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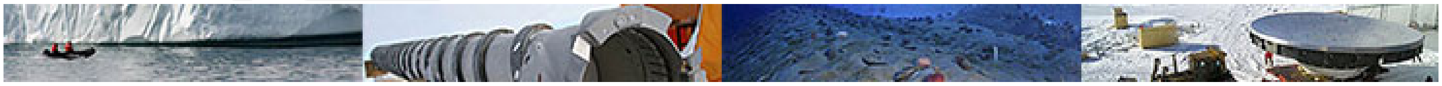
WHERE DISCOVERIES BEGIN



EARTH SCIENCES

Andrew Podoll and Kelly Gorz, undergraduate students under scientist Allan Ashworth, are working on their own project to map the morphologies and topography of their study area in the McMurdo Dry Valleys using GPS with centimeter accuracy. (*NSF/USAP photo by Peter Rejcek*)

Overview

Antarctica is not only one of the world's seven continents, it also comprises most of one of a dozen major crustal plates, accounting for about 9 percent of the Earth's continental (lithospheric) crust. Very little of this land is visible, however, covered as it is by the vast East Antarctic Ice Sheet and the smaller West Antarctic Ice Sheet. These ice sheets average some 3 kilometers deep and form a virtual vault; 90 percent of the ice on Earth is here. And it is heavy, depressing the crust beneath it some 600 meters. These physical characteristics, while not static, are current. Yet Antarctica is also a time machine, thanks to the sciences of geology and geophysics, powered by modern instruments and informed by the paradigm of plate tectonics/continental drift.

Geologists have found evidence that there was once a forested supercontinent, which they call Gondwanaland, in the Southern Hemisphere. Before the Earth's shifting plate movement began to break the continent up 150 million years ago, Antarctica was a core piece of this assembly; the land adjoining it has since become Africa, Madagascar, India, Australia, and South America. Though the antarctic plate has drifted south only about a centimeter a year, geologic time eventually yields cataclysmic results. The journey moved the antarctic plate into ever-colder, high-latitude climates, at a rate of about 4°C for each million years; eventually conditions changed dramatically, and Antarctica arrived at a near polar position. This astounding story—written in the language of rocks and fossils—is locked in beneath the ice and the sea, and in the bedrock below them both.

As the ice sheets developed, they assumed, through their interaction with oceanic and atmospheric circulation, what has become a key role in modulating global climate. As a bonus, the South Pole presents a strategic point to monitor the Earth's seismic activity. Antarctica is the highest continent on Earth (about 2,150 meters above sea level), with its fair share of mountains and volcanoes; thus, many generic questions of interest to Earth scientists worldwide also apply to this region. Some specific issues of interest to the Antarctic Earth Sciences Program include the following:

- exploring new horizons in geology with discoveries that range from new dinosaur fossils to meteorites from Mars;
- determining the tectonic evolution of Antarctica, from its central role in the breakup of the Gondwana supercontinent to the active deformation driving present-day volcanism, rifting, and orogenesis;
- observing unique geologic processes, such as the mysterious formation of subglacial lakes or the aeolian sculpting of the Dry Valleys, in action;
- determining Antarctica's crustal structure;
- determining how the dispersal of antarctic continental fragments may have affected the paleocirculation of the world's oceans, the evolution of life, and the global climate (from prehistoric times to the present);
- reconstructing a more detailed history of the ice sheets, identifying geological controls to ice-sheet behavior, and defining geological responses to the ice sheets on regional and global scales; and
- deciphering paleoenvironmental records, through drilling of the continental margin, to understand Antarctica's role in global climate, ocean circulation, and the evolution of life.

These issues will all become clearer as scientists improve their models of where, when, and how crustal plate movement wrought Antarctica and its surrounding ocean basins. The Antarctic Earth Sciences Program funds investigations into the relationships between the geological evolution of the antarctic plate and the life and processes that can be deduced to accompany it—the paleocirculation of the world's oceans, the paleoclimate of the Earth, and the evolution of high-latitude biota. A current emphasis is the West Antarctic Ice Sheet Program, focused on the smaller of the continent's two ice sheets and conducted jointly with the Antarctic Glaciology Program. Several important research support activities are underway as well:

- **Meteorites:** In partnership with the National Aeronautics and Space Administration and the Smithsonian Institution, the program supports meteorite collection through the antarctic search for meteorites (ANSMET) and chairs an interagency committee that is responsible for curating and distributing samples of antarctic meteorites.
- **Mapping and geodesy:** In partnership with the U.S. Geological Survey, the program supports mapping and geodetic activities as an investment in future research in earth sciences. The U.S. Antarctic Resources Center (USARC) constitutes the U.S. Antarctic Program's contribution to the Scientific Committee on Antarctic Research library system for earth sciences; housed here is the largest collection of antarctic aerial photographs in the world, as

well as many maps, satellite images, and a storehouse of geodetic information.
- **Marine sediment and geological drill cores:** In partnership with Florida State University's Antarctic Marine Geology Research Facility, the program manages and disseminates marine sediment and geological drill cores mined in Antarctica. The collection includes an array of sediment cores as well as geological drill cores from the Dry Valley Drilling Project, the Cenozoic Investigations of the Ross Sea Drilling Program, and the Cape Roberts Drilling Project. The facility fills requests for samples from researchers worldwide and also accommodates visiting researchers working onsite.

