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A Review of the 1967-1968 Summer Season

U.S. Antarctic Research Program

T. O. JONES [1]

Division of Environmental Sciences
National Science Foundation

As has been the custom in past years, this issue of the *Antarctic Journal* is devoted to a review of the United States national program in Antarctica during the preceding austral summer. In addition to the review of support operations presented herein, summaries are given of the individual research projects conducted under the auspices of the National Science Foundation by scientists of many universities and government bureaus throughout the United States. Together, they make up the field portion of the U.S. Antarctic Research Program (USARP), a national scientific endeavor that is part of the international research program pursued by the 12 member nations of the Antarctic Treaty. As in previous years, USARP has been given excellent support by *Operation Deep Freeze,* which is presently under the able command of Rear Admiral J. Lloyd Abbot, Jr.

It is easy to succumb to the temptation to point out the more spectacular accomplishments of a season's work. Quite often it is forgotten that the more tedious, painstaking, and nonspectacular projects may be the more rewarding ones in the long run. For example, little by little, the Continent is being "inventoried" geologically and biologically, and its ice surface, lower and upper atmosphere, and even its subsurface are being mapped. Not forgotten are the long cruises of the research ship *Eltanin,* whose work, together with that carried out continuously at home laboratories, will be the subject of the next issue of the *Antarctic Journal.*

Large-scale interdisciplinary field parties have become a USARP tradition since the 1965–1966 season. The second part of the Marie Byrd Land Survey was successfully completed in the face of adverse weather conditions. More fortunate with respect to the weather was South Pole—Queen Maud Land Traverse III, which completed what may have been the last of the major U.S. oversnow journeys into the unknown areas of Antarctica. In the Weddell Sea, an icebreaker-supported oceanographic and biologic expedition (IWSOE-1968) carried out a survey of a large portion of this huge body of water, much of which had never before been studied. All of these projects are dealt with in detail in the following pages. Touched upon only lightly, however, is the fact that international cooperation was an ingredient of each of them. In the case of IWSOE-1968, it involved the participation of foreign scientists as well as the use of other nations' equipment and facilities. In the case of the other field parties and the fixed stations, foreign scientists either cooperated in achieving overall party objectives or carried out independent investigations. In return, other nations afforded U.S. scientists similar opportunities to do research at their stations.[2] The continued maintenance of these exchanges since 1957 has been an extremely satisfying facet of the antarctic program.

It is also gratifying to note the efforts made in two hemispheres during the past antarctic summer to enhance the future potential of USARP. While the Seabee detachment at Palmer Station, with invaluable assistance from crew members of *Southwind,* was erecting the permanent Palmer Station on Anvers Island, the 125-foot wooden trawler *Hero* was nearing completion at South Bristol, Maine. The ship was launched in March, after which she was fitted out and taken on several shakedown cruises in the North Atlantic. In the northern fall, *Hero* will turn southward toward the Antarctic Peninsula and her home port at Palmer Station.[3]

At present, a number of new techniques are under development to facilitate and enhance the productivity of scientists who will conduct studies in the future. For example, a data-handling system is planned for the replacement South Pole Station, an engineering-feasibility study of automated stations has been completed, and the use of submersibles is under consideration. These and other steps are being taken to maintain the vigor of the U.S. Antarctic Research Program in the years to come.

A recent development with respect to conservation, a theme of consistent significance in antarctic affairs, occurred at the meeting of the Antarctic Policy Group (APG) on June 26. Following up on its action of the past year, when it promulgated policy measures for the management of tourist groups, including the extension to tourists of the application of the Agreed Measures for the Conservation of Antarctic Flora

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[2] Cf. *Antarctic Journal,* vol. III, no. 3, p. 63–64 for a list of 1967–1968 exchanges.

[3] Cf. *Antarctic Journal,* vol. III, no. 3, p. 53–60.

and Fauna, the APG this year established as official policy for U.S. citizens in Antarctica the recognition of 15 Specially Protected Areas and 2 Specially Protected Species. These measures were recommended to governments at the Fourth Antarctic Treaty Consultative Meeting in November 1966 following their formulation by the nongovernmental international Scientific Committee on Antarctic Research.

The adoption of controls over the specially identified species and areas means that permits for the collection of a Specially Protected Species or for the collection of native plants in a Specially Protected Area will be issued only for compelling scientific reasons and then only when collections do not jeopardize the existing natural ecological system or the survival of the species.

This extension of the principles of conservation and the preservation of living resources in the Antarctic is welcomed by scientists and others concerned with the inroads of man on the ecological balance of the south polar regions. The philosophy of the Agreed Measures and the dedication of the Treaty Nations to their fulfillment have been greeted as a significant reversal of the historical succession of exploitation, concern, and tardy protection of a nearly depleted natural resource.

International Weddell Sea Oceanographic Expedition—1968

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Until a few months ago, virtually all knowledge of the Weddell Sea was limited to its periphery. Except for a few observations that had been made along the drift tracks of Wilhelm Filchner's *Deutschland* (1911–1912) and Ernest Shackleton's *Endurance* (1914–1916), waters of the central and western regions of the sea remained largely unknown. With the completion of the first phase of the International Weddell Sea Oceanographic Expedition (IWSOE–1968), knowledge of the physical and biological properties of the sea underlying this hitherto impenetrable ice cover has been greatly expanded.

The U.S. Antarctic Research Program's interest in obtaining oceanographic data in the Weddell Sea dates back several years. Initial plans called for ski-equipped airplanes or icebreaker-borne helicopters to place field teams on the sea ice to drill holes and lower sampling equipment by means of portable winches. Operational difficulties of this approach led to the present concept of an international, multidisciplinary, two-icebreaker oceanographic survey conducted during two austral summers.

The United States assigned to the undertaking its most powerful icebreaker, USCGC *Glacier* (WAGB–4), commanded by Captain O. L. Dawson, USCG, and Argentina provided the icebreaker ARA *General San Martín*.

For service as a research platform, *Glacier* was modified to accommodate five laboratories, an expendable bathythermograph launcher and recorder, a Salinity-Temperature-Depth (STD) winch and recorder, a hydrographic winch, a special luffing crane, a PDP–8S computer, a Precision Depth Recorder, a satellite navigation system (SRN–9), an Automatic Picture Transmission (APT) system for recording satellite photos, and a hastily assembled trawl winch. The APT was backed up by satellite-photo ice analysis provided by the Environmental Science Services Administration. Arrangements were made for some of the research data to be relayed to the United States by communication satellite.

