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Collaborative Research: Volcanic Records from the Siple and Taylor Dome Ice Cores, Antarctica

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Final Report for Period: 08/2000 - 03/2003**Submitted on:** 06/26/2003**Principal Investigator:** Zielinski, Gregory A.**Award ID:** 0096317**Organization:** University of Maine**Title:**
Collaborative Research: Volcanic Records from the Siple and Taylor Dome Ice Cores, Antarctica

Project Participants

Senior Personnel

Name: Zielinski, Gregory**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Post-doc

Name: Kurbatov, Andrei**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Responsibilities included the supervision of undergraduate students in the laboratory. These students assisted in ice processing, sample preparation, and sample filtering and scanning with the electron microscope. He also was involved in sample preparation and in microscope analyses and in the analysis of the volcanic acidity record for the Siple Dome core through the glaciochemical record. He was responsible for the presentation of results at professional meetings and for the writing of manuscripts submitted to professional journals. He also helped to guide visiting primary and secondary school children through the tephrochronology lab during their visits to the Institution.

Graduate Student

Name: Voisin, Daniel**Worked for more than 160 Hours:** Yes**Contribution to Project:**

Responsibilities included ice processing, sample preparation, sample filtering and scanning with the electron microscope to locate volcanic glass. Focus of the M.S. thesis was the volcanic record over the last 2000 years, including both the tephra record and the glaciochemical record. Analyzed samples with the scanning electron microscope and electron microprobe at New Mexico Tech, collaborating institution on this project. Presented results at professional meetings.

Undergraduate Student

Name: Francis, Ryan**Worked for more than 160 Hours:** No**Contribution to Project:**

Assisted in ice processing, sample preparation, sample filtering and the construction of slides for the scanning of samples with the electron microscope

Name: Jess, Lacey**Worked for more than 160 Hours:** No**Contribution to Project:**

Assisted in ice processing, sample preparation, sample filtering and the construction of slides for the scanning of samples with the electron microscope

Name: Stevens, Nathan**Worked for more than 160 Hours:** No**Contribution to Project:**

Assisted in ice processing, sample preparation, sample filtering and the construction of slides for the scanning of samples with the electron microscope

Name: Duan, Hui

Worked for more than 160 Hours: No

Contribution to Project:

Assisted in ice processing, sample preparation, sample filtering and the construction of slides for the scanning of samples with the electron microscope

Name: Smith, Jeremy

Worked for more than 160 Hours: No

Contribution to Project:

Assisted in ice processing, sample preparation, sample filtering and the construction of slides for the scanning of samples with the electron microscope

Name: Decesare, Teresa

Worked for more than 160 Hours: No

Contribution to Project:

Assisted in ice processing, sample preparation, sample filtering and the construction of slides for the scanning of samples with the electron microscope

Name: Houk, Stephen

Worked for more than 160 Hours: No

Contribution to Project:

Assisted in ice processing, sample preparation, sample filtering and the construction of slides for the scanning of samples with the electron microscope

Name: Corio, Chris

Worked for more than 160 Hours: No

Contribution to Project:

Assisted in ice processing, sample preparation, sample filtering and the construction of slides for the scanning of samples with the electron microscope

Name: Burns, Michael

Worked for more than 160 Hours: No

Contribution to Project:

Assisted in ice processing, sample preparation, sample filtering and the construction of slides for the scanning of samples with the electron microscope

Name: Parks, Yehse

Worked for more than 160 Hours: No

Contribution to Project:

Assisted in ice processing, sample preparation, sample filtering and the construction of slides for the scanning of samples with the electron microscope

Name: Dawson, Andrew

Worked for more than 160 Hours: No

Contribution to Project:

Assisted in ice processing, sample preparation, sample filtering and the construction of slides for the scanning of samples with the electron microscope

Name: Friedman, Daryl

Worked for more than 160 Hours: No

Contribution to Project:

Assisted in ice processing, sample preparation, sample filtering and the construction of slides for the scanning of samples with the electron microscope

Name: Story, Sarah

Worked for more than 160 Hours: No

Contribution to Project:

Assisted in ice processing, sample preparation, sample filtering and the construction of slides for the scanning of samples with the electron microscope

Technician, Programmer**Other Participant****Research Experience for Undergraduates****Organizational Partners****Other Collaborators or Contacts**

New Mexico Tech is a collaborating institute in this study, responsible for Scanning Electron Microscope and Electron Microprobe analysis of samples. Dr. Nelia Dunbar is the PI.

