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POWRE: High-Resolution Chronology of Millennial-Scale Lake-Level Fluctuations in the Dry Valleys (Antarctica) From Uranium-Thorium and Radiocarbon Dating

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Principal Investigator: Hall, Brenda L.

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POWRE: High-Resolution Chronology of Millennial-Scale Lake-Level Fluctuations in the Dry Valleys (Antarctica) From Uranium-Thorium and Radiocarbon Dating

Project Participants

Senior Personnel

Name: Hall, Brenda

Worked for more than 160 Hours: Yes

Contribution to Project:

Learned U-Th chemistry and mass spectrometry for dating carbonates
 Collected carbonate samples for U-Th and 14C dating
 Collected water samples for U and 14C analyses
 Performed U-Th analyses, submitted 14C samples to AMS lab
 Interpreted results and wrote papers with Gideon Henderson
 Cored lake sediments
 Logged and interpreted sediment cores
 Collected lake ice for fabric and gas analysis
 Presented results in lectures at University of Maine, Oxford University, University of Waikato, Woods Hole Oceanographic Institution, University of Edinburgh

Name: Henderson, Gideon

Worked for more than 160 Hours: Yes

Contribution to Project:

Assisted PI in learning U-Th chemistry and mass spectrometry
 Collaborated in U-Th data interpretation
 Collaborated in writing up results
 Directed U water-chemistry research
 Supervised undergraduate student
 Sponsored PI during her extended stays at Oxford University and Lamont-Doherty Earth Observatory

Name: Hendy, Chris

Worked for more than 160 Hours: Yes

Contribution to Project:

Accompanied PI in the field
 Provided coring equipment and expertise
 Provided water sampling equipment and expertise
 Sponsored PI during her extended visit to the University of Waikato

Name: Lorrain, Reginald

Worked for more than 160 Hours: No

Contribution to Project:

Directing analysis of lake-ice core (fabric, gas, isotopes) for comparison with buried ice deposits associated with paleo-lake deposits in the Dry Valleys

Post-doc

Graduate Student

Undergraduate Student**Name:** Smith, Andrew**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Performed uranium analyses on water from Dry Valleys

Interpreted these data for senior project

Organizational Partners**Woods Hole Oceanographic Institution**

WHOI provided salary and office facilities for PI for fourteen months while working on project.

Oxford University

I collaborated with Dr. Gideon Henderson at Oxford University. The Department of Earth Sciences provided office facilities for me and appointed me Visiting Postdoctoral Scientist. I had use of Dr. Henderson's expertise, clean lab, chemicals, and TIMS machine for running U-Th samples. This past year, Dr. Henderson and I have been analyzing and interpreting data from U-Th sample runs and writing two papers regarding the results. Dr. Henderson is also supervising a 4th-year undergraduate student who is analyzing U isotopes in lake water from the Dry Valleys to aid in interpreting our U-Th results and in understanding the systematics of U isotopes in such an arid, polar environment.

Columbia University Lamont Doherty Earth Observatory

I collaborated with Dr. Gideon Henderson at LDEO before he moved to Oxford University. The Department of Geochemistry provided office facilities for me. I was appointed an External Postdoctoral Fellow at LDEO. I had access to the clean labs, TIMS machine, and XRD machine at LDEO. Together with Dr. Henderson, I began to run Antarctic U-Th samples.

University of Waikato

I collaborated with Dr. Chris Hendy at the University of Waikato. I had access to office space and lab facilities in the Department of Chemistry. I sampled cores from previous field seasons archived in Dr. Hendy's labs. We perfected and staged gear for the Antarctic field season. Dr. Hendy accompanied me in the field, where we cored lake sediments, collected lacustrine carbonates for dating, and took water samples for radiocarbon dating and uranium analysis.

Universit  Libre de Bruxelles

Regi Lorrain is directing fabric, gas, and isotope studies of a lake-ice core we obtained from Trough Lake. The core will be compared with buried ice deposits that are widely associated with paleolake deposits on the floors of the Dry Valleys.

Other Collaborators or Contacts

Dr. George Denton (University of Maine) and I have been collaborating on the chronology of Antarctic lakes. Dr. Karl Kreutz (WHOI, UMaine) and I have been working on comparison of the lake-level records with the Taylor Dome ice-core chemistry. I also have had contact with over a dozen other scientists concerning different aspects of this work.

Activities and Findings**Project Activities and Findings:**

The primary goal of this POWRE project was to enhance my education by

learning TIMS uranium-thorium dating and chemistry and then to apply this new knowledge to the problems of the radiocarbon reservoir effect in Antarctic lakes and of developing chronologies for past lake-level changes. A secondary goal was to learn lake-water chemistry and coring techniques in the field.

