HOLOCENE GEOLOGY AND HYDROLOGY IN THE VICINITY OF THE MENDENHALL, HERBERT, AND EAGLE GLACIERS, JUNEAU, ALASKA

FACULTY

Robert J. Carson, Department of Geology, Whitman College
Robert M. Newton, Department of Geology, Smith College
P. Jay Fleisher, Department of Earth Sciences, SUNY, College at Oneonta,
M. Todd Shearer, Department of Geosciences, University of Arizona

STUDENTS

Seth Atkinson, Amherst College
Margo Burton, Whitman College
Drew Beckwith, Colorado College
Carissa Carter, Williams College
Marlene Duffy, Williams College
Jessica Darter, Franklin & Marshall College
Christine Metzger, Washington and Lee University
Ben Mirus, Pomona College
Monica Roth, SUNY at Oneonta
Jessica Rowland, Trinity University
Anne Sawyer, Carleton College

VISITING GEOSCIENCE PROFESSIONALS

Cathy Connor, University of Alaska Southeast

VISITING SPONSORS

Dave DeSimone, Williams College
Dave Dethier, Williams College
Dave Harbor, Washington and Lee University
Eric Leonard, The Colorado College
Anna Martini, Amherst College
Dorothy Merritts, Franklin & Marshall College

HOLOCENE GEOLOGY AND HYDROLOGY IN THE VICINITY OF THE MENDENHALL, HERBERT, AND EAGLE GLACIERS, JUNEAU, ALASKA

Robert J. Carson
Department of Geology, Whitman College

Robert M. Newton
Department of Geology, Smith College

P. Jay Fleisher
Department of Earth Sciences, SUNY, College at Oneonta,

M. Todd Shearer
Department of Geosciences, University of Arizona

INTRODUCTION

The Mendenhall, Herbert, and Eagle Glaciers are retreating valley glaciers, nourished by the Juneau Icefield (figure 1). During June-July, 2000, a Keck Geology Consortium "junior" research project was based at the University of Alaska Southeast on Auke Lake 17 km northwest of Juneau, Alaska. Our goal was to study these three valley glacier systems, including bedrock setting, glacier termini, sediments, meltwater, lakes and rivers, taking into account climate and vegetation. We were particularly interested in changes in sediments and water geochemistry from the glaciers to the small fjords east of Lynn Canal. We also hoped to add to the work of Lawrence (1950) regarding Holocene advances and retreats of these three glaciers and the associated landforms.

The project faculty flew to Juneau on 27 June 2000, rented four vehicles, and moved into the residence halls of the University of Alaska Southeast. After the students arrived on 28 June, we took reconnaissance hikes to the ice fronts of the Mendenhall, Herbert, and Eagle Glaciers.

The Mendenhall Glacier (Figure 2) is 5 km northeast of Auke Lake; its southwest terminus can be reached via a 4-km hike along the west shore of Mendenhall Lake. One can get very close to the southeast snout by hiking along the east shore of the lake from the U.S. Forest Service Visitor Center to Nugget Falls, a tributary to Mendenhall Lake. On many project days we used a large inflatable raft to crisscross the lake measuring water depths and collecting water and sediment samples.

The trailheads to both the Herbert and Eagle Glaciers are located about 15 km northwest of Auke Lake. The Herbert Glacier (Figure 3) can be reached via an 8-km hike along a trail that follows the Herbert River to its source at the glacier. The Eagle Glacier (Figure 4) occupies an adjacent valley approximately 5 km northwest of the Herbert Glacier; it is reached via a 10-km trail near the Eagle River. For research on the Eagle Glacier system we stayed in a U.S. Forest Service cabin on the lower of two lakes in front of the glacier.

A small geochemistry laboratory for preliminary water analysis was set up at our residences. Our equipment included laptop computers, GPS receivers, bottom sediment collectors, and various measuring devices including a bathymeter. Mapping was done in a GIS format using ESRI ArcView software.

Near the end of the project we overflew the Juneau Icefield including the three glaciers we studied. We took a boat up Tracy Arm to observe processes and landforms associated with a major fjord and the calving North and South Sawyer Glaciers.

We met for a workshop at Smith College in 2001, to share data and ideas, and to use the GIS and water chemistry facilities at Smith College (see box).

