KECK GEOLOGY CONSORTIUM
PROCEEDINGS OF THE TWENTY-THIRD
ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

ISSN# 1528-7491

April 2010

Andrew P. de Wet
Editor & Keck Director
Franklin & Marshall College

Keck Geology Consortium
Franklin & Marshall College
PO Box 3003, Lanc. Pa, 17604

Lara Heister
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2009-2010 PROJECTS

SE ALASKA - EXHUMATION OF THE COAST MOUNTAINS BATHOLITH DURING THE GREENHOUSE TO ICEHOUSE TRANSITION IN SOUTHEAST ALASKA: A MULTIDISCIPLINARY STUDY OF THE PALEOGENE KOOTZNAHOO FM.
Faculty: Cameron Davidson (Carleton College), Karl Wirth (Macalester College), Tim White (Penn State University)
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COLORADO – INTERDISCIPLINARY STUDIES IN THE CRITICAL ZONE, BOULDER CREEK CATCHMENT, FRONT RANGE, COLORADO.
Faculty: David Dethier (Williams) *Students: Elizabeth Dengler, Evan Riddle, James Trotta*

WISCONSIN - THE GEOLOGY AND ECOHYDROLOGY OF SPRINGS IN THE DRIFTLESS AREA OF SOUTHWEST WISCONSIN.
Faculty: Sue Swanson (Beloit) and Maureen Muldoon (UW-Oshkosh)
Students: Hannah Doherty, Elizabeth Forbes, Ashley Krutko, Mary Liang, Ethan Mamer, Miles Reed

OREGON - SOURCE TO SINK – WEATHERING OF VOLCANIC ROCKS AND THEIR INFLUENCE ON SOIL AND WATER CHEMISTRY IN CENTRAL OREGON.
Faculty: Holli Frey (Union) and Kathryn Szramek (Drake U.)
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MONGOLIA - PALEOZOIC PALEOENVIRONMENTAL RECONSTRUCTION OF THE GOBI-ALTAI TERRANE, MONGOLIA.
Faculty: Connie Soja (Colgate), Paul Myrow (Colorado College), Jeff Over (SUNY-Geneseo), Chuluun Minjin (Mongolian University of Science and Technology)
Students: Uyanga Bold, Bilguun Dalaibaatar, Timothy Gibson, Badral Khurelbaatar, Madelyn Mette, Sara Oser, Adam Pellegrini, Jennifer Peteya, Munkh-Od Purevtseren, Nadine Reitman, Nicholas Sullivan, Zoe Vulgaropulos

KENAI - THE GEOMORPHOLOGY AND DATING OF HOLOCENE HIGH-WATER LEVELS ON THE KENAI PENINSULA, ALASKA
Faculty: Greg Wiles (The College of Wooster), Tom Lowell, (U. Cincinnati), Ed Berg (Kenai National Wildlife Refuge, Soldotna AK)
Students: Alena Giesche, Jessa Moser, Terry Workman

SVALBARD - HOLOCENE AND MODERN CLIMATE CHANGE IN THE HIGH ARCTIC, SVALBARD, NORWAY.
Faculty: Al Werner (Mount Holyoke College), Steve Roof (Hampshire College), Mike Retelle (Bates College)
Students: Travis Brown, Chris Coleman, Franklin Dekker, Jacalyn Gorczynski, Alice Nelson, Alexander Nereson, David Vallencourt

UNALASKA - LATE CENOZOIC VOLCANISM IN THE ALEUTIAN ARC: EXAMINING THE PRE-HOLOCENE RECORD ON UNALASKA ISLAND, AK.
Faculty: Kirsten Nicolaysen (Whitman College) and Rick Hazlett (Pomona College)
Students: Adam Curry, Allison Goldberg, Lauren Idleman, Allan Lerner, Max Siegrist, Clare Tochilin

Funding Provided by: Keck Geology Consortium Member Institutions and NSF (NSF-REU: 0648782) and ExxonMobil

Keck Geology Consortium: Projects 2009-2010
Short Contributions – ALASKA-KENAI

THE GEOMORPHOLOGY AND DATING OF HOLOCENE WATER LEVELS AT JIGSAW LAKE, KENAI PENINSULA, ALASKA

***GREG WILES*:**The College of Wooster;
***THOMAS V. LOWELL*:** University of Cincinnati;
***ED BERG*:** US Fish & Wildlife Service, Kenai National Wildlife Refuge, Soldotna, AK.

