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
Symposium Convenor
ExxonMobil Corp.

Keck Geology Consortium Member Institutions:
Amherst College, Beloit College, Carleton College, Colgate University, The College of Wooster, The Colorado College Franklin & Marshall College, Macalester College, Mt Holyoke College, Oberlin College, Pomona College, Smith College, Trinity University Union College, Washington & Lee University, Wesleyan University, Whitman College, Williams College

---

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)
Students: Lenny Ancuta, Jordan Epstein, Nathan Evenson, Samantha Falcon, Alexander Gonzalez, Tiffany Henderson, Conor McNally, Julia Nave, Maria Princen

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.)
Students: Livia Capaldi, Matthew Harward, Matthew Kissane, Ashley Melendez, Julia Schwarz, Lauren Werckenthien

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
Keckgeology.org

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

INTRODUCTION

Records of decadal fluctuations in precipitation regimes are valuable indicators of regional climate. This study addresses lake level fluctuations by using preserved peat layers to examine a period of approximately 1000 years of lake level change. Twenty-three overlapping lake sediment cores were taken from a series of kettle basins within Jigsaw Lake in the Kenai Lowlands of the Kenai National Wildlife Refuge. Sediment cores and geophysical seismic surveys were analyzed to separate the landscape evolution signal (kettle-development) from the climate signal (regional lake levels). Our work builds upon a previous study at Jigsaw Lake done by D. Kaufmann in 2004 that included physical proxies, radiocarbon dating, testate amoebae and peat analyses. For our study, the 23 sediment coring locations in five kettle basins of Jigsaw Lake were determined based upon detailed geophysical and bathymetric maps, which allowed for precision coring (Figure 1).

Analysis of a widespread preserved peat layer in the cores indicates a lake low-stand and a gradual transition to higher lake levels between approximately 9300-7950 cal yr BP, suggesting that the climate was relatively drier during this time and getting wetter. In the northeast basin of the lake, the submerged peat layer occurs as deep as 11.5 meters below current lake level, suggesting that water level rose by at least this depth over the past ~9300 years. Evidence of paleo-shorelines found 1-2 meters above the present lake level at 82 masl indicates even higher lake levels at some point following glacial retreat about 18,500 years ago. Peat humification analysis on core 0962 supports the possibility of several basin subsidence events as the initial trigger for a 5 meter lake level rise occurring between approximately 8620 cal yr BP, whereas a later lake level rise approximated around 8050 cal yr BP may reflect a true shift in precipitation and moisture availability. Based on the findings of this study, lake level changes in Jigsaw Lake were caused by a combination of basin subsidence and changes in precipitation.

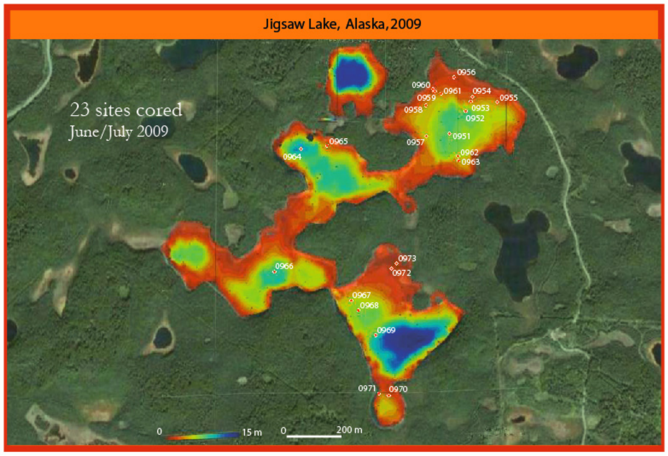


Figure 1. Coring sites at Jigsaw Lake on the Kenai Peninsula, Alaska. Bathymetry of the lake is represented by the color gradient.

