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Collaborative Research: Millennial-Scale Fluctuations of Dry Valleys Lakes: Implications for Regional Climate Variability and the Interhemispheric (a)Synchrony of Climate Change

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Principal Investigator: Hall, Brenda L. **Award ID:** 0124014

Organization: University of Maine

Title:

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Project Participants

Senior Personnel

Name: Hall, Brenda

Worked for more than 160 Hours: Yes

Contribution to Project:

Name: Hendy, Chris

Worked for more than 160 Hours: Yes

Contribution to Project:

Chris Hendy is the PI of the closely linked New Zealand project (we consider ourselves one group). Dr. Hendy is involved in all aspects of this project. His field logistics were supported, in part, by the NSF.

Name: Spaulding, Sarah

Worked for more than 160 Hours: Yes

Contribution to Project:

Sarah has been analyzing diatom samples in the cores. The analyses are funded by the grant.

Name: Fountain, Andrew

Worked for more than 160 Hours: Yes

Contribution to Project:

On a subcontract to this grant, Andrew has been modelling the interaction between lake level and climate in the Dry Valleys.

Name: Berger, Glenn

Worked for more than 160 Hours: Yes

Contribution to Project:

Glenn is a Co-PI and is starting to analyze the cores for OSL. He is funded through a collaborative proposal.

Name: Henderson, Gideon

Worked for more than 160 Hours: Yes

Contribution to Project:

Gideon is helping to analyze and interpret samples from the cores for U/Th dating. The dates are funded by the grant.

Post-doc

Graduate Student

Name: Whittaker, Thomas

Worked for more than 160 Hours: Yes

Contribution to Project:

Tom is a graduate student on the project. He is supported by funds from the grant and will carry out part of the research as his M.S. thesis. He participated in the 2002/03 field season.

Name: Birkel, Sean

Worked for more than 160 Hours: Yes

Contribution to Project:

Sean served as a field assistant on this project. He was supported during this time by project funds.

Name: Croall, Jacob

Worked for more than 160 Hours: Yes

Contribution to Project:

Jake is a graduate student on this project and participated in the field work. Part of the project will form his M.S. thesis. His field logistics were supported, in part, by the NSF.

Name: Milicich, Sarah

Worked for more than 160 Hours: Yes

Contribution to Project:

Sarah was a graduate student on this project. Part of the field work will form the basis of her M.S. thesis. Her field logistics were supported, in part, by the NSF.

Name: Vogan, Nathan

Worked for more than 160 Hours: Yes

Contribution to Project:

Nathan analysed one of the cores from Lake Fryxell, performing grain-size and organic content measurements.

Name: Putnam, Aaron

Worked for more than 160 Hours: Yes

Contribution to Project:

Aaron worked on diatom analyses in the lake cores for one academic year.

Name: Garhart, Kimberly

Worked for more than 160 Hours: Yes

Contribution to Project:

Kim is analyzing Lake Vanda cores for her M.S. thesis.

Name: Ebnet, Amy

Worked for more than 160 Hours: Yes

Contribution to Project:

Amy was funded by the subcontract to Portland State University and wrote a thesis related to this project.

Name: Ebnet, Jon

Worked for more than 160 Hours: Yes

Contribution to Project:

Jon also was at Portland State University and wrote a thesis related to the project.

Undergraduate Student

Name: Hawkins, Amber

Worked for more than 160 Hours: Yes

Contribution to Project:

Amber was an undergraduate assistant in the field. She was funded through this grant.

Name: Schlosser, Aaron

Worked for more than 160 Hours: Yes

Contribution to Project:

Aaron served as an undergraduate field assistant on the project. He was supported by project funds.

Name: Faloon, Katrina

Worked for more than 160 Hours: Yes

Contribution to Project:

Katie was an integral member of the field team and worked for a year
in the laboratory on the mineralogy and sedimentology of the cores.

Name: Roy, Alex

Worked for more than 160 Hours: Yes

Contribution to Project:
Alex was an integral member of the field team and assisted with planning for the field season and has worked in the laboratory part time since his return.

Name: Hofstee, Erica

Worked for more than 160 Hours: Yes

Contribution to Project:
Erica was an integral member of the field team. She also helped with planning for the field season.

