KECK GEOLOGY CONSORTIUM

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

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Students: *HANNAH BOURNE*, Wesleyan University, *JONATHAN GRIFFITH*, Union College, *JACQUELINE KUTVIRT*, Macalester College, *EMMA LOCATELLI*, Macalester College, *SARAH MATTESON*, Bryn Mawr College, *PERRY ODDO*, Franklin and Marshall College, *CLARK BRUNSON SIMCOE*, Washington and Lee University.

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Students: *BRIANA BERKOWITZ*, Beloit College, *DAENA CHARLES*, Union College, *MELLISSA CROSS*, Colgate University, *JOHN MICHAELS*, North Carolina State University, *ERDENEBAYAR TSAGAANNARAN*, Mongolian University of Science and Technology, *BATTOGTOH DAMDINSUREN*, Mongolian University of Science and Technology, *DANIEL ROTHBERG*, Colorado College, *ESUGEI GANBOLD*, *ARANZAL ERDENE*, Mongolian University of Science and Technology, *AFSHAN SHAIKH*, Georgia Institute of Technology, *KRISTIN TADDEI*, Franklin and Marshall College, *GABRIELLE VANCE*, Whitman College, *ANDREW ZUZA*, Cornell University.

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Students: *JESSE GEARY*, Macalester College, *KATHERINE KRAVITZ*, Smith College, *RAY MCGAUGHEY*, Carleton College.

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Keck Geology Consortium: Projects 2010-2011
Short Contributions— Glacier National Park

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CARBON SIGNAL IN ALPINE LAKE SEDIMENT DURING THE HOLOCENE IN GLACIER NATIONAL PARK, MONTANA

SARAH MATTESON, Bryn Mawr College
Research Advisor: Don Barber

INTRODUCTION

Glacial systems can be used as a climatic index due to their sensitivity to changes in precipitation and temperature. These climatic changes can affect glacier size (which influences glacial erosion) and hydrologic energy in the drainage basin; which in turn, produces variations in the sediment flux to proximal lakes. Therefore, sediment preserved in lakes down valley from glaciers has the potential to reveal past records of glacial activity and climatic changes (Karlén, 1976; Leonard and Reasoner, 1998).

Studies and observations of recent changes of glaciers in Glacier National Park, Montana (northern U.S. Rocky Mountains), reveal that the glaciers have been retreating since the end of the Little Ice Age (about 1850) (Carrara, 1989; Johnson, 1980; Krimmel, 2002). Grinnell Glacier is one of the glaciers that has experienced consistent retreat and is considered representative of many of the larger glaciers in the park (Krimmel, 2002). The retreat of Grinnell Glacier has been monitored and compared with changes in local temperature, precipitation, and runoff (Dightman, 1956; Dightman and Beatty, 1952); however, these observations have only been made for short geologic time scales. Relationships between glaciers and climate change have been inferred on larger time scales in other locations (Karlen, 1976; Leonard, 1985; Leonard and Reasoner, 1998), but there has been a lack of these types of studies done in the Glacier National Park area.

Lake cores collected downstream from Grinnell Glacier have been studied and analyzed in order to understand climatic and environmental variability in the area during the Holocene and late Pleistocene (MacGregor et al., 2011). Total organic and inorganic carbon concentrations throughout a core from Swiftcurrent Lake were used to infer changes in the size and hydrologic conditions of Grinnell Glacier. The presence of carbonate and abundance of organic carbon in the lake sediment were proposed to vary as a result of the changing amount of glacially eroded sediment that reaches the lakes in the drainage basin of the glacier. Sediment flux is predicted to be highest after a glacial maximum and during an initial period of glacial retreat (Koppes, 2002; MacGregor et al., 2011). Therefore, low total organic carbon (because of dilution by clastics) and increased inorganic carbon and siliciclastic material are believed to reflect enhanced sediment transport and possibly increased glacial erosion rates during glacial retreat (transition from cold to warm climate). The results from these analyses were compared to the GISP2 climate record to determine possible correlations between the local climatic record from the core and the hemispheric scale climate record throughout the Holocene and late Pleistocene.