Activities and Findings**Research and Education Activities:**

The primary goals of this project were to, 1) evaluate the volcanic acidity record in the Siple Dome A (SDMA) and B (SDMB) ice cores and the Taylor Dome ice core available through the sulfate time series developed by the glaciochemistry group at the University of Maine, 2) undertake a continuous scan of the SDMA core and scan specific sections in the SDMB core to locate and analyze volcanic glass to determine glass composition, and thus source eruptions for the glass and potentially for volcanic sulfate found in the same layer, and 3) evaluate specific sections containing volcanic glass in the Taylor Dome ice core as noted by visible layers in that core. A specific use of these volcanic records is to identify products of known volcanic eruptions, where possible, thereby providing distinct time lines that are used in developing the depth-age scale for the individual ice cores. In addition, the evaluation of volcanic glass can help differentiate signals that originated from local (Antarctica) volcanic eruptions and those originating from mid-latitude southern hemisphere or equatorial eruptions.

Initial step in the process of locating volcanic glass was the melting of samples, filtering and the construction of glass slides for scanning on the petrologic microscope. The optical properties of volcanic glass allow easy identification of this material, thereby locating particular layers that contain glass shards. Samples were analyzed on the Cameca SX-100 Scanning Electron Microscope (SEM)/electron microprobe to determine the chemical composition of the glass found in the core. This included samples from layers with large sulfate spikes even if no glass was found in the scan with the petrologic microscope. It is possible that the glass shards were small enough that they were not easily recognized under the petrologic scope. The composition of glass found in the ice core was then matched to glass from volcanic eruptions known to have occurred around the age of the ice layer sampled or to the composition of products from volcanic centers that are likely to contribute material to this part of Antarctica. Such centers include those in Antarctica. This procedure involved all individuals given above as participating in the study (i.e., high school student, undergraduate students, a graduate student, and a post-doc research associate). Glaciochemistry of samples was determined with a Dionex ion chromatograph.

In addition to the papers published and those being prepared (as discussed in other parts of this report), the findings were presented at several meetings. These include meetings for the individual PIs and colleagues in the Siple Dome project and professional society meetings, such as the American Geophysical Union and a Chapman Conference on volcanism and climate. The paper presented at the Chapman Conference was invited.

Findings:

Several major findings have been achieved in this study, and there remains the probability of several more. The depth-age scale for the Siple Dome A (SDMA) core is still being adjusted, although the Holocene portion of the core is closer to a final product than is the pre-Holocene portion of the record. As the dating for the earlier part of the core becomes closer to being finalized, we may find several additional results from the volcanic record of the SDMA core. Similarly, the depth-age scale for the Holocene portion of the Taylor Dome core is presently being adjusted given the work of Hawley et al. (2003) and the findings from this study. Consequently, the long-term volcanic acidity record from that core is still being adjusted accordingly.

One of the most significant findings to date is the initial identification of several layers in both the Siple Dome A and B cores that contain

volcanic glass, most of which appear to have originated from Antarctica volcanism. As the chronology of Antarctica volcanism is not well known, the findings from this study have made a significant contribution to developing this chronology, particularly for the last few centuries. Unfortunately, the identification of glass shards from known eruptions that could be used to anchor the depth-age scale of the core did not occur. Perhaps the greatest disappointment along these lines was the inability to find any glass from the exceptionally explosive New Zealand Taupo eruption of about 181 in the Common Era. Many samples were filtered and analyzed in an attempt to find glass from that eruption. Once the pre-Holocene depth-age scale is better constrained, we will search for glass in samples that may contain a sulfate spike from the very large Taupo eruption that produced the voluminous Oruanui Ignimbrite.

