauderdale (Florida). ISSN 0749-0208

McCabe, M., Kelly, M. A., Schaefer, J. M., Schwartz, R., Hanson, G. N., and Benimoff, A. I., (2006), Dating glacial features in New York's Lower Hudson Valley - The last deglaciation of the Eastern Laurentide Ice Sheet: Geological Society of America Abstracts with Programs, 38, no. 7, p. 72.

Neal, A., Ground-penetrating radar and its use in sedimentology: principles, problems and progress, Earth Science Reviews, 66, 261-330, 2004.

Sanders, J. E., and Merguerian, Charles, 1994b, The glacial geology of New York City and vicinity, p. 93-200 in A. I. Benimoff, ed., The Geology of Staten Island, New York, Field guide and proceedings, The Geological Association of New Jersey, XI Annual Meeting, 296 p.

Sirkin, Les. *Wisconsinan glaciation of Long Island, New York, to Block Island, Rhode Island*. In: Larson, Grahame J., Stone, Byron D., editors. Late Wisconsinan Glaciation of New England. Dubuque, Iowa: Kendall/Hunt, 1982. p. 35-59.

Williams, S.J., 1976, Geomorphology, shallow subbottom structure, and sediments of the Atlantic inner continental shelf off Long Island, New York, Coastal Engineering Research Center (CERC) Technical Paper 76-2, 123 p

Zolitschka, B., Francus, P., Ojala, A. E. K., & Schimmelmann, A. (2015). Varves in lake sediments - a review. Quaternary Science Reviews, 117, 1-41. https://doi.org/10.1016/j.quascirev.2015.03.019