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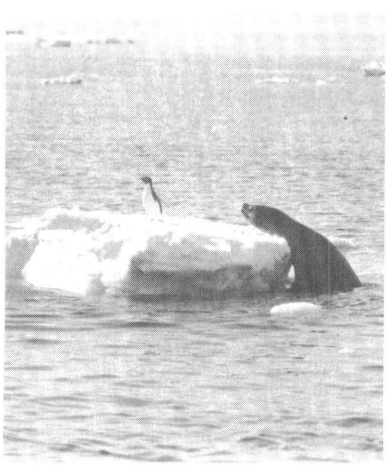
***Editor:* K. G. Sandved**

Head, Polar Information Services
Office of Antarctic Programs
National Science Foundation
Washington, D.C. 20550



COVER PHOTO

Leopard seal trying to catch Adélie penguin on ice floe near the Cape Crozier rookery. This individual got away by diving off the other side of the floe.

(Photo by William R. Curtsinger, USN)

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Greenwich Mean Time is used, except where otherwise indicated.

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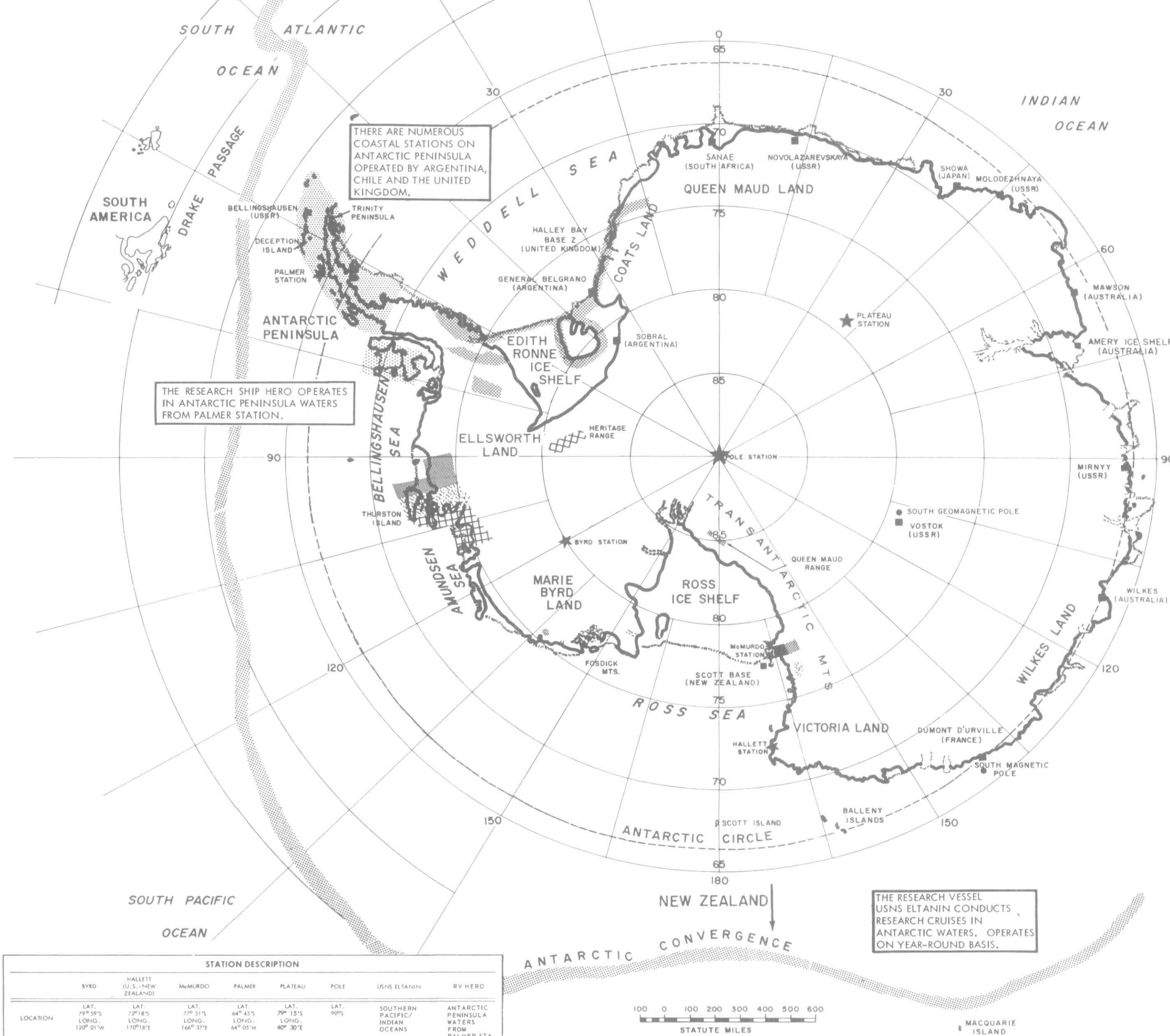

STATION DESCRIPTION

	BYRD	HALLETT (U.S.-NEW ZEALAND)	McMURDO	PALMER	PLATEAU	POLE	USNS ELTANIN	RV HERO
LOCATION	LAT. 79° 59'S LONG. 120° 01'W	LAT. 72°18'S LONG. 170°18'E	LAT. 77° 51'S LONG. 166° 37'E	LAT. 64° 45'S LONG. 64° 05'W	LAT. 79° 15'S LONG. 40° 30'E	LAT. 90°S	SOUTHERN PACIFIC/ INDIAN OCEANS	ANTARCTIC PENINSULA WATERS FROM PALMER STA.
FEET ABOVE SEA LEVEL	5,012	16	102	25	11,890	9,184	-	—
ESTABLISHED	1957	1957	1956	1965	1966	1957	1962	1968
TERRAIN	ON INLAND ICE	ON GLACIAL MORAINE	ON VOLCANIC ASH	ON BEDROCK	ON INLAND ICE	ON INLAND ICE	-	—
METHOD OF SUPPLY	AIR	AIR SEA	AIR SEA	SEA	AIR	AIR	-	—
NUMBER OF BUILDINGS	15	10	70	2	8	11	-	—
MEAN ANNUAL TEMPERATURE (°F)	-18.6	+4.2	+0.1	+20 (estimated)	-69.9	-56.7	-	—
MEAN TEMP. (°F) DEC., JAN., FEB.	+1.6	+28.2	+21.6	+30 (estimated)	-37.9	-25.2	-	—
APPROXIMATE WINTER PERSONNEL (SCIENTISTS) (NAVY)	11 17	SUMMER STATION ONLY	11 146	8 6	STATION CLOSES JANUARY 1969	6 13	scientists 34 MSTS crew 48 (year-round operation)	scientists 10 crew 10 (year-round operation)
AIR DISTANCE FROM McMURDO (STATUTE MILES)	885	380		2,360	1,350	820	-	—

LEGEND

- ★ U.S., U.S. Cooperative Stations
- ■ Foreign Stations
- Aerial Photography for Mapping
- Geological Field Parties
- Map Control
- Biological Field Parties
- Geophysical Investigations

Upper Atmosphere Studies conducted at Byrd, Plateau, Pole, and McMurdo Stations.

U.S. Antarctic Research Program, 1968-1969

Review of the Summer Season

As is customary in the *Antarctic Journal*, we present in this issue reviews and results of activities during the past summer season. Similar reports of the year-round activities in Antarctica, aboard *Eltanin,* and at laboratories in the U.S.A. will be featured in the September-October issue, while some of the international activities will be discussed in the November-December issue.

Nearly 200 scientists and technicians, representing about 50 institutions, participated in the past season's field work. Of the 51 projects conducted, all but 3 are reported on in this issue by the principal investigators and their associates involved in the field work. Twenty-four projects were in biology, 25 in the earth sciences, 1 in topography, and 1 in upper atmosphere physics.

It is possible to describe some highlights of the summer's research, but there were none of the spectacular scientific discoveries or achievements that characterized the 1967–1968 season. There were also some disappointments.

Among the highlights was the arrival of the National Science Foundation's new research vessel, *Hero,* in the Antarctic Peninsula, where she will be working in conjunction with Palmer Station during much of each coming year. Her availability to the scientists at Palmer made a great difference in their ability to move around in the area, and she was utilized for this purpose to the fullest extent both by geologists and marine and terrestrial biologists. International cooperation was furthered by her presence, and her trip to Deception Island in the wake of the volcanic eruption there was a boon to field and stateside scientists awaiting word of the effects of the eruption. In fact, the resulting report was the first account of the destruction based on the observations of trained scientists to be distributed by the Smithsonian Institution's Center for Short-Lived Phenomena.

On the international scene, the highlight was the arrangement which allowed Norwegian and British scientists to work in the Kraul and Shackleton Mountains, respectively. Fielding of these parties was made possible by the expert flying by pilots of Antarctic Development Squadron Six.

The large-scale biologic-geologic-topographic survey that was located in Marie Byrd Land in the 1966–1967 and 1967–1968 seasons, this year concentrated on exposed areas in Ellsworth Land. Despite the adverse weather which prevails in this area of Antarctica most of the time, the multidiscipline party was able to complete its work by late January.

A significant event was the closing in January of Plateau Station, which had been in operation since 1965. Its deactivation again reverted to South Pole the dubious distinction of being the highest, coldest, and most remote of U.S. antarctic stations. Although the data from Plateau have been interesting, the outpost has had more than its share of operational problems, which have affected the research program adversely.

The greatest disappointment of the past season was the failure to retrieve the submerged buoys placed by the International Weddell Sea Oceanographic Expedition—1968 to record data on antarctic bottom waters. It is hoped that ice conditions will be better next season, when another attempt will probably be made to retrieve the scientifically important buoys.

Another disappointment was the unsuccessful attempt to drill into bedrock at the bottom of the 2,164-m hole drilled through the ice at Byrd Station in 1967–1968. Adding to the frustration was the entrapment in the ice of the drill as well as an instrument specifically designed to measure the age of the ice at various levels in the borehole on the basis of small samples (it takes tons of ice to measure the age by the conventional C^{14} methods).

These setbacks should not overshadow the fact that it was otherwise a highly successful season, for they represent only a small portion of the numerous projects conducted. The painstaking investigations carried out by the scientists at the stations, at remote field sites, and aboard ships proceeded well and continued to add to the storehouse of knowledge about Antarctica and its relationships to other parts of the world.

By virtue of the nature of the diversified program, some of the reports presented in the following pages contain conclusions based on analyzed and digested data, but many, if not most of them are preliminary at this point.

No account of field research should fail to mention the continued gratifying and mutually beneficial effects of international cooperation on the program (a list of international exchanges will be given in a later issue). As Dr. A. P. Crary once noted: "No highlight of antarctic activities and accomplishments has yet topped that of the signing of the Antarctic Treaty." It is in this aura of international harmony that the U.S.A. continues to conduct its national program in Antarctica.

K. G. Sandved

The Ellsworth Land Survey

F. ALTON WADE

Department of Geology and Geophysics
Texas Technological College

and

CAMPBELL CRADDOCK

Department of Geology
University of Wisconsin

During the 1966–1967 summer season, the United States began a multidisciplinary, helicopter-supported scientific survey of coastal West Antarctica. The program began near the Ross Ice Shelf in western Marie Byrd Land, and the original plan was to work eastward that season through a series of camps to the Eights Coast. The expected rate of progress was not obtained, however, because of generally poor weather and the limited number of flying days. During the first season, the survey reached eastward to the Ruppert Coast and was conducted from a single camp in the Edsel Ford Ranges. In 1967–1968, two permanent camps and one tent camp were occupied as work progressed eastward to Mount Murphy. During the 1968–1969 season, the survey was completed with studies in the Hudson Mountains, the islands of the Amundsen Sea, Thurston Island, the Jones Mountains, and the Eights Coast.

The scientific party ranged from 9 to 13 during the 1968–1969 season. Three geologists from Texas Technological College, who were responsible for the geological program early in the summer, were relieved by three geologists from the University of Wisconsin later in the season. Botanical studies were conducted by a two-man party from the Ohio State University. One worker from Washington University (St. Louis) collected rock specimens for paleomagnetic investigations. Exchange scientists Boris Lopatin from the Soviet Union and Fernando Munizaga from Chile carried out geological studies in the first part of the season. Four topographic engineers from the U.S. Geological Survey established ground control for cartographic purposes. These scientists were supported in the field by 13 officers and men of the U.S. Army Aviation Detachment (Antarctica Support), 3 U.S. Navy men, and a USARP field assistant.

The Ellsworth Land Survey was conducted from two semipermanent camps, each consisting of four Jamesway buildings. Camp 1 was located on the snow dome of the King Peninsula. Camp 2 was established about 5 miles northwest of the Jones Mountains, near the site of former Camp Minnesota. A fuel cache was laid by a C-130 near eastern Thurston Island so that that area could be worked from either camp.

During the first week of November, Camp 1 was erected and the scientific personnel arrived. Bad weather prevented the start of work until November 15, allowing only eight days in all for helicopter flying that month and December. Nevertheless, the efficiency of the helicopters allowed completion of the necessary work from this camp, and some of the geologists returned to McMurdo December 16. On the same day, four Navy men were flown to the Jones Mountains to begin construction of Camp 2.

The relieving scientific party made three unsuccessful flights to Camp 2 before weather conditions permitted landing on January 5. Camp equipment was transferred on five C-130 flights, and Camp 1 was closed January 10 when the three helicopters flew to Camp 2. Helicopter operations in the Jones Mountains began January 11, and the month proved to be a favorable one for working. Scientific work by either helicopter or motor toboggan was possible on two days out of three, although the helicopters and 14 men were pinned down in Camp 1 January 13-17 after being caught in a sudden storm while working on Thurston Island. Surveys of the Jones Mountains, Thurston, Dustin, and McNamara Islands, and Lepley Nunatak were completed from this base, and Camp 2 was closed on January 30.

The discovery of the rock shelter and camp built on Lepley Nunatak by a party from USS *Glacier* for survival during a storm in February 1961 is of historical interest. A cairn and survey post constructed by the same expedition were also observed on McNamara Island. No trace was seen of Camp Minnesota, established in the Jones Mountains in December 1960.

The planned scientific survey of coastal West Antarctica has now been completed from the Rockefeller Mountains of Marie Byrd Land to the Eights Coast of Ellsworth Land. Preliminary results of the field program are reported in the following pages.

Geology of the King Peninsula, Canisteo Peninsula, and Hudson Mountains Areas, Ellsworth Land, Antarctica

F. ALTON WADE *and* KERBY E. La PRADE

Department of Geology
Texas Technological College

Geologic investigations were the responsibility of a three-man team from Texas Technological College: Craig M. White, basement geologist from the University of Wisconsin; Fernando Munizaga, geochronolo-

Photo: K. E. La Prade

USARP Jamesway building on King Peninsula six weeks after erection. Access is by a tunnel through the drift. Camp included three other Jamesways.

gist from the Instituto Antártico Chileno, Santiago de Chile; and Boris Lopatin, basement geologist from the Institute of Arctic Geology, Leningrad, U.S.S.R.

Rocks of the Hudson Mountains and King Peninsula consist of olivine basalts and tuffs. Well-developed pillow lava occurs at Mount Nickens, but elsewhere the lavas occur as thick layers of scoraceous olivine basalts, typically interstratified with tuffs. Volcanic rocks rest unconformably on basement rocks in the nearby Jones Mountains, but the contact is not exposed in the Hudson Mountains-King Peninsula areas. Rocks exposed on the Canisteo Peninsula and offshore islands consist of the basement complex, principally granites, diorites, and gneisses. The metamorphic rocks were noted in only two exposures, Dyment Island and the unnamed southernmost island of the Sterrett Islands. Granite-diorite rocks contain abundant xenoliths of gneissic material which resemble the gneiss cropping out in the two small islands mentioned above. Gneissic rocks represent the oldest exposed rocks in Ellsworth Land, and probably correlate with the medium-to-high-grade metamorphic outcrops of Mount Petras, the Kohler Range, Bear Island, Schneider Rock, the Fosdick Mountains, and the Mount Gray area of Marie Byrd Land. Radiometric ages of the plutonic and volcanic rocks in the nearby Jones Mountains indicate a Triassic and Cenozoic age, respectively (Craddock *et al.*, 1964; Rutford *et al.*, 1968). At least two periods of intrusive activity are indicated by the presence of plutonic xenoliths, chilled borders, and discordant relationships. Diabasic and gabbroic dikes are common.

Laboratory investigations of collected samples and the analysis of data from a comprehensive geophysical program, including electromagnetic ice-thickness measurements and magnetic measurements of the entire area, are expected to support the hypothesis that Marie Byrd Land and Ellsworth Land are disrupted segments of a once larger East Antarctic Continent.

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The Geology of the Eights Coast

CAMPBELL CRADDOCK, CRAIG M. WHITE, *and* ROBERT H. RUTFORD*

Department of Geology and Geophysics
University of Wisconsin

Responsibility for the geological program during the latter part of the 1968–1969 Ellsworth Land Survey rested with our three-man party from the University of Wisconsin. Part of Thurston Island was studied by White with helicopter support from Camp 1. All of us who worked in the Jones Mountains from Camp 2 used both helicopter and motor toboggan transport. The remainder of the area was studied by Craddock and White in helicopters from Camp 2.

All of the significant and accessible rock exposures along the Eights Coast from Lepley Nunatak to Thurston Island were visited. Most rock outcrops form steep faces that are commonly capped by active ice, and many of these cliffs require significant climbs from the closest landing site at their base. Lepley Nunatak was studied as a unit, 3 outcrops were studied on McNamara Island, 2 on Dustin Island, and 45 on Thurston Island. Detailed work in the Jones Mountains was concentrated in the area of north-facing cliffs near Avalanche Ridge, but helicopter trips were made to previously unvisited localities in the eastern and southern extremities of the range.

Lepley Nunatak consists of a massive, light gray granitoid rock, epidotized along joint surfaces and cut by numerous mafic dikes. McNamara Island is composed of light to medium gray dioritic plutonic rocks with poorly developed foliation. Dustin Island consists of light gray granitoid rock containing numerous angular to rounded inclusions of fine- to medium-crystalline mafic rock.

The outcrops on Thurston Island feature a varied assemblage of igneous and metamorphic rocks. Granite, granodiorite, quartz diorite, and diorite predominate in the western half of the island. The

*Now at the Department of Geology, University of South Dakota.

eastern half consists of gneiss (some banded), amphibolite, metavolcanics, granodiorite, diorite, and gabbro. Contacts are rare, and the relative ages of these rock bodies are in doubt. The Morgan Inlet gneiss may represent the oldest rock on Thurston Island; earlier work (Craddock *et al.*, 1964) gave a Rb-Sr age of 280 m.y. on biotite from this rock.

Studies in the Jones Mountains were mainly on the unconformity between the basement complex and the overlying basaltic volcanic rocks to evaluate the evidence for Tertiary glaciation. Volcanic strata just above the unconformity contain abundant glass and pillow-like masses suggestive of interaction between lava and ice. Tillites with faceted and striated exotic pebbles and boulders are present in several localities in the lower 10 m of the volcanic sequence. Pre-volcanic grooves or striations measured at 50 sites on the unconformity surface indicate a general northward movement of the ancient ice. Specimens of several basalt flows were collected for K-Ar measurements to determine more precisely the age of the volcanic sequence and the inferred early glaciation. Carbonized fossil wood (probably Mesozoic) was discovered in a pyroclastic rock in the basement complex.

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Paleomagnetic Investigations in the Ellsworth Land Area, Antarctica

LeROY SCHARON, AKIRA SHIMOYAMA, *and* C. SCHARNBERGER

Department of Earth Sciences
Washington University

During the austral summer of 1968–1969, paleomagnetic investigations were continued in West Antarctica, thus extending the investigations from Marie Byrd Land into Ellsworth Land. The 68 oriented rock samples collected from 23 sites will produce approximately 400 individual standard core specimens for rock magnetic and paleomagnetic data.

In the Hudson Mountains, in which tuffs and olivine basalt flows occur, 20 oriented samples were taken from 7 sites. The sites were located at Teeters, Velie, Meyers, and Inman Nunataks. Samples were collected from Pryor Cliff and Mounts Moses and Manthe.

Cape Menzel, Shelton Head, Hendersin Knob, and other locations on Thurston Island yielded 21 samples consisting of granites, diabase and mafic dikes, and basalts. At least four plutonic bodies, most of which probably have mafic dikes as well as felsite dikes, are present. In the eastern part of the island, mafic dikes occur in banded gneiss. A diorite-to-gabbroic mass is present in the north central portion of the island. Granite-to-diorite bodies occur in the south central portion of the island and contain "meta-volcanic" rocks and mafic dikes. Granite-granodiorite-to-diorite rocks occur in the western portion of the island. This latter plutonic mass is probably the youngest body in which mafic dikes are also present. About 10 miles southwest of Thurston Island, a medium-grained granodiorite plutonic mass forms Dustin Island, where three samples were collected at Ehlers Knob.

In the Jones Mountains, 27 oriented samples were collected from the area around Pillsbury Tower, on Avalanche Ridge, and at Right Angle Peak, Lepley Nunatak, and Inspiration and Forbidden Rocks. These samples are diabase, diorites, mafic dike material, and basalt. On the granite mass lies a felsite tuff (maximum thickness of 30 m) with mafic and felsitic dikes and, in addition, inclusions of carbonized wood fossils. Above this formation lies a section (40 to 90 m thick) of volcanic pyroclastics and olivine basalt flow layers. K-Ar dating (Craddock *et al.*, 1964) gives 22, 104, and 199 m.y. for the basalt, felsite porphyry, and the granite, respectively.

Previous analyses of rocks of Cretaceous, Tertiary, and Pleistocene ages have produced significant results. During the summers of 1966–1967 and 1967–1968, Cretaceous granites from Marie Byrd Land gave ancient magnetic pole positions of 28°S. 140°W. and

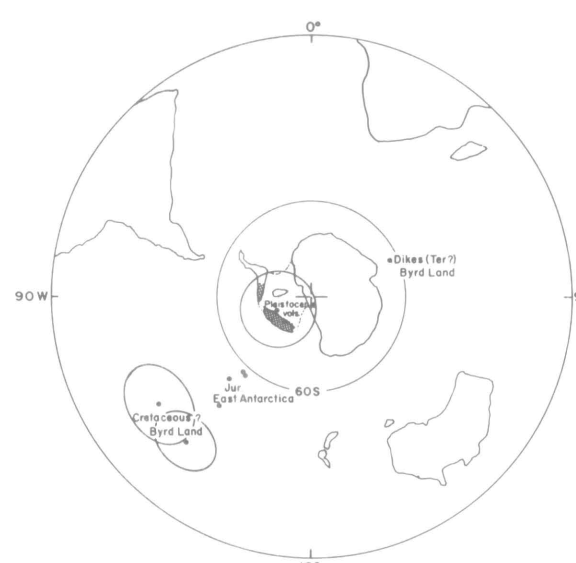

Fig. 1. Projection showing (a) Areas of paleomagnetic field work in Marie Byrd Land and Ellsworth Land, and (b) Ancient geomagnetic poles determined for Marie Byrd Land rocks and some Jurassic rocks from East Antarctica.

29°S. 126°W., respectively. These ancient magnetic poles for West Antarctica are displaced from pole positions for rocks of similar age in East Antarctica (Fig. 1). Tertiary dikes give a pole position of 62°S. 64°E., while Pleistocene volcanics give a pole position of 78°S. 128°W. The paleomagnetic data, especially the Cretaceous rocks, strongly suggest that East and West Antarctica are unrelated geologically or structurally. Schopf (1969), using an analysis of sea-floor spreading, indicates that the reconstruction of Gondwanaland "would be simplified if West Antarctica is not regarded as part of the ancient Antarctic crustal unit." Hamilton (1967) also suggests that the pre-Tertiary complexes of West Antarctica are "disconnected from each other and from the terranes of East Antarctica." Paleomagnetic data further demonstrate that West Antarctica is independent of the ancient antarctic unit.

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Biological Survey of Ellsworth Land

GARETH E. GILBERT

Faculty of Population and Environmental Biology and Institute of Polar Studies

and

TOMMY J. EARLY *and* HAROLD T. KING

Institute of Polar Studies
The Ohio State University

During the 1968–1969 austral summer, a biological survey was conducted in that portion of Ellsworth Land lying within approximately 71°30′ to 75°00′S. and 90°00′ to 104°00′W. Emphasis was placed on the study of rock outcrops associated with the Hudson Mountains, islands off the Walgreen Coast, the Walker Mountains of Thurston Island, Dustin Island, McNamara Island, Lepley Nunatak, and the Jones Mountains. This study, as well as associated studies in the Ellsworth Land Survey, was conducted with helicopters from temporary base camps at the base of the King Peninsula and at the Jones Mountains.

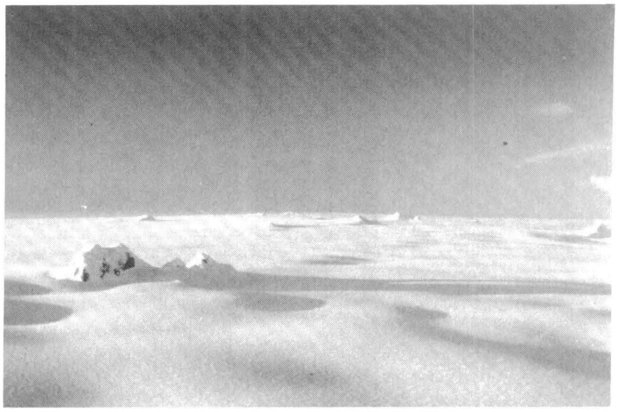


Fig. 1. Walker Mountains, Thurston Island, looking northwestward from 600-m elevation. Mount Dowling in left foreground.

Although laboratory analysis of the many samples collected has not been completed, a summary of the field observations has been compiled (Table 1).

The Hudson Mountains comprise volcanic nunataks, 16 of which were biologically surveyed. Although lichens occurred on 14 of the 16 nunataks, they did not occur in dense communities and were widely scattered. Well-developed moss communities were observed on three of the nunataks, usually either in cracks in rocks or in narrow crannies between boulders.

Rock outcrops occurring on 11 islands off the Walgreen Coast were investigated. All outcrops were found to be of granitic rock, all had associated lichens, and nearly all supported algal communities. Mosses, however, were discovered on only one of the islands. Adélie penguin rookeries were found on eight of the

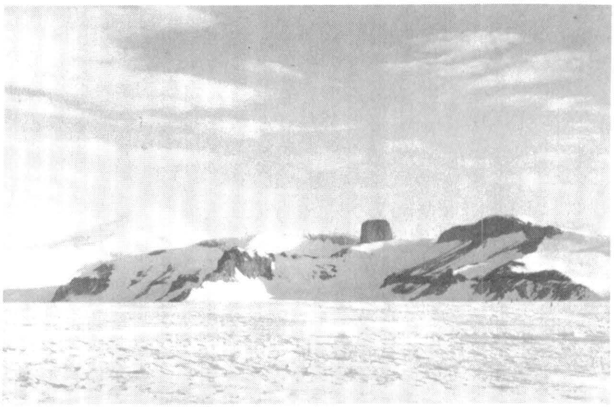


Fig. 2. View of Basecamp Valley toward Pillsbury Tower, Jones Mountains.

islands, the largest rookery containing several thousand birds. Skuas were associated with most of the rookeries.

The Walker Mountains comprise scattered nunataks of quartz-diorite-gneiss, most of which are characterized by steep slopes and are largely snow- and ice-covered. Small rock outcrops are common, but many are inaccessible because of steep slopes, blue ice, and local crevasses (Fig. 1). Thirty nunataks were studied, 27 of which supported lichens; however, their density was usually low. An exception at Boker Rocks was characterized by dense lichen and moss communities frequently dominated by a variety of lichens.

Dustin Island is a small island located east of Thurston Island. It is essentially a low, snow-covered dome with abrupt coastal bluffs, some of which have associated rock outcrops. Only two outcrops were accessible by helicopter: Ehlers Knob and Standifer Bluff. Well-developed lichen communities occurred on both outcrops, especially on the latter, where they were associated with a small Adélie penguin rookery. Mosses were also found on both outcrops.

A biological survey was also made of McNamara Island and Lepley Nunatak, both east of Dustin Island. The only two small accessible outcrops on McNamara Island contained lichens and mosses. Lepley Nunatak is relatively low and is composed of light-gray granitic rock intruded by dark-gray mafic dikes. During our last visit, its upper portion was essentially snow- and ice-free, presenting a continuous rock outcrop approximately 1 km in diameter. Abundant lichens throughout the outcrop were the only kind of organisms observed.

Considerable effort was expended in surveying the complex mosaic of rock outcrops of the Jones Mountains, which are located on the Eights Coast south of Dustin and McNamara Islands (Fig. 2). Briefly, approximately one-half of the 21 rock outcrops studied were associated with Upper Tertiary volcanics, while the remainder were associated with older igneous rocks. Approximately 75 percent of the outcrops supported lichens in varying degrees of density and floristic richness, and approximately half contained mosses. Three outcrops contained depressions with thick algal mats in which individuals of one species of rotifer were common.

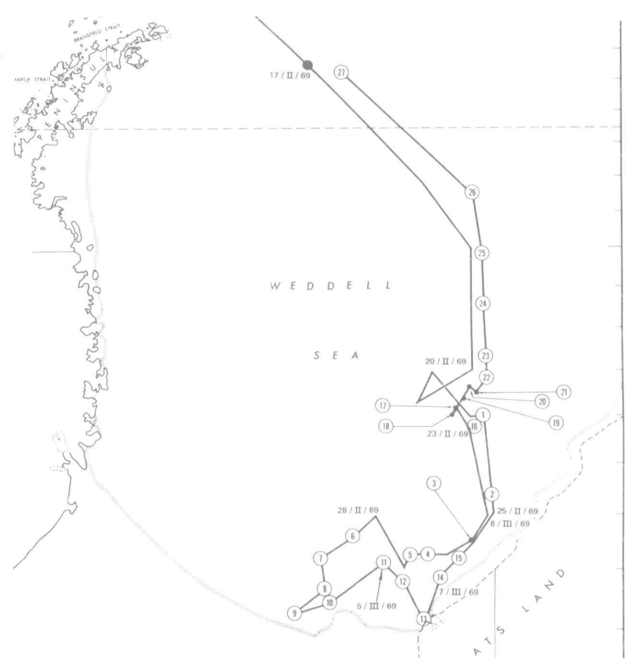
Table 1. Summary of Ellsworth Land Biological Survey.

Location	No. of areas studied	No. of areas with:					
		Algae	Lichens	Mosses	Petrels	Penguins	Skuas
Hudson Mountains	16	1	14	3	5	0	0
Islands off Walgreen Coast	11	10	11	1	0	8	6
Walker Mountains	31	0	23	5	4	1	0
Dustin Island	2	1	2	2	0	1	1
McNamara Island	2	0	2	2	0	1	0
Lepley Nunatak	1	0	1	0	0	0	0
Jones Mountains	21	3	15	9	7	0	2
Total	84	15	68	22	16	11	9

International Weddell Sea Oceanographic Expedition

IWSOE–1969 was conducted from mid-February till late March by USCGC Glacier *and ARA* General San Martín. *The expedition's primary objective, recovery of the four current-meter arrays placed near 74°S. 40°W. during IWSOE–1968,* was not achieved, owing to severe ice conditions. Other research programs were carried out successfully, however, as discussed on the following pages.*

Glacier*'s cruise track, shown at right, was based on a map prepared by Thor Kvinge, University of Bergen (Norway), who served as U.S. Antarctic Research Program Representative on the expedition.*



**Antarctic Journal,* vol. III, no. 4, p. 80-88.

Weddell Sea Benthic Studies

JOHN S. RANKIN, JR., KERRY B. CLARK

and

CHARLES K. BIERNBAUM

Marine Research Laboratory
University of Connecticut

The primary objective of this program was to study the density and diversity of the deep-sea benthos in the Weddell Sea using the anchor dredge and epibenthic sled.

Dredging in 1968 was hampered by ice conditions, loss of sled, and a very primitive winch. No deep-water dredging of over a few minutes' duration on the bottom could be made in pack ice. An A-frame on the starboard after end of the fantail payed out wire into brash ice swept around it by the ship's wash. This brash included chunks of ice too large to permit more than almost 0° wire angle.

In spite of these conditions, 5 successful anchor dredge samples were obtained from depths of 650-4,000 m with densities of 7,290 animals per square meter to 7 per square meter. Three successful epibenthic-sled samples revealed 27 major taxa and 2,029 individuals at 650 m, and 16 taxa, 245 individuals at 1,926 m. After loss of the sled, this same general distribution was observed using a Blake trawl, a biological trawl, and a Van Veen grab.

Dredging on the International Weddell Sea Oceanographic Expedition—1969 (IWSOE–1969) was facilitated greatly by the use of a heavy duty winch and a luffing crane on the starboard fantail quarter, permitting longer and deeper dredging in heavy ice than had been possible in 1968. As the ship moved through pack and heavy floes, the ice was pushed aside amidships and drawn into the wake aft of the ship, resulting in relatively ice-free space by the crane. Also, weight of the wire out, weights 100-500 m in front of the dredge, and use of a pinger permitted wire out at less than 10° angle. Light floes were not pushed aside, but rafted against the wire. The epibenthic sled, therefore, could be used only in areas of newly formed ice or in open water since it required an hour or more on the bottom.

Seventeen successful anchor dredge samples were taken from depths of 250 to 4,700 m. Preliminary results reveal the same general pattern of distribution of animals with depth as found in 1968: on hard substrate, down to about 1,000 m, large numbers of many groups of macroscopic animals; below 1,000 m, on soft bottom, few kinds but large numbers of smaller animals. Because of heavy ice concentration and the necessity of remaining close to IWSOE–1968 station 0001 for possible retrieval of current meters, 9 of the anchor dredge samples were taken from about 12 to 30 miles apart. It is felt that this should permit a much more meaningful analysis of benthic conditions than one from single samples from widely spaced stations.

Four of six epibenthic sled casts in depths from 2,800 to 4,700 m were successful. A surprisingly rich composition of macroscopic animals, unobserved in the anchor dredge samples, was found at depths of 3,000 and 3,700 m. The picture was very similar to that of the shelf. However, very few animals were obtained at 4,700 m.

Data obtained from IWSOE–1968 and IWSOE–1969 emphasize the high density and diversity of benthic organisms in the Weddell Sea. They are quite comparable to those from the North Atlantic Ocean collected by Sanders, Hessler and Hampson (1965), Hessler and Sanders (1967), and Sanders and Hessler (1969), who developed the gear and method of analysis used in the present study. No direct correlation with any single environmental factor can be made at this time except possibly type of substrate. If temperature, salinity, and other parameters are used as indicators of different water masses, and bottom transects made accordingly, some relationships may be found. In general, bottom temperature increases from shelf to deep water. These considerations must await further study of the data.

The eastern region of the Weddell Sea seems to be as productive as the southwest and western regions, if not more so. A thick bloom of phytoplankton, estimated to cover about 15,500 km^2 (6,000 mi^2), was observed on February 10, 1968, near the Filchner Ice Shelf by El-Sayed (1968). An even greater bloom, covering an estimated 52,000 km^2 (20,000 mi^2), was encountered on March 15–17, 1969, between 72°51.4′S. 30°46.2′W. and 70°52.7′S. 30°23.2′W. Large numbers of seals, petrels, and Adélie penguins on the surface, as well as an abundant benthic fauna below, are evidence of the richness of the whole area.

About 500 lbs of preserved material and sorted sediments were returned to the University.

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Research Program in Cooperation with Argentina, 1968-1969

LUIS R. A. CAPURRO

Department of Oceanography
Texas A&M University

On the basis of the results obtained during the International Weddell Sea Oceanographic Expedition 1968 (IWSOE–1968), the Hydrographic Office of the Argentine Navy prepared for the participation of the icebreaker ARA *General San Martín* in IWSOE–1969. Different tentative lines of oceanographic stations were scheduled to be occupied during the cruise, subject to ice and meteorological conditions.

As information on the ice conditions, obtained from satellite information as well as aerial reconnaissance in the area, was not very favorable, it was decided to occupy the stations wherever conditions were appropriate.

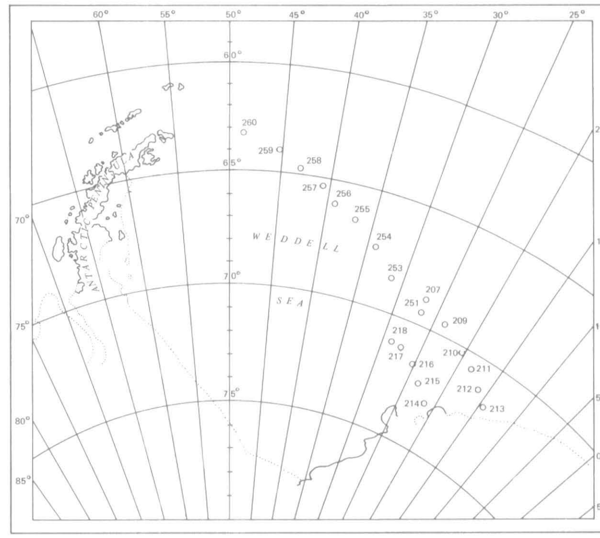
During February, most of the 20 stations shown on the map were occupied. At each station, the classical oceanographic elements were measured and continuous salinity-temperature-depth (STD) recording and bathythermograph casts were made. Samples were collected for primary-productivity determinations and plankton analysis.

Some of the preliminary findings seem to indicate the following:

1. Physical and chemical data are in agreement with those of former cruises, as far as the water-mass identification is concerned.
2. Wide variations in temperature and salinity found in the upper 50 m were due mainly to local ice conditions.
3. Winter water was detected at the normal depths (50 to 75 m) and the deep, warm water at 250 to 500 m.
4. Antarctic Bottom Water, characterized by its temperature and salinity values (0.6°C. and 34.66 ‰), was found at stations 256, 257, 258, and 259 from 3,500 m downward.
5. In a 100-mile-wide area WNW of Cape Norvegia, an indication was found of rather warm water, believed to be the influx of the Circumpolar Current into the Weddell Sea and the main source of the formation of the eastern coastal channel.
6. Dissolved oxygen shows values similar to those obtained on former cruises, although they are smaller than those found by *Eltanin* at great depths.

The stations occupied in the past in the Weddell Sea are now being studied for quality control, water-mass analysis, and their dynamic implications. Dr. Theodore D. Foster, of Yale University, who participated in the cruise, is working on his research program on the mechanism of seawater convection, more specifically in the origin of the Weddell Sea bottom water.

Plans are being developed to carry out additional work in the austral summer of 1969–1970 and in the winter of 1970 at the Argentine General Belgrano Base.



Stations occupied by ARA *General San Martin*

U.S. Coast Guard Oceanographic Unit's Participation in IWSOE–1969

GARY L. HUFFORD *and* ROBERT B. ELDER

U.S. Coast Guard Oceanographic Unit

The U.S. Coast Guard Oceanographic Unit again participated in the International Weddell Sea Oceanographic Expedition (IWSOE) from February 13 to March 24, 1969. The program consisted of physical oceanographic measurements, determination of nutrients and related chemical features of seawater, and bottom photography. The purpose of this work was to increase our knowledge of this little-known area and, in particular, to investigate the formation of Antarctic Bottom Water.