STUDY SITE

Tracking longterm changes in regional groundwater tables provides important information about former water budgets and stratigraphic changes in preserved sediments. By reconstructing the paleo lake-levels at Jigsaw Lake in the Kenai Lowlands, a proxy record can be developed for basin subsidence and moisture variability in this region during the Holocene. Deglaciation occurred in this area at about 18,500 cal yrs BP, and Jigsaw Lake is one of many kettle lakes in a chain of northwest-southeast oriented lakes formed after the glaciers receded to the North (Reger et al., 2007). Jigsaw Lake is an ideal site for the study of past relative moisture changes as the lake sits at an elevation of 82 m perched on a groundwater drainage divide. This makes the lake sensitive to changes in precipitation, as the lake levels are directly dependent on the regional groundwater table.

METHODS

2.1 Field research

Field research at Jigsaw Lake in the Kenai National Wildlife Refuge was conducted in June and July of 2009 by a six-person team of student and faculty investigators. Geophysics research utilized a combination of a Hummingbird 798 SI sidescan sonar and a SyQwest Stratabox™ sub-bottom profiler to survey all kettle basins of the lake. Upon examining the profiles, twenty-three sites were selected for coring. A modified Livingston piston coring device was mounted on a platform on two canoes. This portable coring platform was anchored at the coring sites, where 1m overlapping thrusts of cores were extracted. Initial processing of the cores included stratigraphic correlation, photographic documentation, and magnetic susceptibility (MS) sampled every centimeter using a Bartington magnetic susceptibility meter.

2.2 Research done at Middlebury College, 2009-2010

Six cores were brought to Middlebury for further research, including 0951, 0955, 0959, 0962, 0968, and 0970 (Figure 1). Additional analyses include loss on ignition (sampled every 2 cm using a Leco TGA-701 thermogravimetric analyzer). Additionally, three samples from core 0951 were examined with the XRD to determine mineral composition within the peat, tephra, and sand. A colorimetric peat humification analysis was carried out on a 80 cm peat section of coring site 0962 (sampling every centimeter). The protocol used for this analysis was developed by Blackford and Chambers (1993). Finally, three AMS dates (from the top and bottom of the peat layers in 0962 and the bottom of the peat layer in 0951) were sampled and submitted to BetaAnalytic Inc. for radiocarbon dating.

PEAT HUMIFICATION ANALYSIS

The longest recovery of continuous peat within the cores was approximately 80 cm long in core 0962. Based on the initial AMS dates, this peat grew in 800 years, at an approximate rate of 10 cm/100 years (Ed Berg, pers. comm.). Normal rates on the Kenai Peninsula appear to vary between 1-5 cm / 100 years (data from Ed Berg, personal communication). Ten centimeters per 100 years is therefore an extremely fast growth rate for peat, which makes the species composition of great interest. Due to the decomposition of the peat, however, distinct species have been difficult to identify. Nevertheless, preliminary examinations suggest that the majority of species are *Sphagnum*, specifically *Spaghnum fuscum*, which is one of the driest sphagnum moss species (Ed Berg, pers. comm.). Since peat humification may vary based on the diversity of species present throughout the peat layer, it is important to consider species variation when performing peat humification analysis throughout a varied core (Yeloff and Mauquoy, 2006). In the case of core 0962, this does not appear to be a problem since species variation is limited.

The degree to which the peat has humified may provide important clues about climate variability at Jigsaw Lake. Peat humification is directly related to the surface moisture conditions when the peat was formed (Aaby & Tauber, 1975). Wet conditions prevent humification and dry conditions allow the peat to humify more completely. To determine the degree of humification, the Blackford & Chambers (1993) protocol was used, which involves boiling peat samples in 8% NaOH and measuring the percent light transmission of the filtered solution. Determining the degree of peat humification throughout the peat sequence in core 0962 provides a relative scale of moisture conditions during ~8,790 – 7,950 years BP (determined by AMS dates). A sample was taken every centimeter, and occasionally two consecutive samples were combined if they did not individually yield 0.2g of dried mass. Since the 80cm section of peat represents ~800 years of growth, each centimeter of peat represents approximately 10 years. This age estimate assumes constant growth and does not adjust for any variations in growth speed or compression of deeper layers, though presumably one centimeter in the lower layers would represent a longer time span than one centimeter in the uppermost layers. This high resolution of peat sampling allowed for a detailed look at the moisture variability over 800 years.

