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In this issue...

For the first time in 160 days, the sun begins to rise over McMurdo Station, Antarctica, on 19 August 1997. Though austral spring is still a month away, the sun's return means resumption of flights to and from the base—and the end of isolation for the 154 Americans who spent the winter at the station. Within days of the sunrise, 60 new staff members as well as fresh food, newspapers, and mail were delivered to McMurdo. The rising sun also marks the beginning of a new field season on the southernmost continent.

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The *Antarctic Journal* has had several changes since its inauguration in 1966 as a medium for information about, and related to, the U.S. Antarctic Program. The magazine belongs to you, its contributors and readers. As always, NSF welcomes ideas for improvement. Comments should be sent either to WReuning@nsf.gov or to Editor, Antarctic Journal, Office of Polar Programs, National Science Foundation, 4201 Wilson Boulevard, Arlington, Virginia 22230.

The *Antarctic Journal* invites contributions from members of the antarctic science, logistics, and policy communities who want to communicate their work and ideas to an audience that combines specialists and scientifically literate nonspecialists. The *Antarctic Journal* is not peer reviewed but rather provides reports on U.S. activities in Antarctica and related activities elsewhere and on trends in the U.S. Antarctic Program.

***Reminder:* The deadline for submitting articles for the 1997 review issue of *Antarctic Journal of the United States* is 30 November 1997. The September 1997 online issue contains author guidelines for the 1997 review issue, as well as information about submitting materials for the new online issues.**

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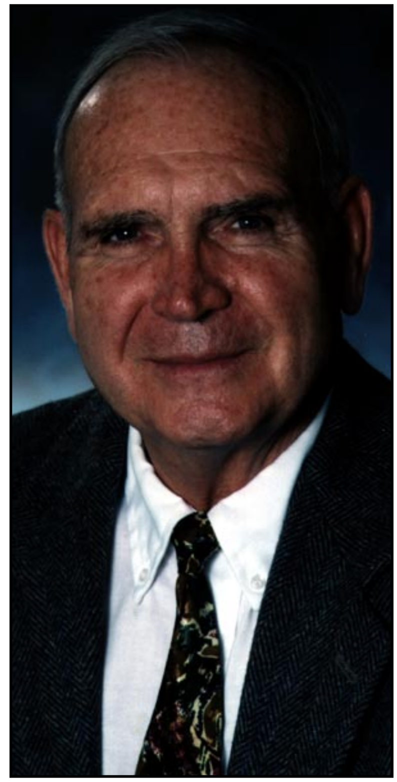
Interim head of the Office of Polar Programs appointed



The National Science Foundation (NSF) named John B. Hunt to serve as the Acting Director for the Office of Polar Programs (OPP). On 8 September 1997, Hunt assumed the post, which had formerly been held by Cornelius W. Sullivan.

Before becoming Acting Director of OPP, Hunt served as Acting Assistant Director for the Directorate of Mathematics and Physical Sciences (MPS) at NSF and, before that, had served in several other positions in MPS, beginning with Executive Officer of the Division of Chemistry and advancing to positions of increasing responsibilty within the directorate.

Before joining the NSF Chemistry Division in 1983 as a visiting scientist, Hunt was Professor of Chemistry at Catholic University of America in Washington, D.C., where he had been on the faculty since 1962. At Catholic University, his research dealt primarily with mechanisms of reactions of transition metal complexes. Following a sabbatical in the early 1970s at the National Institutes of Health (NIH), however, he turned his attention to metal ion-protein interactions. His other affiliations have included

- consultant to the Electrochemistry Division of the Naval Ordnance Laboratory in the area of fused salt batteries;
- consultant to the Red Cross Blood Services Laboratory on research related to blood platelets;
- member of the Board of Directors of the Marine Science Consortium at Wallops Island, Virginia, where he also taught courses in chemical oceanography; and
- member of the Strategic Advisory Committee of the Council for Chemical Research.

Hunt received his undergraduate degree in chemistry from Tulane University in 1955. He earned a masters degree in inorganic chemistry from Georgetown University in 1960 and a doctorate in inorganic chemistry from the University of Chicago in 1962. Hunt also served as an officer in the U.S. Navy for four years, two years aboard the USS *Iowa* and two years teaching chemistry at the U.S. Naval Academy.

At NSF/OPP, Hunt may be reached by electronic mail at *jbhunt@nsf.gov*, by phone at (703) 306-1030, and by fax at (703) 306-0645.

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Highlights of the 1997–1998 research season

The U.S. Antarctic Program will support 175 research projects, involving more than 750 science-team members, during the 1997–1998 austral summer season. This number is significantly higher than recent summer seasons because of the addition of a major oceanography program. In addition to oceanography, research will be performed in the scientific disciplines of biology, climate systems, geology and geophysics, atmospheric sciences, glaciology, and astronomy and astrophysics.

Projects are based out of three research stations—McMurdo, Amundsen–Scott South Pole, and Palmer—as well as on two research vessels—the R/V *Nathaniel B. Palmer* and a new vessel, the R/V *Laurence M. Gould*. In addition, researchers will be deployed to numerous small field camps.

The Cape Roberts Project

Preparations for ocean-bottom core drilling to 500 meters below the seafloor were begun in August at Cape Roberts on the Victoria Land coast about 125 kilometers northwest of McMurdo Station. The holes were to be positioned to provide an aggregate stratigraphic thickness of about 1,500 meters to give the first comprehensive data for the Cretaceous–Paleocene period (100 to 30 million years ago) in the Ross Sea region and East Antarctica. During that geologic period, the megacontinent of Gondwanaland underwent its final rupture as New Zealand and Australia moved northward away from Antarctica. The nearest existing sources for this period are in New Zealand, the southern ocean, and the northern Antarctic Peninsula.

Six nations are involved, including the United States. New Zealand has overall responsibility for the project's activities, which include the drill operations from a 2-meter-thick sea-ice platform. Researchers will have two goals as they study the cores extracted from the seafloor:

- to discover if ice sheets covered Antarctica causing fluctuation in worldwide sea levels before the glaciations of the last 36 million years and
- to date the rifting of the antarctic continent to help understand the formation of the Transantarctic Mountains and the Ross Sea.

For an update on the Cape Roberts Project, see "Sea-ice conditions force Cape Roberts drill team to withdraw early."

Glaciology studies continue at Siple Dome, end at Vostok

A field camp at Siple Dome near the east side of the Ross Ice Shelf will support up to 75 investigators studying the geophysics and glaciology of West Antarctica. Major fieldwork will involve airborne geophysics using an instrumented Twin Otter airplane, deep ice drilling, and instrumentation lowered into the ice-core holes. Researchers hope to improve understanding of the marine-based west antarctic ice sheet, which may yet be responding to global warming that has occurred since the end of the last ice age.

Siple Dome, a mound of ice between two fast-flowing ice streams that drain the ice sheet and are critical to its stability, is a key location for studying the west antarctic ice sheet. By studying the annual layers of ice deposited—and with them, the cloud water, atmospheric gases, and dust carried to Earth as snow fell and became ice—scientists hope to determine the nature of the current changes in the ice sheet and, ultimately, predict its future. In addition to studying the cores, scientists will also study the ice sheet's movement by dropping instruments into water-filled holes in the ice to measure vertical deformation of the ice. These in-hole instruments will take the first direct measurements of vertical velocity at a deep ice-core site.

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The joint U.S.-Russian-French project drilling the world's deepest ice core at Vostok Station will come to an end during the 1997–1998 season. Drilling stopped in January 1996 at a depth of 3,350 meters, a depth that covered about 400,000 years of snowfall and four glacial-interglacial cycles. This season, drillers will go 300 meters deeper, stopping about 50 meters above Lake Vostok to avoid contaminating the huge lake sealed beneath the ice sheet. For additional information, see the home page for the U.S. National Ice Core Laboratory.

LTER work at the McMurdo Dry Valleys and near Palmer Station

In the ice-free polar deserts of the McMurdo Dry Valleys, researchers will continue work on the Long-Term Ecological Research (LTER) project. McMurdo LTER scientists seek to understand the influence of physical and biological constraints on the area's ecosystems and how material transport modifies these ecosystems. Projects for 1997–1998 will include

- glacier mass balance, melt, and energy balance;
- chemistry of streams, lakes, and glaciers;
- flow, sediment transport, and productivity of streams;
- lake and soil productivity;
- meteorology;
- RADARSAT studies of wind transport of material; and
- ground-penetrating radar measurements of glaciers and frozen lakes.

The central hypothesis of the Palmer LTER project is that the annual advance and retreat of sea ice is a major physical determinant of spatial and temporal changes in the structure and function of the antarctic marine ecosystem. The 1997–1998 Palmer LTER studies will focus on the processes controlling the space/time variability of phytoplankton biomass and production. Team members will deploy near Palmer Station as well as aboard the R/V *Laurence M. Gould*.

The Joint Global Ocean Flux Study

During the 1997–1998 field season, the Joint Global Ocean Flux Study (JGOFS) will continue its international effort to examine the annual and seasonal variations in primary production rates. The movement, or flux, of carbon between the atmosphere and the ocean is greatly influenced by what happens in the southern oceans, and JGOFS researchers hope their studies will quantify and clarify those processes.

Two cruises aboard the R/V *Nathaniel B. Palmer* and four aboard the Scripps Institution of Oceanography vessel R/V *Roger Revelle* will take scientists to the Ross Sea and the Antarctic Polar Front Zone, respectively. In the Ross Sea, scientists will study the initiation of the phytoplankton bloom, the role of trace metals in controlling rates of production, and the fate of biogenic material. In the Polar Front Zone, the emphasis will be on the physical, chemical, and biological influences affecting the phytoplankton bloom; the temporal variability of the blooms; and the apparent paradox of high fluxes of biogenic material to the sea bed in a region of low mean annual primary production.

Long-duration ballooning

The National Scientific Balloon Facility will launch, track, and recover data and payload from an 81,200-cubic-meter, helium-filled long-duration balloon that will circumnavigate Antarctica in naturally occurring air currents at an altitude of about 38 meters for about 10 days. Two separate projects, one from the National Aeronautics and Space Administration's Goddard Space Flight Center in Maryland and one from the University

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of California at Berkeley, will gather information from the balloon's instrumentation. Sensors will measure gamma rays and x rays possibly originating from the highest known energy sources in the Universe: neutron stars, black holes, the center of the Galaxy, and other deep-space features.

The launches will be from McMurdo Station's Williams Field, on the Ross Ice Shelf, and will involve an LC-130 Hercules flying under the balloon to download data. As the balloon completes one circumnavigation of the continent, the mission will be terminated by radio from a plane, and the payload will be recovered.

Astrophysics research at Amundsen–Scott South Pole Station

AT the geographic South Pole, astrophysics projects will continue to collect data from the earliest moments after the Big Bang, taking advantage of superior observing conditions in the infrared portion of the spectrum provided by the extremely clear and dry atmosphere overhead.

