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

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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

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Students: Adam Curry, Allison Goldberg, Lauren Idleman, Allan Lerner, Max Siegrist, Clare Tochilin

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Keck Geology Consortium: Projects 2009-2010
Short Contributions – SVALBARD

HOLOCENE AND MODERN CLIMATE CHANGE IN THE HIGH ARCTIC, SVALBARD, NORWAY

Project Faculty: ***AL WERNER***: Mount Holyoke College
STEVE ROOF: Hampshire College
MIKE RETELLE: Bates College

DIRECTLY-CONTROLLED LICHEN GROWTH CURVES FOR WESTERN SPITSBERGEN, SVALBARD

TRAVIS BROWN: College of Wooster
Research Advisor: Greg Wiles

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CHRISTOPHER FISHER COLEMAN: Wesleyan University
Research Advisor: Suzanne O'Connell

LINNÉ GLACIER METEOROLOGICAL STUDY OF SURFACE ABLATION DURING THE 2006-2008 ABLATION SEASONS

FRANKLIN DEKKER: Franklin & Marshall College
Research Advisor: Christopher J. Williams

MODERN SEDIMENTATION PROCESSES IN A PROGLACIAL LAKE, LINNÉVATNET, SVALBARD, NORWAY

JACALYN GORCZYNSKI: Mount Holyoke College
Research Advisor: Al Werner

334 YEARS OF CLIMATE CHANGE RECONSTRUCTED FROM VARVED SEDIMENTS: LINNEVATNET, SVALBARD

ALICE NELSON: Williams College
Research Advisor: Mea Cook

SEDIMENT CHRONOLOGY DEFINED BY CESIUM-137 IN THE DEEP MAIN BASIN OF PROGLACIAL LINNÉVATNET, WESTERN SPITSBERGEN, SVALBARD

ALEXANDER NERESON: Macalester College
Research Advisor: Karl Wirth

ALKENONE-INFERRED TEMPERATURE RECONSTRUCTION FROM KONGRESSVATNET, SVALBARD

DAVID A. VAILLENCOURT: University of Massachusetts Amherst
Research Advisors: William J. D'Andrea and Steven T. Petsch

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INTRODUCTION

Varved sediment records from proglacial lakes have the potential to be used as proxies for climate change because the laminations reflect seasonal and annual sedimentation, which is controlled by factors such as winter snow accumulation, summer precipitation, glacier mass balance, and summer temperature. By calibrating lamination thickness to climatology in a time period with instrument records, we can reconstruct climate history that predates instrumental monitoring.

Previous research in Linnévatnet (Lake Linné) has focused on sediment traps and cores from sites in the proximal basin near the Linnéelva (Linné River) inlet where sedimentation rates are high because it was believed that cores from the deep distal basin would have laminations too diffuse for further analysis (Fig. 1). A problem with cores from the proximal basin is that the lamination stratigraphy reflects annual layers as well as layers that are weather related or event-based because sediment input in the proximal basin is greatly affected by discharge (McKay, 2005) which in the summer, is primarily controlled by precipitation (Matell, 2006). In the proximal basin, it is difficult to distinguish laminations that are event based, such as a spring flood or turbidite, from laminations that represent an entire melt season or year, which makes it difficult to accurately correlate lamina to individual years. Preliminary analysis of cores from site G in the deep main basin suggests that while the laminations from this site are thin (mm to sub mm) due to low sedimentation rates, the stratigraphy is varved, and it is possible to count and measure the annual layers (Pompeani et al., 2009). Analysis of cores from site G indicates that varve thickness measurements correlate positively to summer temperature (Pompeani et al., 2009). In this project, I studied a core from site I and correlated varve thickness with summer temperature, glacier ablation, and winter precipitation for the time period between 1912 and 2009. The reconstructed climate history places current change within a historic context, which will help us to understand how the Arctic is responding to global warming.

RESEARCH AREA

During late July 2009, a group of scientists and students from the Keck Geology Consortium cored site I which is at 35 m water depth in the deep main basin of Linnéevatnet (Fig. 1). The largest sediment source to the lake is inflow from Linnélva, which drains an area of approximately 27 km^2, including Linnébreen (Linné Glacier) and several smaller glaciers (Snyder et al., 2000). The sediments in Linnévatnent range from coarse silts to clays, most of which enter the lake during a short melt period from mid-July until early August during which sedimentation rates are high and grain sizes are large (McKay, 2005). McKay (2005) found that the largest peak in grain size (median grain size = 53 μm) is associated with the spring melt and that these deposits are significantly coarser than sediments deposited during the rest of the year (median grain size = 16 μm).

Like many glacial lakes, Linnévatnet is characterized by varved sediment layers throughout most of the basin. Varves result from seasonal differences in grain size between the sediments deposited during the spring, summer, and winter. The laminations appear in spring-winter couplets, which can be counted as annual layers. The annual depositional structure created by the seasonality of flow is a fining upwards couplet with sand and silt being deposited during the spring and clay being deposited during the winter (Svendsen and Mangerud, 1997).