Geography

The Juneau Ice Field straddles the Coast Range along the Alaska-British Columbia boundary. To the west is the fjord of Lynn Canal which extends from the Juneau area north toward Haines and Skagway. To the southeast is the Taku River which flows across the Coast Range from British Columbia to the salt

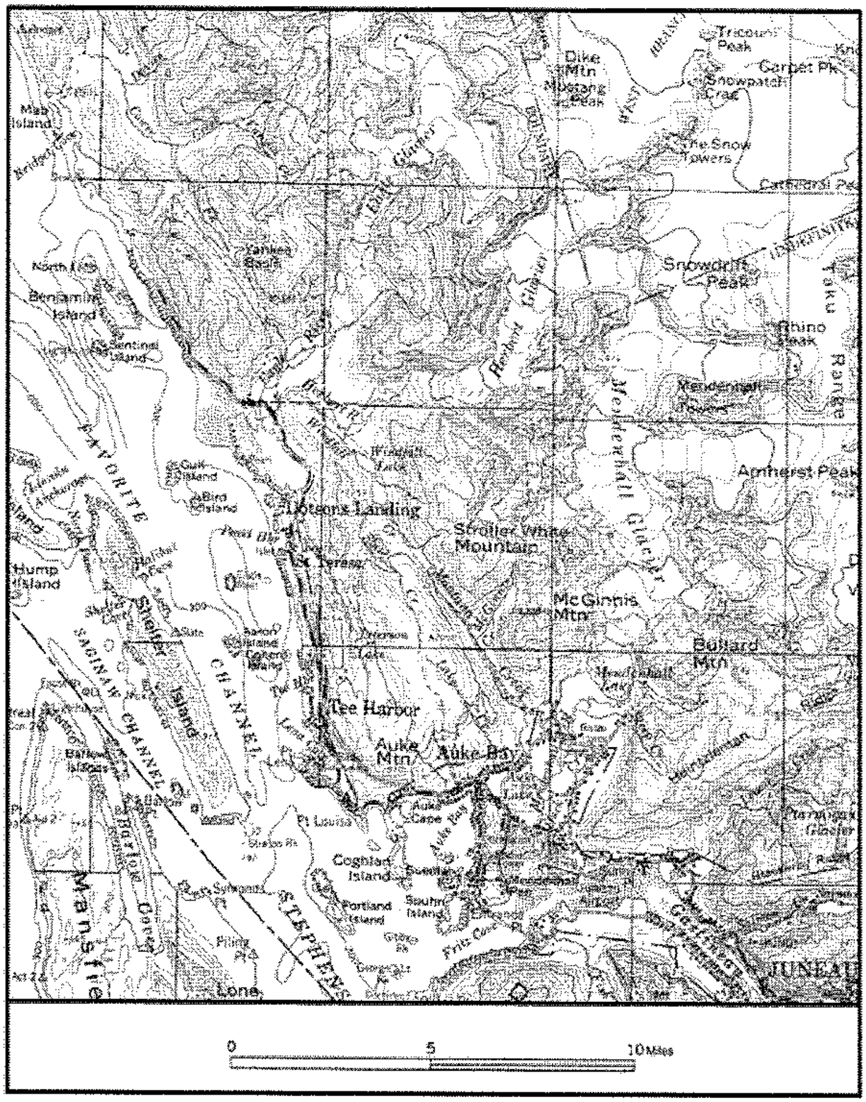

Figure 1. Juneau area, with portion of Juneau Icefield in northeastern third of the map. (Each square on the map is 10 km on a side.) The Eagle, Herbert, and Mendenhall Glaciers are at the western edge of the icefield. Favorite Channel and other small fjords are at the western edge of the map.