ANDRILL.

David M. Harwood, University of Nebraska–Lincoln; Robert M. DeConte, University of Massachusetts; Thomas R. Janecek, Florida State University; Terry J. Wilson, Ohio State University; and Ross D. Powell, Northern Illinois University.

Antarctic Drilling (ANDRILL), an international program representing over 150 scientists from Germany, Italy, New Zealand, the United Kingdom, and the United States, is designed to investigate Antarctica's role in Cenozoic global environmental change. ANDRILL will obtain a record of important Eocene, Neogene, and Holocene stratigraphic intervals in high southern latitudes and will address four themes:

- the history of the antarctic climate and ice sheets,
- the evolution of polar biota,
- antarctic tectonism, and
- Antarctica's role in the Earth's ocean-climate system.

This research will lead to insights into

- the development of the antarctic cryospheric system (ice sheet, ice shelf, and sea ice);
- the magnitude and frequency of cryospheric changes;
- the influence of ice sheets on Eocene to Holocene climate, the modulation of thermohaline ocean circulation, and eustatic change; and
- the evolution and timing of major tectonic episodes and the development of sedimentary basins.

The successful retrieval of cores and excellent depth of penetration from fast-ice, ice-shelf, and land-based platforms is ensured by the improved drilling system. The program will provide new, seismically linked and well-constrained Cenozoic stratigraphic records from locations proximal to the antarctic cryosphere. Empirical data garnered from these records will calibrate numerical models and will allow new constraints to be placed on estimates of ice volume variability, marine and terrestrial temperatures, the timing and nature of major tectonic episodes, and the development of Antarctica's marine, terrestrial, and sea-ice biota.

This research will contribute to the development of strategies to cope with future climate change, provide insight into relationships between ice-sheet fluctuations and volcanic and seismic hazards, and improve models of glacially influenced sedimentary rift basins.

During the 2006-2007 austral summer, we will deploy current meters through the sea ice at the ANDRILL drill site in southern McMurdo Sound. One field party will travel by tracked vehicle to the drill site and establish a field camp. Using a hole melter to create one or more holes in the sea ice, they will deploy an acoustic Doppler current profiler tethered to the sea-ice surface. They will also deploy a string of physical current meters positioned at various depths in the 530-meter water column. These meters, attached to a cable that is anchored to the ocean floor and tethered to the sea-ice surface, will record 6 to 8 weeks of oceanographic current velocity data, are required in advance of drilling operations at the site to model the sea-riser riser behavior under variable tidal current velocities at various water depths. A second field team will recover the instruments in late November.

The project will also contribute to other international science goals, bring together international teams, and provide opportunities to share antarctic earth science with the global community. ANDRILL will foster strong partnerships with established educational programs to develop a broad array of activities designed to educate policymakers, K– teachers, students, and the community at large. (G-049-M; NSF/OPP 03-42484, NSF/OPP 03-42407, NSF/OPP 03-42408, NSF/OPP 03-42436, and NSF/OPP 03-42445)

Age, origin, and climatic significance of buried ice in the western Dry Valleys, Antarctica.

David R. Marchant, Boston University, and Joerg M. Schaefer, Lamont-Doherty Earth Observatory, Columbia University.

Buried ice deposits represent a potentially far-reaching archive of atmosphere and climate on Earth extending back many millions of years. These deposits are terrestrial analogs to widespread and young buried ice on the Martian surface as identified by recent data from Mars Odyssey. Just as earlier researchers asked whether a climate record was stored in the modern ice sheets of Antarctica and Greenland, we now ask whether ancient, debris-covered glaciers in the western Dry Valleys hold similar records of temperature and atmospheric change, but on time scales that are perhaps an order of magnitude greater than those for the deepest existing ice core.

The ice to be examined is over a million years old, making it by far the oldest ice yet known on Earth. An alternative view is that this buried ice is more recent segregation ice from the *in situ* freezing of groundwater. Distinguishing between these hypotheses is key to understanding Neogene climate change in Antarctica.

Our research is aimed at the following:

- better understanding the surface processes that permit ice preservation,
- testing the efficacy of cosmogenic and argon analyses in dating tills above buried ice,
- further assessing the use of cosmogenic-nuclide analyses and argon analyses of ashfall deposits to date buried ice, and
- using these data to help resolve the debate between the young and old ice scenarios noted earlier.

