GEOLOGY AND GEOPHYSICS

A helicopter lifts off the ice at Beardmore Camp in the Transantarctic Mountains. Although ski-equipped C-130 air transports are used to move scientists and their equipment to remote sites, USAP often uses helicopters to support local fieldwork from large field camps like Beardmore Camp. (*NSF/USAP photo by Kristan Hutchinson, Raytheon Polar Services Corp.*)

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Overview

Near the Beardmore Glacier in the Transantarctic Mountains, paleontologists and geologists set up a camp to study the rock in the surrounding hills and peaks. The research in 2003 unearthed new

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 (m). 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.

dinosaur bones, ancient plants and other clues to what Antarctica was like hundreds of millions of years ago. (*NSF/USAP photo by Kristan Hutchinson, Raytheon Polar Services Corp.*)

Geologists have found evidence that there was once a forested supercontinent, which they call Gondwanaland, in the Southern Hemisphere. Before the Earth's constantly 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 rock and fossils—is locked in beneath the ice and the sea, and in the bedrock below both of them.

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 m 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 Geology and Geophysics Program include the following:

- determining the tectonic evolution of Antarctica and its relationship to the evolution of the continents from Precambrian time (600 million years ago) to the present;
- 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 geologic controls to ice-sheet behavior, and defining geologic responses to the ice sheets on regional and global scales; and
- determining the evolution of sedimentary basins within the continent and along the continental margins.

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 Geology and Geophysics Program funds investigations into the relationships between the geologic 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 Glaciology Program. Several important research support activities are underway as well:

- **Meteorites:** In partnership with the National Aeronautics and Space Administration (www-curator.jsc.nasa.gov/curator/antmet/antmet.htm) 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, http://usarc.usgs.gov/) 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 the Antarctic Marine Geology Research Facility at Florida State University (www.arf.fsu.edu/), 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 geologic 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.

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Antarctic mapping, geodesy, geospatial data, satellite image mapping, and Antarctic Resource Center management.

Jerry L. Mullins, U.S. Geological Survey.

Antarctic mapping, geodesy, geospatial data, satellite image mapping, and the U.S. Antarctic Resource Center (USARC) constitute some of the activities necessary for the successful operation of a multifaceted scientific and exploratory effort in Antarctica. Year-round data acquisition, cataloging, and data dissemination will continue in the USARC in support of surveying and mapping. Field surveys are planned as part of a continuing program to collect the ground control data required to transform existing geodetic data into an Earth-centered system suitable for future satellite-mapping programs and to reinforce extant control of mapping programs to support future scientific programs. Landsat (Land Remote-Sensing Satellite) data will be collected as funding permits to support satellite image-mapping projects. These maps will provide a basis for displaying geologic and glaciologic data in a spatially accurate manner for analysis. They will also support future expeditions by providing a basis for planning scientific investigations and data collection. In addition, spatially referenced digital cartographic data will be produced from published maps.

Geodetic projects are planned as part of a continuing program aimed at building a continent-wide geodetic infrastructure (GIANT) that will support a wide range of U.S. and international scientific research objectives by:

- establishing and maintaining a framework of permanent geodetic observatories,
- extending and strengthening the existing network of stations linked to the International Terrestrial Reference Frame,
- establishing geodetic coordinates at identifiable points for georeferencing satellite image-mapping projects,
- maintaining and calibrating tide-gauge instrumentation,
- carrying out absolute gravity measurements,
- carrying out absolute gravity measurements,
- expanding the online geodetic database with new and historical data.

The geodetic field program is supported by a cooperative arrangement with Land Information New Zealand. (G–052–M/P/S; NSF/OPP 02–33246)

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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:

- 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.

We will analyze a minimum of six cosmogenic-depth profiles to determine if and how cryoturbation reworks sublimation tills and assess the average rate of sublimation for three glaciers. We will use finite-element analyses to model at least three buried glaciers and compare the flow rates with those based on radiometric dating of surface deposits. We will also collect 10 ice cores.