Name: Essig, Megan

Worked for more than 160 Hours: Yes

Contribution to Project:
Megan performed grain size, loss-on-ignition, carbonate content, and mineralogic analyses on lake cores for two academic years.

Name: Chase, Brenda

Worked for more than 160 Hours: Yes

Contribution to Project:
Brenda performed grain size, loss-on-ignition, carbonate content, and diatom analyses on lake cores for one summer.

Name: Smith, Andrew

Worked for more than 160 Hours: Yes

Contribution to Project:
Andrew analysed the uranium content of lake and stream waters for his 4th-year project (equivalent to M.S.) at Oxford University.

Technician, Programmer

Other Participant

Research Experience for Undergraduates

Name: Doughty, Alice

Worked for more than 160 Hours: Yes

Contribution to Project:
Alice performed grain size, loss-on-ignition, carbonate content, and diatom analyses on lake cores for two academic years and one summer.

Organizational Partners

University of Nevada Desert Research Institute
I am collaborating with Dr. Glenn Berger, who is providing OSL dates through a collaborative proposal.

University of Colorado at Boulder
I am collaborating with Dr. Sarah Spaulding, who is providing diatom analyses.

Portland State University
I am collaborating with Dr. Andrew Fountain, who is funded through a subcontract to model the lake hydrology.

Oxford University
I am collaborating with Dr. Gideon Henderson at Oxford University on the U/Th dating of the cores. Dr. Henderson has hosted me several times at Oxford, where I have worked in his lab on the samples.

University of Waikato

This is a close, collaborative effort with Dr. Chris Hendy at the University of Waikato. Both of us are involved in all aspects of the project. We both are involved in supervising and advising each others students. Two of the graduate students on this project are from the University of Waikato. Dr. Hendy obtained support from Antarctica New Zealand and the University Grants Committee in support of our joint project.

Columbia University Lamont Doherty Earth Observatory

A Ph.D. student at Lamont (Susan Zimmerman) has been conducting a pilot study to see if paleointensity data can be used to date our cores.

Other Collaborators or Contacts

The information gained in this project is of use to other researchers, particularly biologists and neotectonics researchers. We have had many informal contacts through email and at meetings regarding lake history and its relationship to biological communities. We are also providing information to a graduate student of Terry Wilson's who is looking at neotectonism and tilt of lake shorelines.

Activities and Findings

Research and Education Activities:

During 2002/2003 and 2003/2004, we spent mid-December through early February in the field collecting sediment cores from the bottoms of Lakes Fryxell, Vanda, Bonney (East Lobe), and Joyce. We also made reconnaissance trips to the Convoy Range where we discovered evidence for past large proglacial lakes similar to those in the Dry Valleys. . Altogether, more than 35 cores were obtained, including one more than 8 m in length (more than tripling the depth that had been reached previously). We developed new techniques for coring, allowing us to core through water depths in excess of 75 m.

Cores from Lake Fryxell, Bonney and Joyce have been largely analysed (although some diatom work is still proceeding). Most of the lab work is also complete for Lake Vanda (with the exception of diatoms), and will culminate with the completion of a graduate thesis on the lake this academic year. With other funds, we set up a diatom lab at the University of Maine and now have the capability to analyse our cores in much greater detail than previously proposed.

This work has resulted in tremendous educational and research experiences for students (see participant list). Fifteen students, both graduate and undergraduate, have participated in meaningful ways to this work. Those initially employed by this project as lab assistants have subsequently had other opportunities (both in Antarctica and elsewhere) as a result of their experience with this project. All of the undergraduate students (so far) have gone on to M.S. programs.

This project also included a TEA teacher, and productive interactions with her have lasted well beyond the lifespan of the field season.

Our work now is to publish the massive amount of data that we have acquired. The first papers emerged this year (Hendy and Hall; Henderson et al., Hall et al.). Two papers are in review (Whittaker et al., Esposito et al.) and two papers will be submitted this month. Seven additional papers and one M.S. thesis are in progress. More papers are likely to follow.