USING PEAT HUMIFICATION FOR HIGH RESOLUTION LAKE LEVEL RECONSTRUCTION: JIGSAW LAKE, KENAI LOWLANDS, ALASKA.

ALENA GIESCHE
Middlebury College
Research Advisors: Jeffrey Munroe and Pete Ryan

BASIN SUBSIDENCE INFERRED USING GEOPHYSICAL DATA, JIGSAW LAKE, KENAI PENINSULA, ALASKA

JESSA V. MOSER
University of Cincinnati
Research Advisor: Thomas V. Lowell

RECONSTRUCTING THE PALEO-ENVIRONMENT: EARLY HOLOCENE MOISTURE VARIABILITY OF THE KENAI LOWLANDS, ALASKA

TERRY RACE WORKMAN
The College of Wooster
Research Advisor: Gregory Wiles

Funding provided by: Keck Geology Consortium Member Institutions and NSF (NSF-REU: 0648782)

Keck Geology Consortium
Franklin & Marshall College
PO Box 3003, Lancaster Pa, 17603
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TERRY RACE WORKMAN
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INTRODUCTION

Fluctuations in regional groundwater tables through the early Holocene were investigated via the analysis of twenty-three overlapping lake sediment cores extracted from a closed basin Lake of Alaska's Kenai Peninsula. Sediment coring locations were determined based upon detailed geophysical and bathymetric maps, which allowed for precision coring (Figure 1). Sediment core analyses include the description of stratigraphy, magnetic susceptibility, loss on ignition, macrofossil sampling for radiocarbon ages, and taxonomic peat analysis. Detailed three dimensional sediment packages, mapped using sediment cores and geophysical surveys, were analyzed to separate the landscape evolution signal (kettle-development) from the climate signal (regional lake levels) in this region where an interior dry-cold Alaskan climate dominates today.

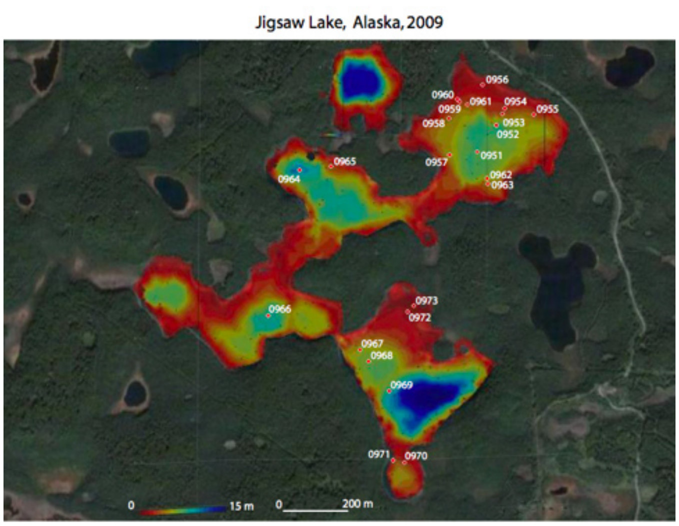

Figure 1. Bathymetric profile of Jigsaw Lake. North ↑

Radiocarbon data suggests a paleo-lake level transgression from terrestrial peat-lacustrine gyttja ca. 7,930-8,630 cal years B.P. The timing and character of the increase in lake levels are interpreted in the context of higher shorelines recognized in the region and variations in circulation patterns in the North Pacific, specifically the onset of a strengthened Aleutian Low. The intensive sampling, use of geophysics, locally consistent stratigraphies, and recognition of tephras have produced a well-constrained record of past climate and past changes in landscape as relative lake levels are reconstructed and criteria to recognize local kettle development and regional lake level variations are assessed.

STUDY SITE

A potential coring site was selected according to topography and regional geomorphology. The site of Jigsaw Lake is a nutrient-poor lake situated in the lowlands of the northern Kenai Peninsula in south-central Alaska. The Kenai Peninsula is connected to the mainland to the north by Portage Passage and bordered on the west by Cook Inlet. The Kenai Mountains, which reach 2,015 m and are mantled by the Harding, Sargent, and Spencer-Blackstone ice fields, extend across the eastern Kenai Peninsula.