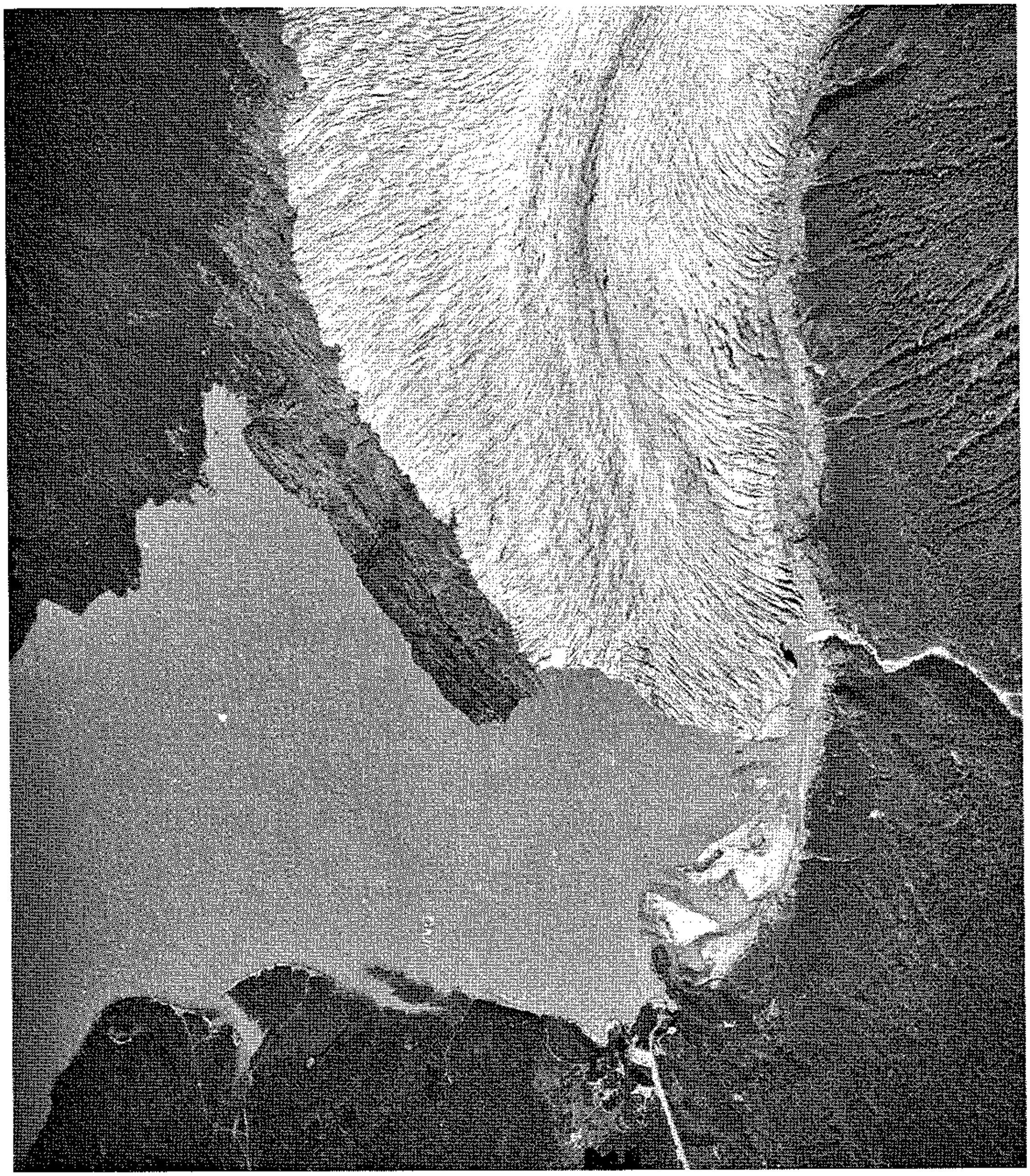

Figure 2. Terminus of Mendenhall Glacier, the “rock rib”, and eastern Mendenhall Lake, approximate scale 1:14,000 (USDA air photo 184-186, 14 August 1984). Since 1984 the southeastern corner of the Mendenhall Glacier terminus retreated to north of Nugget Falls. Note icebergs in lake.

Figure 3. Terminus of Herbert Glacier and headwaters of Herbert River, approximate scale 1:14,000 (USDA air photos 184-147 and 184-186, 14 August 1984). Since 1984 the northern meltwater channel in the narrow bedrock canyon has been abandoned; the Herbert Glacier terminus has retreated far enough east for all of the meltwater to be deflected south by the bedrock ridge.

