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Putting the West Antarctic Ice Sheet into Context

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Preview of Award 1042728 - Final Project Report

[Cover](#) |
[Accomplishments](#) |
[Products](#) |
[Participants/Organizations](#) |
[Impacts](#) |
[Changes/Problems](#)
[| Special Requirements](#)

Cover

Federal Agency and Organization Element to Which Report is Submitted:	4900
Federal Grant or Other Identifying Number Assigned by Agency:	1042728
Project Title:	Putting the West Antarctic Ice Sheet into context
PD/PI Name:	George H Denton, Principal Investigator Brenda L Hall, Co-Principal Investigator
Recipient Organization:	University of Maine
Project/Grant Period:	09/01/2011 - 08/31/2015
Reporting Period:	09/01/2014 - 08/31/2015
Submitting Official (if other than PD\PI):	Brenda L Hall Co-Principal Investigator
Submission Date:	09/14/2015
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	Brenda L Hall

Accomplishments

* What are the major goals of the project?

This project is designed to examine the former marine-based ice sheet in southern South America and use the history of this ice sheet to place the West Antarctic Ice Sheet (WAIS) in context. Another major aspect of the project is to reconstruct the climate conditions that have led to abrupt climate change in the high southern latitudes at the start of the last termination that would have impacted behavior of the WAIS. These factors include changes in sea-surface temperatures, movement of oceanic and atmospheric fronts, shifts in the westerly wind belt, and variations in sea-ice extent.

Our specific goals were as follows:

- 1) Reconstruct the timing of ice recession in southernmost South America, particularly in the Cordillera Darwin icefield.
- 2) Assess the climate conditions necessary to cause ice recession.
- 3) Compare the South American history to other Southern Hemisphere climate proxy records
- 4) Use the combined Southern Hemisphere records to isolate possible mechanisms for the cause of the Southern Hemisphere termination.
- 5) Relate WAIS behavior to Southern Hemisphere climate changes to assess the sensitivity of the ice sheet to large-scale climate changes.

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

Major Activities:

We carried out two seasons of field work, one on each side (north and south) of Cordillera Darwin. During this time, we mapped glacial deposits in several areas, including Bahia Pia, Beaver Mountain, Holanda, Bahia Ainsworth, Bahia Brooks, Bahia Inutil, and Caleta Le Che. We determined a chronology for these deposits using radiocarbon dates of sediment cores taken from peat bogs and from cosmogenic ages of glacial erratics. We used this chronology to reconstruct a history of ice behavior and compared this history to other Southern Hemisphere records of glacier activity, including that of the West Antarctic Ice Sheet. We also compared our glacial data with other proxies of climate change, including the WAIS Divide ice core temperature and carbon dioxide records.

We carried out activities that had broader impacts. Several graduate students and undergraduates were supported on this project and gained significant experience both in the field and laboratory. Data and photographs from this class have been used in undergraduate and graduate classes at the University of Maine and are posted on our website. Our work has been the subject of reporting by student journalists at the Medill School of Journalism and stories appeared on their website.

Specific Objectives:

We determined that the Cordillera Darwin ice field collapsed rapidly shortly after 18 ka. Both radiocarbon and cosmogenic isotope dates indicate that ice retreated from the LGM position back into the heart of the mountain range, at least to the late-glacial position, as early as 17.5 ka and likely earlier. Ice was within 800 m of the late Holocene position by 15 ka. This geologically instantaneous ice retreat reflects rapid warming characteristic of the start of the Southern Hemisphere termination.

Significant Results:

Moreover, the data suggest to us that most of the warming that accompanied the end of the ice age occurred within about 1000 years of the start of the termination. Such a rapid end to the ice age requires us to rethink hypotheses concerning the origin of terminations.

Our results from Cordillera Darwin differ significantly from those we have obtained in the Antarctic. While ice was collapsing in Cordillera Darwin, the Antarctic ice sheet was expanding to its maximum position of the last ice age. This difference suggests to us that the warming of the termination, rather than causing melting of

the Antarctic ice sheets, led to increased precipitation which promoted ice growth for a time.