Findings:

Observations indicate significant water-level and environmental changes over time at all of the lakes, as recorded by sedimentology, mineralogy, stable isotopes, and diatom assemblages. These data bear out our earlier interpretations based on lake shorelines and add a new continuity to the record. Our combined 14C and U/Th chronology is providing a timeframe for the cores (see below), although this has not been without challenges. Modelling work from this project and results developed elsewhere have led us to a better understanding of the relationship between lake level and climate. The most important conclusion is that the lakes have undergone periodic and systematic fluctuations on millennial timescales. Lake-level rise is a response to greater meltwater production, which results from increased absorbed solar radiation. Increased absorption is a function both of the incoming radiation, local albedo (a function of snowfall), and snowcover on the glaciers. We interpret high lake levels as occurring during times of low precipitation and albedo (and increased local absorption of solar radiation). We suspect that this dry environment may be a function of sea-ice expansion in the Southern Ocean, which increases distance to open water moisture sources, as well as the general dryness of the atmosphere during cool periods.

Lake Fryxell

We took 20 cores along two transects at Lake Fryxell from 4 to 20 m water depth. Our longest core is 8.5 m long (most are 2 m). Our data suggest that the longest core extends back ~50,000 years. As we did not reach refusal, this would be an ideal site to reoccupy at a future date to extend the record back potentially to Stage 6. All cores show the same stratigraphy.

The Holocene record shows a relatively stable Lake Fryxell, with only minor water-level changes. We do not see evidence of the postulated dry down of the lake 1200 years ago (namely, there is not any gypsum or halite in the cores, nor are there any hiatuses in deposition, all of which should be present had the lake dried up).

The lake cores also show quite clearly the transition from Glacial Lake Washburn to the present lake. In addition, during the Glacial Lake Washburn stage, there is evidence of lake fluctuations, which we believe may correlate with those recorded by shorelines and deltas. Onset of Glacial Lake Washburn - at least the deep-lake phase - occurred only about 20,000 years ago, later than we anticipated. This has implications for the timing of the Ross Sea Ice Sheet advance. The record prior to GLW (in the 20-50,000 year range) is that of a small lake, similar to that which exists at present. There is no evidence of a Stage 3 Ross Ice Sheet/Glacial Lake Washburn equivalent. Both magnetic susceptibility and grain-size variations show millennial-scale fluctuations, although the exact age of these fluctuations has not yet been determined. Uranium-thorium dates of carbonates afford information on at least three times when the lake became supersaturated and carbonate precipitation occurred. These represent times of low lake level.

Lake Bonney

Work at Lake Bonney focussed on the late Holocene. We cored both East and West Lobes, although our best data come from the West Lobe (East Lobe contains dihydrohalite, which melts instantly upon pulling the core up from the bottom). Detailed work has revealed a history of changing water levels at Lake Bonney, including three lowstands in the last 1500 years. These lowstands may correlate with cool periods in the Taylor Dome ice core, which is located just up the flowline from Lake Bonney. The chronology of Lake-Bonney sediments is well-constrained, with U/Th dates commonly having 2 sigma errors of less than 8 years.

Lake Joyce

We obtained only two cores from Lake Joyce (with more than a dozen attempts). Based on our work, we have determined that most of the lake bottom consists of well-sorted fine to medium sand, which enters the lake from a large fan-delta on the north shore. The consistency of the sediment meant that it did not stay in the core barrel when it was extracted. Nevertheless, we were able to obtain two cores. Both consist of coarse sand and gravel. One contained rare carbonate layers, which afford information on Holocene lake-level change.

Lake Vanda

Lake Vanda has a spectacular record. Unlike Fryxell, which shows rather muted variations, Vanda records large-scale changes. We believe this is the most sensitive of the large lakes in the Dry Valleys and should be the focus of a more detailed study. The lake is highly sensitive because it 1) is in a closed basin, 2) has negligible precipitation or groundwater input, and 3) has what is essentially an on/off switch - the Onyx River. During years of high flow, the lake rises rapidly. During times of low or no flow (some years the river does not flow), the lake drops quickly. Flow of the Onyx River is controlled almost entirely by climate over the Wilson Piedmont Glacier.

The Lake Vanda work is still underway, but again indicates large-scale, repeated, cyclical changes in water level, both on a millennial timescale and possibly centennial. Because of its geographic setting and very simple hydrology, the Lake Vanda record has the potential to be the best of all the Dry Valleys lakes. Our present thinking is that the changes are driven by solar radiation absorption - possibly a combination of solar variability and cloudiness.