The Antarctic Muon and Neutrino Detector Array (AMANDA), which places photomultiplier tubes between 1 and 2 kilometers deep in the ice sheet as a giant detecting medium, will record the arrival of very-high-energy neutrinos from active galactic nuclei or supernova remnants. AMANDA promises to be a large contributor to the new field of neutrino astronomy.

A new infrared and submillimeter telescope called VIPER will be installed, tested, and put into service at the South Pole during the 1997–1998 season. Using a large-aperture mirror that allows for better data resolution than was previously possible, VIPER will collect data about cosmic background radiation stemming from the early formation of the Universe.

Ozone depletion and ultraviolet-B effects

WHEN more than half of Antarctica's ozone cover disappears each austral spring, ultraviolet-B (UV-B) radiation from the Sun penetrates the stratosphere to the Earth's surface and into the sea. Scientists want to know how these increased UV-B levels affect the embryos and larvae of invertebrates in the shallow waters near Palmer Station on the Antarctic Peninsula. Another project at Palmer Station will study the photochemistry of seawater surrounding cells in organisms that are bombarded by increased UV-B. Such chemistry can influence how much damage is done to the cell surface. Still other work will quantify how ultraviolet light affects plankton, the base of the ocean food chain.

For information about the National Science Foundation's UV-B monitoring project, see http://www.biospherical.com/research/nsfrsrch/updates/austral/austral.htm and for the National Aeronautics and Space Administration's total ozone mapping updates, see http://jwocky.gsfc.nasa.gov/eptoms/epanim97.html

The 1997–1998 field season at the three U.S. stations

MCMURDO Station on Ross Island is the operational center for the U.S. Antarctic Program's continental portion, which includes work at Amundsen–Scott South Pole Station and remote field camps. During the 1997 winter, the McMurdo population was 154. Four C-141 Starlifter flights from Christchurch, New Zealand, in mid-August raised the population to over 300, enabling early-season science projects and preparation for summer. Summer operations began on 30 September and will continue until late February 1998. Although McMurdo's population could peak at 1,200, the weekly average is expected to be nearer 1,000.

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Amundsen–Scott South Pole Station at the geographic South Pole summer operations are scheduled to begin on 3 November 1997, preceded by two operational flights on 27 October. Thirty-seven science groups and 12 technical events are planned in physics, earth sciences, aeronomy and astrophysics, and climatology. In early December, the National Science Foundation will begin renovating existing facilities to modernize some and to make others safer for program participants at South Pole. Included in the renovations are the construction of a new garage and shop, fuel storage system, and power plant will be built. During the 1997–1998 season, the site will be prepared and a new arch to house the garage and shop will be erected. The new Atmospheric Research Observatory, completed in January 1997 to replace the old Clean Air Facility, will be dedicated in January 1998. The new observatory provides twice the space of the Clean Air Facility for research on climate, ozone, ultraviolet light, and other atmospheric studies. Winter isolation at South Pole Station will begin on 15 February 1998, when 28 people will remain through November to operate the station and conduct winter experiments.

Palmer Station, on Anvers Island west of the Antarctic Peninsula, will have 17 research and related events. Six more projects will be supported aboard the new R/V *Laurence M. Gould*, which will replace the now-retired R/V *Polar Duke.* Palmer Station opened on 15 September with the arrival of the R/V *Nathaniel B. Palmer*. Seven year-round monitoring projects will remain active when the station closes for the winter, despite the fact that few people stay at the station during the winter months.

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Sea-ice conditions force Cape Roberts drill team to withdraw early

Disappointed researchers abandoned work on Saturday 25 October 1997 at the first drill hole site for the Cape Roberts Project, an international effort to learn about the climate history of Antarctica by studying sediment cores from the ocean floor. A two-day storm in the southern ocean broke the sea ice around the drilling platform to within about a kilometer of the rig. In accordance with established safety procedures, drillers were evacuated from the rig when conditions were deemed dangerous. An aerial reconnaissance of the ice on which the drilling platform had been constructed revealed fresh sea-ice cracks and a risk of further ice movement. When the storm had passed, 20 drillers and support staff, working around the clock, disassembled the rig and pulled it, along with other equipment, 25 kilometers back to the base camp close to shore.

Dennis Peacock, section head, Antarctic Sciences Section of the Office of Polar Programs (seated near the window), and Steve Kottmeier of Antarctic Support Associates (standing next to Peacock), examine the core retrieved on 17 October by the Cape Roberts Project drillers.

Before the site had to be abandoned, it produced one core. About 30 meters of Quaternary sedimentary cover, which represents the recent advances and retreats of ice, and more than 90 meters of Miocene sediments were recovered on 17 October. The Miocene sediments fill a gap in current records, so they will be valuable for scientists trying to construct a picture of paleoenvironmental evolution. Working at the drill site and at McMurdo Station, a team of about 50 scientists from 28 institutions around the world has been studying the core samples, some as old as 17 to 22 million years, since their retrieval.

The Cape Roberts team had hoped to drill a second hole closer to shore to reach ocean-floor sediments expected to be 30 to 70 million years old, but the unseasonably warm temperatures and southerly storms caused the team to abandon drilling for the rest of the season. Chief scientist Peter Barrett of Victoria University in Wellington, New Zealand, praised the hard work of the project team in establishing the camp in bitter weather and recovering the core sample from a difficult hole, and he expressed regret that in the end, the team had to abandon the site on short notice. "We have made some significant finds," Barrett said, "proven that the technology works in this environment, and built operational science teams that put us in good stead for next year." Another hole is planned to be drilled in October and November 1998.

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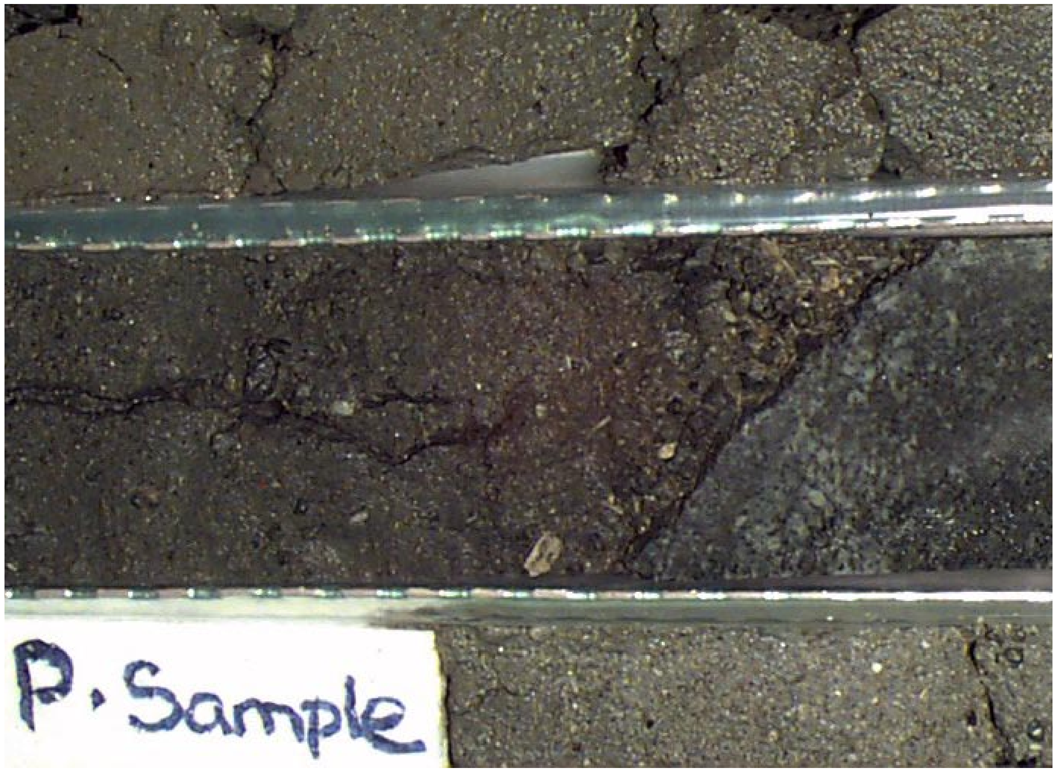

Section of the core recovered on 17 October. It was 1:30 a.m., but it was broad daylight, when the first core emerged, and the temperature was about –18˚C. When the first core came up, project director Peter Barrett knew that the team faced a race against the spring thaw to extract as much core as possible while temperatures were still low enough to keep the sea-ice beneath the drilling platform stable. He had hoped the drilling could continue until late November, but unseasonably warm temperatures and punishing storms threatened to break apart the sea ice much earlier in the season. For the safety of the crew and equipment, the drilling site was abandoned on 25 October.

For more information, see the Antarctica New Zealand Web site for press releases, and go to http://www.erim.org/CES/CapeRoberts for RADARSAT and other photos of the area.

Teachers at the Poles

Each year the National Science Foundation (NSF) sends a group of high school science teachers into the field to experience what life and work are like for U.S. scientists doing research in the polar regions. Over the next year, five teachers will head to the Antarctic and three to the Arctic to team up with NSF-sponsored researchers. The eight teachers will share their experiences with their schools back home via the Internet while they are away and in day-to-day interactions with their colleagues and students when they return home.

It's TEA time

This hands-on research experience program, called Teachers Experiencing the Antarctic/Arctic (TEA), owes its existence to a Massachusetts teacher named Peter Amati. In 1992, one of Amati's students was named to the NSF's Young Scholars Program. Amati accompanied the student to the orientation workshop and learned that one of the goals of the Young Scholars Program was to extend the participant's science experience to the classroom. A teacher could do that even more effectively than a student could, Amati thought. Participating young scholars, he reasoned, may gain a great deal from the program, but then the student graduates and moves on, and his or her impact on younger students in the school's science program is minimal. Teachers, on the other hand, could relate what they learned to other teachers, the students, and the community for the rest of their professional lives. NSF took Amati's suggestion, and in the inaugural year of the TEA program, Amati spent two months with scientists aboard a research vessel in the Weddell Sea, Antarctica.

NSF funds the TEA program for each teacher participant, covering costs for meetings and workshops, transportation, and the required medical exam. NSF also provides funds to the school district to hire a substitute teacher. Cold weather gear is loaned to the teacher by the U.S. Antarctic Program, and meals and housing are provided by the institution sending the research team, to which the teacher is paired, to the field.

Prospective participants are nominated by principal investigators of NSF-sponsored teacher enhancement programs and then must complete an extensive application. To be accepted into the TEA program, each TEA participant must

- have participated in an NSF-funded teacher enhancement or research project;
- be certified in his or her science discipline at the high school level; and
- be able to pass a rigorous physical examination.

Once in the program, each TEA teacher must

- arrange with the school district for his or her absence from the classroom and participation in the program, making plans to enhance classroom impact of his or her experience;
- participate in the summer research preparation and the field experience; and
- meet or surpass the NSF expectations for sharing his or her experiences with teachers, students, and the community through presentations, by developing classroom materials, and by keeping, and sharing, a journal.