Key outcomes or
Other achievements:

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

This work has led to the training and professional development of three graduate students and four undergraduates. These students have gained experience in field work and laboratory analyses, including preparation of radiocarbon and cosmogenic samples for dating and the creation of geologic maps. They also have received opportunities to present their work at professional meetings.

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

Our work has been presented at professional meetings and in publications.

Products

Books

Book Chapters

Conference Papers and Presentations

Putnam, A., Schaefer, J., Denton, G., Kaplan, M., *Koffman, T., Hall, B., Lowell, T., Barrell, D., Rowan, A., and Finkel, R. (2014). *Two pulses of warming and extensive glacier recession at Southern Hemisphere middle latitudes during Heinrich Stadials 1 and 0*. Geological Society of America Annual Meeting. Vancouver. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Putnam, A., Schaefer, J., Denton, G., Hall, B., Lowell, T., Porter, C., Barrell, D., Andersen, B., *Koffman, T., *Lennon, J., *Rowan, A., Finkel, R., Rood, D., Schwartz, R., Vandergoes, M., Plummer, M., Brocklehurst, S., *Kelley, S., and *Ladig, K. (2013). *Warming and extensive glacier recession at Southern Hemisphere middle latitudes during Heinrich Stadial 1.* American Geophysical Union Fall Meeting, San Francisco, CA. Status = PUBLISHED; Acknowledgement of Federal Support = Yes

Inventions

Journals

Hall, B., Porter, C., Denton, G., Lowell, T., and Bromley, G. (2013). Collapse of Cordillera Darwin glaciers in southernmost South America during Heinrich Stadial 1.. *Quaternary Science Reviews*. 62 49. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI:

Licenses

Other Products

Databases.

Metadata for this project have been submitted to the Global Change Master Directory and can be found at:

http://gcmd.nasa.gov/getdif.htm?Cordillera_Darwin_Radiocarbon_Data

Other Publications

Patents

Technologies or Techniques

Thesis/Dissertations

Jennifer Lennon. *10Be exposure age chronology of the Tres Hermanos and Rosa Irene moraines near Bahia Inutil, Chilean Patagonia*. (2014). University of Maine. Acknowledgement of Federal Support = Yes

Websites

Current Research

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

This site provides updates on our current research projects, including the one funded by this grant.

Participants/Organizations

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Denton, George	PD/PI	2
Hall, Brenda	Co PD/PI	5
Lowell, Thomas	Faculty	2
Putnam, Aaron	Postdoctoral (scholar, fellow or other postdoctoral position)	2
Dowey, Colin	Graduate Student (research assistant)	4
King, Courtney	Graduate Student (research assistant)	1
Lennon, Jennifer	Graduate Student (research assistant)	12
Introne, Alexander	Research Experience for Undergraduates (REU) Participant	1
Mason, Zachary	Research Experience for Undergraduates (REU) Participant	0
Overturf, Kaj	Research Experience for Undergraduates (REU) Participant	1
Pelto, Jillian	Research Experience for Undergraduates (REU) Participant	1

Full details of individuals who have worked on the project:

George H Denton

Email: george.denton@umit.maine.edu

Most Senior Project Role: PD/PI

Nearest Person Month Worked: 2

Contribution to the Project: This person directed the overall project, including the field program, advised students, participated in field work, and contributed to publications and presentations.

Funding Support: Salary was supported by the University of Maine.

International Collaboration: Yes, Chile

International Travel: Yes, Chile - 0 years, 2 months, 0 days

Brenda L Hall

Email: BrendaH@Maine.edu

Most Senior Project Role: Co PD/PI

Nearest Person Month Worked: 5

Contribution to the Project: This person co-directed the project, organized and participated in the field work, directed the coring program, advised students, contributed to papers and presentations, and analyzed samples for radiocarbon and cosmogenic dating.

Funding Support: Salary was partially supported by NSF, the remainder came from the University of Maine.