A total of 27 stations was occupied despite extremely heavy ice. Nansen casts were made at 25 locations to determine water temperature, salinity, pH, and dissolved oxygen, and to measure inorganic phosphate, nitrate, nitrite, ammonia, and silicate content.

Salinity was determined with an inductive salinometer, dissolved oxygen by a modified Winkler method, and pH with a pH meter. Nutrient analysis was performed at sea for inorganic phosphate, nitrate, nitrite, and silicate. Additional water samples were frozen for onshore analysis of ammonia. At most stations, samples were obtained as close to the sea floor as possible to detect any changes in the parameters studied.

At eight stations, a continuous trace of salinity and temperature versus depth was obtained using an STD (salinity-temperature-depth) recording system. Nansen casts were also taken at these stations so that a comparison could be made between the salinity and temperature recorded by the STD and those measured by reversing thermometers and salinometer. STD casts were not taken at all stations because of failure of the salinity sensor.

Bottom photographs were taken at five locations on the shelf, slope, and abyssal plain of the southeastern Weddell Sea. The compass-oriented photographs revealed many organisms and their activity, as well as current lineations.

The second IWSOE has added more information about the virtually unknown southern part of the Weddell Sea. This year's data coincide with the data from IWSOE–1968 and give insight to waters under perennial ice. A possible mechanism for the formation of Antarctic Bottom Water in the summer will soon be published. Use of preformed nutrients, apparent oxygen utilization, and specific alkalinity in tracing water masses has augmented as well as supplemented the physical data.

Population Study of Seals in the Weddell Sea

ALBERT W. ERICKSON, DAVID R. CLINE *and* ROBERT J. HOFMAN

James Ford Bell Museum of Natural History
University of Minnesota

From mid-January to mid-March 1968, a study was commenced to gain information on the status and population dynamics of antarctic seals. Such information is deemed vital to the welfare of the animals in the face of expected future commercial exploitation. Use of the icebreaker USCGC *Glacier* on the International Weddell Sea Oceanographic Expedition—1969 (IWSOE–1969) enabled us to gain further knowledge pertaining to seals inhabiting ice-pack areas of the little-studied Weddell Sea.

A total of 76½ hours of seal census from shipboard was accomplished between February 18 and March 24, 1969, as *Glacier* penetrated the pack ice. All animals sighted within 220 yards on either side of the ship were tallied. Adverse weather conditions limited aerial census work using shipboard helicopters.

Distances traveled during census periods were determined in three different ways: (1) measuring distances between satellite fixes, (2) dead reckoning, and (3) drawing detailed course plots of the ship's track. The last technique was believed most accurate since changes in both ship's course and speed were considered. Distances determined from the detailed plots averaged 24 percent greater than the dead reckoning determinations and 19 percent greater than computations from the satellite fixes. Final seal density estimates have been based on the detailed course plots.

The crabeater seal (*Lobodon carcinophagus*) was by far the most abundant of the four species of antarctic seals encountered in the Weddell Sea (Table 1). The average density determined for this species was 5.99 per square nm, nearly identical to that determined on IWSOE–1968. A peak count of 149 crabeaters per square mile was made on March 9 between 74°22.45'S. 32°10.1'W. and 74°19.85'S. 32°24.7'W. Observed densities of leopard seals (*Hydrurga leptonyx*), Weddell seals (*Leptonychotes weddelli*), and Ross seals (*Ommatophoca rossi*) were less than one individual per square mile. It was substantiated that a fifth seal species occasionally frequents the southern Weddell Sea when an adult elephant seal (*Mirounga leonina*) was sighted at 77°S. 34°W. on February 26.

Table 1. Seals observed in the pack ice of the Weddell Sea, February-March, 1969

Species	Total number seen	Animals per sq n mi.	Animals sighted per hr.	Percent
Crabeater	1136	5.99	14.85	97.01
Leopard	22	0.14	.29	1.88
Weddell	10	0.06	.13	.85
Ross	3	0.02	.04	.26
Total	1171	...	15.31	100.00

During the late summer, seals were not found in large groups. Approximately 61 percent of the crabeaters were seen as lone individuals; the largest pod consisted of 16 animals. Leopard and Ross seals were always observed as lone individuals.

The effectiveness of anesthetic drugs used to immobilize seals for biological studies was also examined. Phencyclidine hydrochloride (Sernylan) in combination with the tranquilizer promazine hydrochloride

(Sparine) was used to immobilize 30 crabeaters, 3 Weddells, 2 Ross, and 1 leopard seal in 1969. The drugs were administered with an extension syringe device. Twelve seals of three species were brought aboard ship to monitor drug responses and to establish suitable dosage rates. Results indicated that the drug combination rate of 1 cc Sernylan with 2 cc Sparine (or between .40 and 1.00 mg/kg Sernylan) is well suited for immobilizing crabeater, Ross, and leopard seals for up to several hours. However, the Weddell seal has proven extremely sensitive to this drug combination, as evidenced by the death of several subjects during the past two years, even though dosages below .25 mg/kg were administered.

Blood samples were collected from the 38 immobilized animals. These will be analyzed by electrophoresis to determine possible racial and phylogenetic affinities, establish base line hematology, and evaluate the physical condition of seals. A study of karyotype characteristics was also initiated to further study inter- and intra-specific biological relationships of the seals. Blood samples and body temperature data were collected from captive seals at different times of day to study possible circadian rhythm influences on seal behavior.

Shipboard counts of sea birds were conducted in conjunction with the seal census. Fewer species were sighted this year than in 1968, with the Adélie penguin again by far the most numerous (Table 2). The emperor penguin was the only species to show a profound change in abundance between years. This change was attributed partly to the fact that this year, the ship remained in waters closer to their rookeries in the southern reaches of the Weddell Sea.

Table 2. Birds observed in pack ice areas of the Weddell Sea during IWSOE 1968-1969.

Species	Number Seen		Percent Composition	
	1968	1969	1968	1969
Adelie Penguin	6,571	3,473	69.53	68.95
Snow Petrel	1,686	673	17.84	13.36
Arctic Tern	567	335	6.00	6.65
Emperor Penguin	310	449	3.28	8.91
Antarctic Petrel	202	93	2.14	1.85
Wilson Storm Petrel	31	1	.33	.02
Cape Pigeon	25	—	.26	—
Dove Prion	24	—	.25	—
Chinstrap Penguin	23	—	.25	—
Giant Petrel	8	8	.08	.16
Skua	4	5	.04	.10
Total	9,451	5,037	100.00	100.00

***Above, right:* A specimen of Ross seal (*Ommatophoca rossi*) on the pack ice of the Weddell Sea, with USCGC *Glacier* in background. *Right:* A crabeater seal (*Lobodon carcinophagus*) being hoisted aboard *Glacier* for immobilization, karyotype, and circadian-rhythm studies.**

Marine Geology of the Weddell Sea

RICHARD D. Le FEVER, TERRY CHRISS, *and* LAWRENCE A. FRAKES

Geology Department
University of California, Los Angeles

and

JERRY L. MATTHEWS

Scripps Institution of Oceanography
University of California, San Diego

A program of piston coring for marine geology was carried out aboard USCGC *Glacier* during the International Weddell Sea Oceanographic Expedition 1969 (IWSOE–1969). Because of limited time and extremely heavy ice conditions, the shipboard sampling program, including the coring plan, was somewhat restricted. In spite of these and other difficulties relating to the widespread rocky bottom, the coring program should be considered a moderate success.

Twenty-one cores were obtained from 19 stations in 23 attempts. Mean core length is 259 cm; longer cores might have been obtained in some areas, but difficulties were encountered in rigging for cores longer than 20 feet (610 cm). Penetration was limited in other cases by the rocky bottom. Once on deck, the cores were sealed and capped in the plastic liners, labelled, and stored under refrigeration for transport to the United States. They are currently under study, along with Phleger cores obtained by the Coast Guard coring operation of IWSOE–1968 and *Eltanin* cores from the Ross Sea.

Preliminary laboratory studies include radiography, grain-size analysis, and microfossil separations. Whole cores and split cores were photographed by Ter Chien Huang in the laboratory of H. Grant Goodell at Florida State University, and the X-ray photographs were analyzed for sedimentary structures at the University of California, Los Angeles (UCLA). Sedimentary units observed constitute five general categories: massive diamicton, stratified diamicton, massive clays and muds, interlaminated sandy silts and clays, and highly disturbed and burrowed clays and diamictons. The massive diamictons are particularly important because they are almost identical to terrestrial tills in appearance, yet have apparently been deposited in a marine environment. The interlaminated sandy silts and clays are apparently restricted to the continental slope.

Grain-size analysis is performed using the continuous-recording, automatic particle-size analyzer designed and developed by Ronald J. Gibbs of UCLA. This unit records the continuous size distribution of samples weighing only 50 to 1,000 mg and permits the sampling and analysis of sedimentation units less than 1 cm thick. Information is recorded on a strip-chart recorder and later analyzed by a digital computer. Grain-size parameters of Folk (1965) and Inman (1952) have been modified for the portion of the size distribution between 6 and –2 ϕ (15.6 microns to 4 mm) in an attempt to make our techniques and interpretations applicable to consolidated rocks.

Statistical analysis of laboratory results involves distinguishing between tills and sediments of mudflow and ice-rafting origin using multivariate analysis based on textural parameters (Landim *and* Frakes, 1968). A modified discriminant function technique is extremely successful in eliminating overlap between environments. With this method, it is possible to distinguish the Ross and Weddell Sea sediments from very similar sediments laid down as terrestrial tills and as subaerial mudflows. Work now in progress will attempt to define subenvironments of deposition within the Ross and Weddell Seas.

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Dr. William D. McElroy New NSF Director

Dr. William D. McElroy, formerly Chairman of the Biology Department of Johns Hopkins University, has been appointed Director of the National Science Foundation. He replaces Dr. Leland J. Haworth, who retired on June 30.

Additional information on the appointment will be given in the September–October issue of the *Antarctic Journal.*

Translations in Preparation

The following Russian monographs have been submitted to the Clearinghouse for Federal Scientific and Technical Information for translation under the Israel Program for Scientific Translations:

Arctic and Antarctic Scientific-Research Institute. Radiophysical methods of research in the Arctic Basin and in Antarctica. Leningrad, 1968. 216 p. (*Its* Transactions, vol. 284).

Arctic and Antarctic Scientific-Research Institute. Problems in polar geography. Leningrad, 1968. 255 p. (*Its* Transactions, vol. 285).

Other Scientific Programs

BIOLOGY

Microbial and Ecological Investigations of Recent Cinder Cones, Deception Island, Antarctica

R. E. CAMERON

Bioscience Section
Jet Propulsion Laboratory
California Institute of Technology

and

R. E. BENOIT

Department of Biology
Virginia Polytechnic Institute

During the austral summer of 1968–1969, field trips were made to cinder cones that arose in the sunken caldera of Port Foster, Deception Island (62°57'S. 60°38'W.), which is included among the South Shetland Islands (Fig. 1). The new craters are within the northwest sector of Deception Island, in Telefon Bay.* A preliminary report of the results of the eruption was made by Chilean investigators (Valenzuela *et al.*, 1968). The new island is roughly oval, about 930 m long and 200 m wide, and composed of three principal craters and a satellite crater (Fig. 2). The principal and highest crater was indicated as having a height of 170 m.

Previous investigations have been made on Deception Island for phanerogams and cryptogams (Longton, 1967), bacteria and yeasts from lakes (Stanley *and* Rose, 1967), and soil of penguin rookeries (Sieburth, 1965). No microbiological studies had been made on relatively uncontaminated soils and the new craters until our present investigation.

The main purposes of our preliminary investigations on the new island were to determine whether or not any biota had become established since the eruption and, if present, the life forms and the factors that enabled them to adapt to their environment.

A campsite for environmental measurements was established at site 702 with living quarters in an abandoned whalers' hut, across from the west crater, in the vicinity of a wrecked Argentine *refugio*. Samples of "soil," primarily from the surface 2 to 5 cm, were collected by aseptic techniques from 20 sites throughout the new island and across from it. Water samples also were collected in sterilized bottles from ponds within the craters and in the water surrounding the craters. Bacteriological fallout plates of trypticase soy agar were placed at 6 sites for 10- and 20-minute periods to detect aerial contaminants. These plates were subsequently incubated at + 20°C. on board *Hero*, with additional incubations made at JPL and VPI. Gas samples were taken from the atmosphere above the soil at site 702, and on the outside slope of

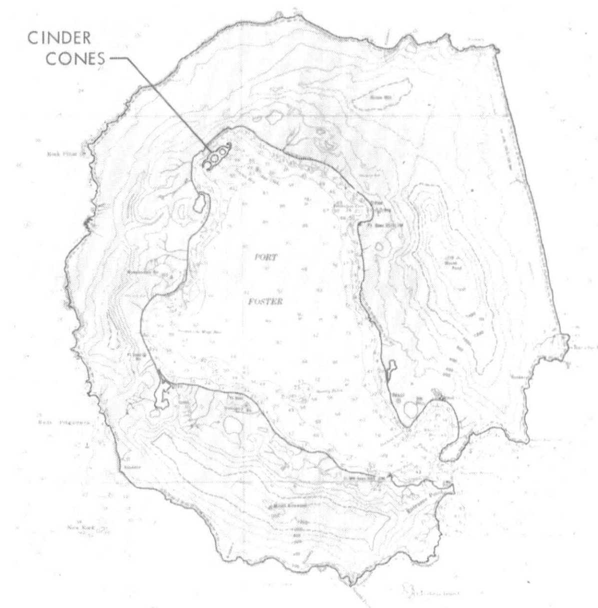
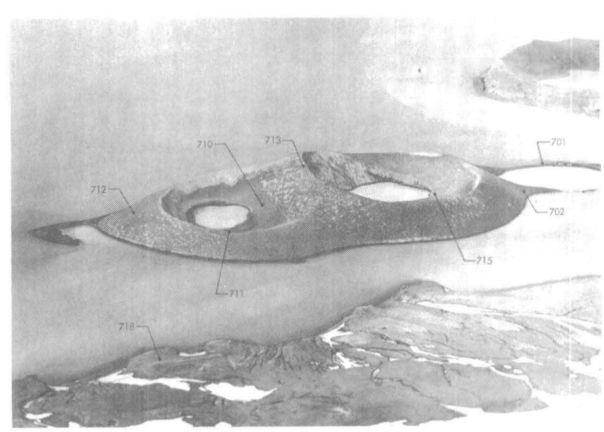


Figure 1. Deception Island, showing location of new cinder cones.

Figure 2. New volcanic islet within Port Foster, Deception Island, January 1969.



U.S. Coast Guard Photo

*Unofficial names applied to the craters are "Isla Yelcho" by Chile and "Islote Marinero Suárez" by Argentina. Personal communication, Fred G. Alberts, Geographic Names Division, U.S. Army Topographic Command.

the eastern crater, halfway up from the beach. Gas samples were also taken from two fumaroles, sites 705 and 713 (Fig. 2), and subsequently analyzed by mass spectrometry. Weather permitting, some environmental measurements were made every three hours from noon to 9:00 p.m., on January 25 to 29, 1969.

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Physiological Studies of Antarctic Mosses, 1968–1969

JAMES R. RASTORFER *and* JOHN M. GNAU

Institute of Polar Studies

and

College of Biological Sciences
The Ohio State University

The second year of a two-year program directed toward physiological studies of antarctic mosses was completed during the past austral summer at Palmer Station. Following several reconnaissance field trips, five moss taxa were selected for comparative studies. These taxa consisted of *Polytrichum* sp., *Brachythecium* sp., *Drepanocladus* sp., and *Pohlia* sp. from the easternmost of the Corner Islands (Argentine Islands) and *Dicranum* sp., *Drepanocladus* sp., and *Brachythecium* sp. from Litchfield Island.

The new, well-equipped biology laboratory at Palmer Station permitted the authors to carry out assays and tests on plant materials as they were collected from the field. Chlorophyll, protein, and carbohydrate contents were determined spectrophotometrically on the five selected moss taxa. In addition, photosynthetic and respiratory rates were measured under controlled conditions by using differential respirometry to measure oxygen exchange over a wide range of temperatures and light intensities.

Except for *Dicranum*, the above moss taxa were cultured on mineral agar and yeast extract in mineral agar to test their regenerative capacities. There were appreciable differences among the taxa tested in this respect. Also, tissue samples of the above five taxa and a few others were washed, dried, ground, bottled, and shipped back to the University for element assays. Approximately one square foot of each of the selected moss taxa was air dried, packaged in plastic bags, and returned to the States for further physiological investigations. Herbarium specimens consisting of 165 packets were prepared from plant materials collected from various localities in addition to the Corner Islands and Litchfield Island sites. The authors wish to acknowledge their appreciation to the personnel of USCGC *Edisto* and the research vessel *Hero* for their cooperative field support.

Results of Bryological Field Work in the Antarctic Peninsula, Austral Summer 1968–1969

R. M. SCHUSTER

Department of Botany
University of Massachusetts

During a period extending from early January to February 7, 1969, intensive field work was pursued in the Antarctic Peninsula from Hook Island, north of Adelaide Island, northward to Admiralty Bay, King George Island.

From 18 localities visited, approximately 750 specimens were collected, giving a good cross section of the bryophyte flora. Owing to a snowstorm on January 25 and 26, collections at the northernmost point reached were very limited. The opportunities for field work on the northern sectors of the Peninsula were also restricted because of the tight schedule of *Hero* and the fact that her trip was chiefly for support of field parties. In spite of these limitations, the results outlined below show clearly the spectacular additions to the known flora of the Antarctic.

Before my field activities of last summer, a small number of Hepaticae had been found in the Antarctic. These have been assigned to only two families, Lophoziaceae and Cephaloziaceae.

According to my survey, 12, and possibly 13, species occur. The most interesting additions are 4 species of *Cephaloziella* (family Cephaloziellaceae), 1 of *Anthelia* (Antheliaceae), *Pachyglossa dissitifolia*, and *Clasmatocolea georgiensis* (Lophocoleaceae). Five genera and three families are new to the Antarctic. An increase in the liverwort flora of two and one-half to three times has resulted. Most of the Hepaticae were worked up at Palmer Station.

Of the taxa collected, *Cephaloziella autoica*, *C. hispidissima*, and *Lophozia antarctica* are new to science.

The Musci have been labeled and their identification is being undertaken by Dr. H. Robinson of the Smithsonian Institution. A report on these will follow.

In addition to the bryological results, two finds are noteworthy:

1. A Basidiomycete, *Gerronema* sp., apparently new to science, was found at Norsel Point. This is only the fifth or sixth Basidiomycete known from the Antarctic and is the southernmost find of a Basidiomycete; the genus is new to the Antarctic.
2. A large collection of the chironomid midge, *Belgica antarctica,* was made on Hook Island; this represents by far the southernmost find of a dipteran in the Antarctic, and, except for Collembola, the southernmost known site for insects in the Antarctic.

Whenever feasible, bryophyte collections were made sufficiently large so that 2 to 6 duplicates can be distributed eventually. Thus, a wide spread of bryological material in institutional herbaria will result. In addition, when time permitted, collections of lichens were made for Dr. I. M. Lamb, Director of the Farlow Reference Library, Harvard University.

Freezing Resistance in Fishes of the Antarctic Peninsula

A. L. DeVRIES

Department of Food Science & Technology
University of California, Davis

Some of the *Trematomus* fishes inhabiting McMurdo Sound, Antarctica, have been observed to rest on masses of ice crystals in freezing seawater. Recent studies have shown that such fishes have low blood-serum freezing points (—1.9° to —2.0°C.) throughout the season and are extremely resistant to freezing (DeVries *and* Wohlschlag, 1969). Sodium chloride, the most abundant salt in the blood of temperate water fishes, accounts for only 50 percent of the serum freezing-point depression in the *Trematomus* fishes. Most of the remaining freezing-point depression can be attributed to a serum freezing-point depressant, glycoprotein. This compound has been isolated and its properties are described elsewhere (DeVries *and* Wohlschlag, 1969).

In contrast to McMurdo Sound, the waters of the northern Antarctic Peninsula area are warmer and are relatively ice-free during the summer. The fish fauna of the Peninsula waters is also different from the fauna inhabiting McMurdo Sound; nototheniid fishes of the Peninsula fauna belong primarily to the genus *Notothenia,* and chaenichthyids are much more abundant than in the McMurdo fauna. During the months of January and February of 1969, three species belonging to the family Chaenichthyidae and three species of *Notothenia* were caught and their resistance to freezing studied. Fishes were collected with an eight-foot otter trawl from R/V *Hero.* Most of the trawls were made in the shallow waters (40 to 200 m) on the relatively smooth banks westward of Brabant, Hoseason, and Deception Islands. Fishing in the waters adjacent to the Peninsula was unsuccessful because of the extremely rough bottom. Several specimens of *Trematomus bernacchii* were also caught by setting baited wire traps in a shallow-water channel between the Melchior Islands. Fishes caught in trawls were put in running seawater aquaria and their blood was immediately drawn hypodermically from the heart. Serum was collected from clotted blood, frozen, and later analyzed at the biology laboratory at Palmer Station. Analyses included determination of serum freezing points using a Fiske osmometer, determination of concentrations of sodium chloride in the serum, and determination of freezing points of dialyzed serum. Some of the live fishes were transported to Palmer Station and freezing-resistance experiments carried out in refrigerated aquaria. Body tempera-

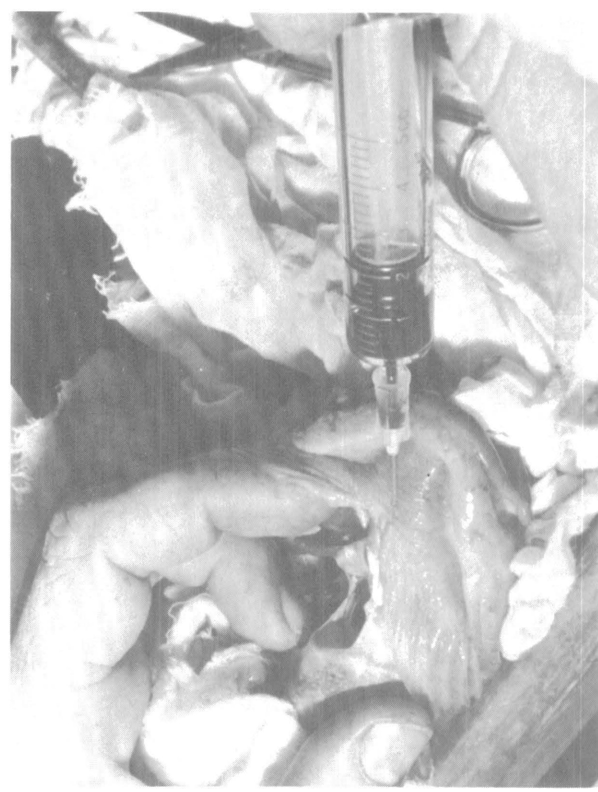

Photo by W. R. Curtsinger, USN

Dr. DeVries extracting blood sample from the heart of a fish of the genus *Notothenia*.

tures of two species of *Notothenia* and one species of *Trematomus* were also measured.

Preliminary analyses of the data from serum freezing-point measurements and freezing experiments indicate that *Notothenia coriiceps* and *N. gibberifrons* are as resistant to freezing as the species of *Trematomus* living in McMurdo Sound. *Notothenia larseni* and *N. nudifrons* are slightly less resistant to freezing compared to *N. coriiceps*. In spite of the higher temperature of the Peninsula waters, no difference could be found in the level of freezing resistance when *T. bernacchii* from the Peninsula waters were compared to those of McMurdo Sound. Studies on 12 *Chaenocephalus aceratus*, 2 *Champsocephalus gunnari*, and 2 *Pseudochaenichthys georgianus* indicate that these chaenichthyid fishes are only moderately resistant to freezing; the 3 species had serum freezing points of about —1.2°C. Experiments in which fishes were subjected to freezing conditions showed that there was good agreement between the freezing temperature of all fishes and the freezing point of their serum. Body temperature measurements using a thermistor showed that the body temperature in both resting and moderately active fishes are only 0.02° to 0.05°C. higher than the temperature of the surrounding water, regardless of the water temperature. This finding indicates that freezing resistance in antarctic fishes cannot be attributed to thermogenesis as has been suggested by some investigators (Potts *and* Morris, 1968).

As in the fishes of McMurdo Sound, there is only sufficient sodium chloride in the blood of the *Notothenia* species to account for half of the serum freezing-point depression. Dialysis experiments showed that a nondialyzable freezing-point depressant was present in the serum of all the fishes studied, although in the chaenichthyids it was present in low concentration. Electrophoretic observations and amino-acid analyses indicate that the freezing-point depressant is the same glycoprotein which has been identified in the blood of the McMurdo Sound fish *Trematomus borchgrevinki* (DeVries *and* Wohlschlag, 1969). A detailed characterization of this substance is now in progress.

This work was supported by National Science Foundation grant GA–3919 and by a National Institutes of Health postdoctoral fellowship to A. L. DeVries.

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Benthic Zonation on Submarine Cliffs in the Vicinity of Arthur Harbor, Antarctica[1]

JOHN C. McCAIN[2] *and* WILLIAM E. STOUT

Marine Science Center
Oregon State University

For an examination of the zonation of benthos on vertical rock faces, two sampling transect stations were established in the vicinity of Arthur Harbor. Station A, in an area of low surf activity, was located on the rocky point adjacent to Palmer Station; station B, in an area of high surf activity, was established on the low-lying rocks southeast of Outcast Islands.

At both stations, 0.25 m² samples were scraped from the rocks by the authors while scuba diving and placed in a 1-mm mesh net bag with a 50-cm opening. By using the opening of the bag as a guide, we were able to estimate the size of the sampled area.

The rock face at station A was nearly vertical and extended to a depth of approximately 45 m. Here the rocky face met a gently sloping mud bottom. Down to 15 m the water was murky due to surf action, but it cleared below this depth. The water temperature at station A increased with depth, ranging from 0.4°C. at the surface to 0.8°C. at 38 m. Between 12 and 15 m the water temperature increased 0.2°C., probably indicating the lower limit of extreme surf mixing.

At station A, samples were collected at 1.5-m intervals to a depth of 15 m, and at 3-m intervals from 15 to 30 m. The limpet *Patinigera polaris* and encrusting algae were practically the only organisms present on the flat surfaces from the surface to a depth of 8 m, *Patinigera* reaching a maximum of 50 per 0.25 m² at 1.5 m and extending well below the limits of our survey. The cracks and crevices from the surface to 8 m were generally filled with gravel and shell fragments and free of mud and silt. Several large organisms occupied these areas, notably the sea urchin *Sterechinus neumayeri* and a species of the alga *Desmarestia*.

The rock from 8 to 15 m had only a slight silt cover and the kelp *Phyllogigas grandifolius* dominated. This kelp lies flat on the rock, providing cover for numerous large invertebrates, such as brachiopods, sea stars, and the isopod *Glyptonotus antarcticus*, along with a multitude of smaller invertebrates.

Below 15 m, the rock was heavily silted. Here the organisms of the overlying kelp zone merged with

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[2] Now at the Smithsonian Oceanographic Sorting Center, Smithsonian Institution.

those of the mud bottom in a transitional zone. Gorgonians, glass sponges, and nemerteans, together with the kelp zone organisms, extended into this region.

Station B had a different zonation in the upper levels. As at station A, limpets, algae, and sea urchins dominated the upper 8 m; however, the cover of *Desmarestia* was markedly denser. The density of limpets at this station dropped rapidly from 44 per 0.25 m^2 near the surface to 10 per 0.25 m^2 at 14 m. On the single dive that we were able to accomplish at station B because of the heavy surf, we took 0.25 m^2 samples at 3-m intervals to a depth of 15 m and made counts of limpets at 1.5-m intervals to the same depth.

A few general results are apparent from the sorting and identification of the organisms from the quantitative samples, begun at the Smithsonian Oceanographic Sorting Center. There are three distinct zones between the surface and 30 m on the submarine rock faces around Arthur Harbor: an upper surf zone, a middle kelp zone, and a lower transitional zone between the kelp zone and the mud bottom. The surf zone probably is a direct result of ice-scouring during the winter and is maintained by surf action during the summer. The upper limit of the kelp zone apparently represents the lower limit of ice scouring, with its lower limit corresponding to the lower limit of extreme summer surf action. Below the kelp zone, currents and turbulence are weak and allow silting of the rocks and the formation of the transitional zone.

Smithsonian Institution Collections from the First Antarctic Cruise of *Hero*

JOHN C. McCAIN*

Marine Science Center
Oregon State University

During the latter part of February 1969, collections of benthic invertebrates were made by the author aboard *Hero* for the Smithsonian Oceanographic Sorting Center (SOSC). These collections from Adelaide, Brabant, Low, Deception, and Hoseason Islands should provide valuable information on the benthos in the shallow waters of the Antarctic Peninsula, supplementing the deep-sea collections of USNS *Eltanin*.

In addition to Blake trawl, Petersen grab, and trynet samples from these islands, 10 bottom-camera stations were occupied in Port Foster, Deception Island. These camera stations, taken before the February 21 eruption, will provide information for the scientists of the Instituto Central de Biología of the Universidad de Concepción, Chile, who are currently carrying out research on the effects of the eruptions on the benthos of Port Foster.

Because of the irregular, rocky bottom of much of the Antarctic Peninsula, benthic sampling is difficult; however, besides the camera stations, 13 sampling stations were successfully occupied. From these stations, over 200 gallons of benthic invertebrates were removed and shipped to SOSC for processing.

A collection of fishes used by Dr. Arthur DeVries, of the University of California at Davis, for his study of freezing resistance in fishes, was preserved for shipment to SOSC. The 50 gallons of fishes included numerous specimens of hemoglobin-free fishes and several rare skates.

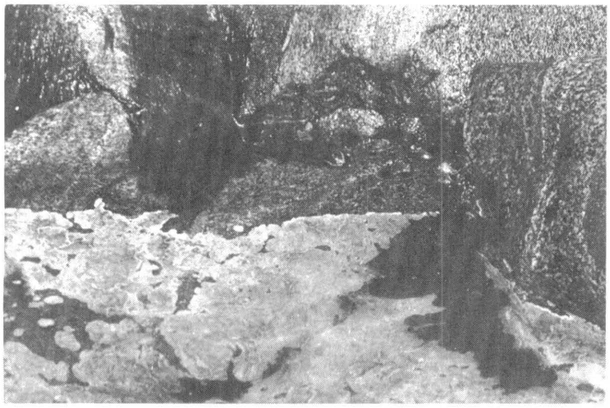
*Now at the Smithsonian Oceanographic Sorting Center, Smithsonian Institution.

Preliminary Observations of Life Between Tidemarks at Palmer Station, 64°45'S. 64°05'W.

JOEL W. HEDGPETH

Marine Science Center
Oregon State University

The ice-worn granite shore at Palmer Station appears, at first glance, to be barren at low tide, although the tidal range is about five feet. The tides are of the mixed semidaily and daily types; the lowest intertidal level may at times be exposed for several hours. During the summer months, a well-defined band of filamentous green algae, including such genera as *Enteromorpha, Ulothrix,* and *Cladophora,* gives a green tint to the lower foot of the intertidal region. Here and there are small thalli of various red algae, including *Leptosomia simplex, Curdiea racowitzae,* and *Iridaea* sp., sparingly scattered in crevices and sheltered places up to at least mid-tide level. These red algae sometimes form patches in shallow pools well above low tide. There is a sparse population of small amphipods, worms, etc. among the algae. The most conspicuous feature of the tidal region is the grayish-pink covering of the crustose red alga *Hildenbrandia,* which occurs in permanent tide pools at mid-tide levels and forms an even line marking the limit of tide zero in some places. Interspersed in the filamentous algal belt, but more characteristically in standing water, are diatom colonies forming a brown, slimy, fur-like growth, made up of such species as *Achnanthes subsessilis, Licmophora belgicae* var. *minor, Fragilaria planctonica, F. islan-*



Low tide at Palmer Station. *Hildenbrandia* below, with patch of *Iridaea* sp. at right. *Patinigera polaris* is in center, and patch of filamentous green algae at left. Tide level about 4-6 in. above zero.

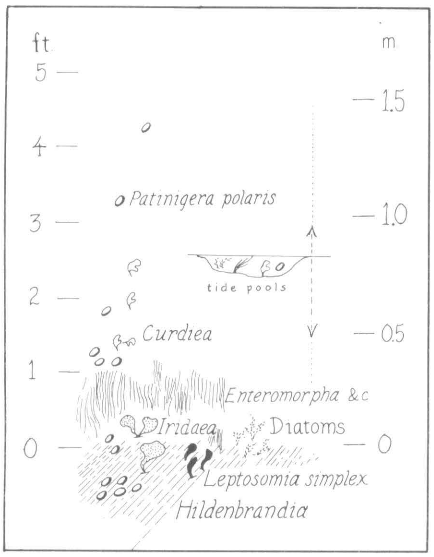


Diagram of intertidal zonation at Palmer Station.

dicae var. *stricta, Achnanthes parvula,* and *Navicula directa* (in relative order of abundance).

The only large intertidal animal of this region of the Antarctic is the limpet *Patinigera polaris.* Although not conspicuously abundant, it may be found in clusters well above the low-tide line, and on sheer wave-swept faces (as on Litchfield Island, opposite Palmer Station) it may occur sparsely several feet above high-tide line. This limpet is much more abundant below the low-tide line, attaining densities of perhaps 200 per m^2 at depths of 2 to 3 meters, according to observations by John McCain and William E. Stout.

Surface temperatures of the water at the low-tide line were about 1.0°C. and air temperatures immediately adjacent to exposed limpets were 8.0 to 10.0° in late January. The limpets appear to avoid situations where they may be exposed to direct sunlight, but these surfaces are also for the most part exposed to the action of brash ice during the summer, which may be a more significant factor than temperature in controlling intertidal distribution of the limpets. Judging from the aggregations of limpet shells at feeding stations on rocky eminences well above the sea, *Patinigera polaris* is obviously a significant item of diet for some bird, probably the Dominican gull, although feeding was not directly observed. These middens consist of several hundred shells. Some of the shells are surprisingly large, being nearly three inches long and two inches high. If, as observed elsewhere (*fide* B. Stonehouse, *in litteris*), the gulls do not feed on the bare rock surface but at the water's edge or slightly below it, there must be a constant upward movement of limpets during the ice-free periods of the year. It is possible that they feed on the seasonal algal growth.

In his general summary of the features of intertidal life on antarctic shores, Knox (1968) indicates that *Patinigera polaris* occurs primarily in pools. It may be that this limpet can invade bare intertidal surfaces only in sheltered regions protected from summer ice, and even in such situations, may be removed by predation in regions where gulls are abundant.

The development of intertidal life in the Palmer Station area is one of the simplest found anywhere, restricted as it is to the lower foot or 0.3 m of the intertidal region. The complete absence of barnacles of any kind is noteworthy, and the apparent sparseness of intertidal life is approached elsewhere on the bare sunbaked rocks of the Galapagos, where there are a few small snails, no upper zone barnacles, and no limpets whatever (Hedgpeth, 1969). The conspicuous growth and well defined upper limit of the crustose alga *Hildenbrandia,* in the Palmer region, below approximately tide zero, supports the suggestion by Gauld and Buchanan (1959) that the "Lithothamnia zone" is one of the most universal and characteristic phenomena of the seashore in all parts of the world. At the Equator, the most significant factor limiting distribution in upper intertidal regions may be the heating of the sun, whereas, in the Antarctic, the action of ice may be the most significant controlling factor.

I wish to thank Dr. M. Neushul for determinations of the algae and N. Ingram Hendey for determining the diatoms and estimating their abundance.

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Studies of Respiration in Antarctic Hemoglobin-Free Fishes

EDVARD A. HEMMINGSEN

Scripps Institution of Oceanography
University of California, San Diego

and

EVERETT L. DOUGLAS

Department of Zoology
University of Missouri, Columbia

The mobility provided by R/V *Hero* to the Antarctic Peninsula biology programs has solved earlier problems of collection of marine material. The new, well-equipped laboratory at Palmer Station has added further capabilities for experimental studies in the area. Utilizing these facilities during the past austral summer, physiological studies were carried out on fishes of the family Chaenichthyidae. These fishes, found only in antarctic and subantarctic waters, lack hemoglobin in their blood, and oxygen is transported only in physical solution. With the exception of some fish larvae, and a few other trivial cases, the absence of hemoglobin is unique among the vertebrates.

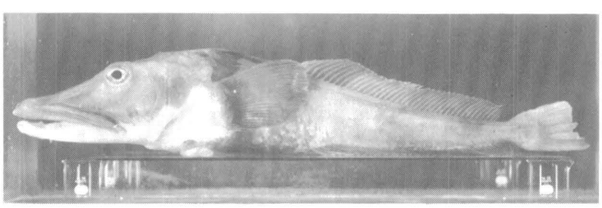

Photo: E. A. Hemmingsen

Chaenocephalus aceratus. This specimen is 61 cm long.

Thirty-four specimens of *Chaenocephalus aceratus* and one specimen of *Pseudochaenichthys georgianus* were collected in the vicinity of Arthur Harbor. Most of the specimens were caught on baited set-lines, which proved more effective than bottom trawling. The fishes were kept at the station up to four weeks in improvised holding tanks with running seawater. The temperature-controlled aquaria in the wet laboratory were used for the experiments. Oxygen consumption at rest was determined in either closed or flow-through respirometers. Twenty-three determinations in 13 specimens of *C. aceratus*, weighing from 566 to 2,160 g, gave a mean rate of 0.020 cm^3 O_2/g/hr. at 1°C. The oxygen consumption of *P. georgianus* (35.7 g) was 0.028 cm^3 O_2/g/hr. under the same conditions. These rates are one-third to two-thirds those of most other antarctic and arctic fishes which possess hemoglobin. The rate of oxygen uptake was little affected by the oxygen tension in the water at values higher than 50 mm Hg. However, the rate decreased sharply below this oxygen tension. Cutaneous respiration was found to be substantial and may be of importance. Measurements of the oxygen tension in pre- and post-gill water indicated that the gill efficiency was moderate; only 10 to 15 percent of the inflowing oxygen was taken up. The lactic acid concentration in arterial and venous blood was strikingly low, even after moderate anoxic stress; this indicates that conventional anaerobic metabolism does not play an especially important role in these animals. The blood volume was found to be about 8 percent of the body weight, a value 2 to 4 times higher than that of other teleosts. Thus, the major adjustment to the lack of hemoglobin in the blood appears to be in the circulatory system. Material was prepared and preserved for studies of vascularization of the tissues, fins, gills, etc.

The following fishes were incidentally collected near the station: *Notothenia gibberifrons, N. coriiceps, N. nudifrons, Parachaenichthys charcoti, Harpagifer bispinis,* and *Cygnodraco mawsoni.*

Systematic Survey of Ciliated Protozoa from the Antarctic Peninsula

JESSE C. THOMPSON, JR.

Department of Biology
Queens College

and

JOHN M. CROOM

Department of Biology
Davidson College

A taxonomic survey of ciliated Protozoa, primarily of the order Hymenostomatidae, was extended to the Antarctic Peninsula during the period of December 17, 1968, to February 5, 1969. Extensive collections were made within a 40-mile radius of Palmer Station with helicopter support from USCGC *Edisto*; support by R/V *Hero* permitted collecting from more distant areas, such as Deception Island, Aitcho Islands, Livingston Island, and King George Island.