A major result of this research is that I have learned how to do TIMS U-Th dating, including sample selection, chemistry, mass spectrometry, trouble shooting, and data analysis. This knowledge was gained through intensive work periods at Lamont-Doherty Earth Observatory and Oxford University. I analyzed samples from the Antarctic lakes while learning the new skills. I now have over 40 dates, predominantly from carbonates. I also did a small amount of experimental work with gypsum and algae. Dr. Henderson and I are now in the process of writing up the results. The work carried out with Dr. Henderson has set the stage for ongoing collaboration in Antarctic research.

Another educational goal of the POWRE project was to learn field techniques for lake chemistry and coring. I spent a month and a half at the University of Waikato testing and perfecting coring equipment for the field season with Dr. Chris Hendy, and gaining insight into hydrology and water chemistry by assisting him and his students in field research on the North Island of New Zealand. Dr. Hendy accompanied me in the field in Antarctica, where we spent about a month coring lakes, mapping and collecting lacustrine carbonates, and collecting water samples for radiocarbon dating and uranium concentrations.

Other research and educational activities include the undertaking of a senior project by Andrew Smith, an undergraduate at Oxford University. He is carrying out U analyses on water samples collected from Dry Valleys lakes during 1999-2000. His results will aid in our interpretation of U/Th isotope data and will yield information concerning U-series systematics in a hyperarid polar environment. In addition to his work, Prof. Regi Lorrain of the Universit e Libre de Bruxelles is analyzing the fabric, gas content, and isotopes of a lake-ice core for comparison with buried ice associated with paleo-lake sediments in the Dry Valleys.

Project Training and Development:

One major finding is that the new U/Th and ^{14}C dates show conclusively that there is a reservoir effect in lake-bottom sediments at least in some lakes. U-Th and ^{14}C dates of carbonates (and associated algae) were offset by as much as 3600 calendar years at Lake Vida. The results suggest a lake-level lowering event about 9500 calendar years ago, accompanied by a massive algal bloom. The reason for such high productivity at that time is not known and may be an avenue for investigation. This event was apparently unique and may represent a fundamental change in the hydrology of the Dry Valleys lake systems from the glacial to interglacial period.

The past reservoir effect at Lake Vida is believed to result from lack of aeration of bottom waters, probably due to a perennial ice cover and/or stratification. Moreover, we are exploring the possibility that it may be possible to use the magnitude of the reservoir effect in some lakes to identify prior lake-level decreases. We also dated a sample from a moraine laid down in Glacial Lake Trowbridge (Miers Valley) at the grounding line of the Ross Sea ice sheet. This sample yielded a huge reservoir effect of about 18,000 years. The reason for this offset (to my knowledge, the largest ever reported for Antarctica) probably is the proximity of the sample location to Ross Sea ice sheet meltwater which must have contained old

CO₂. This result suggests that caution is needed when dating material from ice-marginal positions.

Water samples were collected from different depths in several proglacial lakes in order to understand the magnitudes and causes of the present-day reservoir effects. Our priority was Trough Lake (Pyramid Trough), which is a large proglacial lake and the best analog for the lakes that existed at the LGM. Our data indicate a reservoir effect of about 1500-2000 years for lake water - even at the lake bottom (85 m depth) adjacent to the grounding line - and an age of zero for meltwater entering the lake. These data indicate that the lake-bottom reservoir effect is not likely to exceed a couple thousand years, except perhaps in extreme situations. Moreover, they support a critical conclusion of Doran et al. (1999), that meltwater streams entering lakes (and thus algae living in those streams) yield modern ages.

One major goal was to learn how to operate coring equipment and to collect cores of lake sediment. This work was carried out primarily on Lake Fryxell, from whence we obtained four sediment cores, ranging from 1-1.75 m in length. These cores, which are currently being analyzed, show large sections of rhythmically bedded, varve-like layers, as well as thick sections of layered carbonates. These cores suggest great promise for future work to look at water-level changes, especially since there is so much carbonate, which is useful for chronologic and stable isotope purposes.

Research Training:

This project provided invaluable research experience for the PI to learn a new skill. I had never done U-Th dating (or even thermal ionization mass spectrometry or geochemistry) before. I now have the ability and confidence to carry out TIMS U-Th dating on my own. I can do U-Th geochemistry in the lab and run a mass spectrometer. As Dr. Henderson was setting up his lab when I arrived in Oxford, I also gained some experience and knowledge in equipping a clean lab for U-Th geochemistry. The University of Waikato (where I spent last fall) is in the early stages of planning a U-Th clean lab and my advice was solicited and I participated in planning meetings. I also am party to an effort at the University of Maine to acquire a new clean lab and ICP-MS. An opportunity to learn a new skill such as this in a completely different field (I am a glacial geologist) is rare, particularly at this stage in my career. I also gained other skills, such as experience in lacustrine water chemistry and methods of lake sediment coring.

This research also provided opportunities for students. An undergraduate (Andrew Smith) is currently finishing up his senior project on U isotopes of Dry Valleys lake water. The lake cores and carbonates collected also afford other student learning opportunities. One student will begin isotopic analyses of the carbonates next fall as part of a directed study.

