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U.S. Geological Survey Scientific Activities in the Exploration of Antarctica: 1995–96 Field Season

By Tony K. Meunier
Richard S. Williams, Jr., and Jane G. Ferrigno, Editors

Open-File Report 2006–1114

U.S. Department of the Interior
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Introduction[1, 2, 3, 4]

The U.S. Geological Survey (USGS) mapping program in Antarctica is one of the longest continuously funded projects in the United States Antarctic Program (USAP). This is the 46th consecutive U.S. expedition to Antarctica in which USGS scientists have participated. The financial support from the National Science Foundation, which extends back to the time of the International Geophysical Year (IGY) in 1956–57, can be attributed to the need for accurate maps of specific field areas or regions where NSF-funded science projects were planned. The epoch of Antarctic exploration during the IGY was being driven by science and, in a spirit of peaceful cooperation, the international scientific community wanted to limit military activities on the continent to logistical support. The USGS, a Federal civilian science agency in the Department of the Interior, had, since its founding in 1879, carried out numerous field-based national (and some international) programs in biology, geology, hydrology, and mapping. Therefore, the USGS was the obvious choice for these tasks, because it already had a professional staff of experienced mapmakers and program managers with the foresight, dedication, and understanding of the need for accurate maps to support the science programs in Antarctica when asked to do so by the U.S. National Academy of Sciences. Public Laws 85–743 and 87–626, signed in August 1958 and in September 1962, respectively, authorized the Secretary, U.S. Department of the Interior, through the USGS, to support mapping and scientific work in Antarctica. The USGS mapping and science programs still play a significant role in the advancement of science in Antarctica today. Antarctica, the planet's 5th largest continent (13.2 million km^2 (5.1 million mi^2)), it contains the world's largest (of two) remaining ice sheet and it is considered to be one of the most important scientific laboratories on Earth. This USGS open-file report provides documentation of USGS scientific activities in the exploration of Antarctica during the 1995–96 field season. (Mullins and Meunier, 1995).

Figure 1 shows the primary geographic locations for the scientific work by the USGS during the 1995–96 field season. Figures 2 and 3 are facsimiles of the two cachets for the field season, one cachet for work of the aerial mapping photography program, including the search for an over-ice route to the Amundsen-Scott South Pole Station and the other cachet for the other projects. Both were drafted by USGS cartographer and artist Kenneth W. Murphy.

[1] See Open-File Report 2006–1117, U.S. Geological Survey Scientific Activities in the Exploration of Antarctica: Introduction to Antarctica (including USGS Field Personnel: 1946–59) at *http://pubs.usgs.gov/of/2006/1117/*.

[2] See Open-File Report 2006-1116, U.S. Geological Survey Scientific Activities in the Exploration of Antarctica: 1946–2006 Record of Personnel in Antarctica and their Postal Cachets; U.S. Navy (1946–48, 1954–60), International Geophysical Year (1957–58), and USGS (1960–2006) at *http://pubs.usgs.gov/of/2006/1116/*.

[3] See Open-File Report 2006–1113, U.S. Geological Survey Scientific Activities in the Exploration of Antarctica: 2002–03 Field Season at *http://pubs.usgs.gov/of/2006/1113/*.

[4] See Meunier (1979).

Figure 1. Index map to the principal geographic features of Antarctica and locations of USGS operations in the 1995–96 field season (black dots).

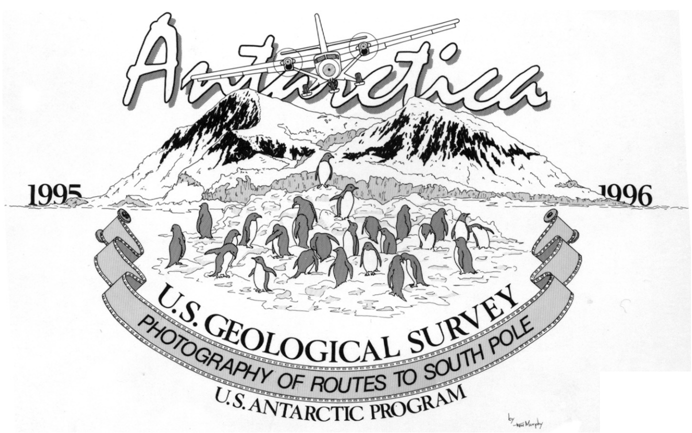

Figure 2. Cachet depicting Twin Otter aerial photographic surveys of outlet glaciers, penguin rookeries, and mapping photography for geologic studies. Design by Kenneth W. Murphy, U.S. Geological Survey.

