KECK GEOLOGY CONSORTIUM

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

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2010-2011 PROJECTS

FORMATION OF BASEMENT-INVOLVED FORELAND ARCHES: INTEGRATED STRUCTURAL AND SEISMOLOGICAL RESEARCH IN THE BIGHORN MOUNTAINS, WYOMING
Faculty: *CHRISTINE SIDDOWAY*, *MEGAN ANDERSON*, Colorado College, *ERIC ERSLEV*, University of Wyoming
Students: *MOLLY CHAMBERLIN*, Texas A&M University, *ELIZABETH DALLEY*, Oberlin College, JOHN *SPENCE HORNBUCKLE III*, Washington and Lee University, *BRYAN MCATEE*, Lafayette College, *DAVID OAKLEY*, Williams College, *DREW C. THAYER*, Colorado College, *CHAD TREXLER*, Whitman College, *TRIANA N. UFRET*, University of Puerto Rico, *BRENNAN YOUNG*, Utah State University.

EXPLORING THE PROTEROZOIC BIG SKY OROGENY IN SOUTHWEST MONTANA
Faculty: *TEKLA A. HARMS*, *JOHN T. CHENEY*, Amherst College, *JOHN BRADY*, Smith College
Students: *JESSE DAVENPORT*, College of Wooster, *KRISTINA DOYLE*, Amherst College, *B. PARKER HAYNES*, University of North Carolina - Chapel Hill, *DANIELLE LERNER*, Mount Holyoke College, *CALEB O. LUCY*, Williams College, *ALIANORA WALKER*, Smith College.

INTERDISCIPLINARY STUDIES IN THE CRITICAL ZONE, BOULDER CREEK CATCHMENT, FRONT RANGE, COLORADO
Faculty: *DAVID P. DETHIER*, Williams College, *WILL OUIMET*. University of Connecticut
Students: *ERIN CAMP*, Amherst College, *EVAN N. DETHIER*, Williams College, *HAYLEY CORSON-RIKERT*, Wesleyan University, *KEITH M. KANTACK*, Williams College, *ELLEN M. MALEY*, Smith College, *JAMES A. MCCARTHY*, Williams College, *COREY SHIRCLIFF*, Beloit College, *KATHLEEN WARRELL*, Georgia Tech University, *CIANNA E. WYSHNYSZKY*, Amherst College.

SEDIMENT DYNAMICS & ENVIRONMENTS IN THE LOWER CONNECTICUT RIVER
Faculty: *SUZANNE O'CONNELL*, Wesleyan University
Students: LYNN M. GEIGER, Wellesley College, KARA JACOBACCI, University of Massachusetts (Amherst), GABRIEL ROMERO, Pomona College.

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

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GEOLOGIC, GEOMORPHIC, AND ENVIRONMENTAL CHANGE AT THE NORTHERN TERMINATION OF THE LAKE HÖVSGÖL RIFT, MONGOLIA
Faculty: *KARL W. WEGMANN*, North Carolina State University, *TSALMAN AMGAA*, Mongolian University of Science and Technology, *KURT L. FRANKEL*, Georgia Institute of Technology, *ANDREW P. deWET*, Franklin & Marshall College, *AMGALAN BAYASAGALN*, Mongolian University of Science and Technology.
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.

LATE PLEISTOCENE EDIFICE FAILURE AND SECTOR COLLAPSE OF VOLCÁN BARÚ, PANAMA
Faculty: *THOMAS GARDNER*, Trinity University, *KRISTIN MORELL*, Penn State University
Students: *SHANNON BRADY*, Union College. *LOGAN SCHUMACHER*, Pomona College, *HANNAH ZELLNER*, Trinity University.

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.