Outreach Activities:

I have assisted students with science fair projects related to Antarctica. I also have answered questions about climate change for a student taking the NY Board of Regents high school exit exam. I have submitted information to the Glacier Project at the American Museum of Natural History. I have visited elementary schools to talk about Antarctica. I spoke at the Earth System Science Teacher Workshop at the University of Maine.

Journal Publications

- Brenda L. Hall, George H. Denton, Bret Overturf, "Glacial Lake Wright, a high-level Antarctic lake during the LGM and early Holocene", *Antarctic Science*, p. , vol. 13, (2001).) Accepted
- B.L. Hall and G.M. Henderson, "²³⁴U/²³⁰Th dates of lacustrine carbonates at Lake Vida: Implications for the radiocarbon reservoir effect", *Antarctic Journal of the United States*, p. , vol. , (2000).) Accepted
- E. Domack, B. Hall, J. Hayes, "Accurate Antarctic dating techniques sought by Quaternary community", *EOS*, p. 591, vol. 80(49), (1999).) Published
- B.L. Hall and G.M. Henderson, "Use of TIMS Uranium-Thorium Dating to Determine Past Reservoir Effects in Lakes: Examples from Antarctica", *Earth and Planetary Science Letters*, p. , vol. , () For submission in near future

Books or Other One-time Publications

Web/Internet Sites

URL(s):

Description:

Other Specific Products

Contributions

Contributions within Discipline:

The new U-Th dates indicate that there is and has been a reservoir effect for lake-bottom carbonates and associated algae in some Dry Valleys lakes. This lake-bottom reservoir effect has been suspected before and has been shown to occur in some modern lakes, but never has been quantified for the old lake deposits in the Dry Valleys. The new data show that there is an offset of about 3600 calendar years between radiocarbon dates and U-Th dates of the same carbonates adjacent to Lake Vida. This offset is important for understanding the chronological significance of lake-bottom deposits that have been dated elsewhere in the valleys and used for understanding glacial history. This work suggests that dates of lake-bottom deposits in the Dry Valleys should be considered maximum ages only, unless they can be shown to be accurate by some other means. These new data do not affect the dates of deltas in the Dry Valleys which have recently been shown to be free of a reservoir effect by Doran et al. (1999). The work carried out under this project has suggested several new avenues of investigation, which may afford clues about depth and stratification variations in the reservoir effect within the past lakes. Although still under development, we are exploring a way in which the magnitude of the reservoir effect in certain lakes can be used to infer past hydrologic changes. Another major finding is that TIMS U-Th dating can be used with good success to date lacustrine carbonates in Antarctica. This method will allow us to extend our chronology back in time, beyond the range of radiocarbon dating.

Contributions to Other Disciplines:

As mentioned in the previous section, the documentation of the lake-bottom reservoir effect at Lake Vida indicates that dates of lake-bottom sediments in the Dry Valleys should be considered only maximum ages, unless otherwise proven. Dates of deltas, in conjunction

with dates of lake-bottom sediments, have been used commonly in the Dry Valleys to develop glacial chronologies. Although those chronologies based solely on data from deltas remain unaltered, those based on lake-bottom algae may need to be shifted forward in time. The date from the moraine at Glacial Lake Trowbridge, which showed an offset of about 18,000 years illustrates the caution needed when interpreting radiocarbon dates from ice-marginal positions. This bears not only on Antarctic work, but on glacial geochronology worldwide.

One other interesting aspect of this work is that it documents a massive algal bloom in Lake Vida about 9500 calendar years ago. The carbonates dated in this study formed as a result of this algal bloom. The reason for such high productivity is unknown, but it appears to have been a unique event. This event may be of interest to the biologists, particularly the McMurdo LTER, working on these lakes.

Contributions to Human Resource Development:

This project has resulted in a significant increase in the P.I.'s knowledge of U-Th dating, specifically, and geochemistry and mass spectrometry in general. The P.I. is now capable of working independently with such samples (outlined earlier). This work has also led to additional collaborations including work with Drs. S. Colman, J. Bischoff, and C. Oviatt on samples from the Great Salt Lake, and work with Dr. G. Henderson on U-Pb chemistry of carbonates and Ra/Ba dates of Antarctic shells. Future research with Dr. C. Hendy and Dr. G. Henderson on lake sediments also is planned.

This project has contributed to the scientific development of students. Andrew Smith, an undergraduate is doing his senior project on the U-chemistry of Antarctic lake waters collected during this project.

Contributions to Science and Technology Infrastructure:

Database of U-Th dates registered in the Antarctic Master Directory (<http://www-nsidc.colorado.edu/NSF/NADCC>) under the title 'Lake Vida Uranium/Thorium Dates'

Beyond Science and Engineering:

The underlying goal behind all of this research is to understand the causes of abrupt climate change. If we ever attain this goal, it will have a direct impact on the public by affording us some knowledge of the behavior of our climate system and thereby increase our predictive capacities.

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