BOULDER DISTRIBUTION AT WILDWOOD STATE PARK: IMPLICATIONS FOR GLACIAL PROCESSES

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## Introduction

Long Island is home to many interesting geological features, most of which are the result of the glaciation responsible for its formation. Among these are glacial erratics, often carried great distance by glaciers (Hanson, 1996). Many erratics have been found at Wildwood State Park, situated on the north shore of Long Island (fig.1, fig. 1a). The park rests atop 50-foot bluffs overlooking the beach. Boulders have been found in this area, as well as on the beach. The dominant lithology of these boulders is granite and granite gneiss, which is similar to rocks found in southeastern Connecticut known as the Avalonian Terrane. These rocks are part of a unit of rock dipping southward underneath Long Island Sound and Long Island itself. It is thought that these boulders are the same type of rock belonging to this unit.

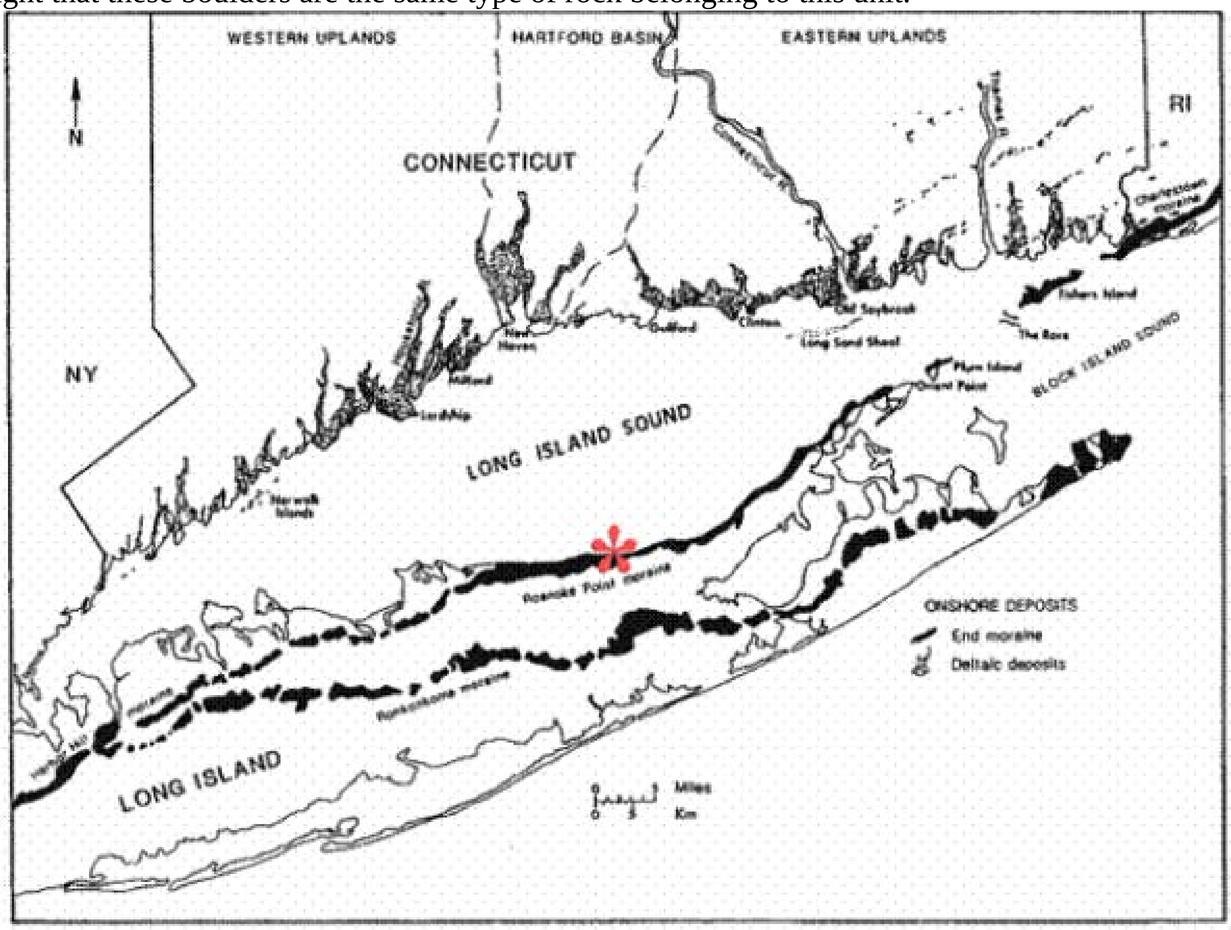


**Figure 1. Map of Long Island Sound, showing moraines running across Long Island, as well as southern Connecticut. Location of Wildwood State Park is marked with an asterisk (modified from Lewis and Stone, 1991).**