RESULTS AND DISCUSSION

3.1 Visual Stratigraphy

A fence diagram of several of the cores in the northeastern basin provides a good visual correlation of the changes in stratigraphy spanning the basin (Fig. 2). It is apparent from this diagram that the transition layers (peat to lacustrine and sandy nonorganics to peat) are consistently present throughout the cores. This suggests that there is an apparent relation between stratigraphies of all cores throughout the basin even though the story of lake level change is complex.

3.2 LOI and Magnetic Susceptibility

Loss on ignition (LOI) data matches the visual stratigraphy and magnetic susceptibility readings of the cores. Taking core 0962 as an example (Fig. 3), the LOI data appears to correlate well with magnetic susceptibility (MS) except within the peat section. Here, LOI deviates from a high-carbon content, and seems to suggest that a non-organic layer must be present in the peat. Perhaps this layer represents erosional deposits from a significant flooding event. Nevertheless, it is interesting that this deviation does not record in the magnetic susceptibility or humification measurements.

3.3 Peat Humification and AMS dates

The high-resolution peat humification record of core 0962 provided a relative moisture record for ~8,790-7,950 cal yrs BP (Fig. 4). Particularly significant is the shift from low transmittance to high transmit-

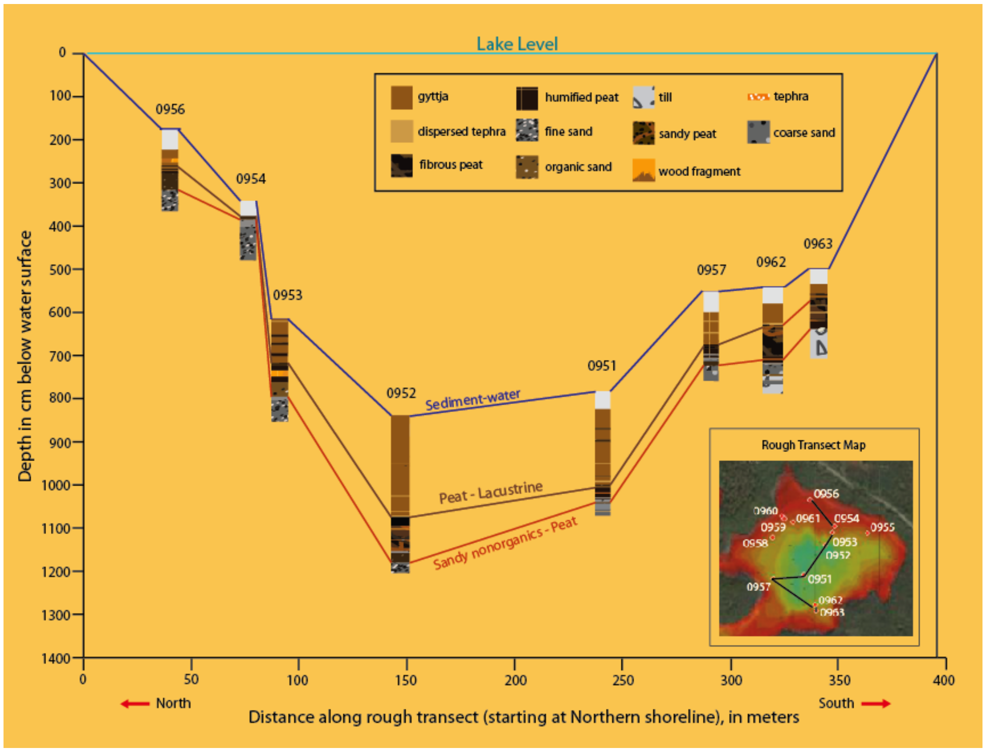


Figure 2. A fence diagram showing stratigraphies of several cores. Cores being analyzed for this study include 0951 and 0962.