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)

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Magmatism in the Dry Valleys: A workshop.

Bruce D. Marsh, Johns Hopkins University.

The most challenging aspect of understanding magmatism is that so little of the integrated nature of the full cycle can be directly examined in any realistic context. Planetary magmatism is a multifaceted process involving a spectrum of interleaved chemical and physical processes responsible for the chemical transformation of the initial primitive magma into the final product. Each essential component can be found well exposed somewhere on Earth, and each has been studied for nearly a century, but finding and studying any reasonable example of the entire process in a fully integrated context has proven singularly elusive.

The Ferrar dolerites of the McMurdo Dry Valleys exhibit in exquisite exposures the three-dimensional structural evolution of an extensive magmatic system that formed 180 million years ago. This system contains, on a manageable scale, all the essential features of major magmatic systems, which are seen only piecemeal elsewhere in the world. Because this unusual area is so inaccessible, we will hold a 2-week field workshop to introduce 20 to 25 researchers to the wonders of the McMurdo Dry Valleys, to stimulate cutting-edge research, and to delineate the unsolved problems posed by this magmatic system. This working conference will have discussions and laboratory work at McMurdo Station and fieldwork in the Dry Valleys.

Four magmatic processes will be considered:

- magma transport and differentiation in a mush column (East Bull Pass),
- crystal transport and sorting in ponding magma (East Dais),
- solidification front instability in sills (Pandora Spire/Solitary Rocks), and
- mechanics of sill emplacement (Victoria Valley and East Wright Valley).

To have the widest possible impact, participants will be researchers working on other parts of the Ferrar system, senior researchers studying layered intrusions and basaltic sills worldwide, young researchers studying magmatic processes, researchers studying ocean ridge magma chambers and melt sheets, and graduate students in igneous petrology. Undergraduates may also be involved. The workshop is intended to help enunciate a specific fundamental theme common to all magmatic processes, to understand the regional dynamics of the Ferrar-Transantarctic magmatic province, and to stimulate scientists to new horizons through exposure to a singular field area. (G–056–M; NSF/OPP 02–29306)

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The antarctic search for meteorites (ANSMET).

Ralph P. Harvey, Case Western Reserve University.

Since 1976, ANSMET (the antarctic search for meteorites 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 2004–2005 field season, ANSMET's main field party (eight people) will work at the LaPaz icefields, approximately 250 miles from Amundsen–Scott South Pole Station. More than 1,000 meteorites were recovered from the site during visits in 1991, 2002, and 2003. This year's field team will continue systematic searches of the icefields in an effort to recover a representative sample of the extraterrestrial material falling to Earth.

A second team consisting of four people will conduct high-level reconnaissance at a number of icefields throughout the midrange of the Transantarctic Mountains. The team has three goals:

- to search for new meteorite stranding surfaces,
- to fully explore the potential of poorly known meteorite sites, and
- to wrap up collection efforts at sites where a full season by a large team is logistically not practical.

The team will visit poorly known or previously unvisited icefields, recovering meteorites and identifying their potential for more detailed searches during future seasons. In general, the team will move from south to north, starting near Zaneveld Glacier and ending near Buckley Island, with varying lengths of stay at key sites and constant re-evaluation of priorities depending on the density of meteorite finds, icefield conditions, and logistical needs.

The team will generally move between target sites and camps by plane. On a few occasions, the team will use a "flying traverse," where the plane ferries the gear while the team travels by snowmobile. This style of traverse works well for targets that are linked by a safe route and are relatively close together (>30 kilometers). The field team will also be able to traverse such routes in emergencies. (G–058–M; NSF/OPP 99–80452)

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Evolution and biogeography of Late Cretaceous vertebrates from the James Ross Basin, Antarctic Peninsula.