Background Setting

Grinnell Glacier is located in the Many Glacier region of Glacier National Park, east of the continental divide. It is positioned in a cirque that is confined by the south-west wall called the Garden Wall (Dightman, 1956; Johnson, 1980). Grinnell is situated such that it is actively eroding stromatolitic Siyeh limestone of the Helena formation, which is the only source of bedrock dolomite in the valley (Horodyski, 1983; MacGregor et al., 2011). Therefore, the presence and abundance of dolomite in the lake sediment in the drainage basin reflects an increase in the amount of glacially-eroded sediment that reaches these lakes. Upper Grinnell Lake is located directly at the north end of the glacier. The drainage basin is located to the northwest and is comprised of four lakes. Moving downvalley (towards the northeast), the order of the lakes are Upper Grinnell (most proximal), Grinnell, Josephine, and Swiftcurrent (see project summary Fig. 1).

One concern with the conclusions from the MacGregor et al. (2011) study is the spatial barriers of the sediment transport. Swiftcurrent Lake is the farthest downstream from the glacier of the three lakes in the valley. Consequently, interpretation of glacial activity from sediment in this lake is complicated by the upstream lakes. In this study, cores from Lake Josephine are analyzed and compared to cores from Swiftcurrent to determine if a better link between the sediment record, glacial activity, and climate can be made from a more proximal lake. Despite the proximal locality of lower Grinnel Lake to the glacier, the sediment in the lake is affected by multiple high energy, stochastic, mass wasting events that interfere with the correlation to glacier erosion through the full Holocene record. Therefore, the sediment from Josephine is anticipated, in general, to yield a better record of glacial activity.

METHODS

The sediment core from Lake Josephine, GNP-JOS10-2A, was collected on July 6, 2010, at the location N 48.78299, W 113.67226 (project summary Fig. 2). Coring was executed using three different techniques. The first drive was a surface (push) core, the second drive used a modified Livingstone coring technique, and the final four drives employed the Livingstone coring technique (Wright, 1991). The core from the first drive was extracted in good condition; however, the subsequent cores from lower drives contained uncertainties in the depth of the sediment due to losses of sediment while bringing the core up to the surface, slush from recore (particularly in the second drive), and some pressure-induced folding and suction at the top of the cores. These issues make it difficult to determine sedimentation rates on the lower cores, and therefore, correlating the lower sections to glacial erosion is problematic. Because of these concerns, this study focuses solely on the top drive (GNP-JOS10-2A-1P).

The collected cores were split, described, photographed, and sampled at LacCore, University of Minnesota. Due to the length of the push core, it had to be separated into two cores for storage purposes: GNP-JOS10-2A-1P-1 (top 141.5 cm of the drive; sediment from 9.5cm-151cm in one polycarb tube) and GNP-JOS10-2A-1P-2 (the rest of the drive; sediment from 0.5 cm-31 cm in the second tube). Carbon coulometric analysis was conducted to evaluate the amount of carbon throughout the core. The coulometry samples were collected every 0.5 cm for the top 50 cm of the core (9.5cm-59.5cm) and every 1 cm for the rest of the drive (59.5cm-151cm of JOS10-2A-1P-1 and 0.5cm-31cm of GNP-JOS10-2A-1P-2). The samples were freeze-dried and sent to Bryn Mawr College to be stored and analyzed. The analysis was run using UIC Model 5014 CO2 Coulometer to measure the total carbon (TC) of each sample in weight percent (Fraisse and Andrianjafintrimo 1971).

A second Josephine core, GNP-JOS10-2B-1P-1, was collected and extruded in the field on July 7, 2010. The core site location is adjacent to the GNP-JOS10-2A coring site at N 48.78300 latitude and W 113.67229 longitude. The core was collected for lead-210 dating and Loss-on-Ignition (LOI) analysis so that an age-model could be created to confine the age of the long core at the 2A coring site. Samples for LOI were collected every 0.5cm for the top 50cm and every cm for the rest of the core.