The Kenai Mountains are comprised of Mesozoic bedrock, while the lowlands to the west exhibit a flat to rolling surface formed by several Wisconsin-age glaciations, and composed of organic-rich late-glacial and Holocene peat, interbedded with layers of volcanic ash (Reger et al., 2007). The Turnagain Arm lobe of the Naptowne glaciation (32,000–16,000 cal yr BP) did not extend much farther west than the Kenai Mountains, as indicated by the absence of till or moraines of Naptowne age (Reger et al., 2007). Ice moved across Cook Inlet from the west to cover much of the northern Kenai lowlands during the Naptowne glaciation (Reger et al., 2007), and geologic evidence suggests small ice-free refugia existed in the northwestern Kenai Mountains.

Jigsaw Lake is located at an elevation of 90 m above sea level (N 60°44'32.18, W 150°29'23.76) in the central lowland region of the Kenai Peninsula (Figure 2), and was chosen because it is a post-glacial or "kettle" lake. Lacustrine deposits are one of the best archives of continental climate and its environmental impacts, because lake deposits often span long periods of time and yield moderately high temporal resolution (Fritz, 2001).

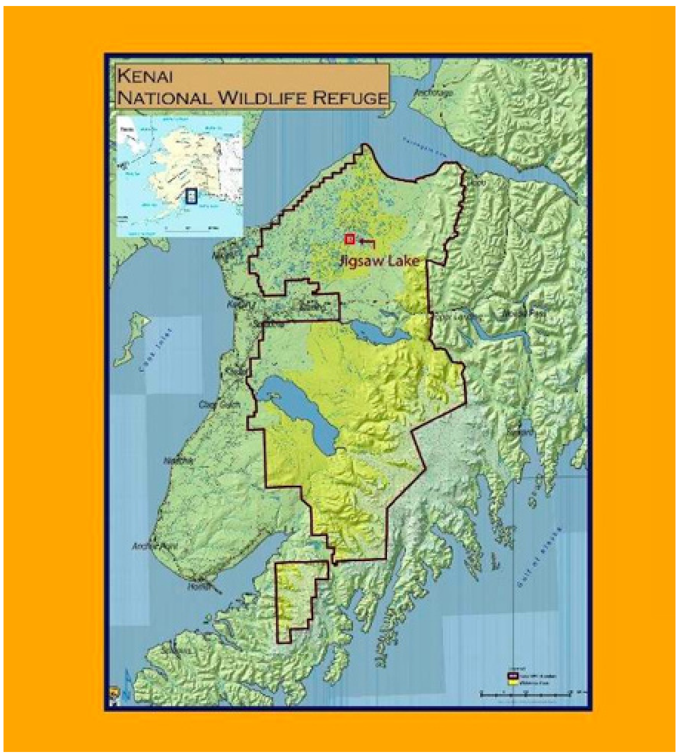

Figure 2. Jigsaw Lake Site, Kenai National Wildlife Refuge

Lake level fluctuations provide evidence of past variations in the global hydrological balance (Viau et al., 2001). A study of the stratigraphy, geochemistry, and microfossil content of lake sediments from closed basins may be particularly valuable in deciphering lake history (Bradbury et al., 1981). Jigsaw is a closed basin lake that sits atop a groundwater divide. Therefore, there is no influx of water into the system other than precipitation; this makes Jigsaw Lake an ideal location to measure variability in the regional groundwater table. Since the groundwater table is a direct reflection of the amount of precipitation this region receives, one may correlate lake level fluctuations to changes in the net amount of available water. Being a closed basin, the Lake is endoreic thus water loss is almost entirely due to evaporation though some may be lost through groundwater outflow.

Accumulation rates in lakes are often high, so lake sediments offer the potential for high-resolution records of past climate (Bradley, 1999). In modern lake basins, periods of positive water balance are generally identified by abandoned wave cut shorelines and beach deposits/exposed lacustrine sediments (Bradley, 1999). When the majority of lakes in a region fluctuate in a similar fashion, climate is probably the dominant controlling factor (Viau et al., 2001), though one must consider the possibility for ice melt out and kettle development.

FIELD METHODS

Geophysical & Bathymetric Analysis

In order to determine the best location for obtaining a sediment core, a bathymetric profile of Jigsaw Lake was created with the assistance of Jessa Moser, a graduate of the University of Cincinnati. We deployed two instruments to acquire three different geophysical properties. All equipment used is portable and was rigged to canoes. The sensors all feed into a waterproof Panasonic laptop to record and analyze data. Location information is derived from a Hummingbird unit and independently from a handheld Garmin GPS.