Tephra was initially found in seven layers in the SDMA and SDMB cores and in three layers in the Taylor Dome core as detailed in Dunbar et al. (2003, in press). Since that initial work, many other sections containing volcanic glass have been found. These are presented later in this summary. As presented in the work by Dunbar et al., the number of shards in these sections varied by quite a bit (less than ten to many hundred) with most shards being in the 5-10 micron size range (Figure 1). Composition of all shards found were basanitic or trachytic. Most glass from the trachytic eruptions are thought to have originated from the Pleiades volcanic center, although the sample from the 36.7-37.2 m depth in the SDMA core appears to be more similar to the composition of material from Mt. Melbourne (Figure 2). This is the first time glass from these volcanic systems has been found in Antarctica ice cores. Basanitic eruptions typically have less variability in their composition, thus it is more difficult to identify the likely source volcanoes for the glass found in these cores. However, the most likely source for the basanitic material in the Siple and Taylor Dome cores appears to be from a cinder cone located between the Koettlitz Glacier and the Royal Society Range. The age of the layers that contain the glass analyzed generally fall between 1776 and 1805 of the Common Era. This is the first evidence for eruptions in Antarctica during this time interval.

Within the scope of this overall finding, the composition of the volcanic glass found at the 97.2-97.7 m depth in the Siple Dome B core, drilled about 150 m from the main Siple Dome Core (SDMA), was found to match glass in a visible layer at the 79.155 m depth in the Taylor Dome ice core (Figure 3). The glass appears to match the composition of material from the Pleiades volcanic system, Northern Victoria Land. Consequently, a significant stratigraphic marker has been identified in the Ross Sea region from the tephrochronology studies on the Siple Dome and Taylor Dome ice cores. The age of the layer in the SDMB core containing this glass is between 1286 and 1292 of the Common Era. In addition to finding this regional time-line, the age of the layer helps confirm the new dating in the upper section of the Taylor Dome ice core. Using vertical strain relationships, Hawley et al. (2003) developed a procedure for dating the firm section of ice cores. As such, the 79 m depth in the Taylor Dome core is suggested to be about 1320 ± 25 years of the Common Era, within the uncertainty of the age of the matching layer in the SDMB core. Interestingly, this glass was not found in the SDMA core.

Another significant finding from the tephrochronology work in this study is the identification of glass believed to have originated from South American volcanism during the Holocene. This is the first evidence of volcanic glass from that continent in an Antarctica ice core. The South American eruptions that appear to be recorded in the SDMA core are from the Chilean volcanoes of Cerro Hudson and Mt. Burney. Further support for a South American source is the fact that the composition of the glass found in these layers does not match that from any of the Antarctica volcanic centers. In addition, we know of no equatorial or New Zealand volcanoes with the same composition as the SDMA glass that erupted around the time represented by the ice core layers containing this glass. A manuscript describing these findings is in preparation in collaboration with volcanologists working on the record of volcanism in South America.

An initial evaluation of tephra in the pre-Holocene section of the core has identified glass that may correlate to an eruption that occurred from Mt. Berlin, Marie Byrd Land (Sample 8000, Figure 4). This correlation is problematic as of now, because the layer in the SDMA core containing this glass is dated to about 71,000 years ago, whereas the correlative Mt. Berlin eruption dates to about 120,000 years ago (Figure 5). Continued revisions of the depth-age scale for the pre-Holocene portion of the SDMA core is occurring, thus it is possible that this apparent discrepancy will be resolved.

In addition to the tephra records being developed, particularly for the SDMA core, the volcanic acidity record was constructed, thereby applying a multiparameter approach to development of the complete volcanic records from these ice cores. Both a robust spline and an empirical orthogonal function (EOF) analysis (Figure 6) were applied to the non sea-salt sulfate record for the SDMA core to develop the volcanic acidity record. These same techniques were used to develop the volcanic record for the GISP2 core, and the same record will be developed for the Taylor Dome core when the Holocene dating is finalized. A detailed list of the signals recorded over the last 2000 years in the Siple Dome core is given in Table 2 (Kurbatov et al, in preparation). A summary of the volcanic signals per century over the last 12,000 years is given in Table 3 from that same manuscript. Although there is evidence of the significance of local volcanism in this record from the tephra analyses undertaken, the possibility remains that hemispheric and global eruptions also are recorded by the sulfate spikes observed. Given the dating of the core at this time there are signals over the last 2000 years that may be linked to several known equatorial eruptions recorded in other Antarctica ice cores as well as in ice cores from Greenland. These include the historical eruptions of Mt. Parker (1641), Nevado del Ruiz (1595) and Kuwae (possibly in the 1450s). Interestingly, there does not appear to be a signal that may be easily linked to large eruptions such as Tambora (1815) and Huaynaputina (1600). This may be a factor of the error in the dating, but more likely it is because of the potential for biogenic sulfate masking some of the signals. The acidity record in the Siple Dome is not as 'clean' as those from sites such as

GISP2 in Greenland, South Pole and Dome C, Antarctica. The possibility of a greater stratospheric input to those other sites also may lead to more distinct signals from these large equatorial eruptions. Furthermore, the Siple Dome core appears to record many local eruptions from the recently active volcanoes just upwind in Northern Victoria Land. Nevertheless, the complete volcanic record developed from the SDMA core (acidity and tephra records) is important for deciphering the global record of volcanism and the potential atmospheric and climatic impact of those eruptions, especially because it may assist in differentiating local signals from equatorial signals in other Antarctica ice cores.