Judd A. Case, Saint Mary's College of California, and James E. Martin, South Dakota School of Mines and Technology.

The Campanian through the Maastrichtian Ages (80 to 65 million years ago) are important in the history of vertebrate biogeography (dispersals and separations due to moving landmasses) and evolution between Antarctica and the rest of the Southern Hemisphere. Moreover, unresolved questions in paleontology relate to the dispersal of terrestrial vertebrates such as dinosaurs and marsupial mammals from North America to Antarctica and beyond to Australia via Patagonia and the Antarctic Peninsula, as well as the dispersal of modern birds from Antarctica northward. Dispersals include vertebrates in marine settings as well. Both widely distributed and localized marine reptile species have been identified in Antarctica, creating questions about their dispersal in conjunction with terrestrial animals.

The Weddellian Paleobiogeographic Province extends from Patagonia through the Antarctic Peninsula and western Antarctica to Australia and New Zealand. Within this province lie the dispersal routes for interchanges of vertebrates between South America and Madagascar and India, and also Australia. On the basis of our previous work, we theorize that an isthmus between more northern South America and the Antarctic craton brought typical North American dinosaurs, such as hadrosaurs (duck-billed dinosaurs), and presumably marsupials traveling overland and marine reptiles swimming along coastal waters to Antarctica in the late Cretaceous. This region also served as the cradle for the evolution, if not the origin, of groups of modern birds and the evolution of typical Southern Hemisphere plants.

To confirm and expand on these hypotheses, we will continue our investigations into late Cretaceous marine and terrestrial deposits in the James Ross Basin. We have previously recovered the following vertebrates from these sedimentary deposits: plesiosaur and mosasaur marine reptiles; plant-eating dinosaurs; a meat-eating dinosaur; and a variety of modern bird groups, including shorebirds, wading birds, and lagoonal birds. Moreover, we recently discovered the bones of what we believe to be an entirely new species of carnivorous dinosaur—one related to tyrannosaurs and velociraptors. These animals evidently survived in the Antarctic, which then had a climate similar to that of the Pacific Northwest, long after they had been succeeded by other predators elsewhere.

Our research will result in important insights into the evolution and geographic dispersal of several vertebrate species. We will collaborate with scientists from the Instituto Antártico Argentino and with vertebrate paleontologists from the Museo de La Plata, both in the field and at our respective institutions in Argentina and the United States. (G–061–E; NSF/OPP 00–03844 and NSF/OPP 00–87972)

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

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

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 will address questions about the motion history of the antarctic and other plates and improve plate reconstructions by surveying gravity, magnetics, and swath bathymetry on three selected transit cruises by the U.S. research icebreaker *Nathaniel B. Palmer*.

In July and August 2004 during a transit (cruise NBP 04–06) from Capetown, South Africa, to Auckland, New Zealand, we will survey in the Indian Ocean and the Tasman Sea several major features of the Africa and Australia plates that relate to their history of spreading away from the Antarctic Plate. These include fracture zones, part of the Broken Ridge and Diamantina fracture zones southeast of Australia, and Cenozoic magnetic anomalies formed by the spreading of the Capricorn and Australia plates away from Antarctica.

During January and February 2005 during the transit from McMurdo Station to Punta Arenas, Chile (cruise NBP 05–01), project team members will survey several major features of the Antarctic Plate, including fracture zones, the fossil spreading system in the Adare Basin, and Cenozoic magnetic anomalies formed by the spreading of the Australia Plate away from West Antarctica.

These data will be used in combination with GPS-navigated data from the Pitman fracture zone, at the southwestern end of the plate boundary, and magnetic anomalies from previous cruises near the Menard Fracture Zone to improve high-precision plate reconstructions and evaluate the limits of possible internal deformation of the Pacific and antarctic plates in this sector.