Utilizing a Stratabox ™ marine geophysical instrument with a high resolution echo sounder and acoustic systems, a two dimensional image of the lake bottom could be constructed. This unit is typically used for precision seafloor exploration and

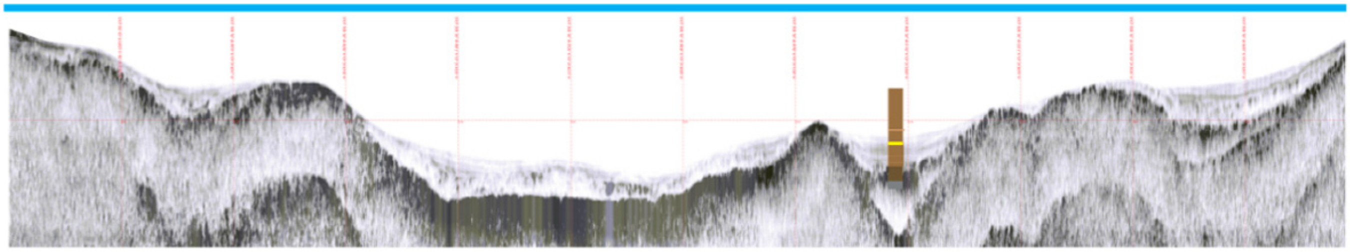

Figure 3: Geophysical sub-bottom profile demonstrating precision coring site JS0957. The use of sub-bottom profiles gave us the opportunity to specifically target sediment packages within geological features such as this basin.

incorporates side-scan sonar technology. For water depth and surface texture we used a consumer fish finder with side-scan sonar. The specific unit is a Hummingbird 798 SI combo. The maximum advertised depth for the side-scan is 50 m. The Stratabox ™ unit made by SyQwest was deployed to examine the sub-bottom sediments. This unit is a portable high-resolution imaging instrument for inland and coastal marine surveys up to 150 m water depth and under optimal conditions some 40 m of sediment. Resolution is stated to be 15 cm. The sending/ receiving unit is a dome with an approximate diameter of 0.5 m.

The unit was rigged to a canoe outfitted with a trolling motor and would cross the lake in transects at a constant rate, taking depth measurements of the lake bottom. The canoe would make several passes across the lake at different angles to provide an accurate portrait of lake depth throughout Jigsaw Lake. The Stratabox ™ was connected to a laptop which illustrated a two dimensional display of the lake bottom. Navigation, depth, texture, and sub-bottom information were incorporated within a software package called Sonarwiz.MAP. This software permits data processing, geo-registration and output in various formats. The deepest point of the site is ideal for coring because most of the sediment throughout the entire lake basin will wash from the hill slopes to the center of the basin (Lutz et al., 2006).
Coring

Two series of cores labeled “A” and “B” were extracted from each site within the multiple basins of Jigsaw Lake utilizing a modified Livingston corer developed by Tom Lowell of the University of Cincinnati. Where multiple sediment cores are available from a lake, it may be possible to detect in the sedimentary facies former shallow water conditions and to thereby date periods with lower lake levels. The coring rig was mounted atop two canoes bridged with a wooden platform. The canoes were then navigated to the desired coring location upon the lake, and all four corners of the coring rig were anchored for stability. Sediment was collected by forcing the Livingston coring device into the lake sediments in 1-meter intervals. Each core was removed from the barrel, wrapped in cellophane, and placed in PVC for transport and storage. Each was given a number and the top was labeled. In all, 23 sites were cored in which several one-meter thrusts were extracted, utilizing extension rods for increasing depth. A depth chart for each core and a preliminary description of the sedimentation was created. The process was repeated for the upper thrusts (“B” cores) within a meter of the original coring site, so that two or more overlapping cores could be correlated in a laboratory setting.

LABORATORY ANALYSIS

Core Description

Upon reaching the laboratory, each sediment core was arranged and catalogued for further examination. Each core was removed from its PVC casing and cellophane layer and cut in half. The core was placed alongside a meter stick for reference. The lithological characteristics of each core were described in detail noting any variation in visual lithology such as changes in color or structure.

After the lithology of each core had been described, the sample was carried into the adjoining lab and photographed. Each photograph captured a 10 cm increment of the core. The photographs, taken with a digital camera, were compiled using Adobe Photoshop (Fig. 4). Each image was printed and positioned in respect to the others to create a composite stratigraphic depth chart. These photographs would later be referenced to determine variability in visible lithology and thus locate possible locales for further analysis.