Figure 3. Cachet depicting the repositioning survey of South Pole, surveys from the Shackleton Glacier Base Camp, measurements of absolute gravimetry, and establishment of Global Positioning System (GPS) reference stations at McMurdo Station and Amundsen-Scott South Pole Station. Design by Kenneth W. Murphy and Tony K. Meunier; graphics by Kenneth W. Murphy; U.S. Geological Survey.

Scientific Objectives for the 1995–96 Field Season

The USGS mapping projects during the 1995–96 field season were directed at areas of specific interest that only have relatively small-scale maps, including a major effort to provide aerial mapping photographs to produce large-scale maps for multidisciplinary projects in stratigraphy, geophysics, and geology; geodetic ground-control surveys at numerous field sites; establishment of absolute gravity base stations in Antarctica; geodetic research; determination of the hydrologic importance of glacial melt and stream flow during the austral summer from the terminus of hanging glaciers in Taylor Valley; paleoclimate studies of boreholes in ice at Taylor Dome and Taylor Glacier, and a borehole in Taylor Valley; a USGS seismology project experiment to record and transmit real-time seismic data for a full year from Wright Valley; and management of the digital cartography and Geographic Information Systems (GIS) program at McMurdo Station.

Scientific Accomplishments

Aerial Mapping Photography

Aerial mapping photography was acquired with a Wild RC–10 metric aerial camera with a GPS pulse converter and GPS receivers aboard a DeHavilland Twin Otter aircraft. The instrumentation provided precise geodetic positioning of the camera platform and accurate positioning of the fiducial centerpoint of each photograph. The airborne kinematic data acquisition method reduced the need for conventional, extensive geodetic ground control to meet the required map-accuracy standards. Photographic aerial survey missions supported science projects in a number of locations along the outlet glaciers flowing through the Transantarctic Mountains into the Ross Ice Shelf. J.L. Mullins, an aerial photography mapping specialist operated the RC–10 camera during the flights. Close ground support by T.K. Meunier, J.C. Campbell, and G.H. Shupe was required to maintain the entire system during each of the five missions.

NSF-chartered DeHavilland Twin Otter photographic missions were flown from the McMurdo Sound sea-ice runway over the Skelton Glacier (Trimetrogon Aerial (TMA) flight lines 3116–23), the McMurdo/Ross Ice Shelves shear zone (TMA flight lines 3124–31), and Leverett Glacier (TMA flight lines 3110–15), in close support of the South Pole Inland Traverse (SPIT) reconnaissance project, which was a cooperative effort between The Ohio State University (OSU), U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), USGS, and Antarctic Support Associates (ASA). The SPIT team was looking for a safe, crevasse-free route up the Skelton and Leverett Glaciers onto the Polar Plateau, so that an over-ice tractor train could supply the large volume of material needed to build the new Amundsen-Scott South Pole Station. A tractor-train composed of a John Deere tractor weighing 100 tons, pulling a sledge carrying building materials of similar weight, was preferable to resupply by hundreds of Lockheed, ski-equipped, LC–130 Hercules aircraft flights. However, the SPIT investigation, along with analysis of the aerial-photographic coverage of the heavily crevassed routes up the two outlet glaciers, eventually led to the conclusion that there was no practical route for a tractor convoy onto the Polar Plateau.

Vertical aerial mapping photography was also acquired to support two geologic-mapping projects in the Shackleton Glacier region using the RC–10 camera-equipped Twin Otter operating out of the Shackleton Glacier Field Camp. The two sites were in the Roberts Massif (TMA flight lines 3148–55) and the Bennett Platform (TMA flight lines 3156–67) areas.