EOCENE TECTONIC EVOLUTION OF THE TETONS-ABSAROKA RANGES, WYOMING
Faculty: *JOHN CRADDOCK*, Macalester College, *DAVE MALONE*, Illinois State University
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— Hövsgöl Rift, Mongolia

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Project Faculty: KARL W. WEGMANN: North Carolina State University, TSALMAN AMGAA: Mongolian University of Science and Technology, KURT L. FRANKEL: Georgia Institute of Technology, ANDREW P. deWET: Franklin & Marshall College, AMGALAN BAYASAGALN: Mongolian University of Science and Technology

MAPPING AND RELATIVE AGE DATING OF MORAINES IN THE HOROO GOL VALLEY, HÖVSGÖL RIFT, MONGOLIA
BRIANA BERKOWITZ, Beloit College
Research Advisor: Susan Swanson

PALEOLIMNOLOGY AND PALEOCLIMATE ENVIRONMENT REVEALED THROUGH HOLOCENE LAKE SHORE SEDIMENTS FROM HÖVSGÖL, MONGOLIA
DAENA CHARLES, Union College
Research Advisor: Donald Rodbell

A MULTI-PROXY STUDY OF HOLOCENE PALEOCLIMATE AND DEPOSITIONAL ENVIRONMENT, HÖVSGÖL, MONGOLIA
MELLISSA CROSS, Colgate University
Research Advisor: Bruce Selleck

CORRELATION OF TREE RING ANALYSIS AND CLIMATOGICAL RECORDS IN THE LAKE HÖVSGÖL REGION OF MONGOLIA
JOHN MICHAELS, North Carolina State University
ERDENEBAYAR TSAGAANNARAN, Mongolian University of Science and Technology
BATTOGTOH DAMDINSUREN, Mongolian University of Science and Technology
Research Advisor: Karl Wegmann

LATE PLEISTOCENE GLACIATION AND TECTONICS AT LAKE HÖVSGÖL
DANIEL ROTHBERG, Colorado College
Mongolian Participants: Esugei Ganbold, Aranzal Erdene
Research Advisor: Eric Leonard

TIMING AND EXTENT OF LATE QUATERNARY GLACIATIONS NEAR LAKE HÖVSGÖL, MONGOLIA: IMPLICATIONS FOR CLIMATE CHANGE IN CENTRAL ASIA
AFSHAN SHAIKH, Georgia Institute of Technology
Research Advisor: Kurt L. Frankel

THE PALEOSEDIMENTARY ENVIRONMENT AND PALEOCLIMATIC CONDITIONS REVEALED BY STRATIGRAPHY IN HOLOCENE BOG AND TERRACE SEDIMENTS, NORTHWEST OF LAKE HÖVSGÖL, MONGOLIA
KRISTIN TADDEI, Franklin and Marshall College
Research Advisor: Dr. Andy deWet

PLEISTOCENE GLACIATION OF THE EASTERN SAYAN RANGE, NORTHERN MONGOLIA
GABRIELLE VANCE, Whitman College
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Research Advisors: Bob Carson and Nick Bader

LATE-CENOZOIC VOLCANISM IN THE HÖVSGÖL RIFT BASIN: SOURCE, GENESIS, AND EVOLUTION OF INTRAPLATE VOLCANISM IN MONGOLIA

ANDREW ZUZA, Cornell University
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PALEOLIMNOLOGY AND PALEOCLIMATE ENVIRONMENT REVEALED THROUGH HOLOCENE LAKE SHORE SEDIMENTS FROM LAKE HOVSGOL, MONGOLIA

DAENA CHARLES, Union College
Research Advisor: Donald Rodbell

INTRODUCTION

The Earth's history is comprised of complex and ever changing cycles of climate with varying changes in the ecosphere and atmosphere. These changes in climate can affect both local and global ecosystems by causing extinction, increases in ecosystem productivity, or speciation and have been steadily recorded in various archives in the Earth. These records can be derived from lake and ocean sediments, ice cores from glaciers, windblown sediments and sedimentary rocks, coral reef systems, tree rings, and for the most recent climatic changes, modern instrumentation. Climate records allow scientists to look at how fluctuations in climate have affected the Earth and humans in the past, allowing them to predict what can occur in the future.