During the 2006–2007 austral summer, our group will be divided into two field teams. Working in Beacon Valley, one group will attempt to determine the age, origin, and climate significance of buried ice in the western Dry Valleys region. This team will drill and collect approximately 15 cores from buried ice. The second team will study Dry Valley microclimates At Don Juan Pond to better understand ancient and current climate processes on Mars. This team will document the range of surface geomorphic processes in at least three discrete microclimate zones (a coastal-thaw zone, and inland-mixed zone, and a stable-upland zone) in the Dry Valleys.

Better understanding of surface processes above buried ice on Earth will permit researchers to gain access to a record of atmospheric and climate change that could well cover intervals that predate Quaternary time. Since the conditions in the Dry Valleys are analogous to those found on Mars, extending the results could bring valuable insight into the potential for life on Mars. (G-054-M; NSF/OPP 03-38291 and NSF/OPP 03-38244)

3-D dynamics of the Ferrar magmatic mush column, McMurdo Dry Valleys, Antarctica.

Bruce D. Marsh, Johns Hopkins University.

A fundamental difficulty in understanding the highly integrated nature of planetary magmatism is that so few of the deeper aspects of the true dynamic nature of an active system can be directly observed. The historic concept of a deep source of magma connected by a simple conduit to a high-level expansive magma chamber is being replaced by the concept of a magmatic mush column a vertically extensive stack of sills or high aspect ratio chambers interconnected by a plexus of pipe-like and/or dike-like conduits stretching over significant depths beneath areas of active volcanism.

The Ferrar dolerites of the McMurdo Dry Valleys system represent *perhaps* the best exposed, most highly integrated, and most petrologically diverse crustal expression of a magmatic mush column on Earth.

The goal of this research is to determine the dynamics of establishment and operation of this system through a series of pivotal studiesby

- building a 3-D image of the entire system based on the detailed and regional geology;
- using the Opx tongue crystals within the 3-D magmatic structure as tracers to gauge the pattern of filling, understand the dynamics of entrainment, transport, and deposition of these phenocrysts, and determine the ultimate provenance or source characteristics of the Opx load itself;
- exploring a process of granite dike production and re-injection associated with sill formation, which is of fundamental importance in chemically contaminating Mush Columns; and
- seeking to numerically simulate the texture, crystal size distributions, and physical properties of basaltic magma during solidification and then to use the lattice-Boltzmann method to study the texture for critical physical properties.

The insights and results of this work are being used to understand the mitigation of magmatic hazards at Yucca Mountain; to understand ore deposition at Sudbury, Ontario, and to design museum exhibits. The work is also being interwoven with undergraduate research and in writing special lectures for the K–students, including students with learning disabilities. (G-056; NSF/OPP 04-40718)

The antarctic search for meteorites (ANSMET).

Ralph P. Harvey, Case Western Reserve University.

Since 1976, the antarctic search for meteorites (ANSMET) program has recovered more than 14,000 meteorite specimens from locations along the Transantarctic Mountains. Antarctica is the world's premier meteorite hunting ground for two reasons:

- First, although meteorites fall at random all over the globe, the likelihood of finding one is enhanced if the background material is plain and the accumulation rate of terrestrial sediment is low; this makes the East Antarctic Ice Sheet the perfect medium.
- Second, along the margins of the sheet, iceflow is sometimes blocked by mountains, nunataks, and other obstructions; this exposes slow-moving or stagnant ice to the fierce katabatic winds, which can deflate the ice surface and expose a lag deposit of meteorites (a representative portion of those that were sprinkled throughout the volume of ice lost to the wind). When such a process continues for millennia, a spectacular concentration of meteorites can be unveiled.

The continued recovery of antarctic meteorites is of great value because they are the only currently available source of new, nonmicroscopic extraterrestrial material. As such, they provide essential "ground truth" about the composition of asteroids, planets, and other bodies of our solar system. ANSMET recovers samples from the asteroids, the Moon, and Mars for a tiny fraction of the cost of returning samples directly from these bodies.

During the 2006–2007 austral summer the main ANSMET field team will conduct a full-scale systematic meteorite recovery from icefields at sites near the Grosvenor Mountains in the central Transantarctic Mountains. Three key sites are targeted:

- the Larkman Nunatak icefield, where 80 specimens were recovered in just a few days during the 2004–05 field season;
- the Mt. Block / Mt. Mauger icefields, which have not been previously visited;
- and the Mt. Raymond / Mt. Cecily area, where 164 meteorites were recovered during the 1985 and 1995 field seasons.

At all three locations the field team will establish a base camp and then begin systematic recovery of meteorite specimens through overlapping transect searches of exposed blue ice. (G-057-M and G-058-M; NSF/OPP 99-80452)

Late Cenozoic volcanism and glaciation at Minna Bluff, Antarctica: Implications for antarctic cryosphere history.

Thomas Wilch, Albion College.