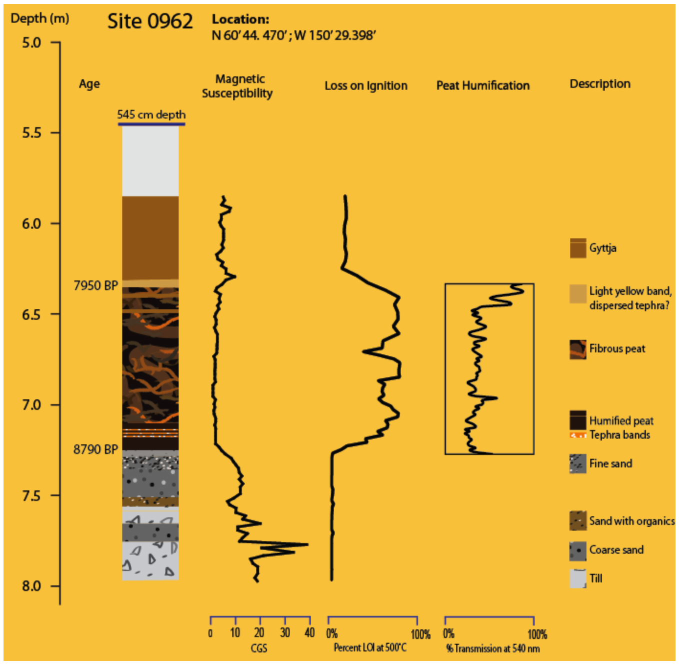
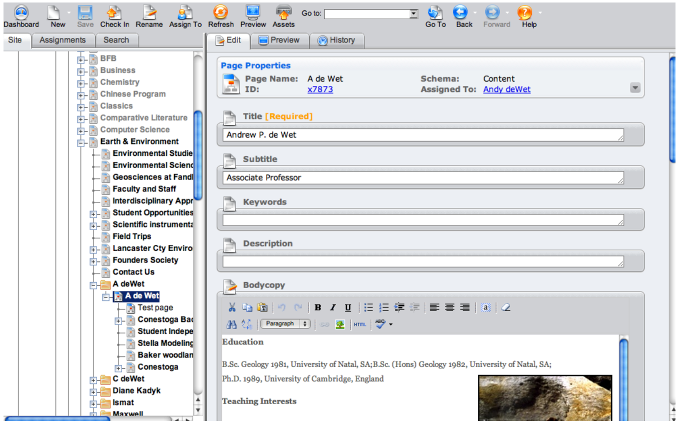


Figure 3. Core description for site 0962. LOI deviates from MS trends only within the peat. Peat humification is a measure of the percent light transmitted at 540 nm after following the Blackford & Chambers (1993) protocol.



Page Properties

Page Name: A de Wet

ID: x7873

Schema: Content

Assigned To: Andy deWet

Title [Required]: Andrew P. de Wet

Subtitle: Associate Professor

Keywords:

Description:

Bodycopy

Education

B.Sc. Geology 1981, University of Natal, SA;B.Sc. (Hons) Geology 1982, University of Natal, SA;

Ph.D. 1989, University of Cambridge, England

Teaching Interests

Table 1. Table of all AMS dates, including three dates from a preliminary study done by Kaufmann in 2004.

tance (more than a 30% shift in one centimeter) at 58 cm. There are large oscillations in moisture from 58 cm depth until the top of the peat at 48cm, while the rest of the core is mostly low transmittance. One large spike at 104 cm reflects a layer of more well-preserved peat (indicating moister conditions). The entire story starts to get far more inter-