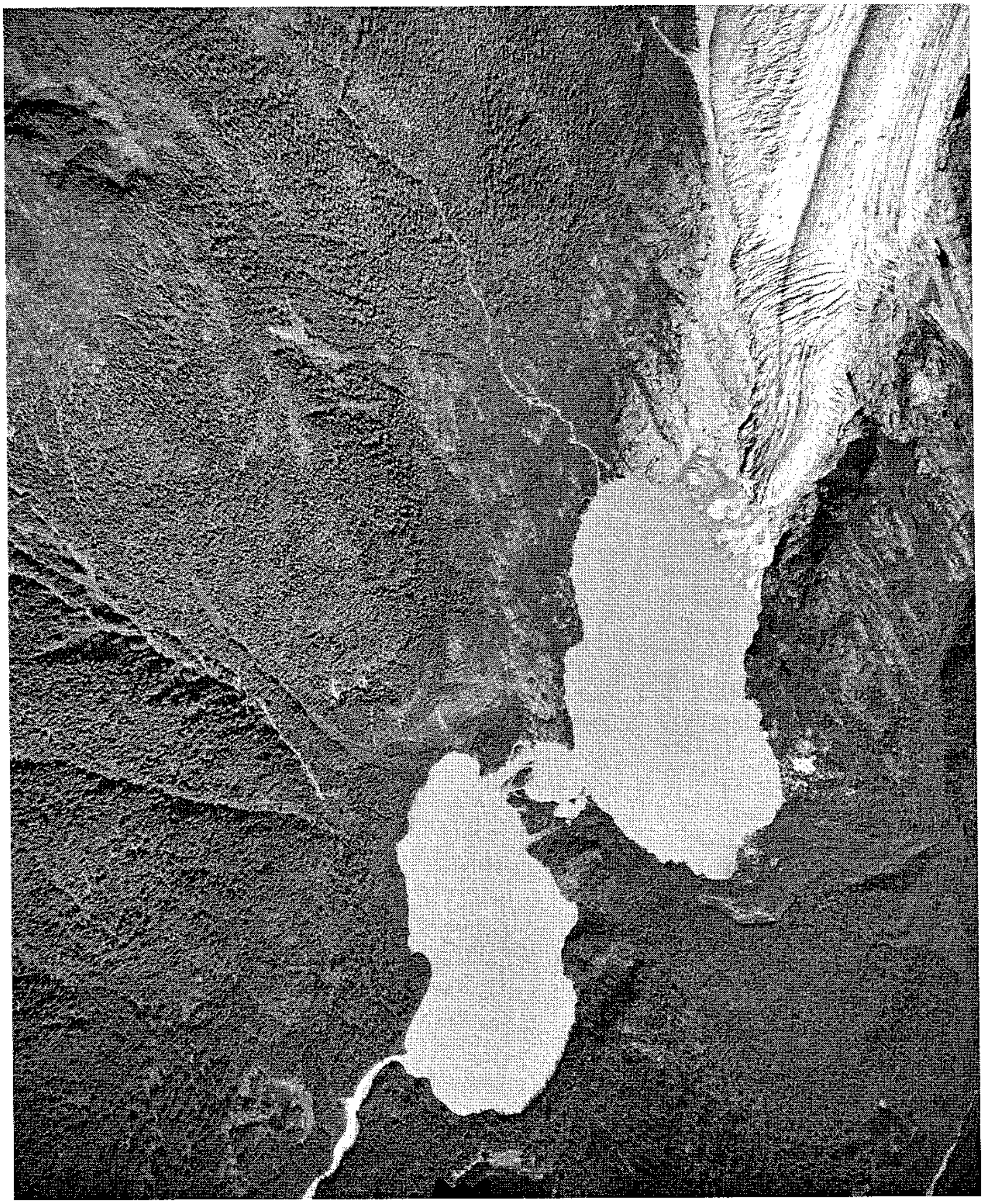

Figure 4. Terminus of Eagle Glacier, delta, and two proglacial lakes, approximate scale 1:14,000 (USDA airphoto 184-107, 14 August 1984). Since 1984 the Eagle Glacier terminus has retreated far enough north for there to be a canyon between the ice and the delta.

water of Stevens Passage. The Juneau Icefield reaches elevations above 2000 m; its outlet glaciers extend nearly to sea level. Three of the outlet ice streams are the Mendenhall, Herbert, and Eagle Glaciers. Southeastern Alaska has a mild maritime climate. The mean annual temperature of Juneau is 13°C; winter temperatures are mostly above -7°C, and summer temperatures are generally below 18°C. (http://www.Juneau.lib.ak.us/junfacts.htm). Mean annual precipitation varies from place to place, with Juneau getting 2060 mm/yr, including an average of 2.8 m/yr of snow (Knopf, 1912).
The U.S. portion of the Juneau Icefield lies mostly within the Tongass National Forest, a temperate rain forest. The dominant conifer is Sitka spruce; there are also Western hemlock and lodgepole pine. Deciduous trees include cottonwood and alder. Treeline varies but is near 600 m in the vicinity of the Mendenhall, Herbert, and Eagle Glaciers.