To understand and respond to global warming and its accompanying threats of sea level rise and agricultural disruptions, well-dated and characterized reconstructions of the antarctic cryosphere are critical. This study will use volcanic and glacial records at Minna Bluff in the western Ross embayment of

Antarctica to interpret antarctic cryosphere history. Minna Bluff, a 50-kilometer-long peninsula, is a significant topographic barrier that has effectively blocked the Ross Ice Shelf and the former Ross Sea Ice Sheet from flowing southward into McMurdo Sound.

In addition to providing a record of the emergence of the topographic barrier, the Minna Bluff study should yield a discontinuous but reliable record of synvolcanic expansions of the Ross Sea Ice Sheet. The study will include geologic field mapping, sampling, and lithofacies analysis fieldwork. Pilot studies include Argon-40/Argon-39 dating, petrography, and geochemical analyses; stable isotope evaluation of alteration environment of glaciovolcanic deposits; and Chlorine-36 dating of post-volcanic glacial deposits. The research also has direct relevance on the ANDRILL project and provides a complementary terrestrial record to the marine record, and project results and outreach will be coordinated and shared with the ANDRILL community.

The project also features a McMurdo Station series of short geological field trips as an outreach component geared to the non-science McMurdo Station community. Additional outreach efforts include educational programs targeted at public schools and community groups near our home institutions, exhibits for a science museum, and a project website. (G-062; NSF/OPP 05-38342)

Deducing the climate in late Neogene Antarctica from fossil-rich lacustrine sediments in the Dry Valleys.

David R. Marchant, Boston University, and Allan C. Ashworth, North Dakota State University.

Ancient lake sediments deposited alongside former outlet and alpine glaciers in the Dry Valleys are sensitive indicators of past climate and ecological change. We will analyze 17 former lake sites above 1,000 meters on the north wall of central Taylor Valley and in north-facing valleys of the Asgard and Olympus Ranges. Chronological control comes from argon isotope analyses of interbedded volcanic ash. Lake sediments over 13 million years old contain layers of well-preserved pleurocarpous mosses, diatoms, woody stems, and insects; younger sediments lack such fossils. The fossil-rich lacustrine sediments of the Dry Valleys contain the only known in-situ tundra-type flora and fauna in the Transantarctic Mountains outside the Beardmore Glacier region.

Our objectives include

- developing a better characterization of the distribution of ancient lakes and their flora and fauna,
- securing a more refined chronology,
- producing a geochemical signature for glass within ice-marginal lakes, and
- providing a comparison for previously mapped terrestrial vegetation in the central Transantarctic Mountains.

Our results will help place the modern Dry Valleys lakes in a long-term framework and will facilitate dating among deposits across the Transantarctic Mountains. Moreover, our work will improve dating in marine cores from nearby Cape Roberts.

The key questions we will address are as follows:

- When did the polar desert replace the Neogene tundra?
- Was the climate change that caused the biotic turnover unidirectional and permanent, or did short-lived, warmer climatic conditions, supporting tundra, return to the Dry Valleys after the mid-Miocene?
- Were warmer conditions regional or continental?
- What variation is there in species content and richness among Neogene fossil sites in the Transantarctic Mountains?
- Was the extinction of Gondwanaland biota gradual, or were there dispersal episodes during warmer intervals that replenished the biota from South America, New Zealand, and Tasmania, thus delaying extinction until the Pliocene?

This research will introduce students to a unique synthesis of the Dry Valleys; results will be disseminated in scientific journals and in a special volume of the American Geophysical Union's Antarctic Research Series. (G-063-M; NSF/OPP 04-40711 and NSF/OPP 04-40761)

Collection of marine geophysical data on transits of the *Nathaniel B. Palmer.*

Joann M. Stock, California Institute of Technology, and Steven C. Cande, University of California–San Diego, Scripps Institution of Oceanography.

Well-constrained plate reconstructions of the antarctic region are critical for examining a number of problems of global geophysical importance. During this 3-year project, we are addressing questions about the motion history of the antarctic and other plates and improving plate reconstructions by surveying gravity, magnetics, and swath bathymetry on selected transit cruises by the U.S. research icebreaker *Nathaniel B. Palmer*.

In October 2006 during a 14-day cruise aboard the *Nathaniel B. Palmer*, we will test seismic reflection equipment and host a marine geophysics class for undergraduate and graduate students. Beginning in Lyttleton, New Zealand, the cruise will transit about 2 days to the east-northeast to get out of shipping lanes and into deeper waters. The approximate survey region will be bounded by latitudes 40 °S to 43 °S and longitudes 177 °E to 173 °W, all within New Zealand territorial waters. After the transit, we will conduct 10 days of streamer testing and geophysical surveying, followed by a 2-day transit back to Lyttleton. Our research team will survey magnetics, conduct multi-beam swath bathymetry, and collect echo sounder data whenever possible.

The survey area is on the northeast side of the Chatham Rise, New Zealand. Our primary research objective is to study the boundary between the Hikurangi Plateau and the Chatham Rise. This boundary is believed to be a fossil (Cretaceous) subduction zone in which the edge of the oceanic Hikurangi plateau was forced beneath the continental crust of the Chatham Rise, which was part of West Antarctica. A better understanding of the oceanic basement structure here will help in models of Cretaceous plate tectonics along the antarctic margin. (G-071-N; NSF/OPP 03-38317 and NSF/OPP 03-38346)

Dry Valley Seismic Project.

