Surface Exposure Dating of Glacial Features in the Lower Hudson Valley Using the Cosmogenic Nuclide ^{10}Be

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Research Proposal
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Introduction

Quaternary Geological History of the New York Bight Region

During the Late Pleistocene Epoch, the Laurentide Ice Sheet (LIS) covered most of northern North America (Figure 1). The southward advancing ice sheet sculpted the landscape, eroding and transporting rock and sediment, altering the course of rivers, and depositing till. In the New York Bight Region, the LIS terminated during the Last Glacial Maximum (LGM) in a relatively horizontal line marked by large end moraines extending from Long Island to central New Jersey. Large erractics (glacially transported boulders), moraines, kames, and exposed bedrock are important geographic features in the lower Hudson Valley region that provide evidence of the LGM extent and subsequent retreat of the LIS.

Surface Exposure Dating

Surface exposure dating of features such as erratic boulders and glacially striated bedrock provides temporal constraints upon the maximum extent and retreat of the ice sheets. The surface exposure dating method relies on the measurement of cosmogenic nuclides produced in near-surface rocks by the bombardment of primary and secondary cosmic rays (Lal, 1988; Nishiizumi *et al*., 1989). The premise of this dating method is that the upper surface of a rock is exposed to cosmic rays, which causes the production of the cosmogenic nuclide ^{10}Be within the mineral lattice of quartz. ^{10}Be is produced in the lattice by spallation, negative muon capture and fast muon reactions. Spallation generates a low production rate of ^{10}Be in quartz (a few atom per gram of quartz and year), which has a half-life of 1.51 million years (Kelly, 2003; Hoffman *et al*., 1987). The properties of ^{10}Be thus allow the dating of exposure periods as long as 5 million years (Kelly, 2003). The ratio of ^{10}Be/^{9}Be (where ^{9}Be serves as a laboratory blank) is used to determine the concentration of ^{10}Be in the mineral quartz (SiO_2). Mineral quartz is a principle target mineral due to its common abundance and its weather resistance (Kelly, 2003).

Prior Research

Dr. Schaefer and a previous intern have sampled and dated boulders on the terminal moraine on Long Island and glacially polished rock surfaces in Central Park. Results of this study determined that ^{10}Be ages from Long Island and Manhattan have a mean age of 18.3 ± 1.5 kyr (Schaefer, 2004). The similarity between the ^{10}Be ages of the terminal moraine and from the retreat features of the glacially polished surfaces of Central Park indicate the LIS retreated relatively quickly over this 50-mile distance (Schaefer, 2004).

Hypotheses

This research attempts to answer the following questions:

1. When did the LIS retreat, thus exposing the surface along the Hudson River Valley?
2. How rapid was this retreat?

Methods

Sampling Site Selection

It is imperative that the methodology includes choosing sampling sites that are representative of the geology event to be dated. Geological maps were consulted to locate moraine and kame deposits along the Hudson River Valley. Harriman State Park has been chosen as the first sampling location. A preliminary survey and GPS mapping of the geology along the white trail (near Kakiak) were conducted on June 17, 2005. Subsequent sampling sites will be located and rock samples will be collected and processed to measure the concentration of ^{10}Be.

Large boulders with the following characteristics will be sampled along the Hudson River Valley:

- are greater than $3m^3$ in size and whose geomorphic context suggest they have not been moved nor have had their surfaces altered since glaciation
- have a generally flat surface upon which cosmic rays directly bombard the rock

- have visible quartz veins or are of a lithology with a relatively high quartz content
- boulder surfaces which lack visible postdepositional weathering rind
- boulder surfaces which lack lichen which impede visibility of grains
- resides on a thin layer of till close to bedrock