Another interesting finding concerns the lake-bottom radiocarbon reservoir effect in the Dry Valleys. We have now documented past lake-bottom reservoir effects in Lake Bonney as great as 15,000 years. These great ages tell us something about the history of these lakes, for they cannot have lost their ice cover in that time (loss of ice cover would result in wind-driven mixing and equilibration of 14C with the atmosphere). Lake Fryxell reservoir effects seem to be less, although still 4000-5000 years during the late-glacial period. Vanda is only 1200 years, consistent with the fact that the lake nearly dried up and lost its ice cover at that time.

As mentioned above, we made a reconnaissance visit to the Convoy Range and found evidence in several places of high paleolakes, indicating that the phenomenon is not limited to the Dry Valleys.

Finally, one component of our work (as a subcontract to A. Fountain) was to model the hydrology and paleoclimate associated with the lakes. The modelling work on paleolakes has followed two paths. First, a statistical model of water runoff from glaciers has been developed. Essentially, the model uses a statistical relation between air temperature and ice melt, a method common to hydrological studies in alpine environments. It is particularly apt for this proposal because we have only a vague understanding of temperatures in the distant past and essentially no information on other important variables, such as wind, snowfall, etc... This model was developed for current glaciers and is now

being adapted for the paleoglacier conditions.

The second approach has been to employ a detailed energy balance model to explore the range of meteorological conditions conducive to melt production other than simply temperature. Because the conditions in the Dry Valleys are typically below freezing in summer, small changes in the energy flux by a variety of means can change melt production, irrespective of temperature. This work is in the final stages.

Training and Development:

Each field experience provides many opportunities to gain experience and to use research and teaching skills, even for senior members. Six graduate students used or are currently using parts of this project for their M.S. theses. Three other graduate students are carrying out paleoclimate projects which benefitted from the knowledge gained by working on this project. Nine undergraduate students also gained valuable research experience, one as an REU student. This experience has already led to one undergraduate gaining a chance to return to the Antarctic for a M.S. thesis with a different group. All of the undergraduate students so far have gone on to M.S. projects. Finally, our teacher (2002/2003)also learned how research is conducted in the Antarctic and came away with lots of information to use in classroom situations. She has maintained close contact with our group since her return to the US.

Outreach Activities:

All of us try to participate in outreach activities. Within the time frame of this project, I have visited more than a dozen elementary school classrooms to talk about Antarctica and climate change Tom Whittaker, Amber Hawkins, and Katie Faloon have visited other classrooms. Mary Ann DeMello (teacher)has given more than 25 presentations to schools and community groups, as well as more than 20 interviews.

Journal Publications

Hall, B.L., Hendy, C.H., and Denton, G.H., "Chronology of proglacial and lateral lakes in the Dry Valleys, Antarctica", INQUA Congress Abstracts, Reno, NV, p. 0, vol. , (2003). Published

Hall, B.L., Denton, G.H., and Overturf, B., "Evidence for millennial-scale fluctuations of Dry Valleys lakes", Geological Society of America Abstracts with Programs, National Meeting, Seattle, WA, p. 464, vol. , (2003). Published

Whittaker, T.E., Hall, B.L., Hendy, C.H., Henderson, G.M., Spaulding, S.A., Berger, G.W., "Recent and abrupt variations in depositional environment at Lake Fryxell, Antarctica", Geological Society of America Abstracts with Programs, National Meeting, Seattle, WA, p. x, vol. 36, (2004). Published

Hall, B.L., Hendy, C.H., and Denton, G.H.,, "Lake-ice conveyor deposits: Their geomorphology, sedimentology, and importance in reconstructing the glacial history of Antarctica", Geomorphology, p. 143-156, vol. 75, (2006). Published

Henderson, G.M., Hall, B.L., *Smith, A., and *Robinson, L.F.,, "Control on (234U/238U) in lake water: A study in the Dry Valleys of Antarctica", Chemical Geology, p. 298-308, vol. 226, (2006). Published

Hendy, C.H., and Hall, B.L., "The radiocarbon reservoir effect in proglacial lakes: Examples from Antarctica", Earth and Planetary Science Letters, p. 413-421, vol. 241, (2006). Published

Whittaker, T., Hall, B., Hendy, C., Henderson, G., Spaulding, S., and Berger, G., "Recent and abrupt variations in depositional environment in Lake Fryxell, Dry Valleys, Antarctica", GSA Abstracts with Programs, National Meeting, Seattle, WA, p. 414, vol. x, (2003). Published