The results from these Josephine cores are compared to LOI data from a Swiftcurrent lead-210 core, GNP-SWF10-3B-1P-1. The lead-210 core was collected and extracted in the field on July 3, 2010 at N 48.79008 latitude and W 113.66434 longitude. This site is located adjacent to the core collected in 2005, which had a location of N 48.790101 latitude and W 113.664461 longitude (MacGregor et al., 2011).

RESULTS

Figure 1 presents the results for coulometry and LOI. The %TC values from coulometry vary from 1.31% C to 2.63% C and have an average analytical 1σ uncertainty of ± 0.11% C. The raw data from the LOI analyses were converted to %organic matter, %carbonate (CaCO3), %inorganics (siliciclastic material + diatoms), %TIC, and %TOC (Craft, Seneca, and Broome, 1991; Dean, 1974). %TC was also calculated from LOI by adding the %TOC and %TIC values together.

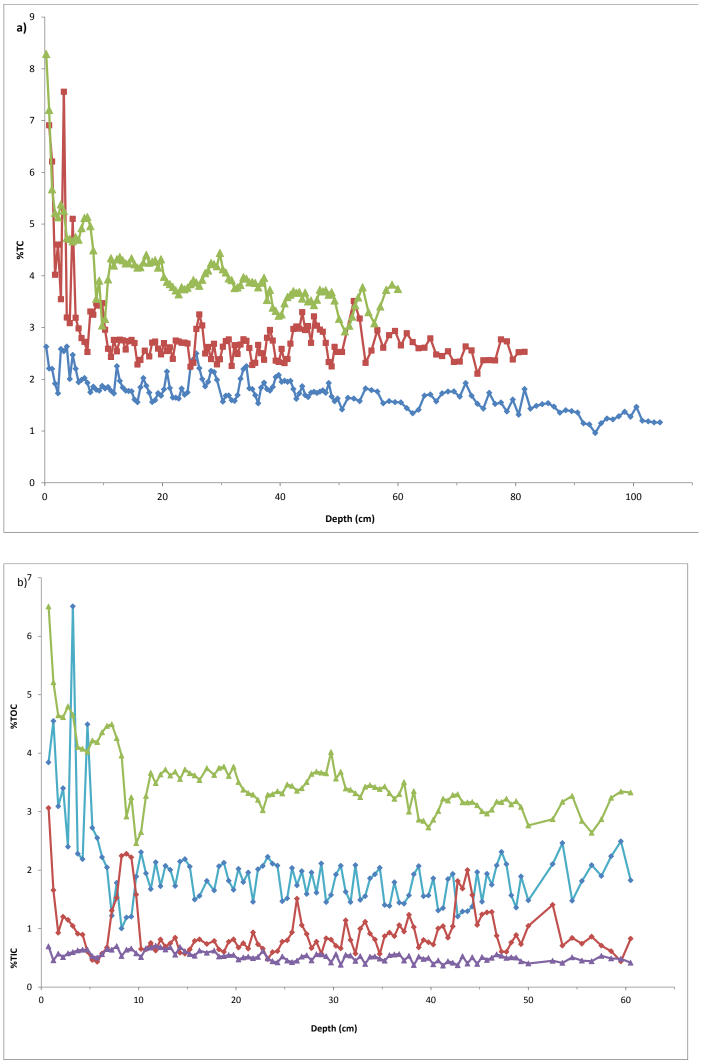

Figure 1. Results of coulometric analysis on JOS10-2A-1P core and LOI analysis on JOS10-2B-1P core and SWF10-3B-1P-1 core. A) Comparison of %TC values from the three cores. The blue line represents the JOS-2A core, the red line represents the JOS10-2B-1P core, and the green line represents the SWF-3B core. B) Compares %TOC calculated from LOI at 550°C from the JOS-2B core (blue line) and the SWF-3B core (green line); and compares %TIC calculated from LOI at 1000°C from the JOS-2B core (red line) and the SWF-3B core (purple line).