Training and Development:

The Post-Doc Research Associate developed his expertise in the use of ice cores in research on the volcanism-climate system. The graduate research assistant used these results as part of the requirements for the M.S. degree. Essential skills acquired were use of a petrologic microscope and the SEM/microprobe as well as the overall design of a research program for answering a specific scientific question. The undergraduate and high school laboratory assistants have learned basic procedures in scientific research and the importance of certain procedures critical to achieving specific research goals.

Outreach Activities:

As of this time, there have not been any significant opportunities for public outreach specifically related to this project. Discussions about volcanism and climate through public lectures have incorporated some general facts from the Siple Dome project in them. One such presentation was part of a public lecture series through the Chewonki Foundation, Wiscasset, ME.

Journal Publications

Hawley, R.L., E.D. Waddington, D.L. Morse, N.W., Dunbar and G.A. Zielinski, "Dating firn cores by vertical strain measurements", *Journal of Glaciology*, p. 401, vol. 48, (2000). Published

Dunbar, N.W., G.A. Zielinski, D. Voisin, "Tephra layers in the Siple Dome and Taylor Dome ice cores, Antarctica: Sources and correlations", *Journal of Geophysical Research*, p. , vol. , (2003). Accepted

Kurbatov, A.V., G.A. Zielinski, N.W. Dunbar, P.A. Mayewski, E.A. Meyerson and S.B. Sneed, "Holocene explosive volcanism recorded in the Siple Dome ice core, Antarctica", *Journal of Geophysical Research*, p. , vol. , (). about to be submitted

Books or Other One-time Publications

Web/Internet Site

URL(s):

www.ngdc.noaa.gov/paleo/icecore/antarctica/siple/siple.html

Description:

World Data Center for Paleoclimatology. This site contains data from all institutions involved in the Siple Dome project.

Other Specific Products

Contributions

Contributions within Discipline:

The primary contribution of this project within the discipline is the identification of previously unknown time periods when Antarctica volcanoes were more active, thus improving on the chronology of volcanism for that continent. Similarly, the identification of volcanic glass from South American eruptions will improve on the chronology of eruptions from that region, a chronology that has not been developed to a great extent given the remoteness of some of the volcanic centers in the middle and southern Andes. The overall volcanic acidity record will be used in combination with all other ice cores to estimate better the impact of previous volcanic eruptions. Foremost, the tephrochronology developed in these cores will be compared to the tephrochronology of the Law Dome Core over the last 700 years, as presently being developed, and to a core from South Pole that will be analyzed in conjunction with the Law Dome core. All of these studies will then provide a much refined chronology of Antarctica volcanism, and a means to differentiate the signals of local eruptions from equatorial eruptions that had an impact on global climate.

Contributions to Other Disciplines:

As of now, there are no significant contributions to disciplines other than to the volcanism-climate system and to volcanology in a general sense.

Contributions to Human Resource Development:

The experience gotten by Andrei Kurbatov throughout this study assisted in his promotion to Research Scientist from Post-doc Research Associate. He is responsible for the publication of manuscripts arising from the results of this study. The graduate research assistant learned many aspects about scientific research programs and improved his writing skills greatly from when he first began the study. Although he did not finish his M.S., he is a co-author on one of the papers published and on several abstracts presented at professional meetings. He was able to secure a position in the environmental profession given the experience he attained in this project. The 13 undergraduate and 1 high school laboratory assistants all were able to use their experience to increase their understanding of various scientific concepts.

Contributions to Resources for Research and Education:

There are no additional contributions to these fields, at this time, other than those already stated.

Contributions Beyond Science and Engineering:

There are no additional contributions to these fields, at this time, other than those already stated.

Categories for which nothing is reported:

Organizational Partners

Any Book

Any Product