Evidence for a varved sediment record in Linnévatnet is supported by previous core analysis (Svendsen and Mangerud, 1997; Pompeani et al., 2009) and by recently collected sediment trap data (Arnold, 2009). In Linnévatnet, the varve structures are well preserved because a lack of biological activity prevents bioturbation from disturbing the sediments. Previous research in Linnévatnet has found the number of varve couplets to correlate with the estimated age of the cores studied (Svendsen and Mangerud, 1997).

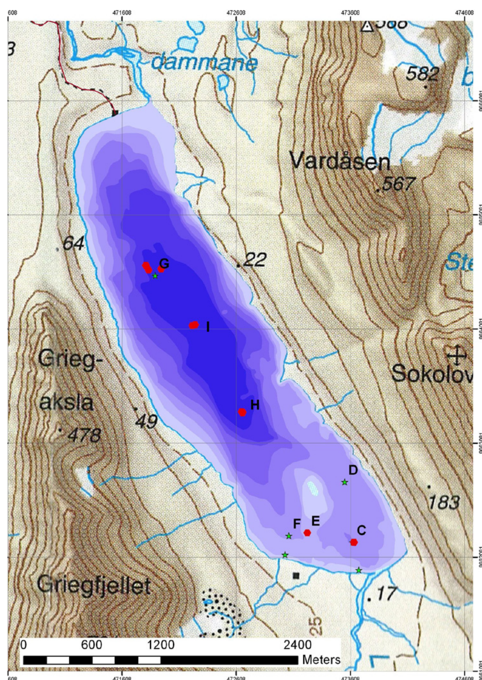

Figure 1: Bathymetric map of Linnévatnet with coring and mooring sites labeled. Cores were collected in the summer of 2009 at site I at a depth of 35 m (Adapted from Pompeani et al., 2009).

METHODS

We collected two cores from site I using a Universal surface corer, which was lowered into the water from the edge of a Zodiac. Both of the cores retrieved from site I retained distinct sediment-water interfaces, which indicates that the most recent layer of sediment was preserved. After dewatering and drying, we transported the cores by boat and then by air back to the United States where we processed them in a lab at Mount Holyoke College.

I split the core tubes using standard laboratory procedures and then photographed and described the split surfaces. I noted the approximate depth and thickness of distinctive lamina and described them based on color and texture. I sub-sampled one half of the split core for thin section analysis and used a fluid displacive resin embedding technique to prepare the soft sediments for thin-sectioning. This technique, modified from Kemp et al. (2001), involved replacing the water in the sediment with acetone and then embedding the samples with resin. This method, while time intensive, is preferred over freeze-drying because it enables the fine lamina to be continually supported and therefore minimizes the potential for disturbance and cracking.
After I replaced all the water in the samples with acetone and then resin, I let the samples sit in the resin for a week and then cured them in a vented oven at 50°C for twenty-four hours. After curing, the resin block was hard, translucent, and completely inert and the samples could be cut down into thin sections.

I counted and measured the varves using a method adapted from Francus et al. (2002). I scanned each thin-section slide onto a computer at 4800 dpi and increased the brightness of the images in Photoshop to make the individual lamina more visible.
In Photoshop, I marked the varves with horizontal lines along a vertical axis using the Pen Tool in the Paths function. I marked each varve at the boundary between the winter and spring layer, which I determined by the abrupt change in sediment color from a darker, finer grained layer to a lighter, coarser grained layer. I then determined the thickness of each varve by measuring the distance between the horizontal line segments with the Ruler Tool.

I created an age model by counting the lines created in Photoshop and assigning a year to each varve. I assumed the most recent sediment layer at the top of the core to be the spring of 2009 and then dated each subsequent layer accordingly. Where it was difficult to distinguish individual varves due to cracking, due to the sediment in the thin section being polished too thinly and therefore becoming too light in color, or due to ambiguity in the grain sizes, I added 0.5 ± 0.5 years to the age model. For plutonium dating, I took 0.5 g dry samples, which I freeze dried and sent Northern Arizona University where they were analyzed with a VG Axiom MC inductively coupled plasma mass spectrometer for the 1963 plutonium spike (Ketterer et al., 2004).

RESULTS

Sediment core IC09.1 is 53.1 cm long. The bottom 6 cm of the core were disturbed during the thin section preparation and were not used for further analysis due to extensive cracking. Additionally, 1.3 cm of sediment are missing from the thin sections at a depth of approximately 36 cm. The top 47.1 cm of the core contains a total of 1154 varve couplets of which 334 have been measured. When taking into account the 1.3 cm of missing sediment, it is estimated that the core contains 1188 ± 22.5 varve couplets. Based on the estimated number of couplets in the core, the sedimentation rate at site I is 0.40 mm/year. The measured varves range in thickness from 0.07 mm to 2.39 mm with a mean thickness of 0.39 mm (Fig. 2).