Model predictions of long term climate change cannot be validated through repeated forecasts and analysis cycles such as those found in day to day weather forecasts (Hargreave, 2009). Due to a much longer time scale, future long term weather models need an input of information spanning thousands of years. Terrestrial records such as lacustrine sediment cores gives climate change a local perspective as it records the natural variability of an area. Lake deposits provide science with archives of earth and ecosystem history that are both highly resolved in time and long in duration (Cohen, 2003). Unlike other paleoenvironmental archives, lake sediments provide a high resolution record of events both on land and in the atmosphere. They provide one of the most durable paleoenvironmental archives since they are most likely to persist over a long period of time, even after the lake itself or it geomorphology has been destroyed. Lake sediments also provide a local record that permits the interpretation of climate change at a specific region or location. For the purposes of this report, in order to understand how climate change affected the northern region of Lake Hovsgol, Mongolia lacustrine sediments are best suited to understand its paleoenvironmental history. In this study, focus will be kept on a small section of the northern tip of Lake Hovsgol. The study area is indeed a part of Lake Hovsgol but is separated from it by a bog-like structure, creating a closed smaller lake system. This newly formed lake is officially un-named but will be referred to as Pickle Lake (Fig. 1). In order to understand how climate changes have affected the northern Mongolia area, sedimentary samples taken from a trench leading into Pickle Lake were analyzed. This location was chosen due to its clearly visible 3-m stratigraphy and easy access.

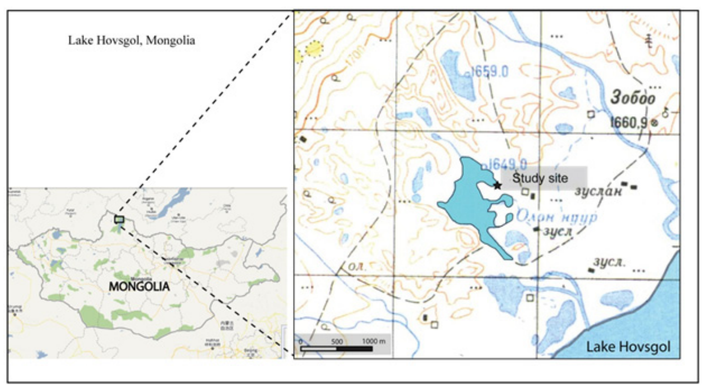

Figure 1. A location map of Lake Hovsgol, Mongolia and study site located on the banks of an unnamed lake referred to in this paper as Pickle Lake.

Stable isotope analysis and carbonate analysis is of most importance in relating lacustrine changes to variations in climate. δ13C and δ14N will provide understanding of aridity, and productivity of the lake along with other paleoenvironmental proxies such as percent calcium carbonate, organic carbon, magnetic susceptibility and δ18O. The core will also be dated to provide a time scale of events, permitting correlations between Pickle Lake and other lakes and climate events regionally and locally.

METHODS

Location for sampling was established by surveying bog-like topography to find an area that would lead to good depositional layers viable for sampling. The chosen location referred to as Pickle Lake is an unnamed shallow lake, located north of the much larger Lake Hovsgol. Due to the remote location of the study site, and the available tools on-site, a trench was dug on what seemed to be an older section of Pickle Lake that was exposed due to lowering of the lake or tectonic uplift. A trench was dug to ~3 meters depth in a series of steps (Fig. 2). For each visible layer, notes where taken of approximate grain size, color (based on the Munsell Color Chart) for soils, depth of each layer, and any other noticeable field observations such as the presence of organics, mica, marl or shells. A sample of the sediment from each layer was obtained and stored in zip-lock plastic bags and labeled.