Our results will contribute to knowledge of plate kinematics and dynamics, and lithospheric rheology. Moreover, we will integrate research and education by teaching 2 on-board marine geophysics classes to a total of 30 graduate and undergraduate students (some of them minorities). Classes will consist of daily lectures about the instruments and the data they record. In addition, each student will spend several hours a day standing watch and processing data and will also work on an individual independent research project. (G–071–N; NSF/OPP 03–38317 and NSF/OPP 03–38346)

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Stability of landscapes and ice sheets in the Dry Valleys, Antarctica: A systematic study of exposure ages of soils and surface deposits.

Jaakko Putkonen, University of Washington.

The near-perfect preservation of ancient, *in situ* volcanic ash and overlying sediments suggests that hyperarid cold conditions have prevailed in the McMurdo Dry Valleys for over 10 million years. The survival of these sediments also suggests that warm-based ice has not entered the valley system and that ice sheet expansion has been minimal. However, other evidence suggests that the Dry Valleys have experienced considerably more sediment erosion than is generally believed:

- The cosmogenic exposure ages of boulders and bedrock all show generally younger ages than volcanic ash deposits used to determine the minimum ages of moraines and drifts.
- There appears to be a discrepancy between the suggested extreme preservation of unconsolidated slope deposits (more than 10 million years) and adjacent bedrock that has eroded 2.6 to 6 meters during the same interval.

The fact that till and moraine exposure ages generally postdate the overlying volcanic ash deposits (a clear contradiction) could reflect expansion of the continental ice sheet into the Dry Valleys with cold-based ice, thus both preserving the landscape and shielding the surfaces from cosmic radiation. Another plausible explanation of the young cosmogenic exposure ages is erosion of the sediments and gradual exhumation of formerly buried boulders.

We will measure the accumulation of multiple cosmogenic isotopes in rock and sediment profiles to determine the minimum exposure ages, degree of soil stability or mixing, and shielding history of surfaces by cold-based ice to obtain unambiguous minimum ages for deposits. In addition, we should be able to identify areas disturbed by periglacial activity, constrain the timing of such activity, and account for the patchy preservation of important stratigraphic markers such as volcanic ash.

In a complex landscape such as the McMurdo Dry Valleys, individual exposure analyses will seldom give unambiguous ages for the surfaces. By contrast, our approach of looking at vertical profiles and multiple isotopes at a few sites will be considerably more informative. The result will be a better understanding of the stability of the East Antarctic Ice Sheet, which could fundamentally change how we view the dynamics of Southern Hemisphere climate on time scales of millions of years. (G–076–M; NSF/OPP 03–38224)

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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 (m) deep] and a vertical short-period instrument at 30 m. 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 thence to the Albuquerque Seismological Laboratory for general distribution to the international seismological community. This data set has beautifully complemented 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)

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Transantarctic Mountains Deformation Network: Global positioning system (GPS) measurements of neotectonic motion in the antarctic interior.

Terry J. Wilson and Dorota Brzezinska, Ohio State University, and Larry D. Hothem, U.S. Geological Survey–Denver.

We will conduct global positioning system (GPS) measurements of bedrock crustal motions in an extension of the Transantarctic Mountains Deformation Network (TAMDEF) to document neotectonic displacements caused by tectonic deformation within the West Antarctic Rift or mass changes in the antarctic ice sheets. By monitoring the U.S. and Italian networks of bedrock GPS stations along the Transantarctic Mountains and on offshore islands in the Ross Sea, we will tightly constrain horizontal displacements related to active neotectonic rifting, strike-slip translations, and volcanism. We will use GPS-derived crustal motions, together with information from other programs on the ice sheets and from ongoing structural and seismic investigations in Victoria Land, to model glacio-isostatic adjustments due to deglaciation and to modern mass changes in the ice sheets. The integrative and iterative nature of this modeling will yield a holistic interpretation of neotectonics and ice sheet history that will help us discriminate tectonic crustal displacements from viscoelastic/elastic glacio-isostatic motions.