Robert C. Kemerait, U.S. Air Force Technical Applications Center.

One recurrent issue in seismography is noise: that is, background phenomena that can interfere with clear and precise readings. The Dry Valley Seismic Project, a cooperative undertaking with the New Zealand Antarctic Program, was established to record broadband, high-dynamic-range, digital seismic data from the remote Wright Valley, a site removed from the environmental and anthropogenic noise that is ubiquitous on Ross Island.

The Wright Valley site provides one of the few locations on the continent with direct access to bedrock. The station there consists of a triaxial broadband borehole seismometer [100 meters deep] and a vertical short-period instrument at 30 meters. The seismological data are digitized at the remote location, telemetered by repeaters on Mount Newall and Crater Hill, and received eventually by the recording computer at the Hatherton Laboratory at Scott Base, where a backup archive is created.

From Hatherton, they pass along a point-to-point protocol link to the Internet at McMurdo Station and then to the Albuquerque Seismological Laboratory for general distribution to the international seismological community. This data set complements the data from other seismic stations operated by the Albuquerque Seismological Laboratory at Amundsen-Scott South Pole Station, Palmer Station, and Casey, an Australian base. (G-078-M; NSF/OPP DoD MOA)

Mount Erebus Volcano Observatory II (MEVO II): surveillance, models, impacts, and outreach.

Philip R. Kyle, New Mexico Institute of Mining and Technology.

Mount Erebus, Antarctica's most active volcano, is known for its unique geochemistry and for a persistent convecting lake(s) of anorthclase phonolite magma in its summit crater. It is one of only a handful of volcanoes worldwide that have permanent lava lakes and exhibit readily observable and nearly continuous Strombolian explosive and associated internal activity. The volcano also serves as a natural laboratory to study magma degassing associated with an open convecting magma conduit as well as a test-bed for evaluating instrumentation and power systems in antarctic and volcanic environments.

The primary goal of this study is to develop an understanding of the Mount Erebus eruptive and noneruptive magmatic system using an integrated approach from geophysical, geochemical, and remote sensing observations by

- sustaining year-round surveillance of on-going volcanic activity primarily using geophysical observatories;
- understanding processes within the convecting conduit that feeds the persistent lava lakes; and
- comprehending the impact of Erebus eruptive activity the antarctic environment.

In addition to contributing fundamental knowledge to the understanding of volcanic processes, this research will be included in a special issue of the *Journal of Volcanology and Geothermal Research* devoted to Erebus volcano. We will also work with various media organizations and filmmakers and include graduate and undergraduate students and a science teacher in our laboratory and field studies. (G-081; NSF/OPP 05-38414)

Integrated study of East Antarctic Ice Sheet tills (ISET): Tracers of ice flow and proxies of the ice-covered continental shield.

Kathy J. Licht and R. Jeffrey Swope, Indiana University, Purdue University–Indianapolis; John W. Goodge, University of Minnesota; and G. Lang Farmer, University of Colorado-Boulder.

Our interdisciplinary study of glacial deposits in the Ross embayment will help constrain Antarctica's Late Quaternary glacial history (about 18,000 years ago) and improve our knowledge of the rocks underlying the East Antarctic Ice Sheet. While constraining changes to till during transport, we will use till provenance to evaluate models for the last glacial maximum and to characterize rocks eroded from the East Antarctic Craton.

Although progress has been made in constraining the extent and timing of the last glacial maximum in the Ross Sea, reconstructions vary substantially. For example, some studies have concluded that ice streams derived from the west were dominant features of the Ross Ice Sheet during the last glacial maximum, while others show roughly equal inputs from east and west. Glacial sediments from the Ross embayment can be used to test these models.

Despite limited data, our previous work suggests that:

- the east-to-west variations in the sand composition of Ross Sea till can be linked to eastern and western sources and that the ice sheets contributed equivalent volumes to the Ross Ice Sheet during the last glacial maximum,
- tills from West and East Antarctica are distinguishable and can be related to Ross Sea tills, and
- detritus from specific glaciers in the Transantarctic Mountains can be isotopically fingerprinted.

We will collect till samples from moraines at the heads and mouths of the Amundsen, Beardmore, Byrd, Liv, Nimrod, Reedy, Scott, and Shackleton Glaciers. We will then characterize particle size distribution, clast lithology, sand petrography, isotopic composition and elemental abundance of the silt/clay fraction, and ages of detrital zircons.

We will build predictions of the ice sheet's response to changing climate and rising sea level from models that accurately predict past configurations. Detailed sampling will allow us to characterize changes to till produced by the processes that modify sediment during transport and to determine constraints on the transport distances of eroded bedrock, as well as provide evidence of unmapped, buried rocks.