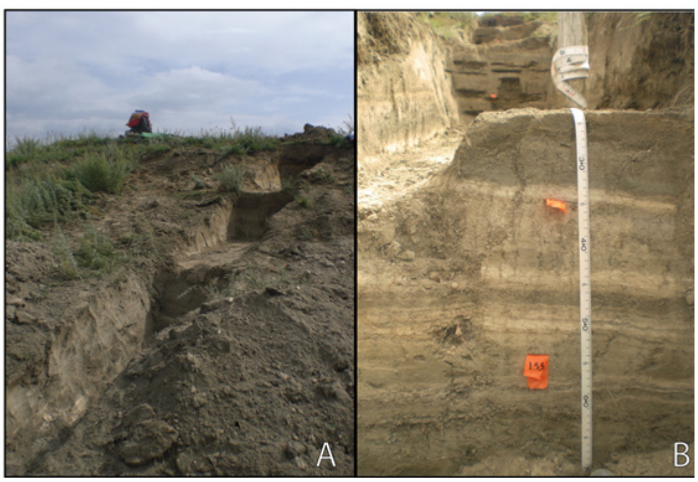

Figure 2. Along the banks of Pickle Lake, a trench was dug in steps (A) to reveal lacustrine depositional layers (B).

Samples were first freeze dried in a VerTis freeze dryer. Water content could not be determined from the difference in weight of fresh to freeze dried sample due to the conditions samples were stored in, allowing for a large source of error due to moisture evaporation. The freeze dried samples were then measured for magnetic susceptibility at both high and low frequency using a Bartington Magnetic Susceptibility Meter. Frequency dependent susceptibility of each sample was calculated automatically using the program Bartington Instruments Multisus. Total carbon and inorganic carbon were analyzed using a CM 5012 CO2 Coulometer. Both total and inorganic carbon was analyzed using 10 mg of CaCO3 as the standard with results recorded in percentage (%). Percent CaCO3 was determined by dividing the percent inorganic carbon by 0.12, the molar fraction of carbon in CaCO3. Organic carbon was then determined by subtracting inorganic carbon from the total carbon.

Twenty-two out of the total 50 samples collected were sent off-site for analysis of δ13C, δ15 N and C/N ratio of the organic material in the samples. Samples chosen for analysis were based on attempting to get a consistent record that would represent the entire sediment column. Preparation included placing ~5mg of sediment in silver capsules, bathed in hydrochloric acid then placed in a drying oven. Samples were measured via a Finnigan MAT Delta Plus XL mass spectrometer in continuous flow mode connected to a Costech Elemental Analyzer at Iowa State University. Twenty-five out of the total 50 samples collected were also sent off-site for analysis of δ13 C and δ18O of the inorganic material in the samples. Samples chosen for analysis were based on which layers displayed the highest amounts of percent CaCO¬3. Samples were measured via a Finnigan MAT Delta Plus XL mass spectrometer in continuous flow mode connected to a Gas Bench with a CombiPAL autosampler at Iowa State University. Plant fragments acquired from layers with high organic matter were dated by 14C dating. Results for radiocarbon dates were corrected for isotopic fractionation according to the conventions of Stuiver and Polach (1977).

A comprehensive figure of all paleoenvironmental data and sediment characteristics was created using the Adobe Illustrator CS5 program (Fig. 3). The figure is sectioned into four parts, A through D, based on what appears to be significant changes in the column. CaCO3, low frequency susceptibility and organic carbon were used as the factors for determining these sections.

RESULTS & INTERPRETATIONS

The total column observed is ~300cm in depth. The lowest obtained sediments in the column were rich in marl and little organic matter. This marl layer was particularly thick in nature reaching an unknown depth and light grey in color; characteristics rarely found in the rest of the column. This layer sharply shifts into another massive layer, one of black, mica-rich sediment with very fine, silty to sandy particles. As one follows along the column to the most recent deposition, layers become smaller in size, some as thin as 1cm. Very few repetitive patterns were observed. One pattern observed only twice was a shift from Very pale brown, CaCO3 nodule filled sediment transitioning into a brown organic rich sediment (180-164cm & 28-21cm) (Fig. 3). Gravity cores from Lake Hovsgol in previous studies indicate consistent patterns of lithologic change throughout the Lake Hovsgol basin. From the last glacial maximum layers of calcareous clayey silt with intermixed coarse materials such as sand and gravel are present (Prokopenko, 2005). It was also proposed that during the last glaciation, a three-member lithologic succession occurred approximately eight times: from calcareous clayey silt to finely laminated carbonate muds, followed by deposition of diatomaceous clayey ooze. These lithologic transitions were interpreted to be signals of Pleistocene lake transgressions related to global climate change (Abzaeva, 2009). These three-member succesions were not seen in the acquired sediment column.