Bacterized cultures were made from 434 water samples. Selected ciliates were studied with phase microscopy, and phase cinematography was used to record morphological data from living Protozoa. Animals were subsequently fixed and 244 permanent slides were made, using the Chatton-Lwoff silver-nitrate impregnation technique. Preliminary studies of these slides have revealed the following marine genera: *Pseudocohnilembus, Uronema, Cyclidium, Pleu-*

ronema, Parauronema, Uropedalium, Euplotes, and several unidentified hypotrich genera. Freshwater genera observed included: *Cyclidium, Vorticella, Spathidium, Bursaria, Halteria, Microthorax, Lacrymaria,* and several unidentified hypotrich and gymnostome genera.

No new genera were noted from the Antarctic Peninsula, and the genera identified have been found commonly on other continents.

Oxygen Consumption of Some Antarctic Pycnogonids

EVERETT L. DOUGLAS

Department of Zoology
University of Missouri, Columbia

JOEL W. HEDGPETH

Marine Science Center
Oregon State University

and

EDVARD A. HEMMINGSEN

Scripps Institution of Oceanography
University of California, San Diego

During January and February 1969 at Palmer Station, the oxygen consumption of several large pycnogonids was measured in a closed respirometer. Physiological and biochemical studies of this worldwide group of animals have been neglected, partly because of the rather small size of species accessible to researchers in temperate and tropical locations. The accessibility and large size of several shallow-water species of antarctic pycnogonids made it possible to measure their oxygen consumption (Fig. 1). All the species examined turned out to be hardy laboratory animals, living for weeks in aquaria with running seawater, withstanding such treatment as being dipped in and out of aquaria, being carried by hand from one place to another, and being subjected to bright lights for motion picture photography.

The animals were collected by bottom trawls from R/V *Hero* and by scuba diving. Sequential measurements of respiration were made during 24-hour periods on 14 individuals representing 7 species. Oxygen consumption of the individual pycnogonids at temperatures from 0° to 1.2°C. ranged from .004 to .014 cc O_2/g/hr. (Table 1). Compared with values for arctic isopods of similar size, these results are about 3 times lower (Scholander *et al.*, 1953). These low values may be due to the possible absence of respiratory pigment (Redmond *and* Swanson, 1968), or to the rate of diffusion of oxygen through the chitinous exoskeleton. Because of their shape, pycnogonids have a very large surface area to volume ratio. In order to obtain some idea of the areas and volumes involved, the areas and volumes of the legs were calculated as if they were continuous cylinders, with the mid-point diameter used as the mean diameter (Table 1). The tarsal segments were not measured. Inclusion of the trunk and proboscis would produce even larger surface areas, but it seems likely that these surfaces are not as critical in respiration because of the structure of the circulatory system and the frequent covering of trunk segments by epizoic animals. It is possible that the animals clean their legs with the shepherd's crook-like terminal part of their ovigers to maintain the surface for respiration.

Table 1. Pycnogonida observed at Palmer Station, January-February 1969

Species	Sex	Surface area (cm²)*	Volume (cm³)*	Net Weight (g)	O_2 consumption (cm³/g/hr)
Ammothea carolinensis Leach	F.	53.2	3.9	2.9	0.011
Ammothea carolinensis Leach	M.	55.6	4.2	4.0	0.012
Ammothea carolinensis Leach	M.	52.8	2.3	3.7	0.014
Pallenopsis cf. *patagonica* (Hoek)	F.	56.3	3.4	2.2	0.013
Pallenopsis cf. *patagonica* (Hoek)	M.	29.8	1.5	1.4	0.007
Colossendeis australis Hodgson	F.	136.2	17.0	11.0	0.006
Colossendeis australis Hodgson	M.	114.3	12.1	7.3	0.009
Colossendeis megalonyx Hoek	M.	35.3	1.8	0.8	0.014
Colossendeis robusta Hoek	M.	42.2	2.6	1.9	0.014
Colossendeis scotti Calman	F.	95.0	10.1	9.4	0.010
Colossendeis scotti Calman	F.	124.9	14.7	5.9	0.009
Colossendeis scotti Calman	M.	82.0	7.4	7.2	0.008
Decolopoda australis Eights	F.	84.0	6.8	4.9	0.004
Decolopoda australis Eights	M.	53.0	3.7	3.0	0.011

*Calculated by W. E. Stout.

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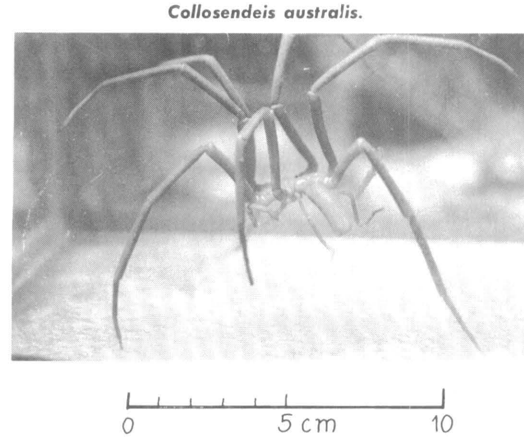
Collosendeis australis.



Arthropods of Southern Victoria Land

WILLIAM J. VOSS* *and* SPURGEON B. STRANDTMANN

Department of Entomology
Bernice P. Bishop Museum

Owing to the illness of Dr. Russell Strandtmann, the Principal Investigator, work planned for the Fosdick Mountains in Marie Byrd Land in the 1968–1969 summer could not be carried out. A program under the direction of William Voss, assisted by Spurgeon Strandtmann, was carried out in the dry valleys of southern Victoria Land, on Ross Island, and on several smaller islands in McMurdo Sound. These activities consisted of becoming acquainted with the conditions and methods of collecting in the Antarctic and surveying and making collections from new as well as previously studied areas. Since moisture sources and populations of arthropods vary from year to year, it is not always possible to re-collect in exactly the same spots every year. However, several sites were selected as close as possible to previous ones.

The main impetus of the work last season was directed toward collecting large samples, consisting of 250 or more individuals of each species at each site, from fewer areas. These mites will be prepared, measured, and subjected to statistical analysis. Populations of arthropods from different areas on Ross Island will be compared, and these in turn will be collated with specimens collected in the dry valleys. One study, made with specimens of the mite *Stereotydeus mollis* collected during the 1967–1968 season, has provided some interesting results on variations within the populations as well as consistent characteristics of the species compared.

The areas in which sites were selected for re-collecting included Cape Royds, Cape Crozier, The Strand Moraines, and Observation Hill in the McMurdo Station region. In addition, searches were conducted at sites in several previously uncollected areas of Taylor Valley, Garwood Valley, and the Dailey Islands. Large collections were made from all of these areas except on Observation Hill, which has been greatly disturbed by construction activities.

Though attempts to rear several groups of mites in the McMurdo biology laboratory were, for the most part, unsuccessful, one very large group of mites was collected in a mummified seal eyeball and maintained within it for over 12 weeks. It was not determined whether the mites were feeding on the dried flesh or on a protistan growing within the eye.

*Present address: Department of Natural Science, Fort Worth Museum of Science and History, Fort Worth, Texas.

At most collection sites, the spatial distribution of mites and springtails was rather uniform and the numbers present somewhat sparse under those rocks damp enough to support them. At almost all collection sites, the mites were more numerous than the Collembola. However, on December 21, 1968, at The Strand Moraines, approximately 77°44'S. 164°31'E., a small pool of water surrounded by rocks and pebbles was observed. We found that almost every rock within the immediate proximity sheltered a vast population of the springtail *Gomphiocephalus hodgsoni*. It was possible to pick up two rocks, knock them together, and dislodge several dozen specimens at a time. Very few mites were evident, and an hour-long search turned up only a small number. The reasons for this unusally large number of springtails is not known.

Biological Weathering in Antarctica

F. C. UGOLINI *and* C. C. GRIER

College of Forest Resources
University of Washington

Two major factors may govern biological weathering in Antarctica: (1) the amount, type, rate of accumulation, and composition of the biological material; and (2) the mechanism by which biological material and mineral substrata are brought into sufficiently close contact that chemical interactions can occur.

The first factor may be evaluated by examination, characterization, and analysis of those soils having a biological component, whereas the second factor is primarily a function of the moisture status of the soil or weathering surface. The field study of the 1968–1969 austral summer consisted of a series of observations and experiments to evaluate these two factors.

Antarctic soils which have a significant biological component are the Ornithogenic soils (guano soils) of penguin rookeries and the Protoranker (moss-covered) soils. Lichens also contribute to soil formation through chemical weathering by organic exudates.

The Ornithogenic soils were sampled at Cape Royds (Ross Island) in the Adélie penguin rookery. The samples were taken along a sequence from sites presently occupied by penguins to sites abandoned for some time. Ahumic soils (Tedrow *and* Ugolini, 1966) from the same area, uncontaminated by penguin excreta, were also sampled as a control. Samples were also taken from a rookery at "Blacksand Beach" near Cape Royds which had been reported by the *Terra Nova* expedition of 1910 as abandoned at that time.

The characteristic odor of guano was still present in these soils after at least 60 years.

The Ornithogenic soil samples are presently being analyzed for changes in both the biological and mineral components. Also, the uric acid-oxalic acid ratios of the different-age soils have been examined as a possible technique for providing the relative age of guano and thus indirectly of the site.

The Protoranker soils were sampled at Marble Point, on the Kar Plateau, and at The Flatiron (southern Victoria Land) to gain information on the contribution of mosses to weathering and soil-forming processes. These samples will be analyzed for organic components and for changes in the mineral substrata brought about by the organic material.

Lichen samples attached to rocks were taken from both the Kar Plateau and The Flatiron. This study is a continuation of the one reported by Ugolini and Perdue (1968) on the weathering of rock surfaces by lichens.

Under the desert conditions of the ice-free areas of southern Victoria Land, ionic transport in continuous liquid-phase water films is believed to be the most important mechanism by which biological material and the mineral substrata are brought into chemical contact. As part of investigating ionic transport, the hydrothermal regimen of the soil and some micrometeorological parameters were measured at chosen sites located at Cape Royds, in lower and upper Wright Valley, and on the Kar Plateau. Radioactive sodium chloride ($NaCl^{36}$) was placed either at the surface of the frost table or at the surface of the ice-cemented permafrost. Approximately one month afterward, soil samples were collected and the redistribution of Cl^{36} was determined. It was found that at Cape Royds the moist (approximately six percent water content), dark, volcanic Ahumic soil had thawed by the end of December to a maximum of 27 cm. The radioactive chloride tracer had moved to the surface, covering a distance of 21 cm in 40 days (Fig. 1). Thawing had extended only 7 cm in the lower Wright Valley, where the soils are lighter in color, extremely dry (1–2 percent water content) and colder than those at Cape Royds. Here, the radioactive Cl^{36} had moved only 7 cm in 25 days of temperatures continuously below freezing. In the upper Wright Valley, the maximum movement of Cl^{36} was approximately 7 cm (Fig. 2). The soil here has a water content intermediate between that of the soils of Cape Royds and of the lower Wright Valley.

These experiments clearly indicate that ionic migration occurs and that soil formation is proceeding under extreme dry and cold conditions. Although migration of ions in soils under continuous freezing conditions has been demonstrated in the laboratory (Murrmann, Hoekstra *and* Bialkowski, 1968), our findings are the first to be recorded under field conditions.

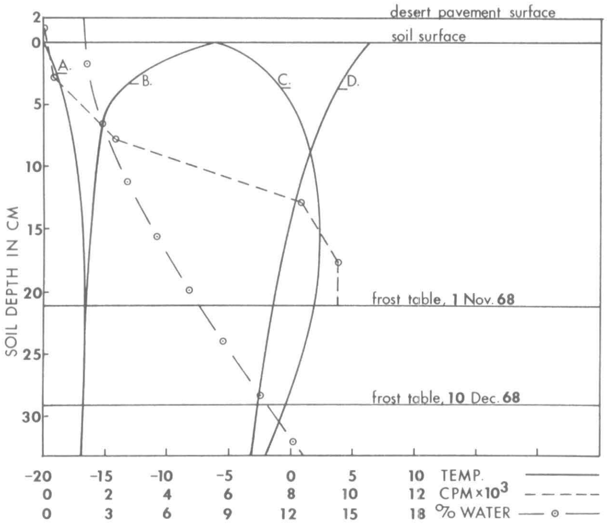


Fig. 1. Ahumic soil profile, Cape Royds, Ross Island. Soil temperatures: (A) Nov. 1, 1968, 0430; (B) Nov. 1, 1968, 1830; (C) Dec. 10, 1968, 0230; (D) Dec. 10, 1968, 1630. Soil water content (by weight) Nov. 1, 1968, and Cl^{36} distribution in counts/min. Dec. 10, 1968. All times are local.

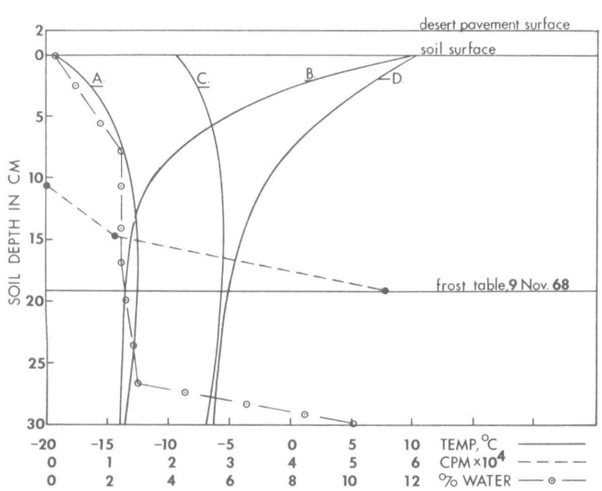


Fig. 2. Ahumic soil profile, upper Wright Valley, Southern Victoria Land. Soil temperatures (A) Nov. 9, 1968, 0500; (B) Nov. 9, 1968, 1430; (C) Dec. 3, 1968, 0300; (D) Dec. 3, 1968, 1400. Soil water content (by weight) Nov. 9, 1968 and Cl^{36} distribution in counts/min. Dec. 3, 1968. Frost table level remained unchanged throughout experiment. Ice-cemented permafrost was found at 30 cm. All times are local.

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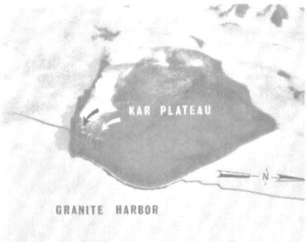
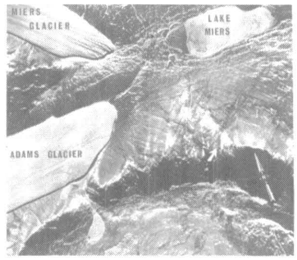


Fig. 1.



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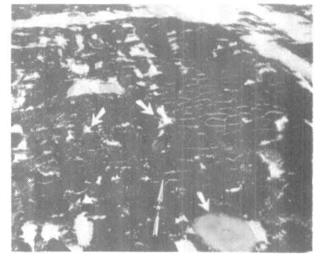

Fig. 3.

Fig. 4.

Factors Influencing the Distribution of Antarctic Terrestrial Plants

EDMUND SCHOFIELD *and* EMANUEL D. RUDOLPH

College of Biological Sciences
and
Institute of Polar Studies
The Ohio State University

During the second field season of this study (November 1968 to February 1969), the climatic and microclimatic observations begun the previous season were continued and other types of observations were initiated. The study areas in Victoria Land (Kar Plateau and the south ridge of Miers Valley—Figs. 1 and 2, respectively) and on Ross Island (Cape Royds and the Cape Crozier region—Figs. 3 and 4, respectively) were visited several times for periods of three to ten days each. Twenty-four-hour observations were made of air (at various heights), soil (surface and subsurface), rock, and plant temperatures; wind velocity; total (sun plus sky) radiation; light intensity; relative humidity; soil moisture; and cloud cover. Biological specimens (lichens, algae, and mosses) and soil, water, snow, and rock samples were again collected when required for use in correlating plant distribution with environmental factors. The acetylene-reduction technique was used with soil and biological specimens to detect nitrogen fixation. Some mapping of species distribution was done.

The preliminary conclusions reached during the previous field season were generally corroborated. Depending upon the species, lichen distribution was related to such diverse environmental factors as wind, soil composition, soil moisture, substrate characteristics, and atmospheric water-vapor content. In some cases—at Cape Royds, for example—local geography was found to be of prime importance in terms of presence or absence of plants.

Results to date indicate that an environmental factor can be classified according to two schemes (Fig. 5): (1) as either *primary* or *secondary*, depending upon its position in a "cause-and-effect chain of factors" culminating in either the presence or the absence of plants, or (2) as either *promotive* or *inhibitive* to plant growth. Each factor is classified under both schemes, and, as Fig. 5 shows, can even be both inhibitive and promotive in a single area, depending upon the way subsequent factors modify its effect on the environment. At Cape Royds, wind is either a primary inhibitive or a primary promotive factor, depending upon the mediating influence of topographic features. At Kar Plateau, wind is the primary promotive factor in a chain resulting in the growth in one quite restricted area of the lichen *Neuropogon*

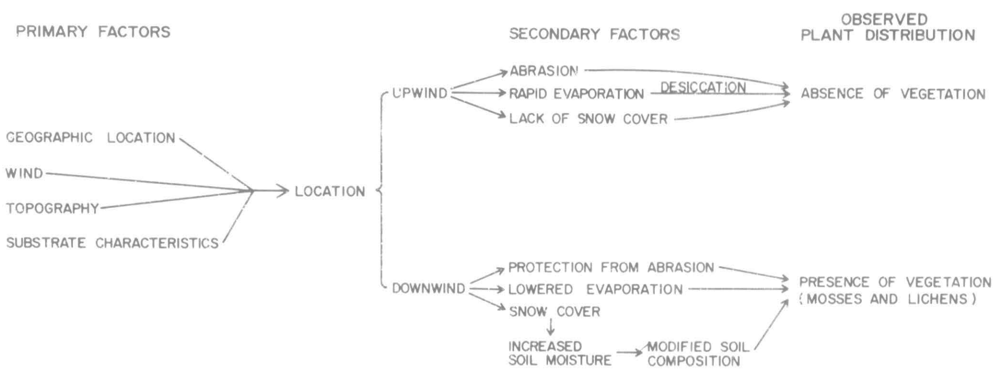

Fig. 5. Diagram of the interrelationships among environmental factors that influence lichen distribution at Cape Royds. The factors are linked in a cause-and-effect chain that originates with four primary factors that together determine or modify the secondary factors, and that ends in either the presence or the absence of vegetation.

antarcticus (Fig. 6). In the Cape Crozier area, wind is also a primary promotive factor for this species, but its effects appear to be modulated by a different series of secondary factors. Near Miers Valley, on the other hand, wind is a primary inhibitive factor. There, as at Cape Royds, wind-carried ice and sand particles prevent lichen growth by abrading upwind rock surfaces. However, there is no promotive influence in downwind locations comparable to that at Cape Royds.

Secondary factors include soil composition and soil moisture. At Cape Royds, there is a definite correlation between soil salt content and the occurrence of mosses and lichens. Soil salt content seems to depend upon several of the other environmental factors, the most important being soil moisture.

At Capes Royds and Crozier, there is a conspicuous horizontal, north-south zonation of lichen species and a similar vertical one which further analysis of collections may explain.

A moisture source is the *sine qua non* of antarctic plant growth. For lichens, the sources are the following: (1) atmospheric moisture (water vapor), (2) precipitated snow, (3) blowing snow, (4) permafrost moisture, and (5) least likely, liquid runoff. The physical characteristics and orientation (aspect) of the substrate determine the availability to a lichen of such moisture sources.

Comparative temperature measurements indicate that, under certain conditions at least, a kind of temperature "regulation" may occur in lichen thalli. Two species of lichen, *Buellia frigida* (black) and *Caloplaca elegans* var. *pulvinata* (orange), were consistently 1.5° to 4° C. colder than their substrates (Table 1). Photographs taken with black-and-white, infrared-sensitive film through appropriate filters show that the thallus of *C. elegans* var. *pulvinata* reflects a very high proportion of the near-infrared wavelengths (Fig. 7). A lower thallus temperature would, in theory, increase the amount of atmospheric water vapor available to lichens by (1) raising the relative humidity above them, (2) causing actual condensation, depending upon the ambient temperature, and (3) lowering the rate of evaporation of water from the thallus. An analogous temperature effect—*i.e.*, a lower temperature in the vicinity of a lichen—was found for *N. antarcticus* at Cape Crozier. Such temperature-induced water-vapor sinks should be sought as possible auxiliary sources of moisture for lichens and other plants in the arid McMurdo Sound area.

In an effort to determine the presence of microfungal disseminules in the air, sterile Petri dishes were exposed at Miers Valley and McMurdo Station. The microfungi trapped are being studied in the laboratory. The majority of them belong to the genus *Penicillium*.

We are indebted to Messrs. K. Eissinger, R. Todd, F. Brownworth, and K. Anderson, U.S. Geological Survey topographic engineers, for maps of two of the study areas; to photographers R. Martin of Antarctic Development Squadron Six, J. K. T. Craig of Antarctic Support Activities, and H. Steiner of Naval Construction Battalion Unit 201, for aerial photographs of the study areas; and especially to Messrs. Ray E. Showman and Joseph B. Harvey, field assistants, who aided in all aspects of the laboratory and field work.

Fig. 6 (top, below). Part of an extensive covering of *Neuropogon antarcticus*, a fruticose lichen, on a deposit of sandstone on Kar Plateau. The lichen occupies an area of about 1 m².

Fig. 7 (bottom, below). *Caloplaca elegans* var. *pulvinata* on dark kenyte near Cape Royds study area, photographed with Kodak High Speed Infrared Film and Kodak Wratten Filter No. 89B. The near-infrared wavelengths from about 700 to 900 nm, with maximum sensitivity from 770 to 840 nm, are recorded. The brilliance of the lichen thallus is due to high surface reflection, strong fluorescence by algal chlorophyll, or both. High surface reflection would account for the observations presented in Table 1. The arrows are 6 cm apart.

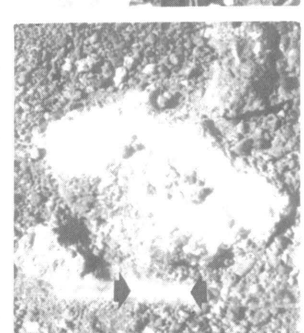

Table 1. Comparisons of Lichen-Thallus and Adjacent Rock-Surface Temperatures
Tested in bright sunlight with Wallac Thermex Thermoanemometer, Model GGA2B, with Probe NI-103.

Date (1968)	Average Temperature, C[a] Rock Surface	Lichen Thallus	Temperature Difference (Lichen—Rock), C°	Number of Determinations
		Caloplaca elegans var. *pulvinata* on Black Rocks at Cape Royds		
January 3	16.0	12.0	−4.0	1 each
January 23	18.1	14.9	−3.2	Lichen: 6 Rock: 4
		Buellia frigida on Dark Red Rock at Cape Crozier		
December 14	14.5	13.0	−1.5	5 each

[a] The probe was moved at intervals of about 15 seconds from place to place on the surface being measured until a constant reading was obtained.

Comparative Biochemistry of Proteins

ROBERT E. FEENEY

Department of Food Science and Technology
College of Agricultural and Environmental Sciences
University of California, Davis

During the last antarctic summer, there was a six-member team from the University of California, Davis doing biochemical research and collecting specimens on Ross Island and at Hallett Station. These members were: graduate student Augusto Trejo-González; student assistants James Moore and James Norris; faculty colleagues, Dr. Jerry L. Hedrick and Frank L. Strong; and Project Director, Robert E. Feeney. The party continued the programs of this laboratory on the study of the physical and chemical properties of proteins, including enzymes, of antarctic species.

One program last antarctic summer was concerned with the study of eggs of Adélie penguins from three different rookeries: Cape Crozier, Cape Bird, and Cape Hallett. No demonstrable differences were found in the egg-white proteins from these three different rookeries, indicating close genetic relationships. Two emperor penguin eggs were obtained frozen by chopping them from the sea ice at the Cape Crozier emperor rookery. One of these eggs was in perfect biochemical condition for protein studies, while the second was in good condition and was useful for adjunctive and confirmatory tests. In addition, eggs of two New Zealand penguins were supplied by the New Zealand Wildlife Division and are being included in a general comparative study of the eggs of penguins.

The main program concerned the blood and muscle proteins of two cold-adapted antarctic fish, *Trematomus borchgrevinki* and *Dissostichus mawsoni*. The *T. borchgrevinki* were caught on hooks at the surface and the *D. mawsoni* were captured alive from seals in McMurdo Sound. In addition, small numbers of *T. hansoni* and *T. bernacchii* were trapped at the bottom of McMurdo Sound. Blood plasma from these species is being used to fractionate and purify the freezing-point-depressant glycoprotein present in their bloods. Definitive physical and chemical characterization of this constituent is under way at the University of California. Red blood cells were collected from several of the species for the study of the physical and chemical characteristics of the hemoglobin, and, in particular, the effect of temperature on these properties. This work is also in progress. In addition, a new program was started in muscle enzyme phosphorylase. The characterization of this protein and studies of the effects of temperature on its properties are under way.

The Ecology of Antarctic Protozoan Ponds

RAYMOND D. DILLON, GARY L. WALSH,

and SAMUEL R. HETH

Department of Zoology
University of South Dakota

Additional studies to collect and enumerate meltwater protozoans and their environment were undertaken at Hallett Station between December 28, 1968 and January 18, 1969. Lakes and ponds in the dry-valley area of McMurdo Sound and on Ross Island were also examined in December 1968.

At Hallett Station, collections were made at weekly intervals for three weeks and at hourly intervals during one 24-hour period. Snow-melt ponds heavily colored with penguin guano were contrasted with clear meltwater ponds used by skuas as bathing pools. While fixed samples were being collected, samples for chemical analysis were taken, millipored, and stained for further enumeration and identification of protozoan and biotic forms.

Chemical studies revealed pH values near 8 in colored ponds with water temperatures 10°–12°C. above air temperatures. Clear ponds had pH values around 6 and temperatures 5°–9°C. above ambient.

Water samples from turbid ponds colored by guano had to be diluted up to 400 times and filtered in order to do the colorimetric determinations for NH_3. Extremely high alkalinity and conductivity, caused by greater concentration of electrolytes, also appeared in the guano ponds as compared to the clear ponds. A reverse trend was found with regard to NO_2 and NO_3. PO_4^{--} and SO_4^{--} were markedly higher in the colored ponds.

From a biological point of view, a large number of a few species of algae and ciliates were observed in the colored ponds. Their presence was due to the rich contribution of penguin guano through fecal and food contamination or by wash-in from the rookery.

On the other hand, a restricted population of protozoans of a more diverse variety was found in the clear ponds of meltwater origin which gain some of their enrichment from skuas that defecate or frolic in them. Identification and enumeration of Millipore filter samples and further culture isolation from soil and meltwater ponds are continuing at the University.

Physical and chemical limnological data were collected from 17 lakes and ponds in the area of McMurdo Sound and Ross Island. In general, surface water temperatures were markedly higher than air temperatures; temperature stratification within the water was most pronounced in shallow ponds. Oxygen concentration was high at all locations, with pH values always on the basic side. Conductivity readings indicated high electrolyte concentration in certain ponds, which may be explained by their close proximity to the ocean, soil leaching, wind-borne material, or contamination by birds. For instance, when melted, the ice of Coast Lake at Cape Royds containing skua fecal material indicated variable readings from 68 to 1,200 μmhos.

PO_4 and iron were found to be low at all sites, as was NH_3. The one exception was Pony Lake ("Home Lake") at Cape Royds, which is adjacent to a penguin rookery and sources of human contamination. NO_3 and NO_2 were low or absent at most sites except in the chemocline of Lake Vanda and Pony Lake. SO_4 varied between collection sites, but was highest at "Pond II" on Cape Evans.

The physiochemical information will be compared at a future date with statistical data of protozoan populations from identical sites as indicated.

Biology of Deep Diving in Antarctic Birds and Mammals

G. L. KOOYMAN *and* W. B. CAMPBELL, JR.

Scripps Institution of Oceanography
University of California, San Diego

This first season's field work on the study of various behavioral and physiological aspects of deep diving was primarily concerned with the emperor penguin (*Aptenodytes forsteri*) and the Weddell seal (*Leptonychotes weddelli*).

The late-winter flight to McMurdo Station, Antarctica (September 3, 1968), permitted us to conduct some experiments on behavioral responses to night diving in Weddell seals. Procedures similar to past work were used in these and later experiments with emperor penguins (Kooyman, 1968). Winter-night observations are of particular interest because of the navigational problems inherent in finding isolated holes under such low levels of light. Thus far, our results indicate that the seals are quite conservative in their diving efforts at night. However, confirmation of any general trend will require more experiments.

Efforts to obtain certain physiological parameters from unrestrained Weddell seals were initiated. Heart rates on freely diving seals and complete recordings of short dives, some lasting slightly over five minutes, were obtained. Rates were also obtained from seals sleeping in ice holes and in post-dive states, some after dives of over 40 minutes.

An analysis of certain pulmonary functions was also begun on seals diving from our ice station by inducing them to breathe between dives into a small two-way valve mounted over the breathing hole. One seal became so adjusted to the valve arrangement over the hole that she slept under it for a number of hours. This method enabled us to determine post-dive tidal volumes and oxygen consumption rates and should work equally well for measuring alveolar gas composition and total lung capacity.

Applying techniques similar to those used in diving studies of Weddell seals, we analyzed the diving capacities of emperor penguins. We observed dives of this largest of aquatic birds in excess of 15 minutes, longer than those reported for any other freely diving bird. We also began to compare these and other observations made at the dive station with behavior in more open water. These latter studies are still in progress.

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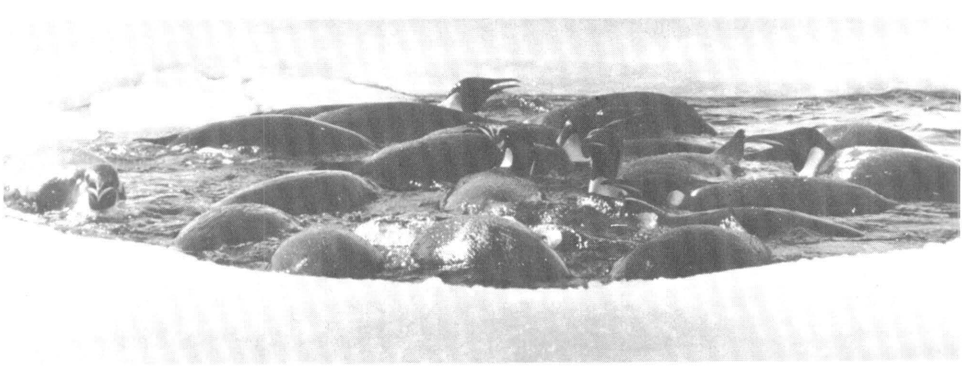

Photo: G. L. Kooyman

Emperor penguins diving from an isolated hole in thin sea ice. The 10-foot diameter hole was at times occupied by as many as 30 birds simultaneously.

Studies of the Rate of Development of the Adélie Penguin Embryo

JOHN R. BAKER

Department of Zoology
Iowa State University

In November 1967 at Hallett Station, I found that when the Adélie penguin (*Pygoscelis adeliae*) egg is laid, the embryo is at the same stage of development and of the same size as the unincubated chick blastoderm. The naturally incubated penguin embryo reaches the primitive streak stage in 3–4 days compared to 15–18 hours for the artificially incubated chick embryo. In November 1968 at Hallett Station, two studies were done to determine whether this slow development is due to egg exposure or is the natural rate of development at any temperature.

For the first study, eggs 0–4 hours old were collected and stored 1–5 days at 15°C. The eggs were then incubated artificially in two groups, one at 34°C. and the other at 38°C. Development was followed to stage 13 of Hamburger and Hamilton (1951), equivalent to a 2-day, 19-somite chick embryo. The rate of development at 34°C. was similar to that reported by Herbert (1967). Even with incubation at a constant 34°C., the Adélie penguin embryo required 3–4 days to reach the primitive streak stage. Therefore, cooling by exposure is not the only cause of the slow early development observed with natural incubation. Incubated at 38°C., the penguin embryo required 2–3 days to reach the primitive streak stage, and reached stage 13 in 5 days. At 34°C., the penguin embryo reached stage 13 in 7 days. Some factors in addition to temperature must control the rate of development of the penguin embryo since it could not be accelerated to that of the chick by incubation at 38°C.

For the second study, my assistant (Mr. DeVere Burt) observed the brooding behavior of pairs with eggs of known (to within 4 hours) incubation age. At comparable incubation periods, these embryos were compared to embryos artificially incubated at 34°C. The poor-brooding peripheral pairs lost so many first eggs that it was not possible to compare the rate of development of embryos incubated by good and poor brooders. The rate of development, even with good brooders, was found to be more variable than with embryos incubated artificially at 34°C., probably due to cooling of the egg associated with movements of the brooding penguin.

This cooling is rapid under the severe conditions under which these penguins breed. It would seem advantageous for a bird breeding in the cold to hold the egg (in the uterus) until embryo heat production is higher than heat loss. The Adélie penguin may be such a recent colonizer of the Antarctic that no such mechanism has evolved.

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Adélie Penguin Orientation under the Northern Sun

R. L. PENNEY *and* DONALD K. RIKER

Institute for Research in Animal Behavior
New York Zoological Society and Rockefeller University

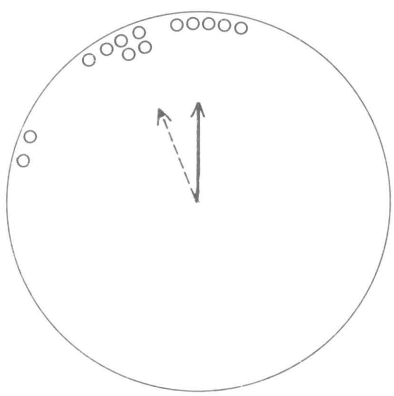
Adélie penguins (*Pygoscelis adeliae*) artificially displaced to featureless snow areas in Antarctica use the sun azimuth and a biological clock to steer straight courses NNE with respect to their home longitude. This behavior necessitates a clockwise compensation for sun azimuth motion at the rate of 15° per hour (Emlen *and* Penney, 1964; Penney *and* Emlen, 1967). Adélie penguins released under the northern sun and using the same system of orientation should make errors averaging 30° azimuth per hour because of the apparent reversed sun azimuth motion. The purpose of the present experiment was to determine if such errors were indeed observable.

On November 30, 1968, five pairs of penguins were captured at 2100 hrs. (0900 hrs. GMT) at Cape Crozier, Ross Island, Antarctica (77°28′S. 169°14′E.), and confined to individual transport boxes. By helicopters, trucks, and jet aircraft, the birds were transported to Grand Forks Air Force Base, Grand Forks Co., North Dakota (47°47′N. 97°25′W.), within 58 hours of capture. During this period and the next six days, the birds were subjected to varying light intensities and possible photoperiodic phase shifts due to intermittent confinement in semidarkened boxes and a small room with one window, and constant low-intensity fluorescent lighting.

All releases were made under clear skies on partially snow-covered fields between 0900 and 1600 hrs. local time (CST). Two different release sites were used. The first, used on December 3, was a stubble field extending approximately 650 m E-W and 900 m N-S. The second site, used on December 5 and 6, consisted of stubble and plowed fields extending approximately 800 m E-W and 750 m N-S, with few visible landmarks.

The penguins were released by hand one at a time in varying directions. After the birds had moved off at least 50 m, their bearings were recorded every 2 minutes using a survey transit until they reached a distance of 170 to 320 m. At the time of the final observation, the headings of the birds were estimated while closely observing the birds through the 25X transit telescope. Estimated headings, when compared to observations of the tracks of the birds, were found to be accurate within ± 5°. After the final observation, we immediately drove out to recapture the bird and returned to the release point, measuring the approximate distance by odometer. A total of 41 releases was made with 10 birds.

Plotting the headings of the birds with respect to true direction at the release points revealed no preferred direction. Headings plotted with respect to an expected N. 10°E. direction for Antarctica on assumed clock settings (using Cape Crozier time) and an expected error rate of 30° per hour also showed no preferred direction. These results indicate either a complete lack of orientation to the sun or, not surprisingly, a breakdown in clock synchrony between birds during transport from Antarctica while confined under lighting regimes vastly different from that of their natural habitat.



Shift in departure orientation and mean vector (dashed arrow) for penguins released twice in the same day, compared to the expected shift (solid arrow).

Change in departure orientation for penguins released twice during the same day.

Bird	Time between releases	Expected change in orientation*	Actual change in orientation
1	5 hr. 20 min.	149°cw	159°cw
9	3 hr. 55 min.	107°cw	82°cw
8	2 hr. 20 min.	67°cw	70°cw
1	2 hr. 15 min.	60°cw	28°cw
3	2 hr. 0 min.	50°cw	12°cw
2	2 hr. 40 min.	72°cw	46°cw
3	2 hr. 40 min.	73°cw	54°cw
4	2 hr. 20 min.	74°cw	5°cw
7	2 hr. 35 min.	72°cw	85°cw
5	2 hr. 30 min.	73°cw	4°ccw
9	2 hr. 25 min.	68°cw	65°cw
1	2 hr. 35 min.	73°cw	65°cw
10	2 hr. 30 min.	73°cw	53°cw

*Calculated on the basis of true sun-azimuth motion for local latitude and the actual time period between releases.
cw = clockwise
ccw = counterclockwise

Entrainment of a circadian rhythm to a new set of *Zeitgeber* takes at least a few days (Aschoff, 1967; Hoffman, 1965), yet a predictable clockwise change in orientation should exist for the same bird released on two occasions just a few hours apart. In 12 of 13 such repeat releases (see table), the change in direction selection was clockwise and on an order of magnitude approximating the expected error rate of 30° per hour. In the figure, the dashed arrow is the vector mean for the departure directions, which differs by 22° from the expected or hypothetical shift in departure orientation. This difference is not significant when subjected to appropriate statistical tests (Watson *and* Williams, 1956; Stephens, 1962; Batschelet, 1965), indicating that the penguins were indeed orienting to the sun and making the expected errors. The two birds which showed the least shift were individuals which on both releases appeared to be attracted to a series of white house trailers west of the release site.

This work was supported by National Science Foundation Grant GA-1488 and is part of a general project concerned with the behavioral and physiological bases of Adélie penguin sun orientation. Many people gave assistance throughout the project; special thanks are due to officers and men of Grand Forks Air Force Base, the Military Airlift Command, and the U. S. Navy Antarctic Development Squadron Six.

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Behavioral and Electrographic Study of Sleeping and Waking Patterns in Weddell Seals

JAY T. SHURLEY *and* ROBERT E. BROOKS

Veterans Administration Hospital (Oklahoma City)
University of Oklahoma Medical Center

and

ROBERT ELSNER*
and DOUGLAS D. HAMMOND

Scripps Institution of Oceanography
University of California, San Diego

In order to extend our previous biobehavioral observations (1967 and 1968) of sleeping and waking patterns in human beings, several related studies were made on the Weddell seal (*Leptonychotes weddelli*) at Turtle Rock, Erebus Bay, near McMurdo Station, Antarctica, in November 1968, and in the marine aquarium laboratory at Scripps in La Jolla, California, in December 1968.

