Final Report

ISEN Early Career Investigator Award:
Rare Records of Last Interglacial Arctic Warmth from NW Greenland Lakes
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Background & research objectives

This pilot research focused on obtaining and beginning to characterize rare sedimentary records of Arctic climate from a geologically recent (~120,000 years ago) warm period known as the Last Interglacial or Eemian period. This was the last time the Arctic as a whole likely experienced temperatures several degrees warmer than present day and comparable to some forecasts for 2100 A.D. Thus, the Last Interglacial provides an opportunity to reconstruct (in unusual detail, geologically speaking, due to its geologically young age) how critical parts of the Arctic system behaved in a warmer climate analogous to Earth's near future.

Very few lakes from the glaciated Arctic have yielded records from the Last Interglacial because advancing ice sheets and mountain glaciers during the succeeding glacial period (the Last Glacial Maximum, LGM, ~26,000 to 19,000 years ago) scoured out many polar lake basins, removing any pre-glacial sediments. Lakes in these glacierized settings contain sedimentary records that only date back to the last deglaciation, i.e., ~11,000 years ago, the beginning of the Holocene (our current interglacial period). Continuous records of terrestrial Last Interglacial conditions around the Arctic are therefore very rare. While conducting NSF-funded research on the Holocene climate history of northwest Greenland near Thule Air Base, my collaborators and I discovered a site where pre-LGM lake sediments (yielding non-finite ^{14}C ages and warm, interglacial faunal assemblages) appeared to be preserved *in situ* beneath a Holocene sediment package.

ECIA funding from ISEN allowed for further sampling of these rare sedimentary records, geochronological confirmation of their antiquity, and paleoecological and geochemical analyses to derive initial paleoclimate reconstructions. ISEN-funded pilot data will ultimately be used to submit a proposal for further work to fully develop this unique paleoclimate archive (with submission planned in 2016, in collaboration with NU Assistant Professor Magdalena Osburn).

Summary of research outcomes

- During the Summer 2014 field season, we successfully obtained additional sediment cores from WLL Lake capturing the transition from Holocene to greater-density, ^{14}C-dead (i.e., pre Last Glacial Maximum) sediments. Cores from this site are the first from Greenland (and among the first few from the glaciated Arctic) to capture this type of ancient record.

- We have obtained initial geochronological data from the new cores. As hoped, core stratigraphy combined with ^{14}C ages indicate that the 2014 cores are more complete and cover a longer time span than those obtained initially in 2012. Additional samples have been submitted to WHOI-NOSAMS for ^{14}C dating, with the goal of pinning down the exact depth of the transition (uncomformity/hiatus) between pre-LGM and Holocene sediments. Optically stimulated luminescence (OSL) dating was attempted, but unfortunately the abundance of quartz was too small for our initial set of samples to yield reliable ages. We plan to sample again for OSL this winter, and possibly to utilize an experimental new method analyzing feldspars instead of quartz.

- In a new collaboration with Assistant Professor Magdalena Osburn (NU Dept. of Earth and Planetary Sciences), we have generated the first downcore molecular biomarker data from northern Greenland. Ph.D. student Jamie McFarlin is conducting this research in combination with chironomid faunal analyses, to obtain independent, complementary estimates of paleotemperatures throughout the Holocene and Last Interglacial. McFarlin plans to present her initial results at the December meeting of the American Geophysical Union (see "Conference presentations" below).

- Initial biostratigraphic data from the 2012 and 2014 sediment cores supports the preliminary interpretation that the pre-LGM sediments in WLL Lake date to a prior interglacial period warmer than present-day. In fact, McFarlin has identified microfossils in the pre-LGM sediments that suggest summer temperatures at least 8 degrees C warmer than today. This is a very large temperature anomaly, suggesting intense warmth. We will test this inference with independent evidence from geochemical indicators in the lake sediment records we have recovered.

- Two graduate students were supported with this funding. One (McFarlin) successfully obtained a NSF Graduate Research Fellowship to continue her work on the Last Interglacial in northwest Greenland.

- In addition to conducting downcore reconstructions of past climate, both project graduate students have designed investigations that will promote understanding of novel geochemical proxy methods. The results of their work will aid their interpretations of proxy data from the Holocene and a prior interglacial, improving the confidence and thus broad utility of the climate reconstructions generated as part of this research.

