INTERSTADIAL DURATION OF THE HERBERT GLACIER BASED ON SAND ANALYSIS OF A BURIED FOREST SOIL, SOUTHEAST ALASKA

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INTRODUCTION

The Herbert Glacier and its surrounding region provide a useful record of the late Quaternary glacial history of Southeast Alaska. The Little Ice Age, which was an interval of cooler temperatures spanning the 13th to 19th centuries (Lamb, 1977; Calkin and Wiles, 1991), caused the most recent advance of the glacier. This advance and subsequent retreat was studied by Lawrence (1950), who dated the terminal and end moraines in the area by using the theory of ecological succession. The currently receding glacier has recently exposed a buried forest soil that was overridden during the Little Ice Age advance. This soil is best preserved in patchy sections on the stoss side of a roche moutonée to the west of the glacier (fig. 1). The soil is formed on a Pleistocene till, and is composed of a thick peat mat and underlying mineral soil horizons. Both lodgement and ablation till from the latest advance and ensuing retreat overlie the exhumed soil.

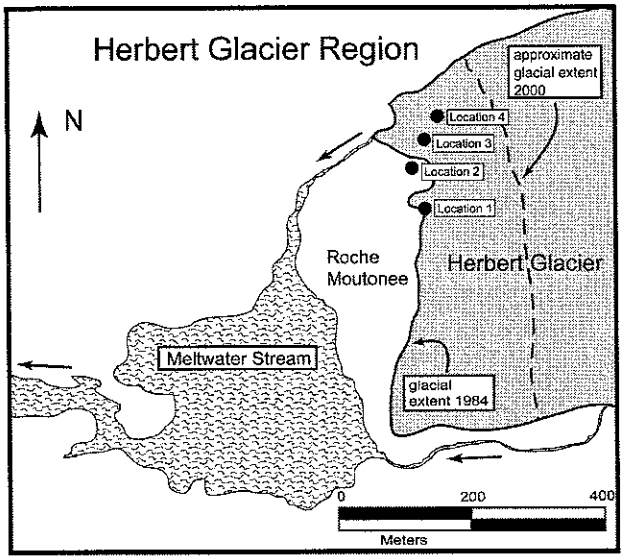

Figure 1. This graphic shows the ice extent and meltwater flow as traced from a 1984 air photo of the Herbert Glacier region. The coordinates of the sample locations were determined with a handheld GPS receiver.

The glacial activity of Herbert Glacier preceding the Little Ice Age advance is relatively unknown, and consequently the buried forest section was studied in order to determine how long this area was exposed to surficial weathering prior to the Little Ice Age advance. Since sparse vegetation appears on till within about three years of deglaciation, the degree of soil development in the region tends to approximate the interstadial duration (Chandler, 1943). From a radiocarbon date taken by Robert Carson (Geochron Laboratories sample no. GX-24424-LS), it is known that the glacier advanced over this forest during the Little Ice Age about 770±40 years ago. Therefore, the duration of the interstadial that separates the penultimate retreat and the last advance of the glacier can be estimated by the degree of soil development within the tonalitic parent material which contains the buried forest section. Soil development is assessed by the etch pit density viewed on feldspar grains from several soil horizons.

METHODS

Samples of the buried forest soil were studied at four different outcrops proximal to the glacier, Location 1 – Location 4 (fig. 1). If there were more than one suitable profile in a specified location, the profiles were further named Location 1a and 1b, for example. Peat was also sampled for radiocarbon dating, as well as wood from an apparently *in situ* tree stump of Sitka spruce that was sheared in the direction of advancing ice flow.

Eighteen soil samples were analyzed in the lab, and with the use of a Gilson sieve shaker, they were each separated into six different sized sand fractions ranging from -1 to 4.5 phi in order to estimate the average grain size of each soil horizon. Selected sieved fractions were cleaned of clays and iron oxides by soneration for 10-30 minutes by the Buehler Ultramet V Sonic Cleaner. The suspended clays were decanted and the remaining grains were washed repeatedly. The samples were then mounted on aluminum stubs with doublestick tape for scanning electron microscope analysis. About 50-100 grains of each sample were randomly mounted, using mainly the 3-4 phi and the 1-2 phi sand fractions. The mounts were then coated with Au-Pd by the Anatech Limited Hummer X sputter coater for three minutes in order to enhance electrical conductivity under the SEM. The JEOL JSM-840A