We will do repeat surveys of key sites southward about 250 kilometers along the Transantarctic Mountains. These measurements will cross gradients in predicted vertical motion due to viscoelastic rebound. The southward extension will also allow us to determine the southern limit of the active Terror Rift and provide a better baseline for constraints on any ongoing tectonic displacements across the West Antarctic Rift system as a whole. Further, we will investigate unique aspects of GPS geodesy in Antarctica to determine how the error spectrum compares with that found in mid-latitude regions and to identify optimum measurement and data processing methods. The geodetic research will improve position accuracies within our network and will also yield general recommendations for other deformation-monitoring networks in polar regions.

An education and outreach program targeted at Ohio State University undergraduates who are not science majors will illuminate the research process for nonscientists. This effort will educate students about science and inform them about Antarctica and how it relates to global science issues. (G–079–M; NSF/OPP 02–30285 and NSF/OPP 02–30356)

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Mount Erebus Volcano Observatory and Laboratory (MEVOL).

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

Mount Erebus, Antarctica's most active volcano, is a rare example of a persistently active magmatic system. This volcano, which has a history of low-level eruptive activity associated with a highly accessible summit vent complex, also features one of Earth's few long-lived lava lakes. We are developing an interdisciplinary geophysics/geochemistry laboratory on Mount Erebus to pursue basic research on the eruption physics and associated magmatic recharge of active volcanoes. Erebus is especially appropriate because of its persistent open-conduit magmatic system, frequent eruptions, ease of access (by antarctic standards), and established scientific and logistical infrastructure, including real-time data links and relative safety.

The key integrated data-gathering components we will rely on include video surveillance and seismic, infrasound, Doppler radar, infrared, volcanic gas, and geodetic studies. To collect the data, a combination of core Mount Erebus Volcano Observatory and Laboratory (MEVOL)-supported personnel and their students (with specialties in seismology, gas studies, and general volcanology) will collaborate with internationally recognized volcano researchers (with specialties in infrared, Doppler radar, gas studies, and infrasound).

We will then develop quantitative models of the magmatic system of an active volcano, including eruptive energy balance (gravity; explosive gas decompression; and thermal, seismic, acoustic, and kinetic components) and magma recharge (volcanic tremor, convection, residence time, gas emissions, and deformation). We expect this research to contribute substantially to basic knowledge of active volcanoes around the world.

Another part of our work involves a project to develop and deploy integrated low-power, low-cost, real-time-telemetered volcano monitoring stations at Erebus and other active volcanoes. (Many volcanoes, particularly in the developing world, have little or no modern instrumentation.) The goal is to contribute to the development of low-power, low-cost interdisciplinary geophysical observatories within the larger seismology, geodesy, and geophysical communities.

Our work also includes the education of graduate and undergraduate students in volcanology and geophysics, the dissemination of information to high school audiences, and the provision of year-round monitoring information to the National Science Foundation and to McMurdo Station. Finally, to convey the excitement and relevance of volcanology and other aspects of earth science to society, we expect to continue public outreach through lectures, media interaction, and inquiry response. (G–081–M; NSF/OPP 02–29305)

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SHALDRIL, a demonstration drilling cruise to the James Ross Basin.

John B. Anderson, Rice University; Patricia Manley, Middlebury College; and Sherwood W. Wise Jr., Florida State University.

For over three decades, U.S. scientists and their international colleagues exploring the shallow shelves and seas along the margins of Antarctica have been consistently frustrated by their inability to penetrate the overcompacted glacial diamictons encountered at shallow subbottom depths (within the upper 10 meters) over these terrains. This has been particularly frustrating because advanced high-resolution seismic reflection techniques clearly show the presence of older successions of Neogene and even Paleogene sequences lying just beneath this thin veneer of diamictons in many areas. Until the means to recover these sequences are developed, a detailed history of the antarctic ice sheets—an essential prerequisite to understanding Cenozoic paleoclimates and future climate change on a global scale—will remain an elusive and unobtainable goal.