Also, we will host curriculum development workshops for 30 Indiana earth science educators, thus allowing us to reach over 600 students from diverse backgrounds. (G-084-M; NSF/OPP 04-40885, NSF/OPP 04-40160, and NSF/OPP 04-40177)

Gneiss dome architecture: Form and process in the Fosdick Mountains, Antarctica.

Christine S. Siddoway, Colorado College, and Christian Teyssier, University of Minnesota-Twin Cities.

Gneiss dome formation involves material and heat transfer from middle or deep crustal levels and therefore represents a fundamental orogenic or mountain-forming process. Recent breakthroughs in understanding the role of migmatitic gneiss domes result from the geophysical exploration of contemporary mountain belts that reveal a thick, midcrustal layer of partially molten crust within the orogenic system. As middle crust exposures, gneiss domes offer the means to study structural and metamorphic processes that cannot be observed directly in contemporary orogens and to undertake a detailed analysis of structures beyond the resolution of seismic imaging.

In the Fosdick Mountains of the Ford Ranges of western Marie Byrd Land are excellent three-dimensional exposures of an elongated migmatite dome derived from sedimentary and plutonic protoliths. Preliminary findings suggest that peak metamorphism occurred about 105 million years ago at depths of about 25 kilometers, followed by decompression as the Fosdick Dome was emplaced to 16 to 17 kilometers, or possibly 8.5 kilometers, by 99 million years ago. Near-isothermal conditions, favorable for producing substantial volumes of melt, were maintained during ascent. Because mineral assemblages record decompression and because the ages of argon isotopes indicate rapid cooling, the gneiss dome has been interpreted as a product of extensional exhumation. This is a viable interpretation from the regional standpoint, because the dome was emplaced during the mid-Cretaceous with the rapid onset of divergent tectonics along the proto-Pacific margin of Gondwanaland.

However, the complex internal structures in the Fosdick Mountains have not been integrated into the extensional exhumation model, and alternative models have not been explored. Possible alternatives are upward extrusion within a contractional setting or lateral flow within a transcurrent attachment zone. To address this question, we will use detailed structural analysis, paired with geothermobarometry and geochronology, to determine the flow behavior and structural style that produced the Fosdick Dome. Our study will be relevant to research on the role of gneiss domes for material and heat transfer in orogeny and on mechanisms of gneiss dome formation.

In addition to multidisciplinary research, students will be involved in developing curriculum materials. (G-088-M; NSF/OPP 03-38279 and NSF/OPP 03-37488)

Global seismograph station at Palmer Station and the South Pole.

Rhett G. Butler, Incorporated Research Institutions for Seismology.

Seismology, perhaps as much as any other science, is a global enterprise. Seismic waves resulting from earthquakes and other events can be interpreted only through simultaneous measurements at strategic points all over the planet. The measurement and analysis of these seismic waves are not only fundamental to the study of earthquakes, but they also serve as the primary data source for the study of the Earth's interior. To help establish the facilities required for this crucial scientific mission, the Incorporated Research Institutions for Seismology (IRIS)was created in 1985.

IRIS is a consortium of universities with research and educational programs in seismology. Ninety-seven universities are currently members, including nearly all U.S. universities that have seismological research programs. Since 1986, IRIS, through a cooperative agreement with the National Science Foundation (NSF) and in cooperation with the U.S. Geological Survey (USGS), has developed and installed the Global Seismographic Network (GSN), which now has about 137 broadband, digital, high-dynamic-range seismographic stations around the world; most of these have real-time communications.

The GSN seismic equipment at Amundsen-Scott South Pole Station and at Palmer Station was installed jointly by IRIS and USGS, which continue to operate and maintain them. The GSN sites in Antarctica are vital to seismic studies of Antarctica and the Southern Hemisphere, and they contribute to the international monitoring system of the Comprehensive Test Ban Treaty. The state-of-the-art seismic instrumentation is an intrinsic component of the NSF effort to advance seismology and earth science globally.

In 2003, with the completion of the South Pole Remote Earth Science and Seismological Observation (SPRESSO) in the Quiet Sector, the GSN seismic instrumentation was moved to the SPRESSO site, 8 kilometers from the Pole, and deployed into 300-meter deep boreholes in the ice below the firn. The new GSN site achieves the quietest conditions on Earth at frequencies above 1 hertz.

At Palmer Station, a science technician will continue to monitor the GSN seismometer installed there. (G-090-P/S; NSF/EAR 00-04370)

Geomagnetic field as recorded in the Mount Erebus volcanic province: Key to field structure at high southern latitudes.

Lisa Tauxe, Hubert Staudigel, and Catherine Constable, Scripps Institute of Oceanography.

This project's research focuses on the Earth's magnetic field. Paleomagnetic data play an important role in a variety of geophysical studies of the Earth, including plate tectonic reconstructions, magnetostratigraphy, and studies of the behavior of the ancient geomagnetic field. During a previous study, we sampled 70 sites in the high Southern Latitudes. For this study we will obtain paleomagnetic and geochronological data samples from lava flows in these targeted regions. These samples will be essential to an enhanced understanding of the time-averaged field and its long-term variations.