After returning from the field, many TEA teachers continue to collaborate with their research teams. Some visit the research institution during the following summer to complete the project, write their findings in journal articles, and involve their students in research.

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Read all about it

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Five teachers to the South Pole

During this past summer, the teachers involved in the 1997–1998 program visited the antarctic researchers at their home universities for training on their specific research projects. Teachers were also prepared for the expeditions by meeting with past TEA teachers and attending an NSF orientation program.

This year's teachers, and the research teams with which they have been paired, come from all corners of the United States:

- *Tom Geelan* teaches biology and evolution at the City Honors School in Buffalo, New York. Tom is spending October and November 1997 at McMurdo Station working with biologist Donal Manahan's team of researchers from the University of Southern California. Working on the ice near McMurdo and at Crary Science and Engineering Center at the station, Tom will investigate embryonic and larval development of antarctic echinoderms.

- *Besse Dawson* is a marine science teacher and science department chair at Pearland High School in Pearland, Texas. During January and February 1998, Besse will work aboard the NSF's new research vessel, the R/V *Laurence M. Gould*, with a team from the University of Hawaii headed by biologist David Karl. Besse will collect samples from the waters around the Antarctic Peninsula and will visit Palmer Station.

- *Kim Giesting*, from Connersville, Indiana, teaches astronomy, oceanography, environmental science, and earth/space science at Connersville High School. From 18 January to 20 February 1998, Kim will work with marine geologist John Anderson's team from Rice University in Houston, Texas, aboard the R/V *Nathaniel B. Palmer* as part of a long-term study of the antarctic continental shelf stratigraphy and the fluxes of the west antarctic ice sheet.

- *Paul Jones* teaches high school science in the Montezuma Community Schools, Montezuma, Iowa. Paul will join a research team from the University of Alabama lead by earth scientist Berry Lyons from mid-November to late December 1997. Paul will help monitor stream flow in the McMurdo Dry Valleys as part of the McMurdo Long-Term Ecological Research project.

- *Sandra Shutey*, from Butte High School in Butte, Montana, will join a team headed by glaciologist Mary Albert from the U.S. Army's Cold Regions Research and Engineering Laboratory in Hanover, New Hampshire. During November 1997, Sandra will participate in ice-core drilling on Siple Dome.

Read all about it

A detailed description of the program and the participants and some of the teachers' journal entries are available on the World Wide Web at http://www.glacier.rice.edu/chapters/tea/tea_introduction.html.

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U.S. Antarctic Program news

National Science and Technology Week '98 to focus on the poles

HOW are the Arctic and the Antarctic different? Why do scientists consider the Antarctic to be a desert? How does the southernmost continent affect the weather in my town? What animals live at the poles? Questions like these will be the focus of the 1998 National Science and Technology Week (NSTW), "Polar Connections." NSTW's goal is to engage children and adults in communities across the country in science activities that are both fun and informative and to help all participants understand how science and technology benefit them daily.

Started in 1985, the NSTW is an education and public outreach program of the National Science Foundation (NSF). During the upcoming NSTW, 26 April to 2 May 1998, thousands of other organizations, including schools, museums, zoos, community groups, businesses, and professional organizations, will join with NSF to sponsor activities designed to encourage program participants to do what scientists studying the polar regions do: to ask questions; to collect, observe, and analyze data; and to draw conclusions.

"Few areas of the world capture the imagination like the unspoiled wilderness of the polar regions," says Julia Moore, NSF's director of legislative and public affairs. "Their rich natural and human history is one of triumphant adaptation to extreme conditions, and their undeniable impact on our lives challenges us to exciting scientific exploration and discovery."

Four antarctic naval commands receive commendations

FOR achievements that included transporting more than 50 million pounds of fuel and cargo to antarctic bases, carrying more than 5,000 passengers to the Antarctic and from site to site on the continent, and responding rapidly in two life-threatening emergencies, four U.S. Navy commands serving in Antarctica were awarded the Meritorious Unit Commendation on 14 March 1997.

The award, which covered the period from 1 April 1995 through 31 March 1996, was presented to

- U.S. Naval Support Force, Antarctica;
- Antarctic Development Squadron SIX;
- Naval Support Force, Antarctica Detachment McMurdo; and
- U.S. Naval Antarctic Support Unit, Christchurch, New Zealand

in recognition of the superior performance and achievements of these commands during Operation Deep Freeze 1995–1996.

OPP staff welcomes Dr. Marinelli

ROBERTA L. Marinelli, whose home institution is Skidaway Institute of Oceanography in Savannah, Georgia, has joined the Office of Polar Programs (OPP) staff to serve for two years as the associate program manager for Polar Biology and Medicine. Dennis S. Peacock, section head of the Antarctic Section of OPP, reports that Marinelli's field of research "is broadly defined as benthic biological oceanography, with an emphasis on the ecology of individuals and populations in sedimentary systems. She incorporates chemistry, physics, and mathematics to address issues in the relationship among organ-

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isms and their environment. Her experience is not only benthic, but includes research in intertidal, subtidal, continental-shelf, and open-ocean systems. This interdisciplinary background will make her a very valuable member of the OPP team."

Marinelli can be reached at OPP by electronic mail at *rmarinel@nsf.gov*, by phone at (703) 306-1033, or by fax at (703) 306-0139.

Artists and Writers Program participant publishes book about Antarctica in UK

"First you fall in love with Antarctica and then it breaks your heart," begins the Kim Stanley Robinson science fiction novel *Antarctica* released by Harper-Collins in the United Kingdom in September 1997 and slated for release in the United States soon. Robinson says the opening line of his novel very much reflects his own feelings about the continent, which he visited as a 1995–1996 participant in the National Science Foundation's (NSF) Artists and Writers Program. "[Antarctica] has a strange power over the emotions," Robinson says. "Almost everyone who is down there has a feeling for it and wants to go back, becomes an advocate of it and falls in love with it." But, he adds, "Antarctica is sensory deprivation. ...even though you fall in love with it, you come back to New Zealand, and you are just overwhelmed by the smells and by the greenery, and you realize that there is a beautiful, beautiful world, and Antarctica is not beautiful. It is sublime, but it is not beautiful."

Robinson, whose literary awards for his science fiction writing are many, recently received the 1997 Hugo award for *Blue Mars*, the third novel in his *Mars* trilogy. Famed science fiction writer Arthur C. Clarke proclaimed Robinson's trilogy "required reading for the colonists of the next century." *Antarctica*, an eco-thriller, envisions a future in which Antarctica has been overtaken by oil reconnaissance teams who plan to plunder the continent for its natural resources, adventure travelers who litter the landscape with trash, and strategic interests who plot to gain influence.

The NSF Antarctic Artists and Writers Program annually supports a small number of scholars from the arts and humanities to participate in the U.S. Antarctic Program. The artists and writers work at U.S. stations and camps to create works that portray the region or human activities there. During the 1997–1998 season, three participants will travel to Antarctica under the auspices of the program:

- Gretchen L. Legler, an assistant professor of English and Creative Writing from the University of Alaska at Anchorage, will write a nonfiction book, as well as essays and magazine articles, about the natural world of Antarctica.
- Norbert Wu, an underwater photographer from Pacific Grove, California, will collect photographs that illustrate the natural history of the McMurdo Sound region.
- Rebecca L. Johnson, a South Dakota writer who has published several books about Antarctica, will write a book about antarctic fossils for middle schoolers.

Deadline for new LExEn competition set for 15 January 1998

The National Science Foundation (NSF) is highlighting its interest in the Life in Extreme Environments (LExEn) interdisciplinary program by sponsoring a special competition. Proposals for 2- to 5-year research projects that will enhance understanding of the microbial systems on Earth, particularly with respect to their diversity and the mechanisms that allow them to survive in and alter extreme environments, are invited.

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Funds available to support projects under this special competition are expected to total approximately $6 million. NSF anticipates making approximately 20 awards in fiscal year 1998. Review and processing of proposals will take about 6 months.

Possible antarctic geological repository considered

The National Science Foundation's Office of Polar Programs (OPP) estimates that since the 1960s, about 36,000 samples of rock and other geologic materials have been retrieved from the Antarctic by 82 funded investigators during multiple field studies. Because the U.S. Antarctic Program (USAP) has no centralized antarctic rock storage and curation facility, these samples are kept at various institutions scattered across the country. Lack of a centralized facility means that

- other researchers often have no access or poor access to collected materials;
- samples, which are not only costly to collect from Antarctica but which are virtually irreplaceable because of the inaccessibility of some antarctic locales, are in danger of becoming lost or misplaced;
- institutions may discard samples when the investigator who collected them retires, changes employment, or dies;
- no central catalog of collected samples exists.

To remedy this situation, OPP is investigating the possibility of organizing an antarctic rock and fossil repository and welcomes input from the science community on whether a repository should be established and, if so, how it should be structured and run. Suggestions and proposals will be most helpful if received by 1 February 1998.

An update on the Gould*: Dedication held in Louisiana*

Edison Chousest Offshore, Inc., of Galliano, Louisiana, has nearly completed the construction of the R/V *Laurence M. Gould*, the National Science Foundation's (NSF) new year-round antarctic research vessel. The ice-strengthened *Gould* replaces the research ship *Polar Duke*, chartered by NSF from 1985 to 1997. The *Gould*, which boasts accommodations for 26 research scientists, is capable of 75-day missions. In addition to supporting oceanographic and marine biological research in the Antarctic Peninsula region, the *Gould* will carry passengers and supplies between Palmer Station and South American ports. A dedication ceremony on 9 October 1997 marked the start of the *Gould*'s antarctic mission.

Laurence McKinley Gould, for whom the ship was named, was not only a polar explorer with Admiral Byrd, he was also a geologist, teacher, and president of Carleton College. He died at the age of 99 in 1995 and was remembered in moving tributes at the dedication ceremony by several of his long-time co-workers from Carleton College and from the University of Arizona, where he also taught. The *Gould* was christened by Ruth Siple, widow of Paul Siple, who had been the first U.S. science leader at the South Pole during the International Geophysical Year (1957–1958) and who, as a Boy Scout, had accompanied Byrd and Gould to Antarctica in 1929.

The *Gould* will arrive in Fourchon, Louisiana, on 3 November for sea trials and will then depart for Punta Arenas, Chile, on 8 December. The ship is scheduled to arrive in Punta Arena for its first cruise in January 1998.

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The NSF-chartered research vessel *Laurence M. Gould*, named for the second in command to Admiral Richard E. Byrd on his first antarctic expedition (1929–1930), was dedicated in a ceremony near New Orleans on 9 October 1997. Photo credit: Teresa McLain, USAP.