Carbon 14 dating of 5 samples reveals that the sediments are Holocene in age with the oldest sample, 5390 ±70 at 305-307cm (bottom-most part of the marl layer). The top-most part of the same marl layer (283-285cm) revealed an age of 5185 ±120 cal yr BP. At a depth of 155-157cm, plant fragments indicate an age of 3765 ±65 cal yr BP and at 88-90cm an age of 3210

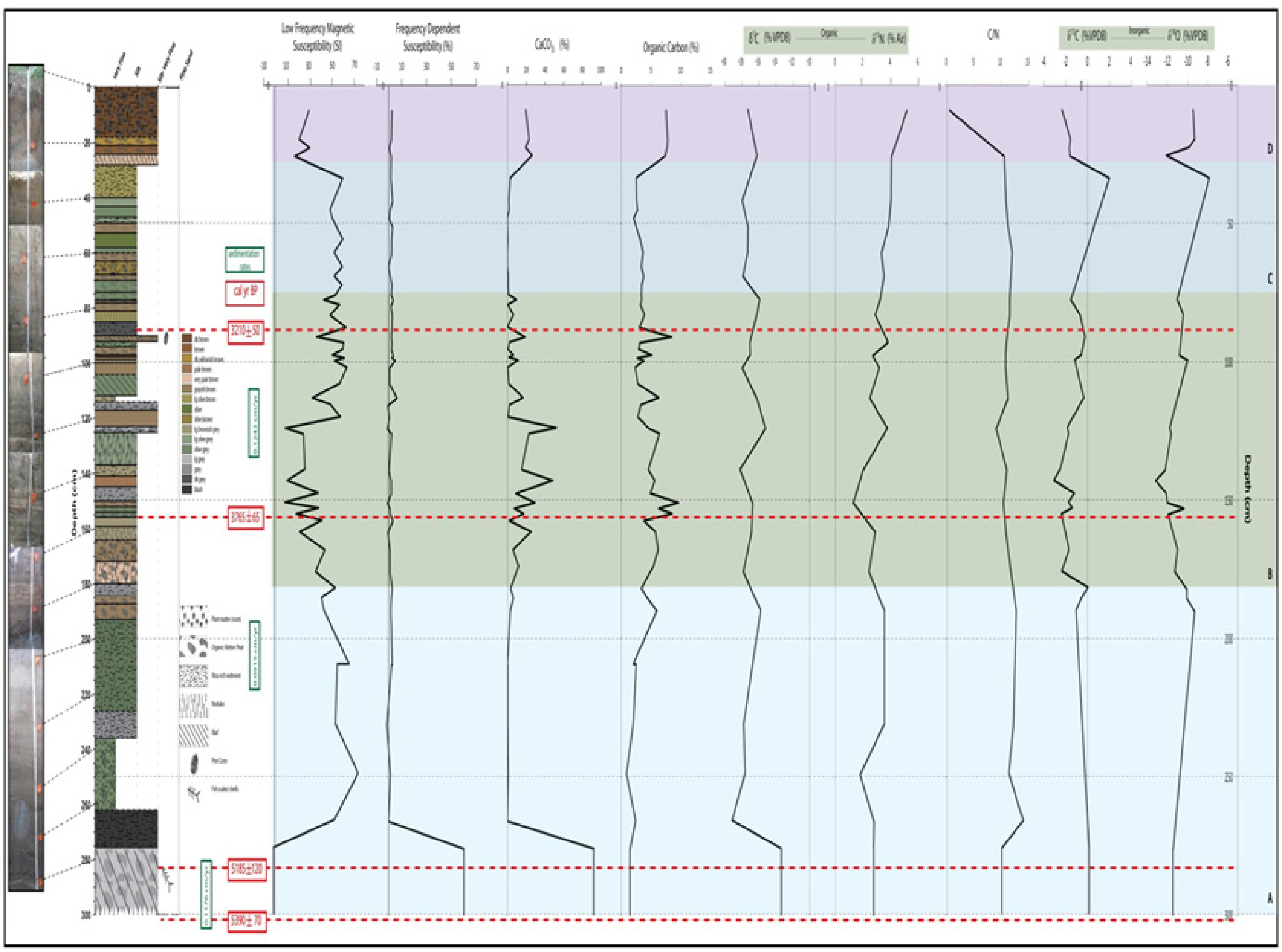

Figure 3. A comprehensive diagram of the analyzed paleoenvironmental proxies and stratigraphy column of the sediments from Pickle Lake. Sediment characteristics and Munsell color are indicated by the legend. To the left of the stratigraphy column, a photo column of the sediments analyzed, illustrates the laminations in sediment core that were analyzed.

Cal year BP	Sedimentaion Rate cm/yr
3210 ± 50 to 3765± 65	0.1243
3765± 65 to 5185± 120	0.0915
5185± 120 to 5390± 70	0.1176

Table 1.Sedimentation Rate for Pickle Lake

±50 cal yr BP. The sample at the topmost depth of 40cm, revealed an age of 9290 ± 140 cal yr BP, an age much higher than that found at the deepest layer. It is assumed that due to an exceedingly low amount of extractable carbon from this sample, the age resulted from contamination of some sort and will be excluded from this paper's findings. Sedimentation rates indicate that deposition slowed from 3765±65 to 3210±50 cal yr BP (Table 1) (Figure 3).

Section A

A dry period from 5390± 70 to 5185± 120 cal yr BP is seen in the sediments taken from 270 to approximately 300cm depth in the acquired stratigraphic column. Magnetic susceptibility is a measure to which a material can be magnetized (Thompson, 1986) and in this period, low frequency susceptibility (LFS) is at very low values, < 0. This may imply that sediment input via stream run-off