Boulders on the beach appear to be distributed non-randomly, and we have performed statistical tests to verify this hypothesis. The manner in which the boulders are distributed may give one insight into their history and mechanism of transport. We have devised three hypotheses to attempt to explain this distribution. The purpose of this study is to trace the history of these boulders from transport away from their source by studying their pattern of distribution at the park; to attempt to locate the source of the boulders; and to deem any one of these hypotheses as valid. We have obtained results from this study via three basic types of observations: boulders on the beach, boulders on top of the bluffs (in campground and on trails), and boulders uncovered via ground-penetrating radar (GPR) surveys.

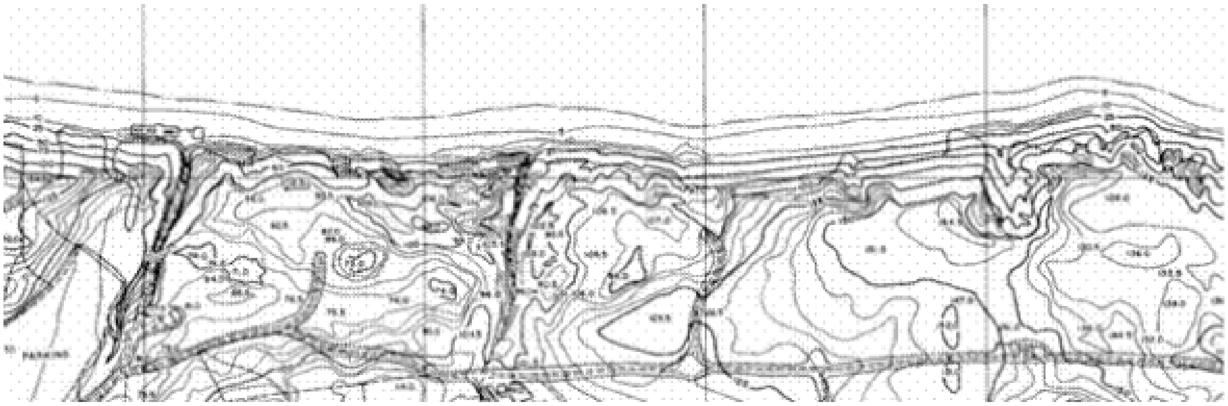

Figure 1a. Part of a topographic map, showing the northern edge of Wildwood State Park. Original scale of 1 inch equals 200 feet (Suffolk County Department of Public Works, 1974).

## Proposed Hypotheses for Distribution

The first hypothesis suggests that there are isolated clumps of boulders scattered in the park and on the beach, with no real pattern or trend to suggest anything about transport mechanisms. Boulder clumps in the park do not have any linear connectivity with boulder clumps found on the beach. Boulders are situated in a topographic low, and as the glacier runs over the area, the flow of fluid slows it, causing it to drop its load. A good way to test this model is to circumnavigate any boulder clumps revealed via GPR. If more boulders are not found, it would lend credence to this model. If more boulders are uncovered via this method, it may be indicative of some other phenomenon.

The second hypothesis suggests the presence of linear trends of boulder clumps in the direction of propagation of the glacier (in this case a roughly north-south trend). This would imply that there are distinct sources for each of the clumps which are seen. This model gains support if the clumps on the beach and in the park have a linear connectivity in the direction of glacier movement as discussed in literature. Once again, a method such as circumnavigating the clumps found via GPR is a good way to test for this. The model fails if the GPR surveys do not show evidence suggesting this situation, or if the directions of glacier movement do not fall within a reasonable range.

The basic motivation for the final hypothesis is tectonic process. This model suggests that the boulder clumps are situated along strike, or normal to the direction of glacier movement, which may give clues about the transport mechanisms involved. For example, it may be possible that the glacier ran into obstruction and had to ramp up, thus dumping its load of detritus. Evidence of a boulder distribution suggesting such a trend, or any indication of tectonic process where a change in the decollement can cause the glacier to dump its load, uncovered via GPR surveys would make this model very favorable.

## Results

We studied 647 boulders on the beach along a line parallel to the shoreline and over a distance of 1.3 kilometers. We classified them according to several important characteristics, including roundness (measure of how smooth or angular the edges are; Pacholik and Hanson, 2001), apparent diameter, lithology, and position along the beach. Officials at the park maintain that they are either native to the beach or had been previously located in the bluffs overlooking the beach (Nellen, 2001). As the coastline eroded back, the boulders would tumble down out of the cliffs into gullies or cascade down the sides of gullies, particularly during a storm, and end up on the beach. One question is whether the distribution of boulders is the result of a beach process, or if it is related to their history and mechanism of transport, as shown by one of three models we have devised. The results of this study clearly show that the distribution of boulders on the beach is non-random, apparent from the distinct clumps in which they are found (fig. 2).