Suitable needle electrodes were hand-implanted in a mature, 850-lb., nonlactating female confined in a small pen on the ice and temporarily immobilized with an intramuscular injection of Sernylan and TranVet. Her bilateral brain wave and single channels of her eye movements, cardiogram, muscle tone, and heart and respiratory rates were electrographically recorded on magnetic tape continuously for 30 hours through several periods of behavioral sleep and waking.

A second, similar 30-hour recording was made from a 12-week-old, 200-lb. female seal pup stranded and confined in the channel of the marine aquarium laboratory at Scripps. Finally, continuous behavioral observations of 1 male and 1 fema'e Weddell pup in the ring tank at Scripps were recorded for 48 hours to determine the spontaneous allocation of time between activity, alert inactivity, and behavioral sleep under natural 24-hour light-and-dark cycles.

At this time it is possible to report only that, during both continuous summer sunlight on the ice at Turtle Rock and the 24-hour light-dark cycles at La Jolla, there are periods of behavioral sleep, alert inactivity, and active movement interspersed in each 24-hour period, with no apparent fixed intervals between cycles. Further, from qualitative inspection only, it is possible to discern EEG patterns within the sleeping periods which are closely similar to, if not identical with, human patterns classifiable as Rapid-Eye-Movement (REM) and Slow-Wave (delta) sleep, with intermediate stages in the non-REM portion. Quantitative analyses of periodic phenomena and sleep patterns remain to be completed.

*Now at the Department of Human Physiology and Pharmacology, University of Adelaide, South Australia.

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Electroencephalographic and Blood Gas Correlates During Simulated Dives in Weddell Seals

ROBERT ELSNER*
and DOUGLAS D. HAMMOND

Scripps Institution of Oceanography
University of California, San Diego

and

JAY T. SHURLEY *and* ROBERT E. BROOKS

Veterans Administration Hospital (Oklahoma City)
University of Oklahoma Medical Center

This joint project for a preliminary, correlated biochemical and electrographic study of the physiology of diving asphyxia in the Weddell seal followed on earlier work by Kooyman (1966), which determined the natural diving time and depth of Weddell seals to be in the order of 40 to 50 minutes and at least 600 m, and by Elsner *et al.* (1968), which determined circulatory changes in the pregnant female seal and fetus during diving asphyxia.

Since the extreme sensitivity to hypoxia of the mammalian brain makes 6 to 8 minutes the outer limit for breath holding without irreversible brain damage in man and in most terrestrial mammals, it is of interest to understand brain tissue response in the marine mammal, where natural dive times are increased by a factor of 10.

Using deep intramuscular injections of succinyl choline chloride, which produces extremely long (up to 3 hours) periods of respiratory paralysis, we subjected, in November 1968, three adults and three pups of the Weddell seal species captured from the Turtle Rock colony in McMurdo Sound to repeated simulated dives by disconnecting the oxygen flow from a Bird respirator or by 100 % nitrogen administration.

*Now at the Department of Human Physiology and Pharmacology, University of Adelaide, South Australia.

Measurements of blood pH, pO_2, and pCO_2 were made on the spot with a Radiometer blood gas analyzer, using blood drawn from a catheter implanted retrograde in the left common carotid artery and flushed periodically with heparinized N-saline. Bioelectrical potentials from the brain, eye, nuchal musculature, heart, and chest wall of the animal were fed to a Beckman biomedical recording and display system for amplification, conditioning, and recording on a seven-channel Ampex Model SP-300 FM magnetic tape recorder. Signals were simultaneously monitored on a four-channel oscilloscope as they went on or off the tape.

The electrical activity of the brain, the eye movements, muscle tonus, heart beat, and respiratory excursions of the chest wall were thus continuously surveyed in clinical fashion while experimental breath-holding (diving) asphyxia and pure nitrogen breathing experiments were carried out in serial fashion, interspersed with periods of normal aeration of lung tissue with pure oxygen. The change in brain rhythms from resting alpha and low-voltage fast to high-voltage delta was taken as a measure of brain tissue metabolic impairment, following which time and degree of recovery were assessed by restoration of normal vital signs and alpha-blocking response under photic stimulation. Serial measurements of carotid blood pH, pO_2, and pCO_2 were made at critical points.

After a breath-holding dive of 65 minutes and a second asphyxial period of 30 minutes of pure nitrogen, the first adult was released to return to the colony in apparently normal condition, but was not seen again. The second and third adults and all three pups were eventually experimentally dived to exitus.

Normal profiles of blood pH, pO_2, and of brain, heart, muscle, eye movement, and impedance pneumogram were established for the adult and immature seals, and approximate hypoxia thresholds for irreversible brain-tissue impairment, with death as an eventual end point, were established. These data suggest that Weddell seals possess an increased brain-tissue tolerance for low oxygen tension when compared with comparable data from terrestrial mammals.

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Circulatory Responses to Asphyxia in Pregnant Weddell Seals

ROBERT ELSNER*
and DOUGLAS D. HAMMOND

Scripps Institution of Oceanography
University of California, San Diego

The second season of a study of physiological responses of diving Weddell seals was carried out in McMurdo Sound during September, October, and November 1968. Investigations of the first season (Elsner *et al.*, 1968) were centered on the determination of natural diving times of pregnant animals, respiratory properties of maternal and fetal blood, and preliminary measurements of uterine artery blood flow in the pregnant seal during the prolonged asphyxia of simulated dives.

The natural diving time studies were completed during the past season. A total of 5 pregnant animals were tested, and 41 dives lasting longer than 20 minutes were recorded. Maximum diving times for these seals ranged from 39 to 60 minutes (Elsner *et al.*, 1969). The observations of both seasons suggest that pregnancy does not seriously interfere with natural diving since they compare favorably with Kooyman's (1966) study of nonpregnant animals.

A prolonged dive by a pregnant seal might well be an extreme example of maternal and fetal adaptation to asphyxia. In an attempt to determine what special physiological adjustments may occur and how these might be related to the well-known circulatory redistribution in diving seals for protection of vital organs like the brain, blood-flow studies were carried out in five pregnant Weddell seals. Doppler ultrasonic blood-flow transducers were implanted aseptically around uterine arteries of four animals. Since renal blood flow has been shown to react to diving asphyxia by profound reduction, one animal was instrumented by implantation of a blood-flow transducer on the renal artery.

After recovery from surgery, the animals were subjected to experimental simulated dives while blood flow was recorded. Asphyxiation always produced a prompt and extreme slowing of the heart rate, as has been noted in a great variety of diving mammals and birds, as well as terrestrial animals and man during submersion. Blood flow in the renal artery was promptly reduced to about one-tenth of the resting value, but uterine artery flow was reduced only slightly and was sometimes unimpaired.

The maintenance of adequate uterine circulation is

*Now at the Department of Human Physiology and Pharmacology, University of Adelaide, South Australia.

essential for the fetus. The mechanism displayed in Weddell seals is probably adapted to assure that, through a long dive, the fetus can draw on the source of oxygen stored in the large maternal blood volume. The first season's studies of respiratory characteristics of Weddell seal blood showed a very large maternal blood volume with high oxygen capacity. These characteristics, combined with increased affinity of fetal blood for oxygen, suggest enhancement of gas exchange at the placenta. Thus several factors can be seen to operate to protect the fetus.

This study has been supported by National Science Foundation Grant GA-1215, National Institutes of Health Grant HE-08323 and NIH Research Career Development Award 5 K03 HE07469.

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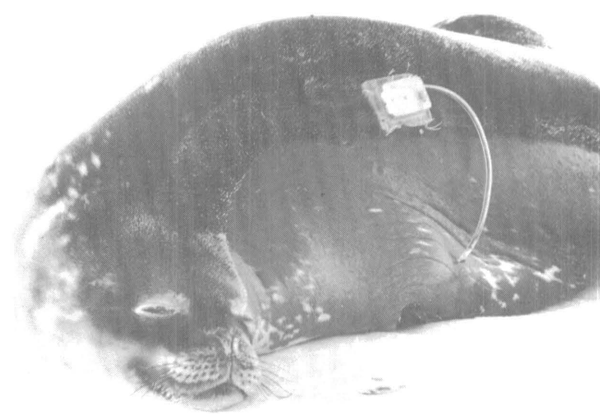
Population Studies of Weddell Seals at McMurdo Station

DONALD B. SINIFF, JOHN R. TESTER *and* LARRY B. KUECHLE

Museum of Natural History
University of Minnesota

To obtain information on the population dynamics of antarctic seals, one must study census methods, migration patterns, population discreteness, and other areas which aid in interpreting changes in population levels. During the 1969 field season at McMurdo, we carried out three distinct projects: (1) conducted telemetry studies to gather information on the activity patterns of Weddell seals, (2) collected blood samples from seals around the Ross Sea area for electrophoretic analysis, and (3) initiated an aerial census based on photographs made with a mapping camera of the U.S. Navy's Antarctic Development Squadron Six (VXE-6).

For the telemetry studies, a small fish house was located at Hutton Cliffs, approximately 10 miles from McMurdo Station. Small radio transmitters broadcasting a continuous signal around 50 MHz were attached to Weddell seals with suture material (Figs. 1 and 2). The signal was received and converted to a voltage output which triggered an Esterline-Angus



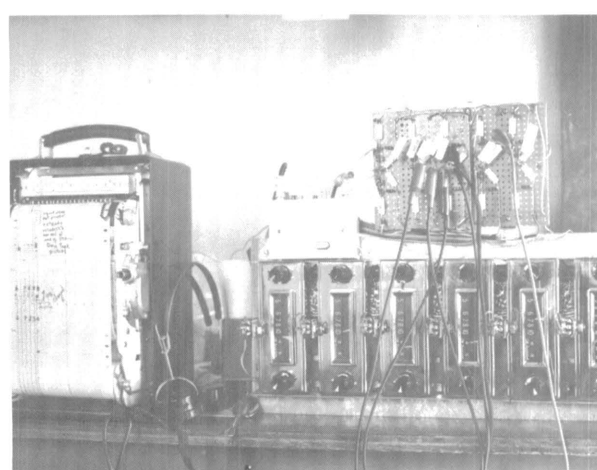


Fig. 1 (top). Radio transmitter being attached to female Weddell seal.
Fig. 2 (center). The seal with transmitter in place.
Fig. 3 (bottom). Recorder used to monitor the seals' activities.

strip-chart recorder (Fig. 3). When the seals were present on the surface of the sea ice, the signal was recorded. When they entered the water, the signal was attenuated. Each time the seals surfaced to breathe, the signal was again recorded, which enabled us to determine the duration of dives. The strip-chart recorder monitored these animals 24 hours a day and provided a fairly accurate picture of the daily activity pattern of individuals. Nine female Weddells with pups and one barren female Weddell were instrumented and monitored for approximately three weeks. The peak activity occurred from approximately midnight to 10 o'clock in the morning and the peak of haul-out occurred around noon to early afternoon. Weather conditions recorded at McMurdo Station are presently being evaluated to determine possible influences of environmental variables on these activity patterns. A more detailed analysis will be published at a later date.

Fifty 250 cc blood samples were taken from seals around Ross Island and Hallett Station. Forty-nine of these were from Weddell seals and one from a crabeater. The blood is now being analyzed by electrophoretic techniques in an attempt to measure differences in the protein structure of seals from various areas of the Antarctic. These data will be analyzed and compared with samples collected in the Weddell Sea in 1968 and 1969.

Earlier investigations have utilized shipboard and helicopter counts to obtain population estimates of seals in the antarctic pack ice. These reports provided the first density estimates and gave information on the physical characteristics of the pack ice which were attractive to seals. However, the logistic requirements for such censuses are great and variables are difficult to control. This past summer, in an effort to get more standardized data in a short period of time, we initiated studies of the feasibility of black-and-white aerial photography as a census technique. Transects were flown over an area of the Ross Sea north of Ross Island, and aerial photographs were taken approximately every mile along the transects. These pictures are now being examined to obtain density estimates of seals. At the present time, this method appears to be acceptable for obtaining gross estimates of seal abundance. Identification of species of seals in the photos does not yet seem possible utilizing these techniques. However, differences in behavioral and migration patterns separate species in time and place, to some extent, and estimates of the species composition may be possible using this information. This approach is currently being evaluated.

CARTOGRAPHY

Topographic Mapping Field Operations, 1968–1969

PETER F. BERMEL

U.S. Geological Survey

The U.S. Geological Survey (USGS) assigned four engineers to the Antarctic for the 1968–1969 summer to establish geodetic control for topographic mapping and to support other programs.

The USGS also assigned a photographic specialist to advise Antarctic Development Squadron Six (VXE-6) on visual navigational and photographic procedures for the mapping photography flights. This specialist also inspected and evaluated the resultant aerial negatives to insure that they met mapping specifications.

The field engineers were deployed on the Ellsworth Land Survey, where they established control in the Hudson Mountains-Thurston Island-Jones Mountains-Farwell Island area. The initial survey station was an astronomic position established by daylight stellar observations in the Jones Mountains, from which the traverses radiated. The party completed 1,059 miles of primary and 275 miles of secondary electronic traverse. They occupied 84 stations and set 12 permanent bench marks. This control will be sufficient for compilation of nine reconnaissance topographic maps at a scale of 1:250,000, which will cover approximately 40,600 square miles. During this phase of the field season, the engineers were assisted by the U.S. Army Aviation Detachment (Antarctica Support) of Fort Eustis, Virginia.

The field engineers also compiled large-scale planetable topographic maps of two biological study areas in the McMurdo Sound area, established two geodetic azimuths at the South Pole Station—one for the Weather Bureau observer and one for the Coast and Geodetic Survey geomagnetic observer—and reobserved the astronomic position at the South Pole Astro Pier. The annual reobservation at the Astro Pier is essential to the determination of the rate of movement of the existing Pole Station. These data will help decide the exact location of the new South Pole Station, when it is built, so that it will drift through the pole proper at the midpoint of its expected life span.

During the field season, VXE–6's photoconfigured Lockheed LC–130F aircraft flew approximately 76,320 of the programmed 169,600 square miles of tricamera aerial mapping photography. After the aerial film had been inspected and evaluated in Christchurch, New Zealand, approximately 50,000 square miles was determined to be of mapping quality, pending later inspection of the contact prints in Washington, D.C.

The major photographic effort this year continued to be in the Antarctic Peninsula region, an area known for its extremely bad weather conditions. Because the Peninsula photographic areas were outside the range of the LC–130 aircraft flying from the McMurdo Sound air facilities, it was necessary to stage the aircraft out of Byrd Station for the southern Peninsula area and out of Punta Arenas, Chile, for the northern Peninsula area. However, neither the information from weather satellites nor the relocation of the aircraft helped in photographing this region. Photographic fill lines were also flown in the Thurston and Berkner Islands areas, in eastern Ellsworth Land, and along the Coats Land coast.

In addition, 75 percent of the programmed special multidiscipline photographic projects were flown. On these missions, black-and-white film was used for penguin- and seal-population censuses, and color and color infrared film was used for geologic investigations in the Transantarctic Mountains and in Marie Byrd Land.

UPPER ATMOSPHERE PHYSICS

Investigations of Energetic Particles and Radiation in the Polar Cap with Balloon-Borne Instruments

MARTIN A. POMERANTZ
and GEORGE A. BAIRD*

Bartol Research Foundation of the Franklin Institute

Investigations of the propagation of energetic particles into the polar cap are relevant to an understanding of the character of the magnetic regime in the region where the field lines extend in an unclearly defined manner far into space. Balloon-borne instruments launched near the geomagnetic pole afford a unique means of observing in detail, at a specific location, the characteristics and temporal history of enhanced fluxes of energetic particles of X–rays generated in the upper atmosphere by electrons, and of nuclear γ-rays produced by protons with energies below the atmospheric cutoff.

Many studies of polar cap absorption (PCA) events and of electron precipitation effects in the auroral zone have been conducted. At very high geomagnetic latitudes, where the magnetic field is perpendicular to the Earth's surface, attenuation is produced by the atmosphere rather than by the magnetic field; hence, solar particles are "stopped" through collisions rather than through magnetic deflection. The geomagnetic field configuration and, in particular, the dynamics of the magnetospheric tail give rise to differences in the propagation of solar particles to different points within the polar cap. These propagation differences would manifest themselves as intensity differences that might be detectable with identical balloon-borne detectors flown simultaneously at different locations or as time variations at a single location.

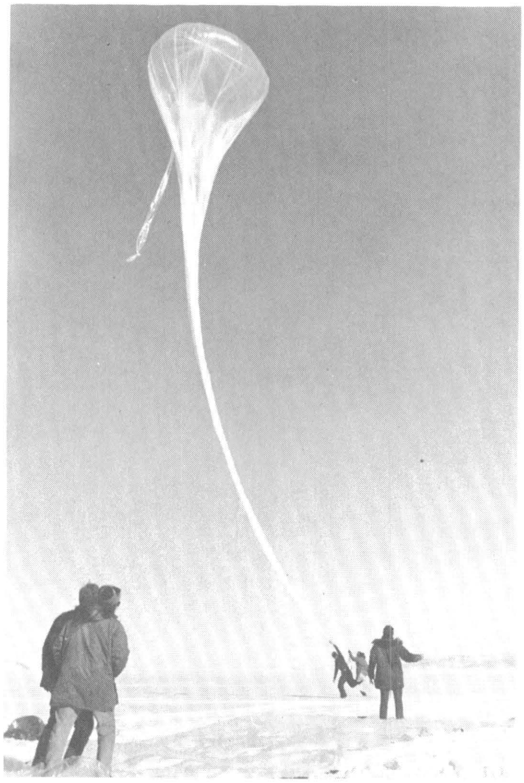
It has been observed that auroras occur when particles are precipitated near the outermost region of the Van Allen belt and that the trapped flux simultaneously increases. This observation has led to the suggestion that a local acceleration mechanism exists. On the other hand, discrete auroral forms have been observed at high latitudes where the field configuration is not compatible with particle trapping.

Very-high-latitude studies of PCA events have been made with riometer and ionospheric forward-scatter techniques to measure the effect of interactions of solar particles as manifested by the ionosphere. However, there has been a dearth of direct particle and X-ray measurements poleward of the auroral zone. A series of 7 flights was conducted at McMurdo Station early this year, as the first step in an investigation of particle phenomena in the polar cap with balloon-borne instruments.

The instrument packages, carried aloft by 135,000-cu.-ft. plastic balloons, contained three Geiger-Mueller counters operating singly and in coincidence, and a NaI crystal scintillator with pulse height discrimination providing output signals corresponding to X-ray energies >25 Kev., >50 Kev., >75 Kev., >100 Kev., and >500 Kev. The objective of this program was to carry out a preliminary reconnaissance for determining the gross characteristics of events occurring deep in the polar cap.

Since the data analysis is still in progress, it is pre-

*On leave from the Physics Department, University College, Dublin, Ireland.



NSF Photo

Cosmic-ray balloon being launched at McMurdo.

mature to cite the results. Extremely quiet solar conditions prevailed during the very brief period available in the antarctic summer for launching the flights. Therefore, any intensity variations that might have occurred were of very small magnitude and are much more difficult to resolve than effects which would manifest themselves during solar particle events or during extreme geomagnetic disturbances.

One of the goals was to search for possible diurnal variations in the cosmic ray intensity. For this reason, the launching times were staggered to insure a round-the-clock coverage at ceiling altitude (7 mb.). Preliminary analysis has revealed that the noon-midnight ratio is very close to unity, but the possibility that small but significant time variations occurred can not yet be excluded. Machine programs are now being developed to push the analysis to the ultimate limits imposed by statistical and experimental uncertainties.

These flights demonstrated that McMurdo is an excellent site for carrying out investigations with balloon-borne instruments. Some flights remained at high altitudes and within radio range for more than two days. This limit could be significantly increased by selecting a more effective location for the receiving antenna and by adding a minimal ballasting arrangement.

EARTH SCIENCES

Carbon Dating of Ice at Byrd Station, Antarctica

C. C. LANGWAY, JR. *and* B. L. HANSEN

U. S. Army Cold Regions Research and Engineering Laboratory

and

H. OESCHGER *and* B. STAUFFER

University of Bern (Switzerland)

Results from earlier research on carbon-dating of ice, performed in Greenland using a melt-vacuum vessel technique (Langway *et al.,* 1965; Oeschger *et al.,* 1966) and later a unique, down borehole technique (Oeschger *et al.,* 1967) suggested the feasibility of developing a new system to be used in conjunction with the current antarctic deep core-drilling program (Ueda *and* Hansen, 1967; Ueda *and* Garfield, 1968). The objective was to develop a remotely controlled melt-extraction system that could operate and make collections in a liquid-filled or a dry borehole over entire vertical profiles of an ice sheet for carbon-dating purposes and other solid, liquid, or gas collections.

During the 1968–1969 field season, Cold Regions R&E Laboratory and University of Bern researchers conducted preliminary investigations related to the carbon-dating program in the deep, liquid-filled borehole (2,164 m) and in a shallow, "dry" borehole (220 m) at Byrd Station. The pilot probe and auxiliary extraction lines, initially designed and engineered solely for CO_2 collections, were exhaustively tested in the main trench (–20°C.) and in the 200-m deep dry hole. The tool is 7.2 m long, has a 15.4 cm diameter, and can be lowered to any depth in a borehole where a collection is desired. When in place, two hydraulically controlled seals are released to block a 3½-m long portion of the borehole. Special precautions are taken to avoid contamination. The space between the seals is cleaned of its drilling fluid by releasing CO_2-free wash water from a heated tank. Melting the ice along the borehole wall to collect the sample is initiated by injecting additional pure water. The meltwater is then passed through an ion-exchange column that collects the HCO_3^- and CO_3^-; the purified meltwater flows through a heater for recirculation. With this system, about one ton of ice can be melted in 30 hours with a 10 KW power supply. One down-hole gas sample was collected before a malfunction occurred in a motor within the probe, creating an emergency situation that resulted in freezing-in of the probe at the 200 m depth. Initial attempts to free the probe by using a glycol solution and hydraulic jacks were not successful.

The field trials showed that the melt-extraction principles are sound. Valuable experience gained during the tests will lead to improved design and construction criteria being incorporated into the new probes that are currently being built at the Institute of Physics, University of Bern, for use at Byrd Station in 1969-1970.

In addition to the borehole sample, five CO_2 samples were extracted from different depth levels in the "Lead-Mine" ice tunnel at Byrd Station. Each sample consists of a few hundred liters of air pumped from the firn and trapped on molecular sieves. These samples will contribute to the understanding of the processes of air inclusion during transition from firn to glacier ice.

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Core Studies and Related Glaciological Investigations

ANTHONY J. GOW

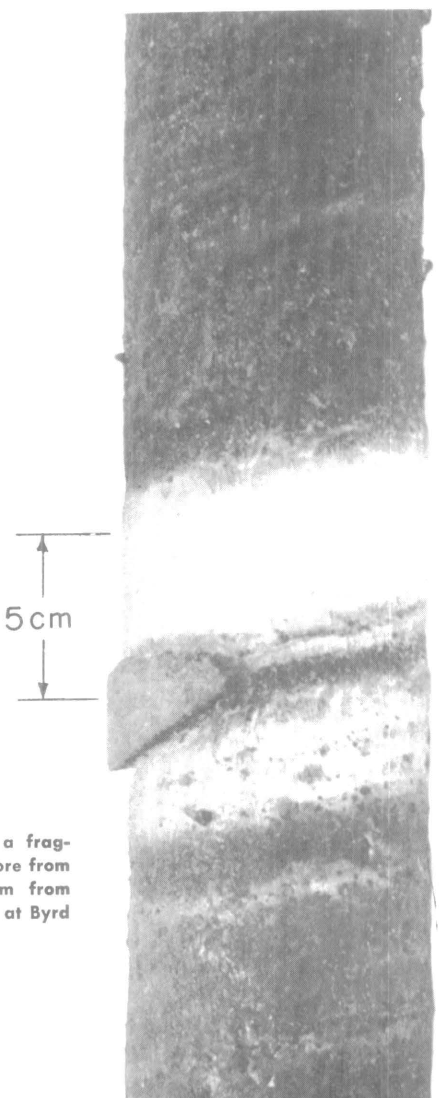
U. S. Army Cold Regions Research and Engineering Laboratory

Participation in the 1968–1969 antarctic field season was limited to processing cores from the deep drill hole at Byrd Station, conducting further measurements of closure in the 309-m drill hole at the old Byrd Station, and remeasuring accumulation at snow stakes around Byrd Station.

Approximately half of the total length of ice cores (1,100 m) from the deep drill hole was packed and returned to the United States aboard USNS *Wyandot*. The shipment reached Davisville, Rhode Island, on March 15, 1969, and the cores were then transferred by refrigerated truck to cold storage facilities at Littleton, New Hampshire. The assistance of the drill crew and personnel of Task Force 43, who together performed most of this work, is gratefully acknowledged.

The drill hole at "Old Byrd" (drilled in the 1957–1958 summer) is still accessible for temperature and deformation measurements above 200 m. Originally 14.6 cm in diameter and 309 m deep, this hole has closed off to less than 6.0 cm at 200 m. Closure rates in the top 200 m have remained essentially linear at these lower stresses, in marked contrast to the accelerating closure rates observed at the higher stresses below 200 m.

Results of seven years' measurements along two 10-km-long accumulation-stake lines that traverse the undulating snow surface around Byrd Station show that the snow has been accumulating at the rate of



Dirt-ice bands and a fragment of granite in core from 2,162-m depth (2 m from bottom of ice sheet) at Byrd Station.

10 to 11 cm of water equivalent annually. This is approximately 50 percent less than that measured at "Old Byrd" during the IGY. Depressions are still accumulating appreciably more snow than the crests of these undulations. Surface elevations were remeasured to determine if these undulations are actually migrating, but the results were inconclusive.

Core studies in the laboratory at Hanover, New Hampshire, show that the cores are still relaxing (manifested by a density decrease with time) and that expansion due primarily to crack formation has been greatest (0.6 percent in 16 months) in brittle ice from between 800- and 900-m depth. Deeper bubble-free ice shows little evidence of brittle cracking; this lack of cracks is attributed to the strongly oriented crystal structure of the ice, which is apparently able to dissipate much of the strain associated with expansion upon release from high confining pressures. The disappearance of air bubbles in the ice between 900 and 1,100 m, after bubble diameters have decreased to about 0.15 mm, suggests attainment of a critical diameter of bubble, which at the prevailing overburden pressures (80 to 100 bars between 900 and 1,100 m) encourages air molecules to diffuse into the ice, possibly as clathrate hydrates of air. Bubble-like inclusions of air are now appearing in some abundance in ice originally devoid of all trace of bubbles.

Glaciology and Glacial Geology on Deception Island

JEAN-ROLAND KLAY[1] *and* OLAV ORHEIM[2]

Institute of Polar Studies
The Ohio State University

Deception Island (63°S. 60°40′W.) is a circular volcanic caldera with a radius of about 6 km (Fig. 1). In November and December 1967, a series of explosive volcanic eruptions occurred which blanketed part of the island with volcanic material. The effects of this eruption on the glaciers and geomorphology were investigated during January and February 1969 by a three-man party from the Institute of Polar Studies.

Through stratigraphic studies (carried out under glaciological investigations conducted by Orheim), measurements of snow thickness and ablation, and meteorological observations, the mass balance was determined for an unnamed valley glacier (G 1 in Fig. 1, Fig. 2). The ash layer from the 1967 eruption (from

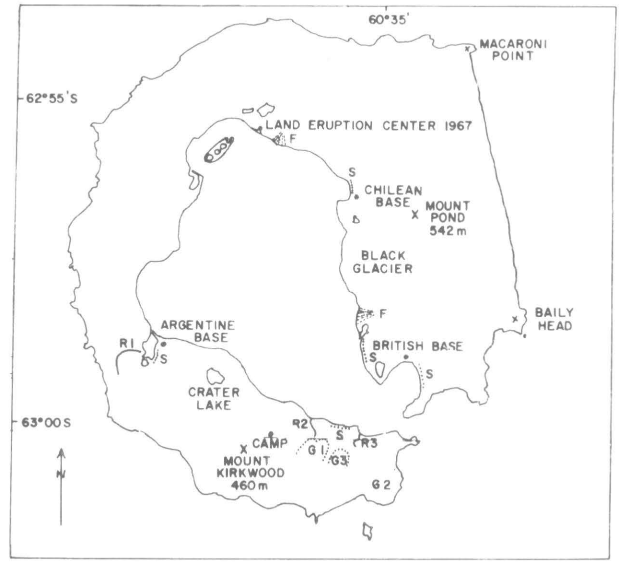


Fig. 1. Deception Island.

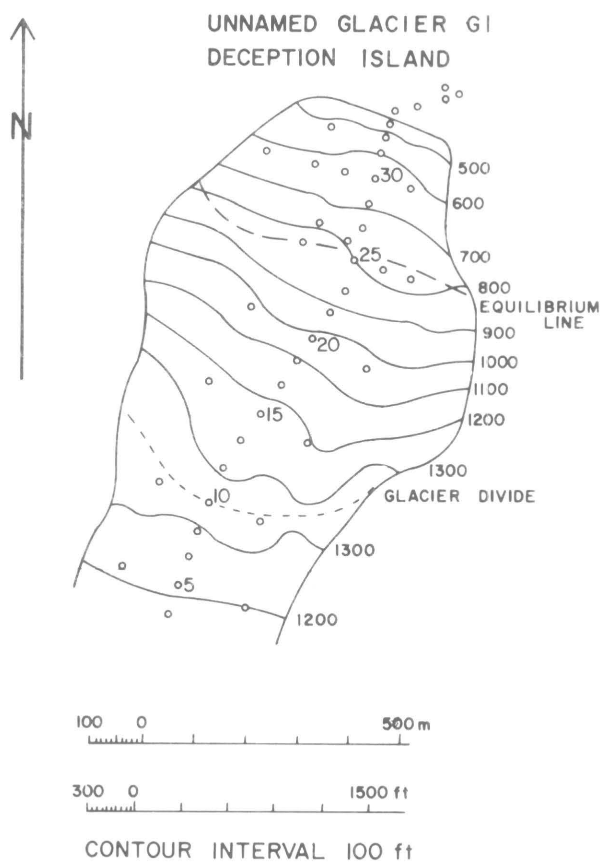


Fig. 2. Unnamed glacier G 1, Deception Island. Based on Directory of Overseas Survey map of Deception Island, scale 1:25,000. The circles and the numbers refer to the stakes.

1–2 cm thick in the accumulation area) was extremely well marked and will be an excellent reference horizon for future stratigraphic studies. In the abla-

[1] Glacial Geology.
[2] Glaciology.

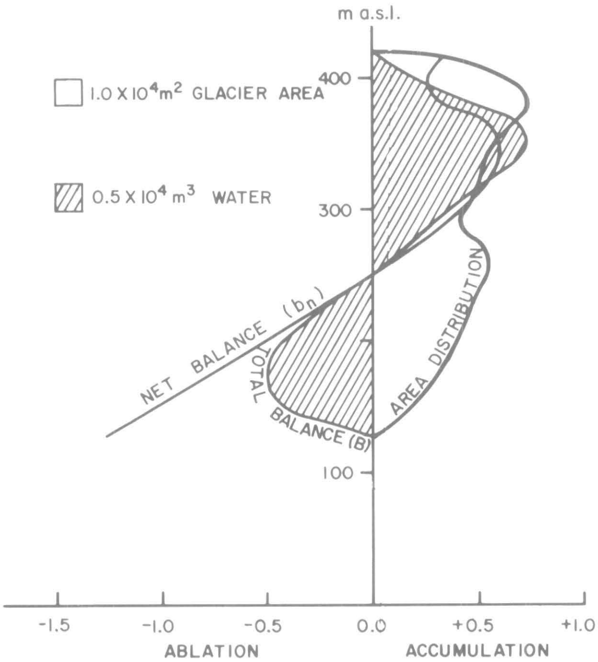


Fig. 3. Variation of glacier area and net balance with elevation. The shaded area shows total balance (negative on left side of elevation scale).

tion area, the ash had been extensively reworked by running water.

The mean equilibrium line was determined by stratigraphy to be about 250 m above sea level. Snow-temperature measurements to a depth of 4 m and climatic evaluations indicate that the glacier is temperate.

The net balance curve (Fig. 3) is fairly regular except near the top, where considerable deflation takes place.

The total positive balance for the accumulation area was 14.1×10^4 m^3, while the negative balance for the ablation area was -8.7×10^4 m^3. The total balance, when evenly distributed over the glacier surface, corresponds to a mean areal net balance of $+ 0.10$ m (all values expressed as water equivalents). The subglacial ablation is not included in the above figures.

The influence of the 1967 ash on the mass balance of the glacier was not very significant. In the accumulation area, the ash is generally quickly buried, and the only effect is to increase the absorption of short-wave radiation at shallow depths. In the ablation area, the ash influences the heat balance only where the washing has caused local secondary accumulations of ash; these occur as small ridges.

The glacier surface is dominated by five steps, 30–50 m high and 100–200 m apart, increasing in steepness downglacier. For a better understanding of the formation and movement of the steps, a detailed strain net of 42 stakes was established.

Klay found, through glacial-geology investigations, that more than half of Deception Island is ice covered; the remainder, except for some bedrock outcrops and recent lava flows, is blanketed with ash and debris. The ash and debris also mantle the lower portions of some glaciers, and seem to control the landform development on Deception Island. Because of its small clay-sized fraction, water passes through the ash and debris and drains off along the bedrock/debris or ice/debris interface. In addition, features formed by this loose material remain stable. The low thermal conductivity of the ash and debris layer has an insulating effect on the underlying ice. Dead-ice masses were interpreted as glaciers severed by subglacial eruptions that covered the glacier remnants with thermally insulating volcanic debris.

The 2-m-thick layer of ash and debris that covers the lower portions of some glaciers originated in eruptions like the one of 1967. This layer is incorporated in the ice in the accumulation zone of a glacier and washed off by meltwater in the ablation zone. The covering accumulates again on the lower portions of some glaciers, forming a thermally insulating layer. When meltwater streams, heavily loaded with ash and debris, flow on snow, mudflow-like features form.

Investigation made on "Black Glacier" (Fig. 1) showed that surface undulations were ice-cored and reached a height of more than 5 m from the debris/ice boundary. They resembled the ridges in front of glaciers G 1 and G 2. The surface slope on "Black Glacier" is about the same as that of glacier G 1.

Several hypotheses could explain the formation of these features: (1) bedrock control, (2) glacier retreat, (3) variation in thickness of deposited ash and debris, or (4) Thule-Baffin type moraines, as described by Bishop (1957).

Undoubtedly, the debris and ash cover blanketing the lower parts of some glaciers is, to some extent, responsible for the existence of surface undulations.

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Structural Glaciology of Meserve Glacier

GERALD HOLDSWORTH

Institute of Polar Studies
The Ohio State University

From the results of dimensional and deformational measurements (Holdsworth, 1966; 1967) on the ice tongue of Meserve Glacier, it is possible to recognize characteristics of the surface-velocity distribution, the principal strain-rate orientations, and the geometrical form of the snout. The characteristics are directly analogous to the flow line and stress solutions for the classic parallel plate problem (Geiringer, 1937) for a perfectly plastic substance (Fig. 1).

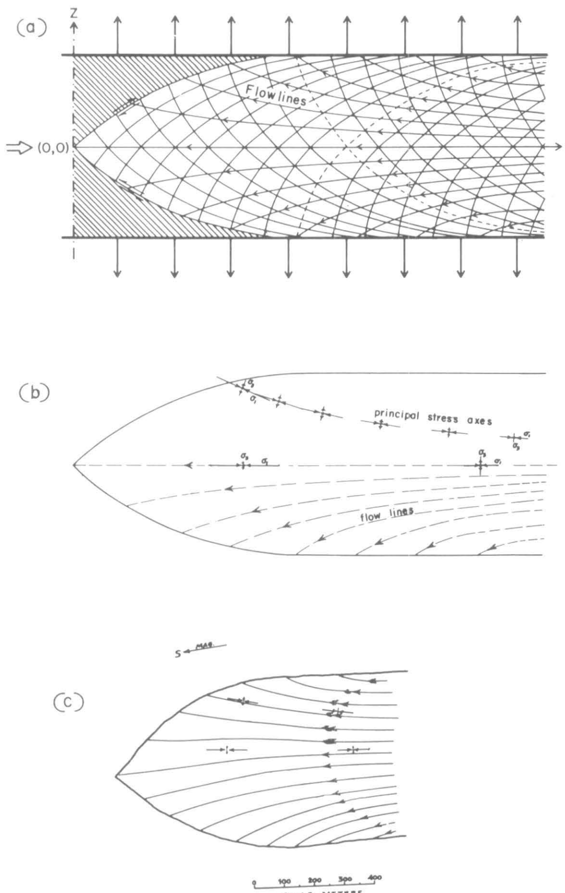

Fig. 1. (a) Classic parallel plate problem for a perfectly plastic substance (all directions reversed); (b) model derived from (a) showing flow lines and orientations of the principal stresses; (c) Meserve Glacier tongue.

The important boundary condition of the base (*i.e.*, no sliding), which is a consequence of the low basal temperatures (—17.5° to —18°C.), combined with low internal temperatures (minimum —19.7°C.) and the thinness of the ice tongue (about 50 to 70 m on the centerline), ensures slow deformations (0.9 to 1.8 cm day $^{-1}$ on the surface) and the maintenance of a cliffed margin. This latter structure derives its existence from the marked change in rheology of ice at thicknesses of about 20 m combined with natural ablation processes, including dry calving. In the perfectly plastic model, the cliff height would be $2K/\bar{\rho}g \approx 22$ m, for a yield stress $K = 1$ bar and a mean density $\bar{\rho} = 0.9$ g cm^{-3}.

Five broad flow zones of transitional character are recognized within the region of the glacier tongue:

1. The surface compression zone, where the ice is at least 15 to 20 m thick. The compression is assumed to be maximum at the surface and decays with depth, as has been demonstrated elsewhere (Glen, 1956; Paterson, 1962; Holdsworth, 1969a).
2. The laminar flow zone, where the shear strain rate is dominant and is related to the shear stress in the form: $\gamma = k\tau^n$, where $k \approx 0.9 \times 10^{-8}$ bar^{-n} .sec^{-1} and $n \approx 1.81 \pm 0.1$ (Holdsworth, 1969a; Holdsworth *and* Bull, 1969); it is apparent that n may be as low as 1.6 ± 0.1.
3. A zone of enhanced laminar flow, where n is expected to reach values of 3 or 4 at shear stresses greater than 1 bar, corresponding to depths greater than 45 m. The existence of this zone is based on indirect evidence.
4. A basal zone of enhanced creep (at least 1 m thick), which appears to be laminar flow to a good approximation, except in regions very close to the base around obstructions. Even though shear stresses are less than 1 bar, n may reach values of 5 or 6. The increased creep rate is attributed to the presence of diffused salts and finely dispersed debris in the basal ice. Salts appear to have diffused upward 5.5 m, and macroscopic debris has reached heights of 45 to 85 cm. The dispersion of this material is probably governed by the theory of Weertman (1968) with certain modifications (Holdsworth, 1969a).
5. A "semi-rigid" zone containing the cliff ice and that portion a few meters back. Paradoxically, this zone is generally an extremely constricting boundary for the flow of the glacier tongue.