General San Martín also was equipped to make STD measurements and to carry out other physical oceanographic studies on a limited basis.

The primary objective of IWSOE–1968 was to place four Norwegian instrumented buoys on the Weddell Sea's continental slope to measure, for a period of one year, the temperatures and deep currents that are believed to be associated with the formation of antarctic bottom water. In addition, a minimum of 53 oceanographic stations were planned for occupation over the two-year period in order to provide a reasonable evaluation of the physical and biological characteristics of the sea. These stations, which were selected to permit investigation of the waters of the continental shelves, slopes, and deeps at average intervals of about 100 nm, were plotted without regard to ice concentration. The studies carried out were of primary productivity (Texas A&M University), benthic zonation (University of Connecticut), sub-ice productivity (University of Miami), sedimentation (Florida State University), trace metals (Yale University), and seal populations (University of Minnesota). The Coast Guard Oceanographic Unit (CGOU) obtained hydrographic data, bottom photographs, cores, and samples for trace-metal analysis.

*USARP Representative on the expedition.

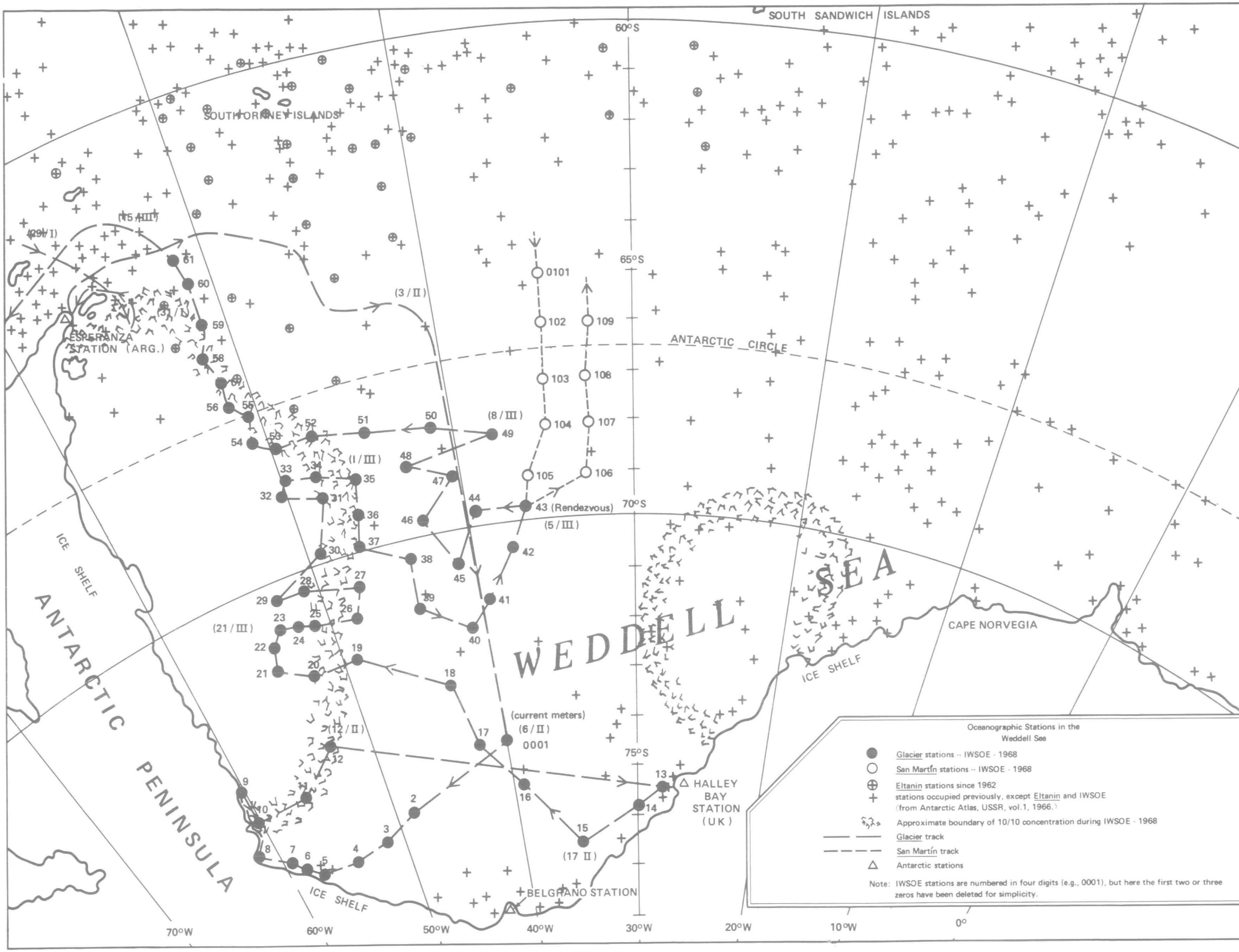
Oceanographic station summary (IWSOE–1968).