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RADARSAT: Making a digital mosaic of Antarctica

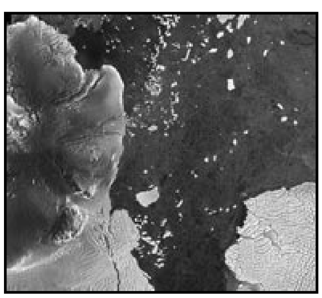
WHEN the Canadian Space Agency's RADARSAT mission began transmitting images of Antarctica as part of the Antarctic-1 Mapping Mission (AMM), National Aeronautics and Space Administration (NASA) officials were astounded at what they saw. "The quality of these first images is quite stunning," said Robert Thomas, program manager for polar research in NASA's Office of Mission to Planet Earth, Washington, D.C. "Antarctica is the only continent on Earth that has not been properly mapped. Despite many years of research, we still do not know whether this massive ice sheet is growing larger or smaller. RADARSAT's Antarctic Mapping Mission should help us answer this question, and many related questions about its potential for affecting global sea levels."

Unprecedented detail of a massive continent

FOR about 18 days in September and October 1997, RADARSAT took over 5,000 digital synthetic aperture radar (SAR) images of Antarctica, a region the size of Canada and Alaska combined. Over the next 1½ years, the Byrd Polar Research Center of Ohio State University will use the data gathered by RADARSAT to produce a high-resolution mosaic of the entire continent. Byrd cartographers have dubbed the project "RADARSAT: The Antarctic Mapping Project," or RAMP.

The RADARSAT-based map will not only help scientists understand the dynamics of the antarctic ice sheets but also will provide them with a benchmark for testing the predicted effects of global warming on Antarctica's ice and for determining the effects of human activity on the continent. Antarctica holds nearly 70 percent of the Earth's freshwater, so changes in this enormous reservoir directly influence world sea level and climate; monitoring changes is vital. Using the RADARSAT data, scientists will be able to examine, at high resolution and on a continent-wide scale, the effects of complex climatological, glaciological, and geological processes on Antarctica.

Initial images reveal details of antarctic ice streams and crevices as well as of the old, long-buried aircraft runway and structural remains of the international South Pole research station established in the 1950s. The image of the old station and several other images are available on the Internet at http://radarsat.space.gc.ca and http://radarsat.space.gc.ca/ENG/AMM/amstn.html. RADARSAT is capable of acquiring high-resolution images of Earth's surface day or night and under all weather conditions—even under conditions of smoke, haze, and smog. It can capture images as wide as 500 kilometers and can detect objects as small as 8 meters.



Bear Peninsula, Smith Glacier, and a portion of the Thwaites Glacier located in Pine Island Bay (106˚W 75˚S) are shown in this RADARSAT image. This region was first mapped during the late 1940s as part of Operation High Jump, which included participation by Admiral Richard Byrd. Thwaites Glacier drains about 7 percent of the interior east antarctic ice sheet. It reaches a velocity of nearly 3 kilometers per year.

International effort pays off to chart the last unmapped regions on Earth

ON 4 November 1995, NASA launched the Canadian satellite from Vandenberg Air Force Base. In exchange for NASA's launching of RADARSAT, Canada agreed to provide U.S. sci-

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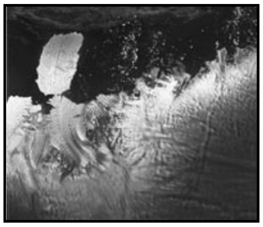
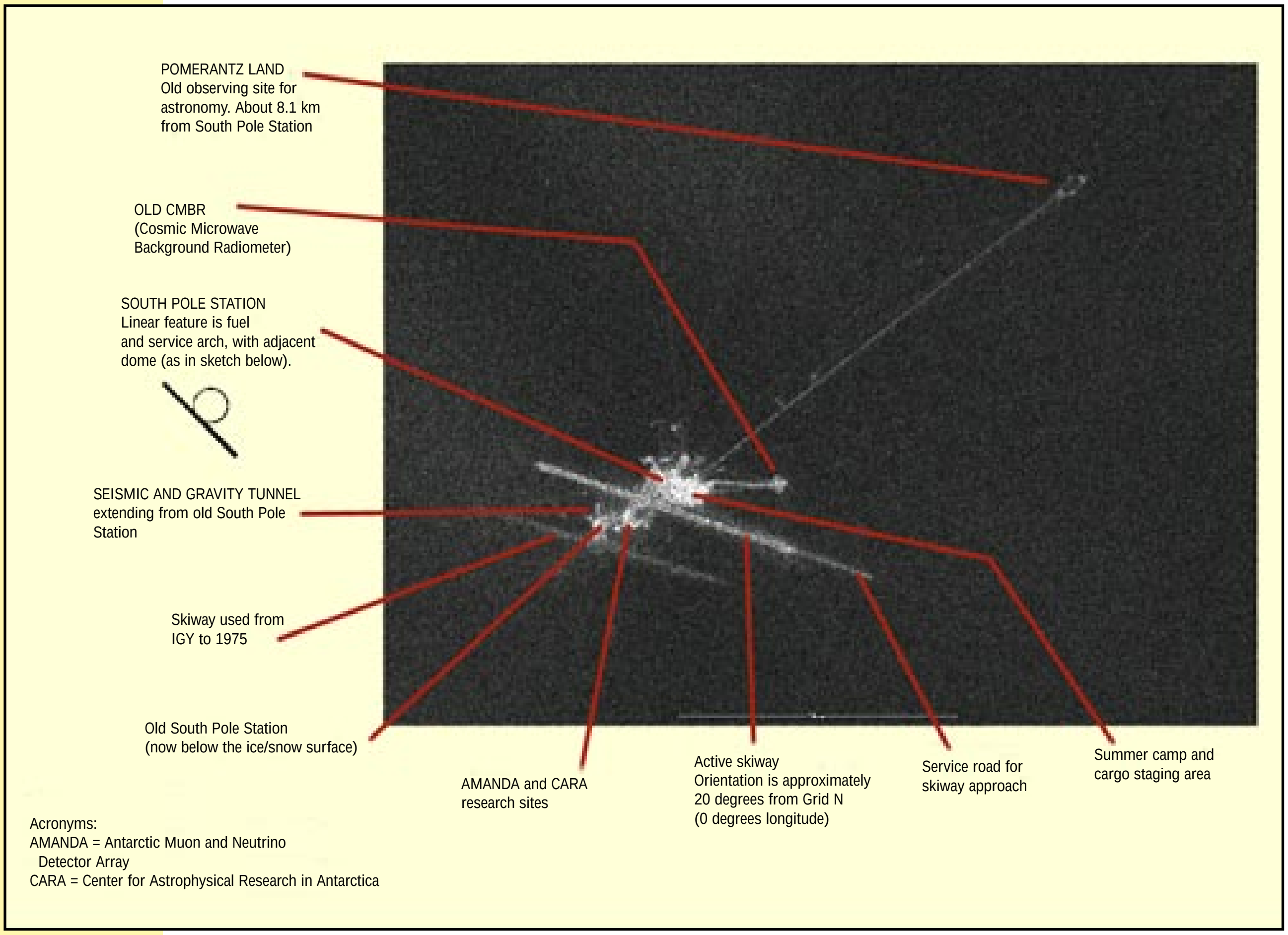
entists with a proportionate amount of the data gathered and to execute a yaw maneuver that would put the normally right-looking satellite into what mapper's termed the "Antarctic Mode," a 180˚ rotation to allow the radar to image to the left of the satellite track. Earlier satellites could not get an image of the entire continent because of their orbit inclinations, their field of view, or both.

The coast of Princess Elizabeth Land in East Antarctica is shown in this RADARSAT image. An enormous tongue of glacial ice (about 20 kilometers long) has broken off from a glacier and formed a serrated iceberg. Glacier flow patterns are clearly evident.



NASA's Alaska SAR Facility in Fairbanks served as the primary data collection site and was supported by collections at the Canadian Gatineau and Prince Albert Ground Stations. Receiving stations forwarded the data to Byrd Polar Research Center. When the final mosaic is complete, it will be distributed on CD-ROM through the Alaska SAR Facility and the National Snow and Ice Data Center in Boulder, Colorado.



Both the old and new facilities are visible in this RADARSAT image of Amundsen–Scott South Pole Station.

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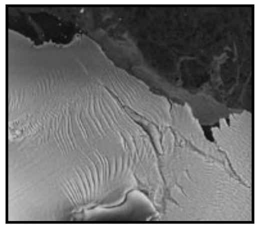
Although the United States and Canada were the primary collaborators in this effort, support from the international science community has been invaluable. "The job of mapping one of the last largely unexplored regions of the Earth is truly a mission of international collaboration that includes scientists from Great Britain, Germany, Japan, and Australia in addition to the United States and Canada," said Kenneth Jezek, a professor of geological science and director of the Byrd Polar Research Center. "In that way, the Antarctic Mapping Mission is in keeping with the spirit and intent of the Antarctic Treaty, which serves to preserve the continent for peaceful scientific research by any nation."



This RADARSAT image shows a portion of the Princess Ragnhild Coast. Ice flows around a central island causing cavernous rifts to form. One of the rifts nearly cuts through a 30-kilometer-long slab of ice shelf and, eventually, will form a tabular iceberg of the kind characteristic of Antarctica.

Science notebook—
News from Antarctica and beyond

Researchers endure record temperatures

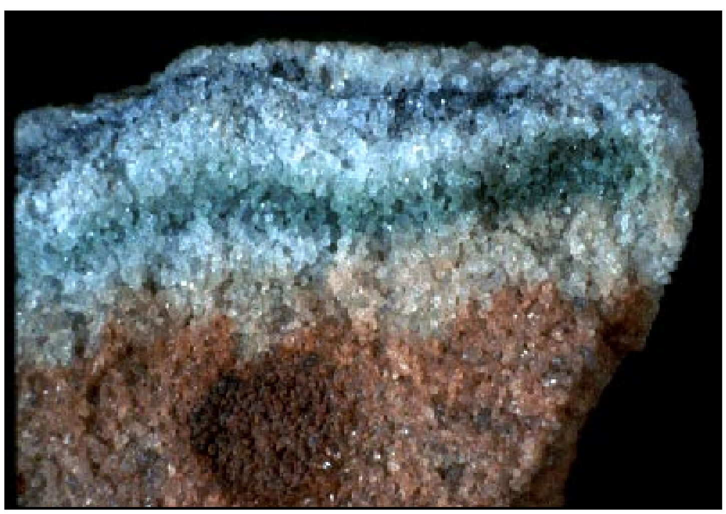
Temperatures in July at Amundsen–Scott South Pole Station were the coldest ever recorded since records began being kept in January 1957. The average monthly temperature at the station was –66.0˚C (–86.8˚F), breaking the old record of –64.3˚C (–83.7˚F) set in July 1965. The lowest temperature during the month, –77.9˚C (–108.2˚F) recorded on 29 July, broke a previous record for the date set in 1979.