External funding resulting from ISEN ECIA research:

NSF Early Career Investigator (CAREER) Award

Title: *CAREER: South Greenland's Holocene Climate History Reconstructed Using Three Paleolimnological Approaches* (PI: Yarrow Axford)
Amount: $598,048 plus field logistics support
Sponsoring agency: National Science Foundation (NSF) Division of Polar Programs
Project dates: 8/1/2015-7/31/2020

National Geographic Society Grants for Research and Exploration

Title: *Glacier Loss and Climate Change in Southwest Greenland: Long-term Perspectives from Lake Sediments* (PI: Yarrow Axford)
Amount: $19,600
Sponsoring agency: National Geographic Society
Project dates: 9/25/2015-2/25/2016

NSF Graduate Research Fellowship

Title: *Quantitative Reconstruction of Interglacial Climate Using Chironomid-Inferred Temperatures and Compound-Specific D/H in Northwest Greenland* (to Ph.D. student Jamie McFarlin)
Amount: $138,000
Sponsoring agency: National Science Foundation (NSF)
Project dates: 6/1/2015-5/31/2018

Publications and presentations stemming from ISEN research:

Journal articles submitted:

Axford, Y., Levy, LB., Kelly, M., Francis. D.R., Hall, B., Langdon, P.R., and Lowell, T. Timing and magnitude of early Holocene warmth in East Greenland inferred from chironomids. Submitted to *Quaternary Science Reviews.*

Briner, J.P., McKay, N., Axford, Y., Bennike, O., Bradley, R.S., de Vernal, A., Fisher, D., Francus, P., Frechette, B., Gajewski, K., Jennings, A., Kaufman, D.S., Miller, G., Rouston, C., and Wagner, B. Holocene climate change in Arctic Canada and Greenland. Submitted to *Quaternary Science Reviews*.

Conference presentations:
* indicates student first author supported by ISEN ECIA

Axford, Y., Lasher, G.E., McFarlin, J., Francis, D.R., Kelly, M.A., Langdon, P.G., Levy, L.B., Osburn, M., and Osterberg, E.C. 2015. Invited. Holocene temperature shifts around Greenland: Paleolimnological approaches to quantifying past warmth and documenting its consequences. AGU Fall Meeting (San Francisco, California).

*Lasher, G.E., Axford, Y., McFarlin, J., Kelly, M.A., Osterberg, E.C., Farnsworth, L., and Kotecki, P. 2015. Holocene climate in NW Greenland inferred from oxygen isotopes of preserved aquatic organic material. AGU Fall Meeting (San Francisco, California).

*McFarlin, J., Axford, Y., Osburn, M.R., Lasher, G.E., Francis, D.R., Kelly, M.A., and Osterberg, E.C. 2015. Lacustrine records of continental climate in northwest Greenland

through the Holocene and Last Interglacial. AGU Fall Meeting (San Francisco, California).

*Lasher, G.E., Axford, Y., McFarlin, J., Blair, N.E., Kelly, M.A., Osterberg, E.C., Kotecki, P., and Farnsworth, L. 2015. Northwest Greenland Holocene temperatures inferred from organic archives of lakewater oxygen isotopes. GSA North-Central Section Annual Meeting (Madison, Wisconsin).

*McFarlin, J., Axford, Y., Osburn, M.R., Kelly, M.A., Osterberg, E.C., Lasher, G.E., Farnsworth, L., and Francis, D.R. 2015. Holocene and Last Interglacial continental climate inferred from insects and n-alkanes in lake sediments from northwest Greenland. GSA North-Central Section Annual Meeting (Madison, Wisconsin).

Public lectures & panels relevant to this award:

Meltdown or snow job? Scientific perspectives on climate change in the Arctic and beyond. Evening lecture for Masters in Project Management instructors, Northwestern University. November 2014.

Q&A on climate change and Arctic research with minority youth as part of a summer enrichment program, Northbrook/Evanston YOU program. August 2014.

Climate Change and Sustainability workshop. Lecture and curriculum development work with K-12 science teachers, Office of STEM Education Partnerships, Northwestern University. August 2014.

Arctic meltdown? Past and present-day climate change in the Arctic. Evanston Science Café. May 2014.

Media

NU Media Relations used our video footage from the 2014 field season in Northwest Greenland to create a video ("Extreme Science in the Arctic") about our Greenland research. NSF and ISEN are acknowledged in the accompanying story.

http://www.northwestern.edu/newscenter/stories/2015/02/extreme-science-in-the-arctic.html