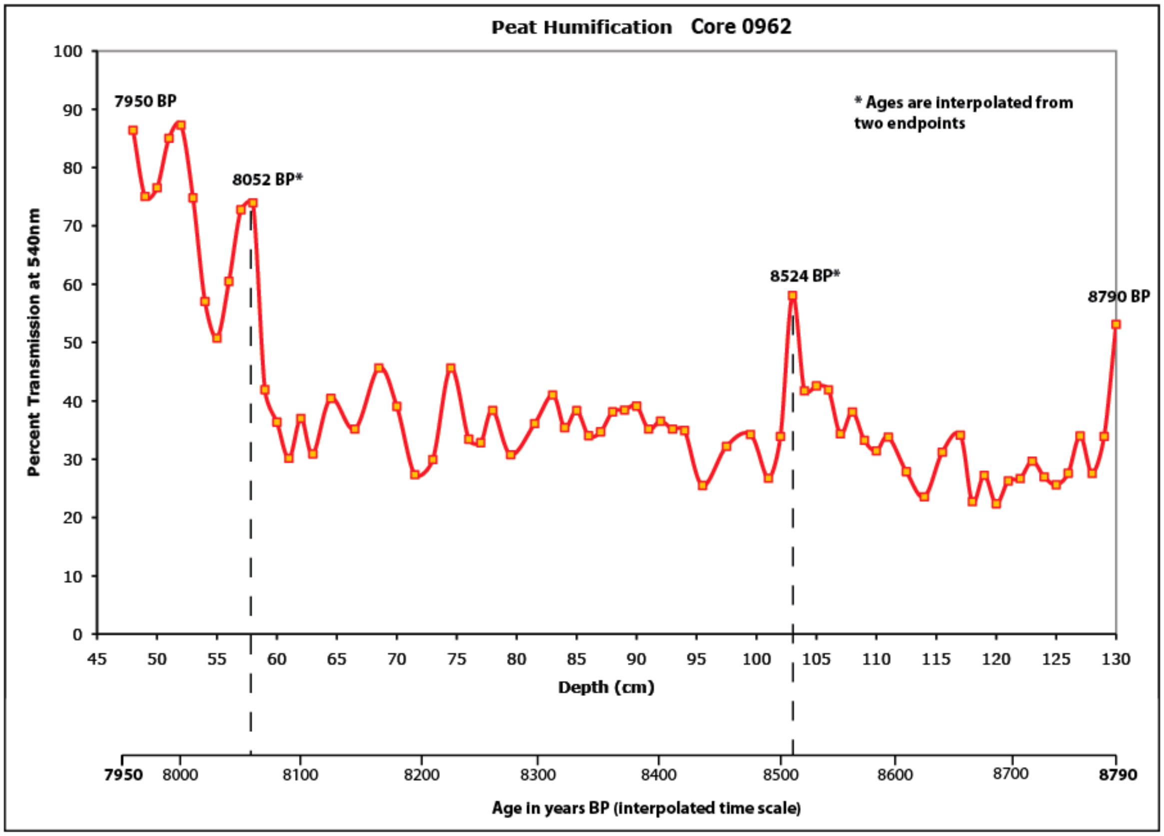


Figure 4. Peat humification for site 0962. Higher percent light transmittance indicates less humification, and therefore wetter conditions at time of growth.