Magnetic Susceptibility

Magnetic susceptibility measures the concentrations of primarily ferri-magnetic minerals in sediment, and provides a rapid assessment of a number of environmental variables, especially erosion rates. Using a magnetic susceptibility meter one may measure the concentration of magnetic material within a sample, in this case a sediment core. High magnetic susceptibility has been correlated with higher rates of erosion as well as an increase in windblown silt known as loess, which is more magnetic than the surrounding organic gyttja. Higher rates of erosion as well as an increase in loess have also been correlated with a relative loss of vegetation as would be seen should the climate become colder and/or dryer e.g., during glaciations or droughts. A spike in magnetic susceptibility therefore is interpreted as a proxy for a climatic change leading to the loss of vegetation (McLauchlan, 2003).

Magnetic susceptibility readings were taken using a Bartington field susceptibility meter. All metallic and potentially magnetic materials were removed from the test area and each core was unwrapped and placed alongside a meter stick in the observation area. Measurements were taken by placing the tip of the probe to the plastic wrapped core every 2 cm. Before each measurement, the sensor was reset to zero by pressing tare. This was undertaken for each of the 23 thrusts and the data were compiled in an Excel file for later examination (Figure 5).

Loss on Ignition

Loss on ignition refers to the difference in relative weight before and after the burning of organic material. This is done via the ignition of organic material in an oven at 550°C. The loss on ignition of a sample, usually taken at 4 cm intervals of a sediment core, demonstrates the amount of organic material at any given interval. High loss on ignition reflects high levels of organic material and thus a period of greater vegetative growth. Therefore, periods of relatively low organic loss on ignition would serve as a direct measurement of low organic content, i.e. periods of glaciations and drought (Wendland 1974). The Loss on Ignition procedure is used to calculate the percentage of a sample that is organic vs. inorganic. Having cleaned and evaporated the water within, a series of numbered crucibles were weighed. Utilizing a small plunger, a 1-cm3 sample of sediment was taken at 4 cm intervals of the core and added to each crucible. The crucibles were then placed in a laboratory oven at 110° C for 6 hours until the moisture had completely evaporated from the samples. The crucibles were then removed from the oven and weighed. The original weight of the crucible was subtracted from this number to calculate the weight of the sample alone. The crucibles were then placed in a laboratory oven at 550°C for one hour. The weight was then subtracted from the original sample weight and the percent organic composition of each sample was recorded.

Conventional and AMS Radiocarbon Dating

Conventional radiocarbon dating is only possible with a sizeable piece of organic material to calculate the number of half-lives the 14C has undergone.

Figure 4. JS0963 Core Photo-mosaic: ← Top, 1.75m

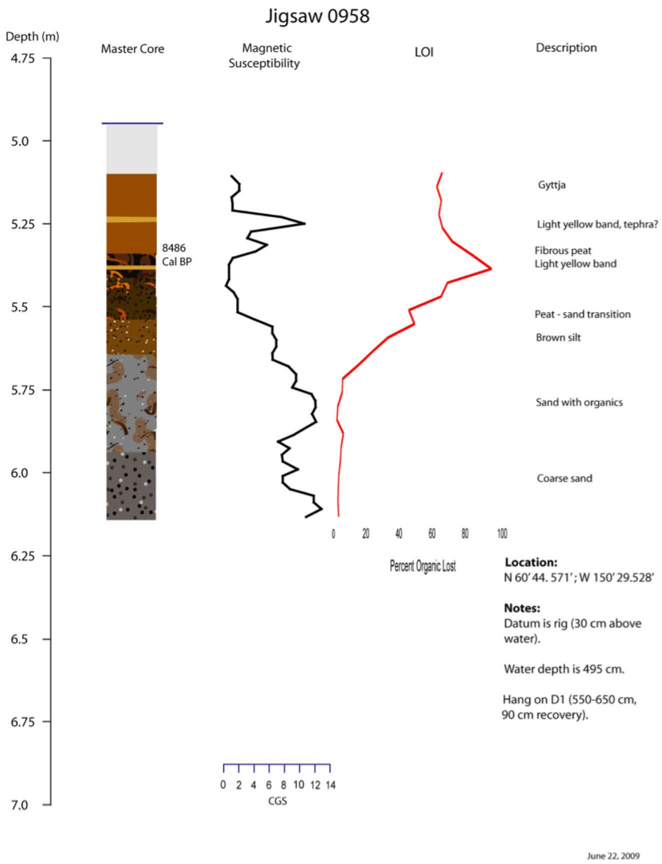

Figure 5: Composite Stratigraphic Column JS0958 displaying LOI and Magnetic Susceptibility Data.