DISCUSSION

Comparison of Methods

Two issues arise when using carbon data from LOI. When comparing the two Josephine cores, %TC calculated from LOI tends to be higher than %TC from coulometry (Fig. 1a). Since LOI requires a much larger sample than coulometry, the LOI samples are likely to contain pieces of organic material that would be missed in the samples collected for coulometry. Therefore, %organic matter calculated from LOI at 550°C predicts larger values of %TOC than would be predicted from coulometry. Therefore, when doing the calculations to determine %TOC, LOI predicts larger values of %TOC then coulometry does, which in turn affects the calculation of %TC. However, Figure 2 shows that the values for %TC calculated from coulometry on the JOS-2A core and %TC from LOI on the JOS-2B core are close to 1:1, with some variation due to the difference in sampling size for the two methods, slight differences in what the two methods are measuring (LOI measures mass loss by combustion, where mainly CO_2 is lost, whereas coulometry directly measures carbon), analytical error in measurement, and error in aligning the lead-210 core (site 2B) to the core from site 2A. The general agreement between the data sets allows for good confidence in the quality of the data.

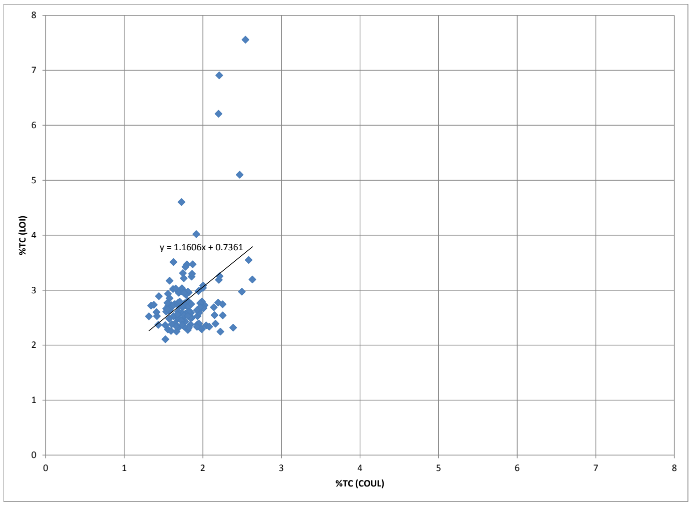

Figure 2. Comparison of %TC calculated from coulometry on the JOS-2A core to %TC from LOI on the JOS-2B core. The linear trendline of the plot is close to 1:1 (equation: y = 1.1606x + 0.7361), with variation resulting from analytical error in measurement and error in aligning the lead-210 core (site 2B) to the core from site 2A.

A second issue occurs when determining %TIC from LOI data. Since the sediment from the cores is clay rich, it is likely that some water of hydration is not lost until the carbonate burn at 1000°C (Dean, 1974). Thus, it should be recognized when analyzing the data that %TIC calculated from LOI is not as reliable as %TIC from coulometry.