International Collaboration: Yes, Chile

International Travel: Yes, Chile - 0 years, 2 months, 0 days

Thomas Lowell

Email: thomas.lowell@uc.edu

Most Senior Project Role: Faculty

Nearest Person Month Worked: 2

Contribution to the Project: This person participated in field work, analyzed satellite images, and helped mentor students.

Funding Support: Costs were covered by his home institution.

International Collaboration: Yes, Chile

International Travel: Yes, Chile - 0 years, 2 months, 0 days

Aaron Putnam

Email: aputnam@ideo.columbia.edu

Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)

Nearest Person Month Worked: 2

Contribution to the Project: This person participated in field work, contributed to presentations, and helped supervise and advise students.

Funding Support: Costs were covered by his home institution.

International Collaboration: Yes, Chile

International Travel: Yes, Chile - 0 years, 2 months, 0 days

Colin Dowey

Email: Colin.dowey@maine.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 4

Contribution to the Project: This person performed laboratory analyses.

Funding Support: This grant.

International Collaboration: No

International Travel: No

Courtney King

Email: courtney.king@maine.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 1

Contribution to the Project: This person performed laboratory analyses and maintained the project posts on the website.

Funding Support: This grant

International Collaboration: No

International Travel: No

Jennifer Lennon

Email: jennifer.lennon@maine.edu

Most Senior Project Role: Graduate Student (research assistant)

Nearest Person Month Worked: 12

Contribution to the Project: This person participated in field work, carried out laboratory analyses, created geologic maps, and wrote a thesis.

Funding Support: This grant.

International Collaboration: Yes, Chile

International Travel: Yes, Chile - 0 years, 1 months, 0 days

Alexander Introne

Email: alexander_introne@umit.maine.edu

Most Senior Project Role: Research Experience for Undergraduates (REU) Participant

Nearest Person Month Worked: 1

Contribution to the Project: This person participated in field work.

Funding Support: This grant.

International Collaboration: No

International Travel: Yes, Chile - 0 years, 1 months, 0 days

Year of schooling completed: Junior

Home Institution: University of Maine

Government fiscal year(s) was this REU participant supported: 2013

Zachary Mason**Email:** Zachary.mason@umit.maine.edu**Most Senior Project Role:** Research Experience for Undergraduates (REU) Participant**Nearest Person Month Worked:** 0**Contribution to the Project:** This person worked less than a person month, but contributed to laboratory analyses associated with this project.**Funding Support:** This grant.**International Collaboration:** No**International Travel:** No**Year of schooling completed:** Junior**Home Institution:** University of Maine**Government fiscal year(s) was this REU participant supported:** 2015

Kaj Overturf**Email:** kaj.overturf@maine.edu**Most Senior Project Role:** Research Experience for Undergraduates (REU) Participant**Nearest Person Month Worked:** 1**Contribution to the Project:** This person performed laboratory analyses.**Funding Support:** This grant.**International Collaboration:** No**International Travel:** No**Year of schooling completed:** Freshman**Home Institution:** University of Maine**Government fiscal year(s) was this REU participant supported:** 2015

Jillian Pelto**Email:** Jillian_Pelto@umit.maine.edu**Most Senior Project Role:** Research Experience for Undergraduates (REU) Participant**Nearest Person Month Worked:** 1**Contribution to the Project:** This person participated in laboratory analyses, particularly the characterization of the physical details of the sediment cores collected in this study.**Funding Support:** This grant.**International Collaboration:** No**International Travel:** No**Year of schooling completed:** Junior**Home Institution:** University of Maine**Government fiscal year(s) was this REU participant supported:** 2015, 2014

What other organizations have been involved as partners?

Name	Type of Partner Organization	Location
Lamont-Doherty Earth Observatory	Academic Institution	New York
University of Cincinnati	Academic Institution	Cincinnati, OH

Full details of organizations that have been involved as partners:

Lamont-Doherty Earth Observatory

Organization Type: Academic Institution

Organization Location: New York

Partner's Contribution to the Project:

Facilities

Personnel Exchanges

More Detail on Partner and Contribution: Some exposure-age samples collected during field work were analyzed at Lamont-Doherty Earth Observatory by graduate student Jennifer Lennon.