Alaska Project: A workshop at Smith College
Northhampton, Massachusetts 2001

Most of the Alaska Project students, faculty, and sponsors met at Smith College in January 2001 for a workshop directed by Bob Newton. At the beginning and at the end of the workshop, each student summarized his/her past, present, and future research. Jon Caris of Smith College made a presentation on Geographic Information Systems (GIS) and was available to help students in the Spatial Analysis Laboratory. Mark Brandiss of Smith College summarized the bedrock geology and plate tectonics of southeastern Alaska.

Data analysis and working with aerial photographs and GIS occupied most of the workshop time. Samples were prepared for and analyzed by x-ray diffraction (XRD) and scanning electron microscopy (SEM). XRD is being used for analysis of sediments. SEM is useful for grain surface morphology, including etch pits and chatter marks.

Bedrock Geology

Southeastern Alaska is just onshore of where the north-trending Queen Charlotte strike-slip fault merges with the west-trending Aleutian thrust (Drummond et al., 1981). Here small terranes have accreted to North America since the Mesozoic, and earthquakes are common. Gold mining drove the geologic exploration of southeastern Alaska, with 12 U.S. Geological Survey reports published or in preparation from 1898 to 1912 (summarized by Brooks *in* Knopf, 1912, p. 5-6). Of particular interest to this research project is the report by Knopf (1912) on the geology in the vicinity of the Mendenhall, Herbert, and Eagle Glaciers. Knopf (1912) noted that all bedrock geologic features (strata, foliation, etc.) strike northwest and dip steeply northeast. He determined that the slate, greywacke, and greenstone are Carboniferous, Jurassic, and Cretaceous. Knopf (1912) observed the transition going inland from these rocks to phyllite and schist and gneiss. He believed the metamorphism to be associated with late Mesozoic intrusion of quartz diorite at the core of the Coast Range.

In the area of the study site, the geologic map of southeastern Alaska (Gehrels and Berg, 1992) shows, from southwest to northeast: Jurassic and Cretaceous sedimentary and volcanic rocks: marine greywacke and mudstone, subordinate conglomerate, minor limestone; andesitic to basaltic flows, flow breccia, agglomerate, and tuff; "...regionally metamorphosed and deformed equivalents of these strata. Metamorphic grade generally increases from subgreenschist facies or nonmetamorphosed on southwest to greenschist and in some areas amphibolite facies to northeast." Permian to Cretaceous sedimentary and volcanic rocks: shale, mudstone, and greywacke, subordinate limestone, chert, and conglomerate; andesitic or basaltic flows and locally fragmental rocks; "...metamorphosed and deformed equivalents of these rocks. Regional metamorphic grade... generally increases from subgreenschist facies on southwest to amphibolite facies torward northeast." Cretaceous and Paleocene tonalite: hornblende-dominant, biotite-bearing tonalite and subordinate quartz diorite.

The bedrock geology can be summarized as follows: ancestral North America lies to the northeast; the Yukon terrane (adjacent to ancestral North America) and then the Wrangelia terrane (at the snouts of the Mendenhall, Herbert, and Eagle Glaciers) were accreted; subduction of the Kula plate led to intrusion of the Coast Plutonic Complex (near the boundary of the two terranes) (Mark Brandiss, Smith College, oral communication, 2001). "Granitic" erratics eroded from the Coast Plutonic Complex are common on the Wrangelia sedimentary, volcanic, and metamorphic rocks in the vicinity of the snouts of the three glaciers.

Quaternary Geology

All of southeastern Alaska was covered by the Cordilleran Ice Sheet during the glacial epochs of the Pleistocene (Hamilton and Thorson, 1983). Deglaciation at the end of the Pleistocene, coupled with active tectonism, has resulted in uplift rates much higher than Holocene sea level rise. For example, a date of 13060±40 radiocarbon years was obtained from organics in glaciomarine drift at an elevation of 791 m near Juneau (Cathy Connor, University of Alaska Southeast, oral communication, 2000). Without even considering postglacial sea level rise, this indicates an uplift rate of greater than 6 cm/yr.