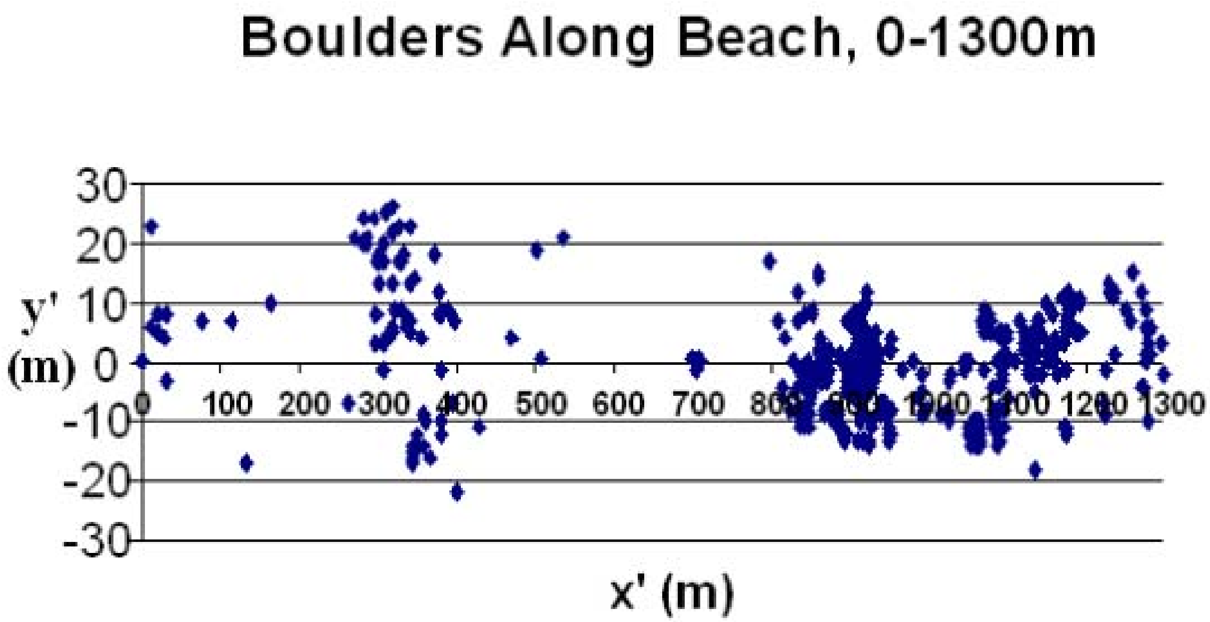


**Figure 2. Plot showing positions of boulders along the shoreline at Wildwood State Park. X' axis is distance along the beach (parallel to shoreline, y' axis is normal distance (perpendicular to shoreline). Exaggeration is roughly 6:1 in the y' axis direction.**

Furthermore, there is not a significant amount of northward transport in this process. That is, when the boulders tumble out of the cliffs, they do so more in a z direction (down) than in either the x or y directions. This results in the final position of the boulders being within approximately 10 meters of the original position. This lends credence to the idea that this distribution is not the result of beach processes, and may reveal something about their transport.

We conducted a GPR survey on the park trails from May to June 2003. 200 MHz antennas were used for most of the GPR lines run, and several were conducted using 50 MHz antennas. Both yielded a presence of boulders within a restricted layer near the surface. This layer appears to be a capping diamict that rises upward. It is possible that the boulder-bearing layer rises up with it. The radargram in figure 3 shows boulders occurring in clumps at a depth of about 5 meters beneath the surface.