Hall, B.L., " Chronology of proglacial and lateral lakes in the Dry Valleys", INQUA Congress Abstracts, Reno, NV, p. x, vol. , (2003). Published

Whittaker, T., and Hall, B., "Surface-level changes at Lake Fryxell, Taylor Valley, from aerial photographs", Antarctic Science, p. , vol. , ( ). Submitted

Whittaker, T., "Lake-level flucuations in the Fryxell Basin, Eastern Taylor Valley", M.S. Thesis, University of Maine, p. 227p, vol. , (2004). Published

Croall, J.G., "Late Holocene cool climate episodes, recorded in Lake Bonney, an Antarctic amplifier lake", M.S. Thesis, University of Waikato, p. 177p, vol. , (2005). Published

Millicich, S., "Origin of paleo proglacial lake sediments in Taylor Valley, Antarctica", M.S. Thesis, University of Waikato, p. 180p, vol. , (2005). Published

Whittaker, T., Hall, B., Hendy, C., and Spaulding, S., "Holocene climate and water-level variations at Lake Fryxell, Antarctica", The Holocene, p. , vol. , ( ). For submission this month

Hall, B.L., Denton, G.H., Hendy, C.H. Overturf, B., Fountain, A., Whittaker, T., and Garhart, K., "Millennial-scale lake-level changes suggest in-phase climate between Antarctica and New Zealand during the LGM", Nature, p. , vol. , ( ). To be submitted later this month.

Esposito, R., Spaulding, S., Lubinski, D., McKnight, D., Hall, B., and Whittaker, T., "Antarctic freshwater diatoms from the McMurdo Dry Valleys, Antarctica", Canadian Journal of Botany, p. , vol. , ( ). Submitted

Amy Ebnet, "A temperature-index model of melt water in Taylor Valley, McMurdo Dry Valleys, Antarctica.", M.S. Thesis, Portland State University., p. 1, vol. , (2006). Published

Jon Ebnet, "Subsurface melting on the glaciers of the McMurdo Dry Valleys", M.S. Thesis, Portland State University, p. 1, vol. , (2006). Published

Books or Other One-time Publications

Web/Internet Site

URL(s):

http://gcmd.nasa.gov/getdif.htm?Dry Valleys Lake Cores

Description:

Metadata are available on the GCMD website and can be viewed at the above URL.

Other Specific Products

Contributions

Contributions within Discipline:

This project shows that there have been marked environmental changes in the Dry Valleys lakes. These changes occur on a millennial and perhaps even centennial timescale and probably are related to variations in aborbed solar radiation. This record has strong potential to provide a detailed record of climate change in the Antarctic over at least the last 50,000 years.

Contributions to Other Disciplines:

The results will have implications for the broader field of climate change, including information on the causes of abrupt climate change and possibly the nature of Termination 1.

In addition, our data have contributed to other projects in the Dry Valleys. Information on the former lake levels has been of interest to biologists working with the LTER. In addition, we are providing data and information to a student at Ohio State who is calculating neotectonic change in the Dry Valleys using lake shorelines.

Contributions to Human Resource Development:

This project supported nine graduate students (through a combination of stipends, student employment, and logistical support). Six of these students have completed or will shortly complete graduate theses. It also provided research experiences for nine undergraduates (one on an REU supplement). In addition, a teacher participated with our group as a TEA and maintains close contact with all of us.

This project further strengthened collaborative ties among a number of groups, particularly the University of Maine, University of Waikato, University of Oxford, and the University of Colorado/USGS. This close collaboration has allowed the students access to other institutions and expertise. One student from the University of Maine now holds a fully funded fellowship at the University of Waikato for his Ph.D. (a direct result of this project). Such a move also seems likely for at least one more of the students in our group.

Contributions to Resources for Research and Education:

The TEA with our group has developed educational resources for teachers, including lesson plans and lists of key websites. These are available on the TEA website.

Our work also has contributed data to the new Antarctic diatom database (http://huey.colorado.edu/diatoms/about/database.php)

Contributions Beyond Science and Engineering:

Our work eventually may contribute to the public welfare by generating a better understanding of climate change and its impact on our society. We hope our educational efforts also will help the public to understand climate change.

Categories for which nothing is reported:

Any Book

Any Product