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# Collaborative Research: Sensitivity of Local Glaciers in Central East Greenland to Holocene Climate Change

Brenda Hall

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## Preview of Award 0908081 - Final Project Report

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### Cover

Federal Agency and Organization Element to Which Report is Submitted:	4900
Federal Grant or Other Identifying Number Assigned by Agency:	0908081
Project Title:	Collaborative Research: Sensitivity of local glaciers in central East Greenland to Holocene climate change
PD/PI Name:	Brenda L Hall, Principal Investigator
Recipient Organization:	University of Maine
Project/Grant Period:	08/01/2009 - 07/31/2013
Reporting Period:	08/01/2012 - 07/31/2013
Submitting Official (if other than PD\PI):	Brenda L Hall Principal Investigator
Submission Date:	09/03/2013
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	Brenda L Hall

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### Accomplishments

#### \* What are the major goals of the project?

The major goal of this project was to understand the signature and cause(s) of Holocene climate change. A subsidiary goal was to place the present changes in the Arctic within a longer-term framework. How do present-day changes

relate to ice-extent over the last 10,000 years?

**\* What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?**

Major Activities:

During this project we carried out numerous major activities. These are detailed in our annual reports and are summarized here. Note: this is a collaborative project. I summarize here the results from the entire group. However, in the products and personnel pages, I list only those products/people who are at the University of Maine.

1) We carried out two field seasons in East Greenland. During field work, we selected and sampled 19 lakes that ranged from non-glacial (control) lakes to glacially fed lakes. Many of these were threshold lakes - lakes that receive glacial sediments only when the ice is at or beyond a certain extent. Field work consisted of producing a bathymetric map for each lake and taking sediment cores from the deepest and/or most interesting locations. We also produced some subsurface geophysical data. We retrieved many hundreds of meters of cores, half of which are archived at the Limnological Research Center at the University of Minnesota. We also collected subfossil, in situ plant remains that are melting out of retreating ice.

2) We performed laboratory analyses on the cores, including basic stratigraphy, sedimentology, grain size, color, loss on ignition, carbonate, and magnetic susceptibility. We also obtained numerous radiocarbon dates to constrain the chronology. Some cores also were analyzed for diatoms, pigments, amino acids, and chironomids.

3) We held two group meetings to discuss the data and logistics.

4) We presented results from this project at numerous meetings. Papers have been published and are in progress. Seven graduate students have completed theses either entirely related or partially related to this project.

Specific Objectives:

We have the following significant results:

Significant Results:

1) The Little Ice Age was the most extensive event of the Holocene in East Greenland.

2) The Little Ice Age was underway by AD 1150 at low elevation in East Greenland. This age is compatible with some of the best-defined Northern Hemisphere records for the onset of the LIA, but is earlier than some commonly cited dates of onset, such as AD 1400 from ice-core chemistry records.

3) Glacial expansion during the LIA may have been underway slightly before AD 1150 at high, interior elevations in East Greenland. Comparison of our records, which lie along geographic and elevational transects, indicates the utmost importance of multiple records when constructing glacial chronologies. In particular, our data point to the importance of the effects of geography on initiation of glaciation.

4) Deglaciation of East Greenland following the late-glacial period (Milne Land Stade) was rapid. Ice was near or behind present-day positions by about 11 ka.

5) During most of the Holocene, glaciers in East Greenland were behind present-day positions. Some ice caps may have vanished.

6) A pervasive, millennial-scale glacial signal can be seen in records from those glaciers that survived throughout the Holocene.

7) Our results are consistent with solar or oceanic forcing, but do not support recent hypotheses concerning volcanic forcing of the LIA.

Key outcomes or  
Other achievements:

**\* What opportunities for training and professional development has the project provided?**

This project has provided numerous opportunities for training and development. We mentored 7 graduate students, all of whom produced a thesis. Undergraduates also have assisted in the labs. Furthermore, we have developed a collaboration with a new female faculty member, who is working on samples from this project.