was low as magnetic susceptibility may be regarded as an erosion indicator, whether it be from precipitation or wind erosion (Thompson, 1986). A surprisingly high frequency dependent susceptibility (FDS) value of 60% may be indicative of forest fires or an increase in wind-blown, super-paramagnetic magnetite into the lake at that time. Fires give rise to secondary magnetic materials as heat enhances the magnetic susceptibility of soils. The heating of soils also breaks the soil down into much finer soil grains that may become easily transported via wind. It is difficult to differentiate whether a FDS greater than 2% (which is deemed significant) is specifically a factor of forest fires or increased wind activity as there are no written records of forest fires in the area to compare against. However, the presence of high FDS is interpreted as an indication of aridity which may also lead to nearby forest fires.

A high calcium carbonate value of 92.02%; a value much higher than that found in the rest of the record, also indicates a period of dry weather. With increased temperature there is increased evaporation; this removes CO2 out of the lake causing disequilibrium which promotes CaCO3 precipitation (Cohen, 2003). Increased primary productivity can also cause an increase in calcium carbonate. A less negative δ13Corg of -23.45% may also suggest that C4 plants became more abundant as the climate was drier during this time. Although the climate appears to be warm and dry, there is uncertainty as δ18O does not support this because, δ18O should be much more positive. This is inferred because when water evaporates lighter oxygen ions evaporate leaving behind an isotopically heavier lake which should be expected. However, this is not the case at 270- 300cm.