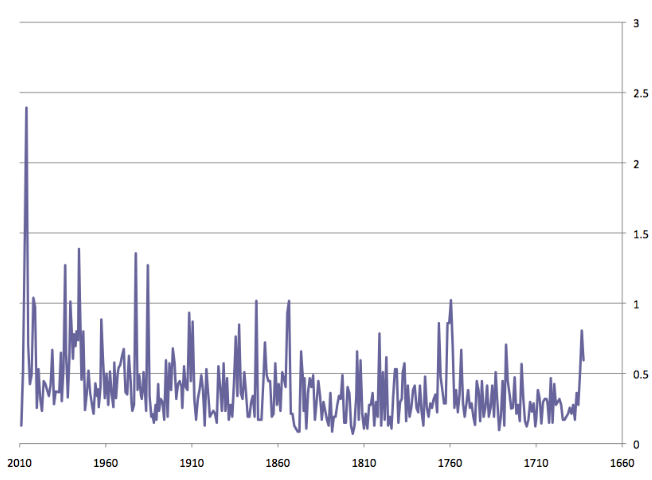

Figure 2: Graph showing varve thickness versus calendar year.

The age model of the measured varves is shown in Figure 3 and the oldest layer measured dates to 1682.5 with an error of 17.5± 17.5 years. The age model places the year 1963 at a depth of 3.0 cm, which is consistent with plutonium dating, which indicates that 1963 occurred between 3.0 and 3.5 cm. The varve-thickness measurements (y) correlate positively to summer temperature (JJA) (x) data from the Longyearbyen airport (Fig. 4) with the following linear least-squares relationship:

$$y = 0.08x + 0.15$$
where: $r^2 = 0.03$ and $p = 0.06$

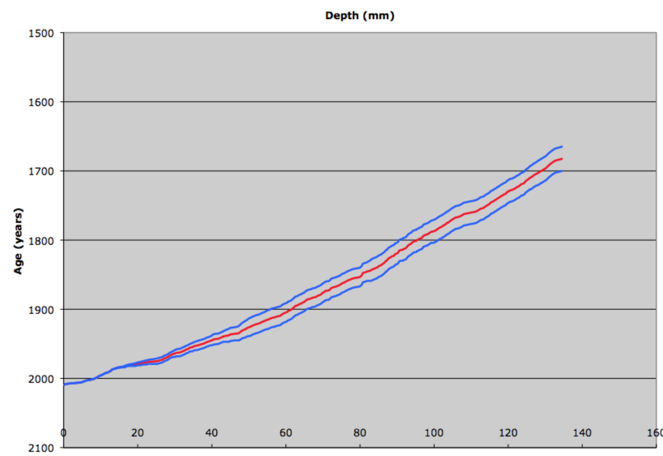

Figure 3: Graph showing the calendar year of the varves versus depth. The blue lines are the error showing the maximum and minimum ages at each depth.

DISCUSSION

Figure 4 shows that there is a statistically significant positive correlation between varve thickness and summer temperature. This relationship is expected because higher summer temperatures result in greater snow and ice melt both in the valley and on Linnébreen, which increases discharge in Linnéelva causing greater sediment loads and thicker varves. While the p value of 0.06 indicates that the positive relationship between varve thickness and summer temperature is statistically significant, the r^2 value of 0.03 indicates that there are other factors besides summer temperature, which influence varve thickness. Two possible additional factors influenc-

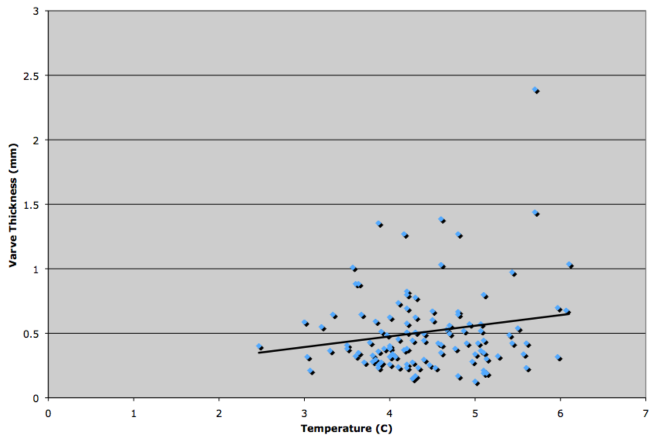

Figure 4: Comparison of summer temperature (JJA) to varve thickness. Summer temperature has a significant positive correlation to varve thickness.

ing discharge in Linnéelva are winter and summer precipitation. Winter snow accumulation affects Linnéelva discharge by determining the amount of the snowmelt the following summer and summer precipitation influences discharge regardless of the amount of snowmelt.

CONCLUSION

Varve thickness in Linnévatnet has varied through time and one of the climatological factors that positively influences thickness is summer temperature. This research is a work in progress, which will also include comparisons of varve thickness to glacier ablation and winter precipitation and these correlations will be compared to determine the climatological parameters that most influence varve thickness. These correlations will be used to create an extrapolated climate record for the last 1,000 years, which includes the Little Ice Age and Medieval Warm Period. Understanding the climate in Linnédalen during naturally-occurring climate variations for the last 1,000 years will give us a greater understanding of present day warming trends and the current retreat of Linnébreen.

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