Sample Processing

The sample processing consists of two steps: 1) the physical separation and purification of quartz from whole rock samples or veins, and 2) the chemical extraction of ^{10}Be from quartz. Rock samples will be crushed with a hydraulic rock splitter and ground to 0.25-0.71 mm-sized grains in a disc mill. Samples will then be run through a Frantz isodynamic separator, which will isolate the nonmagnetic from the magnetic grains. The nonmagnetic grains are the target sample and consist of quartz, feldspar, and silicates. The quartz will be isolated from other nonmagnetic grains through a series of chemical procedures. Initially, the nonmagnetic fraction will be boiled in phosphoric acid to dissolve aluminum silicates. The supernatant liquid will be discarded and the fraction washed and subsequently cleaned when boiled in sodium hydroxide. The supernatant will be discarded and the fraction will be washed and dried. The remaining sample will be shaken in dilute hydrofluoric acid and nitric acid to dissolve other silicates until only pure quartz remains after repeated washing and shaking steps. The purity of quartz will be tested using an ICP-AES. If the quartz is greater than 99% pure, approximately 50-100g of quartz will be used for the chemical isolation of ^{10}Be. The ^{10}Be isotope ratio will be calculated based on the $^{10}Be/^{9}Be$-sample ratio measured by Accelerator Mass Spectrometry (AMS), the amount of ^{9}Be carrier, and the weight of the pure quartz sample. The age of a rock sample will be calculated from measured isotope abundances using production rates of 5.1 ± 0.3 atoms/g/yr (at sea level and high latitude) (Stone, 2000). This production rate will be subsequently scaled to the sample locations.

Applications

1. Findings of this research may be correlated with lake sediment cores and radiocarbon dating from nearby locations to better reconstruct the LGM and to predict future climate change.
2. The rate of retreat will be calculated using existing ^{10}Be dates.

References

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Figure 1. The extent of the Late Pleistocene glaciation in North America.6
(Courtesy of USGS http://3dparks.wr.usgs.gov/nyc/morraines/quaternary.htm)

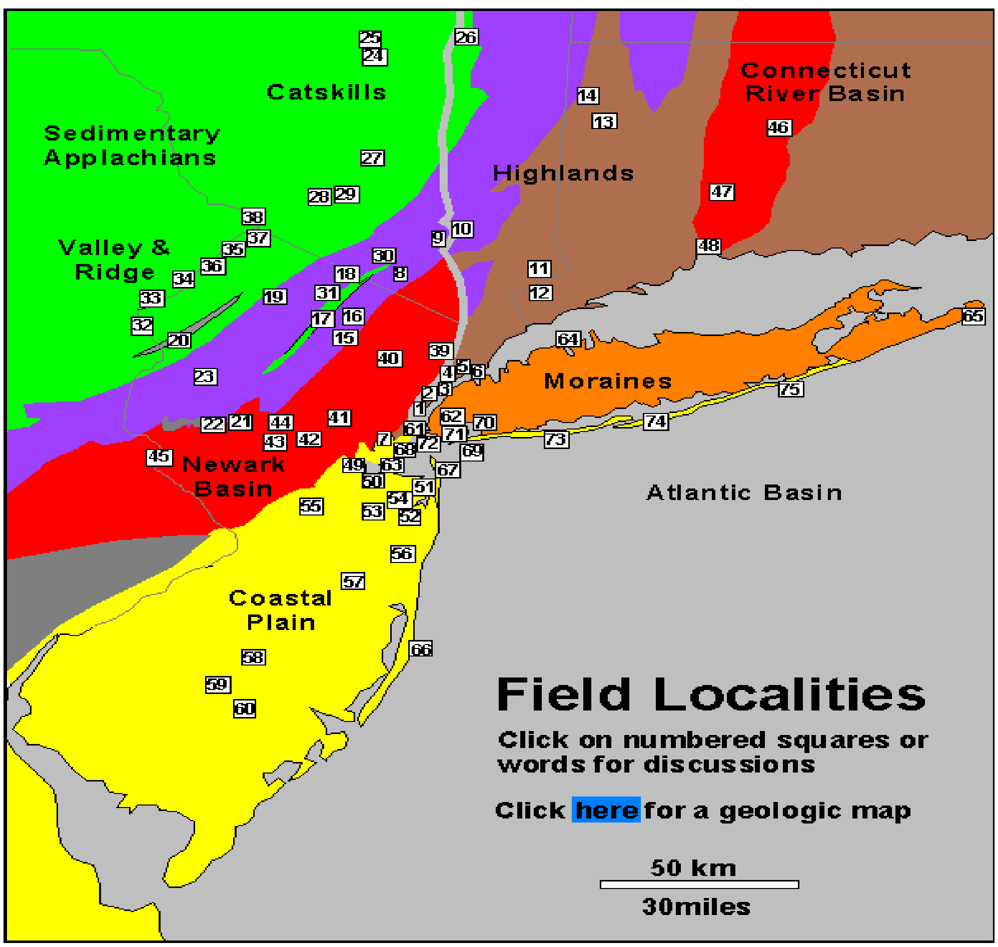

Figure 2. Possible sampling locations of moraines; sites 8, 9, 10, and 27. (Courtesy of USGS http://3dparks.wr.usgs.gov/nyc/common/locations.htm).