The climate around the lake then shifts dramatically after 5185 cal yr BP from a warm and dry climate to a cooler and wet climate. This wet period is seen from 270 to 180cm depth. The shift from very high calcium carbonate content to ~0% calcium carbonate may suggest that conditions were not conducive for the precipitation of calcites. An increased stream flow, increased precipitation or rise in lake level may be responsible for this lack of calcium carbonates which is seen in increased values of LFS -1 to 53 SI and continues to increase until 236cm. In previous studies, lake level rise has been associated with reduced mineralization of Lake Hovsgol waters suggested by rapidly declining carbonate content in lake sediments as seen in this stratigraphic column (Abzaeva, 2009). Changes in sediment properties are also observed, as this shift is marked by a sharp transition from the previously mentioned massive marl layer to a black mica rich layer at 276-262cm. CaCO3 and organic carbon are relatively low after the transition from marl to mica rich sediment. Organic δ13 C and δ15 N appear to have little similarity in their plots with one another in section A. There is also very little change from the bottom most layer to 180cm in inorganic δ13 C and δ18O (Figure 3).

Section B

Section B is the area where many of the paleo-proxy data becomes very interesting, shifting from a relatively quiet record to a period of varying changes in sedimentary properties. One general observation noted is that %CaCO3 is roughly the inverse of LFS (Figure 3). In many sedimentary layers, when LFS decreases, % CaCO3 increases. Section B is a period of shifting climate that switches from wet and cool to warm and dry in a cyclic motion. Although there are oscillations in the record, conditions at Lake Hovsgol during this period is at an overall drier state than the wet/cool period in section A because the LFS on average is lower in section B with values reaching as low as 9 SI. There are two periods of high CaCO¬3 content at 141-145cm (48.06%) and 123-125cm (51.99%). These layers of high CaCO3 content also correlates with increases in δ13Corg. Increases in both δ13Corg and CaCO3 may be an indication that productivity in the lake, although at a drier and warmer climate was higher, as organic carbon increased during periods of lowered LFS. A general increase in δ15Norg is also noted in section B with a sharp increase (3.75%) which correlates with the sharp increase in δ13Corg found at 123-125cm. At this prominent change in the record at 123-125cm, organic δ13C is -25.22% indicate that the climate was warmer allowing for growth of C4 plants, but only a few. Inorganic δ18O is also at its lowest in Section B with values reaching as low as -13.16. As in section A, the oxygen isotope record is questionable as values should be more isotopically heavy than light, however it does trend with great similarity to inorganic δ13C.

Section C

In section C, Pickle Lake once again experiences a wet/cool period with very low %CaCO3 values. Lake level rise may contribute to the increase in low frequency magnetic susceptibility (LFS) with values ranging between 51.4 to 60.4 SI. The LFS record is however oscillating in a zigzag pattern ending in a sharp decrease at 24-27cm to 17.8 SI. Organic carbon has very little change from 80-25cm depth indicating steady lower levels of lacustrine productivity. There is also little change in δ15Norg and C/N. Inorganic δ13C and δ18O both increase to their highest values at 27-40cm which is consisted of marl with calcite nodules where another climate shift occurs. Organic δ13C values of ~-27% indicate that the climate was cool and moist enough to support growth of C3 plants.

Section D

The upper most sediments of this section contain large amounts of organic matter, very fine-silty soils and plant matter. LFS decreases to 17.8 SI from a previously high record in section C. Inversely, calcium carbonate increases with a similar trend. Organic carbon also increases from 2.50 to 7.34% indicating an increase in productivity. Also the organic δ15N record shows a general increase from the bottom of the record to the most recent depositional layer. As the top most layer is exposed to modern day precipitation and short grass growth, nitrogen content is expected to be highest in the upper most layer. C/N ratios throughout sections A-C show very little change with the exception of a sudden decrease-increase at the same 123-125cm layer. Sediments observed at 123-125 cm are light grey marl with organic matter and silty to very fine sandy grain size. C/N ratios indicate that for most of the record Pickle Lake was dominated by lacustrine organisms and even more so in section A.

CONCLUSIONS

From the acquired data, Pickle Lake has had cyclic changes in climate from warm/arid conditions to cooler/wet conditions. From the bottom to the top of the record, we see a change in climate from warm and arid to wet and cool (section A), warm with oscillating wet periods (section B), wet and cool (section C) then at the most recent, warm (section D). Many of the paleoclimate data supports this conclusion, however further interpretation is needed for δ18O as it supports the complete opposite of these findings.

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