KECK GEOLOGY CONSORTIUM

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

April 2011
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2010-2011 PROJECTS

FORMATION OF BASEMENT-INVOLVED FORELAND ARCHES: INTEGRATED STRUCTURAL AND SEISMOLOGICAL RESEARCH IN THE BIGHORN MOUNTAINS, WYOMING
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INTERDISCIPLINARY STUDIES IN THE CRITICAL ZONE, BOULDER CREEK CATCHMENT, FRONT RANGE, COLORADO
Faculty: *DAVID P. DETHIER,* Williams College, *WILL OUIMET*. University of Connecticut
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Faculty: *KELLY MACGREGOR*, Macalester College, *CATHERINE RIIHIMAKI*, Drew University, *AMY MYRBO*, LacCore Lab, University of Minnesota, *KRISTINA BRADY*, LacCore Lab, University of Minnesota

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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KECK SIERRA: MAGMA-WALLROCK INTERACTIONS IN THE SEQUOIA REGION
Faculty: *JADE STAR LACKEY*, Pomona College, *STACI L. LOEWY*, California State University-Bakersfield
Students: *MARY BADAME*, Oberlin College, *MEGAN D'ERRICO*, Trinity University, *STANLEY HENSLEY*, California State University, Bakersfield, *JULIA HOLLAND*, Trinity University, *JESSLYN STARNES*, Denison University, *JULIANNE M. WALLAN*, Colgate University.

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

GEOMORPHIC AND PALEOENVIRONMENTAL CHANGE IN GLACIER NATIONAL PARK, MONTANA, U.S.A.
Project Faculty: KELLY MACGREGOR, Macalester College, CATHERINE RIIHIMAKI, Drew University, AMY MYRBO, KRISTINA BRADY LacCore Lab, University of Minnesota

LINKAGES BETWEEN CLIMATE CHANGE, VOLCANISM, AND DIATOM PRODUCTIVITY OVER THE PAST 12,900 YEARS IN SWIFTCURRENT LAKE, GLACIER NATIONAL PARK, MONTANA
HANNAH BOURNE, Wesleyan University
Research Advisor: Tim Ku

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Research Advisor: Donald Rodbell

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CLARK BRUNSON SIMCOE, Washington and Lee University
Research Advisor: Romain Meyer

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km^2 and elevation ranges from ~1490 m to ~2000 m (MacGregor et al., 2011). The basin contains Rocky Mountain Cordilleran Flora, with the primary arboreal species being limber pine, lodgepole pine, sub-alpine fir, Englemann spruce and mountain alder. These species have hugely variable fire regime adaptations; for example, the Lodgepole pine has adapted to a fire return interval range (number of years between two successive fire events) of 30-300+ yrs and Engelmann spruce of 35 to 200+ yrs (Johnson, 2001).