Station	Ice conc. (10ths)	Depth (m)	Nansen cast (m)	STD (m)	Primary productivity: Secchi disk (m)	Sub photo-meter used	Vertical plankton tow	Van Dorn cast	Bottom photo	Cores (cm)	Sub-ice productivity: Light reading	Water sample	Ice sample	Benthic zonation sampling gear	Seal/penguin blood sampling [1] (retained specimens in italic)
0001	6	650	629		13		X	X	[2]		X			Epibenthic sled, anchor dredge.	4 crabeaters.
0002	6	544	515	515			X	X		44.5			X	Epibenthic sled.	2 Weddells. 1 crabeater
0003	9	503		458	42	X	X	X							
0004	4	476		392											
0005	0	450	434	434	12	X		X	[2]	[2]		X	X	Epibenthic sled,[2] Van Veen grab.	1 Adelie
0006	0	360	319	319											
0007	6	433	380	380											
0008	6	640			03		X	X					X		1 *crabeater*
0009	9	603		456										Van Veen grab.	
0010	8	604	566	566	09		X	X	[2]						
0011	10	454	415	415	21		X	X	B&W	30.48		X		2 Blake trawls.	4 Weddells. 2 crabeaters
0012	9	421		400											
0013	5	507	499	499	24	X	X	X	Col/B&W	20.3/43.8/ 21.6	X	X		Blake trawl,[2] Van Veen grab.[2]	
0014	5	243		194	24		X	X							
0015	0	768	518	518											
0016	0	384	356	↑	21	X	X	X	B&W	39.37/45.22					
0017	1	695	597						B&W						
0018	4	1,926	1,869		20	X	X	X	B&W	51.34/52.32	X	X		Epibenthic sled, anchor dredge.	2 crabeaters.
0019	8	2,008	2,003		24		X	X	B&W	55.88/70.61	X				5 crabeaters.
0020	9	1,472	1,333												
0021	10	1,780	1,775		23		X	X	[2]	65.02/70.61		X			
0022	10	2,315	2,310	[3]	24		X	X	[2]			X			3 Weddells.
0023	10	2,561	2,545						B&W						
0024	10	2,551			25		X	X				X			1 crabeater. 1 *emperor*
0025	9	2,926	1,103				X								
0026	4	3,142	2,935		17		X	X		88.0/25.5		X		Epibenthic sled.[2]	
0027	7	3,173	1,035												
0028	9	3,264	3,260		31.5		X	X				X		Van Veen grab.[2]	2 crabeaters. 1 Adelie
0029	9	3,167	959												2 *emperors* 2 *Adélies*
0030	9	3,655	3,649	↓			X								
0031	9	3,440	1,000/3,434		26		X	X	B&W			X			7 crabeaters.
0032	10	3,535	1,000/3,532	2,000	39.5		X			Double Core.[2]		X			
0033	10	3,512		3,000											
0034	9	3,475	500		44.5		X	X				X			
0035	9	3,877	2,066						Col						
0036	9	3,884	1,024	2,000	31	X	X	X				X			1 Weddell, 3 crabeaters.
0037	10	3,861	3,855	2,000						Double Core.					
0038	10	3,713	1,015		19.5	X	X	X						Anchor dredge.	
0039	8	3,432	3,428	2,000				X							
0040	9	3,371	1,018		22	X	X	X			X	X		Anchor dredge.	2 crabeaters
0041	8	3,895	1,000/3,890	2,000			X	X							
0042	1	4,023	1,000/4,013		13	X	X	X			X	X		(Mid-water trawl.)[2]	2 crabeaters
0043	0	4,219	1,150/4,213	2,000											
0044	0	3,995	988		13.5	X	X	X		Double Core.				Anchor dredge.	
0045	0	3,887	1,000/3,881	2,000			X	X	B&W						
0046	0	3,877	1,006		13.5	X	X	X						(Mid-water trawl.)	
0047	0	4,178	1,000/3,615	2,000			X	X		112.0					
0048	0	4,133	1,020		20	X	X	X							
0049	0	4,404	1,000/4,401	2,000										(Mid-water trawl.)	
0050	0	4,279	1,000		34	X	X	X							
0051	9	3,713	1,000	3,100											
0052	9	3,838	1,000/3,828	1,000	38	X	X	X		81.28/83.82	X	X		Anchor dredge.	1 crabeater.
0053	9	3,585	1,014		46	X	X	X			X	X			
0054	10	3,663	1,000/3,658	2,000			X	X	B&W						
0055	9	3,338	1,014		43	X	X	X			X	X	X	Biol. bot. trawl.	
0056	9	3,109	1,000/2,931	3,000			X	X		81.28/86.36					
0057	9	3,210	929			X	X	X			X	X			
0058	9	3,219	1,321/3,200				X		B&W						
0059	9	3,146	1,013		21.5	X	X	X				X			
0060	9	2,487	1,000/2,100	2,420	34	X	X		Col/B&W	93.34/74.93				Anchor dredge.[2]	1 Weddell. 1 *Weddell*
0061	8	1,317							B&W						

[1] Three crabeaters were sampled and retained before reaching station 0001, and one leopard seal and five elephant seals were sampled after leaving station 0061 (the leopard seal was retained).

[2] Attempt unsuccessful.

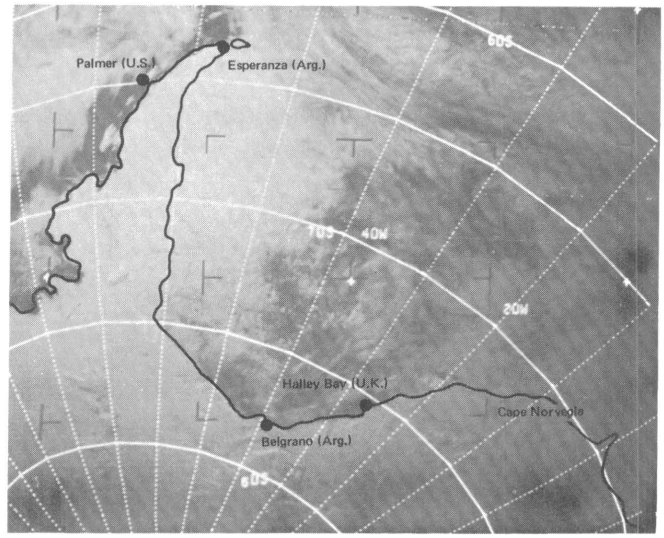
[3] STD inoperative from station 0016 through station 0030.


SOUTH SANDWICH ISLANDS
SOUTH ORKNEY ISLANDS
ESPERANZA STATION (ARG.)
ANTARCTIC CIRCLE
WEDDELL SEA
ANTARCTIC PENINSULA
ICE SHELF
CAPE NORVEGIA
HALLEY BAY STATION (UK)
BELGRANO STATION
(current meters)
(6/II)
0001
43 (Rendezvous)
(5/III)
60°S
65°S
70°S
75°S
70°W
60°W
50°W
40°W
30°W
20°W
10°W
0°
Oceanographic Stations in the Weddell Sea
Glacier stations -- IWSOE - 1968
San Martín stations -- IWSOE - 1968
Eltanin stations since 1962
stations occupied previously, except Eltanin and IWSOE (from Antarctic Atlas, USSR, vol.1, 1966.)
Approximate boundary of 10/10 concentration during IWSOE - 1968
Glacier track
San Martín track
Antarctic stations
Note: IWSOE stations are numbered in four digits (e.g., 0001), but here the first two or three zeros have been deleted for simplicity.

Oceanographic stations in the Weddell Sea.

←

One of numerous satellite photos used in ESSA's analysis of ice conditions in the Weddell Sea during IWSOE–1968. Heavy concentration of ice in the western region is prominent (see chart on facing page). Outline of continent has been added. (Photo taken by ESSA–3 satellite, orbit 6,233, frame 11, February 10, 1968.)