"These very cold days provide the best conditions for astronomical observations—clear skies and low wind," commented South Pole meteorologist Matt Wolf, one of 28 people spending the winter at the research station. "On the downside," Wolf added, "power usage is at a maximum and vehicle operation is almost impossible." Amundsen–Scott South Pole Station, run year round by the National Science Foundation, supports ongoing studies in astronomy, astrophysics, atmospheric sciences, and other disciplines.

Temperatures in August followed suit. Although the monthly average did not break a record, two record daily lows were reached. On 30 August, the temperature dipped to –76.1˚C (–105.0˚F), breaking the previous record for the date of –72.0˚C (–97.6˚F) set in 1995, and on 31 August, the low of –76.4˚C (–105.5˚F) broke the old record for the date of –73.9˚C (–101.0˚F) also set in 1995.

Life in Extreme Environments award initiative examines the limits of life on Earth—and elsewhere

Scientists have found microbial life in some of the most unlikely places on Earth—in hyper-arid deserts, deep in the Earth's crust thousands of meters below the surface, entombed in ice sheets at the poles, in the bone-crushing, deep-ocean pressure of the Japan Trench, and even in human-engineered environments such as those created for industrial processes. To explore what life forms from these extreme habitats might tell us about the history of life on Earth as well as the possibility of life beyond our planet, the National Science Foundation (NSF) has launched a $6 million research initiative, Life in Extreme Environments (LExEn), involving more than 20 research projects and 40 scientists.



This Beacon sandstone from the McMurdo Dry Valleys gives evidence to the presence of life in extreme environments. The blue bands are layers of algae, fungi, and bacteria know as cryptoendolithic organisms, or organisms that live just below the surfaces of rocks. Photo courtesy of E. Imre Friedmann.

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"Life flourishes on Earth in an incredibily wide range of environments," explains Mike Purdy, coordinator of the NSF award initiative. "These environments may be analogous to the harsh conditions that exist now, or have existed, on Earth and other planets. The study of microbial life forms and the extreme environments they inhabit can provide new insights into how these organisms adapted to diverse environments and can shed light on the limits within which life can exist."

One contingent of the LExEn awards will focus on microbial life in Antarctica. Four studies will examine the relationship between microbes and the harsh south polar environment.

- "Protistan biodiversity in antarctic marine ecosystems: Molecular biological and traditional approaches." David A. Caron from Woods Hole Oceanographic Institute in Massachusetts will identify algae and protozoa in the sea ice, sediment, and ocean environments of the Ross Sea.

- "Microbial life within the extreme environment posed by a permanent antarctic lake." Christian H. Fritsen from Montana State University will examine the survival mechanisms of viable microbial cells found in sediment aggregates in the permanent ice covers on the lakes of the McMurdo Dry Valleys.

- "Longevity and diversity of microorganisms entrapped in tropical and polar ice cores." John N. Reeve from Ohio State University will identify and study microorganisms found in ice cores taken from high-altitude environments in tropical latitudes, such as the Tibetan Plateau and the South American Andes, and from both polar regions.

- "Biology and ecology of south pole snow microbes." Gordon T. Taylor from the State University of New York at Stony Brook will attempt to confirm signs of microbial life found recently near Amundsen–Scott South Pole Station and, if the presence of life is confirmed, will attempt to determine if it is indigenous to the interior region or if it was brought in from coastal Antarctica, where microbial life is known to exist.

All 20 LExEn projects will involve finding techniques for isolating and culturing microbes found in extreme environments, developing methods of studying these microbes in their natural habitats, and devising technologies for recovering noncontaminated samples.

Antarctic ice sheet may not be as stable as scientists once thought

On the North Island of New Zealand, scientists have uncovered a remarkable record of sea-level fluctuations in a section of ancient coastline. Researchers believe that the story written on that nearly 5-kilometer-thick rock reveals that the massive east antarctic ice sheet has melted and frozen repeatedly and—on a geologic time frame—rapidly during its history. Further, researchers reason, New Zealand's coastline could not have been the only one to experience dramatic changes; other coastlines of the world must have varied as well.

Scientists once considered the antarctic ice sheet to be one of the most stable features on the Earth's surface. During the last decade, however, some scientists have begun to question that stability, pointing to new research that suggests that the ice sheet diminished greatly sometime in the last several million years. Understanding just how stable the ice sheet has been over history will help scientists predict how global warming might affect sea levels in the future. Should the ice in Antarctica melt completely—an unlikely scenario—the world's oceans would rise 60 meters, the height of a 12-story building.

Gary Wilson, a postdoctoral fellow at the Byrd Polar Research Center at Ohio State University, believes that the New Zealand find points to a volatile, rather than a stable,

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history for the east antarctic ice sheet. "The most striking thing about this record is the variability it shows," Wilson said. "There are more than 30 rises and falls of global sea level—changes of as much as 65 feet—between 2 and 6 million years ago." Wilson believes that these changes can be attributed to growing and shrinking of the antarctic ice cover. Large-scale changes, during which the mass of the current ice sheet diminishes or increases by half, occur about every 3 million years, according to Wilson's theory, and small-scale changes, reductions and increases of about a quarter of the current mass of the ice sheet, could be occurring, he believes, as often as every 300,000 years.

Fossil crayfish finds suggest earlier date, warmer clime for the origin of this species

In an ancient glacial lake bed on Mount Butters, John Isbell, a geologist from the University of Wisconsin at Milwaukee, made an unexpected find: a fossilized crayfish claw far older than any other ever found. Until now, scientists believed that crayfish first appeared about 220 million years ago, during the Mesozoic Era. Isbell's find pushes that date back 65 million years to the Carboniferous–Permian boundary, late in the Paleozoic Era. "For the first time, we now have fossils of freshwater decapod (10-legged) crustaceans that date back to the Paleozoic Era," commented Loren Babcock, associate professor of geological sciences at Ohio State University, who first determined that the fossil was the end of a crayfish's fixed finger, the stationary part of the claw. "The presence of crayfish in deposits this old," Babcock explained, "tells us that there probably were very complex freshwater ecosystems thriving by the end of the Paleozoic."

Babcock estimates that the crayfish from which the claw came was 15 to 30 centimeters long. Then as now, crayfish served both as a vehicle for cycling nutrients through freshwater ecosystems and as a primary food source for other animals. The fossil claw, Babcock speculates, was probably what was left from a predator's meal.

Another find, this one by Vanderbilt University geologist Molly Miller and Ohio State University professor emeritus of geological sciences Jim Collinson, not only supports the early development of crayfish indicated by Isbell's find, but also indicates that when the species first appeared, Antarctica was far warmer than it is now. Miller and Collinson found intricate networks of ancient crayfish burrows in deposits of rock along Kitching Ridge, about 37 kilometers from Isbell's find on Mount Butters. Some of the burrows are over 100 centimeters long and up to 15 centimeters in diameter, and they strongly resemble the burrows of modern crayfish digging in warm stream banks. "Crayfish have a very narrow temperature range within which they have to live," Babcock pointed out. "They usually must have free running water that is between 10˚C and 20˚C (50˚F and 68˚F) for at least three months out of the year. So if they were there, the climate had to be at least that warm." If Antarctica were that warm, Babcock extrapolated, "I don't know what that means for total world temperature, but my impression is that it would be pretty warm."

Famous Martian meteorite to be studied in greater depth

After headlines around the world announced that a meteorite found in the Allan Hills region of Antarctica might hold fossilized evidence of microbial life on Mars, both the National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA) called for further research. Working together, the two agencies have launched an interdisciplinary program and funded studies (19 by NASA, 7 by NSF) to investigate possible traces of ancient Martian life in the meteorite, designated ALH84001 by the researchers who found it in 1984.

Some research will analyze ALH84001 itself; other studies will focus on terrestrial regions that have features similar to those of ancient Mars, such as hot springs and other extreme

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Robot tests complete—Ready for missions to Antarctica, the Moon, and Mars

habitats of Earth microbes, to provide a better context for understanding the structure of ALH84001. The new research will include

- scanning for extremely fine-scale alteration of the mineral interface by microbes;
- analyzing oxygen and carbon isotopes to determine if they reflect a ratio typical of microbial life;
- developing a chemical method to find signs of biological activity in meteorites;
- examining mineral particles—oxides and sulfides of iron—which have potential as biomarkers (signs of past life);
- describing the type of carbonate and associated minerals found in ALH84001 and determining the conditions and mechanisms that formed these minerals;
- understanding the sources and possible biogenicity of carbon in ALH84001; and
- delineating the rock's temperature history and its past infiltration by fluids.

Robot tests complete—Ready for missions to Antarctica, the Moon, and Mars

WEIGHING in at 720 kilograms, a four-wheeled robot named *Nomad* successfully completed 45 days of testing during June and July 1997 in Chile's barren, cold, and rugged Atacama Desert, paving the way for its use in Antarctica and on space missions to other worlds. During its testing, Nomad, which is about the size of a small car, traveled farther than any remotely controlled robot ever had, logging in 215 kilometers over extremely rough, high-elevation terrain, and proved its capability to respond to commands, gather samples, and send back color stereo video with human-eye resolution. Though usually controlled by scientists more than 8,700 kilometers away, Nomad often worked on its own, putting to use its four-wheel drive, four-wheel steering, and expandable chassis to avoid obstacles. It recognized meteorites planted in the desert by testers and retrieved them, and it may even have found a fossil.

"During different phases of testing," said Dave Lavery, telerobotics program manager at the National Aeronautics and Space Administration, which funded the development of the robot by Carnegie-Mellon University in Pittsburgh, "we configured the robot to simulate wide-area exploration of the Moon, the search for past life on Mars, and for the gathering of meteorite samples in the Antarctic. Nomad met or exceeded all of our objectives for this project."

Nomad's successor will join its human counterparts to search for meteorites in Antarctica during 1998 and 1999, but so far it has not been scheduled for any upcoming space missions.

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Current Antarctic Literature *highlights*

Current Antarctic Literature, regarded as the world's most comprehensive antarctic abstracting and indexing service, is the monthly awareness service of the *Antarctic Bibliography*. As of 1 January 1997, it is no longer available as a printed publication. The complete *Antarctic Bibliography* file, which extends back to 1951, will be available for online searching on the Library of Congress Project World Wide Web site in 1997.

Uncopyrighted items cited in *Current Antarctic Literature* are available from the Library of Congress, Photoduplication Service, Washington, DC 20540.

The Office of Polar Programs, National Science Foundation (NSF), sponsors *Current Antarctic Literature* as part of the Cold Regions Bibliography Project, Science and Technology Division, Library of Congress, which enjoys substantial collaboration with Scott Polar Research Institute, Cambridge, England. Comments may be sent to the project (**crbp@loc.gov**) or the sponsor (**gguthrid@nsf.gov**).