Often it is not possible to obtain large enough samples of organic material for a conventional date. In such a case, an accelerated mass spectrometer (AMS) is used on the macro-organics to count the individual atoms of the sample. This is useful when dating intervals within sediment cores suspected to reflect periods of relatively low vegetation such as a drought event.

The purpose of macrofossil sampling is to obtain enough carbon/organic material for AMS radiocarbon dating. 1 cm^3 of sediment was extracted before intervals representing a major lithologic transition and added to a 90 mL solution of distilled water and 10 mL solution of KOH. This solution was placed in a beaker and heated in a laboratory oven at 60-70° C for approximately 90 minutes to disaggregate. The disaggregated sediment is then passed through a 350 µm sieve, the collected sediment being placed in a plastic Petrie dish. The remaining sediment was then picked though under a dissecting microscope. All organic material; plant debris, insect parts, and shell fragments were placed within a small glass vial and labeled.

Radiocarbon dates must first be calibrated to take into account the variation in the amount of ^{14}C present in the system throughout time. Conventional radiocarbon ages were calibrated using the program CALIB.

RESULTS

Jigsaw Lake Magnetic Susceptibility and LOI Data
Magnetic susceptibility was catalogued alongside composite stratigraphic columns for each core site JS0951-JS0973 (Fig. 5). Magnetic Susceptibility values are highest with numerous spikes at the base of the cores and generally decrease upward along with increasing organic content measured via LOI, and the two are inversely correlated. Prominent peaks in magnetic susceptibility generally coincide with unidentified tephras layers. Readings demonstrate more magnetic basal sand layers transitioning upward towards less magnetic/more organic peat layers to organic rich gyttja. Spikes in magnetic susceptibility were utilized as horizon markers demarcating volcanic ash layers (tephra) as well as interlaced sand beds.

The loss on ignition data demonstrates little to no (0-20%) organic loss in basal sands which transition upward to high (80-100%) organic loss of peat and gyttja. LOI data was compiled alongside composite stratigraphic columns and magnetic susceptibility readings.

Land Deformation and Peat Analysis

Geophysics and regional stratigraphy suggests that peat accumulation occurred during a low stand which is contemporary with the Holocene thermal maximum and was punctuated by a shift and strengthening of the Aleutian low leading to more pluvial conditions. The suggested presence of ancient shorelines suggests that it may have taken a while for the lake to dry out though the shorelines could just have easily been produced during periods where the rise in the water column was stable. The problem of course is that you have to account for 15 meters of water. If pluvial conditions set in around 8200 BP and the region continued to stay pluvial throughout the Holocene, it is very difficult to date any fluctuation that didn't completely dry the lake enough to start growing peat.

According to the work of Ed Berg on the peat analysis, the basin was fairly homogeneous with the driest species of peat throughout at differing elevations. To have the driest Sphagnum growing at the bottom of the depression would indicate that these were extremely dry times leading up to the paleo-lake level transgression, and thus an abrupt and dramatic shift in climate regimes.

JIGSAW LAKE RADIOCARBON DATA

A total of 11 radiocarbon dates were taken from 9 sediment cores representing varying elevations within the basins of Jigsaw Lake (Table 1). These dates were taken at transitions demarcating changes in visual lithology. Cores JS0952, JS0957, JS0958, JS0962, and JS0964 were all dated at the transition between peat and gyttja reflecting a facies change from terrestrial to lacustrine environments. These transitions yielded dates ranging from 7,930-8,630 cal years BP. The same transition from peat to gyttja was dated in core JS0966 and yielded a younger date range from 6,185-6,310 cal years B.P. Core JS0963 was dated at the transition from glacial till to terrestrial peat. This date range from 9,240-9,500 cal years B.P. represents the "fen-bottom" date. Additional dates taken from a previous study (Kaufman et al., 2009) are also represented. Kaufman et al. (2009) yielded a conventional date at the transition from peat to gyttja of 8,580 +/- 60 B.P. (cal 9,475-9,680 B.P.). The study also yielded a cove basal peat conventional date of 7,975 +/- 20 B.P. (cal 8,755-8,990 B.P.). Where a unique date was needed I have used the weighted average of the calibration probability function (Telford et al., 2004) by which the dates have been rounded to the nearest decade. This single date represents the most statistically significant possible date within the calibrated date range.