(Photo by ESSA)

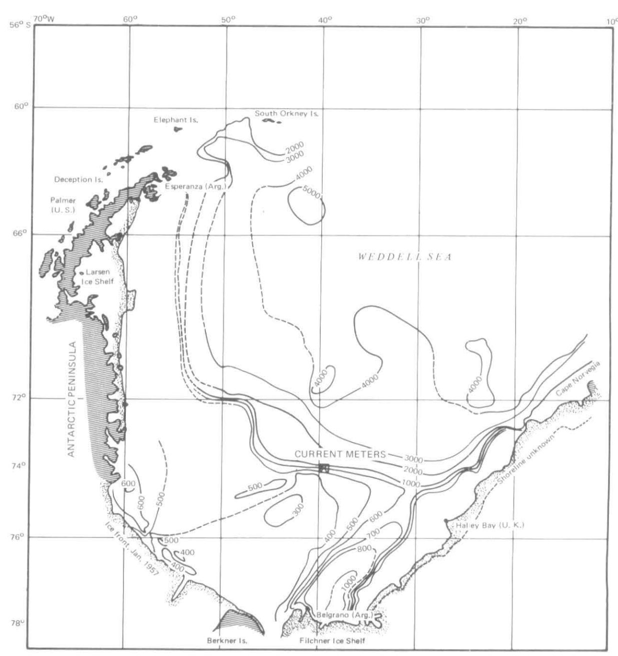
Analyses of sea-ice conditions from satellite photos made prior to the commencement of IWSOE indicated the possibility that less ice would be present during the 1967–1968 austral summer than had been expected. Therefore, it seemed prudent to attempt to complete, in the first season, those stations planned for the areas considered to be perennially covered by ice, since it might prove to be more difficult to penetrate them the following year. It was expected that *Glacier* would be able to occupy about half of the proposed stations during the period planned for the 1968 expedition (from January 20 to March 15).

Glacier's departure from Punta Arenas, Chile, where 12 USARP and 8 CGOU participants boarded the ship, was delayed six days to await the arrival of a multiple water sampler that was to be attached to one of the bottom-water current meters. Surface samples and temperature measurements were obtained in the Drake Passage and the Scotia Sea. Two rendezvous were made with *San Martín* to exchange scientific information—one at Esperanza Station and the other at station 0043. During the ship's passage through the Weddell Sea, four large, tabular icebergs encountered at widely spaced intervals were marked for possible charting of their later movements.

After an intensive bathymetric survey to confirm the configuration of the continental slope at approximately 74°S. 40°W., the four Norwegian current meters were emplaced at station 0001. Attached to one of the arrays was the water sampler, set to collect a sample of water every 10⅔ days.

After completing station 0012, the schedule was interrupted for a few days while *Glacier* proceeded directly to Halley Bay in response to a medical emergency.

Considerable revision of the proposed station schedule was necessary when progress was slowed by ice conditions or lengthening periods of darkness as the ship steamed northward. The schedule was gradually changed to one which allotted two hours at Local Apparent Noon (LAN) for collecting data on productivity and eight hours at night for making Nansen casts and obtaining STD data, bottom photography, and cores. In addition, both scuba divers and seal-



(Compiled by T. Kvinge)

Preliminary bathymetric chart of the Weddell Sea. Isobaths are based on satellite navigation (SRN–9) fixes and temperature-corrected echo soundings.

census parties were placed on floes by boat or helicopter. Trawling operations and seal-census flights were carried out as opportunities arose.

In all, *Glacier* and *San Martín* occupied 70 stations, which was more than twice the number planned for the first season. The information obtained (the types of which are indicated for each station in the table) will become available, after refinement and filing, through the National Oceanographic Data Center. Because the data were collected at locations precisely fixed by satellite navigation, their value is expected to be considerably greater than would have been the case otherwise.

Among the numerous side benefits of the expedition were the compilation of an updated bathymetric chart of a large part of the Weddell Sea and the development of techniques for obtaining significant quantities of physical data even where 10/10 concentrations of ice were encountered. About 80 percent of the 5,000 nm covered by *Glacier* in the Weddell Sea were through ice, and 90 percent of the stations were occupied in areas where no oceanographic research had been conducted previously.

IWSOE–1969, which will commence early next January, will have as its objectives the retrieval of the submerged buoys, further collection of data from the waters under perennial ice, and extension of the survey grid to the southwestern and northeastern portions of the sea. The cruise, which is expected to be of 12 weeks' duration, will consist of two parts—the first into areas of heavy or medium ice concentration, and the second into areas of light ice concentration. In addition to the scientific equipment *Glacier* now carries, she will have gear for taking deep cores, which should enhance the geologic potential of next year's phase of the expedition.

Descriptions of projects conducted during IWSOE–1968 are given in the following articles.

Investigations of Currents Related to the Formation of Antarctic Bottom Water

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University of Bergen

and

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Antarctic bottom water is formed principally in the southwestern part of the Weddell Sea. It is a mixture of warm deep water and water formed on the continental shelf. The shelf water gets its particular properties by vertical convection due to cooling and ice formation. Owing to the nonlinear dependency of density of sea water on temperature and salinity, the processes determining the formation of bottom water are hampered or even prevented until a certain stage has been reached. The formation of bottom water may, therefore, appear as a sudden flow, with related strong, or at least perceptible, current speed.

Opportunity for performing investigations of these conditions was provided by the National Science Foundation through arrangements it made for the authors to participate in IWSOE–1968.

The investigations were based on four submerged buoy stations, each consisting of instruments set to measure temperatures and current speeds and directions at one-hour intervals. The battery and tape-storage capacities of the buoys are sufficient to record about 14 months of observations. One of the buoys was equipped with a multiple water sampler provided by Professor H. Stommel of the Massachusetts Institute of Technology. The water sampler was programmed to take one sample each 10⅔ days in Pyrex containers free of bacteriological or metallic-ion contamination.

The buoys were placed on the continental slope near 74°S. 40°W. at a depth of about 700 m. All instruments were located about 20 m above the bottom, and each buoy was equipped with an acoustic release mechanism, which will free the anchor weight when triggered to do so.

Provided that the recovery of the instruments is successful in IWSOE–1969, it is expected that the data will give valuable information on the formation, magnitude, and extent of antarctic bottom water.

U.S. Coast Guard Oceanographic Unit's Participation in IWSOE–1968

ROBERT B. ELDER

U.S. Coast Guard Oceanographic Unit
Department of Transportation

The Coast Guard Oceanographic Unit's program in IWSOE–1968 consisted of physical oceanographic measurements, nutrient and pH determinations, bottom photography, and gravity coring. This work was planned to augment or supplement other programs sponsored by the National Science Foundation.