**\* How have the results been disseminated to communities of interest?**

Results from this project have been presented at numerous meetings, including INQUA, which reached a wide, international and interdisciplinary audience. We co-organized a Greenland session at that meeting. Results also have been incorporated in courses, in internal presentations, and to K-12 schools. We have maintained information about the project on our website.

## Products

### Books

Axford, Yarrow; Carrio, Catherine; Corbett, Lee; Francis, Donna R.; Hall, Brenda L.; Kelly, Meredith A.; Levy, Laura B.; Lowell, Thomas V.; Osterberg, Erich C.; Richter, Nora; Roy, Ellen (2013). *Fly's-eye views of the Holocene (and Last Interglacial?) on Greenland: Insect-based paleothermometry from the east and northwest Greenland Ice Sheet margins* AGU Fall Meeting. San Francisco, CA. Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Hall, B., Kelly, M., Lowell, T., Baroni, C., Bennike, O., \*Honsaker, W., \*Levy, L., and \*Lusas, A.R. (2011). *Late glacial and Holocene ice fluctuations, Scoresby Sund, East Greenland*. International Quaternary Association Congress. Berne, Switzerland. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Honsaker, W., Lowell, T.V., Sagredo, E., Kelly, M.A., and Hall, B.L. (2010). *Polar ice caps: A canary for the Greenland Ice Sheet*. American Geophysical Union Fall Meeting. San Francisco, CA. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Kelly, M., Levy, L., Lowell, T., and Hall, B. (2013). *Late glacial-early Holocene fluctuations of Greenland Ice Sheet outlet glaciers and adjacent local ice caps in central east Greenland*. CLIVAR Meeting. Boston, MA.. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Laura B. Levy, Meredith A. Kelly, Thomas V. Lowell, Brenda L. Hall, Patrick Applegate, Yarrow L. Axford, Jennifer A. Howley (2013). *→A comparison of Holocene fluctuations of the eastern and western margins of the Greenland Ice Sheet* AGU Fall Meeting. San Francisco, CA. Status = SUBMITTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Levy, L., Kelly, M., Lowell, T., Hall, B. (2011). *Holocene fluctuations of Bregne Ice Cap, Scoresby Sund, eastern Greenland*. American Geophysical Union. San Francisco, CA.. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Lowell, T., Kelly, M., Hall, B., Bennike, O., \*Honsaker, W., Levy, L., and Lusas, A.R. (2011). *Late Holocene ice cap activity in East Greenland and implications for the Greenland ice sheet*. International Quaternary Association Congress. Berne, Switzerland. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Lowell, T., Wilcox, P., Hall, B., Medford, A., Kelly, M., and Levy, L. (2013). *Late Holocene expansion of the Greenland Ice Sheet and implications for its current decay*. CLIVAR Meeting. Boston, MA.. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Medford, A., Hall, B.L., Lowell, T., Kelly, M., \*Levy, L., \*Wilcox, P., and Axford, Y. (2013). *Holocene glacial history of Renland, East Greenland, reconstructed from lake sediments*.. Northeast Geological Society of America Meeting. Bretton Woods, NH. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Wilcox, P., Lowell, T., Hall, B.L., Kelly, M., Medford, A., Levy, L., and Axford, Y. (2013). *Holocene stratigraphy of lakes in Graben Land, East Greenland: implications for an expanded ice sheet*. Northeast Geological Society of America Meeting. Bretton Woods, New Hampshire.. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

## Book Chapters

## Conference Papers and Presentations

### Inventions

Nothing to report.