Topographic and geologic maps (scale 1:62,500) were made in connection with U.S. Geological Survey research in 1909 and 1910 (Brooks, *in* Knopf, 1912). The topographic map shows the limits of the Mendenhall, Herbert, and Eagle Glaciers; the terminus of the Eagle Glacier formed two lobes separated by a bedrock hill in the middle of the glacial trough. Neither Mendenhall Lake or any other large lakes existed in any of the three valleys.

Knopf (1912) briefly discussed the three glaciers, mentioning a buried forest in front of the Mendenhall Glacier, and diorite erratics at elevations up to 3400 feet (>1000 m). "The large glaciers have the sloping fronts characteristic of retreating glaciers; they are also nearly free of morainal material carried on their backs, a feature due in part to their shrunken condition. Retreat of the glaciers is indicated by the bare glaciated bedrock along their sides not yet covered by the rapidly advancing vegetation and by claim stakes of prospectors, which a few years ago were placed as near the ice as possible, but are now several hundred feet distant from it (Knopf, 1912, p. 12)."

Maynard Miller and others have been studying the glaciers in the vicinity of Juneau as part of the ongoing Juneau Icefield Research Program (e.g., Field and Miller, 1950). One of the first publications included the results of studies on the Herbert, Eagle, and Mendenhall Glaciers (Lawrence, 1950). Lawrence examined the semicircular moraines west of the Herbert Glacier (Figure 3) and determined by tree rings that the terminal moraine dated from about 1765 A.D. and that the area in front of the terminal moraine had not been glaciated since before 1350 A.D. Tree rings showed that two of the 12 or 13 recessional moraines dated from 1786-88 and 1844-46 A.D. When Lawrence (1950) studied the Eagle Glacier area (Figure 4), there was only one lake in front of the ice. He believed that the area beyond the terminal moraine had not been glaciated since before 1300 A.D. With tree rings he determined that one of the oldest recessional moraines dated from 1785-1787 A.D. Lawrence (1950) determined that the snout of the Mendenhall Glacier (Figure 2) had not been beyond its terminal moraine since before 1300 A.D. With tree rings Lawrence (1950) dated the terminal moraine at about 1767-1769 A.D., and specific younger recessional moraines at 1832-1834, 1865-1867, 1883-1885, and 1901-1903 A.D. He believed that a minor readvance occurred between 1832 and 1865 A.D. Miller's (1975) surficial geologic map of Juneau and vicinity identifies Pleistocene and Holocene deposits, including glaciomarine, marine, beach, and deltaic deposits, alluvium, drift, and colluvium. Miller (1975) did more denchronology on moraines of the Mendenhall Valley, and radiocarbon dated wood, shells, peat, and carbon. Wood dated at 2780 and 2800 years before present suggests that the Mendenhall Glacier overran a forest at that time.

Student Projects

Seth Atkinson studied the aqueous geochemistry of the Herbert, Eagle, and Mendenhall Glacier systems in hopes of understanding the sources of solutes, and thus the nature of chemical weathering in these systems. In Alaska he collected water, sediment, and rock samples. The meltwater and meteoric water samples were later analyzed for major ion chemistry and oxygen isotopes.

Drew Beckwith investigated the basin between the retreating terminus of the Herbert Glacier and the bedrock ridge just downvalley (figure 3). The retreating ice has exposed lower meltwater outlets so that there are multiple kame terraces at the northwestern corner of the glacier. He is also attempting to determine the source of the large rounded boulders in the vicinity of the Herbert Glacier terminus. In addition, he is dating and interpreting a stratigraphic section containing multiple drift units.

Margo Burton is studying the area recently deglaciated by the Mendenhall Glacier (Figure 2), and considering earlier studies by Knopf (1912), Lawrence (1950), and Miller (1975). She is comparing retreat rates for various time periods in the twentieth century with tree cores from the area. In addition, she mapped the depositional and erosional features in the recently deglaciated area.

Carissa Carter's project focuses on patchy coatings of calcite-cemented silt and sand grains on the "rock rib" in front of the Mendenhall Glacier. The "silt skins" have both striated and corrugated morphologies. She used hand specimens, thin sections, scanning electron microscopy, and x-ray diffraction to study the "silt skins". In addition, she determined the chemistry of basal ice and subglacial water to discover the origin of the calcite cement.

Jessica Darter analyzed suspended sediment samples and bottom samples from Mendenhall Lake. She considered the geologic features near the lake, bottom topography, and potential glaciolacustrine processes. Sediment distribution patterns were determined with the help of a Laser Particle Analyzer. She also studied the mineralogy of the lake sediment to help determine its source.