A group of U.S. scientists called the SHALDRIL Committee has identified at least two diamond coring systems deemed suitable for use on existing U.S. Antarctic Research Program ships. We will use one of these systems on the research icebreaker *Nathaniel B. Palmer* to demonstrate the feasibility of both ship-based diamond coring and downhole logging. We will core along a high-resolution seismic reflection dip line off Seymour Island, Antarctic Peninsula, an area of high scientific interest in its own right. Here the well-defined geologic section is estimated to range from Eocene to Quaternary in age, effectively spanning the "greenhouse-icehouse" transition in the evolution of antarctic/global climate. A complete record of this transition has yet to be obtained from anywhere along the antarctic margin.

We will correlate the record we obtain with detailed fluctuations of the ice margin recently recorded at higher latitudes in the eastern Ross Sea. If successful, SHALDRIL will be able to further explore the gap in our technical capability to explore the antarctic shelves between the shoreline/fast-ice margin and the continental slope. This technological breakthrough will not only address major outstanding scientific issues of the past three decades, but will also favorably affect many other current antarctic or drilling-related initiatives. (G–083–N; NSF/OPP 01–25922, NSF/OPP 01–25480, and

NSF/OPP 01–25526)

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Global seismograph station at 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 for 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, IRIS (the Incorporated Research Institutions for Seismology) 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 jointly 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, QSPA, achieves the quietest conditions on Earth at frequencies above 1 hertz. (G–090–P/S; NSF/EAR 00–04370)

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High-resolution seismic tomography and earthquake monitoring at Deception Island volcano, Antarctica.

William Sam Douglas Wilcock, University of Washington.

Deception Island volcano, located in Bransfield Strait, is an active, back-arc stratovolcano with a flooded caldera. All historical eruptions have occurred near the ring fracture and extended around the caldera. The three most recent, in 1967–1970, are unusual in that each involved simultaneous eruptions from multiple vents.

Although the volcano has not erupted for 30 years, it is still very active, but the size, distribution, and interconnectivity of subsurface magma bodies and their relationship to resurgence, the eruptions, and the distribution and style of faulting are poorly constrained. On the one hand, chemical differences between lavas would be best explained if the eruptions were fed by isolated shallow intrusive pods, but their synchronicity and distribution suggest that they may have been driven by an extensive magma body underlying the caldera. On the other hand, a recent model suggests that the caldera was formed by progressive passive extension rather than catastrophic collapse and implies that magma may be less widely distributed underneath.

Many experiments have monitored seismicity at Deception Island, but they have all been small and lacked seafloor stations. We will therefore deploy a joint marine-land seismic network around Deception Island for an antarctic summer to monitor seismicity and to conduct a high-resolution active-source tomography experiment. Our goals are to understand:

- the distribution of magma and its relationship to recent volcanic activity,
- the resurgence in the northeastern portion of the caldera, and
- the distribution of faulting and the state of stress and its relationship to volcanic and tectonic processes.

We will collaborate with a Spanish group and join cruises on the Spanish research ships *Hespérides* and *Las Palmas*. We will contribute 14 short-period, 3-component ocean bottom seismometers (OBSs) for the 10-week deployment of an earthquake network comprising these OBSs and about 10 land stations; some of these will include both short-period and broadband seismometers. This will be followed by the active source experiment using the airgun array on the *Hespérides* to shoot to a very dense land network and to the OBS sites. The P-wave tomographic image of the volcano we obtain will clarify the relationship between the seismic structure, the distribution and nature of earthquakes, and volcanic processes at Deception Island volcano. (G–135–E; NSF/OPP 02–30094)

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University NAVSTAR Consortium (UNAVCO) global positioning system survey support.

Bjorn Johns, UNAVCO.

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 (GPS) 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)

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