Outreach activities will include development of web-based middle and high school classroom materials about the Earth's magnetic field and plate tectonics with the goal of expanding these materials for college-level introductory classes. (G-182; NSF/OPP 05-38392)

An integrated and geomagnetic and petrologic study of the Dufek Complex.

Jeffrey S. Gee, Scripps Institution of Oceanography.

The Dufek Complex of Antarctica (including the Dufek Massif and Forrestal Range) provides a unique setting to test hypotheses relating to

- the intensity and directional stability of the Earth's magnetic field in the Jurassic,

- the extent to which secular variations of the geomagnetic field are averaged in slowly cooled intrusive igneous rocks, and
- the magmatic construction and thermal history of this large layered intrusion.

This research features an integrated petrologic and magnetic study, which should provide powerful constraints on the magmatic construction and thermal history of the Dufek Complex and its relationship to the Ferrar diabases and Kirkpatrick basalts.

We plan to integrate our research efforts with graduate and undergraduate education by including students in the data collection and interpretation. The chemical data collected will be made available via the internet and on CD/DVD media and the magnetic data will be archived in the paleomagnetic database (http://www.earthref.org/MAGIC/index.html). This research complements and extends planned German/Chilean International Polar Year activities in the Dufek area. The study's results will be presented at international conferences and in published papers. (G-192; NSF/OPP 05-37609)

UNAVCO global positioning system survey support.

Bjorn Johns, UNAVCO.

The University Navstar Consortium (UNAVCO) is a nonprofit, membership-governed consortium funded through the National Science Foundation and the National Aeronautics and Space Administration (NASA) to support and promote high-precision measurement techniques for the advancement of earth sciences. UNAVCO provides complete support for permanent stations, surveying, mapping, and other applications of the global positioning system to U.S. Antarctic Program investigators and maintains a satellite facility with a full range of geodetic GPS equipment and support services at McMurdo Station during the austral summer research season.

A large pool of high-precision GPS receivers and associated equipment is provided for short-term surveys through multiyear data collection in Antarctica. Regular equipment upgrades ensure a steady influx of modern equipment, including

- state-of-the-art dual-frequency GPS receivers,
- power and communication systems for remote locations,
- GPS monument and antenna mount options, and
- accessories for kinematic and real-time kinematic (RTK) surveys.

UNAVCO staff provides year-round support to help ensure the success of field projects and subsequent data management. The level of support is scalable and includes

- survey planning,
- field survey and data processing training,
- custom engineering solutions,
- system integration,
- field assistance,
- GPS station maintenance, and
- data retrieval, flow monitoring, processing, and archiving.

UNAVCO also operates a community RTK GPS base station that covers McMurdo Station and provides maintenance support to the NASA GPS Global Network station MCM4 at Arrival Heights. (G-295-M; NSF/EAR 03-21760)

Controls on sediment yields from tidewater glaciers from Patagonia to Antarctica.

Bernard Hallet, University of Washington.

Using Patagonia and the Antarctic Peninsula region as an ideal natural laboratory, this project will examine the role of glacier dynamics in determining glacial sediment yields via glaciology and marine geology techniques. Prior studies of the region have noted a significant decrease in glaciomarine sediment accumulation in the fjords along a southward transect, and the fjords constitute accessible and nearly perfect natural sediment traps. We hypothesize that rates of glacial erosion are a function of sliding speed and are therefore expected to diminish sharply as basal temperatures drop below the melting point.

To test this hypothesis, we will measure both sediment accumulation rates in fjords and dynamic characteristics of the glaciers producing the sediments, from fast-moving temperate glaciers in Patagonia to slow-moving polar glaciers on the Antarctic Peninsula. For each of the six tidewater glaciers, we will define an empirical relationship between glacial erosion rates and ice dynamics by

- assessing sediment yields and, by inference, erosion rates by determining sediment accumulation rates within the fjords using seismic profiles and core data, and
- measuring dynamic properties and basin characteristics of the glaciers, all of which have distinctly different ice fluxes and basal thermal regimes.

The results of the project will contribute to a better understanding of the linkages between climate, tectonics, and topography in all high mountain ranges; of the climate record archived in glaciomarine sediments; and of the drastic retreat of the glaciers in Fuego-Patagonia and the Antarctic Peninsula.

Educational outreach activities will encourage participation of underrepresented groups, especially younger women in the sciences and K– educators. The study also will include a cross-disciplinary exchange and collaboration with Chilean glaciologists and marine geologists. (G-411; NSF/OPP 03-38371)

The connection between mid-Cenozoic seafloor spreading and the western Ross Sea embayment.

Steven C. Cande, Scripps Institution of Oceanography, and Joann Stock, California Institute of Technology.