Nansen Bottle Casts. Nansen casts were made at 52 locations to determine the water's temperature, salinity, and pH, and to measure its nitrite, phosphate, silicate, and ammonia content. Temperatures were measured at each observational level by pairs of well-calibrated and protected reversing thermometers, and at alternate levels below 15 m by pressure thermometers. Salinity was determined by a Bissett-Berman model 6220 inductive salinometer. Dissolved oxygen was determined by a modified Winkler method. A Beckman model-G pH meter was used to measure pH. Nutrient analyses were performed according to methods described in Strickland and Parson's *A Manual of Sea Water Analysis.* Because the spectrophotometer used to perform the nutrient analyses became inoperative during the cruise, some samples were not analyzed aboard ship but were frozen for later study at the Coast Guard Oceanographic Unit. Additional samples were frozen and retained for trace-metal analysis. Particular care was taken to select the proper sampling levels so that no significant inflection points would be missed. At most stations, samples were obtained at closely spaced intervals immediately above the bottom in order to detect any changes in the parameters that might be associated with those levels.

Salinity-Temperature-Depth (STD) System. A continuous trace of salinity and temperature versus depth was obtained at 29 stations by means of a Bissett-Berman model–9006 STD recording system. At 20 of these stations, Nansen casts were also made. In addition, a Nansen bottle was attached to the STD wire just above the sensor unit in order that a comparison could be made between the salinity and temperature recorded by the STD and by laboratory salinometers and reversing thermometers.

Bottom Photography. Compass-oriented bottom photographs were taken at 13 locations on the shelf, slope, and rise of the western Weddell Sea. A Thorndike-type bottom-contact camera was used. The trigger wire and lens were adjusted for close-up oblique photography, each frame revealing the form of the bottom over an area of about 3 m^2. The most obvious features revealed by the photos are signs of animal activity. However, of equal interest are the consistent orientation of current lineations and the deflection directions of sessile organisms, indicated by worm tubes and sea pens.

Gravity Cores. Gravity cores were taken at 14 locations. Two Alpine Geophysical Associates' model–210 gravity-coring rigs with four-foot barrels were attached to a bridle so that double cores could be obtained during each lowering. This procedure worked quite well in the soft bottom of the Weddell Sea. Generally, the cores were about three feet long. Analyses of the cores, which are being performed by Florida State University, should prove helpful in planning IWSOE–1969's enlarged geology program, which will include piston coring.

Operations in the ice. One of the most intriguing, and at times frustrating, problems of conducting an oceanographic program in ice concentrations such as those of the western Weddell Sea is that of setting the ship properly. Generally, the success of such an operation is inversely proportional to the ice concentration. In heavy ice, it was usually possible to ease into an opening and let the wind hold the ship against the ice on the downwind side. In ice that was not firm enough to keep the ship from drifting, the ice would frequently converge in the ship's "wake" and endanger any gear that was put over the side. Open pack presented the greatest difficulty because it was impossible to predict when floes would drift in and entangle or break the oceanographic cable.

Occasionally, it was necessary to maneuver the ship in a polynya to set her properly for oceanographic work. Obviously, this would greatly stir up the near-surface layer of the water column. Therefore, measurements made in the upper layers were performed late in the station procedure to allow the water column to return to a relatively normal condition.

Zonation of the Weddell Sea Benthos

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Marine Research Laboratory
University of Connecticut

and

BRUCE W. FOUND

University of Rhode Island

The objective of this project was to study the distribution of benthic organisms at different depths, primarily by means of an epibenthic sled and a modified anchor dredge. Ice conditions, rocky shallow bottoms, and soft ooze, as well as the occasional loss of a sled, necessitated use of other gear, including a Van Veen grab, a Blake trawl, and a small biological trawl. Physical data and photographs were provided through the courtesy of R. B. Elder of the Coast Guard Oceanographic Unit. All sediment samples were washed through sieves, the finest of which had a 0.42-mm mesh. All macroscopic organisms were identified to the group level and preserved for future analysis. Fine, medium, and coarse sievings were also preserved.

Eleven stations were occupied successfully. Results indicate the existence of two major zones that have distinct physical and biological characteristics.

The first zone is near the ice shelf at depths of 400–1,000 m. It is characterized by a hard bottom consisting of material ranging from fine sand to large boulders. Its average temperature was —1.90° C., and its average salinity, 34.7‰. A great number and variety of relatively large animals were observed in this zone.

The second zone extends from a depth of 1,000 m to more than 4,000 m. The bottom is made up of soft ooze, pebbles, and a few small stones. The average bottom temperature was —0.70°C., and the average salinity, 34.6‰. Few numbers and kinds of relatively very small animals (except Foraminifera, some of which were about 3/4-inch long) were observed.

Representatives of 36 classes or orders were collected in the shallow zone, but only 7 were taken from the deeper zone (sievings not included). Siliceous sponges, which are common to all depths, make up the largest faunal component of each zone. Gorgonaceans, ophiuroids, echinoids, polychaetes, isopods, and amphipods compose the largest segment of the remaining fauna in the shallower zone. Foraminifera, amphipods, ophiuroids, and polychaetes make up the largest remaining part of the deeper zone.

Bottom photographs not only corroborate these observations but provide information on behavior. About 350 pounds of preserved material was returned to the university.

Population Dynamics of Antarctic Seals (IWSOE—1968)

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The January-March 1968 cruise of USCGC *Glacier* in support of the first phase of the International Weddell Sea Oceanographic Expedition provided an opportunity to obtain estimates of seal and bird densities over the pack ice of the Weddell Sea. This study represented the beginning of a project aimed at providing information on the population dynamics of antarctic seals.

Counts were made both from the ship and its HC-19E helicopters. All seals and birds (including penguins and flying birds) were counted within 1/4 of a mile of the ship as it passed through the ice. A total of 98 hours of census-taking was achieved, with counts being made for two hours at selected times throughout the day. Seven aerial censuses were taken from an altitude of about 90 m, and the numbers of seals and penguins sighted within 1/4 of a mile on either side of the flight line were tallied. Poor weather and the navigational range of the helicopters combined to limit the number of aerial transects that could be made.

The shipboard and aerial censuses showed that the crabeater seal (*Lobodon carcinophagus*) was by far the most numerous and widespread seal in the pack ice of the Weddell Sea (see table). This species was

Basic census data collected during IWSOE–1968.

