PROCEEDINGS OF THE TWENTY-EIGHTH ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

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Keck Geology Consortium: Projects 2014-2015
Short Contributions— Environmental Change in Glacier National Park, MT Project

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GEOMORPHIC AND PALEOENVIRONMENTAL CHANGE IN GLACIER NATIONAL PARK, MONTANA, U.S.A.

KELLY MACGREGOR, Macalester College
AMY MYRBO, LacCore/CSDCO, University of Minnesota

INTRODUCTION

Understanding controls on past climate variability is key to assessing potential future environmental change. The climate history of the northern Rocky Mountains is known primarily from lacustrine paleoecological records that are widely spaced in Montana, Idaho, and Wyoming (e.g., Karsian, 1995; Doerner and Carrara, 1999; Millspaugh et al., 2000; Doerner and Carrara, 2001; Brunelle and Whitlock, 2003; Hofmann et al., 2006; Shapley et al., 2008). There are few lacustrine records from the northern U.S. Rockies spanning the late Pleistocene and Holocene and therefore our knowledge of the timing of major climate shifts in the region is incomplete.

Glacier National Park, Montana (GNP) is sensitive to climate change as observed through glacial retreat (e.g., Key et al., 2002) and ecosystem adjustments (e.g., Klasner and Fagre, 2002), and there is widespread interest in the effects of future climate change in this unique and public space. Our research project was aimed at understanding environmental and climate change variability in a near-pristine alpine basin in North America, with the goal of collecting data that is relevant to the debate about landscape response to climate change in the northern Rockies since the Last Glacial Maximum. The research project has relevance to the research communities in geomorphology, Quaternary geology, glaciology, and paleoclimatology, as well as to the general public interested in the history of climate change since the retreat of Ice Age glaciers.

The choice of lakes on which to focus during the project was based on a substantial body of past work in the Many Glacier Region of eastern GNP. In 2005 and 2010, we collected cores in Swiftcurrent Lake, Lake Josephine, and lower Grinnell lakes, all of which are located downstream of Grinnell Glacier (Figure 1). Past work has focused on a continuous core (SWF05/10-3) from Swiftcurrent Lake spanning ~17,000 years. A major result of previous studies on this core show that dolomite presence and percent total inorganic carbon (%TIC) are high during periods when the region was likely cool and glaciers were larger, such as the Younger Dryas and late Pleistocene. A stratigraphic break in the valley occurs at the base of the Grinnell Glacier cirque basin, with rock at/above the cirque comprised of primarily dolomitic material, and argillites below. Higher concentrations of detrital carbonate likely reflects increased glacial erosion, enhanced sediment transport downvalley, and/or an advanced glacier terminus position and the subsequent removal of additional lakes/sediment sinks in the system (MacGregor et al., 2011; Schachtman et al., in press). Further work on a core from Lake Josephine showed a similar increase in %TIC during the Little Ice Age (LIA; Anderson et al., in review). Other studies have focused on the effects of historic climate warming and land use changes (Anderson et al., in review), the history of fires and ecologic changes in the region (Kutvirt, 2011; Locatelli, 2011), and fingerprinting volcanic ash units found in the cores (Schachtman et al., in press). In 2014, our coring efforts focused on the collection of long/deep cores from two sites in Lake Josephine (where cores of only a few meters in length had been collected), and one site in the northern/downstream subbasin of Swiftcurrent Lake. The primary objective of core collection efforts was to examine the spatial and temporal variability in inorganic carbon as a proxy for Grinnell Glacier dynamics over the late Pleistocene and Holocene. A downvalley transect of cores spanning ~20,000 years could provide a wealth of information about ice dynamics, geomorphic change, and ecologic shifts associated with dramatic climate variability during this time. In addition, we collected rock samples from the valley to constrain the mineralogy and geochemistry of the units contributing sediment to the lakes, in particular to assess whether additional sources of inorganic carbon in the valley exist. Finally, we were interested in examining recent (centuries to millenia) environmental change in the Many Glacier area. Changes in glacier size,