Sample	Lab ID(AMS) Beta Analytic	Location/ Transition	^{14}C Age(BP) Measured	^{14}C Age(BP) Conventional	Cal Age(BP) Range	Weighted Average
JS0957	B-264876	Tephra 2	6220 +/- 50	6130 +/- 50	6890-7164	7030
JS0966	B-264877	Peat-Gyttja	5450 +/- 40	5450 +/- 40	6185-6309	6250
JS0957	B-265843	Peat-Gyttja	7600 +/- 60	7530 +/- 60	8311-8406	8330
JS0958	B-265844	Peat-Gyttja	7760 +/- 60	7680 +/- 60	8389-8582	8480
JS0963	B-264845	Till-Peat	8390 +/- 60	8360 +/- 60	9241-9501	9370
JS0962	B-270589	Peat-Gyttja	7210 +/- 50	7130 +/- 50	7932-8003	7950
JS0951	B-270587	Bottom Peat	8310 +/- 50	8330 +/- 50	9295-9430	9340
JS0964	UC Irvine	Hpeat-Fpeat		7065 +/- 20	7867-7899	7900
JS0952	UC Irvine	Peat-Gyttja		7850 +/- 20	8598-8632	8620
JS0964	UC Irvine	Fpeat-Gyttja		7115 +/- 25	7934-7968	7940
JS0962	B-270588	Bottom Peat		7930 +/- 50	8628-8983	8790
Kaufman 01		Tephra-Dispersed		8350 +/- 40	9275-9472	9370
Kaufman 01		Peat-Gyttja		8580 +/- 60	9475-9681	9560
Kaufman 01		Cove BasalPeat		7975 +/- 20	8754-8991	8870

Table 1. Radiocarbon data from Jigsaw Lake-Kenai, Alaska 2009.

DISCUSSION AND CONCLUSIONS

Over the course of this study I have attempted to reconstruct Holocene moisture variability for the Kenai Lowlands of Alaska. This was undertaken through the analysis of transitions from terrestrial to lacustrine sediments found within lake sediment cores obtained from Jigsaw Lake. Radiocarbon data collected at transitions demarcated by changes in visual lithology suggests formation of the basal peat (glacial till-peat) began ca. 9,240-9,500 Cal years B.P. Stratigraphic data, referenced utilizing core photography and stratigraphic columns, suggests a transition from terrestrial to lacustrine sediments ca 7,930-8,630 Cal years B.P. The visual lithology suggests a regional rise in the water table transforming what was once a fen, dominated by terrestrial peat, into a lake. This transition is marked by the onset of lacustrine sediments, mainly gyttja. The increase in regional precipitation is suggested to have lead to a rise in the regional groundwater table forming Jigsaw Lake with a maximum depth of 15 meters.

An analysis of the Kenai Peninsula by Jones et al. (2008) culminated in a 14,000 year record of peat accumulation on the Kenai. Increased peat preservation and the occurrence of wet meadow species suggest high moisture from 11,500 to 10,700 cal yr B.P., in contrast to drier conditions in southeastern Alaska; this pattern may indicate a strengthened Aleutian Low (AL). Drier conditions on the Kenai Peninsula from 10,700 to 8,500 cal yr BP may signify a weaker AL. Decreased insolation-induced seasonality resulted in climatic cooling after 8,500 cal yr B.P., with increased humidity from 8,000 to 5,000 cal yr B.P. (Jones 2008), which corresponds well with the peat data from this study (Berg, personal correspondence 2009). A long-term shift in regime may be a threshold response to a gradually changing forcing, such as insolation, or alternatively a response to an abrupt climatic shift (Fritz, 2001). Hu et al. (1999) suggest that an increase in North Pacific precipitation ca. 8,000-9,000 cal years BP was a function of a strengthened Aleutian Low propagated by the catastrophic breakup of the Laurentide Ice Sheet resulting in the rearrangement of atmospheric circulation following drainage of Glacial Lake Agassiz and Ojibway. With the waning of the Laurentide Ice Sheet, the polar front was shifted northward as were the westerly winds. The paleo-lake level reconstruction for Jigsaw Lake, suggesting an increase in regional precipitation, lends credence to the northward expansion of the polar front producing increased pluvial conditions in the North Pacific and arid climate in the North American mid-continent (Hu et al. 1999; Wolfe 1996). After approximately 8,000 cal years B.P., as the ice sheet waned, dramatic changes in lakes in central and eastern North America suggest altered circulation patterns across North America. In central North America, lake-level dropped and in the grassland regions, many lakes became saline because of evaporative concentration of salts (Fritz, 2001). The presence of evaporative salts suggests extensive periods of drought in the American mid-continent contemporaneous with pluvial activity in the North Pacific.