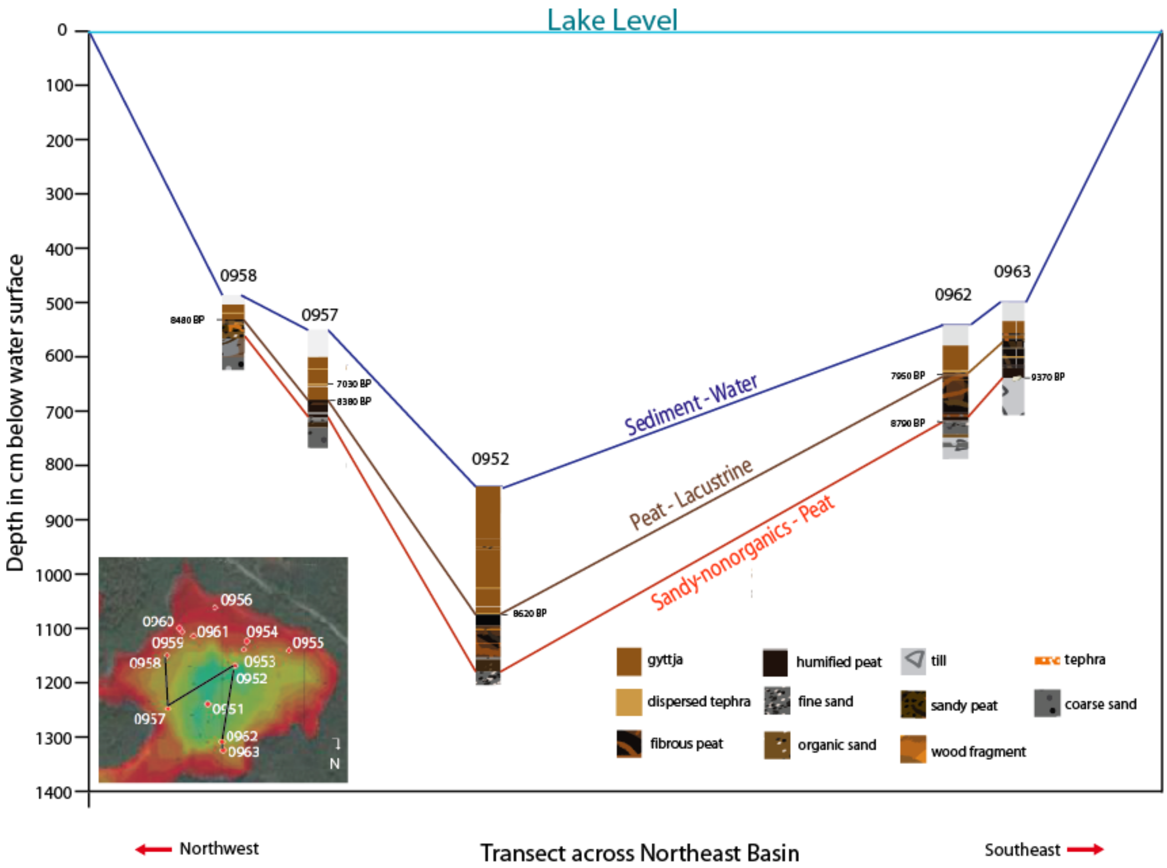


Figure 5. Core stratigraphy fence diagram of sites 0958, 0957, 0952, 0962, and 0963. AMS dates provide a reference for correlation.

esting when you add the complexities of peat layers in other cores found at various depths, AMS dates of multiple transitions from till to peat and peat to gyttja (Table 1), and the occurences of historical subsidence events such as ice block melts or seismic activity.

Using all the data available and drawing upon previous studies of climate history in the Kenai region, a potential scenario for lake level changes in Jigsaw Lake was developed as follows (see Figure 5 for visual stratigraphic reference):

1. Within the basin, peat begins growing on top of the deglaciated terrain around 9340-70 cal yrs BP (basal date of peat in the northeast basin). This was a relatively drier climatic period (Jones et al., 2009); however, high seasonality, snowfall, and glacier melt kept peat growing and well preserved during this time. The basal date of a fen surface peat core from the southern shore of the northeast basin (used for testate amoebae analysis by Edward Mitchell in a prior study) was dated to 9640 cal yrs BP. This peat showed no evidence of flooding, therefore the 1-2 m higher paleo-shorelines must have been formed prior to this date and lake level never again rose above this height (Ed Berg, pers. comm.).

2. The climate continues to get drier, and peat becomes more humified.

3. At approximately 8,620 cal yrs BP (date of the peat-gyttja transition in core 0952), the kettle basin subsides by as much as 5m around the center of the basin (core 0952) due to a melting ice block (see geophysics analysis by Jessa Moser) or seismic activity (Dick Reger, personal communication). This conclusion is based on geophysical data that shows evidence of slumping and deformation in lake sediments. Water fills in the depression and gyttja begins to accumulate directly over well-humified peat. Peat continues to accumulate at the higher elevation sites (0957, 0958, 0962, and 0963).

4. Between 8500-8200 cal yrs BP, the climate becomes cooler and moister (Jones et al., 2009). Peat humification analysis on core 0962 records a spike of moisture at ~8520 cal yrs BP.

5. Due to increased precipitation, lake levels continue to rise. Due to a melting ice block or seismic activity, the basin subsides again ~8480-8330 cal yrs BP along the northwestern shore of the lake, affecting sites 0957 and 0958. The peat is inundated with water, and peat accumulation stops at these sites. Peat continues to grow at sites 0962 and 0963 by the southeastern shore.

