Quantitative Analysis of Shoreline Erosion at Magnolia, Seattle

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Abstract

The shoreline and bluffs of Magnolia hill in Seattle have undergone significant erosion since the last glaciation. The Puget Lobe of the Cordilleran Ice Sheet advanced southward from Canada and covered Seattle and the rest of the Puget Lowland. When the ice sheet advanced and withdrew from the Seattle area ~15,000 years ago, it left thick deposits of unconsolidated glacial sediments. As sea level rose due to the melting of large continental ice sheets, wave and tidal action began to erode into the unconsolidated glacial sediment comprising the many drumlin-shaped hills along the Seattle shoreline, including Magnolia hill. Due to its high bluffs with ocean and mountain views, Magnolia has long been a desirable residential neighborhood, but its bluffs are also prone to frequent landslide activity that contributes to the long-term erosion of the hill. Little work has been done to determine long-term erosion rates, though this information would be useful to the scientific community as well as the city and neighborhood residents. The goal of this project is to establish relatively accurate erosion rates for the coastline of Magnolia using a variety of research methods. Analysis of LIDAR digital elevation models provides a baseline estimate for a long-term erosion rate, and measurements on historic aerial photos provide data on the variable nature of short-term erosion. Landslides from the coastal bluffs, primarily at Discovery Park, at the north end of Magnolia, deposit sediment and boulders on the tidal platform (Figure 1). By obtaining exposure ages for the lag boulders (which were previously buried in the till source) and surveying their location in relation to the present-day bluff, accurate bluff retreat rates for these locations may be calculated. Beryllium-10 isotope dating will used to obtain exposure ages from the samples that have been collected.

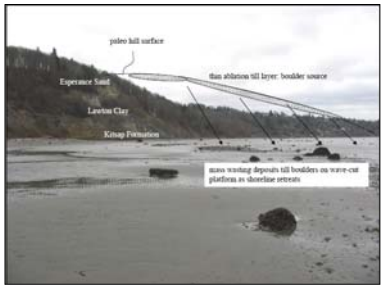

Figure 1: Southeast facing photo of bluffs at Discovery Park, with geologic units labeled and an overlay of the theory on deposition of till boulders on the wave-cut platform.

Exposure Age Dating: Methods

- granitic boulders were sampled because of their quartz content; cosmogenic Beryllium-10 (^{10}Be) is produced in quartz (SiO_2) when it is exposed to the cosmic flux
- collected 5 rock samples from a selection of granitic till boulders on the wave-cut platform (see Figure 6 for sample locations)
- crushed and sieved rock samples
- separated quartz grains from the other mineral constituents
- partially dissolved quartz in HF acid to remove surface impurities and any other remaining mineral grains
- cleaned quartz will be dissolved with Be carrier, analyzed on the ICP for Al and Be content, and sent to an Accelerator Mass Spectrometry (AMS) lab for ^{10}Be counting
- resulting ^{10}Be concentration will be input to a computational model to calculate an exposure age, taking into account the shielding effects of terrain and tides

Figure 2: Collecting rock samples with Dr. Terry Swanson.

Aerial Photos and LIDAR: Methods and Results

Historic aerial photos from 1946, 1965, 1985, and 1995 were scanned from the Suzallo Maps Collection and georeferenced in ArcGIS. Control points for georeferencing were based on a 2002 USGS orthophoto.

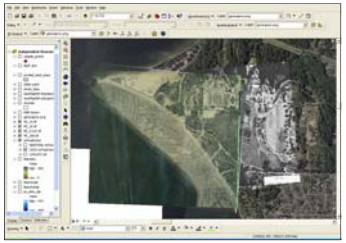

Figure 3: Georeferenced aerial photos as layers in ArcGIS.

Figure 4: Close-up view of 1946 photo, with bluff line traced in yellow.

Figure 5: Close-up of 2002 orthophoto, with 1946 bluff line overlay in yellow. Note erosional gap between the 1946 and 2002 (shown as magenta dashed line) bluff lines.

⟶ Measuring the difference in location between the 1946 bluff line and the 2002 bluff line, and dividing by the time difference, gives a maximum bluff retreat rate of approximately **50 cm/yr**.

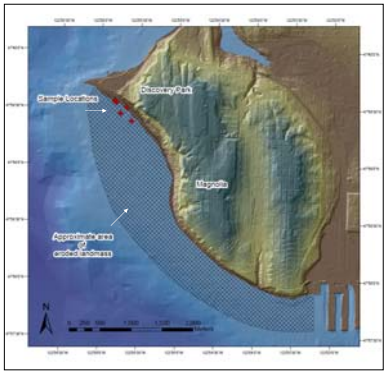

Figure 6: LIDAR DEM of the Magnolia vicinity, with rock sample locations marked and the approx. total area of erosion shaded.

A Digital Elevation Model (DEM) created from LIDAR data (Light Detection and Ranging) was used to estimate a long-term shoreline erosion rate. The western half of the Magnolia Hill drumlin has been eroded and the sediment redistributed in the Puget Sound and over a wide wave-cut platform. The width of the wave-cut platform is a rough approximation of the total area of erosion since eustatic sea level reached its present elevation ~4000 years ago. This assumes that there has not been significant submarine erosion of the wave-cut platform.

⟶ Measuring the width of the wave-cut platform at its widest point, and dividing by 4000 years, gives an average shoreline retreat rate of up to **30 cm/yr** along this portion of the Magnolia shoreline.

Future Work

- continue processing rock samples in lab for cosmogenic ^{10}Be dates
- refine exposure age model for site, based on model developed by Heather Rogers for Whidbey Island
- conduct more detailed geologic mapping to delineate local stratigraphy and sedimentary source for the till boulders
- resolve potential prior-exposure issues: what would this indicate about the boulder source unit, nature of deposition, etc.?
- address the effects of 1 meter of land subsidence at West Point about 1000 years ago; evidence for this rapid subsidence was published by Brian Atwater (USGS, UW ESS) and Andrew Moore (UW ESS) in 1992, and will need to be taken into account when calculating exposure ages and interpreting results

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