Animal	Count and its percentage of total for animal group			
	From shipboard	Percentage	From helicopter	Percentage
Seals:				
Crabeater	879	95.5	260	82.0
Weddell	25	2.7	57	18.0
Leopard	15	1.6	0	0
Ross	1	0.1	0	0
Penguins:				
Adélie	6,571	95.2	1,733	93.1
Emperor	289	4.2	129	6.9
King	21	0.3	0	0
Chinstrap	23	0.3	0	0
Other Birds:				
Snow petrel	2,086	71.3		
Antarctic petrel	202	6.9		
Giant petrel	8	0.3		
Cape pigeon	27	0.9		
Wilson storm petrel	31	1.1		
Tern	567	19.4		
Skua	4	0.2		
Whales:				
Killer, sei, and rorqual	81			

contagiously distributed, a phenomenon which may be related to the animal's behavior and to regional differences in the abundance and availability of food. However, more detailed study is required to document the actual causes. Weddell seals (*Leptonychotes weddelli*), although encountered only infrequently, were most numerous in the southwestern portion of the Sea, 200–300 miles from the Filchner Ice Shelf. Leopard seals (*Hydrurga leptonyx*) have been reported to prefer the perimeter of the dense pack ice; true to prediction, this predator was sighted only on those few days when the ship was entering or leaving the northern reaches of the pack ice. Contrary to what has been suggested, the remote and heretofore inaccessible expanse of heavy pack ice does not appear to harbor substantial numbers of the Ross seal (*Ommatophoca rossi*). Only one individual was identified during the 42 days spent in the ice, and it was seen about 60 miles off the northern tip of the Antarctic Peninsula.

Another aspect of the seal-population study was the collection of blood samples from representative animals. *Glacier*'s helicopters and small boats placed the investigators on ice floes for this purpose. A Palmer Cap-Chur projector and a hypodermic syringe mounted on a six-foot pole were used to inject the central-nervous-system depressant Sernylan (phencyclidine hydrochloride) in combination with the tranquilizer Sparine (promazine hydrochloride) to anesthetize a total of 56 seals. Samples were collected from 37 crabeater, 13 Weddell, 5 elephant, and 1 leopard seals. The elephant-seal samples were taken while the ship was at Palmer Station. It had been intended to obtain at least 10 blood samples from each of the five species, but the seals' distribution was such that this goal could not be achieved. The samples collected last season and in future seasons will be analyzed by electrophoresis to determine if racial differences exist among the widespread populations of the Weddell Sea. The studies may disclose yet unknown phylogenetic relationships between these and other seals of the world.

The census data pertaining to 12 species of birds observed in the Weddell Sea are expected to provide valuable information on their densities and distributions. Preliminary results clearly indicate that among the penguins, the Adélie is the most ubiquitous and numerous. Among the flying species, the snow petrel (*Daption capensis*) was seen most frequently.

Thirteen blood samples were collected from emperor (*Aptenodytes forsteri*) and Adélie penguins for analyses similar to those to be performed on the seal samples.

Whales were seen as far south as 75°S. (at 52°W). As shown in the table, a total of 81 killer, sei, and southern rorqual whales was sighted.

Microalgae and Protozoa of Antarctic Pack Ice

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Our objective during IWSOE–1968 was to study the microalgae and Protozoa in the Weddell Sea pack ice during the period of greatest development and disappearance of these organisms. In addition, *in situ* observations were made of submarine ice conditions, light penetration of snow and ice was studied, and water samples were collected beneath and within the ice layer. For observation and collection, great dependence was placed on sensors and samplers hand-carried by scuba divers. Twenty-two stations were occupied within the ice.

Light energy within the visible spectrum was measured by a hand-held spectroradiometer; data were obtained on incident light, light reflected from the snow's surface, light transmitted through snow and ice, and light transmitted through open water to various depths between the surface and 7.5 m. Water samples were collected with hand-carried Van Dorn samplers at levels just below the ice surface and at a depth of 5 m. Algal cells in the samples were filtered for taxonomic analysis, pigment determination, and culture study. Laboratory measurements of the photosynthetic capabilities of microalgae based on C^{14} uptake were made by means of incubation equipment tested at McMurdo Station during the 1966–1967 season. Determinations of chemical and physical parameters (oxygen content, salinity, pH, alkalinity, and dissolved nutrient content) of seawater and meltwater were made aboard ship by the U.S. Coast Guard Oceanographic Unit. Aliquots of particulate matter recovered after filtration were frozen and returned to Miami for subsequent carbon analysis.

Productivity of the Weddell Sea

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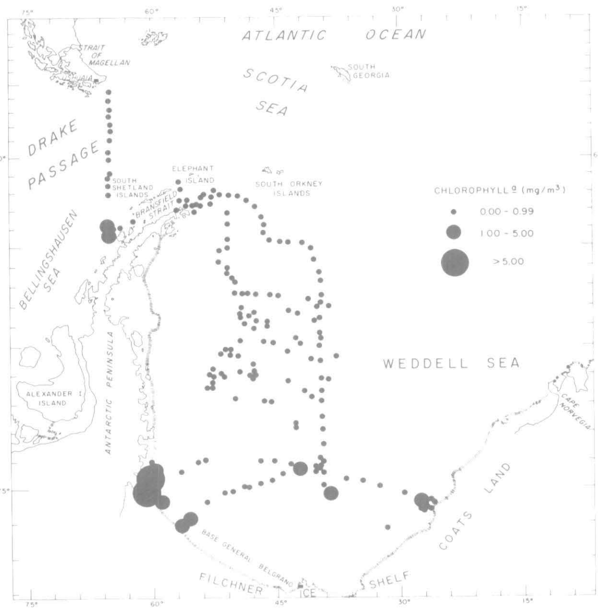
Although a biological-productivity investigation of the northern and eastern parts of the Weddell Sea was conducted by the author a few years ago, the IWSOE (January-March 1968) marks the first attempt to study the productivity of the virtually unknown southern and western parts of that sea.

A total of 40 stations was occupied at local apparent noon (LAN) in order to (1) determine light penetration in the water by means of a submarine photometer; (2) estimate the concentration of chlorophyll *a* and phaeophytin (the former is used as an index of the standing crop of phytoplankton); (3) estimate the photosynthetic activity of the phytoplankton, by means of the C^{14} uptake method, at various depths in the euphotic zone; (4) collect phytoplankton and zooplankton by means of vertical and horizontal tows; (5) determine the concentration of nutrient salts (phosphates, silicates, and nitrites) at various depths; and (6) collect water samples at various depths for quantitative study of the phytoplankton.