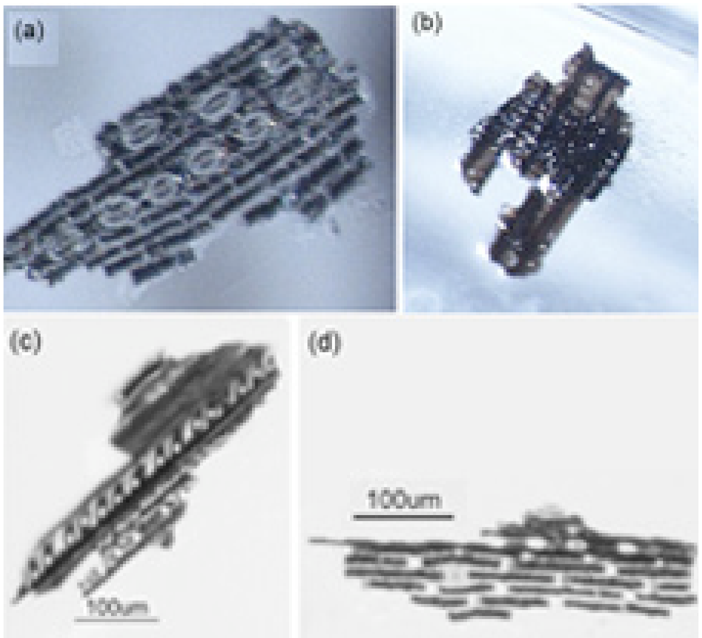

Figure 2: Photos of charcoal pieces (a) and (b) from the Swiftcurrent Lake core and (c) and (d) from Ferry Lake in Wisconsin (Jensen et al. 2007). In this study, each charcoal piece was identified after Jensen et al. (2007). The type of charcoal depends on the plant combusted by fire (eg., grass yields a unique type of charcoal (a) and (d) than coniferous trees (b) and (c).

METHODS

Charcoal Methods

Surface sediment samples were collected from the 0.58-m SWF10-3B (^{210}Pb core) at 0.5 cm intervals. The SWF05-3A core was sampled at 1-cm intervals for 4.60 m to the Mazama ash unit. All samples were collected as 2 cm^3 volume, treated with 6% H_2O_2 (50°C for 24 hrs) to remove non-charcoal organic matter, sieved through 125 µm sieves and dried in plastic petri-dishes. The 125 µm sieve size was chosen because these larger charcoal pieces are most likely to come from local fires (<7km from the lake) rather than regional fires (Whitlock and Larsen, 2001). Each petri-dish containing the >125 µm sediment fraction was examined using a standard dissecting microscope.

Charcoal pieces and morphotypes were identified (after Jensen et al., 2007), tallied and totaled (Fig. 2). Tallies were then normalized based on the number of particles per cm^3 and input into Charster program, a statistical analysis tool for charcoal studies. Fire history was reconstructed using parameters set in Charster by selecting a background window of 500 yr and a re-sampling integer of 10 yr. The Charster program differentiates background charcoal levels (BCHAR) with charcoal peaks that are higher than the background (CHAR). We assume these peaks represent local fire events within or near the basin (Whitlock and Millspaugh, 1996). Background charcoal (BCHAR) has been interpreted as secondary, indicative of erosion and/or longer-term, regional fire activity (Marlon et al., 2006).

Chronology

Our age model is based on radiocarbon dates from both a 2010 surface core and existing dates from the 2005 long core (MacGregor et al., 2011). Correlation between the 2005 and 2010 cores were conducted using loss-on-ignition (LOI) analysis and visual correlation. Data from ^{210}Pb ages, four calibrated radiocarbon dates and the Mazama Ash fingerprint date (7630 ± 130 a) was combined to create an age-depth model using the Bacon model (Fig. 3) (Blaaw and Cristen, in press).

RESULTS

The ~7630 yr record shows distinct changes in charcoal accumulation in the southern Swiftcurrent Basin (Fig. 1). Charcoal concentrations vary from 88 pieces of charcoal/cm^3 down to 0 pieces/cm^3. Based on the sedimentation rates and charcoal concentrations, the charcoal accumulation rates (CHAR) are calculated as ranging from 0 to 33.08 pieces/cm^2/yr. Using a locally weighted scatter plot smoothing (LOWESS) regression analysis, frequency of CHAR peaks were differentiated from BCHAR levels (Fig. 1).

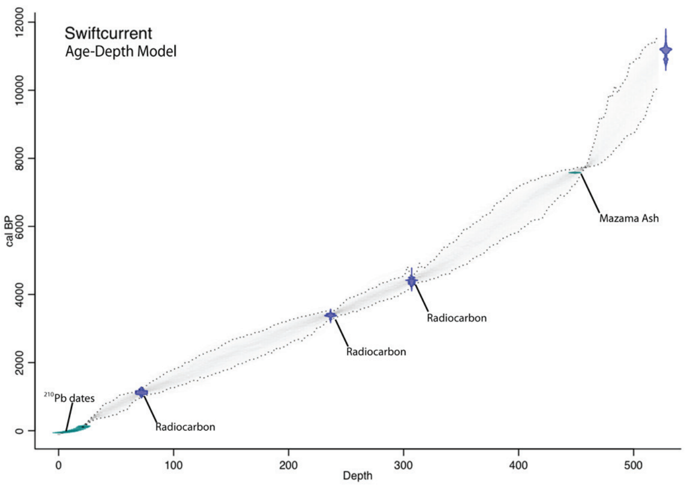

Figure 3: Recent Swiftcurrent age depth model. Teal indicates ages from 210Pb dating, blue indicates ages using radiocarbon dating and point represents the Mazama ash tephra date (7630 ± 130 a) (MacGregor et al., 2011). Shades of grey in between dates represent uncertainty, lighter means more uncertain and darker means less uncertain. Graph produced using Bacon model (Blaaw and Cristen, in press).