Marlene Duffy studied the effect of the "rock rib" on the flow of the Mendenhall Glacier. Significant changes in striation direction were noted on the stoss face of the "rock rib", as well as on smaller stoss-and-lee features. Using regression analysis, she attempted to determine which dimensions (e.g., height, width, slope) of the stoss-and-lee features had the greatest effect on ice flow.

Christine Metzger and Jessica Rowland investigated the buried forest near the terminus of the Herbert Glacier. They obtained radiocarbon dates to help interpret the complex history of ice advance and retreat, forest growth and death, and soil formation. Christine used clay mineralogy and cation exchange capacity of the buried soil in an attempt to determine the duration of forest development. This amount of time was used as a proxy for the length of the interstadial that preceded the most recent advance of the Herbert Glacier. Jessica used scanning electron microscopy to observe etch pits on feldspar grains in different soil horizons. She also measured weathering rinds on cobbles to try to determine the age of the paleosol.

Ben Mirus studied the suspended sediment in the meltwater systems of the three glaciers. He filtered the sediment from water collected at the glacier snouts and in the lakes and rivers. Concentration, grain size, and mineralogy of the sediment were determined. He also compared stage variations with suspended sediment concentrations.

Monica Roth investigated various aspects of Mendenhall Lake in an attempt to understand a lake system in front of a non-surging glacier. She created a bathymetric map from depth profiles obtained from a raft. Temperature, salinity, and conductivity data were obtained at water sample sites. Turbidity was determined from water samples.

Anne Sawyer's project involved stage and discharge measurements for the meltwater systems downvalley of the Mendenhall, Herbert, and Eagle Glaciers. She used a datalogger with a pressure transducer to collect continuous stage data. She collected discharge data from highway bridges over the Mendenhall, Herbert, and Eagle Rivers. She was also able to collect limited ablation data on the Mendenhall Glacier. For comparison, she obtained historical stage, discharge, and climate data.

Acknowledgments

The Alaska project and workshop would not have been possible without the support of the W.M. Keck Foundation, the National Science Foundation and the 12 schools in the Keck Geology consortium. The cooperation of the personnel of Tongass National Forest, the University of Alaska Southeast, and Auk Ta Shaa are appreciated. Our particular gratitude is extended to Professor Cathy Connor and to the Housing and Computer staffs at the University of Alaska Southeast. Special thanks go to Heidi Reinfenstein and Jeff Moorehouse of Auk Ta Shaa for the loan of a raft to explore Mendenhall Lake rain or shine, and to Patti Moss and Geoff Kunz for word and image processing.

References Cited

Carson, R.J., 1999a, Glaciers: a workshop in southeastern Alaska: Proceedings, Twelfth Keck Research Symposium in Geology (Carleton College, Northfield, Minnesota, p. 5-6.

Carson, R.J., 1999b, Reconnaissance of Herbert and Mendenhall Glaciers, Juneau Icefield, Alaska: Northwest Scientific Association Annual Meeting (Tacoma, WA), Abstracts, p. 28.

Drummond, K.J., and others, 1981, Plate-tectonic map of the circum-Pacific region, northeast quadrant: American Association of Petroleum Geologists, scale 1:10,000,000.

Field, W.D., and M.M. Miller, 1950, The Juneau Ice Field Research Project: The Geographical Review, v.40, no.2, p.179-190.

Gehrels, G.E., and H.C. Berg, 1992, Geologic map of southeastern Alaska: U.S. Geological Survey Miscellaneous Investigations Series Map I-1867, scale 1:600,000.

Hamilton, T.D., and R.M. Thorson, 1983, The Cordilleran Ice Sheet in Alaska, *in* S.C. Porter, The Late Pleistocene, v.1 of H.E. Wright, Late Quaternary environments of the United States, p. 38-52.

Knopf, Adolph, 1912, The Eagle River region, southeastern Alaska: U.S. Geological Survey Bulletin 502, 61p.

Lawrence, D.B., 1950, Glacier fluctuations for six centuries in southeastern Alaska and its relation to solar activity: The Geographical Review, v.40, no.2, p. 191-223.

Miller, R.D., 1975, Surficial geologic map of the Juneau urban area and vicinity, Alaska: U.S. Geological Survey Miscellaneous Investigation Series Map I-885, scale 1:48,000.