Relative and Absolute Gravity

Relative and absolute gravity readings were obtained by G. Sasagawa and T.K. Meunier between 11 November and 1 December 1995. The unit of gravity measurement is the milligal (mGal) or microgal (μGal) and is the acceleration of a mass due to the force of gravity. The LaCoste-Romberg relative gravimeter, an instrument in general use even today, is equipped with a small mass, counterbalanced by a sensitive spring. The measurement of the length change in the spring when the instrument is moved from location A to location B is the measure of relative gravity difference between the two points. By tying this network of points into a known base station, gravity value can be assigned to each location. The drawback of this instrument is that environmental factors affect the spring length, and the measurements are not repeatable. In an attempt to find a better system, an FG5/102 laser interferometric, absolute gravimeter that measures the free-fall acceleration of a small mass with respect to a vibration-isolated mass, had its first U.S. deployment in Antarctica during the 1995–96 field season. Both the relative and absolute gravimetric observations were made at McMurdo and Terra Nova Bay Stations to compare results. Use of the absolute gravimeter permitted the calculation of the local geoid and ellipsoid separation at the gravity-base stations, for the first time, with absolute, rather than the changeable, relative gravity values. Repeat measurements with the FG5/102 instrument were done at McMurdo Station after 3 weeks and after 4 months, when the instrument was returned to the Table Mountain Gravity Observation (TMGO) Station in Colorado to ensure that the deployment to Antarctica had not introduced errors. "Absolute gravity measurements at McMurdo Station and Terra Nova Bay proved to be successful, with estimated accuracies of order ±2μGal...repeat measurements at McMurdo and TMGO showed no instrument offsets or anomalies. Relative observations also agreed with the absolute results...These first epoch measurements provide valuable geodetic information on the geoid-ellipsoid separation, as well as highly accurate base station data for relative gravimeter networks...Future reoccupation with absolute instruments... will also allow the detection of μGal level gravity changes and/or vertical changes on the order of 6 mm. Applications of such results include detection of sea level change, tectonic motions, volcanic processes, and viscoelastic deformation due to time varying ice load history." (Sasagawa and others, 2004) The successful test of the absolute gravimeter yielded very accurate measurements. However, the large size of the instrument made it difficult to transport, and the instrument did not function properly when confined in a Scott Tent under conditions of high wind gusts. New designs are under development to eliminate these problems.

Geodetic Surveys

Geodetic surveys were conducted by G.H. Shupe and J.C. Campbell, who installed and operated the Airborne Positioning System (APS) (Shupe and Campbell, 1996). The APS provided a GPS pulse for each camera shutter event, thereby establishing geodetic control for the vertical photography for the season's five aerial flight missions. Twenty-two hours of flight time were positioned by the APS using two dual frequency P-code, GPS receivers, recording data at a rate of 1 Hz. In addition, two geodetic ground reference stations were collected during each airborne mission to provide static control to enhance the accuracy of the kinematic aircraft data (differential GPS offset).

Geodetic ground-control points were also established by G.H. Shupe and J.C. Campbell at multiple sites. The Shackleton Glacier Project was supported by helicopter from the Shackleton Glacier Base Camp. Eight new geodetic-control stations were established, paneled, and photographed using a hand-held camera from a helicopter 610 m above the control points. One existing and three new stations were occupied at Bennett Platform. One existing and three new stations were occupied at Roberts Massif. Two additional new stations were established for OSU to be used as height references for geological surveys (Webb and others, 1996). In addition, three stations already established in the area from the USGS 1962–63 Topo East Traverse were recovered. Because these stations were previously positioned in the Camp Area Datum of 1962, their recovery was significant and showed a good consistency within the original network when compared to the current International Terrestrial Reference Frame (ITRF94) datum.

In addition, geodetic ground control was acquired in three other areas to support large-scale (1:25,000) mapping by the International Consortium for Antarctic Research (ICAR) (USGS, 2002a, b). Three new stations and four recovered stations were positioned with differential GPS surveys on the Hut Point Peninsula. On Cape Crozier, large-scale mapping project surveys for ICAR established four new stations and reoccupied one existing marker. Five stations were reoccupied that surround the McMurdo Station permanent tracking station established 2 years before to measure the stability of the geologic setting of the area. Precision Lightweight GPS Receivers (PLGR) with encrypted precise positioning service (PPS) code were tested and used for the first time in Antarctica, giving instantaneous 2–4 meter (x, y) accuracy in the field. This accuracy has been used to obtain rapid static control of identifiable control points for the preparation of satellite-image maps. The first deployment of the U.S. Department of Defense PLGR outside the U.S. by USGS personnel in Antarctica established a precedence for subsequent international deployment by U.S. civilian agencies for other scientific applications.