DISCUSSION

Swiftcurrent Fire and Pollen History

Four time periods of distinct charcoal accumulation rates and fire activity trends have been established as SWF-1 through SWF-4 (Fig. 1). Between 7630 and 3900 ybp (SWF-1), the fire activity is low overall; from 3900 to 2100 ybp (SWF-2) fire activity is generally high until ~3100 ybp and then decreases until 2100 ybp. From 2100 ybp to 1000 ybp (SWF-3) the overall fire activity lower, but contains significant and high peak charcoal concentrations. For the past 1000 years (SWF-4), fire activity as been consistently low with minor peaks. The past ~200 yrs has shown a slight but measurable increase in fire frequency in the basin.

Pollen counts on the Swiftcurrent Lake cores indicate varied trends in vegetation that have been grouped into Zone 1 (5745 - 2204 ybp), Zone 2 (2204 – 1255 ybp), Zone 3 (1255 – 767 ybp) and Zone 4 (767 - 78 ybp) (Locatelli, this volume). The resolution of the pollen record is highest and most suitable for comparison with the charcoal record in Zone 3 and 4. Zone 3 demonstrates overall increase in arboreal pollen while these levels decrease steadily from 767 ybp until present during Zone 4 (Locatelli, this volume). Arboreal pollen levels were higher during Zone 3 (1255 - 767 ybp) than they were in Zone 4 (767 - 78 ybp). Arboreal pollen levels have been linked to burnable fuels, an increase of which is often tied to higher fire activity (Marlon et al., 2006).

Fires and Local Environmental Change

We first compare the Swiftcurrent Lake charcoal and pollen records to other data gathered from the same core (SWF05-3A) used in MacGregor et al. (2011) to reconstruct a local environmental history. The proxies examined in this study were percent total organic carbon (%TOC), carbon/nitrogen ratios (C/N), grain size and mineralogy. Climatic interpretations were made by tying %TOC to solar forcing and C/N ratios representing type and origin of organic material, (e.g. input of terrestrial vs. aquatic organics) (MacGregor et al., 2011).

The mid-Holocene SWF-1 (7630-3900 ybp) is characterized by an environment more stable than the remainder of the Holocene. This period also seems to be warmer, generally, than the late Holocene as reflected by high and stable %TOC values. Mineralogical data suggests that Grinnell Glacier is smaller and less active during this period as well (MacGregor et al., 2011). The fire record is consistent with local data reflecting a period of climate stability.

Late-Holocene SWF-2 (3900-2100 ybp) is defined by major swings in climatic conditions (MacGregor et al., 2011), simultaneous with the highest CHAR rates in the Swiftcurrent record. High peaks in C/N ratio mark the distinct transition from the mid to late-Holocene while steadily increasing %TOC and C/N ratios indicate warming temperature and terrestrial carbon dominance (MacGregor et al., 2011). The increase of terrestrial carbon in the record is especially interesting alongside high fire activity as a possible indicator of an increase in forest cover and burnable taxa. High CHAR characterizes the entire period, with especially high fire activity spanning 3600-3100 ybp. All existing proxy records for the lake indicate major environmental changes, possibly driven by increased climate variability (MacGregor et al., 2011).