This last zone is important because it contributes strongly to the maintenance of the surface compression, which starts in and continues below the icefall as a result of bed curvature, thinning of the tongue, and increased ablation down-glacier (Carnein, 1968). The expression of this longitudinal compression, which is estimated from surface strain rates to be initially 4.8 to 5.1 bars, is deduced to be the series of more than 13 buckles (or undulations) produced as a result of surface instability (Fig. 2). These undulations initially have wavelengths of 50 to 55 m with a dominant value of 53 m. Amplitudes (up to 3 m) vary, resulting from continued compression within the wave train and modification from ablation and other effects.

Using the theory of Biot (1960), it is possible to demonstrate (Holdsworth, 1969a) that under certain conditions (1) ice fulfills the basic requirements of the theory, and (2) the dominant evolving buckle wave-

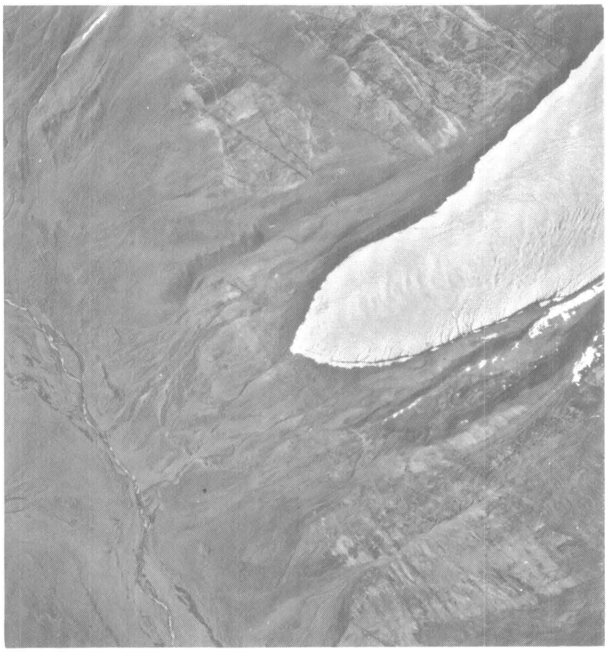

Photo by U.S. Navy for U.S. Geological Survey

Fig. 2. Meserve Glacier tongue, showing surface buckles or undulations.

length can be predicted from a knowledge of the density of ice, the surface compression, and its decay with depth. The calculated value (Holdsworth, 1969a) of about 55 to 60 m is close to the measured values.

It is hypothesized that the theory may also be applied to the case of longitudinal tension, and, thus, be used to explain the spacings of transverse crevasses (Holdsworth, 1965; 1969b). The theoretical results and the measured values are given by Holdsworth (1969a).

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Chemical-Physical Weathering, Surficial Geology, and Glacial History of the Wright Valley, Victoria Land

ROBERT E. BEHLING *and* PARKER E. CALKIN*

Institute of Polar Studies
The Ohio State University

The major objectives of the past field season included accumulation of data for a surficial geologic map and a preliminary determination of the relative ages of axial and alpine glacier advances throughout the Wright Valley. Criteria such as relative position of moraines, drift lithology, surficial boulder weathering, shallow seismic profiles, and some isotopic data were utilized to differentiate at least four major glacial advances each from the Wright Upper Glacier (inland ice plateau) and Wright Lower Glacier (Ross Sea ice advances), and three major advances of the alpine glaciers of Wright Valley. The three alpine advances recognized were apparently out of phase with the westward invasions from the Ross Sea. However, time relations of alpine and Ross ice advances with the eastward movements of the Wright Upper Glacier and inland ice are less well defined. Distributions of drift suggest that there has been no through-valley movement of the inland ice since the formation of basaltic volcanic cones on the valley floor some 4 million years ago.

Observations made during the field season in the adjacent Victoria Valley system to the north, and in the Taylor Valley and Mount Discovery areas will facilitate correlations of the Wright Valley sequence with that of the whole McMurdo Sound region.

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*Now at the State University of New York at Buffalo.

Detailed studies of soil-profile development and sampling for laboratory evaluation of weathering was initiated throughout the valley by Behling during the latter part of the season. This work makes up the second phase of the project and is intended to help clarify the age relationships of axial to alpine glaciation and perhaps suggest the climatic and physical environment under which mineral alteration processes have acted and are now acting.

Surveys of markers on a rock glacier in Wright Valley, on the Packard Glacier, and on the sand dunes below the Packard Glacier in Victoria Valley were undertaken to complement geomorphic studies initiated in 1961.

Patterned Ground Studies in Victoria Land

ROBERT F. BLACK *and* ARTHUR A. TWOMEY

Department of Geology and Geophysics
University of Wisconsin, Madison

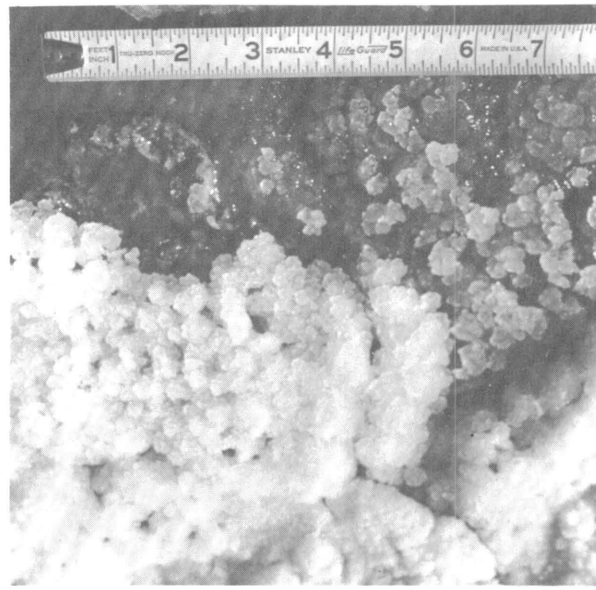

Photo: Robert F. Black

Fig. 1. Mirabilite crystallizing out of a small pond in the terminal moraine area in front of the Hobbs Glacier.

During the 1968-1969 field season, the writers visited all field stations on Ross Island and in the dry valleys where patterned ground is controlled by bench marks. Widths of all controlled wedges were measured. This season, as in previous years, measurements were not always made at the optimum time, *i.e.,* when ground temperatures reach their maximum and maximum closing of contraction cracks takes place. Measurements at other times record more growth between bench marks than actually has occurred. Any one austral summer varies sufficiently from the norm to make the precise time when measurements should be made almost unpredictable. As a consequence, correction factors must be applied to each year's measurements in order to determine annual variability of growth rates. The correction factor is obtained from ground temperatures recorded continuously throughout the year at McMurdo and in Taylor Valley. These two recording stations were serviced immediately on arrival in order to insure continuous thermal data during the field season. Correction factors for locations in Wright and Beacon Valleys and elsewhere are made by extrapolations. The thermal data and contraction data are now being reduced.

During the 1967-1968 field season, Arthur Twomey installed a recording setup to determine the timing of ice-wedge cracking at McMurdo Station. Ice wedges forming Y-intersections were controlled to see whether the three components of the Y cracked simultaneously. Preliminary analysis of the data suggests that individual limbs of two Ys cracked at different times. Another Y-intersection was controlled for continuation of the test during 1969.

Samples of pond water in which mirabilite was precipitating (Fig. 1) were collected from the Hobbs Glacier area. Analyses for carbonate were made in the field by titration, and the remainder of the dissolved constituents will be determined in the laboratory. Sulphur and oxygen-isotope studies of the materials are under way in New Zealand at the Institute of Nuclear Sciences. Studies of evaporite mineralogy and brine compositions are being carried out at the University of Wisconsin.

Another saline discharge was examined and sampled at the terminus of Taylor Glacier at Lake Bonney. This discharge came from the same location and was of the same size as that studied earlier by Black and Bowser (1968) and Black, Jackson, and Berg (1965). (See also Black, 1969.) The samples from the discharge are being analyzed at the University of Wisconsin.

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Diagenetic Syngenite from Victoria Land, Antarctica

ROY C. LINDHOLM *and* FREDERIC R. SIEGEL

Department of Geology
George Washington University

and

WAKEFIELD DORT, JR.

Department of Geology
University of Kansas

Vesicular basaltic rocks coated by thin layers of secondary minerals were collected from an exposed face of small lava flow that issued from a local vent on one side of "Roaring Valley" about 5 miles northeast of Mount Dromedary and about 1 mile south of the terminus of Walcott Glacier, at an elevation of 1,500 feet. These encrustations are 0.05 to 1.0 mm thick and white to greenish-yellow. X-ray diffractograms show the crust to be composed of calcite, gypsum, and syngenite ($K_2SO_4.CaSO_4H_2O$). Chemical analysis of representative crust material shows the presence of 11.1 percent of potassium.

Petrographic analysis was complicated by the similar birefringence (dependent on orientation) and relief of syngenite and gypsum, and the fine grain-size of the minerals. This necessitated identification of each grain in areas of the crust studied. Each grain was identified and recorded on a sketch (Fig. 1). Syngenite and gypsum were distinguished by optic sign and birefringence; syngenite is biaxial negative with a birefringence of 0.017, whereas gypsum is biaxial positive with a birefringence of 0.009 (Winchell *and* Winchell, 1951).

Some crusts are nearly monomineralic. Where two or three minerals are present in the same crust, the calcite is adjacent to the basaltic rock and the syngenite forms an outer layer. Gypsum is found between the calcite and the syngenite. The calcite-sulfate contact is sharp, whereas the two sulfates are usually intergrown at their contact. Calcite is finely crystalline (range of 2 to 8 microns). Calcitic portions of the crust are 0.05 to 0.5 mm thick and thinly laminated with individual laminae ranging in thickness between 5 and 30 microns. In some cases, the matrix of the basaltic rock under the crust has been partially replaced by calcite.

Gypsum composed of grains that range in size between 0.05 and 0.4 mm also occurs interstitially between well-formed syngenite crystals (Fig. 1-C), but shows no good crystals, although cleavage is sometimes noted.

The grain size of the syngenite ranges between 0.03

Table 1. D-spacings of the mineral syngenite

ASTM Card 11-117 (1965)	Antarctic sample
9.52 A	9.50 A
5.71	5.71
4.63	4.62
3.16	3.16
3.04	3.04
2.86	2.86
2.74	2.74
2.51	2.51

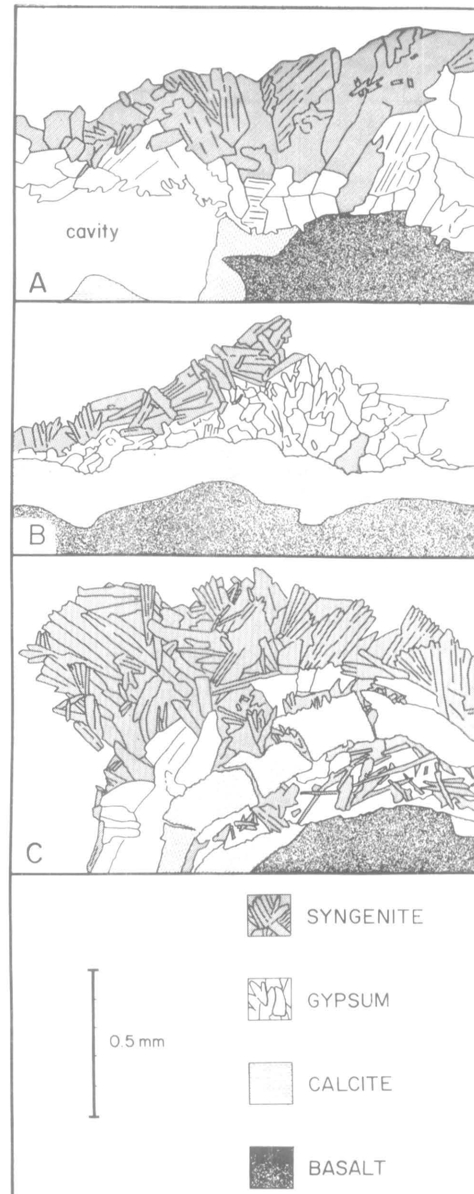

Fig. 1. Secondary mineral crusts on basaltic rock. Traced from photomicrographs of thin sections from three different samples (A, B, C). Laminations in calcitic portion of crusts are not shown. X50.

and 0.8 mm. Many of the smaller grains are well-formed acicular crystals that are 0.03 to 0.3 mm long and 0.02 to 0.01 mm wide. Fluid inclusions, 0.5 to 4.0 microns in diameter, are abundant in the syngenite and the gypsum.

The textures described clearly show that calcite was the first mineral to form on the basaltic rocks. Gypsum crystallized after the calcite. There is no apparent genetic relationship between the calcite and the gypsum, as indicated by the sharp contact between the two and the fact that gypsum commonly is in direct contact with the host rock (where no calcite is present).

The syngenite seems to be a diagenetic product formed at the expense of the gypsum. Evidence is the presence of well-formed acicular syngenite crystals in more massive gypsum. This is best developed on one area where the calcitic crust has been mechanically separated from the basaltic rock, probably by displacive growth of the gypsum (Fig. 1-C). The occurrence of syngenite as the exterior layer of the crust suggests that contact with the atmosphere was a controlling factor in the formation of syngenite.

In studies of antarctic atmospheric chemistry, reports reveal that aerosols range in composition from nearly pure sulfuric acid droplets to nearly pure ammonium sulfate so that sea salts and other particles could react with sulfuric acid to give sulfate salts, (Cadle *et al.*, 1968; Fischer *et al.*, 1969); the H_2SO_4 may have been formed by oxidation of SO_2 in aqueous droplets containing sea salts. It was also reported that SO_2 concentration maxima were highest on the Ross Ice Shelf and at upper stations on Mount Discovery, which is in the general area of the syngenite development, as well as at 10,000 feet altitude over Mount Discovery. This SO_2 may originate from the stratospheric aerosol layer of sulfate near 20 km, first described by Junge *et al.* (1961), which is thought to undergo its greatest downward mixing by subsidence in the winter.

No reliable analyses of the potassium content of the areosols in the area have yet been made (J. P. Lodge, Jr., telephone communication, 1969). Potassium content of firn samples from the vicinity of Roi Baudouin Base is 190 ppb, of which 15 ppb may be oceanic contribution (Brocas *and* Picciotto, 1967). The syngenite described above may be the product of slow reactions of the sulfate-rich aerosols with potassium and the underlying gypsum. There is no evidence thus far that the syngenite was produced from volcanic gases; if it were, the syngenite should be present in the vesicles of the host rock.

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Geological and Geophysical Studies in the Ice-Free Valley Area of Victoria Land

SCOTT B. SMITHSON, DONALD MURPHY, *and* DAVID J. TOOGOOD

Department of Geology
University of Wyoming

During the 1968–1969 austral summer, detailed mapping was continued in Victoria and Wright Valleys at a scale of 1:3,000. Regional mapping was done at a scale of 1:12,000; Taylor Valley and the Skelton Glacier area were included in the studies.

Detailed mapping at Mount Insel in Victoria Valley determined structural geometry that was more complex than previously recognized. Three fold systems are present in the marbles and calcium-silicate schists that comprise the metamorphic rocks in this locality. The first and second fold systems consist of isoclinal folds with near-horizontal axial planes. The third fold system includes tight to isoclinal folds with near-vertical northwest-trending axial planes. The second and third fold systems have northwest-trending axes; this coincidence of fold axes has made recognition of the separate fold systems more difficult. Granitic dikes which are now folded and lineated were emplaced between formation of the second and third fold systems and show that these fold systems were separate events in time. In Wright Valley, large folds representing the third system are exposed in the valley walls. The metamorphic rocks in this locality are granitic gneisses and calcium-silicate schists. Two fold systems are easily recognized here, but the presence of three fold systems is uncertain. Augen gneiss is closely associated with calcium-silicate metasedimentary rocks in this locality. Three fold systems are also present in metamorphic rocks in the foothills of the Royal Society Range.

Metamorphism ranges from gneiss-schist facies to uppermost amphibolite facies. Coexisting orthoclase and sillimanite indicate that metamorphic rocks in Victoria Valley belong in the uppermost amphibolite facies. In the foothills of the Royal Society Range, coexisting muscovite and sillimanite indicate middle amphibolite facies. In the Skelton Glacier area, sedimentary rocks show slight metamorphism. Primary sedimentary structures and probable detrital grains are common in the rocks, but some metamorphic biotite is present and the rocks exhibit varying degrees of recrystallization. Graywackes, mudstones, calcareous sandstone, limestones, siliceous limestones, and marls constitute the slightly metamorphic sedimentary rocks along the Skelton Glacier. These rocks have the appropriate composition to be low-grade equivalents of the sillimanite-grade marbles, calcium-silicate schists, and quartzo-feldspathic gneisses in the ice-free valley area. Rocks of the Ant Hill Limestone show large-scale folds and fracture cleavage developed in marly layers.

Diopside-plagioclase or diopside-quartz granofels is a common rock type among high-grade calcium-silicate rocks that were most likely derived from calcareous sedimentary rocks. In places where diopside-rich rocks are boudinaged, they became amphibolitized so that they were surrounded by rims of amphibolite. Some of the amphibolite rims formed from diopside-plagioclase granofels have compositions near basalt. These occurrences have an important bearing on the amphibolite problem because they demonstrate that amphibolites of igneous composition can form from sedimentary rock.

Larsen Granodiorite forms a large, distinctive pluton in Wright and Taylor Valleys. Contacts of Larsen Granodiorite are gradational with augen gneiss over hundreds of meters. Foliation is distinct and common in Larsen Granodiorite and parallels axial planes of the third fold system; lineation consisting of large hornblende prisms plunges northwest similar to axis of the third folds. This body of Larsen Granodiorite can be called synkinematic with respect to the third fold system. Other areas of granitic rocks and migmatite are quite different and may not be related to Larsen Granodiorite. Vida (Irizar) granite forms distinctive, crosscutting postkinematic plutons. Studies of areal variation in composition show the Vida Granite to be quite uniform.

Gravity measurements were completed at the Dailey Islands, in Taylor Valley, and from Cape Archer to Alatna Valley near MacKay Glacier. Bouguer gravity anomalies are near zero around McMurdo Sound, decrease rapidly just west of McMurdo Sound, and reach values of —150 mgal in the westernmost part of the ice-free valleys. High gradients west of the coast must be due to a shallow unexposed disturbing mass.

Paleomagnetism of Igneous Rocks from Île Amsterdam, Kerguelen, and Îles Crozet

N. D. WATKINS *and* C. E. ABRANSON

Department of Geology
Florida State University

The paleomagnetism of oceanic islands is generally valuable in understanding the genesis of ocean basins in which large and complex tectonic movements are suspected.

Although Tertiary paleomagnetic poles cannot be used to detect east-west crustal movements, longitudinal drift such as that which has been proposed for the Indian Ocean (Le Pichon *and* Heirtzler, 1968) is ideally suited to paleomagnetic testing, particularly if reference points have been established for oceanic islands in different, but known, tectonic regimes.

Paleomagnetic results from the Indian Ocean are restricted to those from a limited sampling of Heard Island (Irving *et al.*, 1965), but reference points have been established for large collections from the Middle and Late Tertiary volcanics of several Atlantic islands (Watkins *et al.*, 1966a, 1966b, 1968; Richardson *and* Watkins, 1968).

From February to April 1969, over 500 cores were collected from more than 100 lavas and dikes in known stratigraphic sequences from Île de l'Est and

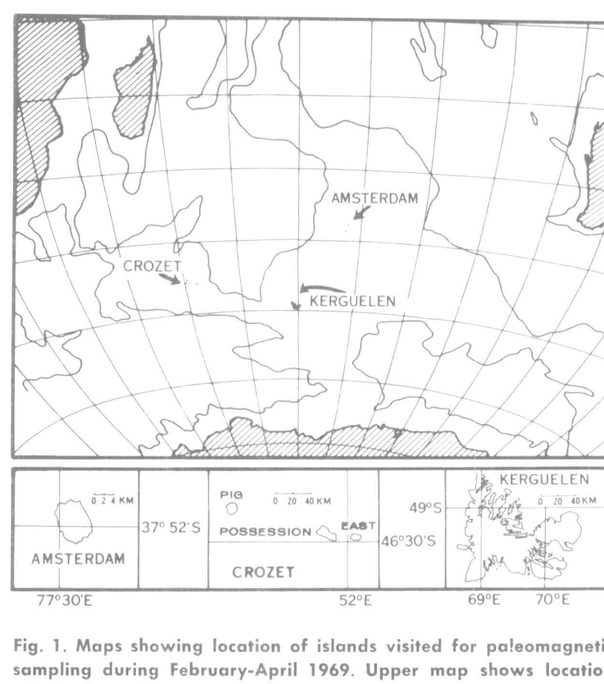

Fig. 1. Maps showing location of islands visited for paleomagnetic sampling during February-April 1969. Upper map shows location of islands with respect to the Indian Ocean rise system (4,000-m bathymetric contour included).

Île de la Possession (in the Îles Crozet), Kerguelen, and Île Amsterdam (Fig. 1). This work was made possible by the generosity of the Administrator Pierre Rolland of the Territoire des Terres Australes et Antarctiques Françaises, who provided transport aboard the vessel *Galliéni* from Île de la Réunion, helicopter transport on the islands, and all other logistic support.

In addition to paleomagnetic studies, potassium-argon dating and geochemical and petrological examinations will be performed on the materials collected.

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Calcium Salts from Taylor Glacier, Southern Victoria Land

GEORGE C. STEPHENS
and FREDERIC R. SIEGEL

Department of Geology
George Washington University

During the 1968–1969 antarctic field season, a study of selected evaporite deposits was continued in the dry valleys west of McMurdo Sound. In the course of the field reconnaissance, an orange-colored material issuing from the foot of Taylor Glacier was collected. This orange matter is apparently disseminated zonally in the glacier approximately halfway (8 m) from the top. In addition, red, euhedral crystals, approximately ⅛ in. long, were found lining steeply dipping fractures in the glacier; these fractures are visible on the sides of the glacier and are thought to be tensional in origin.

Petrographic and X-ray diffraction analyses of the fine-grained orange material and the red, euhedral crystals show the former to be calcite and the latter to be gypsum. In both cases, the coloring is attributed to iron staining; the calcite contains 0.68 percent Fe. Detrital, fine- to coarse-grained, poorly sorted, sub-angular to sub-rounded sand-size grains of quartz, feldspar, biotite, hornblende, and miscellaneous accessory minerals were found mixed with the fine-grained calcite. Some of the larger grains (greater than 0.5 mm in diameter) are granitic rock fragments. Many of the detrital sand-size grains are also strongly iron stained.

This material occurs as an isolated patch within the ice and is not laterally continuous. Field observations suggest that the deposit is not controlled by, nor concordant with, the layer of ice accumulation within the glacier. The sediment was probably incorporated in the glacier as it overrode a small evaporitic lake or pond deposit, and the salts and detrital minerals were subsequently forced up into the glacier along tensional fractures. The gypsum has crystallized in place along the fractures as evidenced by its euhedral crystal shape.

Acknowledgement is made of the assistance given by a National Science Foundation Grant, GA–1143.

A Reinvestigation of the Mawson Tillite, Victoria Land, East Antarctica

HAROLD W. BORNS, JR.,
and BRADFORD A. HALL

Department of Geological Sciences
University of Maine

The objectives of this program were to reinvestigate the age and origin of the Jurassic Mawson tillite, which was first described by Gunn and Warren (1962). A later New Zealand expedition (Ballance *et al.,* 1965) cast doubt on its glacial origin and tentatively suggested a volcanic origin. They also indicated that the rocks at Carapace Nunatak, which contain fossils used by Gunn and Warren (1962) to date the "tillite," were of different origin from the "tillite" in its type area at Allan Hills. Thus, the age and origin of the Mawson tillite were opened to question.

Our own field work consisted of a total of four weeks on Allan Hills and Battlements and Carapace Nunataks. The geology on Allan Hills and Battlements Nunatak produced no evidence of a glacial origin for the Mawson tillite, but did produce ample evidence that the major part of the deposit is volcanic, consisting of debris flows emplaced by gravity after original extrusion, probably as explosion breccias. The evidence of such an origin consists, in part, of numerous graded beds within the Mawson, the rock fabric, and probable source vents of Mawson rock on Battlements Nunatak.

Rocks similar to the Mawson tillite of Allan Hills are present on Carapace Nunatak beneath volcanic sandstones assigned by Ballance *et al.* (1965) to the Beacon group. We concur with the Jurassic age assignment of the Mawson by Gunn and Warren (1962). In addition to the conchostracans and ostracods previously reported from Carapace (Gunn *and* Warren, 1962; Ballance *et al.*, 1965), a newly discovered locality produced well-preserved, large insect and crustacean remains. Their paleoclimatic and paleogeographic significance has not yet been assessed.

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Fossiliferous Rocks in Moraines at Minna Bluff, McMurdo Sound

H. J. HARRINGTON

Department of Geology
University of New England
Armidale, N.S.W., Australia

In 1959, limited exploration of moraines at Minna Bluff and White Island in McMurdo Sound yielded a few fragments of gray, white-weathering mudstones or vitric tuffs, similar to diachronous facies in New Zealand that range in age from Late Cretaceous to Early Oligocene. It was naturally assumed that the antarctic erratics would be within that age range.

From a small Minna Bluff erratic, G. H. Scott extracted a few Foraminifera, and L. M. Cranwell obtained a small pollen component and abundant hystrichosphaerids and dinoflagellates. The age of this fossil biota, probably Paleocene or Eocene, has been discussed in a number of papers (Cranwell *et al.*, 1960; Cranwell, 1962, 1963, 1964a, 1964b, 1966; Harrington, 1965). The biota is of paleoclimatic and paleogeographic significance in indicating that the sea in which it accumulated was "normal" and was adjacent to land warm enough to support a *Nothofagus* forest. It also proved that this part of Antarctica could have acted as a migration route or dispersal center for Tertiary plants, linking the Andean region with New Zealand and eastern Australia.

Further searches were unsuccessful until 1966, when some calcareous sandstone blocks, collected at Black Island by P. Vella and A. O. Frame, were found to contain a microflora and a microplankton similar to those in the Minna Bluff specimen, but preserved in a different facies (McIntyre *and* Wilson, 1966; Wilson, 1967). More recently Wilson (1968) has found that derived palynomorphs of Lower Tertiary age are widespread in Holocene sediments on the floor of the Ross Sea. In the 1968-1969 summer, Tertiary macrofossils were found in a glacial erratic boulder at Cape Crozier, Ross Island.

In January 1969, the writer, assisted by R. Korsch, spent a week of intensive re-collecting at Minna Bluff. Three days and over 60 km of slow and careful traversing yielded only two pieces of Tertiary mudstone, but during the remainder of the week, several hundreds of fragments of mudstones, calcareous sandstone, and conglomerate or diamictite were found. The distribution of the erratics is, in fact, erratic or unpredictable, being governed by the fact that the different lateral and terminal moraines on the north side of Minna Bluff form distinctive groups. Some consist of basaltic rocks from the McMurdo volcanics, others of blocks of trachyte and calcareous sandstone, and yet others of plutonic and metasedimentary rocks with scattered patches and streamlines of Tertiary mudstones. The microfossils in the sediments will be processed in 1969 by L. M. Cranwell and others.

The source of the fossiliferous erratics is a matter of considerable interest. It is considered very unlikely that they have been derived from the west side of the Transantarctic Mountains in East Antarctica. It is considered probable, however, that a Cretaceous and Tertiary sedimentary sequence of the New Zealand type is widespread in Marie Byrd Land and possibly also under the floor of the Ross Sea and the adjoining continental terrace. Any attempt to be more specific is difficult. Crary (1961, 1966) and Crary *et al.* (1962) have shown, by seismic investigations, that over 1,300 m of low-velocity sediments occur beneath the eastern Ross Sea near Kainan Bay and cover 645 m of higher-velocity sediments, which Crary thought might be of the same general type as the Beacon sandstones, but which could be a Cretaceous and Tertiary sequence. Crary has also shown that there are thick sediments beneath the Ross Ice Shelf south of Minna Bluff.

The discovery of Tertiary fossiliferous sediments (and other rocks such as ignimbrites) as glacial erratics in McMurdo Sound is important in itself, but it also indicates that very little is yet known about the age and tectonic history of the Ross Sea. It could be, in part, a new ocean formed by rifting during the Cenozoic. That problem, and others related to it, point the way to research which could have economic significance in future exploration for hydrocarbons beneath the Ross Ice Shelf and adjoining oceanic areas.

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Geology of the Roberts Massif, Queen Maud Range, Transantarctic Mountains, Antarctica

KERBY E. La PRADE

Department of Geology
Texas Technological College

The Texas Technological College field party consisting of Charles King, William Schaefer, Fernando Munizaga (geochronologist from Instituto Antártico Chileno, Santiago de Chile), Navy Photographer First Class Bruce F. Moore, and the author was lifted out of Ellsworth Land to McMurdo Station on December 16, 1968, and relocated for a week's investigation of the Roberts Massif, on the edge of the polar plateau, on December 21.

A tent camp was established adjacent to the Massif, immediately south of Misery Peak. Motor toboggans provided transportation in the field. Objectives of the short survey were to determine the age and correlation of exposures of Beacon sedimentary rocks by measuring sections and collecting a suite of plant and possible animal fossils. This information was needed to complete the survey of the Shackleton Glacier area.

Beacon Group sediments cropping out at Roberts Massif consist of about 450 m of massive, light-gray, feldspathic sandstone alternating with thin to massive units of gray shale. The age of the sediments is indicated to be Triassic by the presence of *Dicroidium dutoitii* sp. in beds exposed at Misery Peak (Townrow, 1967). A thin, coaly section crops out near the ice level on the north side of the Massif and probably represents sediments of the Permian Buckley Formation, first described in the Beardmore area by Grindley (1963). Massive diabase sheets of Jurassic age are coexistent with the sediments.

Beacon rocks have been named Mount Kenyon Formation for thick exposures in Mount Kenyon (85°13′S. 174°25′W.), 45 km to the northeast. The Mount Kenyon Formation correlates with either, or both, of the Fremouw and Falla Formations of the Beardmore area, as recently redefined by Barrett (unpublished National Science Foundation report).

Sedimentary rocks of the Roberts Massif were formerly identified as Triassic Dominion Formation (Grindley *et al.,*1964; Wade *et al.,* 1965a, 1965b; and McGregor, 1965), because *Dicroidium* was believed distinctive for the Dominion Formation, which was described by Grindley *et al.* (1964) as overlying the Falla Formation, reported to be nonfossiliferous (Grindley, 1963). Barrett (unpublished National Science Foundation report) reinvestigated the Beardmore area in 1966-1967 and found the Dominion and Falla Formations to be one and the same, with both carrying the *Dicroidium* flora.

Fossils collected at Roberts Massif during last season have not been identified. It is expected they will include additional Triassic *Dicroidium* fossils.

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Weathering and Soil-Forming Processes in the Antarctic Dry Valleys

STEPHEN C. PORTER

Department of Geology
University of Washington

The objectives of this two-year study are: (1) to observe the type and intensity of weathering and soil-forming processes in southern Victoria Land; (2) to evaluate the effects of climate, parent material, and time on weathering and soil formation; and (3) to determine the degree to which the soils of southern Victoria Land reflect soil-forming processes now active in the ice-free areas.

Approximately two months of field work by George O. Linkletter in the dry valleys from late October to late December 1968 concentrated on a reconnaissance of various till-mantled areas which have been assigned limiting absolute ages by George H. Denton (personal communication, 1968) and sampling of soils at selected sites in the Taylor Valley, on The Bulwark, in front of the Hobbs and Walcott Glaciers, and in Garwood Valley. Parent materials at 28 study sites included till (19), bedrock (6), cavernously weathered boulders (2), and alluvial-fan sediment (1). The depth of the open pits range from 10 cm on the fresh lateral moraine of an alpine glacier to more than 2 m on till dated greater than 3.4 million years.

Observations and measurements made included surface weathering characteristics at each site, variation of temperature with respect to both time and depth at most sites, the location of nearby snowbanks, and the attitude and microtopography at each site. Each profile sampled was carefully described and gross lithology was determined by pebble counts made in four size ranges at various depths.

Photo: George O. Linkletter

Excavating soil-study pit on young till in front of the Walcott Glacier.

The project is primarily a laboratory investigation; however, preliminary field observations may be summarized as follows:

(a) Tills which have been assigned limiting ages frequently show horizon development commensurate with their relative ages. Older tills commonly display a noticeable segregation of carbonates from the more soluble salts and distinctive color variation with depth.

(b) The depth to ice-cemented permafrost, often assumed to be a function of the age of the deposit, is frequently a function of topography and other factors which allow snowbanks to accumulate.

(c) None of the tills sampled showed any indication of a lithologic discontinuity above the ice-cemented layer.

(d) Moderately developed to well-developed structure encountered in some older soils often is related to carbonate or salt concentrations at a given level. In a few locations, no evidence of carbonates or salts was found in the structured horizon, indicating the possibility of an illuvial clay concentration.

Analysis of the samples obtained during the 1968-1969 field season is now being pursued at the University of Washington.

Structural Studies in the Scotia Arc: Livingston Island

IAN W. D. DALZIEL

Lamont-Doherty Geological Observatory
Columbia University

The South Shetland Islands lie on the southern limb of the Scotia Arc, separated from the Antarctic Peninsula by the Bransfield Strait (Fig. 1). During the 1968-1969 antarctic summer, the author and his assistant, S. J. Brocoum, spent approximately seven weeks in the southeastern part of Livingston Island, the largest of the group, carrying out geological and geophysical studies pertinent to the tectonic history of the Arc. This particular location was selected in order to study the so-called False Bay schists, which were tentatively assigned a Precambrian age by Hobbs (1968), and a deformed but unmetamorphosed sedimentary sequence, the Miers Bluff Formation (Hobbs, 1968).

The False Bay schists occur on the eastern side of False Bay. They are mainly hornblendic, look like part of a regionally metamorphosed assemblage, but occur only as xenoliths within a coarse-grained tonalite. As pointed out by Hobbs (1968), there is no conclusive evidence on Livingston Island concerning their age. In an attempt to settle this question, material was collected for radiometric dating, which is now being undertaken by Martin Halpern of the Southwest Center for Advanced Studies. Specimens of the tonalite are also being dated; it is presumably a member of the Andean intrusive suite.

Most of the available time in the field was spent studying the Miers Bluff Formation, which forms the Hurd Peninsula between South Bay and False Bay. It is a flysch-type sequence of alternating shales and thin graywackes which also contains numerous beds of relatively mature sandstone. Only plant fossils were found and it is not yet known whether any of these are diagnostic. Although tentatively correlated with the Trinity Peninsula Series by Hobbs (1968) on lithic grounds, the rocks are remarkably similar to the Cretaceous sediments at Cape Legoupil, directly across the Bransfield Strait on the Antarctic Peninsula, as described by Halpern (1965; *see also* Adie, 1964).

The rocks of the Miers Bluff Formation dip northwest at a low or moderate angle. They were regarded by Hobbs (1968) as a normal upward-facing succession. However, the present study has shown that they lie on the inverted limb of a recumbent fold of nappe proportions which is refolded by at least two later sets of structures. The hinge line of the recumbent fold can be deduced from cleavage/bedding relations to strike northeast-southwest parallel to the trend of the Scotia Arc at this point, and the fold faces southeast. The structural history of the Miers Bluff Formation is similar to that of the Cape Legoupil Formation as outlined by Miller (1966).

Two other projects were undertaken during the field season. Approximately 150 cores were collected for paleomagnetic study from the Miers Bluff Formation, the tonalite body, and numerous crosscutting dikes. Also, a portable high-gain seismograph was operated for 10 days before it was damaged in transit.

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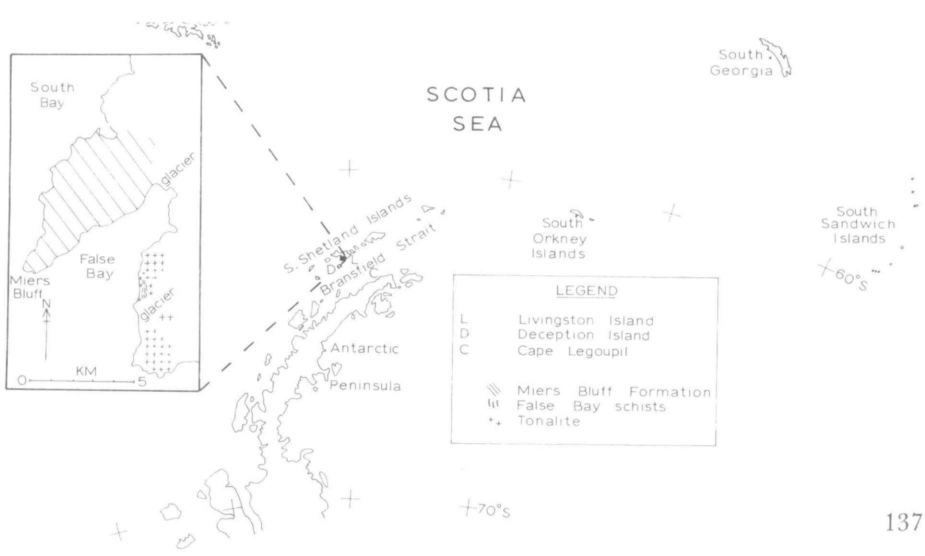


The Scotia Arc showing location of Livingston Island and (inset) the geology of the southwestern part of the island.

Pedology of the Trinity Peninsula and Offshore Islands

K. R. EVERETT

Institute of Polar Studies
The Ohio State University

During the austral summer of 1968-1969, a reconnaissance soil survey was made of part of the Antarctic Peninsula and South Shetlands Islands. Tentatively, eight soil types have been identified and are considered at this time to be regionally significant:

1. Moderately well-drained to well-drained upland soils. These soils display well-developed horizons and occur on relatively stable sites, generally bedrock outcrops, which offer protection from high winds. Vegetation cover is slight, consisting of scattered mosses and *Usnea* sp.
2. Moderately well-drained soils developed on moraine material associated with pre-Recent valley glaciers. The upper 12 inches of the profile may be developed in scoria, while the depth of leaching in the till ranges from 12 to 16 inches. Vegetation consists of lichens, particularly *Usnea* (two species), mosses, *Deschampsia antarctica,* and *Colobanthus crassifolius.* In some cases, extensive areas have 100 percent coverage of *Deschampsia antarctica* and mosses. Birds are important in the genesis of this soil type.
3. Similar to 2, but developed principally on raised beaches, occasionally on kame deposits. Scoria may make up a significant proportion of the upper 12 inches of the profile. Vegetation composition and coverage is approximately the same as 2 although *Usnea* sp. may be absent. Birds are very important in its genesis.
4. Moderately well-drained to imperfectly drained organic soils. These soils are generally developed on steep, northward-facing slopes. Horizons of poorly decomposed and/or moderately decomposed organic material overlie sandy mineral soil which may have a high organic matter content or lie directly on blocky talus. Permafrost frequently occurs within 10 inches of the surface. Birds appear to be necessary for soil formation. Soils are commonly associated with giant petrel nest areas. However, this association is not the case on Litchfield Island.
5. Very poorly drained to water-logged soils under moss carpets. These soils commonly occur in poorly drained basins which receive snowbank melt or are extensively developed on broad, poorly drained raised beaches on the Byers Peninsula, Livingston Island. Where water-logged conditions prevail, little or no horizon development is apparent. Organic matter accumulation is less than one inch. Slightly improved drainage results in well-defined horizons. Thin, buried organic horizons are common. Permafrost is usually less than 24 inches. Soils are generally sandy and low in organic matter.
6. Very poorly drained organic soils under moss carpets. Organic matter is coarse and fibrous and may exceed 10 inches in depth. These soils occur in sites similar to those for soil 5.
7. Poorly drained to imperfectly drained rookery soils. Vegetation ranges from absent or scattered to a nearly complete cover of *Prasiola* sp.
8. Well-drained to moderately well-drained, shallow, slightly oxidized sands or silts over bedrock. Sites are subjected to intense frost action and deflation. Vegetation is absent.