Suggestions for items to be cited are welcome (**crbp@loc.gov**). Please include complete bibliographic information. Suggested items should be consistent with the project's Sponsor Interest Profiles and Selection Criteria, on the Cold Regions Bibliography Project home page. For the Antarctic, NSF's interests are geographic (limited to the antarctic region) but cover all science disciplines.

U.S. Army Cold Regions Research and Engineering Laboratory
72 Lyme Road, Hanover, New Hampshire, 03755 USA
CRREL Public Affairs Office: or 603-646-4386
Library Web Pagemaster: or 603-646-4238

For bibliographic citations and abstracts see:

http://www.crrel.usace.army.mil/library/aware/antlit.htm.

September 1997 highlights

The moss *Drepanocladus uncinatus* harbors 2 species of mites which tolerate prolonged submersion in freshwater B-57603

Marine food web and krill resource management are affected by regional warming and reduced krill abundance... B-57607

PCR is found to be a useful method to detect bacteria of human origin in antarctic environments B-57618

Antarctic dry valleys are a valuable analogue for detecting microbial life and diversity on Mars B-57626

Colonization of antarctic environments by individual species may have been very recent in evolutionary time scales..B-57627

Acinetobacter ADH-1 could be potentially useful to design bioremediation processes in cold climate areas E-57617

Polar dinosaurs lived under cold climates quite unlike those tolerated by modern reptiles E-57643

Overabundance of iodine and chlorine in antarctic rocks may be caused by terrestrial contamination E-57683

Moderate climate warming could result in basal thickening of the Filchner-Ronne Ice Shelf and increase its longevity F-57605

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1997–1998 austral summer field season begins early

UNDER clear skies, at noon on 21 August 1997, the first Air Force C-141 air transport flight of the 1997 winter-fly-in, or winfly, touched down at the Pegasus runway, which is about 10 kilometers from McMurdo Station. According to the National Science Foundation winter station manager, the flight was greeted by nearly perfect weather—clear skies, no wind, and a temperature of –31˚F. The flight's arrival marked the end of the McMurdo Station's winter period with the arrival of new personnel, fresh food, needed cargo and equipment, and long-awaited mail from friends and families. Despite some weather problems and equipment failures, Air Force pilots were able to complete the four flights of this winter-fly-in by 27 August. About 186 additional people joined the wintering population at the station. These people, along with winter staff, begin preparing buildings, vehicles, and related facilities for the main deployment of personnel in October. Some early-season science projects, such as collecting data on the ozone hole, also started with the winter-fly-in.

The photographs that follow depict the environmental conditions at Pegasus during the 7-day event and were provided by U.S. Antarctic Program participants.

The road grader pulls the proof cart to prepare the Pegasus blue-ice runway for winter fly-in landings.

An Air Force C-141 Starlifter touches down on the Pegasus ice runway on 21 August 1997. Photo by Major Paul Giovino, U.S. Naval Antarctic Support Unit, Christchurch, New Zealand.

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Pegasus Airfield control tower and associated buildings used to support flight operations are surrounded by ground fog caused by the airplanes and vehicles. Photo was taken by Bill Haals, Antarctic Support Associates, on 27 August 1997, when the ambient air temperature was –54˚F.

A C-141 on the Pegasus ice runway near McMurdo Station on 21 August 1997. Photo by Paul Giovino, U.S. Naval Antarctic Support Unit, Christchurch, New Zealand.

Glaciological delineation of the dynamic coastline of Antarctica

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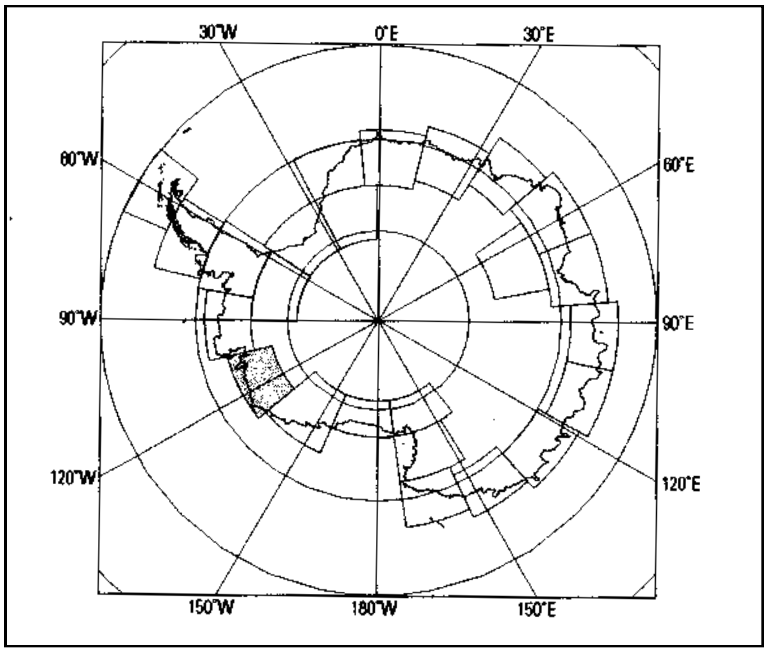
Jane G. Ferrigno, U.S. Geological Survey, Reston, Virginia 22092
Charles Swithinbank, Scott Polar Research Institute, Cambridge, United Kingdom
Baerbel K. Lucchitta, U.S. Geological Survey, Flagstaff, Arizona 86001
Barbara A. Seekins, U.S. Geological Survey, Woods Hole, Massachusetts 02543
Christina E. Rosanova, U.S. Geological Survey, Flagstaff, Arizona 86001

In spite of their importance to global climate and sea level, the mass balance of the antarctic ice sheet and the dynamics of the coast of Antarctica are largely unknown. In 1990, the U.S. Geological Survey, in cooperation with the Scott Polar Research Institute (SPRI), began a long-term coastal-mapping project in Antarctica that is based on analysis of Landsat images and ancillary sources (Williams et al. 1995). The project has five objectives:

- to determine coastline changes that have occurred between the mid-1970s and the late 1980s/early 1990s;
- to establish an accurate baseline series of 24 1:1,000,000-scale maps that defines, from analysis (at a scale of 1:500,000) of Landsat images, the glaciological characteristics (e.g., floating ice, grounded ice, and so forth) of the coastline of Antarctica during the two time periods (figure);



Index map to the planned 24 1:1,000,000-scale Coastal-Change and Glaciological Maps of Antarctica. Bakutis Coast map shown in gray.

- to determine velocities of outlet glaciers, ice streams, and ice shelves from comparison of Landsat images of the same areas taken over time;
- to compile a comprehensive inventory of named (from published maps and Landsat images) and unnamed (from analysis of Landsat images) outlet glaciers and ice streams in Antarctica that are mappable from Landsat images or from ancillary sources (e.g., maps, gazetteers, CD-ROMs, and so forth) (Swithinbank 1980, 1985, 1988; Alberts 1981, 1995; NSF 1989; BAS, SPRI, and WCMC 1993); and

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- to compile a 1:5,000,000-scale map of Antarctica derived from the 24 maps.

Changes in the area and volume of polar ice sheets are intricately linked to changes in global climate. It is not known whether the ice sheet is growing or shrinking (NRC 1985). As a result, measurement of changes in the antarctic ice sheet was given a very high priority in recommendations by the Polar Research Board of the National Research Council (1986) and the Scientific Committee on Antarctic Research (SCAR) (1989).

Methodology

THE primary steps in the compilation of the coastal-change and glaciological maps of Antarctica are as follows:

1. Identification of optimum Landsat multispectral scanner (MSS) or thematic mapper (TM) images for the two time periods (mid-1970s and late 1980s/early 1990s) and enlargement to a nominal scale of 1:500,000.

2. Identification and plotting of ground control points and pass points on Landsat images from geodetic field-survey information (e.g., field notebooks, tables, and vertical and trimetrogon aerial photographs and maps) archived in the U.S. Geological Survey's SCAR Library (Reston, Virginia 22092). Plotting of pass points on overlapping Landsat images and transfer of control points and pass points to transparent overlays to provide ties between images in areas where geodetic ground control does not yet exist.

3. Manual annotation of glaciological features by SCAR Code (SCAR 1980) or Antarctic Digital Database (ADD) Geocode (BAS et al. 1993) on 1:500,000-scale transparent overlays of Landsat images for both time periods. [The ADD project provides a digitized coastline and other cartographic information of Antarctica generalized to a scale of 1:1,000,000 that is available on a CD-ROM (BAS et al. 1993); the ADD CD-ROM provides the best existing coastline information for Antarctica.]

4. Manual transfer of the combined (MSS with TM) annotated overlays to 1:500,000-scale oblique Mercator maps of each map sheet. TM images provide the most geometrically accurate base for combining the annotations derived from analysis of the MSS and TM images.

5. Digitization, at 1:500,000-scale, using the U.S. Geological Survey's MAPGEN software (Evenden and Botbol 1985) and a digitizing program called "digin" written by G.I. Evenden (unpublished), of glaciological annotations and other related information on the oblique Mercator projections by SCAR Code or ADD Geocode.

6. Transformation of digitized annotations to a 1:1,000,000-scale polar stereographic map base (standard parallel at 71˚S) using the U.S. Geological Survey's MAPGEN software (Evenden 1990).

7. Addition of glacier velocities, geographic place names, including codes for unnamed outlet glaciers and ice streams identified on Landsat images and modification of selected topographic form lines (BAS et al. 1993) and bathymetric contours using Adobe Illustrator software.

8. Analysis of coastal changes, glaciological features, and outlet-glacier, ice-stream, and ice-shelf velocities.

The following discussion of the recently completed Bakutis Coast map (currently being readied for printing) is used as an example of the types of coastal-change and glaciolog-

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ical information that can be derived from analysis of Landsat MSS and TM images.

Glaciological features

THE Bakutis Coast (Swithinbank et al. in preparation) shows two dominant glaciological features: relatively narrow fringing ice shelves (Getz, Dotson, and Crosson Ice Shelves) and the Thwaites Glacier system (Thwaites Glacier, Thwaites Glacier Tongue, and Thwaites Iceberg Tongue). The Bakutis Coast map is divided into five ice-front segments by four islands (Dean, Siple, Carney, and Wright) located between DeVicq Glacier and Martin Peninsula. Siple Island, Carney Island, Martin Peninsula, and Bear Peninsula also contain small ice shelves separated by ice walls. Twenty-seven named and 14 unnamed outlet glaciers and ice streams flow into the ice shelves or directly into the Amundsen Sea; three other named glaciers are located in interior mountain ranges.

Coastal change

AS would be expected, the ice fronts, iceberg tongues, and glacier tongues are the most dynamic and changeable features in the coastal regions of Antarctica. Seaward of the grounding line of outlet glaciers, ice streams, and ice shelves, the floating ice margin is subject to frequent and large calving events or rapid flow. Both of these situations lead to annual and decadal changes in the position of ice fronts on the order of several kilometers, even tens of kilometers in extreme cases of major calving events. Although calving does occur along ice walls, the magnitude of change on an annual to decadal basis is generally not discernible on Landsat images; therefore, ice walls can be used as relatively stable reference features against which to measure other changes along the coast; only a single observation date is given for the position of ice walls.