Preliminary analysis of the data indicates that despite conspicuous variations in the productivity of the



Distribution of surface chlorophyll a, *IWSOE-1968.*

areas visited, the southwest and western regions of the Weddell Sea are, by and large, far more productive than the central and southern regions.

On February 10, a very thick bloom of phytoplankton was encountered near the Filchner Ice Shelf. A conservative estimate of the area covered by this bloom is 15,500 km² (6,000 mi²). The bloom, which discolored the water and reduced the depth of the euphotic zone to only 9 m, was found to be composed mainly of the diatom *Coscinodiscus* sp.

Surface-water samples were collected by a plastic bucket at 160 localities between the LAN stations to determine the amount of photosynthetic pigments and the photosynthetic activity of the phytoplankton.

At present, the distribution, abundance, and photosynthetic activity of the phytoplankton are being correlated with the various biotic and abiotic environmental factors. Special attention is being given to such hydrographic features as the Antarctic Convergence, stability of surface waters, thermocline, and turbulence, which are known to affect the productivity of the water masses studied.

Marie Byrd Land Survey II

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For the second consecutive year, the largest scientific field operation conducted by the United States in Antarctica was the Marie Byrd Land Survey. This undertaking, a continuation of the program begun in 1966-1967, will require one more field season to complete. The purpose of the survey is to (1) provide a ground-control network for mapping, (2) produce a general geologic map of this large portion of West Antarctica, (3) designate areas for future detailed geologic study, (4) carry out detailed geologic investigations as time permits, (5) collect biological specimens, (6) produce a species-distribution map, and (7) determine the ice thickness and locations of geologic anomalies by means of geophysical measurements. The last study was not resumed during the second season because an improved instrument for determining continuous ice-thickness profiles was in the developmental stage and would be available in the near future.

Operations

The scientific party consisted of four topographic engineers, five geologists, three biologists, and a paleomagnetician. They were supported by 13 officers and men of the U.S. Army Aviation Detachment (Antarctica Support), a Navy aerographer, two Navy cooks, and a USARP field assistant.

Transportation in the field was provided by three UH-1D turbine-powered helicopters. Camps were spaced so most operations could be conducted within a radius of 100 miles (160 km), thereby eliminating the necessity of caching fuel between camps.

The surveys of the southern half of the Hobbs Coast sector and all of the Bakutis Coast sector were completed with the exception of Mount Siple and the island of which it is the major part.

In order to expedite operations, two sets of three Jamesway huts were provided. The first set was erected at campsite 1 by a Seabee construction crew assigned to the survey by Antarctic Support Activities. When it was ready, the scientific and support personnel moved in. The plan was to erect the second set at campsite 2 for work in that area, after which the construction crew was to move the buildings at camp 1 to campsite 3, and so on until all five planned sites had been occupied. By this method, the maximum time would be available for field operations. The procedure was intended to be flexible so

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that it could be modified as dictated by the weather and the progress of the field work.

The site for camp 1, on the east flank of the Ames Range, was chosen during a reconnaissance flight on October 21. Weather and communication difficulties delayed the construction of the camp, and it was not until October 29 that it was occupied by support personnel; the scientists moved in on the following day. A prolonged spell of bad weather prevented the start of surveying operations until November 16. Operations were possible, however, on 10 of the next 15 days, bringing to completion the geological and biological survey of that immediate area. After a reconnaissance flight by an LC-130F of the campsite 2 area, which included the Executive Committee Range and the USAS Escarpment, it was decided that a tent camp would suffice there. A fuel cache was laid down at the site by VX-6 and the tent camp established by helicopter from camp 1. Two occupations of the camp, one for five days and the other for four, sufficed to finish the work in that area. By December 12, all survey operations had been completed in the vicinities of camps 1 and 2, except around Mount Siple, which could not be reached because of bad weather in that coastal area.

On the basis of a reconnaissance flight made by an LC-130F on November 29, a site was selected for camp 3 a few miles north of Toney Mountain. The second set of Jamesway huts was erected by the Navy construction crew, and the camp was ready for occupancy on December 15. The move was made December 18-19 by means of three shuttle flights by an LC-130F. The three helicopters, their three pilots and three crew chiefs, and the topographic engineers remained at camp 1 in hopes that a break in the weather would make the survey of Mount Siple possible while camp 3 was being settled, but favorable conditions did not develop. As a matter of record, the weather remained poor or marginal until January 6, when operations were begun at camp 3. On New Year's Day, the 10 men left at camp 1 took advantage of a short break in the bad weather to make the flight to camp 3. The remaining equipment was transferred to that camp at a later date.

Although the time available for field work was growing short, maximum use was made of the helicopters during good weather, and the reconnaissance survey was completed in three days. The topographic and paleomagnetic surveys were continued until January 21, when the camp was evacuated.

Operations were conducted with a maximum of efficiency and a minimum of effort. Lessons learned during the first year of the survey in Marie Byrd Land provided the understanding necessary for proper planning and conduct of operations during the second season.

Scientific Programs

Except for the elimination of the geophysical studies, the scientific program was a continuation of the one begun in the 1966-1967 season.

Geological studies again were conducted by a team representing Texas Technological College and by two foreign exchange scientists. All accessible rock exposures in the two sectors were visited, studied, sampled, and mapped, with the exception of those on Mount Siple.

The botanical studies were continued by biologists from the Institute of Polar Studies, Ohio State University. The program included the collection of lichens, mosses, and algae. Rock-surface and meltwater temperatures were measured and recorded. Again, attempts were made to isolate airborne plant propagules at the base camps.

The Washington University (St. Louis) program of paleomagnetic investigations was continued, and many oriented specimens from a variety of localities were collected. The original program stressed a primary interest in Jurassic rocks. As there are no rocks of undoubted Jurassic age in these sectors of Marie Byrd Land, the program was expanded to include the collection of rocks of all ages represented.

The establishment of a ground-control network for aerial photographic mapping was continued by a team of topographic engineers from the U.S. Geological Survey. Whereas during the first season a continuous network was developed, during the second season disconnected networks, for which position control was provided astronomically, were established. This change was made because it would have been uselessly time consuming to survey the wide expanses of unbroken snow and ice encountered. On the scale at which the maps will be published, the accuracy of position determinations will not be reduced.

In the articles that follow, brief résumes of the individual programs (excepting the mapping program, which is described under "Cartography") are given by the investigators who conducted them.