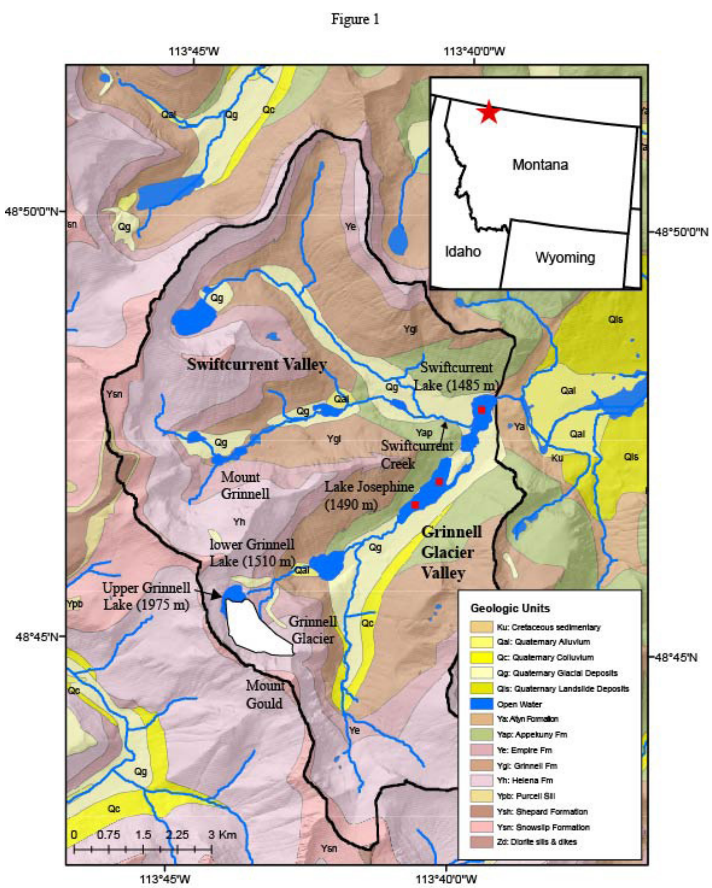

Figure 1. Geologic setting of the Many Glacier area of Glacier National Park, MT. Geologic units are generally either Precambrian meta-sedimentary formations or Quaternary surficial deposits. Lake cores were collected from four lakes within a watershed (black line) covering two main valleys. The southern valley (Grinnell Glacier Valley) has Grinnell Glacier in its headwaters, and serves as the source of water, sediment, and water-borne debris for most of the lake cores. The northern valley (Swiftcurrent Valley) contributes water to the northern subbasin of Swiftcurrent Lake, where a long core was collected in summer 2014. Coring sites from 2014 shown in red squares. Map after MacGregor et al., 2011, courtesy of C. Riihimaki, Princeton University.

hydrology, ecology, fire history, and differences in the geomorphic characteristics of the two adjacent valleys (Grinnell Glacier Valley and Swiftcurrent Valley, Figure 1) during the last 100-1000 years were of interest to the team.

FIELD SETTING

The Many Glacier region of Glacier National Park, Montana is located to the east of the Continental Divide and includes several small cirque glaciers and glacially carved lakes (Figure 1). Swiftcurrent Lake, the most accessible of the formerly glaciated lakes, receives water and sediment from two valleys: the southwestern portion of the lake has a 36-km^2 drainage basin that includes Grinnell Glacier (~2000 m elevation), Upper and lower Grinnell lakes, and Lake Josephine, while the northeastern portion of the lake has a drainage area of 44 km^2 that includes Swiftcurrent Glacier, Fishercap Lake, Swiftcurrent Creek and its tributaries. The Many Glacier Hotel, completed by 1918, sits near Swiftcurrent Lake outlet.

The Swiftcurrent Lake drainage basin is underlain by the Middle Proterozoic Belt Supergroup, which is comprised primarily of siltsones, shales, and sandstones (Figure 1; Horodyski, 1983). Grinnell Glacier is currently eroding the stromatolitic Siyeh Limestone of the Helena Formation, and consists of dolomitic limestone and calcitic argillite (Whipple, 1992). The only bedrock source of dolomite in the valley is within the cirque basin containing Grinnell Glacier, and at the highest elevations of the basin to the north and south.

Lake Josephine and Swiftcurrent Lake are underlain entirely by late Pleistocene tills on order of 1-3 m thick (Earhart et al., 1989; Carrara, 1990; Whipple, 1992). The presence of Glacier Peak G ash (~13.6 ka; Mehringer et al., 1984) overlying this till in several locations in the Park (Carrara, 1989, 1993) suggests the valley below Grinnell Glacier was deglaciated by this time. Radiocarbon ages, the presence of Glacier Peak G ash at ~1600 m elevation (Carrara, 1995), and a minimum age of 11,400 ^{14}C BP for deposition in Otokomi Lake (1976 m elevation; MacLeod et al., 2006) supports this interpretation of widespread deglaciation in the valley by at least 11 ka (Carrara, 1987,1989).