An analysis of changes from Wrigley Gulf on the western part of the Bakutis Coast map to the western part of Pine Island Bay on the east (130–104˚W) indicates the following. West and north of Dean Island, the Getz Ice Shelf advanced from 3 to 12 kilometers (km) between 11 January 1973 and 25 February 1988 across a 51-km-wide ice front. The eastern part of the tongue of DeVicq Glacier (mostly on the Saunders Coast map) receded 6 km. West and east of Carney Island small parts of the Getz Ice Shelf receded from 1 to 5 km between 22 December 1972 and 25 February 1988 and between 23 November 1973 and 25 December 1986, respectively. The 46-km-wide ice front of Dotson Ice Shelf also receded 1 to 5 km between 16 January 1973 and 23 January 1990. The largest changes, however, occurred in the Thwaites Glacier Tongue and in the adjacent Crosson Ice Shelf. From the southeastern end of the ice wall of Hamilton Ice Piedmont (about 110˚W) to the ice wall west of Pine Island Glacier (about 104˚W) is a distance of 186 km. Along a 62-km-wide front of Crosson Ice Shelf that includes the confluence of Smith, Pope, and Vane Glaciers, the ice front receded from 5 to 13 km between 27 December 1972 and 22 January 1988. The irregular 83-km-wide terminus of Thwaites Glacier Tongue advanced about 10 km between 27 December 1972 and 22 January 1988; between 22 January 1988 and 9 February 1989, it advanced another 2 km.

Outlet-glacier, ice-stream, and ice-shelf velocities

VELOCITIES of floating glaciers (e.g., glacier tongues, ice streams, and ice shelves) were determined by two methods: an interactive one in which crevassed patterns are traced visually on images (Lucchitta et al. 1993) and an auto-correlation program developed by Bindschadler and Scambos (1991) and Scambos et al. (1992). Under optimum conditions, errors can be as small as ±0.02 km per year, but for most Landsat image pairs, where registration of features is accurate to only two or three pixels, the accuracy of velocity vectors is ±0.1 km per year. The larger glacier tongues and ice shelves have well-developed rift patterns that can be used for velocity measurements. From 10 to 50 mea-

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surement points were made for each glacier tongue or ice shelf. Thwaites Glacier Tongue has an average velocity of 2.8 km per year, on the basis of Landsat images acquired on 2 December 1984 (50276-14524) and 9 January 1990 (42734-14552) (Ferrigno et al. 1993). On the basis of Landsat images acquired on 13 January 1973 (1174-14325) and 22 January 1988 (42016-14343), the floating tongue of Smith Glacier moved at an average rate of 0.6 km per year, although the velocity decreased to 0.5 km per year near the grounding line. The Smith Glacier tongue increased in velocity to an average of 0.7 km per year between 19 January 1988 and 23 January 1990. Dotson Ice Shelf, into which several named (Singer, McClinton, Dorchuk, Keys, Kohler, Boschert, True, Zuniga, Brush, and Sorenson Glaciers) and other unnamed glaciers flow, has an average velocity of 0.4 km per year (Lucchitta et al. 1993, 1994).

Glacier inventory

PRODUCING a sophisticated glacier inventory of Antarctica according to the requirements of the World Glacier Monitoring Service, as part of their ongoing "World Glacier Inventory" program, is impossible with the present state of glaciological knowledge about Antarctica (Swithinbank 1980). It is, however, possible to use Landsat images, supplemented by other satellite images and photographs south of 81.5˚S (e.g., recently declassified Corona photographs, Systeme Probatoire d'Observation de la Terre images, Soyuzkarta images and photographs, National Oceanic and Atmospheric Administration advance very-high-resolution radar images, and so forth), and available maps to produce a reasonably complete preliminary inventory of named and unnamed outlet glaciers and ice streams and also to define more accurately related glaciological features, such as ice domes, ice piedmonts, ice shelves, ice rises, ice rumples, glacier tongues, iceberg tongues, and so forth. Satellite images and photographs also permit a better distinction to be made of islands and peninsulas, physical features that were often incorrectly identified and defined on earlier maps because of the lack of appropriate data.

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Antarctica and sea-level change

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Does the Antarctic pose a potential danger to humanity through sea-level rise (e.g., Mercer 1978)? Or, as argued by the Intergovernmental Panel on Climate Change (IPCC 1990, pp. 257–281), will Antarctica actually mitigate anthropogenic sea-level rise?

The IPCC Scientific Assessment suggested (1990, p. 276) that

- the contribution of the antarctic ice sheets to sea-level change between 1985 and 2030 is most likely to be a sea-level fall of 6 millimeters (mm) and that the extreme values range from no change to a fall of 8 mm and
- for each degree of global warming, the antarctic ice sheets will cause sea-level fall of 0.3±0.3 mm per year.

Revision of the IPCC assessment is ongoing, but this argument might lead one to believe that the antarctic ice sheets provide protection against sea-level rise during greenhouse warming, at least for the short planning horizon used.

This "optimistic" assessment of the role of Antarctica in sea-level change is ultimately based on two assumptions: that warming brings more snowfall to Antarctica and that rapid changes in ice flow "can effectively be ignored" (IPCC 1990, p. 276) for the time scales considered. Recent research raises serious questions about both of these assumptions and leaves the Antarctic as a potentially major factor in future sea-level rise.

Looking first at the snowfall-temperature link, there is no question that warming increases the moisture-holding ability, and thus the precipitation potential, of saturated air. It is equally clear that this is not the entire story or the Sahara would be the wettest place on Earth. This absurd argument emphasizes that precipitation must depend on atmospheric circulation as well as on temperature.

Arguments in favor of a temperature/snow-accumulation link in Antarctica often are based on spatial correlations—as one moves inland, the temperature falls and the rate of snow accumulation falls (reviewed in IPCC 1990, pp. 257–281). There are exceptions, of course; for example, the Siple Coast of West Antarctica has snow accumulation similar to South Pole despite being roughly 25˚C warmer than South Pole (e.g., Giovinetto and Bentley 1985). Nonetheless, the spatial correlations are often quite strong.

It is worth noting, however, that there is no physical reason why spatial and temporal gradients must be the same. Indeed, in a possibly analogous case, recent studies of the dependence of stable-isotopic compositions on temperature show that the spatial and temporal gradients can differ significantly (Peel, Mulvaney, and Davison 1988; Cuffey et al. 1994).

Some data, such as dilution of beryllium-10, do indicate a temporal correlation between accumulation and temperature over glacial-interglacial times (e.g., Lorius et al. 1985). Such a correlation could arise from thermodynamic control of snowfall but also might reflect changes in synoptic activity coincident with glacial/interglacial temperature changes.

Atmospheric studies cast serious doubt on simple temperature control of snowfall. In East Antarctica, for example, most of the snow falls in the cold winter rather than in the warm summer (Bromwich 1988). For Greenland, synoptic-scale activity is at least as

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important as temperature in controlling snowfall (Bromwich et al. 1993).

Recent work by Kapsner et al. (1995) on the Greenland Ice Sheet Project 2 long ice-core record sought to assess dependence of snow accumulation on temperature through correlation analysis. Temperature was estimated from stable-isotopic composition of ice, after borehole-temperature tests showed that the stable isotopes do contain much temperature information over time at that site (Cuffey et al. 1994). Accumulation was estimated from distances between summer layers in the ice core, corrected for ice-flow and compaction effects.

The result was that for central Greenland, temperature has not exerted strong control on snow accumulation. Over the most recent millennium, warming increased snow accumulation less than expected from thermodynamic relations. During changes between glacial and interglacial climate states, accumulation changed more than can be explained thermodynamically, demonstrating dynamic changes such as storm-track shifts.

Greenland ordinarily is considered more sensitive to storm-track shifts than Antarctica. Nonetheless, the demonstration of such effects in Greenland raises questions about the wisdom of using temperature alone to predict snow accumulation in Antarctica. The need is clear for a better understanding of antarctic meteorology in global-scale atmospheric circulation models, to allow reliable model-based predictions of snowfall.

In addition, annually resolved deep ice cores from the Antarctic should allow assessment of past relations of snowfall and temperature.

Shifting now to ice dynamics, modern data from West Antarctica, paleo-data from the North Atlantic, and our understanding of ice-dynamical processes all argue that ice flow can change rapidly in response to climatic forcing or to internal instabilities.

The stagnation of ice stream C, the thickening of the ice plain of ice stream B, the thinning and speed-up of the head of ice stream B, and various other changes on the Siple Coast of West Antarctica are well-documented (*see*, for example, Shabtaie et al. 1988; Whillans and Bindschadler 1988; Bindschadler 1993). These changes occurred at rates that, if general over the ice sheet, would have significant implications for projections of sea-level change. These changes are not now general, and when summed have little effect on sea level (Shabtaie and Bentley 1987), but they show that ice flow can change rapidly.

The tremendous nonlinearity of ice-dynamical processes makes it relatively easy to create models with large instabilities and rapid changes. For a given gravitational driving stress, observed velocities in modern ice sheets vary by orders of magnitude, and time-evolution from one velocity regime to another is allowed and even expected based on our understanding of the physics. The models of MacAyeal for West Antarctica (1992) and for the Laurentide ice sheet in Hudson Bay (1993a; 1993b) provide excellent examples.

The Heinrich events in the North Atlantic (Broecker 1994) record rapid ice-sheet changes. These were events of greatly enhanced (by more than an order of magnitude) rates of ice-rafted-debris sedimentation (Higgins et al. 1995), correlated with times of cold oceanic conditions, meltwater-diluted surface waters in the north Atlantic (Bond et al. 1992), and widespread climate changes (Broecker 1994). At least most of the events are dominated by debris from Hudson Strait (Grousset et al. 1993; Gwiazda, Hemming, and Broecker 1994).

One might consider that changes in ice shelves contributed to changes in ice-rafted debris reaching the ocean. The role of the ice pump and other processes in promoting

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rapid melting beneath ice shelves causes ice shelves to serve as filters that remove debris from ice before freely floating bergs are calved (e.g., Jenkins and Doake 1991; Jacobs et al. 1992).

However, the rate of sediment delivery during Heinrich events appears too large for any steady-state delivery by grounded ice (e.g., Alley and MacAyeal 1994), indicating that the Heinrich events are sudden surges of the Laurentide ice sheet from Hudson Bay.

Of course, demonstrating that sudden changes in ice flow are possible and have occurred in the past is far from accurately predicting if, and when, a sudden change will occur in the future. The time scales involved (Heinrich events were spaced a few thousand years apart; the west antarctic ice sheet has survived for at least tens of thousands of years) suggest that West Antarctic collapse is a low-probability event over times on the order of a century or shorter. But this certainly is not the same as a zero-probability event, and the potentially high impact commands special attention.