Periods SWF-3 (2100-1000 ybp) and SWF-4 (1000 ybp-present) show moderate fire activity with lower frequency and strength than SWF-2. Percent TOC levels and C/N rations are also lower than SWF-2 (MacGregor et al., 2011). There seems to be a general local cooling trend through this period reflected by this decrease in %TOC, C/N and lower fire activity. The temporally constrained changes in %TOC, C/N and fire activity over the entire record demonstrate that fire activity shows a strong correlation with climate proxies discussed in MacGregor et al. (2011). This allows for confidence in the fire record as supportive evidence of local environmental changes that seem to be partially driven by climate variability. With this confidence in the local record, the Swiftcurrent fire record can be compared with other NRM records in effort to further constrain different temporal and spatial environmental and climate variability in the region.

Swiftcurrent and NRM Fire Records

Here we compare the well-constrained local Swiftcurrent fire history to records from accross the NRM region. We hypothesize that Swiftcurrent Lake will yield a significantly different fire history than records from the opposite side of the Continental Divide. Brunelle et al. (2005) explore how changing precipitation regimes, dictated by topography, affect NRM fire frequency patterns. This comparison is made in effort to constrain the differing effect of climate changes in "summer-wet" and "summer-dry" environments. The Swiftcurrent Lake basin receives most of its precipitation during the summer months, making it a "summer-wet" climate (Fig. 4). Brunelle et al. (2005) show that records from "summer-dry" lakes show fire frequency decreasing over the mid-late Holocene, whereas at the "summer-wet" lakes, show fire frequency increasing over the mid-late Holocene. The Swiftcurrent Lake record seems to be consistent with this hypothesis as the fire frequency has generally increased over the entire mid-late Holocene record. This comparison highlights the importance of site-specific topography and elevation on climatic variation in the NRM.

The influence of regional topography is highlighted in a comparison of Foy Lake and Swiftcurrent Lake environmental proxies. Foy Lake is located just ~90 km southwest of Swiftcurrent Lake, in a "summer-dry" climate (Fig. 4). The Continental Divide runs between the two lakes. The 3800 yr Foy Lake study provides a very high resolution pollen and charcoal record that shows an overall decrease in fire frequency over the late-Holocene, again consistent with the Brunelle et al. (2005) hypothesis that "summer-dry", NRM lakes record decreased fire frequency over the mid-late Holocene. Patterns seen in the "summer-wet" Swifcurrent record are generally contrary to those seen in the Foy record.

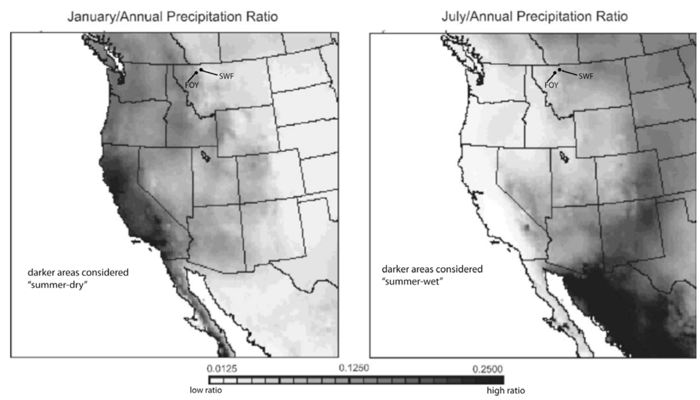

Figure 4: Distribution of precipitation in the western US shown using ratios of January and July to annual precipitation. Darker shades indicate high ratio and lighter indicates a low ratio. Notice SWF is located on the boundary of the high and low precipitation ratios. Figure published in Brunelle et al., (2005).

CONCLUSIONS

The ~7630 yr fire history record of Swifcurrent Lake does show differing trends than similar records from across the Continental Divide. The record is also consistent with the hypothesis proposed by Brunelle et al. (2005) that increasingly strong seasonal variations in precipitation patterns in the NRM cause higher regional variability in fire records over the mid-to late-Holocene. The Continental Divide is not the only factor controlling paleoenvironmental trends, and more localized effects of NRM topographic complexity will be explored. The apparent variability in Holocene fire histories from the NRM proves that the most recent fire trends seem to be part of the normal variable cycle in fire frequency. A broad spatial and temporal perspective must be taken in exploring NRM fire frequency today in order to account for the interactions between local environments and climatic variability.

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