PROJECT OVERVIEW

In July 2014, six students, two LacCore faculty, one camp coordinator and a variety of friends and family converged at the Elkhorn campground in Babb, MT for 14 days of field work. During this time, we worked in teams, using inflatable kayaks to collect bathymetric data and over 65 meters of sediment from Swiftcurrent Lake and Lake Josephine (Figure 1, red squares), despite several days of extremely high winds and hail. The coring craft was transported across the lakes by the Many Glacier Boat Company, and then portaged to Lake Josephine in pieces, and constructed prior to launch. Cores were collected using square rod piston coring devices, with overlapping cores from adjacent boreholes collected when feasible for continuous depth records. One surface core from Lake Josephine was collected for ^{210}Pb analysis and were sectioned in the field at 0.5 cm intervals. In addition to the coring, the group presented our research to the Park Rangers and Boat Company employees. Everyone enjoyed interactions with cold and hot weather, bears, moose, horses, wolverines, and Park visitors!

All cores were transported to LacCore at the University of Minnesota, and we spent two weeks working together in the lab. Measurements of the sediments' geophysical properties (density, magnetic susceptibility) were collected on the whole core (0.5 cm resolution) using the Geotek Multi-Sensor Core Logger (MSCL). Cores then were split lengthwise, cleaned, and imaged at 20 pixels per mm on the Geotek CIS linescan digital camera. Initial core description (ICD) was done following the nomenclature found in Schnurrenberger and others (2003). Smear slides were taken in horizons of interest to look at the clastic, authigenic, and biogenic components of the sediment. Split core sections were then logged on the Geotek XYZ at 0.5 cm resolution for high-resolution magnetic susceptibility and color reflectance. The last several days in the lab each student worked on collecting samples from the cores for their own projects, as well as sampling for ^{210}Pb dating, loss-on-ignition (LOI) analysis for correlating cores, and refining research questions.

Core sediments contained laminations but were not varved, and were generally silt and clay-rich with minor sandy contributions. Diatoms were pervasive in the top several meters of sediments, and clastic units are comprised of several clay minerals, quartz, feldspars, and dolomite. Several ash units, including a Mazama ash (7630±150 cal yr BP; MacGregor et al., 2011, after Zdanowicz et al., 1999), Glacier Peak G (13,710-13,410 cal yr BP; Kuehn et al., 2009) and Mount St. Helens Jy ashes (13,870 ±100 cal yr BP; Foit et al., 1993; Schachtman et al., in press) were present in long cores from both lakes. The thickness of the Mazama ash was ~0.5 m in Lake Josephine cores, but was >3 m thick in the Swiftcurrent Lake core near the Many Glacier Hotel!