We thus see that

- changes in atmospheric circulation are important in controlling snow accumulation and its response to climate change, so that warming is not guaranteed to increase snow accumulation greatly and

- rapid changes in ice flow, especially toward thinning, are to be expected from at least some ice sheets.

Taken together, these suggest great uncertainty regarding the role of Antarctica in future sea-level change and present the possibility of significant or catastrophic sea-level rise.

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Foundation awards of funds for antarctic projects, 1 September 1996 through 31 January 1997

Award numbers for all awards initiated by the Office of Polar Programs (OPP) contain the prefix "OPP." However, funding of awards is sometimes shared by two or more antarctic science or support programs within OPP or between OPP antarctic and arctic science or support programs. For these awards, a listing is included under the heading for each OPP program that funded the project. The first amount represents the funds provided by that individual program, and the second amount, in parentheses, is the total award amount. All of these contain the OPP prefix. Additionally, investigators may receive funds for antarctic research from other divisions or offices of the National Science Foundation, as well as from OPP. When awards are initiated by another NSF division, the three-letter prefix for that program is included in the award number. As with awards split between OPP programs, antarctic program funds are listed first, and the total amount is listed in parentheses.

Biology and medicine

Anderson, Robert F. Columbia University, New York, New York. Management and scientific service in support of the U.S. Joint Global Ocean Flux Study (JGOFS) Southern Ocean Process Study: Hydrography, coring, and site survey. OPP 95-30398. $574,591. ($1,443,359)

Anthes, Richard. University Center for Atmospheric Research, Boulder, Colorado. University Center for Atmospheric Research educational outreach and related activities. OPP 96-43303. $20,000. ($568,243)

Chin, Yu-Ping. Ohio State University, Columbus, Ohio. The effect of dissolved organic matter on the photolysis and bioaccumulation of synthetic organic compounds in two lakes on Ross Island, Antarctica. OPP 96-16287. $9,000. ($50,067)

Day, Thomas A. Arizona State University, Tempe, Arizona. Ozone depletion, ultraviolet-B radiation, and vascular plant performance in Antarctica. OPP 93-17019. $86,064. ($210,021)

Fauchald, Kristian. Smithsonian Institution, Washington, D.C. Biological collections from polar regions. OPP 96-43726. $26,267. ($213,467)

Gardner, Chester S. University of Illinois, Champaign, Illinois. Iron boltzman temperature lidar for studies of middle atmosphere global change. OPP 96-12251. $300,000. ($800,000)

Hofmann, Eileen E. Old Dominion University, Norfolk, Virginia. Synthesis of existing high resolution Long-Term Ecological Research/Icecolors databases to advance physical bio-optical modeling of antarctic primary production. OPP 96-18383. $50,000.

Koger, Ronald G. Antarctic Support Associates, Englewood, Colorado. Logistics support of operations/research activities related to the U.S. program in Antarctica. OPP 96-43915. $40,700. ($12,890,867)

Prézelin, Barbara B. University of California, Santa Barbara, California. Synthesis of existing high-resolution Long-Term Ecological Research/Icecolors databases to advance physical–bio-optical modeling of antarctic primary production. OPP 96-14938. $105,050.

Priscu, John C. Montana State University, Bozeman, Montana. Antarctic lake-ice microbial consortia: Origin, distribution, and growth physiology. OPP 97-40012. $6,225.

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Marine and terrestrial geology and geophysics

Ocean and climate studies

Aeronomy and astrophysics

Glaciology

Environmental research

Services and support

Smith, Raymond C. University of California, Santa Barbara, California. Long-term ecological research on the antarctic marine ecosystem: An ice-dominated environment. OPP 96-32763. $710,000.

Smith, Walker O. University of Tennessee, Knoxville, Tennessee. Management and scientific services in support of the U.S. Joint Global Ocean Flux Study (JGOFS) southern ocean process study: Nutrients. OPP 95-30382. $371,676. ($999,442)

Ware, Randolph H. University Center for Atmospheric Research, Boulder, Colorado. Support of University Navstar Consortium and related activities. OPP 96-15934. $25,000. ($1,955,747)

Weiler, C. Susan. Whitman College, Walla Walla, Washington. Dissertations initiative for the advancement of limnology and oceanography (DIALOG) II. OPP 96-28543. $15,000. ($45,000)

Marine and terrestrial geology and geophysics

Cande, Steven C. Scripps Institution of Oceanography, La Jolla, California. Early tertiary tectonic evolution of the Pacific-Australia-Antarctic Plate circuit. OPP 94-16989. $18,838. ($215,146)

Cole, Julia E. University of Colorado, Boulder, Colorado. Acquisition of a stable isotope mass spectrometer for automated carbonate analysis: Analytical instrumentation for earth science/global change research. OPP 96-28080. $9,500. ($113,487)

Crowley, Thomas J. Texas A&M University, College Station, Texas. Modeling Paleozoic glaciations. OPP 96-15011. $96,200.

Finn, Carol. U.S. Geological Survey, Reston, Virginia. Lithospheric controls on the behavior of the west antarctic ice sheet: Corridor Aerogeophysics of the Eastern Ross Transect Zone (CASERTZ/WAIS). OPP 96-43267. $48,054.

Frey, Frederick A. Massachusetts Institute of Technology, Cambridge, Massachusetts. Evolution of the Kerguelen plume: Constraints from geochemical studies of lava sequences in the Kerguelen Archipelago. OPP 96-14532. $60,000. ($188,500)

Koger, Ronald G. Antarctic Support Associates, Englewood, Colorado. Logistics support of operations/research activities related to the U.S. program in Antarctica. OPP 96-43915. $113,613. ($12,890,867)

Kyle, Philip R. New Mexico Institute of Mining and Technology, Socorro, New Mexico. Mount Erebus volcano observatory. OPP 97-40065. $2,883. ($5,683)

Pittenger, Richard F. Woods Hole Oceanographic Institution, Woods Hole, Massachusetts. Ship operations. OPP 96-43819. $24,000. ($57,500)

Siddoway, Christine S. Colorado College, Colorado Springs, Colorado. Investigation of structures, structural fabrics, and metamorphic associations in northern Victoria Land. OPP 97-02161. $17,969.

Stock, Joann M. California Institute of Technology, Pasadena, California. Early Tertiary tectonic evolution of the Pacific-Australia-Antarctic Plate circuit. OPP 97-40297. $8,335. ($16,670)

Ware, Randolph H. University Center for Atmospheric Research, Boulder, Colorado. Support of University Navstar Consortium and related activities. OPP 96-15934. $25,747. ($1,955,747)

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Aeronomy and astrophysics

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Services and support

Wise, Sherwood W. Florida State University, Tallahassee, Florida. Curatorship of antarctic collections. OPP 96-43483. $21,904.

Ocean and climate studies

Hall, Michael J. National Oceanic and Atmospheric Administration. Washington, D.C. Support for Argos data collection and location system. OPP 96-42925. $20,158. ($638,651)

Koger, Ronald G. Antarctic Support Associates, Englewood, Colorado. Logistics support of operations/research activities related to the U.S. program in Antarctica. OPP 96-43915. $15,568. ($12,890,867)

Stearns, Charles R. University of Wisconsin, Madison, Wisconsin. Antarctic Meteorological Research Center: 1996–2000. OPP 95-27603. $80,000. ($180,000)

Aeronomy and astrophysics

Engebretson, Mark J. Augsburg College, Minneapolis, Minnesota. Induction antennas for British Antarctic Survey automatic geophysical observatories. OPP 93-16750. $90,801. ($174,560)

Fritts, David C. University of Colorado, Boulder, Colorado. Correlative midfrequency radar studies of large-scale middle atmospheric dynamics in the Antarctic. OPP 93-19068. $131,771. ($263,326)

Hall, Michael J. National Oceanic and Atmospheric Administration, Washington, D.C. Support for Argos data collection and location system. OPP 96-42925. $467. ($638,651)

Murcray, Frank J. University of Denver, Denver, Colorado. Ground-based infrared measurements in Antarctica. OPP 95-26913. $35,006. ($139,998)

Rosenberg, Theodore J. University of Maryland, College Park, Maryland. Riometry in Antarctica and conjugate regions. OPP 95-05823. $50,000 ($591,608)

Glaciology

Blankenship, Donald D. University of Texas, Austin, Texas. WAISCORES (west antarctic sheet ice cores) site selection. OPP 96-15251. $148,422.

Chin, Yu-Ping. Ohio State University, Columbus, Ohio. The effect of dissolved organic matter on the photolysis and bioaccumulation of synthetic organic compounds in two lakes on Ross Island, Antarctica. OPP 96-16287. $908. ($50,067)

Conway, Howard. University of Washington, Seattle, Washington. Origin and properties of subfreezing basal ice. OPP 97-40190. $27,669.

Denton, George H. University of Maine, Orono, Maine. Deglacial radiocarbon chronology of the western Ross Sea from relative sea-level curves. OPP 96-15285. $27,550.

Hall, Michael J. National Oceanic and Atmospheric Administration, Washington, D.C. Support for Argos data collection and location system. OPP 96-42925. $1,850. ($638,651)

Jacobel, Robert W. Saint Olaf College, Northfield, Minnesota. Ice-radar and satellite remote-sensing studies of glaciers and ice sheets, II. OPP 95-31501. $18,601. ($67,352)

Jacobel, Robert W. Saint Olaf College, Northfield, Minnesota. Siple Dome glaciology and

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Environmental research

Services and support

ice-stream history. OPP 93-16338. $56,924. ($161,906)

Kurz, Mark D. Woods Hole Oceanographic Institution, Woods Hole, Massachusetts. Chronology of antarctic glaciations. OPP 94-18333. $132,827. ($264,191)

Mayewski, Paul A. University of New Hampshire, Durham, New Hampshire. Scientific management of the National Ice Core Laboratory. OPP 96-17009. $27,574. ($52,574)

Mayewski, Paul A. University of New Hampshire, Durham, New Hampshire. Siple Dome deep ice-core glaciochemistry and regional survey—A contribution to the West Antarctic Ice Sheet Initiative. OPP 95-26449. $140,000. ($202,368)

Mosley-Thompson, Ellen. Ohio State University, Columbus, Ohio. The quantitative assessment of the Mount Pinatubo signal in antarctic snow. OPP 97-40375. $4,964.

Prentice, Michael L. University of New Hampshire, Durham, New Hampshire. An inventory of environmental features in the McMurdo Dry Valleys, Antarctica, and their recent changes using a geographic information system. OPP 96-27625. $3,733. ($296,968)

Raymond, Charles F. University of Washington, Seattle, Washington. Origin and implications of small-scale surface topography on Siple Coast ice streams. OPP 95-26707. $41,698. ($84,026)

Saltzman, Eric S. University of Miami, Coral Gables, Florida. Biogenic sulfur in the Siple Dome ice core. OPP 96-15333. $125,221.

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