6. Moist and cool climate continues to dominate while rising water inundates peat at sites 0962 and 0963 by ~7950 cal yrs BP. Peat humification analysis of 0962 shows significant fluctuations in moisture during the last 10cm of peat accumulation at this site (representing a 100-year time period of ~8050-7950 cal yrs BP). These oscillations are likely recorded so well in this segment because the peat was close to the water table. The oscillations have an approximately 30-year period between wet and dry precipitation regimes, which may be related to regional Pacific Decadal Oscillation (Wiles et al., 2004). Though quantitative peat humification analysis was not carried out on core 0963, there is a visible stratigraphic shift from humified peat (drier conditions) to fibrous peat (wetter conditions) to lake sediment (even wetter conditions) to fibrous peat (lake levels must have dropped enough to grow peat again) and back again to lake sediment (it finally was too wet for peat to keep growing). The appearance of gyttja between peats in this sequence is likely a record of a prolonged wet period. At 0963, the shallower site, this period was recorded as lake sediment, whereas it is recorded as a section of less-humified peat at site 0962 (depth is 45 cm below 0963, so water must have fluctuated by less than 45cm).

7. Lake levels continued to rise and wet conditions persisted until possibly ~5000 years BP, when Jones et al. make the case for drier climatic conditions in this region (2009).

Though there are many uncertainties in the scenario suggested above, this possible scenario begins to unravel the complexity and possible causes of lake level changes over just 9300 years. Glacial environments are highly dynamic, and the combination of basin subsidence and precipitation variation greatly affected lake levels. The ice-block model of basin subsidence assumes that a thin lens of ice persisted under a lake-level high (1-2m higher shorelines) after initial glacier retreat, and in the post-glacial environment under a thin layer of peat for about 10,000 years. Another explanation could be subsidence caused by seismic activity. In this scenario, slumps could be formed during liquefaction (Dick Reger, personal communication). In either scenario, it is remarkable that water level fluctuated by as much as 13.4 meters depth over a relatively short time span, and that several meters could be due to subsidence of the basin.

CONCLUSIONS

The paleohydrologic history of Jigsaw Lake is complex as it combines three possible variables of melting ice blocks, seismic activity, and shifting climate and water budgets. The high magnitude of lake level rises and falls indicate that the post glacial environment was extremely variable, both structurally as kettle basins were forming and climatically as precipitation was changing. This study also illuminates the importance of acquiring a large distribution of cores and dates (even in just one basin of the same lake) in order to begin distinguishing various signals. In many ways, it makes sense to have unraveled a very complex climate history in the sediments of Jigsaw Lake. Rather than distilling Jigsaw Lake sediments into a simple chronology of lake level rise, the range of data from this study have continually diversified the possible explanations. Ultimately, lake level rose by over 11.4 m, but its path towards this point was not a linear progression. Core stratigraphy and cross-correlation throughout the basin confirms a significant shift in lake levels, most likely caused by at least two major subsidence events, at least three large-scale shifts in precipitation regimes on a millenial time scale, and further smaller decadal-scale fluctuations in precipitation patterns that may be evidence of Pacific Decadal Oscillation. Further studies would benefit from examining more sediment cores and peat sections in nearby lakes to continue building a regional hydrologic timeline and narrow down the possible causes of lake level fluctuations.

ACKNOWLEDGMENTS

Terry Race Workman, Jessa Moser, Gregory Wiles, Tom Lowell, Edward Berg, and Dick Reger all contributed to this study in major ways during the field work portion as well as later research. I would also like to thank my advisors, Jeffrey Munroe and Pete Ryan, who should be acknowledged for their dedication to my independent study, numerous suggestions, invaluable help, and encouragement of my research at Middlebury College.

REFERENCES

Aaby, B. and Tauber, H. 1975: Rates of peat formation in relation to degree of humification and local environment, as shown by studies of a raised bog in Denmark. Boreas 4 (1975), pp. 1–17.

Blackford, J.J. and Chambers, F.M. 1993: Determining the degree of peat decomposition in peat based palaeoclimatic studies . International Peat Journal 5, 7-24.

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

Reger, R. D., Sturmann, A. G., Berg, E. E., 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.

Wiles, G. C., D'Arrigo, R. D., Villalba, R., Calkin, P. E., Barclay, D. J. 2004. Century-scale solar variability and Alaskan temperature change over the past millennium. Geophys. Res. Lett., 31.

Yeloff, D. and Mauquoy, D. 2006 (November): The influence of vegetation composition on peat humification: implications for palaeoclimatic studies. Boreas, Vol. 35, pp. 662 - 673. Oslo.