In addition to the soil investigation, the raised beaches of the area were studied. On Livingston Island, a general glacial chronology was developed and related to the beach sequence in the False Bay area.

Deception Island was visited shortly after the February eruption. Surface samples were collected as well as several soil profiles.

Other Research Projects Active During the 1968-1969 Summer

Antarctic Avian Population Studies. Johns Hopkins University; William J. L. Sladen, Principal Investigator.

Effects of Seal and Fish Predation on Certain Benthic Communities. University of Washington; Robert T. Paine, Principal Investigator.

Glacial Geology and Chronology of the McMurdo Sound Region of Antarctica. American Geographical Society; George H. Denton, Principal Investigator.

Antarctic Journal Circulation Increases

The availability of the *Antarctic Journal* through the Superintendent of Documents has increased its circulation significantly. As of July 1, 1969, the Superintendent of Documents had sold 3,650 subscriptions and 300 individual copies (May-June issue). Other distribution by that office includes 579 copies to depository libraries.

Together with the official distribution made by the National Science Foundation, the total distribution of the *Antarctic Journal* has now reached 6,200 copies.

Shackleton Range Traverse

SIR VIVIAN FUCHS

British Antarctic Survey

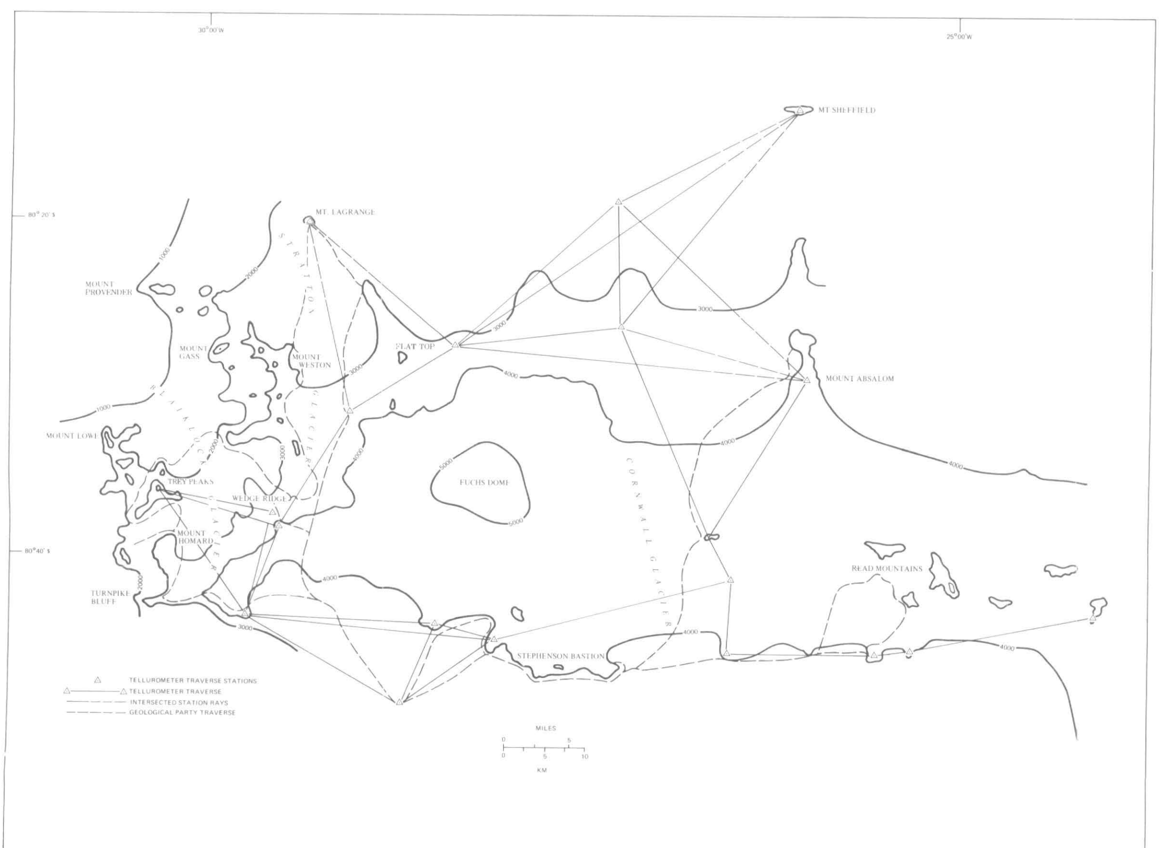
The Shackleton Range was discovered by the Commonwealth Trans-Antarctic Expedition in February 1956. The mountains extend for about 100 miles along an east-west axis between latitudes 80°S. and 81°S. The highest peak is just 6,000 feet. In 1957, surveyors David Stratton and Kenneth Blaiklock made a closed traverse by dog sledge, tied to astro-fixes, through the western part of the range.

In recent years, the British Antarctic Survey has succeeded in reaching these mountains on the ground from Halley Bay, although it entailed a round trip of over 1,000 miles for the tractors and dog teams, which made it impracticable to spend any reasonable length of time at work in the Shackletons. Therefore, the generous offer of the United States to fly a British party of surveyors and geologists from Halley Bay to the mountains in 1968 was particularly appreciated and gratefully accepted.

We were fortunate in being able to get Ken Blaiklock back for this work. Along with another surveyor, Tony True, he flew via Washington, D.C. and Christchurch to McMurdo Sound, where they awaited favorable weather for the flight across the continent. On November 23, their LC–130 landed at Halley Bay, where two geologists, two assistants, and 27 dogs, together with 10,000 lbs of supplies and equipment, were loaded and the plane refuelled.

When the aircraft reached the Shackletons, only a few peaks were visible through low cloud cover, which made it impossible to locate the Stratton Glacier where it was intended to land the party. After circling the mountains for an hour, the pilot saw a small gap in the clouds to the south of the range and was able to make a skillful but very bumpy landing on the sastrugi-cut surface of the great, 40-mile wide Recovery Glacier. At this time, the precise position was unknown, but the plane was quickly unloaded and took off for McMurdo in thick clouds.

When the weather cleared, the party found themselves about 30 miles west-southwest of Mount Greenfield. The three dog teams, therefore, spent several days relaying the depot to a position some eight miles southwest of the mountain. There the party divided, the geologists with one team setting off to work the rock exposure between the Stratton Glacier and



Mount Lagrange at the northwestern end of the range. Next, they worked back across the Blaiklock Glacier, from Mount Homard to Turnpike Bluff in the southwest. Later, a visit was paid to the Herbert Mountains, where Mike Skidmore fell 200 ft. over snow and scree, but was fortunate in suffering only superficial cuts, bruises, and abrasions. His companion, Peter Clarkson, got him back to the depot after a few days, and later they were able to make another journey to investigate the western peaks of the Read Mountains and, finally, Stephenson Bastion. On January 23, 1969, they returned to the depot to await the aircraft.

Meanwhile, the two surveyors and two assistants (Nick Mathys and Harry Wiggans) concentrated on providing precise ground control for the western part of the Shackletons, the air photography having already been flown by the United States. The Tellurometer and theodolite traverse started and closed at the depot, the first station being established on Mount Greenfield. The traverse continued eastward to a nunatak on the east side of Cornwall Glacier, then northwards via Crossover Pass. Unfortunately, as the surveyors were moving into position for the third Tellurometer ray, Nick Mathys broke a leg. He was taken back to the depot, where he was left in the care of Tony True.

This accident left only Blaiklock and Wiggans to continue the traverse, and they necessarily had to travel independently of each other. However, taking particular care, they were able to make a complete circuit of Flat Top and close the traverse on the depot by January 10. There, they found that Nick Mathys and Tony True had observed a series of sun positions for latitude and longitude, besides maintaining a very complete series of aneroid readings for height computations.

The last traverse of the survey party comprised a dogleg from the Cornwall Glacier, along the southern peaks of the Read Mountains to 23°30′W. on the southernmost peak at the east end of the range near Otter Pass.

By January 23, all parties were awaiting pick-up by the U.S. naval aircraft at the depot. Throughout, the party had been in good radio contact with Halley Bay, and on the 24th they heard that flying conditions were perfect. At 0200 hrs on the 25th, the plane landed and the group, together with their equipment, was loaded in 20 minutes.

The return flight was uneventful, except for low clouds at Halley Bay, but this presented little problem. By this time, the relief ship, *Perla Dan*, was at the station and provided a small celebration for the successful conclusion of the joint U.S.-U.K. venture. It is expected that one further season's work will provide adequate ground control for the entire range.

Norwegian Antarctic Expedition, 1968-1969

THORE S. WINSNES

Norsk Polarinstitutt

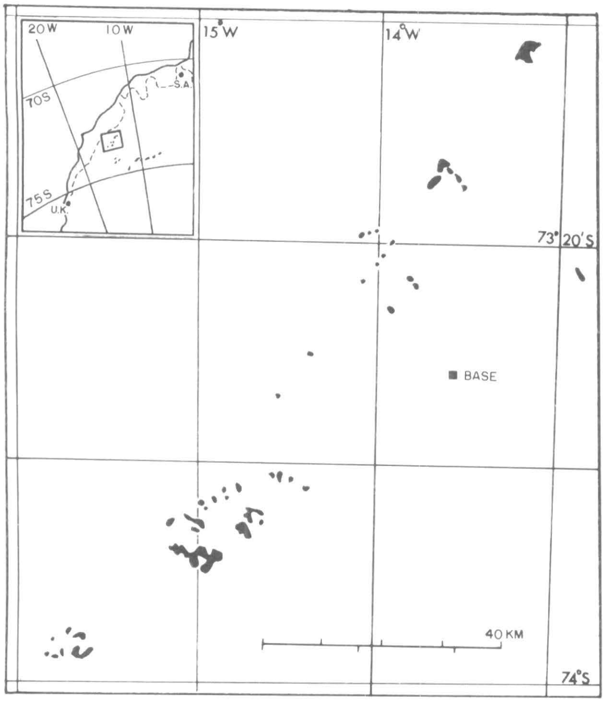
The aim of the Norwegian Antarctic Expedition was to carry out mapping, geological and glaciological investigations of the Kraul Mountains (Vestfjella) in western Queen Maud Land. Members of the expedition included Thore S. Winsnes, geologist and leader; Audun Hjelle, geologist; Torbjørn Lunde, glaciologist; Dag Norberg, topographer; Ola Steine, geodesist; and Kåre M. Bratlien, radio operator.

The expedition, which was organized by the Norwegian Polar Institute, Oslo, received the assistance of the National Science Foundation in the provision of American equipment and arrangements for logistics. Only about 500 kg of scientific instruments were brought from Norway.

The expedition party, ready to leave on November 14, after spending a fortnight at McMurdo Station, was further detained until November 22 by unfavorable weather and radio conditions. The 6 members of the expedition, equipped for 2½ months of field operations, were taken from McMurdo to the Kraul Mountains, making a short stop at Pole Station to refuel the LC–130 Hercules aircraft. After eight hours' flight, the Hercules landed south of the central part of the mountains in a spot particularly selected, after a careful study of aerial photographs, as being the most suitable for landing and base operations.

Work was organized into two field groups, each consisting of one topographer and one geologist, equipped with a motor toboggan and two Nansen sledges for transportation. For safety, the groups travelled together and operated from joint field camps. They were in daily radio contact with the main base, where investigations of snow accumulation and meteorological observations were carried out. In case of emergency, this group could operate with a third toboggan as a rescue team. Radio contact with the "outer world" was maintained through courtesy of the South African National Antarctic Expedition (SANAE) and Halley Bay Bases. The latter forwarded messages to and from McMurdo through Byrd Station.

On several sledge journeys, covering 800 km in all, the geology of the mountains was mapped, triangulations were made, and base measurements were taken. The geology of the Kraul Mountains is rather monotonous, consisting of amygdaloid basic-to-intermediate lavas in thick, nearly flat-lying beds. An ultrabasic



Kraul Mountains

olivine-rich intrusive is dominant in the westernmost part of the mountains. In the east, a small isolated outcrop consisted of sedimentary rocks in a sequence of about 50 m, containing a fossil *Glossopteris* flora of Permian age. All mountains were crossed by dolerite sills and dykes.

Astronomical observations of the sun and stars were made to get an exact location of the mountains; for elevation estimation, a series of pressure readings will be compared with contemporaneous ones from SANAE and Halley Bay. Measurements of the magnetic field were also made. During work in the mountains, animal and plant life were observed, and some samples were taken.

In January, the glaciologist travelled 70 km north to the ice shelf, where a snow pit was dug and core drillings were made in order to compare the conditions there to those at the main base. Facilitated by favorable conditions, the work was finished ahead of schedule. Owing to coarse sastrugi and soft snow, the LC–130 aircraft experienced difficulty in becoming airborne, but succeeded after climbing up a slope and taking off downhill. After a day at the South Pole Station, it arrived at McMurdo Station on January 20.

Animal Airlift, 1968

K. N. MOULTON

Office of Antarctic Programs
National Science Foundation

During the early morning hours of December 2, 1968, a C–141 Starlifter, presently the largest transport aircraft of the Military Airlift Command, lifted off from the sea-ice runway at McMurdo Station with a cargo of penguins, skuas, and seals destined for use in biological research and zoological exhibitions in the United States. The aircraft stopped briefly at Christchurch, New Zealand, and Honolulu, Hawaii, then proceeded to the continental United States where specimens were offloaded at San Diego International Airport; Grand Forks AFB, South Dakota; Scott AFB, Illinois; and Andrews AFB, Washington, D.C. The Starlifter arrived at Andrews Air Force Base at 2130 local time on December 2, just 36 hours after lifting off from McMurdo Station. The touchdown at Andrews brought to a successful conclusion the third animal airlift of the U.S. Antarctic Research Program during the past several years. The primary purpose of the airlift was to support physiological research of Weddell seals being conducted by Drs. Robert W. Elsner and Gerald L. Kooyman at Scripps Institution of Oceanography, and navigational studies on Adélie penguins being conducted by Dr. Richard L. Penney of the New York Zoological Society. To utilize fully the airlift capabilities of the C–141, the National Science Foundation agreed to fulfill several requests from zoological parks and arrange for the return of Adélie and emperor penguins as well as south polar skuas for the Detroit, Cincinnati, St. Louis, and Milwaukee Zoological Parks. Representatives of the zoological parks arrived in late November to assist in the collection of the animals and to accompany them on their return to the United States. Coordination of the field collecting and the selection of specimens was provided by Dr. Penney.

Drs. Elsner and Kooyman and their associates returned four Weddell seals and ten Adélie penguins to San Diego. Dr. Penney selected five skuas and ten Adélies for use in orientation experiments. In addition, he brought back eight skuas for Dr. William J. L. Sladen of Johns Hopkins University. The Detroit Zoo received 20 Adélie and 10 emperor penguins and 5 skuas. The Milwaukee Zoo received 6 emperors while the St. Louis Zoo obtained 8 skuas, 8 emperors and 8 Adélies. Eight Adélies, 4 emperors, and 4 skuas were delivered to the Cincinnati Zoo.

In transit to the United States, the passenger compartment of the Starlifter was kept at the lowest possible temperature and stops en route were kept to the absolute minimum time. Portable air-conditioning units were provided at Hawaii and San Diego airports to maintain a comfortable environment for the animals while on the ground. It reflects credit on the Military Airlift Command, the zoological park personnel who assisted in the handling of the animal cargo, and all others who contributed to the success of the animal airlift that all of the birds and seals were delivered without loss or injury. The most critical layover was at Scott AFB, where the C–141 was delayed 12 hours while awaiting favorable weather conditions at Andrews AFB.

In addition to the airlift effort, a great deal of careful field planning was necessary for the collection of the animals. The Adélie and emperor penguins were collected from colonies at Hallett Station about 395 mi. north of McMurdo Station. While the Adélie penguins were collected from the immediate vicinity of Hallett, the emperors were taken at Cape Roget, about 22 mi. north of Cape Hallett, in an area accessible only by helicopter. Two LH–34 helicopters of Antarctic Development Squadron Six flew from McMurdo to Hallett Station to help collect the emperors. From Hallett, the birds were returned to McMurdo Station aboard an LC–130 aircraft. While at McMurdo, the birds were held temporarily on the ice runway at Williams Field pending arrival of the C–141 Starlifter from New Zealand. At this time, the skuas were collected in the vicinity of McMurdo Station and these, too, were moved to the ice runway to await the arrival of the C–141. The most critical phase of the operation involved the collection of matched Adélies for Dr. Penney, which required a helicopter flight to Cape Crozier timed to allow their return to McMurdo prior to the scheduled departure of the animal airlift. Two attempts were made; the first aborted due to high winds, but on a second try the penguins were collected and flown to Williams Field.

The success of the lift was dependent on the cooperation and assistance of many individuals. The field collections were supported splendidly by the helicopter pilots of VXE–6 and both Navy and USARP ground-support personnel at McMurdo and Hallett Stations. The cooperation of the Military Airlift Command, particularly the crew of the C–141 Starlifter, and of ground personnel at the various stops, was a definite factor in the success of the animal airlift without loss of specimens. The support extended to Dr. Penney by the personnel at Grand Forks AFB was certainly a major contribution to the research objectives of the animal airlift.

Deep Freeze 69: An Overview

HENRY M. DATER

Chief, History and Research Division
U.S. Naval Support Force, Antarctica

In late March, the Navy concluded another season of support to United States scientific research in Antarctica. The successes of that season reflect the experience accumulated over the preceding 13 years—years characterized by continuous, productive efforts to improve techniques and equipment. Time has also seen an increased understanding by both navymen and scientists of one another's objectives and requirements, leading to closer, more effective cooperation.

Evidence of these developments has been visible in the general narrative of this year's logistic activities as presented in previous issues of the *Antarctic Journal*.[1] Further examples appear in the following pages, where certain important activities of *Deep Freeze 69* are discussed in greater detail by some of the men who engaged in them.

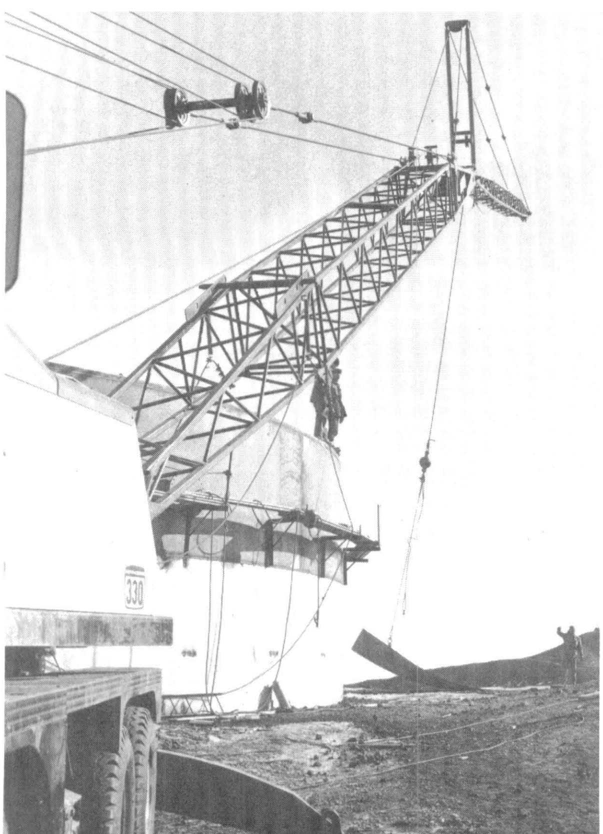
For instance, the trend toward improved facilities is clearly discernible in the season's construction program, which is described by Captain Philip Hall, USA. At the end of the International Geophysical Year of 1957–1958, when the United States decided to continue indefinitely its antarctic involvement, it became apparent that stations hastily built for a limited period of use would require considerable reconstruction and renovation to render them permanently habitable. As early as 1960, a base reconstruction plan was drawn up for McMurdo, and a start made to provide better living and working facilities. During the following years, the plan has been frequently amended and modified to take advantage of greater experience or to meet changing requirements. Captain Hall reviews the progress made this past season, including the noteworthy completion of the service portions of McMurdo Station's central personnel building, the berthing areas of which are to be completed next summer. He also indicates some of the other construction projects planned for the future, among them a replacement for South Pole Station.

In another article, Chief Edwin Groover, USN, deals with one of the installations that has been changing living conditions at McMurdo—the nuclear power plant, with its related water-distillation system.

[1] Vol. III, no. 6, p. 223; Vol. IV, no. 1, p. 12-14; no. 2, p. 47-51; no. 3, p. 79-83.

The availability of the reactor was slightly less than last year, but the total power production was actually greater, as was water production. While fresh water will probably never be abundant at McMurdo or anywhere else in the Antarctic, the station now has sufficient for its basic needs, and work is continuing on water-distribution and sewer systems. Again, the introduction of new techniques and facilities is yielding favorable results.

In his article, Captain Hall mentions a 1,250,000-gallon increase in fuel storage at McMurdo Station. Even without this new capacity, it was evident that the long effort to increase fuel storage was bringing significant results. In past years, if a tanker did not arrive by mid-December, it was frequently necessary to curtail flying. This season, heavy ice conditions caused an 11-day delay in the arrival of *Alatna* with the season's first load of fuels, but Antarctic Development Squadron Six (VXE–6) continued operations unabated. In fact, as Commander E. W. Van Reeth points out in his report, it was precisely in this mid-December period that the squadron carried out one of the busiest weeks in its history.



U.S. Navy Photo by H. C. Steiner

Seabees enlarging fuel tank at McMurdo. This project symbolizes the interrelationship of construction, logistics, and aviation.

Shortly thereafter, another notable event in the squadron's history occurred. On January 1, 1969, its name was changed from Air Development Squadron Six (VX–6) to Antarctic Development Squadron Six (VXE–6). While this redesignation reflected more exactly the squadron's function, it did not affect the experience and skill with which officers and men performed their duties. For the third successive year, the squadron had an accident-free record. An accident-free season was also posted by the U.S. Army Aviation Detachment (Antarctica Support), which provided field support for the Ellsworth Land Survey. At the end of the season, this Army unit was disbanded, and its helicopters were turned over to the Navy, thus bringing to an end a distinguished contribution to antarctic history. VXE–6 pilots will fly the machines in *Deep Freeze 70*.

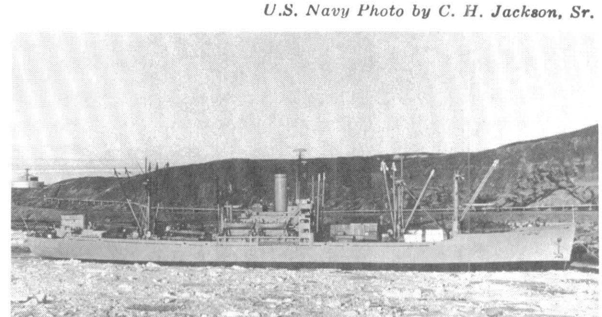
Although the heavy ice conditions in McMurdo Sound did not hamper VXE–6, they did affect ship operations. Not only were the arrivals of *Alatna* and the cargo ship *Pvt. John R. Towle* delayed, but both *Alatna* and the Coast Guard icebreaker *Southwind* suffered ice damage to their propellers. In neither case was the damage serious, but the time required for repair placed *Alatna* farther behind in her tight schedule, giving the latter part of the season the aspect of a cliff-hanger. For a time there was considerable concern as to whether *Alatna* could complete the necessary four trips to McMurdo before worsening weather brought the operating season to an end. As it turned out, the last delivery was not made until March 8, an unusually late date for resupply operations in the McMurdo Sound area.

USCGC *Glacier* (right) encountered heavy ice in both the Ross and Weddell Seas.

USNS *Pvt. John R. Towle* (below) in Winter Quarters Bay, which she reached in mid-January.

Navy Photo by H. C. Steiner

U.S. Navy Photo by C. H. Jackson, Sr.



The persistence of the ice in Winter Quarters Bay also impeded two efforts to further improve cargo operations. One was the installation of protective sheathing on Elliott Quay, the other a hydrographic survey of the harbor to determine whether it can accommodate a large T5 tanker next season. Neither of the efforts was wholly thwarted. By working into late summer, the Seabees completed almost half of the Elliott Quay project, and the soundings obtained indicate water depths are adequate to permit introducing T5 tankers into antarctic service.

The ice conditions did greater damage to the International Weddell Sea Oceanographic Expedition. It had been planned that *Glacier*, after briefly assisting in breaking the channel in McMurdo Sound, was to sail for Valparaíso, Chile, and from there to the Weddell Sea, arriving in the first week of January. As it happened, she could not leave the Ross Sea until January 18, and only reached the Weddell Sea a month later, forcing a drastic reduction of the scientific program. Further setbacks were suffered when *Glacier* found that the Weddell Sea was also heavily iced. In fact, it proved impossible to penetrate far enough into the ice pack to recover three current-meter buoys set out the previous year. Considering the lack of time, the scientists aboard *Glacier* did, however, carry out a substantial amount of oceanographic work.

Heavy ice conditions appear to have occurred in many parts of the Antarctic last season. In mid-February, the U.S. icebreaker *Southwind* went to the assistance of the Australian expedition ship, *Thala Dan*, which had aboard 33 men to occupy Casey Station, the Australians' recently completed replacement for Wilkes Station. Included in the group was a 4-man satellite-geodesy team from the U.S. Army Topographic Command.

Various forms of assistance were also exchanged with the expeditions of other nations: in a record-setting mission that Comdr. Van Reeth describes in his article, British and Norwegian scientific parties were placed in the field by VXE-6 aircraft; a Japanese traverse party from Showa Station received fuel during brief periods of rest at Plateau and South Pole Stations; and the Soviet Union's Vostok Station hosted a party that had flown from McMurdo Station in connection with United States scientific equipment operated at Vostok by the Russians. As has been a long-standing custom, United States and New Zealand personnel worked closely together in both support and scientific activities.

It is, of course, too soon to view *Deep Freeze 69* in full historical perspective, but it is permissible to discern two themes that relate it to the past and the future—enlightened international cooperation and increasing technological competence.

Construction Report, *Deep Freeze 69*

PHILIP L. HALL

Captain, USA
U.S. Naval Support Force, Antarctica

A considerable amount of construction was accomplished during the past summer at the U.S. stations in Antarctica, particularly at McMurdo Station, which is undergoing thorough redevelopment. Under the general supervision of the U. S. Naval Support Force, Antarctica, some 30 projects were accomplished or initiated by Naval Construction Battalion Unit 201 (NCBU–201), whose 6 officers and 252 men were augmented by 1 officer and 25 men of the U.S. Air Force.[1]

It was the third consecutive season of antarctic construction for NCBU–201, and the second in which the Air Force provided a "Prime Beef" team.[2] Deployment to McMurdo began with a 22-man advance party that arrived at McMurdo on October 9. The main group, including the Air Force personnel, arrived a week later, and the McMurdo deployment was nearly complete by the end of the month, when work had begun on a variety of construction projects.

McMurdo Construction

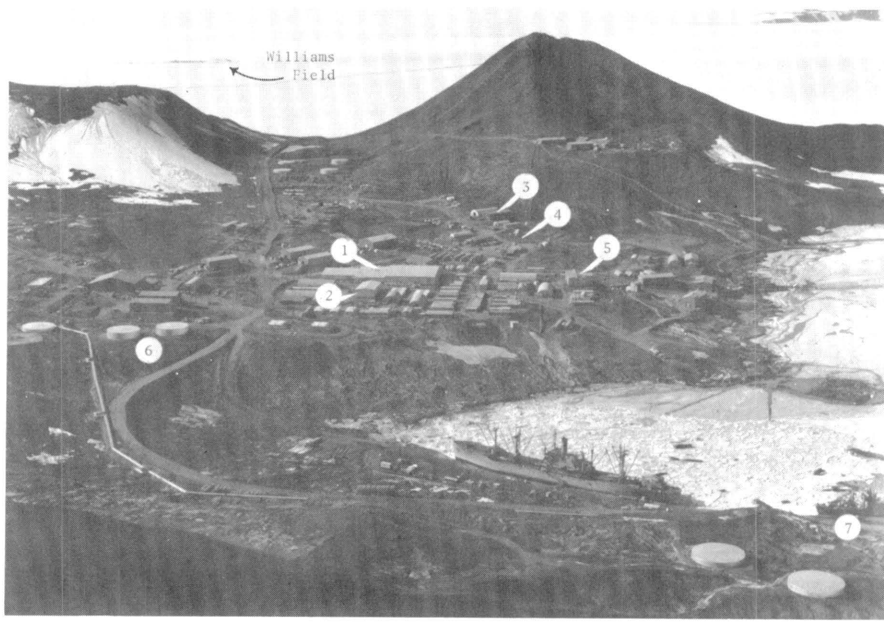
The central and most complex project was the completion of the galley, laundry, and mechanical room that comprise the personnel building's subsistence area. These facilities are equipped with the latest in modern labor-saving appliances and systems, the installation of which required the Seabees to use highly sophisticated construction techniques. The galley, whose dual serving lines can accommodate 1,000 men, received its acceptance inspection on January 22 and served its first meal on the evening of January 30. The mechanical room—site of the building's boilers, water tanks, electrical controls, and other service equipment—also passed an acceptance inspection, while the laundry was accepted by Antarctic Support Activities on February 20. The berthing portion of the personnel building, now partially complete, will be finished next season.

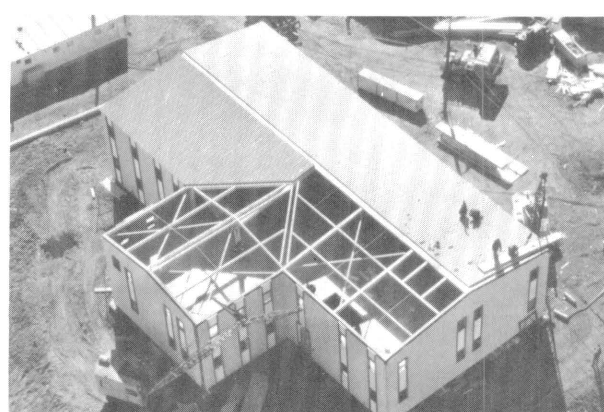
[1] While all of the Air Force personnel were at McMurdo, 32 Seabees (including one officer) deployed separately to Palmer Station, departing Quonset Point Naval Air Station in early December.

[2] The designation is based on an acronym for Base Engineer Emergency Force. Each team is comprised of personnel in various construction skills who assemble from different bases in response to unusual or unexpected needs at other locations.

Among the major McMurdo construction projects shown in these mid-season photos are personnel building (1), in which the galley (above left) and other areas were completed; the frozen foods storage building (2); the USARP field-party processing center (3 and above right); the USARP quarters building (site 4 and below left); and the administration-operations building (5 and below right). Also shown are two of the fuel tanks that were enlarged during the season (6) and the site of the Elliott Quay protection project (7).

(U.S. Navy Photos)



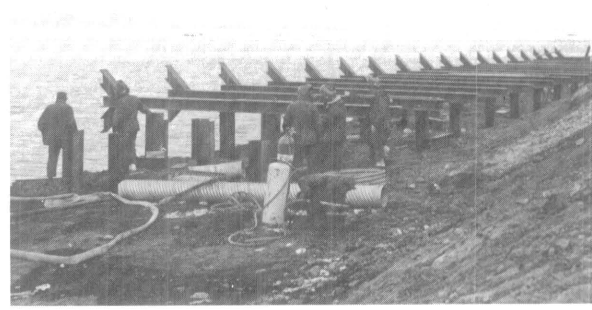


Work done on McMurdo's primary water-distribution and sewage systems will make life easier for this winter's residents. The freshwater system's trunk line, and the secondary lines to the personnel building, the dispensary, and several other buildings were reworked with new heat tape and insulation, restoring them to operation after two years of difficulties. (Secondary connection to the rest of the permanent facilities requiring water and sewer service will be installed next summer.) The water lines were also equipped with an alarm system that monitors the temperature at 100-ft. intervals. If the pipe temperature drops below 40°F., the sensor activates an alarm on the master control panel in the diesel generator plant, which is continually attended. The man on watch can then check the line or, if he considers it necessary, empty the pipe by operating four remotely controlled dump valves that are positioned at intervals in the line.

Much of last season's construction effort was devoted to the erection of new buildings. A new frozen foods warehouse was started and completed during the season, undergoing its final acceptance inspection in early February. The shells of the administration-operations building and the scientists' quarters were erected, with completion scheduled for *Deep Freeze 70*. The USARP field-party and equipment center, begun during *Deep Freeze 68*, was completed on December 8, permitting its use for much of the summer season. The new VXE–6 shops and offices building, also begun the previous season, is now nearly complete, and should be ready for occupancy early in *Deep Freeze 70*.

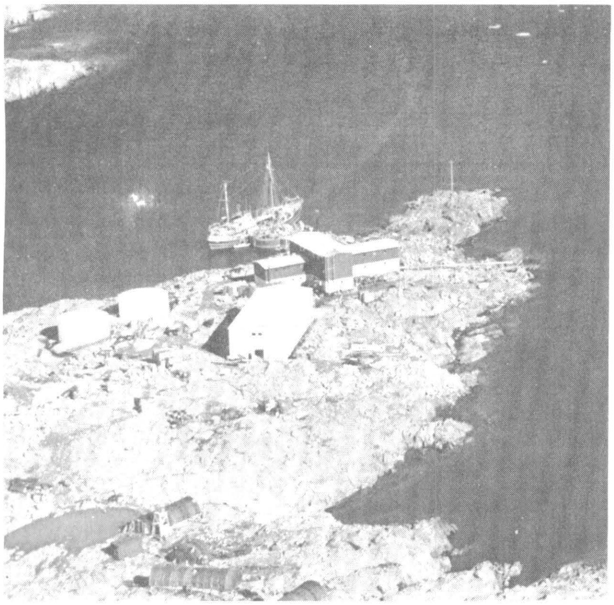
Another major project involved further modifications to McMurdo's fuel storage and piping system. Storage capacity was increased by 1.25 million gallons (to 6.1 million) by the addition of 8-foot high rings to five of the existing tanks. Tanker unloading will be much easier in the future due to the installation last season of a new four-product terminal facility on Elliott Quay; this will permit simultaneous pumping of jet fuel, diesel fuel, aviation gasoline, and automotive gasoline. Additional modifications to the fuel-handling facilities included installation of a fire protection system in the Hut Point pump house and the extension of low-point drains for five tanks. Data for the preparation of calibration tables were collected for 12 tanks.

A major late-season undertaking was the installation of 120 feet of protective facing on Elliott Quay, the ice ledge in Winter Quarters Bay that is used for ship unloading. This ice wharf has suffered progressive deterioration, and the breaking off each season of undercut portions of the ice quay has reduced its usable area. This prompted the design of a cantilevered wood-and-steel facing to protect the ice ledge from damage by wave action, ship offloading, and the



U.S. Navy Photos

Severe undercutting of ice foot (top photo) prompted installation of cantilevers (center photo) that support a protective sheathing for Elliott Quay.



U.S. Navy Photo by W. R. Curtsinger

Palmer Station.

discharge of warm effluent from ships moored to the quay. Plans to install 300 feet of the protective facing—deferred in *Deep Freeze 68* because of the late arrival of materials—were set back again this past season by the extremely late breakout of the ice in Winter Quarters Bay. Consequently, only 120 feet of it was completed, even though a small group of Seabees stayed on the job into March. Plans are to continue this project in future years until a total of 900 feet of protective facing has been installed.

Other McMurdo projects during the *Deep Freeze 69* season included some modifications to the electrical system, further enlargement of the helicopter pad, and the construction of foundation pads for the USARP administration building, the USARP garage and storage building, a flammable-stores warehouse, the communications transmitter building, a warehouse, and two fuel-storage tanks (one to be of 2-million-gallon capacity, the other of 500,000-gallon).

In retrospect, it can be said that very good progress was made last season toward the overall redevelopment of McMurdo Station.

Key Construction Personnel

Task Force 43 Assistant Chief of Staff for Civil Engineering—Cmdr. Archer E. Church, Jr., CEC, USN.

Officer-in-Charge, NCBU-201—Lt. James R. Finn, CEC, USN, to January 16, 1969; thereafter, Lt. John E. Perry, Jr., CEC, USN.

Officer-in-Charge, Prime Beef Team—Capt. Norman S. Peterson, USAF.

Officer-in-Charge, NCBU-201 Platoon Alpha—Lt. Harry G. Anderson, CEC, USN.

Other Station Construction

Construction at Byrd Station included the completion of a project to equip all escape hatch ladders with safety cages (lattice enclosures to prevent serious falls), completion of the vehicle exhaust system, and modification of the generator building's exhaust system. The most noteworthy project was the completion of a cold air plenum, the primary purpose of which is to eliminate excessively high temperatures in tunnel L-7, which contains the generator building and galley. By drawing cold air from the undersnow plenum chamber and ducting it to exhaust over the main heat-emitting buildings, heat-induced tunnel deformation should be reduced considerably.

Work at Pole Station was limited to two projects, a complete rehabilitation of the generator building, and the raising of the GMD tracking instrument radome—which had become drifted in—to 6 feet above the current snow surface.

At Palmer Station, the major projects were construction of the station's second building—a combination warehouse/garage/recreation facility—and finishing the interior of the main station building. The latter project was completed except for some minor work requiring additional material. The shell of the multipurpose building was erected and some interior work was done, with the remainder to be completed next summer. Other work at Palmer Station included construction of a 40 by 40-foot helicopter landing pad made of metal decking panels, some road construction, and the building of a small-boat landing ramp.

Future Construction

The ambitious construction program planned for *Deep Freeze 70* continues the emphasis on McMurdo reconstruction. As has been mentioned above, several major facilities will be completed during the forthcoming season, and much new construction will be undertaken at McMurdo, including a new administration building for USARP, two fuel-storage tanks with a combined capacity of 2.5 million gallons, and an unheated warehouse. In addition, a 180-man mobile quarters complex is to be built at Williams Field.[3]

Further in the future is the construction of a new South Pole Station, a design for which is currently being prepared by the Naval Facilities Engineering Command. Construction is expected to begin in *Deep Freeze 72*, the 1971–1972 season.

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[3] This work is to be done by the Public Works Department of Antarctic Support Activities as part of the Williams Field redevelopment plan described in *Antarctic Journal,* vol. IV, no. 3, p. 77-79. Specifications call for six 30-man units, but exact occupancy figures cannot be cited until contract negotiations are completed.

U.S. Navy Photo by C. H. Jackson, Sr.

LC-130F flying by McMurdo Station. The Hercules continues to be the mainstay of inland logistics.