STUDENT PROJECTS

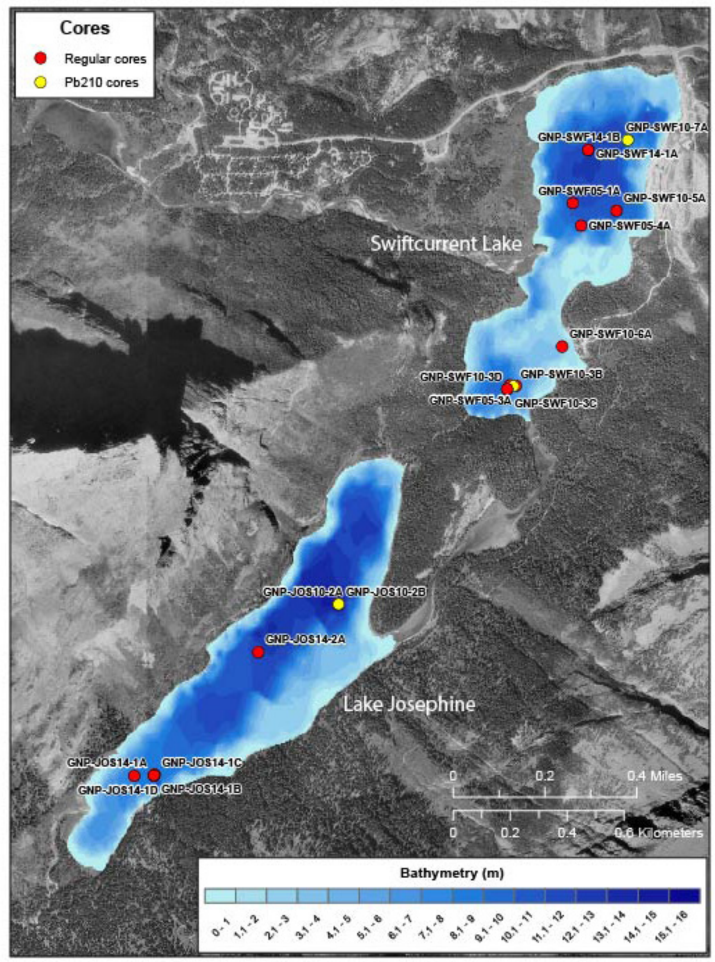

Figure 2. Study lakes colored by water depth, including lake-coring locations symbolized by the type of cores collected. All cores collected over the past decade, including those from 2014, are labeled and colored either yellow (surface cores collected for Pb-210 analysis and historical geochemistry reconstructions) or red (longer cores collected for late Pleistocene-Holocene paleoenvironmental reconstructions). Water depth measurements were also collected in summers 2010 and 2014 and interpolated to make the bathymetric map. Map courtesy of C. Riihimaki, Princeton University.

Figure 3. Field photo of the group and visitors on a sunny day off hiking on the Continental Divide, Glacier National Park, Montana.

While students worked together in the field (Figure 3) and at LacCore, each one worked on a unique project at his or her home institution.

Madison Andres, Colorado College, processed and counted charcoal samples from the overlapping cores collected in the northern basin of Swiftcurrent Lake. Charcoal, in combination with tree ring and/or pollen data, is used to reconstruct regional fire history, and her work documents variability in fire frequency over the past ~1700 years. Using a simple age model for her samples (based on ^{210}Pb age controls from an adjacent 2010 coring site), she found that fire frequency was variable in the region with slight increases during the Little Ice Age, when the region may have been drier. Madison also identified the only historical fire, the Heavens Peak fire in 1936, in the charcoal record. She also compared her findings to another charcoal record in the adjacent upstream subbasin of Swiftcurrent Lake (Kutvirt, 2011), which showed similar timing in environmental change over this period.

Grayson Carlile, Whitman College, and ***Karly Clippinger***, Beloit College, measured carbonate and organic matter abundance in the interval between the Glacier Peak and Mazama volcanic ashes (~13,800-7600 years before present), which includes the late Pleistocene Bølling-Allerød and Younger Dryas periods (warm and cold, respectively), as well as the early Holocene. Karly examined a core in the upvalley end of Lake Josephine, and Grayson studied the downvalley core. This span of relatively well characterized climate provides an ideal background for testing our hypothesis that carbonate mineral content in these lakes is a proxy for glacial extent. Schachtman and others (in press) and MacGregor and others (2011) found that carbonate in Swiftcurrent Lake correlated with presumed glacier position; they both found that presumed glacier advance and retreat indeed correlated with carbonate abundance in the core, and additionally that during periods of low carbonate flux, organic matter abundance may be tied to warmer environmental conditions (MacGregor et al., 2011).

Ashleigh Covarrubias, California State University, San Bernardino, measured the geochemistry and mineralogy of sediments from the last 1100 years in lower Grinnell Lake. She found that there is variability in the amount of some major and trace elements over this time, suggesting the source rock supplying sediment to the lake has also shifted over this time period.

Emily Diener, Macalester College, analyzed the the youngest ~2 meters of sediment from the upvalley core in Lake Josephine for %TIC and %TOC, as well as mineralogy. She found that sedimentation rates at the upvalley site were almost twice those of the downvalley site in Lake Josephine. Percent TIC increased during the LIA window, supporting the interpretation that a larger Grinnell Glacier more efficiently erodes it's bed or more effectively transports dolomite downvalley.

Eric Stephens, Macalester College, collected and analyzed bedrock samples from the Grinnell Glacier Valley from the northeast end of Swiftcurrent Lake to the basin of Grinnell Glacier and Upper Grinnell Lake. The mineralogy and elemental composition of the geologic materials in the valley will be used to fingerprint the sources of clastic sediment to our study lakes. Eric showed that bedrock stratigraphically above Grinnell Glacier is significantly higher in calcium (as CaO) and calcite+dolomite than those below, lending support to our use of carbonate mineral content as a proxy for glacial erosion, and also determined that the tills surrounding the lake are unlikely sources of this carbonate, being relatively depleted. He also identified new tracers - Ti, Sr, and Sm - that are highly enriched in the Purcell Sill relative to all other rocks in the valley, and which, if found in the cores in high enough abundance to be detectable, could be used as tracers of glacial erosion of that particular stratum.

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