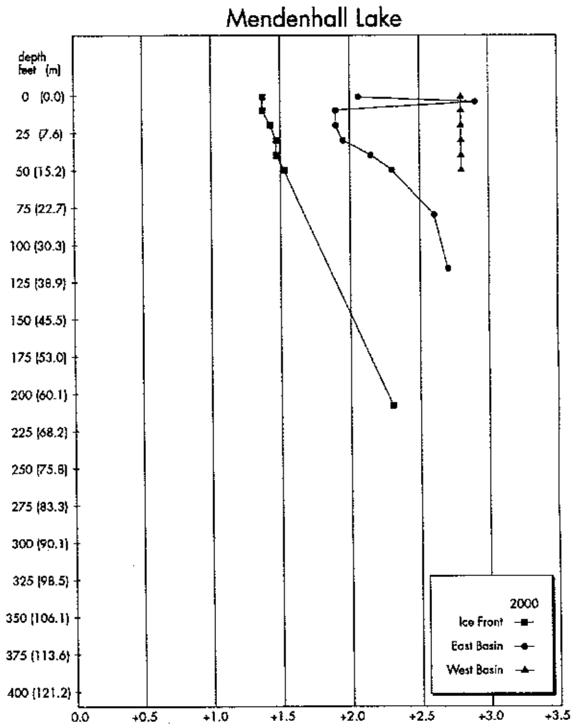

Figure 4. Temperature with depth in the ice front and west basin. The east basin has a peak of high temperature about 3 feet below the surface that may be attributed to the Nugget Falls inlet.

model SEM was used to view the etch pits on the weathered surfaces of feldspar mineral grains. The etch pit density was determined by the number of etch pits that were counted in a randomly selected 90 µ x 120µ area on the feldspar grain surface. The grains were consistently viewed under 1000x magnification and at an accelerating voltage of 25 kV. Potassium feldspar and plagioclase feldspar grains were not distinguished from each other in this study, since they have similar etch pit weathering patterns (Dearman and Baynes, 1979; Berner and Holdren, 1979). However, EDS was used to ensure that feldspar grains were being viewed.

DISCUSSION

Etch pits (fig. 2) occur because of dissolution, mainly at sites of excess surface energy, such as dislocations on grain surfaces, twin boundaries, fractures, microcracks, phase boundaries and exsolution lamellae (Cremeens *et al.*, 1992). Feldspar etch pits are described as prismatic because of their squarish shape, and as weathering advances these pits usually coalesce into elongate etch trenches (Berner and Holdren, 1977; Dearman and Baynes, 1979).