At 90° S. latitude, the geographic South Pole is situated on top of 9,000 feet (2,743 m) of glacier ice. Gravity causes the ice under South Pole Station to flow elastically down slope at about 10 m per year. Since the 1950s, USGS field surveying teams have been requested to position the exact location of this geodetic point, which is the point in the Southern Hemisphere around which the Earth spins on its axis and is known as the South Geographic Pole. The designation of 90° S. latitude is part of the Cartesian coordinate system from which all points on the Earth's surface lie to the north. Special custom-made markers have been placed in the ice each year since the first repositioning using GPS surveying on 1 January 1992. USGS geodetic surveys at the South Pole station, which started in 1973, are used to reposition the monument each year. Relocation of the monument was carried out on 1 January 1996 using static GPS techniques. A new monument was embedded in the ice, which has moved 9.98 m (Mullins and Hothem, 1996) in a northwesterly direction from the original marker placed by a USGS geodetic survey on 1 January of the previous year (1995).

Hydrologic Studies

Hydrologic studies by K.J. Lewis and P. Langevin were conducted in the McMurdo Dry Valleys area. This Long Term Ecological Research (LTER) project studied the role of glacier terminus cliff melt on stream flow in the Taylor Valley. Their conclusion was that peak stream flow of Anderson Creek can be attributed almost entirely to glacier terminus cliff melt (Lewis and others, 1996).

Paleoclimate Studies

Paleoclimate studies by Gary D. Clow (Clow and Waddington, 1996) were carried out in boreholes at Taylor Dome and on Taylor Glacier, and in a borehole in Taylor Valley, McMurdo Dry Valleys. As part of the Taylor Dome Ice Core Project, paleothermic measurements were made in a 554-m-deep borehole drilled into the ice at Taylor Dome (lat 77°50' S., long 159°00' E.). Automatic weather station (AWS) data, current ice-strain rates, long-term oxygen isotopic ratios, and paleotemperature changes were recorded.

Seismic Studies

Seismic studies by USGS Albuquerque Seismological Lab technicians (contractors) J. Idol and W. Brady, in cooperation with New Zealand, continued to maintain a remote year-round seismic station in granitic bedrock in Wright Valley that is sufficiently removed from the environmental and human-activities noise emanating from Ross Island. Seismic data were successfully transmitted to the Global Telemetry Seismograph Network (GTSN), via New Zealand's Scott Base, throughout the Antarctic winter.

USGS, NOAA, and Contractor Personnel in Antarctica in 1995–96 Participating in USGS Science and Mapping Projects

NSF Project S–052:

- Jerry L. Mullins, Supervisory Cartographer; Chief, USGS Polar Programs; Aerial Mapping Photography Program
- Gordon H. Shupe, geodetic ground control surveys; airborne positioning
- Jon C. Campbell, geodetic ground control surveys; airborne positioning
- Glenn Sasagawa, National Oceanic and Atmospheric Administration (NOAA), absolute gravity measurements
- Tony K. Meunier, absolute gravity measurements; Aerial Mapping Photography Program
- Cheryl A. Hallam, Manager, Geographic Information Systems

NSF Project S–042:

- Karen J. Lewis, hydrologist, Long-Term Ecological Research (LTER) Station; stream-flow measurements in Taylor Valley
- Paul Langevin, hydrologist, LTER Station; stream-flow measurements in Taylor Valley

NSF Project S–078:

- Jeff Idol, seismologist (contractor), McMurdo Dry Valleys Seismograph Project
- Wade Brady, seismologist (contractor), McMurdo Dry Valleys Seismograph Project

NSF Project S–171 (Grant No. OPP 92–21261):

- Gary D. Clow, geophysicist, paleotemperate measurements from boreholes at Taylor Dome Ice Core Project, and at Taylor Glacier, and from borehole in Taylor Valley, McMurdo Dry Valleys

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Acknowledgments

Funding of the 1995–96 USGS field season in Antarctica was provided by NSF grants OPP91–14787 and OPP92–11773. Thanks for the assistance of the following USGS personnel: Jerry L. Mullins, Chief, Polar Programs; Gordon H. Shupe, Robert J. Allen and Angel L. Gonzalez, U.S. Antarctic Resource Center, National Mapping Discipline (NMD), Reston, VA; Jon C. Campbell, Director's Office, Office of Communications, and Jane G. Ferrigno, Geologic Discipline (GD), Reston, VA; and Richard S. Williams, Jr., GD, and Janice G. Goodell, ETI, Woods Hole Science Center, Woods Hole, MA; and Glenn S. Sasagawa, Scripps Institution of Oceanography, University of California, San Diego, CA; and Kirsten C. Healey, ETI, Eden, UT.