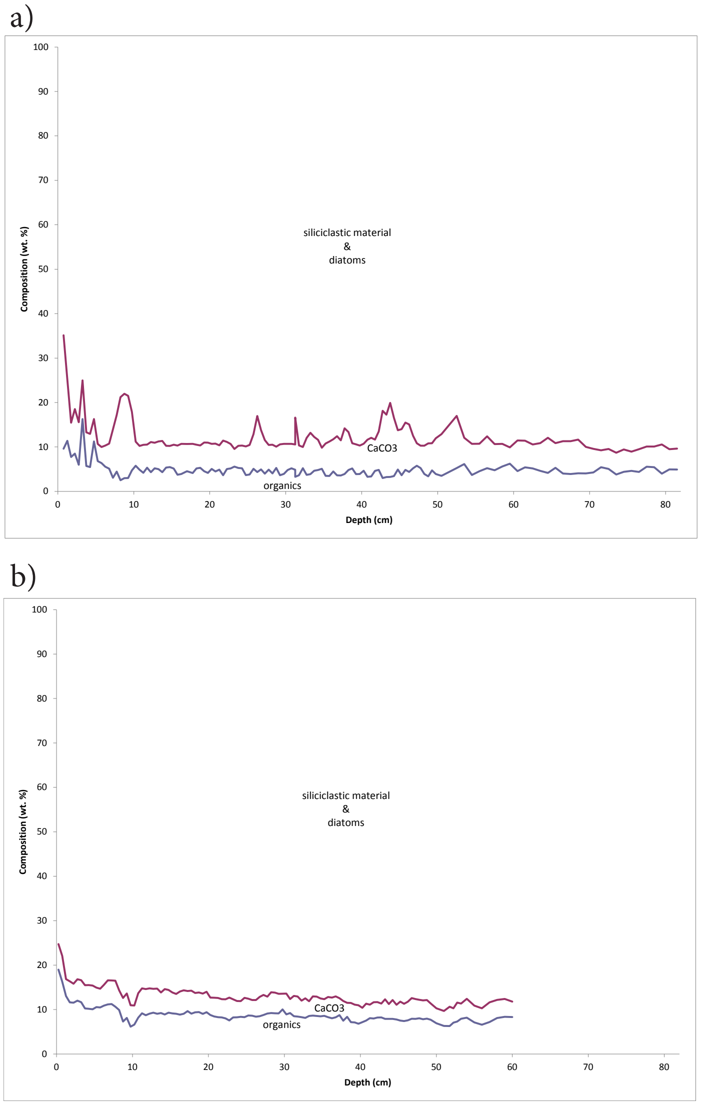

Figure 3. Compares LOI data from both lakes. Results are presented in %organic matter (area below bottom line), %carbonate ($CaCO_3$) (area between the two lines), and %inorganics, which consists of siliciclastic material + diatoms (area above the top line). A) Shows the data from the JOS-2B core. B) Shows the data from the SWF-3B core.

Climatic, Glacial, and Depositional Relationships

The results of the analyses support the hypothesis from MacGregor et al. (2011) that the TIC is coming primarily from glacial erosion. One reason is that with this hypothesis, we would expect to see higher %$CaCO_3$ and %TIC in more proximal lakes because the sediment flux is higher (dolomite being eroded by the glacier does not have to travel as far before falling out of suspension). This is supported by the fact that the Josephine lead-210 core has both higher %CaCO and %TIC than the Swiftcurrent core (Fig. 1b and 3).

The second reason is that we would expect that the proximal lakes would have lower %TOC and %organic matter because of dilution from the increased sediment flux. This is supported by the fact that the Josephine core has lower values for both (Fig. 1b and 3).

Low %TOC values are believed to broadly reflect colder temperatures, since lower values would result from the decreased amount of organic material growing in a colder climate and dilution that would occur from increased sediment flux (MacGregor et al., 2011; Leonard, 1985). Higher %TIC is believed to reflect transitioning temperatures during which there is glacial retreat (increased peak summer water discharge from warmer temperatures), but glacial size is still relatively large. This is attributed to the increased amount of dolomite that would be transported to the lake from increased hydrologic energy and enhanced glacial erosion. Periods when both %TOC is low and %TIC is high are believed to broadly reflect colder climates during transition periods. This condition occurs around 8.25cm (Fig. 1b). Based on age constraints of the Swiftcurrent core (MacGregor et al., 2011), it is likely that the JOS10-2A cores span the LIA into the Medieval Warm Period (roughly 1,000 years). Thus, this variation in carbon content from approximately 6 cm-10 cm may reflect the transition out of the LIA. Two other peaks in %TIC occur approximately around 26.25 cm and 43 cm (Fig. 1b). The second of these peaks corresponds to a low in %TOC as well, which may also represent a climatic transition, specifically the transition into the LIA. However, better age constraints and %TIC values are needed to improve the understanding of glacial and climatic changes preserved by the carbon in the cores.

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