Prior studies indicate 170 kilometers of seafloor spread between East and West Antarctica during the mid-Cenozoic period, between 43 and 26 million years ago. However, the relationship of the seafloor spreading to the continental basins to the south in the Ross Sea embayment area has yet to be established. This study will use a marine geophysical survey to study the structural relationship of the seafloor between the Adare Basin and the northern and central basins of the Ross Sea embayment to determine how this area was accommodated.

This project will acquire magnetic, gravity, swath bathymetry, and multi-channel seismic data from the southern end of the Adare Basin to the northern parts of the northern basin and central trough for testing two hypotheses:

- there is complete structural continuity from the Adare Basin south into the northern basin, and the northern basin of the Ross Sea Embayment also experienced 170 kilometers of extension; or
- there is a structural offset that transferred some of the displacement sideways into the central trough of the Ross embayment.

In addition to furthering an understanding of Ross Sea tectonics, the Adare Basin work will better constrain models of mid-Cenozoic motion between East and West Antarctica; affect study of the global plate circuit linking the plates of the Pacific Ocean to the rest of the world; and contribute to our understanding of rifted margins. The project will support two graduate students, one at University of California, San Diego and one at California Institute of Technology and will have other students as watchstanders. The project will also involve scientists from Australia, New Zealand, and Japan, and, consequently, will foster the broad dissemination of results to the international community. (G-413; NSF/OPP 04-40959 and NSF/OPP 04-40923)

Constraining the petrogenesis and mantle source of Adare Basin seamount lavas.

Paterno R. Castillo, Scripps Institution of Oceanography, and Kurt S. Panter, Bowling Green State University.

The fundamental cause of Cenozoic magmatism associated with the West Antarctic rift system has been explained by a variety of models based primarily on geochemical evidence gathered from igneous rocks from continental West Antarctica. The goal of this project is to collect petrographic, geochronologic, geochemical, and isotopic data to assess these existing, but often conflicting, models on mantle geodynamics and control on magmatism in the region.

To accomplish this goal, we will collect dredged samples from the numerous but relatively small volcanic seamounts in the Adare Basin in the western Ross Sea, northern Victoria Land, which are collectively called Adare Basin seamounts. By establishing that these seamounts are of Cenozoic age and genetically related to other Cenozoic igneous rocks in West Antarctica, researchers should be able to better constrain the "pristine" mantle source composition of West Antarctic magmas and possibly of the whole southwest Pacific.

The project's geochemical database will be available to other researchers addressing similar problems in the Adare Basin region. Outreach activities include fostering faculty and student collaboration and pooling multidisciplinary resources among Scripps Institution of Oceanography, Bowling Green State University, and the New Mexico Institute of Mining and Technology to ensure these multi-user facilities continue to be valuable sites for advanced technological mentoring of science students. (G-430; NSF/OPP 05-38266 and NSF/OPP 05-38374)

Controls on sediment yields from tidewater glaciers from Patagonia to Antarctica.

John B. Anderson and Julia S. Wellner, Rice University, and Bernard Hallet, University of Washington.

Glacial erosion is a principal issue in contemporary research on landscape evolution and high-latitude climate change. In the Himalayas, for example, the spatial pattern and rapid rates of tectonic rock uplift correspond closely to patterns and rates of erosion by ice and water. On a global scale, the onset of widespread glacial erosion is often viewed as responsible for the increase in sedimentation that coincided with a change to a cooler, more variable climate at the onset of late Cenozoic glaciation (about 2 to 4 million years ago). At high latitudes, this increase in sedimentation created clastic wedges up to 5 kilometers thick on continental margins; these sediments contain a rich history of climate change recorded in proxy climate data (ice-rafted debris, foraminifera) and sediment accumulation rates that reflect the production of glacial sediment.

Our aim is to define an empirical relationship between glacial erosion rates and ice dynamics. We will use glaciologic and marine geologic techniques to examine the role of glacier dynamics in determining glacial sediment yields. We hypothesize that glacial erosion rates are a function of sliding speed and will therefore diminish sharply as basal temperatures drop below the melting point. To test this hypothesis, we will study six tidewater glaciers ranging from fast-moving temperate glaciers in Patagonia to slow-moving polar glaciers on the Antarctic Peninsula. For each system, we will

- use seismic profiles and core data to assess yields and, by inference, erosion rates by determining sediment accumulation rates in the fjords, and
- measure the dynamic properties and basin characteristics of each of the glaciers, which have different ice fluxes and basal thermal regimes.

We will base our work in Patagonia and the Antarctic Peninsula because

- the large latitudinal range provides for a wide range of precipitation and glacier thermal regimes over relatively homogeneous lithologies and tectonic settings,
- earlier studies have noted a significant decrease in the accumulation of glaciomarine sediment in the fjords along a southward transect, and
- the fjords constitute accessible and nearly perfect natural sediment traps. (G-435-N; NSF/OPP 03-38137 and NSF/OPP 03-38371)