Deep Freeze 69 Air Operations

E. W. VAN REETH

Commander, U.S. Navy
Commanding Officer
Antarctic Development Squadron Six

At 2020 hours on March 8, 1969, the last ski-equipped LC–130F Hercules departed Williams Field for Christchurch, N.Z., thus ending antarctic air operations for *Deep Freeze 69,* the fourteenth consecutive season in which Antarctic Development Squadron Six (formerly Air Development Squadron Six) has contributed its many skills to the exploration and scientific investigation of the Antarctic. Through diligence and good fortune, it was also the third consecutive season in which the squadron's operations were unmarred by accidents.

An Early Start

This past season, air operations on the Continent began with a September 3 flight to Williams Field by two LC–130Fs. The main purpose of this early fly-in was to transport 13 scientists and 7 helicopter crewmen to McMurdo Station so that late-winter field studies could begin, with local helicopter support, as soon as conditions permitted.[1] Removed from winter storage at McMurdo, the LH–34 helicopters soon were restored to flying status, and the first was test flown in the early hours of September 8. Scientific support flights commenced the next day, when a party from New Zealand's Department of Scientific and Industrial Research was flown to a field site.

As in the preceding season, plans called for a gradual reactivation of facilities on the Continent leading toward full-scale operations in mid-October. Accordingly, two Hercules aircraft landed on Williams Field's skiway on October 7 to commence the season officially. Aboard these aircraft were Rear Admiral J. Lloyd Abbot, Jr., the commander of the U.S. Naval Support Force, Antarctica, and the commanding officers of the various units which would be spending the next five to six months on "the Ice." On October 9, the first C–121 Constellation flight from Christchurch landed on the annual ice runway. Throughout the following week, a series of turnaround flights by LC–130 and C–121 aircraft delivered a steady flow of personnel, equipment, and supplies to the Continent. These welcome flights also returned to New Zealand the majority of McMurdo Station's winter-over party, which had been isolated since February of 1968. On October 15, the squadron's remaining two LC–130Fs arrived at Williams Field to stay, and by October 18, the squadron's deployment was complete, all personnel being in position either at McMurdo Station or with the squadron's heavy-maintenance detachment at Christchurch.

Flights to the Stations

With all four "Hercs" at McMurdo, operations began in earnest. The season's first extended Hercules flight over the Continent was made to reopen Brockton Station on October 10. A few hours later (at 3 minutes past midnight on the 11th), another LC–130 touched down on a finger of snow alongside Cape Hallett, to reactivate the station there, an act that bad weather had delayed for two days. Similarly, repeated attempts to reach Byrd Station were frustrated by extremely adverse weather. Byrd finally received its first flight on October 18, three days later than planned.

The remaining fly-ins were less difficult. The initial flight to Amundsen-Scott South Pole Station was made on November 1, as scheduled, and Plateau Station was reached on November 15 without problems. With all of the permanent outlying stations activated, the resupply of these distant outposts became an almost daily operation for the remainder of the season (see table), although flights to Hallett Station were ended as of November 29 due to the annual deterioration of the sea ice in Moubray Bay.

Field Party Support

The placement of parties in the field and their subsequent resupply were once again major missions of VXE–6. In addition to the numerous field parties placed and supported by helicopter in the McMurdo vicinity, a number of distant investigative groups were

[1] *Antarctic Journal,* vol. III, no. 6, p. 225.

delivered, logistically supported, and retrieved by LC–130. Notable among the latter was the Ellsworth Land Survey, a multidisciplinary effort that occupied two camps in the Eights Coast-Thurston Island area. Scouting the area from a VXE–6 Hercules, representatives of the U.S. Antarctic Research Program and the supporting Army Aviation Detachment chose a site for camp 1 on October 21, but weather and communication difficulties delayed establishment of the camp on the King Peninsula until the 28th. The Army unit, under Major Ben Luck, took delivery of its first helicopter at the site on November 7. Additional frustrating delays were caused by the extremely poor weather, historically prevalent in the area, but all aircraft, researchers, and support personnel were in place by November 14.

With the completion of the scheduled projects at camp 1, the survey group moved to camp 2, which had been previously constructed in the Jones Mountains (near the site of former Camp Minnesota) by a construction crew flown out from McMurdo Station on December 19. Bad weather intervened again, and the construction crew was marooned for several days while storms and zero-zero visibility conditions prevented the move from camp 1.

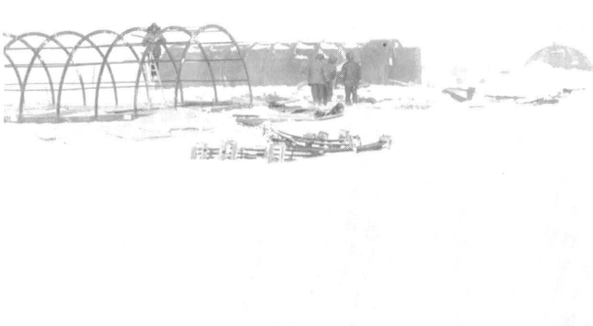
Although conditions permitted the U.S. Army Aviation Detachment (Antarctica Support) to fly during only 26 of the 74 available days at the two camps, it nevertheless conducted 168 flights totalling 314.5 flying hours. In doing so, it completed its second accident-free year in succession. The main users of the helicopters were topographers of the U.S. Geological Survey, biologists of the Ohio State University, and geologists from Texas Technological College and the University of Wisconsin.

Another major field-party support mission by VXE–6 was the transcontinental flight that placed British and Norwegian field parties in the Shackleton Range and the Kraul Mountains, respectively. After a wait of one week for the right combination of favorable weather forecasts over the entire proposed track, the flight departed McMurdo Station on November 22 (in local time, just after midnight on the morning of the 23rd). Refueling at South Pole Station, the Hercules continued onward to the Kraul Mountains (73°10′S. 14°10′W.) to deliver a Norwegian party led by Thore Winsnes to a site over 1,725 nautical miles (1,980 statute miles) from McMurdo—the most distant camp placement yet accomplished.

The aircraft then proceeded about 280 nautical miles southwest to Halley Bay, where it refueled and took aboard an 8-man British group headed by Kenneth Blaiklock. This party, with its 3 sledges, 27 dogs, and other field equipment, was flown to the Shackleton Range. (The ferrying of 27 sledge dogs in an LC–130F is a tale in itself. Suffice it to say that the flight crew earned its pay that day!) The aircraft then flew to the South Pole for a third refueling before returning to McMurdo Station. The entire flight took over 22 hours and covered 3,557 nautical (4,100 statute) miles, and it has been described as a "bold feat" that "strengthened international cooperation in antarctic science." Both field parties were retrieved on schedule in late January.

Helicopter Support Around McMurdo

Helicopter support—always a major contribution of the squadron—was indeed heavy during *Deep Freeze 69*. Twenty-five scientific projects were assisted with 376 flights, and numerous requirements for photographic support, ice reconnaissance, search and rescue, and other purposes were fulfilled. Truly the workhorses of the McMurdo area, the LH–34D aircraft made 531 flights for a total of 1,155 hours, or almost 20 percent more than the 975 hours originally programmed for the season. Included in these figures is a November flight by two helicopters from McMurdo Station to Cape Hallett for the purpose of



U.S. Navy Photo by B. F. Moore

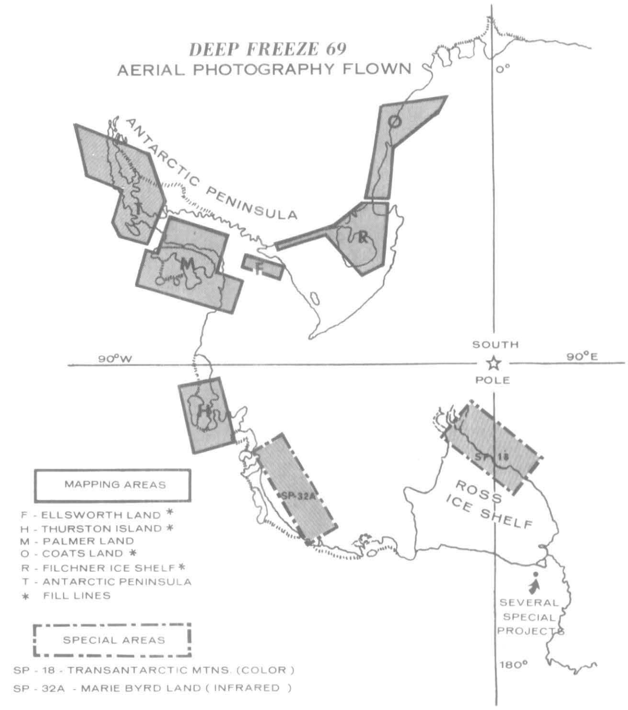
Building the first camp in Ellsworth Land. Survey party was supported by VXE-6 and Army helicopter unit.

U.S. Navy Photo by J. H. Jenkins

U.S. Navy LH-34 helicopters aided New Zealanders in setting up Vanda Station in the dry-valley area.

collecting emperor penguins from the Cape Roget rookery, 25 miles north of Hallett.[2] During the three-day mission, the helicopter crews assisted the scientists in the penguin roundup.

Helicopter operations were not without their anxious moments. On October 27 (the 28th, in local time), an LH–34 returning to McMurdo Station from Cape Crozier encountered high winds and lowering visibility. When it became apparent that the aircraft would be unable to reach McMurdo, the pilot, Lt. Elliott Freeman, landed in near-whiteout conditions on Windless Bight, about 9 miles from Williams Field. As the weather rapidly grew worse and the winds became stronger, survival gear was broken out and tents erected. The crew was able to maintain communications with the Air Traffic Control Center at McMurdo and kept the authorities advised of their situation, but it was not until early the following morning (local time) that the weather permitted a rescue helicopter to reach the stranded crew and aircraft. After preheating their now frozen engine, Lt. Freeman and his companions—Lt. (jg.) Ray LaRochelle and Petty Officer First Class Billy Burkhart—proceeded to McMurdo without further incident.



Aerial Photography

Although the aerial photography program for *Deep Freeze 69* seemingly was not as ambitious as in former years, the major areas chosen for coverage—Graham Land, Palmer Land, and Ellsworth Land—are notorious for extremely poor weather. In these areas, there are comparatively few days of each year that are relatively clear, and fewer yet that are clear enough for precise cartographic photography. To photograph these areas, LC–130F 148320—*Ciudad de Punta Arenas*—operated from Byrd Station and Punta Arenas, Chile. Weather information obtained by satellite and relayed to the staging bases was of great assistance to the meteorologist forecasting photo-area weather, undoubtedly contributing to mission accomplishments; nevertheless, many flights had to be either aborted or but partially flown once the operating area was reached. Despite the severe weather handicaps, approximately 40 percent of the Graham-Palmer-Ellsworth Lands program was completed.

The fill lines[3] scheduled in three areas—Thurston Island, the Filchner Ice Shelf, and Coats Land—were completed except for a small portion of the Filchner photography. Additionally, a number of special aerial photographic requirements, including color and infrared work, were met and sometimes exceeded in the McMurdo area and elsewhere, using both the specially configured LC–130 and C–121 aircraft.

Transoceanic Operations

During the course of the season, VXE–6 aircraft moved more than 3,000 passengers between New Zealand and Antarctica, 80 percent of them travelling on the squadron's two C–121s. The squadron also transported nearly 450 tons of cargo over the transoceanic route, three-quarters of that amount being carried south.

Also operating on the New Zealand-to-McMurdo route for short periods were U.S. Air Force C–141s and C–130H Hercules of the Royal New Zealand Air Force. These wheel-equipped aircraft brought much additional cargo to Williams Field, as well as some passengers. Under the name *Operation Ice Cube*, two RNZAF Hercules made three flights to Williams Field, the first arriving there on October 22, and the last departing on the 24th. The C–141 Starlifters made eight turnaround flights during a 12-day period starting on October 2, each flight bringing about

[2] As reported in *Antarctic Journal*, vol. III, no. 2, p. 52, this 395-mile flight was at the time believed to be the longest nonstop helicopter flight made in the Antarctic. It may be, but it was not the first time that a helicopter was flown from McMurdo to the Cape Hallett area. In October 1958, an Air Force C-124 crashed in the vicinity of Cape Roget, killing 6 and seriously injuring 3 of the 13 crewmen. When surface rescue teams found it impossible to reach the survivors, Admiral Dufek had an HUS helicopter flown from McMurdo, accompanied by a U-1B Otter. While not conclusive, records indicate that the 1958 flight may also have been nonstop.

[3] Flight lines not completed in previous years.

40,000 pounds of cargo to the Continent. Two other C–141 flights were made, one on November 20 to transport a VIP visitor party, and another on December 1 to airlift a collection of seals, penguins, and skuas to the continental United States.

Other Highlights

A highlight of the season was the arrival in December of the squadron's new LC–130R Hercules. An improved version of the LC–130F, this new ski-equipped transport possesses advanced communications and navigation equipment and is capable of carrying up to three times the payload of its predecessor "F" model, four of which have been with the squadron since 1960. The new aircraft, which has been named *Aotearoa* (the Maori name for New Zealand—"Land of the Long White Cloud"), is a welcome addition to the squadron's operational capability.

December also included a period of record activity by the squadron—between December 15 and 22, 574 flight hours were logged, while 1,214,000 pounds of cargo and petroleum products were delivered to outlying stations. During the same period, 286 passengers were manifested on VXE–6 flights, and the squadron's pararescue team amassed 40 practice parachute jumps.

Conclusion

That the Antarctic Air Group completed a highly successful, accident-free season, during which planned objectives were generally met or exceeded, is a tribute to the dedication and skill of the flight and maintenance crews, but it is also a reflection of the cooperation that exists between the interdependent organizations and individuals comprising the antarctic program. Particularly notable is the close relationship between the personnel of the National Science Foundation and of the aviation elements. The aviation effort also owes much to the wholehearted support of the meteorologists, communicators, air traffic controllers, airfield maintenancemen, and other specialists of Antarctic Support Activities. Perhaps nowhere more than in the Antarctic is the interdependence of units and individuals so vividly demonstrated.

Intra-Antarctic Cargo and Passenger Statistics

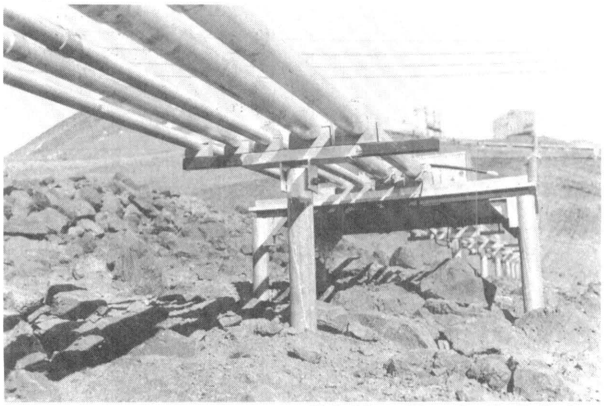
Station or Camp	Number of flights	Tonnage delivered[1]	Tonnage backhauled[1]	Passengers transported
Amundsen-Scott South Pole	128	1,153	170	992
Brockton	12	50	21	58
Byrd	190	1,762	151	854
Hallett	17	93	56	184
Plateau	11	22	49	66
Ellsworth Land Camps	42[2]	186	39	150
Other[3]	20	48	30	144
Totals	420	3,314	516	2,448

[1] Includes passenger weights.
[2] Includes aborted flights.
[3] Byrd Substation, Vostok, and miscellaneous field party sites.

Nuclear Power Operations, *Deep Freeze 68–69*

EDWIN D. GROOVER

Chief Equipment Operator, USN
Naval Nuclear Power Unit
Fort Belvoir, Virginia



U.S. Navy Photo by H. C. Steiner

Fig. 1. In the near future, the electrical power produced by the PM-3A (background) will be conveyed to the main station in these newly installed conduits, which will replace overhead transmission lines.

Operation of the PM–3A nuclear power plant during crew VII's *Deep Freeze 68* tenure was notably successful. Although plant availability was slightly less in calendar year 1968 than in the previous year, a greater quantity of electrical energy was produced. Fresh-water production also increased significantly. Major projects accomplished during the *Deep Freeze 69* summer included the installation of a resistor in the neutral bus of the PM–3A's main generator, relocation of the high-pressure demineralizer to a position outside the containment system, and replacement of the pressurizer relief valves.

Electrical and Water Production Data

The nuclear power plant's availability to meet McMurdo Station's electrical power requirements for calendar year 1968 was 85.05 percent, down 1.19 percent from the previous year. It should be noted, however, that both total electrical production and the amount of exported electrical energy increased, to 10^7 kilowatt-hours and 7.86×10^6 kwh respectively.[1] The plant's availability and electrical energy production are summarized in Table 1, which includes figures for the diesel-fuel equivalent of the nuclear energy production.

[1] Exported energy equals total production minus that energy consumed by the power plant itself.

Table 1. Summary of Electrical Energy Production

Calendar year	Availability[1]	Kilowatt-hours produced		Diesel-fuel equivalent of net production (gallons)[3]
		Gross[2]	Net	
1968	85.05%	10,000,000	7,680,000	569,733
1967	86.24%	9,550,000	7,400,000	548,961
1966	77.42%	8,690,000	6,780,000	502,967
1965	60.87%	6,916,000	5,240,000	388,724[5]
1964	35.89%	3,240,000	2,410,000	178,783
1963	42.20%	4,123,000	3,267,600	242,404[5]
1962	29.03%	2,336,000	1,803,010[4]	133,757[5]
Totals		44,855,000	34,580,640	2,565,329

[1] Authorized and capable of, or actually, exporting power to station.
[2] Taken from PM-3A weekly operating reports.
[3] Computed with a conversion factor (13.48 kwh/gallon of DFA) derived from actual White diesel operation in 1967.
[4] Estimate of exported electricity.
[5] Supersedes previously reported data.

With the installation last year of the second water-distillation unit[2], water production became more than sufficient to meet the needs of McMurdo Station and the PM–3A. This method of producing fresh water has completely supplanted the earlier methods of melting snow and collecting lake water. Water production in 1967 and 1968 is shown in Table 2 according to energy source. The relatively large amount of water produced by diesel fuel in 1968 (over 1.34 million gallons, or 38.25 percent of the year's total) results from the fact that McMurdo Station's electrical demand is beginning to approach the maximum energy capacity of the PM–3A. Therefore, on those occasions when the gross electrical requirement approaches 1,800 kw, it is more economical to power the water-distillation units with diesel fuel and keep the full electrical load on the PM–3A than to split the electrical distribution system and place part of the load on the White diesel-electric plant.

Table 2. Water Production and Fuel Equivalency (Gallons)

	1967	1968
By nuclear energy	1,943,432	2,167,768
By diesel fuel	516,349	1,343,123
Total	2,459,781	3,510,891
Diesel-fuel equivalent of nuclear power*	56,693	63,237

*Computed with a conversion factor (34.28 gals water per gal DFA) derived from Cleaver-Brooks usage of 17.5 gals/hr of DFA and the distillation units' normal water output of 600 gals/hr/unit.

To further secure economical operation in winter, when McMurdo's population is at its smallest, the evaporators were operated at a higher output level than consumption required, with the excess being accumulated in the 55,000-gallon freshwater storage tank. This permitted periodic 6-day shutdowns of the water-distillation plant. Thus, the inefficiency of low-rate production was avoided.

Winter Operations, *Deep Freeze 68*

With the advent of winter, Crew VII settled down to routine operations, but, like all previous crews, it was plagued with several unscheduled shutdowns of the reactor. The most significant of these occurred on Friday, September 13, 1968, when the power cable for the reactor-coolant pump failed at the point where it enters the containment vessel. Lacking a replacement penetration assembly, Crew VII had to fabricate, test, and install one by the most expedient means consistent with safety considerations. This was speedily done, and the power plant was back on the line by September 24.

In addition to its direct operational tasks, Crew VII conducted a winter-long training program. This resulted in the certification during Crew VII's tenure of 12 men as watch supervisors, 5 as equipment operators, and 3 as control-room operators. The training effort laid a sound basis for the annual crew change in the early part of *Deep Freeze 69*.

Crew Relief

Crew VIII arrived at McMurdo Station in October 1968 to begin an intensive in-plant training schedule designed to complete its preparation for assuming the responsibility of safely and efficiently operating the nuclear power plant during its 1968-1969 tenure. The members of Crew VIII performed commendably before the qualifying board, which subjected them to intensive oral examination prior to certifying individuals for positions as operators or maintenance technicians. On November 5, 1968 (the 6th, local time), Lt. James P. Kurtz, CEC, USN, relieved Lt. Comdr. Arthur D. Kohler, Jr., CEC, USN, as officer-in-charge, and the PM-3A became the responsibility of Crew VIII.

[2] *Antarctic Journal,* vol. III, no. 4, p. 147.

Summer Maintenance and Modifications

Annual maintenance on the many and varied systems was accomplished with dispatch, along with some modification projects. Significant modifications effected during the *Deep Freeze 69* summer season included the following:

1. Installation of a resistor in the neutral bus of the PM–3A's main generator to limit electrical failures due to the grounding of one phase of the three-phase electrical system. This is one of the steps necessary to allow extended parallel operations with the White diesel-electric generating plant in the future.
2. Relocation of the high-pressure demineralizer to a position outside the containment vessel enclosing the primary system. This modification will permit routine recharging of the demineralizer resins (which purify the coolant water) with no interruption of reactor operation.
3. Replacement of relief valves in the primary system's pressurizer. The former poppet-type valves were replaced with pilot-type valves in order to reduce pressure leakage to a negligible level while hopefully gaining other advantages.

The latter two modifications both required rerouting of high-pressure piping. Consequently, certain ones of Crew VIII's mechanical technicians were given predeployment training in the art of welding on high-pressure systems. The welding procedures for which these personnel were certified were based on the standards of the Naval Ship Systems Command and the Army Nuclear Power Program, and had the approval of the Naval Facilities Engineering Command.

Plans for Plant Modifications

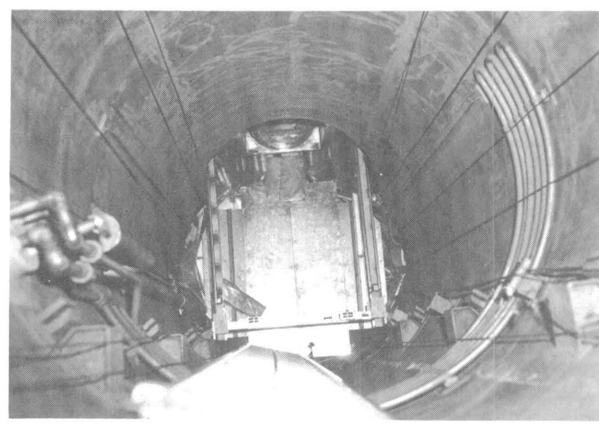
The only major PM–3A modification presently being planned is a two-part project to permit the future use of a new kind of core. The Type IV core, which contains lower enrichment UO_2 rather than the fully enriched cermet fuel in previous cores, is expected to increase the period between refuelings from slightly under 3 to almost 5 operational years. Although of the same overall size as the present Type II core, the Type IV is considerably heavier—3,250 pounds, as compared with 1,685[3].

To accommodate the increased weight, it will be necessary to structurally strengthen the fuel transfer dolly (Fig. 2) that is used to convey a depleted core from the reactor tank to an adjacent storage tank. The spent-core rack in the storage tank also must be strengthened. Accomplishment of this modification is planned for the *Deep Freeze 70* summer season.

[3] The corresponding weights for uranium content are 597 kg and 33 kg, respectively. The Type IV core is of the pellet-in-tube type.

Fig. 2. This remotely operated dolly is employed to transfer a used core from the reactor tank to the spent-fuel tank (photo below). Visible in the lower photo are the dolly operating cables (lower left and right) and a portion of the inter-tank tunnel in which the dolly is positioned when not in use. (Normally, the spent-fuel tank is filled with water to a level just above the heating coils; these photos were taken during refueling operations.)

U.S. Navy Photos



VXE–6 Achieves Safety Mark

Antarctic Development Squadron Six recently completed 30,000 consecutive flight hours without an accident. That mark was passed on May 14, 1969, while Comdr. Eugene W. Van Reeth, the squadron's commanding officer, was at the controls of one of the unit's five LC–130 Hercules aircraft. The 30,000-hour figure, which includes both transport-plane and helicopter time, is the equivalent of one aircraft flying 24 hours a day for nearly 3-1/2 years.

Particular pride is taken in the achievement because it includes many hours of operation under conditions not faced by many other aviation organizations, as Comdr. Van Reeth pointed out at the ceremony marking the achievement.

Drilling in Snow, Ice, and Frozen Ground in Antarctica

R. A. PAIGE

Polar Division
Naval Civil Engineering Laboratory
Port Hueneme, California

Both construction operations and subsurface exploration in Antarctica often require rapid and efficient drilling in snow, ice, and frozen ground. In construction, drilling is needed for wells and for emplacing antenna guy-wire anchors, utility poles, pile foundations, and bollards for ship docking. Exploratory drilling is needed to determine the composition, density, temperature, and other subsurface physical properties of various terrains.

The lack of suitable drilling equipment and techniques has hampered construction activities and exploratory drilling at McMurdo Station and, to a lesser extent, at inland stations. To remedy this, the Naval Civil Engineering Laboratory (NCEL) set out to select and evaluate drilling equipment for antarctic use and to develop efficient techniques for drilling in snow, ice, and frozen ground. Between 1966 and 1968, field tests were conducted by NCEL personnel in the McMurdo Station area (Fig. 1), where an active construction program provided the opportunity to test the equipment under actual operating conditions. The varied terrain there also permitted testing techniques appropriate to frozen ground, volcanic rock, sea ice, fast ice with inclusions of sand and rock, glacier ice, and deep snow.

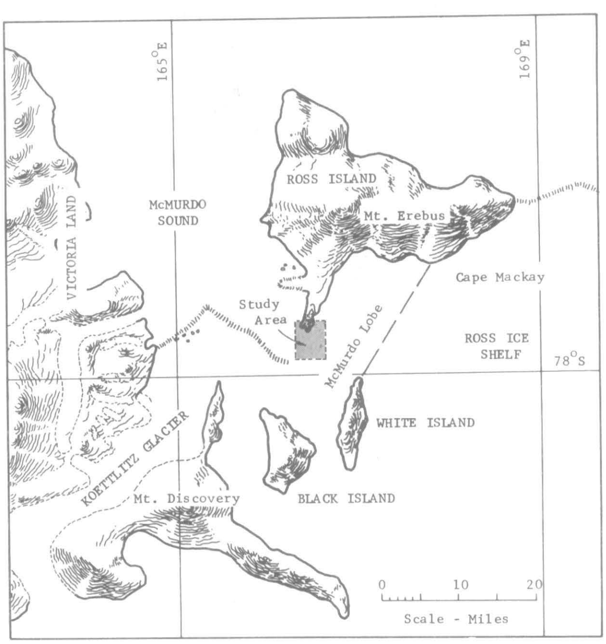


Fig. 1. Map of the McMurdo Sound region showing study area (center).

Experimental construction drilling was performed in frozen ground at McMurdo Station, and in snow and ice at Williams Field and Outer Williams Field. Most of the exploratory drilling was done on the Ross Ice Shelf, but some additional work was conducted in fast ice and ice-rock conglomerate at Elliott Quay in Winter Quarters Bay. Two basic drilling methods were employed: (1) dry drilling, which uses compressed air or mechanical lift to remove the cuttings, and (2) wet drilling, in which a liquid is used for that purpose.

This paper describes the equipment used in these investigations and discusses some of the methods developed for drilling in snow, ice, and frozen ground.

Drilling Equipment and Accessories

Most of the experimental drilling described in this paper was accomplished with commercially available equipment and accessories, although a few accessories were fabricated in the field to improve certain techniques.

Mobile Rotary Drilling Unit. A commercial rotary drilling unit (Fig. 2) was used in developing construction drilling techniques for snow, ice, and frozen ground. This hydraulically powered unit consists of a drivehead (inset, Fig.2), a folding 12-foot tower (that can be tilted from vertical to horizontal for transportation or for angle-drilling), a gasoline engine, and a control panel mounted on a hydraulically powered slide base having 18 inches of movement. The entire unit can be controlled by a single operator. For maximum mobility at McMurdo, the unit was mounted on a 5-ton, 4-wheel trailer fitted with high-flotation tires.

Drill Bits and Augers. Both commercially available and custom-fabricated augers and bits were used during the drilling tests. The types employed included 10-, 12-, and 24-inch diameter, continuous-flight, finger-bit earth augers; a 3-inch-diameter coring auger 6.5 feet (2 m) in length; a 4.75-inch-diameter, tricone-roller rock bit; and a 14-inch-diameter, 9-foot-long tube core drill. All are available from commercial sources.

The 6.5-foot coring auger (Fig. 3) is patterned after the standard 1-m SIPRE coring auger, but with the core barrel extended to 2-m length for better drilling efficiency in deeper holes.

The tricone-roller rock bit is normally used to drill in medium to hard rock formations. The wedge-shaped teeth (Fig. 4) cut by exerting highly localized

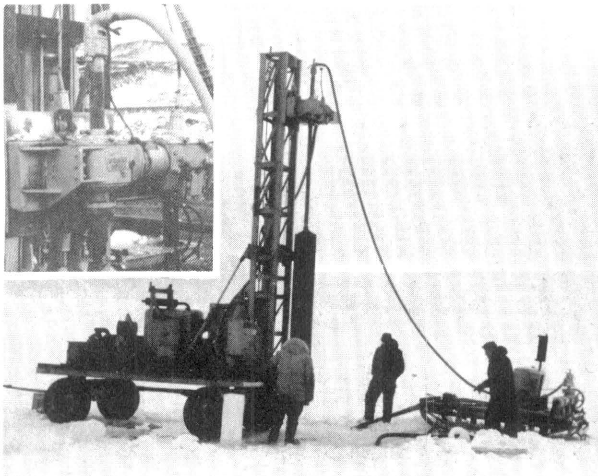


Fig. 2. Mobile rotary drilling unit; drivehead and fluid swivel shown in inset.

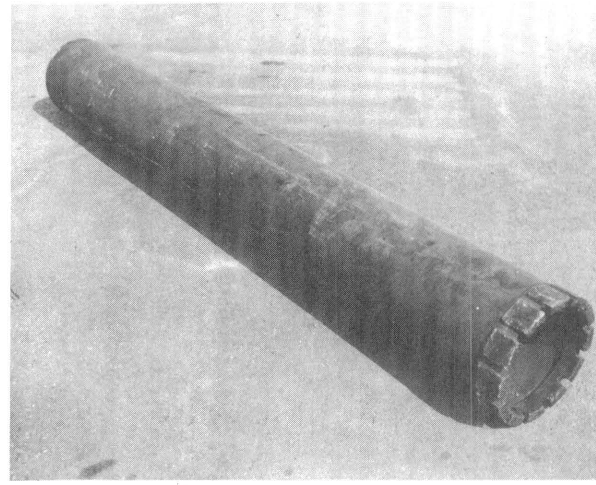


Fig. 5. Tube drill is 9 feet long, 14 inches in diameter.

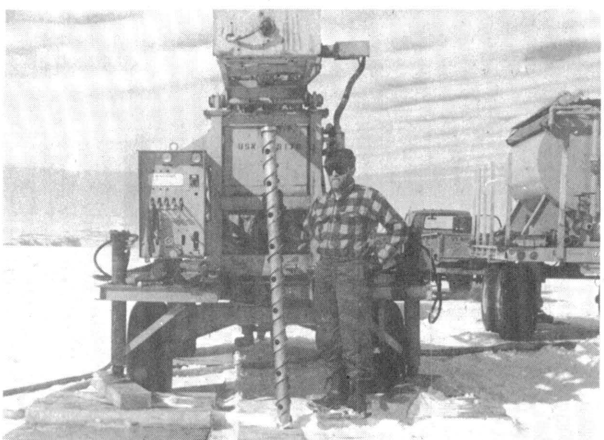


Fig. 3. The NCEL 2-meter coring auger.

Fig. 6. Tube drill's castellated cutting edge, with rock core.

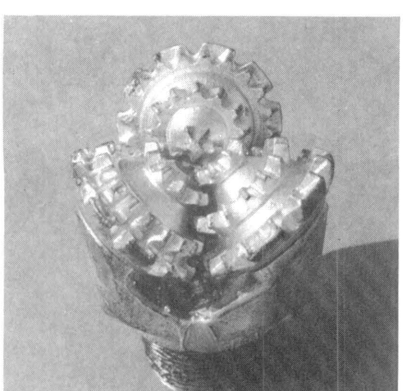


Fig. 4. Tricone-roller rock bit.

U.S. Navy Photos

pressure, causing the rock to fracture or spall. (This requires a steady downward pressure on the bit as it rotates.)

Tube core drilling bits, or tube drills, are normally used to drill large-diameter holes up to 10 feet deep in various rock formations that are too hard for augering but not hard enough to justify more expensive methods. The tube drill used at McMurdo (Fig. 5) was fabricated from a 9-foot length of 14-inch-diameter steel pipe. Its castellar cutting edge (Fig. 6) was faced with tungsten-carbide particles of 1/8– to 1/4–inch size, set in a brazing alloy matrix. This drill cuts a 12-inch diameter core that usually jams in the tube and is removed at the end of each drilling run. The smaller cuttings are removed with a drilling fluid.

Drilling Fluids. Both the tricone bit and the tube drill require a circulating fluid to remove cuttings.

When the tube drill is used, the fluid, usually water, is pumped down the drill rod at a rate of 80 gallons per minute (gpm). The fluid is deflected by the top of the core, flows down the inner diameter of the tube, and washes outward across the cutting edges.

When the ground temperature is above freezing, air, water, or a water-based slurry is usable, but in frozen ground or ice, fuel oil, antifreeze, brine, or similar liquids should be used. When the tube drill or the 4.75-inch-diameter tricone bit is used, the large annular space around the 2.25-inch-diameter rod requires a viscous liquid, preferably with an uphole velocity of about 200 feet per minute (fpm). If compressed air is used, an uphole velocity of about 6,000 fpm is needed.

Because of the small annular space around the tube drill, air or liquid can be successfully used in drilling as deep as 9 feet, the length of the tube drill. At greater depths, the space between the 2.25-inch-diameter drill rod and the 15-inch-diameter hole requires a liquid with the highest possible viscosity.

A self-priming tubular mud pump with a rubber volute was chosen for wet drilling because it is suitable for pumping various liquids as well as mud, dirt, and fine gravel without damage to its parts. The pump is belt-driven by a 2-cylinder, air-cooled gasoline engine equipped with an electric starter. The maximum delivery rate is 84 gpm, with a minimum discharge pressure of 225 psi. The assembly, which includes a discharge pressure regulator, pressure gauge, and a low-point drain, was mounted on a 48- by 66-inch, 2-wheel trailer.

Drilling in Snow and Ice

Exploratory drilling for density, temperature, crystallographic, and other subsurface studies requires good core recovery. Exploratory core drilling to depths in excess of 50 or 60 feet in snow and ice is difficult without adequate power-driven equipment, and is not frequently attempted in glaciological research. Data from greater depths can seldom be obtained because of equipment, labor, and transportation limitations.

Construction drilling in snow or ice usually requires relatively shallow holes of various diameters, depending upon the purposes. As the recovery of cores for scientific purposes is generally of little interest, almost any augering method will suffice, as long as the cuttings can be easily removed.

Core Drilling. Most exploratory core drilling in snow and ice is performed with the standard 3-inch diameter SIPRE coring auger that is 1 meter (3.3 feet) long. For deeper coring, 1-meter extension rods are connected with shear pins. This auger is well adapted for hand drilling, but as the hole depth increases, pulling up the auger to extract the core becomes extremely time consuming and laborious. A 1–hp electric motor can be used with this auger to increase drilling speed, but this does not reduce the time and labor required in retrieving the auger.

The NCEL 6.5-foot, or 2-m, long version of the SIPRE coring auger is more efficient because longer cores are obtained on each run, but the problem of removing cuttings, which are produced with both augers at a rate of 7 to 8 cubic inches per linear inch of hole, remains unchanged. (Cuttings normally occupy about one-third of the barrel length in a full auger core; overdrilling causes the cuttings to spill over the top and jam the barrel when an attempt is made to pull the auger.)

Tube Drilling. The 14-inch-diameter tube drill was found satisfactory for both exploratory and construction drilling. With seawater used to remove cuttings, this drill is highly efficient in ice, where the drilling rate is about 1 fpm. In sea ice up to 9 feet thick, a continuous core can be obtained that is equal to the thickness of the ice. This core normally remains afloat in the hole, from which it can be removed with a rope snare or ice tongs. In fast ice containing rock debris, the core usually remains in the tube, and removal requires a combination of pushing, prying, and pounding with a sledgehammer.

Although the tube drill does not function well in snow because the cutting edges quickly become iced over, holes up to 9 feet deep—one tube length—can be drilled by down pressure alone. (The use of a drilling fluid is unsatisfactory in snow because of absorption and slush formation.)

Auger Drilling. Continuous flight augers with diameters of 10, 12, and 24 inches are suitable for drilling to depths of 10 feet in snow, and for drilling through annual sea ice where complete penetration is possible in a single drilling run. Removal of cuttings is a problem in deeper holes. For example, auger cuttings in deep snow have a granular, "sugary" texture that is free-running and difficult to retain on the auger flight.

Tricone Bit Drilling. The 4.75-inch-diameter tricone bit was used to drill in the fast ice at McMurdo's ice wharf, in sea ice at Williams Field, and in glacier ice at Outer Williams Field. The penetration rate for the tricone bit in ice is 6–8 fpm with cold seawater as a drilling fluid. As ice is impermeable, the cuttings are washed to the surface and present no problem. This bit is most efficient when water is used as a drilling fluid, but compressed air is adequate if provided in sufficient quantity.

Although the only samples yielded by drilling with a tricone bit are cuttings washed to the surface, seven exploratory holes drilled in Elliott Quay in this manner provided good subsurface information because of the strong contrast between ice and the layers of basaltic sand and gravel that occur at various depths.

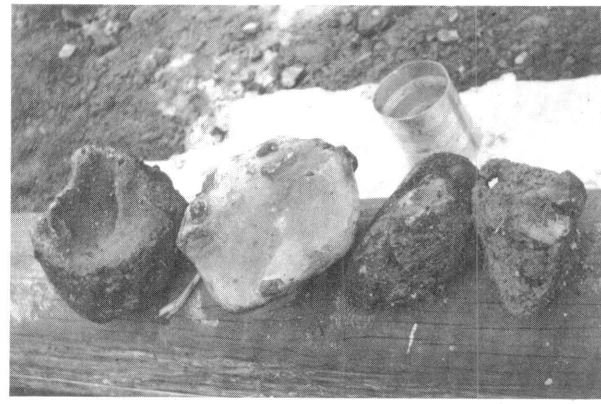
The tricone bit also was used to drill through the Ross Ice Shelf (McMurdo lobe on Fig. 1) near Williams Field. To eliminate the need for a casing and drilling fluid, a coring auger was first used to drill through the 60 feet of permeable snow at this location. After changeover to the tricone bit, hot water (approximately 200° to 210°F.) was used as a drilling fluid to melt the ice cuttings as they formed, thus preventing possible jamming. Similarly, when the tricone bit was used to drill through glacier ice at Outer Williams Field, warm water (40° to 50°F.) alleviated the problem of cuttings and insured against freeze-up.