### Journals

Levy, L., Kelly, M., Lowell, T., Hall, B., \*Hempel, L., \*Honsaker, W., \*Lusas, A., Howley, J., and Axford, Y. (2013). Holocene fluctuations of Bregne ice cap, Scoresby Sund, east Greenland: a proxy for climate along the Greenland Ice Sheet margin.. *Quaternary Science Reviews*. . Status = ACCEPTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Lowell, T., Hall, B., Kelly, M., Bennike, O., \*Lusas, A., Smith, C., \*Levy, L., Travis, S., and Denton, G., (2013). Late Holocene expansion of Istorvet Ice Cap, east Greenland.. *Quaternary Science Reviews*. 63 128. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Lowell, T., Hall, B., Kelly, M., Bennike, O., Smith, C., and Denton, G. (). Reply to Miller et al. (2013) Substantial agreement on the timing and magnitude of Late Holocene ice cap expansion between east Greenland and the eastern Canadian Arctic: a commentary on Lowell et al. (2013). *Quaternary Science Reviews*. in pres . Status = ACCEPTED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Lusas, A., Hall, B., Lowell, T., Kelly, M., Bennike, O., \*Levy, L., Honsaker, W., and Denton, G. (2013). Holocene history of southern Istorvet ice cap, East Greenland.. *Journal of Paleolimnology*. . Status = OTHER; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

### Licenses

Nothing to report.

### Other Products

Nothing to report.

### Other Publications

### Patents

Nothing to report.

### Technologies or Techniques

Nothing to report.

### Thesis/Dissertations

Amanda Rose Lusas. *Holocene fluctuation of the Istorvet Ice Cap, Liverpool Land, East Greenland*. (2011). University of Maine. Acknowledgment of Federal Support = Yes

Aaron Medford. *Holocene glacial history of Renland, East Greenland, reconstructed from lake sediments*. (2013). University of Maine. Acknowledgement of Federal Support = Yes

Krista Slemmons. *The influence of glacial meltwater on alpine and arctic lake phytoplankton throughout the Holocene*. (2013). University of Maine. Acknowledgement of Federal Support = Yes

## Websites

*Glacial geology research group/past projects*

<http://umaine.edu/earthclimate/faculty-staff/faculty-and-staff/brenda-hall/glacial-geology-and-geochronology-research-group/past-projects/>

We put descriptions of our projects aimed at the public on our website.

## Participants/Organizations

### What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Hall, Brenda	PD/PI	3
Lusas, Amanda	Graduate Student (research assistant)	12
Medford, Aaron	Graduate Student (research assistant)	12
Slemmons, Krista	Graduate Student (research assistant)	1

### Full details of individuals who have worked on the project:

#### Brenda L Hall

**Email:** Brendah@Maine.Edu

**Most Senior Project Role:** PD/PI

**Nearest Person Month Worked:** 3

**Contribution to the Project:** Hall was a co-PI on the project. She deployed twice to East Greenland, supervised three graduate students conducting theses on project research (Lusas, Medford, Slemmons), supervised the radiocarbon dating, oversaw lab analyses at the University of Maine, and contributed to the synthesis and presentation of results.

**Funding Support:** NSF, University of Maine

**International Collaboration:** Yes, Greenland

**International Travel:** Yes, Greenland - 0 years, 2 months, 0 days

#### Amanda Rose Lusas

**Email:** Lusas@maine.edu

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 12

**Contribution to the Project:** Amanda participated in field and lab work and wrote her thesis on project research. She actually worked 24 months over the course of the entire project, but this form will not allow me to enter numbers greater than 12.

**Funding Support:** NSF

**International Collaboration:** Yes, Greenland

**International Travel:** Yes, Greenland - 0 years, 1 months, 0 days

**Aaron Medford**

**Email:** aaron..medford@maine.edu

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 12

**Contribution to the Project:** Aaron participated in field and lab work and wrote a thesis on part of this project research. He actually worked 24 months over the course of this project, but I cannot enter numbers >12 in this form.

**Funding Support:** NSF, UMaine.

**International Collaboration:** Yes, Greenland

**International Travel:** Yes, Greenland - 0 years, 1 months, 0 days

**Krista Slemmons**

**Email:** Slemmons@maine.edu

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Krista participated in the lab work and the interpretation of diatom results. She wrote one chapter of her thesis related to this project.