University of Cincinnati

Organization Type: Academic Institution

Organization Location: Cincinnati, OH

Partner's Contribution to the Project:

Collaborative Research

More Detail on Partner and Contribution: Personnel from the University of Cincinnati participated in the field work.

What other collaborators or contacts have been involved?

Nothing to report

Impacts

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

This work substantially improved our understanding of the history of Cordillera Darwin ice field, about which little had been known. This work also provided context for interpreting the history of the West Antarctic Ice Sheet. Despite the proximity of the two ice masses and their gross similarity (both largely marine-based), they show very different reaction to the warming that accompanied the last termination. This difference in behavior affords insight into the mechanisms driving ice retreat. For example, ice in Cordillera Darwin showed large-magnitude, rapid retreat at the start of the termination coeval with temperature rise. Because surface melting from rising air temperature was unimportant in the Antarctic, the warmth of the termination led to ice-sheet expansion from increased accumulation and an overall delay in deglaciation.

What is the impact on other disciplines?

Our work affords insight on the behavior of past and present ice masses in the Southern Hemisphere, which has bearing on past and future changes in sea level. Our work also affords important context for paleoclimate interpretations and for studies of plant and animal distributions in Cordillera Darwin.

What is the impact on the development of human resources?

This work supported a total of seven students, including three women. These students were afforded professional field and/or laboratory experience. This work also afforded field experience to a young professional (postdoc).

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?

The future behavior of the WAIS is of importance because of its projected effect on global sea level. Our work afforded important context for the behavior of the WAIS by providing insight into the factors that control its extent.

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.

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.

 RSR Award Detail

Research Spending & Results

Award Detail

Awardee:	UNIVERSITY OF MAINE SYSTEM
Doing Business As Name:	University of Maine
PD/PI:	George H Denton (207) 581-2190 george.denton@umit.maine.edu
Co-PD(s)/co-PI(s):	Brenda Hall
Award Date:	06/17/2011
Estimated Total Award Amount:	\$ 379,129
Funds Obligated to Date:	\$ 379,129 FY 2011=\$379,129
Start Date:	09/01/2011
End Date:	08/31/2015
Transaction Type:	Grant
Agency:	NSF
Awarding Agency Code:	4900
Funding Agency Code:	4900
CFDA Number:	47.050
Primary Program Source:	040100 NSF RESEARCH & RELATED ACTIVIT
Award Title or Description:	Putting the West Antarctic Ice Sheet into context
Federal Award ID Number:	1042728
DUNS ID:	186875787
Parent DUNS ID:	071750426
Program:	ANTARCTIC GLACIOLOGY
Program Officer:	Julie Palais (703) 292-8033 jpalais@nsf.gov

Awardee Location

Street:	5717 Corbett Hall
City:	ORONO
State:	ME
ZIP:	04469-5717
County:	Orono
Country:	US