The timing and character of the increase in lake levels were interpreted in the context of higher shorelines recognized in the region and variations in circulation patterns in the North Pacific. The intensive sampling, use of geophysics, locally consistent stratigraphies, and recognition of tephras have produced a well-constrained record of past climate and past changes in landscape.

ACKNOWLEDGEMENTS

I would like to thank the Keck Geology Consortium for the opportunity and support given throughout the course of this study as well as the NSF grant, which supported such. Thank you to Ed Berg and the Kenai National Wildlife Refuge for their generous funding and assistance whilst in the field in Alaska. Thanks to my colleagues, Alena Gieche of Middlebury College and Jessa Moser of the University of Cincinnati for their continued collaboration throughout. Thanks to the Copeland Fund for the monetary support needed for the acquisition of two additional radiocarbon dates without which I could not have completed this project. Thanks to Professor Tom Lowell of the University of Cincinnati for his vast expertise and knowledge in the field of Paleoclimatology. And special thanks to Professor Greg Wiles and Professor P. Nick Kardulias, my advisors on this hardly Independent study project.

REFERENCES

Bradley, R.S. Paleoclimatology: Reconstructing Climates of the Quaternary. International Geophysics Series v. 64, Academic Press. 1999.

Fritz, S.L., Metcalfe, S.E. and Dean, W. 2001. Holocene Climate patterns in the Americas inferred from paleolimnological records. Inter-Hemispheric Climate linkages. Academic Press, San Diego, pp. 241-263.

Hu, F.S., Slawinski, D., Wright Jr, H.E., et al 1999. Abrupt Changes in North American Climate during early Holocene times. Nature, 399, 437-440.

Kaufman, Darrell S., Anderson, Scott R., Hu, Feng Sheng, Berg, Edward, Warner, Al. Strengthened Aleutian Low during the Younger Dryas inferred from lake-sediment evidence, southern Alaska. Unpublished data, 2009.

Jones, M. C., Peteet, D. M., Kurdyla, D., and Guilderson, T. 2009. Climate and vegetation history from a 14,000-year peatland record, Kenai Peninsula, Alaska. Quaternary Research 72, 207-217.

Lutz, Brian, Gregory Wiles, Thomas Lowell, and Joshua Michaels, 2007. The 8.2-ka abrupt climate change event in Brown's Lake, northeast Ohio.Quaternary Research, 67, 292-296.

McLauchlan, Kendra, 2003. Plant cultivation and forest clearance by prehistoric North Americans: pollen evidence from Fort Ancient, Ohio, USA. Holocene 13, 4, p.557-566.

Reger, R. D., Sturmann, A. G., Berg, E. E., and Burns, P. A. C. 2007. A guide to the late quaternary history of northern and western Kenai Peninsula, Alaska. State of Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys.

Telford, R.J., Heegaard, E., and Birks, H.J.B., 2004. The intercept is a poor estimate of a calibrated radiocarbon age. Holocene 14, 296-298.

Viau, A.E., and K. Gajewski. 2001. Holocene variations in the global hydrological cycle quantified by objective gridding of lake level databases. Journal of Geophysical Research, Vol. 106, pgs. 31, 703-31, 716.

Wendland, W.M., and Bryson, R.A., 1974, Dating climatic episodes of the Holocene: Quaternary Research, v. 4, P. 9-24.

Wolfe, B.B., Edwards, T.W.D., Aravena, R. and MacDonald, G.M. 1996. Rapid Holocene hydrologic change along boreal tree-line revealed by delta 13C and delta 18O in organic lake sediments, Northwest Territories, Canada. Journal of Paleoliminology, 15, 171-181.