Drilling in Frozen Ground

Drilling in ground that is either permanently or seasonally frozen presents problems that are not usually encountered when drilling in unfrozen soil and solid rock. These problems are caused by the wide diversity of soils and soil textures, variations in ice content, and the low subsurface temperatures that require special and expensive low-freezing-point drilling fluids.

At McMurdo, the black, basaltic surface soil thaws to depths of 8–24 inches during the summer. Organic matter is absent, but silt is found in varying amounts beneath the windswept lag gravel. Relatively few varieties of permafrost occur below the annually thawed layer. The most common consists of angular, basaltic rock particles of all sizes frozen together with varying amounts of ice (Fig. 7). For ease of discussion, this material is here termed ice-rock conglomerate. Another form consists of basaltic bedrock containing ice in joints and other voids.

A knowledge of seasonal ground temperatures at various depths can be valuable in determining freeze-point requirements for drilling fluids, potential heat-flow conditions beneath buildings, and freeze-back rates for structural members emplaced in permafrost or ice. Figure 8 shows three representative ground-temperature profiles obtained at McMurdo Station during the summer of *Deep Freeze 68*. The 49°F. temperature attained at the 1-foot depth on December 30, 1967, coincides with the maximum seasonal intensity of solar radiation and demonstrates the high heat absorptivity of the black, basaltic soil. Below 2 feet, the ground temperature remains under 32°F. throughout the season; consequently, water or mud introduced below that depth freezes rapidly, especially in small-diameter holes. If not promptly used, any hole drilled with a freshwater drilling fluid must be pumped out before the column of water freezes, necessitating redrilling.



U.S. Navy Photo

Fig. 7. Specimens of frozen ground and "ice-rock conglomerate" from McMurdo Station.

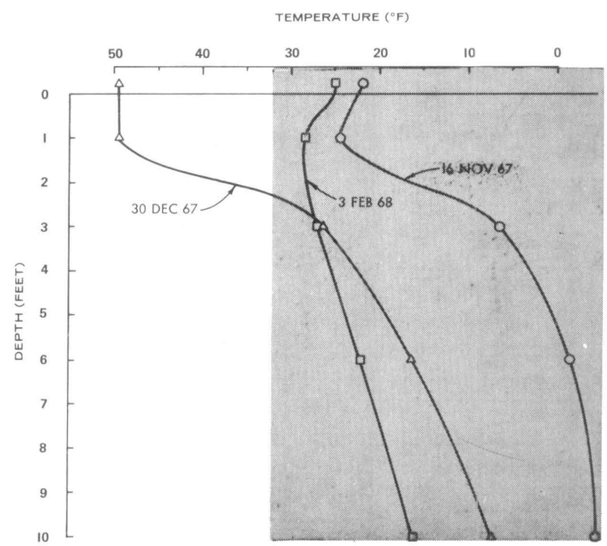


Fig. 8. Representative air-ground temperature profiles at McMurdo Station. Note the marked displacement of the mid-summer (December) curve with depth.

Selecting the best method for drilling in permanently frozen ground depends upon the nature of the permafrost and the purpose of the hole. For construction drilling, the best method is that which will most efficiently produce a hole of the desired depth and diameter. Exploratory drilling requires subsurface data obtained from core sections that are as complete and uncontaminated as possible. The extraction of such cores from the wide variety of frozen soils encountered in the Arctic and Antarctic is difficult because of many factors involving drilling equipment, soil texture, ice content, and ground temperatures. Where good cores are difficult to obtain, holes of sufficiently large diameter will allow examination and sampling along the sides.

Tube Drilling. The 14-inch-diameter, 9-foot-long tube coring bit overcomes many of the problems encountered in both construction and exploratory drilling in frozen ground. A large-diameter construction hole is produced in one or two runs, and most of the material from the hole is removed as a solid mass, facilitating disposal. Good subsurface information is easily acquired in exploratory work as an uncontaminated, 12-inch-diameter core is obtained. In addition, the large diameter hole permits access for further examination and sampling of the walls.

The tube drill is very efficient to depths of 9 feet in frozen ground and ice-rock conglomerate. Once set up, its drilling rate is 6 feet per hour. Although its efficiency progressively decreases with depths greater than 9 feet, 18-foot holes are fairly easy to drill, and holes to 60 feet deep are possible if care is taken to prevent jamming.

During the summer, the tube drill performs most efficiently when either fresh water or seawater at temperatures near 32°F. is used as a drilling fluid. This produces a clean, constant-diameter hole slightly larger than the tube drill. Water warmer than 32°F. melts the frozen soil or ice-rock conglomerate, thus producing holes up to 24 inches in diameter. The melting process causes a great deal of rock debris to cave into the hole, but if the hole is kept clean, the warm-water method can be used to produce large-diameter holes up to 6 feet deep.

Compressed air can be used with the tube drill for holes up to 8 or 9 feet deep if it is provided at the rate of 600 cubic feet per minute. At depths greater than 9 feet, the annular space between the drill rod and the hole is so large that cuttings cannot be blown out of the hole. Also, compressed air introduces heat into the hole; this, combined with heat from drilling friction, melts the permafrost into a dense, sticky mud that quickly freezes if drilling is stopped for any reason, possibly trapping the drill unless it is removed immediately.

When water is used as a drilling fluid, about 2 hours are required to drill 6-foot-deep holes for utility poles, bumper posts, and bollards in the ice-rock conglomerate at McMurdo Station. This time period includes positioning and setting up the drill rig and pump. Excavation of similar holes by air hammer requires two men 1 or 2 days, depending on local conditions. Excavation by jet burner takes less time but leaves a large, bowl-shaped hole that is muddy or watery, and poorly suited for use.

Tricone Bit. The tricone bit, used with either water or compressed air to remove cuttings, is effective in most varieties of frozen ground. Seawater at temperatures near 29°F. is adequate for deep drilling because it freezes slowly and does not cause the sides of the hole to melt and cave in. This is especially important in ice-rock conglomerate where melting may cause rocks to fall into the hole above the bit, wedging it in.

Compressed air is not suitable for drilling to depths greater than 10 feet unless the air is cooled to 32°F. or lower. As with the tube drill, warm air and frictional heat will melt the permafrost into a mud that is not easily blown out of the hole and that quickly refreezes when drilling is stopped.

Experimental drilling with the tricone bit was attempted in the solid basalt at McMurdo Station. This rock is exceptionally hard, and it was found that the drilling rate with compressed air was too slow for practical use.

Conclusions

The tube coring drill is suitable for drilling large-diameter construction holes and for subsurface exploration in ice, ice-rock conglomerate, frozen ground, and solid rock. Efficiency decreases as hole depth exceeds 9 feet, but depths up to 60 feet can be achieved by taking care to prevent jamming. The tricone bit is suitable for rapidly drilling small-diameter holes to great depths in all of these materials except solid rock. Augering is practical only in snow or clean ice to depths of approximately 10 feet.

An ample supply of drilling fluid is most important in deep drilling with either the tube drill or the tricone bit. If drilling fluid is lost or exhausted unexpectedly, the suspended cuttings quickly settle around the bit and jam it in the hole. When completing a coring run or stopping to add drill rod, it is important to run the drill string up and down a few times to allow all suspended cuttings to wash down around the bit and settle at the bottom of the hole.

Further Work in Progress

Present work is directed toward improving the techniques for construction drilling in Antarctica, with emphasis on increased maneuverability of the drill rig and higher penetration rates in ice-rock conglomerate and frozen ground.

Errata in vol. IV, no. 2: on p. 49, the caption for the parachutist photo should read January 11 vice January 9; on p. 52, five pilots should have been cited in connection with the long-distance helicopter flight. On the flight *to* Hallett, one helicopter was piloted by Lt. Comdr. T. Chider and Comdr. D. Eldridge, the other by Lt. P. Thomas and Lt. E. Freeman. Lt. (jg.) J. Wilson arrived at Hallett by LC-130, and on the return helicopter flight, he replaced Lt. Comdr. Childer, who went back to McMurdo aboard the Hercules. (Also see footnote 3 on page 150 of this issue.)

Erratum in Index to vol. II: the page citation for "Pararescue team" should read 74-76 vice 274-276.

Antarctic Engineering[1]

PHILIP M. SMITH

Office of Antarctic Programs
National Science Foundation

Engineering and Social Change

Dean Chauncey Starr of the Engineering College, University of California, Los Angeles, said recently that he thought the engineer was today's true social revolutionary. Whereas in the past, social change may have been a function primarily of political, philosophical, or humanitarian thought, Dean Starr believes that it is created today primarily by the engineer. In some cases, technology has outstripped man's ability to adjust to change; it is here that the social role of the engineer is most exposed.

The role of the engineer as an agent in social change is nowhere better demonstrated than in Antarctica. Our past progress, our present social relationships, and our future prospects in Antarctica are functions of technology. That this is true is illustrated by considering that man's day-to-day experience in Antarctica extends back only 70 years to the winter of 1898, when *Belgica* was entrapped in the Bellingshausen Sea. Her crew became the first men to cope with the severe climate of the south polar winter. They had no radios, no electric power for either science or amenities, and no hope of rescue by any means other than their own. Today, by contrast, men live in comfort year around at the coldest place on Earth.

In 1928, about 30 years after *Belgica*'s entrapment, the engineer's revolutionary role in Antarctica had become clearly apparent with the operational use of aircraft, tracked vehicles, and far-reaching communications on the first Byrd expedition. In other areas—management and financing—change had not yet become apparent. The Byrd expedition still depended on the solicitation of much private support, in contrast to the government support now in effect. In 1928 and 1932, one took what one could get and was grateful for it. One oldtimer told me that the donated supply of a breakfast cereal was so abundant that the dog kennels were floored with it.

In the 40 years since the first Byrd expedition, the antarctic engineering revolution intensified, changing the whole pattern of activity on the Continent. Now, we successfully work throughout the winter in comparative comfort in the interior of the Continent, although we have sometimes come close to disaster and hardship when our equipment or its maintenance has failed. In the austral summer, we place parties all over the Continent virtually at will.

This revolution has also brought changes which are not beneficial. Wastes are visible at many antarctic stations. At McMurdo, for example, smog became a problem a few years ago. On some occasions, smoke from burning trash has reduced visibility on the Williams Field runway. Life style on the expedition has also been affected by specialization and by growth. Tragically, many individuals at McMurdo have become alienated from the program's objectives. Many sailors and officers involved in the support of the operation are so far from the "front-line" that they have no identification whatsoever with the scientists in the laboratories and aviators and scientists in the field.

Parallels Between Antarctic and North American Development

Our experience in Antarctica will not seem unusual if we compare it with events that have taken place on other continents. Through such an examination, we can learn to plan new engineering for the future. In the history of American cities, one finds certain parallels between the development of McMurdo Station and the growth of cities such as Pittsburgh, Pennsylvania, and Louisville, Kentucky. In the period between 1780 and 1820, these frontier cities served as staging areas for man's further travel into the North American interior. In a brief 40-year period, frontier trading gave way to well-organized business and the phenomenon of suburban development. The records of the cities reveal problems of waste disposal, street construction and lighting, and fire protection. In this same period, construction along the river fronts proceeded with no thought for scenic protection; other patterns of land use, which are apparent today when one visits Pittsburgh or Louisville, emerged in this early period.

The struggle in this period of frontier urbanization is paralleled in developments at McMurdo Station in the 13-year period of our tenure. We also have struggled, sometimes vainly, in our effort to improve community services and utilities, often under restrictions created by our earlier construction decisions and outmoded planning principles. We have been somewhat unappreciative of our "million-dollar view" of the Royal Society Range, having obscured it with a maze of telephone poles and wires which offends the eye of the most insensitive person. The history of Pittsburgh and Louisville shows that a continuing planning effort should have been adopted at the outset. The future could not then be predicted, much

[1] Based on a talk given at the opening session of the Second Antarctic Construction Seminar, Naval Construction Battalion Center, Davisville, Rhode Island, May 7, 1968.

(Photos by W. R. Curtsinger, USN)

as we could not in 1955 predict the future of McMurdo Station. But we are not now in the position of the early town fathers in Pittsburgh, for we have some notion of our future in Antarctica. Indeed, we have opportunities today that the planners in North America would find a source of envy.

Antarctic Planning Today and the New Engineering Challenges

We did not believe at the time of the IGY that we would be in Antarctica for more than three or four years. Little America V and the central core of present-day McMurdo were designed as "gold rush" towns. When the new Byrd Station was built in 1961, we knew that the antarctic program would continue for some time, but the decision to extend the program had been so recent that a really effective analysis of our requirements at that station was not possible. Today, Byrd Station provides visible evidence of the evolving program management. Palmer Station is the first station which truly bears the imprint of our new opportunities in planning.

Planning can be done more easily for Antarctica than for most other areas of the world. Dr. A. P. Crary, who until recently was Chief Scientist of the Office of Antarctic Programs, has pointed out that there are no pressing demands of private interests to contend with in the Antarctic.[2] There is no need for crash programs, although some programs seem to take on that appearance at the last minute. Furthermore, there is a store of planning information available. Perhaps most important, there are relatively precise figures available for the cost of the various support services. When a new scientific program is contemplated, the logistic costs can be considered. Our plans are updated annually, giving planners the opportunity to regroup when they fail.

There are also some difficulties in planning for Antarctica. Some problems relate specifically to the mission of the National Science Foundation (NSF), which is responsible for the coordination and funding of the scientific activity. NSF is a nonoperational agency supporting basic research; while our plans may call for certain projects, we cannot hire scientists to carry them out. Instead, we must hope that our plans will be a true reflection of academic and governmental scientific interests. Otherwise, we must hope that some persuasion may bring the opportunities to the attention of qualified workers. Another feature of our planning is that both the Office of Antarctic Programs and the U.S. Naval Support Force, Antarctica operate on level budgets. In planning, a level budget is painful, for it means that any innovation necessitates the curtailment of funds for a project already in progress. Budgetary restrictions can also be advantageous, however, for they provide an opportunity to weed out the moribund. Coordination of our two budgets is particularly important. It would be unwise, for example, for NSF to curtail programs which were at the same time receiving renewed logistic emphasis by the Navy.

Our five-year plan for the period 1968–1972 is now in effect. What does it mean from the standpoint of engineering? First, it is clear that by the mid-1970s, we will operate only three permanent year-round stations—Palmer, Pole, and McMurdo. By then, Byrd Station will be 12 to 14 years old; its maintenance costs will have increased greatly, probably to the point where the station no longer will be economically useful in its present large size. Portable, temporary stations like Plateau may be in continued use, but will have short occupation at any one location. New instrumentation such as the radio ice-thickness sounder will lead to extended use of remote-sensing aircraft. Submersibles and other vehicles will have been intro-

[2] *Antarctic Journal*, vol. III, no. 1, p. 10-14.

duced. Automatic stations are certain to be in operation by virtue of the perfection of isotopic power supplies, communications through synchronous satellites, and other spinoffs of the space age.

Exciting new investigations that heretofore have been technically impossible to conduct will become feasible. One of the most important of these—sampling by remote techniques beneath the Ross Ice Shelf, which is the size of France—has long fascinated workers in several fields. Biologists want to know if life exists there. Oceanographers believe that the bottom water of the world ocean may originate beneath the shelves. Glaciologists have long debated whether the underside is melting or freezing. Consequently, there is a desire to drill a hole, perhaps 4 ft. in diameter, through the floating shelf and lower automatic, remote-sensing equipment into the water beneath. These new and heady projects demonstrate the revolutionary role of the engineer, for none of them would be possible without him.

Elements of a Systems Approach in Future Engineering

How do we proceed in the years ahead to exploit our planning opportunities? We should think carefully about and adopt the systems-analysis approach, now widely used in government for planning, programming, and budgeting. It has a few shortcomings. One of them is that we generally relate it to the inanimate. Actually, our "system" in Antarctica is a human one to a very real extent. If one of us fails in the accomplishment of his responsibility, the whole system breaks down. In thinking of a systems approach to antarctic engineering, I urge that attention be given to the human elements—the interaction of personnel from the design phase on through to the operation and maintenance of a station. A systems-analysis approach does not relieve the individual of responsibility; instead, it strengthens the individual's performance.

The implications of a projected activity become known through the analysis of all elements of the problem, including, in our instance, such diverse factors as transportation schedules, procurement, and ongoing operational expenses. It is quite possible, I believe, to define our needs for a systems examination, since we have better projections of our overall objectives than most planners have. And, we have one major advantage in our use of the systems approach: we can obtain very good feedback. In many engineering activities, such a user feedback is quite difficult to obtain. We know right away from our users—especially the wintering personnel—whether they are happy with our engineering.

As we think of a systems approach to our engineering, we can consider the following factors, all of which are important elements of a systems analysis, along with specific objectives about the project itself:

Our stations are physically isolated, much in the manner of ships at sea. The ebb and flow of trade, supply, and resupply can be precisely measured. Our construction and maintenance is actually more like the construction and operation of a ship—a total environmental system—than a shore facility in the sense that the term is used in regard to naval installations in the United States. It might have been well to include the Naval Ships System Command, which knows the problems of isolation, in the development of a station such as Plateau.

We must use our knowledge of antarctic environmental differences. When the preparations were being made for the first winter support flight to Antarctica, antarctic environmental differences were summarized in messages from the ice. At McMurdo, the terminal of the fly-in, the temperatures were in the neighborhood of —30°C. At Palmer, temperatures were above freezing and there was a drizzle. Meanwhile, at Plateau, it was down to nearly —75°C. The fact that Antarctica is a large continent with many different environments escapes some engineers.

Standardization rather than diversification is possible. We are less dependent on the artificially stimulated demands of society than are most engineering activities. The most modern and the best-looking do not have to be obtained for Antarctica because they are so advertised or even because they are the least costly.

Consolidation of utility systems is possible. All utilities can be maintained by a single operating organization. We do not have separate electric, power, and fuel companies. Consider, for example, the desirability of placing the power lines alongside the water distribution system. This would eliminate the overhead wires and their hazardous maintenance during winter storms. It would permit simultaneous physical inspection by utility men of the water, waste, and power-distribution systems.

Further in our systems analysis, we have the opportunity to consider the efficiency which comes through manpower reduction, not its increase. We have no need for full employment in Antarctica and do not have to make work.

Pressure for the continuation of a bad antarctic plan is small. There are relatively few political and economic implications in our work. Our investment is our own, not the investment of corporate stockholders. It should be noted that we are responsible to the U.S. taxpayer—the real stockholder of our enterprise. Few taxpayers willingly promote increased costs, especially those arising from a planning failure.

In our work, there is the opportunity to utilize new developments from the Arctic. There are cities, such as Inuvik near the mouth of the Mackenzie River, which are a little further along the line from frontier village to city. Our planning should take into account the rapid northward push into Canada and Alaska and the way that the engineering requirements are met.

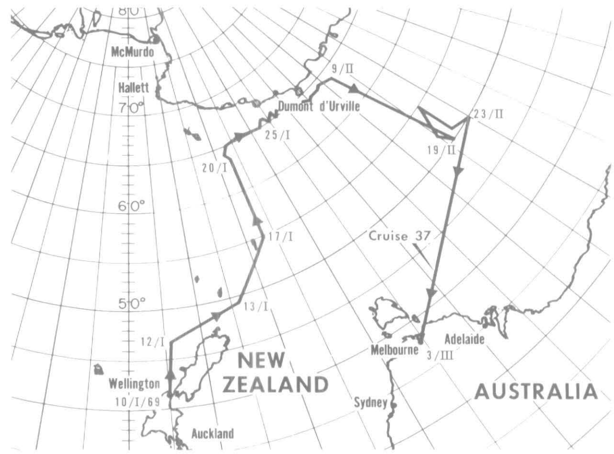
There is one element of antarctic systems planning on which I would like to dissent from the generally held opinion. Among working engineers in the Antarctic, one hears a good deal about the "simplicity principle," the rationale for which is that complex devices will fail more quickly in Antarctica. In some earlier, expeditionary phases of the antarctic program such a principle may have been applicable. Today, however, we are too committed to the engineering revolution to retain or achieve simplicity. But the main reason that I object to the simplicity principle is that it insults man's capability! Man seeks challenge in the unknown and in technological development. The leveling process of simplicity also levels man.

We have a requirement for a new South Pole Station by the early 1970s. There are new scientific projects—some of which I have mentioned and some which I have not—all requiring new technology. Systems analysis can be employed in all of these undertakings.

In Antarctica, we have three great advantages which elude most planners. I have talked at some length about the planning cycle. Secondly, there is the umbrella provided to the program by the Antarctic Treaty: we operate in a favorable national and international climate as a result of the 12-nation agreement of 1961. A third important factor is that, to a large degree, we are in control of our destiny. Our activities in Antarctica are more nearly similar to the emerging development of the North American Continent 100 years ago than they are to the adventures of man in space. We have a handful of engineers at work on our projects, while there are thousands involved in NASA programs. That we have control of our destiny should stimulate desire for excellence on the part of all, and should develop a sense of collective responsibility for our projects.

How Antarctica fits into the distant future cannot be forecast, but it is certain that it will. It is only a 70–year span of time since the *Belgica* expedition in 1898. What we are building at McMurdo today will surely be useful for 20 or 30 years—till the end of this century—in Antarctica. We must constantly think of our broader responsibility for the Antarctic Continent and our collective involvement in planning as we carry out our individual tasks in construction and engineering. At some future point, we will be judged, for the wisdom of our decisions will be evaluated just as we now look back on an earlier phase of antarctic activity and on man's use of North America.

Eltanin Cruise 37



Cruise 37 was oriented towards studies in physical oceanography, with supporting data being obtained in marine geology and geophysics. Objectives of the oceanographic program were to sample the water within topographic depressions on the antarctic continental shelf, determine its mode of formation, and assess its influence on the deeper adjacent water and observe the method by which it escapes to deeper water. The physical-oceanography program was directed by Dr. Arnold L. Gordon, Lamont-Doherty Geological Observatory, who also served as USARP Representative on the cruise. The physical-oceanography group included three students from Flinders University, Australia.

Along the continental shelf between the Balleny Islands and approximately 127°E. are topographic depressions similar to those in the Ross Sea investigated on *Eltanin* Cruises 27 and 32. These depressions may act as traps for the very dense water formed along the coast of Antarctica.

Departing Wellington on January 10, 1969, *Eltanin* proceeded to 47°S. 174°E., then headed southwestward to 55°S. 157°E. She approached to within 100 mi. of Young Island, then turned west along the continental margin of Antarctica on a zig-zag course. Ice conditions prevented a visit to the French station Dumont d'Urville. At 128°E., the ship turned north and proceeded to 51°S. along 125°E., then turned back to 56°S. She then proceeded to 50°S. 120°E., at which point course was set for Melbourne. A total of 64 stations was taken.

The characteristics of the coastal water of Antarctica were studied using STD equipment (with digital magnetic tape recorder), the classical Nansen bottle cast, the Lamont-Doherty designed tripod (bottom current meter, bottom camera, and nephelometer), and XBTs (expendable bathythermographs). Water samples were gathered for determination of dissolved oxygen concentration (Carpenter modification of Winkler method) and amounts of nitrate, phosphate and silicate using the Auto-Analyzer.

Preliminary study of the data indicates that bottom water in a limited amount is produced along the shelf area of the Adélie Coast. This locally produced bottom water has salinities of slightly less than 34.7 ‰ and potential temperatures of approximately —0.6°C. with oxygen saturation of approximately 90%. At 135°E., this water leaves the continental slope and penetrates into the deep ocean. In doing so, it deflects a westward-flowing bottom current made up of water derived from the Ross Sea. This Ross Sea-derived bottom water has salinities of slightly more than 34.7‰, potential temperature of —0.4°C., and oxygen saturation of approximately 62%. It is expected that the Antarctic Bottom Water derived from the Ross Sea has some large-scale significance. However, the bottom water produced along the Adélie Coast is not in sufficient quantity to have more than a fairly localized influence.

In addition to the above work concerned with Antarctic Bottom Water production, the Antarctic Convergence was investigated with XBTs and the STD. The Convergence at 125°E. was crossed three times in order to study temporal variations and the possibility of detecting a double polar front zone which has been found east of the Macquarie Island. No such double polar front was found at 125°E., and the variations during the time of observation were minor.

Three profiles consisting of a total of 20 water samples of 10 l each were processed for a study of the U^{238} content and the ratio of U^{234} to U^{238}. These samples were taken on behalf of Woods Hole Oceanographic Institution.

Surface plankton tows of long duration were taken at four locations in order to obtain enough living foraminiferans for oxygen-isotope ratio determinations at Lamont-Doherty. The plankton net was hung from the bow to avoid contamination.

Other projects carried out during the cruise included:

Bottom coring, Florida State University. The cores obtained on the continental margin showed increasing overall grain size towards the bottom of cores, while those taken north of the margin had decreasing grain size from top to bottom. No fine-grained sediments were obtained on the shelf. Two of the cores contained Foraminifera on top, but not in the lower part of the samples. Some of the FSU cores were turned over to the Lamont-Doherty program and to Professor Konrad H. R. Moelle of the University of Newcastle, Australia.

Professor Moelle also obtained some piston cores of his own (for a total of nine). His particular interest was to search for cosmic spherules, their concentration and mode of deposition, and the depositional fabrics associated with them. While the quality of the cores obtained was generally good, they did not reveal many cosmic spherules.

Meteorology, Bureau of Meteorology, Melbourne. This program included 206 surface observations, 48 radiosonde and 11 rawinsonde observations, and 185 special observations during four crossings of the Antarctic Convergence. Eight carbon-dioxide samples were collected for the Scripps Institution of Oceanography and one oxygen sample for the U.S. National Bureau of Standards.

Geophysics, Lamont-Doherty Geological Observatory. In addition to the normal underway measurements of the geophysical program (gravitometer, magnetometer, and seismic profiler) taken by the Lamont-Doherty geophysical party, a sonobuoy system was incorporated into the program. (A sonobuoy is a buoy used in conjunction with a hydrophone as an economical method of obtaining seismic refraction data without the need for a second ship.) This sonobuoy system utilizes expendable passive sonobuoys (supplied through the Office of Naval Research) to obtain information on the velocity structure of the sediments and uppermost oceanic crust. Sixteen successful sonobuoy stations were made.

All underway geophysical projects were successful with the exception of the seismic profiling, which was not conducted during the first week of the cruise due to a major overhaul of the compressors. Of special geophysical interest were the crossings of the Southeast Indian Rise, the Macquarie Ridge-Arc complex, and the antarctic continental margin.

First *Hero* Cruise in the Southern Hemisphere*

Departing from Miami, Florida, on October 23, 1968, *Hero* proceeded to Valparaíso, Chile, to begin a cruise in southern Chilean waters that lasted from November 12 to December 11. The cruise was undertaken to study the marine mammals of southern Chile, particularly the distribution and variation of small whales, porpoises, and seals. Other objectives

*Extracted from report prepared by Dr. Kenneth S. Norris, senior scientist on the cruise.

included investigations of the chemistry of vision in marine mammals; the collection of materials for gross microscopic and ultrastructural studies of the porpoise ear and eye; the accumulation of information on the life history of the mammals, including their parasites, sexual cycles, and stomach contents; research on porpoise sound processing by means of brain implants on anesthetized animals, and sound-velocity and -dispersion measurements on porpoise tissues thought to be involved in sound transmission; and the recording of underwater sound emissions.

Dr. Kenneth S. Norris, Director of the Oceanic Institute at Waimanalo, Hawaii, and Professor of Zoology at the University of California, Los Angeles (UCLA), served as senior scientist on the cruise. Other participants from UCLA included Edward W. Shallenberger, Robert Barrett, and Kenneth A. Bloome. Also aboard were William E. Schevill, Woods Hole Oceanographic Institution; William N. McFarland, Cornell University; George W. Harvey, Oceanic Institute; William Watkins, Woods Hole Oceanographic Institution; Anelio Aguayo, Director of the Estación de Biología Marina, Montemar, Chile, and Michael Barrett, UCLA.

In addition to the primary objectives, the expedition obtained collections for specialists not directly involved in the cruise. These collections included plants, hagfish, diving petrels, skulls of pinnipeds, and visual pigments of marine vertebrates other than cetaceans.

The cruise yielded an unexpectedly low number of cetaceans, but the complex and obscure genus *Lagenorhynchus* was observed, and a good series of specimens was obtained, allowing study of pattern variation and osteology in *L. australis*. Two specimens of the little-known *Cephalorhynchus commersoni* were recovered from the Straits of Magellan. Sightings of the sea lion *Otaria byronia* and the fur seal *Arctocephalus australis* numbered 2,400; 45 new localities, mostly of *Otaria*, were recorded. Skeletal materials from an entire stranding of the southern pilot whale were obtained. The retinas from eight porpoises were dark-adapted and frozen for later analysis at Cornell University.

The neurophysiological work suffered from the relative scarcity of animals. In the single successful anaesthesia that was performed, a small male of *L. australis* was implanted and recordings made of cerebral signals for about 30 minutes until the animal died.

Many attempts were made to record underwater sounds of marine mammals from *Hero* and the whaleboat, both of which proved to be good listening platforms. When *Hero* was on "silent ship" with all rotary machinery stopped, no ship-generated sounds could be heard. Recordings were obtained from both porpoises and sea lions.

Plants were collected from 26 localities and 1,731 specimens were pressed, dried, and labelled. Among the previously uncollected localities was the extremely interesting Islas Barnevelt east of Cape Horn, Isla Aguirre, and Isla London, and all outlying islands to the Península Brecknock. The plants are presently being catalogued and studied by Mrs. Natalie Goodall of Estancia Haberton, Tierra del Fuego, Argentina. They will be forwarded to Dr. Frederick G. Meyer, Research Botanist, U.S. National Arboretum, U.S. Department of Agriculture, Washington, D.C., who is arranging for their study and distribution.

Twelve collections (several hundred individuals) of hagfish were made for Dr. Carl Hubbs, University of California, San Diego, from the Golfo del Corcovado to Puerto Maxwell, a few miles north of Cape Horn. Visual pigments were obtained from fishes, the steamer duck, kelp goose and magellanic penguins. Five diving petrels were obtained for Dr. Braulio Araya, and a new locality for the very rare magellanic woodpecker was recorded. A few miscellaneous collections were made of invertebrates as well as amphibians, lizards, and tadpoles.

Ten cetaceans (porpoises) and other biological materials from the cruise are either deposited in the United States National Museum or distributed to appropriate scientists for study. The plant collection will be deposited ultimately in the Berkeley Herbarium, at the University of California.

Back Issues of the *USAPO Bulletin* Available

The History and Research Division of the U.S. Naval Support Force, Antarctica will accept requests for certain back issues of the *Bulletin of the U.S. Antarctic Projects Officer,* which was published from 1959 to 1965. The following issues are available: vol. II (1960–1961), special supplement to no. 1*; vol. IV (1962–1963), no. 1*; vol. V (1963–1964), nos. 7, 9, 10, Index and Errata; vol. VI (1964–1965), nos. 1 through 7, Index and Errata.

Only requests from libraries, polar authorities, and current antarctic researchers can be honored at this time. Requests should be submitted on institution letterhead to the Division at Building 210, Washington Navy Yard, Washington, D.C. 20390.

The Library of Congress holds a complete set of *Bulletins* and can provide photocopies of those issues that are not available from the Support Force. A schedule of copying fees may be obtained from the Library's Photoduplication Service, Washington, D.C. 20540.

*In very limited supply.

Command of Naval Support Force Transferred to Admiral Welch

U.S. Navy Photo

In a brief ceremony held at the historic Washington Navy Yard on June 19, the command of the U.S. Naval Support Force, Antarctica was transferred from Rear Admiral J. Lloyd Abbot, Jr., to Rear Admiral David Fife Welch.

Admiral Abbot, who had headed antarctic logistical operations since February 25, 1967, will assume command of Carrier Division 16, based at Norfolk, Va. His tour with *Operation Deep Freeze* was marked by the first scheduled winter flights to Antarctica, the dedication of a permanent Palmer Station, the construction at McMurdo of the Antarctic's largest building, the acquisition of a fifth LC–130 Hercules for Antarctic Development Squadron Six, and increased use of satellite technology. A project of special interest to him was the inauguration of a program to inform support personnel about the objectives, nature, and achievements of antarctic research.

The Support Force's new commander, a native of Indiana, was commissioned in the Naval Reserve in 1941. He subsequently served on antisubmarine duties in the Atlantic, earning the Bronze Star Medal. In 1945 and 1946, he commanded first a high-speed transport and then a destroyer escort. After postgraduate studies, he took command of Underwater Demolition Team One and led that unit in night hydrographic surveys under fire and in reopening the port of Chinnampo, Korea. For his serivce with UDT–1, he was awarded the Silver Star. Admiral Welch's other commands have included USS *Bausell* (DD–845), Mine Squadron 10, the Atlantic Fleet's Amphibious Training Command, and Amphibious Group 4. It was from the last of these that he came to *Operation Deep Freeze*.

Admiral Welch's shore duty has included service as Assistant Chief of Staff for Logistics with U.S. Naval Forces, Europe, for which he was awarded the Legion of Merit, and in senior staff positions with the Military Assistance Command, Vietnam, where he earned a Gold Star in lieu of a second Legion of Merit.

Admiral Welch holds a B.A. in chemistry from Franklin College of Indiana, and an M.A. in education from George Washington University. He has also attended the Naval War College and the NATO Defense College, and taught at the Naval War College. He was promoted to rear admiral in 1968.

Philatelic Mail for *Deep Freeze 70*

Philatelic covers will be accepted during the 1969–1970 season by two U.S. stations in Antarctica and by three *Deep Freeze* ships. Byrd Station and South Pole postmarks may be obtained by placing two addressed covers, each bearing U.S. postage at letter mail rate,* in an envelope addressed to:

DEEP FREEZE PHILATELIC MAIL
U.S. Naval Construction Battalion Center
Davisville, Rhode Island 02854

One cover will be forwarded to each station for postmarking. If only one station's cancellation is desired, the single submitted cover should have either "Byrd" or "Pole" written in the lower left corner. Covers must arrive at Davisville by September 1, 1969, to be processed for shipment to Antarctica. Cancellations will be applied during the austral winter, and collectors may expect to receive the covers between October 1970 and March 1971.

Ship cancellations may be obtained by sending covers to *Deep Freeze Philatelic Mail*, followed by the name and address of the ship whose postmark is desired. The ships' addresses and the 1969 deadlines for receipt of covers are:

USCGC *Edisto* (WAGB–284), Boston, Massachusetts 02109—November 12.

USCGC *Burton Island* (WAGB–283), P.O. Box 20820, Long Beach, California 90801—November 19.

USCGC *Glacier* (WAGB–4), P.O. Box 20900, Long Beach, California 90801—November 19.

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Fifth Consultative Meeting of the Antarctic Treaty Representatives

On November 18, 1968, Representatives of the 12 nations signatory to the Antarctic Treaty met in Paris for their Fifth Consultative Meeting. Ambassador Pierre Charpentier, who signed the Treaty document for France in Washington, D.C. on December 1, 1959, was elected Chairman of the meeting, and Mr. Guy Scalabre was appointed Secretary General. Michel Debré, Minister of Foreign Affairs for France, opened the meeting. The United States Representative and Chairman of the Delegation was Ambassador R. Sargent Shriver, Jr. Other members of the U.S. delegation included Mr. James Simsarian, Department of State; Mr. Henry S. Francis, Jr., National Science Foundation; Captain James E. Heg, USN, Department of Defense; and Mr. Maynard W. Glitman, American Embassy, Paris.

Representatives recommended nine measures to their governments for furthering the principles and purposes of the Antarctic Treaty. The most significant recommendations, perhaps, are those dealing with telecommunications and pelagic sealing. The "Measures for Improving Antarctic Telecommunications" provides for a meeting of experts of the Consultative Parties in Buenos Aires, Argentina, in September 1969 to consider ways and means to facilitate the communication of scientific and other traffic. The proposed meeting of experts will be the second such meeting under the Antarctic Treaty.

Two measures recommended to governments dealt with the conservation of antarctic pelagic seals. The first of these revised the Interim Guidelines for the Voluntary Regulation of Antarctic Pelagic Sealing, originally recommended to governments by Representatives at the Fourth Consultative Meeting in Santiago, Chile, 1966. Based upon the consideration of SCAR, the interim guidelines were revised to designate the limit of permissible catch of specific species, zones and seasons for sealing operations, sealing reserves, and exchange of information. The second conservation measure recommended that the governments consider a convention for the regulation of antarctic pelagic sealing at the next Consultative Meeting, based upon the interim guidelines. These nine measures are now being considered by the twelve countries and will become effective when and if approved by all twelve.

The Representatives, in conclusion, recommended that their governments accept the invitation of the Government of Japan to convene the Sixth Consultative Meeting in Tokyo in 1970, and thanked the Government of France for the splendid and cordial hospitality provided for the Fifth Consultative Meeting.

Deep Freeze 69 Visitor Program

During the 1968–1969 austral summer, slightly more than 100 individuals visited Antarctica as guests of the U.S. Naval Support Force, Antarctica and the National Science Foundation. Most of these made five- or six-day visits during two scheduled periods in November and January, but some, because of the nature of their visits, came at other times.

Visitors in November included representatives of 11 of the nations signatory to the Antarctic Treaty. Their itinerary was reported in an earlier issue of the *Antarctic Journal* (vol. IV, no. 1, p. 34). Also viewing U.S. antarctic operations in November were three congressmen: Rep. Charles A. Halleck (R–Ind.), Rep. Porter Hardy, Jr. (D–Va.), and Rep. William L. Dickinson (R–Ala.), all of the Armed Services Committee. Three other congressmen, accompanied by Dr. T. O. Jones, visited Antarctica in December: Rep. George E. Brown, Jr., (D–Cal.), of the Science and Astronautics Committee; and Representatives Laurence J. Burton (R–Utah) and Theodore R. Kupferman (R–N.Y.), of the Territorial and Insular Affairs Committee.

In January, Sir Arthur Porritt, the Governor-General of New Zealand, visited the Continent, accompanied by his two sons and party. Other prominent visitors from New Zealand were Mr. Charles H. Upham and Mr. Clutha MacKenzie; two members of the New Zealand Parliament, Mr. William L. Young and Mr. Trever Young; and Peter Snell, an Olympic gold medalist. The U.S. Ambassador to Australia, the Hon. W. H. Crook, visited in November, with his 12-year-old son and party.

Distinguished visitors from the world of business and education included Mr. T. J. Watson, Jr., chairman of the board of International Business Machines; Mr. G. K. Funston, chairman of the board of Olin Mathieson Chemical Co.; Dr. W. B. Henley, provost of the University of Southern California's College of Medicine; Mr. G. H. Dixon, president of the First National Bank of Minneapolis; and Mr. F. Shor, associate editor of *National Geographic*.

Among the military visitors this past season was General H. M. Estes, Commander of the U.S. Air Force's Military Airlift Command (MAC). With Gen. Estes were Major General J. S. Sherrill and Brigadier General E. J. White, both of MAC. Others were Air Vice Marshal C. A. Turner of New Zealand; Rear Admiral F. Massey, Commander, Fleet Air at Quonset Point, Rhode Island; and Rear Admiral F. B. Voris, assistant chief of the U.S. Navy's Bureau of Medicine and Surgery. Rear Admiral David F. Welch, preparing to take command of *Operation Deep Freeze* this summer, made a brief visit to McMurdo, Byrd, and Pole in February.

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