Awardee Cong. District: 02

Primary Place of Performance

Organization Name: University of Maine

Street: 5717 Corbett Hall

City: ORONO

State: ME

ZIP: 04469-5717

County: Orono

Country: US

Cong. District: 02

Abstract at Time of Award

1042728/Denton

This award supports a project to develop new insights into the cause and pattern of events during the last glacial termination in South America and Antarctica. One emerging view is that a warming Southern Ocean (SO), driven by a chain of events initiated in the Northern Hemisphere (NH) and tied to the interhemispheric climate seesaw of the last termination, was the underlying mechanism that drove the West Antarctic ice sheet (WAIS) from its Late Glacial Maximum (LGM) position back to present-day grounding lines. This ocean thermal forcing would have impacted WAIS by accelerating basal melt rates on fringing floating ice shelves and tongues. The validity of such a proposition can be examined from detailed chronologies of ice retreat at a variety of middle to high latitude sites. From such chronologies, it can be determined whether or not the intervals of ice recession form a pattern that fits the timing of warming pulses known to have occurred in the SO during the termination. The intellectual merit of this project is that it will test the proposition that warming pulses in the SO, driven by NH stadials, are the key events that culminated in recession of WAIS to its present-day configuration, setting up the possibility of irreversible collapse. This test is based on placing into a global context the timing and structure of glacial recession along a transect from the southernmost Andes to the Ross Embayment. This project will examine the middle of the transect, by establishing the chronology of ice recession following the LGM in southernmost South America and on the northern Antarctic Peninsula. Because of the abundance of datable terrestrial organic material in association with glacial deposits the most rapid progress will be made by starting in southernmost South America. Specifically, cores will be collected from numerous bogs located between the LGM limit and present-day ice in Cordillera Darwin and on Isla Hoste, and use ^{14}C dates of basal organic remains to develop a chronology for ice recession. The broader impacts of this work include a commitment to education and outreach. This work will educate a graduate student and material from this grant will be used in college courses, as well as in presentations to elementary and middle schools and to senior communities. This proposal does not require field work in the Antarctic.

Publications Produced as a Result of this Research

Hall, Brenda L.; Porter, Charles T.; Denton, George H.; Lowell, Thomas V.; Bromley, Gordon R. M. "Extensive recession of Cordillera Darwin glaciers in southernmost South America during Heinrich Stadial 1" QUATERNARY SCIENCE REVIEWS, v.62, 2013, p.49-55

Hall, B., Porter, C., Denton, G., Lowell, T., and Bromley, G. "Collapse of Cordillera Darwin glaciers in southernmost South America during Heinrich Stadial 1." QUATERNARY SCIENCE REVIEWS, v.62, 2013, p.49

Project Outcomes Report

Disclaimer

This Project Outcomes Report for the General Public is displayed verbatim as submitted by the Principal Investigator (PI) for this award. Any opinions, findings, and conclusions or recommendations expressed in this Report are those of the PI and do not necessarily reflect the views of the National Science Foundation; NSF has not approved or endorsed its content.

This project examined a former marine-based ice sheet in Cordillera Darwin, southernmost South America and used the history of this ice to place the behavior of the West Antarctic Ice Sheet (WAIS) in context. Our specific goal was to reconstruct the timing of recession of the Cordillera Darwin icefield and to compare it to that of the WAIS to assess the sensitivity of the ice sheet to large-scale climate changes. We carried out two seasons of field work, mapping glacial deposits and developing a chronology of ice fluctuations using radiocarbon dates of sediment cores taken from peat bogs and from cosmogenic ages of glacial erratics. We determined that the Cordillera Darwin ice field collapsed rapidly from its

[Images \(1 of 2\)](#)

maximum extent to nearly the modern glacier positions shortly after 18 ka. This geologically instantaneous ice retreat reflects rapid warming characteristic of the end of the ice age and requires us to rethink hypotheses concerning ice-age cycles. Our results from Cordillera Darwin differ significantly from those we have obtained in the Antarctic.

This work substantially improved our understanding of the history of Cordillera Darwin ice field, about which little had been known. This work also provided context for interpreting the history of the West Antarctic Ice Sheet. Despite the proximity of the two ice masses and their gross similarity (both largely marine-based), they show very different reaction to the warming that accompanied the end of the ice age. This difference in behavior affords insight into the mechanisms driving ice retreat. For example, ice in Cordillera Darwin showed large-magnitude, rapid retreat at the same time as air temperature rose. Because surface melting from rising air temperature was unimportant in the Antarctic, the warmth led to ice-sheet expansion from increased accumulation and an overall delay in deglaciation.

We carried out activities that had broader impacts. Several graduate students and undergraduates were supported on this project and gained significant experience both in the field and laboratory. Data and photographs from this class have been used in undergraduate and graduate classes at the University of Maine and are posted on our website. Our work has been the subject of reporting by student journalists at the Medill School of Journalism and stories appeared on their website.

Last Modified: 09/14/2015

Modified by: Brenda L Hall

For specific questions or comments about this information including the NSF Project Outcomes Report, contact us.