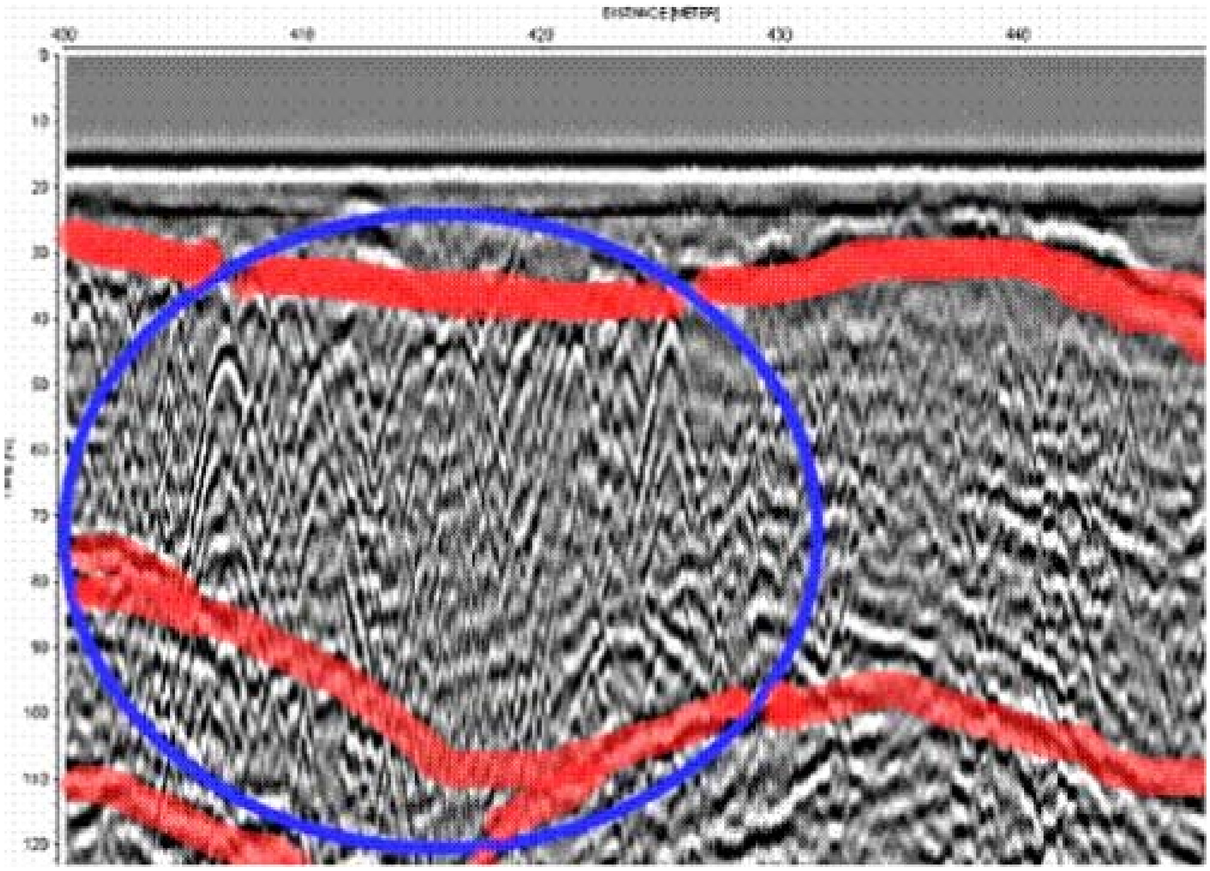


**Figure 3. Radargram from GPR line conducted with 200 MHz antenna. Boulder clump circled in blue. Boulders indicated by hyperbolas. Areas highlighted in red indicate boundaries of till capping layer.**

We compared the boulder density for clumped areas on the GPR line to that for clumped areas on the beach. The results were within very close range of those for the boulders on the beach. Clumped boulder densities for beach boulders and radar boulders ranged from 0.007 to 0.05 boulders per $m^2$, and 0.013 to 0.03 boulders per $m^2$, respectively. These results suggest that the radar clump is of the same order as the beach boulder clump. It may be reasonable to describe the radar clump as a "$4^{th}$ millennium clump." That is, as the cliffs are eroded back, this clump would be visible on the beach in the distant future.

## Discussion

The distribution of boulders on the beach is non-random. This is reflected in their location along a line parallel to shore, as well as in the statistical results. The ground-penetrating radar surveys have uncovered clumps of boulders located below the surface in the park, thus the distribution of these boulders also appears to be non-random. The boulder densities of these clumps fall within the same range as those on the beach, meaning that they are on the same order as the beach clumps.

At this time, hypothesis 3 does not appear to be very viable. The fact that the boulders appearing below the surface in the park are found in a capping diamict layer makes this tectonic model unlikely. Furthermore, if this model was viable, one would expect to see a broader band of boulders on the beach. Hypotheses 1 and 2 are both viable. However, we do not know yet whether the clumps on the beach and in the park subsurface have a linear connectivity, or are isolated. In order to differentiate between the two models, a circumnavigation of the radar clumps is suggested. If no other boulders are found, hypothesis 1 may be more favorable. If more boulders are encountered along the line between beach clump and radar clump, hypothesis 2 would seem more likely. In order to make a more clear distinction between the two unresolved hypotheses, it is important to conduct further GPR surveys in the park.

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