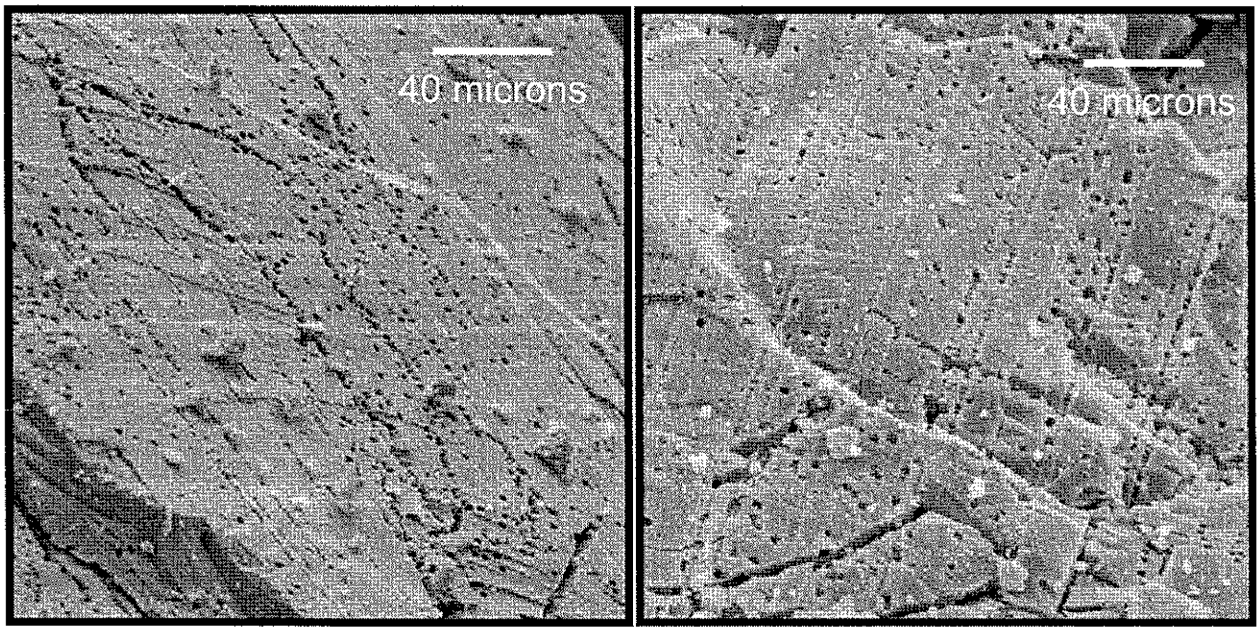

Figure 2. Etch pits on feldspar grains from the A horizon in Profile 1a (sample 008). Etch pits seem to follow the cleavage planes of the mineral. Note adhering clays that were difficult to remove by soneration.

Location 1 is the focus of most of the quantitative etch pit analysis, since it visibly contains the least disturbed soil profile, and has the radiocarbon dated peat layer (fig. 3). It was found experimentally that etch pit density decreases throughout the depth of the soil profile (fig. 4). The etch pit density of the A horizon in both profiles 1a and 1b is around 117. The Bw horizon in profile 1a has an average etch pit density of 41.6, but was not sampled in profile 1b because of its diffuse boundaries. The samples from the C horizon in both profiles 1a and 1b yielded similar values of 12.1 and 10.5, respectively. These comparable values suggest laterally extensive weathering processes across this location. A Pleistocene till, with a composition similar to that of the parent material of the buried forest soil, was sampled from the nearby kame terrace. It was used as the unweathered control with which to compare the weathered soil profiles. The till from the kame terrace has an etch pit density of 14.1, similar to the values of the C horizons in Location 1. This implies that the control till has not undergone pedogenesis, but has undergone similar weathering patterns as the slightly weathered parent material in the C horizon. Again, this indicates the laterally extensive nature of the Pleistocene parent material across the entire area in front of the glacier.

The peat layer of profile 1a was radiocarbon dated in order to effectively constrain the age of the soil, and to provide a framework from which to base weathering rates over time. The topmost layer of the peat was dated at 7330 ±60 BP (Beta-147200), while the bottommost layer of the peat was dated at 5370±70 BP (Beta-147201). The bottommost peat layer of another nearby buried forest soil was also dated at 8380 ±60 BP (Maynard Miller, unpublished data, Beta-131688). However, the radiocarbon dates of the profile 1a peat proved uncertain, as the dates seemed to be logically switched. The *in situ* tree was found to be 2850±70 years (Beta-147202). This indicates that the forest growing in this area may have been composed of multiple forest generations, since this tree was about 2000 years old at the time of the glacial advance. The tree may possibly have been preserved in the growth position, and later become surrounded by a younger generation of spruce.

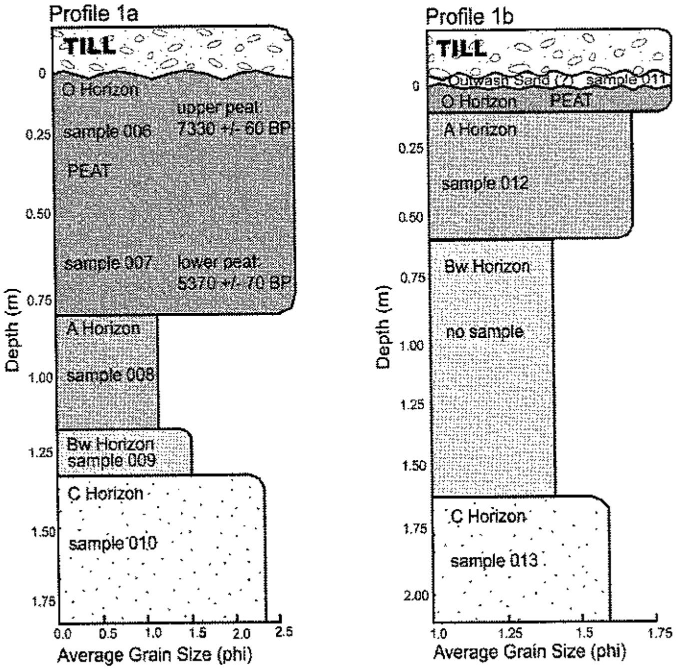

Figure 3. Observed soil profiles for Location 1.