**Funding Support:** UMaine

**International Collaboration:** No

**International Travel:** No

### What other organizations have been involved as partners?

Name	Type of Partner Organization	Location
Dartmouth College	Academic Institution	Hanover, NH
Geological Survey of Denmark and Greenland	Other Organizations (foreign or domestic)	Copenhagen
Northwestern University	Academic Institution	Chicago
University of Cincinnati	Academic Institution	Cincinnati, Ohio

### Full details of organizations that have been involved as partners:

#### Dartmouth College

**Organization Type:** Academic Institution

**Organization Location:** Hanover, NH

#### Partner's Contribution to the Project:

In-Kind Support  
Facilities  
Collaborative Research  
Personnel Exchanges

**More Detail on Partner and Contribution:** This is a collaborative project. We worked on every aspect of this project in close collaboration with personnel at Dartmouth and Cincinnati.

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### **Geological Survey of Denmark and Greenland**

**Organization Type:** Other Organizations (foreign or domestic)  
**Organization Location:** Copenhagen

**Partner's Contribution to the Project:**  
Collaborative Research

**More Detail on Partner and Contribution:** Ole Bennike participated in field work and analyzed floral remains.

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### **Northwestern University**

**Organization Type:** Academic Institution  
**Organization Location:** Chicago

**Partner's Contribution to the Project:**  
Collaborative Research  
Personnel Exchanges

**More Detail on Partner and Contribution:** Yarrow Axford at Northwestern participated in field work and is analyzing chironomids from the cores.

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### **University of Cincinnati**

**Organization Type:** Academic Institution  
**Organization Location:** Cincinnati, Ohio

**Partner's Contribution to the Project:**  
In-Kind Support  
Collaborative Research

**More Detail on Partner and Contribution:** This is a collaborative proposal. We worked very closely in every aspect of this project with people from Cincinnati.

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### **What other collaborators or contacts have been involved?**

NO

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## **Impacts**

### **What is the impact on the development of the principal discipline(s) of the project?**



Our work has improved substantially knowledge of the Holocene glacial history of the East Greenland. We produced the first records to track glacier fluctuations continuously in the Scoresby Sund region. Our work showed that the Little Ice Age was the largest event of the Holocene and that ice extent was smaller than at present for most of the Holocene. Glaciers have not yet receded within their pre-Little Ice Age limits.

### **What is the impact on other disciplines?**

Our work has implications for understanding the causes of abrupt climate change and for placing present-day changes in the Arctic in a longer-term context. For example, the large collapse from the Little Ice Age limit - which is ongoing today - although spectacular - has not yet exceeded Holocene norms. In addition, an understanding of how the glaciers behaved during past warm periods may afford insight into the likely future of Greenland ice masses.

Our work also demonstrated that the start of the Little Ice Age - as recorded by glaciers in East Greenland - was earlier than that suggested by the Greenland ice cores. Recognition of this differences in timing of glaciation onset between climate proxies may afford important information on the mechanism at the root of Holocene climate change. It also leads one to be cautious when using only one proxy to reconstruct climate.

### **What is the impact on the development of human resources?**

This work has resulted in the training of numerous graduate students as well as a new assistant professor. It also has resulted in international collaboration.

### **What is the impact on physical resources that form infrastructure?**

Nothing to report.

### **What is the impact on institutional resources that form infrastructure?**

Nothing to report.

### **What is the impact on information resources that form infrastructure?**

Nothing to report.

### **What is the impact on technology transfer?**

Nothing to report.

### **What is the impact on society beyond science and technology?**

Holocene climate change has and will continue to have a profound impact on societal development and stability. An understanding of why climate changes, how fast it can change, and the global ramifications of local changes can help societies prepare better for the future.

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## **Changes/Problems**

### **Changes in approach and reason for change**

Nothing to report.

### **Actual or Anticipated problems or delays and actions or plans to resolve them**

Nothing to report.

### **Changes that have a significant impact on expenditures**

Nothing to report.

### **Significant changes in use or care of human subjects**

Nothing to report.

### **Significant changes in use or care of vertebrate animals**

Nothing to report.

**Significant changes in use or care of biohazards**

Nothing to report.

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**Special Requirements**

**Responses to any special reporting requirements specified in the award terms and conditions, as well as any award specific reporting requirements.**

Nothing to report.