Interestingly, most mature soils in the Juneau area are spodosols, but the length of time it takes for their development is not a well-established fact. Ugolini (1966) and Alexander and Burt (1996) assert that spodic soil horizons develop relatively quickly in the cool, humid climate of southeast Alaska. The Mendenhall glacier terminus, only ten miles southeast of Herbert Glacier, has mature spodosol development on recessional moraines only 240 years old (Alexander and Burt, 1996). Contrary to these findings, Chandler (1942) and Stevens (1963) found that spodic development in this area is slight at the end of 250 years, and more likely requires between 500-1000 years. The Herbert Glacier soils, though formed on similar parent material, do not show the characteristic E horizon that the Mendenhall spodosols exhibit. This may be because of the decrease in annual rainfall and in the growing season going northward from Juneau. The mean annual rainfall at Juneau is 229.6 cm, compared to the lesser, more northerly values of 142.0 cm at the Juneau airport and 59.7 cm at Skagway (Crocker and Dickson, 1957). These observations suggest that the Herbert Glacier region has a slightly less favorable environment for soil development, because of lower organic accumulation and slower reaction rates per unit time (Crocker and Dickson, 1957). It is known that the rate of feldspar weathering is controlled predominantly by the rate at which dissolution of the mineral grain surfaces occur (Cremeens *et al.*, 1992; Lee and Parsons, 1995), and consequently, a greater amount of water filtering through the soil would allow for more surface weathering. Highly weathered feldspar grains are found in more well-drained soils, where constant flushing of weathering products by freshwater removes the aqueous products from the vicinity of the weathered grain (Cremeens *et al.*, 1992). It is likely that the Herbert soils are less well drained than the Mendenhall moraines, and thus less developed.

CONCLUSION

The Herbert Glacier buried forest soil profile represents one interstadial development of vegetation and soil in a Pleistocene glacial till. However, it is likely that many generations of forests have grown in this area over time, which accounts for the 2850-year-old tree that was dated. The radiocarbon dates for the peat layer show that the soil may be at least 5400 - 7300 years old, if not older. The inverted radiocarbon dates may suggest either contamination in collection, or contamination from younger roots growing deeply through the peat. The dates may also confirm that the glacier effectively disturbed and mixed the overlying older and younger peat layers as it advanced over the forest. This seems the most likely, considering the mass of the overriding glacier. Although the roche moutonée on which many of the soil profiles are preserved may have initially protected this section of the forest soil from complete erosion, it may have also provided a surface against which the soil could have been thrust and mixed. In many places, the soil is visibly thrust upon itself, making it hard to easily quantify the weathering. This glacial disturbance is obvious in clay stringers that run through the peat layers. The stringers most likely represent small crevices created by the thrusting movement the glacier produced as it advanced, which were later infilled by sediment in circulating glacial waters. This glacial disturbance is the most visible in a triplicate peat layer that is exposed at Location 2, indicating extensive thrusting of the soil upon itself.

The interstadial seems to have lasted around 4600 – 6500 years, when taking into account the Little Ice Age advance of the glacier over the forest 770±40 years ago. Thus, the amount of weathering that is found on these soil

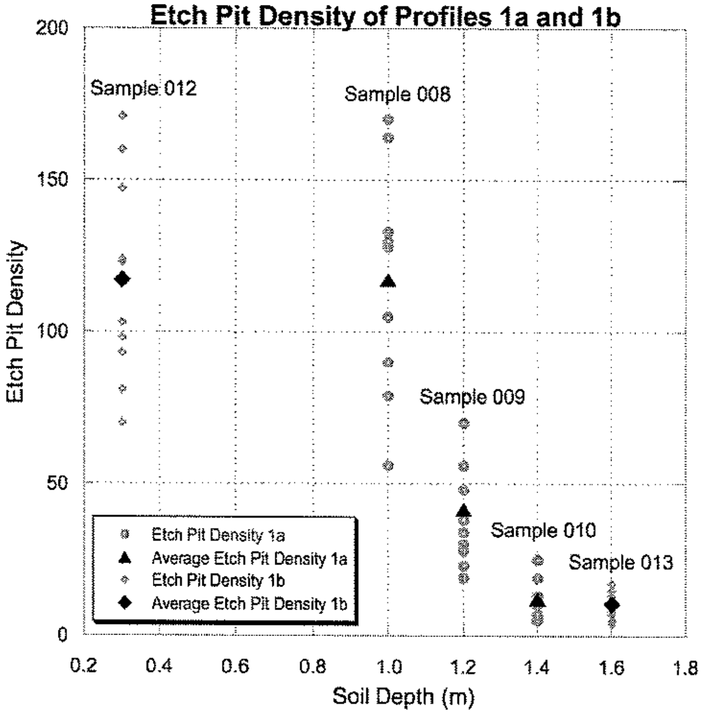

Figure 4. 'Etch pit density' refers to the number of etch pits counted on the weathered faces of feldspar grains with the use of the SEM. The etch pits were counted in a randomly selected 10 cm x 15 cm area on feldspar mineral grains under 1000x magnification and an accelerating voltage of 25kV. Please note that soils were sampled from the mid-section of each horizon.

grains must be typical of weathering in this climate zone over this duration of time. Some weathering of feldspar grains has taken place, but not enough to rid the soils of the feldspars completely. In fact, the original structure of most feldspar grains is still evident throughout the profile. The Herbert Glacier must have less weathered soils than those of the Mendenhall, because of the lower organic accumulation and slower soil reaction rates that are due to less rainfall and cooler temperatures (Crocker and Dickson, 1957). However, the Herbert soils developed for a much longer period of time than those on the Mendenhall moraines, so the differing soil morphologies must also be the product of drainage class. The dense Herbert tills must inhibit the continuous flushing of freshwater through the soils, and consequently the chemical weathering processes are lengthened in the poorly drained soils.

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A COMPARATIVE HYDROLOGIC STUDY OF MELTWATER STREAMS FROM THE EAGLE, HERBERT AND MENDENHALL GLACIERS NEAR JUNEAU, ALASKA.

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INTRODUCTION

Runoff patterns in glaciated basins are highly complex due to a large number of variables. Variations in runoff are affected by glacial processes such as the formation of complex conduit systems within glacier ice and diurnal variations in ablation. Ablation is regulated by air temperature, wind patterns, air pressure, and precipitation (Te Chow, 1964). Other factors such as aquifer potential of glacial deposits in glaciated watershed valleys and hydraulic pressure under ice further complicate a hydrologic analysis in glaciated basins.

The purpose of this project was to analyze and compare fluctuations in discharge of the Herbert, Eagle, and Mendenhall Rivers to determine if runoff from these three glaciated basins fluctuated on the same temperature and precipitation schedule. By monitoring stage and discharge of these systems throughout the month of July, 2000, and examining historical discharge and climate data, I found that there may be differences between these systems that cannot be accounted for by variations in temperature and precipitation alone. My analysis of runoff patterns suggests that watershed size, percent ice and ablation zone cover are not always indicative of the amount of runoff from a glaciated basin. Results also suggest that there is a strong diurnal variation in meltwater discharge from the Eagle, Herbert and Mendenhall glaciers- strong enough to be detected up to 8 kilometers downstream from glacier termini. It is evident from these results that the Eagle, Herbert and Mendenhall systems are highly dynamic and can change their behavior on a daily and yearly basis.

METHODS

Discharge and stage were monitored on the Herbert, Eagle and Mendenhall Rivers throughout the month of July, 2000. Measurements were taken at highway bridges across each river to ensure safety and ease of access. A tag line was set up across each bridge to establish data collection stations across each stream on the side with the least amount of debris, which ranged from gravel bars to abandoned cars. Stage was measured at a designated point under each bridge.

Depth and velocity data were collected at each station along the tag lines. Depth was measured using a rope anchored with a weighted steel pipe. Velocity was measured using a General Oceanics Inc. current meter attached to the weighted rope. The current meter was placed at six-tenths depth of the water column for two minutes in order to obtain the average velocity for each section (Te Chow, 1964). When stream velocity was too great to use the pipe as an anchor, depth was calculated using streambed profiles and average velocity was calculated using the following formula: average velocity =(surface velocity)*0.86 (Mosely and McKerchar, 1993) Stage was measured before and after each depth/ discharge profile to obtain an average. A stage-discharge rating table was created for each system by correlating stage measurements and discharge calculations. Measurements were made approximately once or twice every two days for three weeks.

Twenty-four hour stage, air, and water temperature data were collected using a PDCR 1830-8388 Druck pressure transducer and two thermisters wired to a Campbell Scientific Inc. model 21X micro logger. Each stream was logged for the duration of one week. However, the data logger was placed in Mendenhall Lake rather than in Mendenhall River in order to correlate my data with those from the United States Geological Survey's (USGS) data collection station on Mendenhall Lake. The USGS correlated lake stage with downstream velocity measurements to obtain discharge. My stage and discharge results matched those of the USGS to within ten percent. Thus, for the remainder of the summer, I used USGS discharge data for the Mendenhall River to do a direct comparison with my data from the Herbert and Eagle Rivers.