Geology of the Hobbs and Bakutis Coasts Sectors of Marie Byrd Land

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The geologic portion of the scientific program again was the responsibility of investigators representing Texas Technological College. Included in the three-man party were two expert volcanologists:

Dr. Wesley E. LeMasurier of Cornell University and international exchange scientist Mr. Oscar González of the University of Chile, Santiago (Mr. González has devoted many years to the study of volcanic phenomena in Chile and on the Antarctic Peninsula.) The contributions of these men were invaluable because at least 75 percent of the ranges and isolated mountains investigated proved to be volcanoes that range in age from Tertiary to Recent. During the latter half of the season, a second exchange scientist, Dr. Boris Lopatin of the Institute of Arctic Geology, Leningrad, joined the team. In line with his specialty (igneous and metamorphic petrology), he contributed importantly to the discussions concerning the geology of the "basement complex."

No major differences were noted in the general geologic picture of this portion of West Antarctica from that investigated previously as far west as Cape Colbeck. However, the concentration and distribution of volcanoes in this sector are much greater than to the west. Many are aligned either in roughly north-south or east-west directions, indicating a possible distribution along fractures that are arranged in an orthogonal pattern.

A series of metasedimentary rocks which crop out in the Kohler Range resembles, superficially at least, that which is common in the Ford Ranges. The rocks consist of quartzites and metagraywackes that have been intensely folded. At the one good outcrop in the Kohler Range, the beds have a nearly vertical attitude, and the strike trends roughly east-west. Associated with them are granite-granodiorite intrusions which may be contemporaneous with those of Cretaceous age in the Ford Ranges. Of special interest are the medium- to high-grade metamorphics that crop out at Mount Petras, the Kohler Range, Bear Island (see figure), and Schneider Rock. It is believed that these and the ones previously studied in the Fosdick Mountains and the Mount Gray area are representative of the oldest rocks exposed in Marie Byrd Land. A more definite conclusion will have to await analysis of the field data and completion of the petrologic studies. Radiometric dates undoubtedly will prove helpful.

(Photo by F. Alton Wade)

"Basement" gneiss exposed at Bear Island.

Evidence is slowly accumulating which appears to substantiate the hypothesis that Marie Byrd Land is composed of segments of a disrupted portion of the Antarctic Continent. The presence of sphenochasms between the insular units is likely. It is hoped that the relationship of Marie Byrd Land to the Antarctic Peninsula will be clarified during the 1968-1969 field season. A comprehensive geophysical program that includes electromagnetic ice-thickness measurements and magnetic measurements of the entire area is recommended. No direct tie-in with the Ellsworth Mountains seems to be indicated.

Volcanic Geology of Central Marie Byrd Land

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The 1967-1968 Marie Byrd Land Survey traversed approximately 450 miles of the Hobbs Coast and Bakutis Coast sectors of Marie Byrd Land. Investigations of volcanic geology covered the Ames, Flood, and Executive Committee Ranges, Mounts Flint and Petras, Reynolds Ridge, the USAS Escarpment, Toney Mountain, the Crary Mountains, Mounts Takahe and Murphy, the Kohler Range, and Bear Island.

The volcanic section in this part of Marie Byrd Land is exposed at progressively higher stratigraphic levels as one proceeds from north to south. Exposed in the northern coastal mountains (the Kohler Range and Bear Island) are the prevolcanic basement of metamorphic and plutonic igneous rock and overlying thin, discontinuous sheets of basalt and tuff-breccia. Prevolcanic rock is sparingly exposed around the bases of Mounts Petras and Murphy and parts of the USAS Escarpment. It is overlain in these areas by a thick volcanic section. The more southerly ranges in this sector are composed entirely of isolated or coalescing composite and pyroclastic volcanoes.

Pyroclastic rock is the most widespread and the most voluminous rock type found at the base of the volcanic section. In some localities, lapilli-size fragments of glass and pumice are common, and lenses and pillow-like masses of crystalline basalt are intercalated with the pyroclastic rock. These deposits match descriptions of subglacially erupted volcanic rock in Iceland (Thorarinsson *et al.,* 1959; Saemundsson, 1967).

Mounts Murphy and Takahe are composed almost entirely of pyroclastic rock, whereas all other Marie Byrd Land volcanoes appear to be composite cones, built of tuff-breccia, antarctic kenyte (?), and various feldsparphyric intermediate and acidic lava flows. A few quartz-bearing rock types were found. Basaltic cinders, bombs, and flow rock comprise late parasitic cones on the flanks of most Marie Byrd Land volcanoes. These rocks contain phenocrysts of olivine and plagioclase and, occasionally, ultramafic nodules 2-30 cm in diameter.

The waning stages of volcanism in the Executive Committee Range have evidently extended into historic time. The caldera rim of Mount Hampton is partly encircled by snow-covered pinnacles and towers which very closely resemble inactive fumarolic ice towers that have been described and pictured from the summit of Mount Erebus (Holdsworth *and* Ugolini, 1965). In view of the fragile nature of these features, it is not unreasonable to assume that Mount Hampton is still weakly active.

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Biological Survey of Marie Byrd Land

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Poor weather curtailed biological sampling on the 1967–1968 Marie Byrd Land Survey, as it did on the previous year's survey. Although three base camps were established, the total number of field-sampling locations visited was approximately the same as it was last year. The types of life found at each location are listed in the table. (The author made collections in November, and R. Maigetter and D. Greegor continued the survey through January.)

At most localities above 3,350 m, no life could be detected. The highest altitude at which lichens were collected was 3,400 m on Mount Hampton. With one exception (Toney Mountain), algae were not found above an altitude of 600 m. Mosses were most abundant near sea level, but some were found at an elevation of 850 m near Leister Peak.*

The lichen and moss collections were dried and shipped to Ohio State University. Algal samples were collected in quadruplicate; three were placed in separate sterile disposable Petri dishes, each contain-

Types of life found at locations visited.

Locality	Coordinates [1]		Types of Life			
	S. Lat.	W. Long.	Algae	Lichens	Mosses	Petrels
Brandenberger Bluff	75°58′	136°05′	x	x		
Mt. Berlin	76°05′	135°50′		x		
Mt. Moulton (2,000 m)	76°00′	135°20′		x		
Mt. Moulton (3,000 m)	76°02′	135°15′	no life found			
Bowyer Butte	74°55′	134°50′		x	x	
Mt. Prince	74°55′	134°10′	x	x	x	x
Coleman Nunatak	75°18′	133°50′		x		
Holmes Bluff	74°55′	133°50′	x	x		x
N.W. of Mt. Andrus	75°45′	132°40′		x		
Mt. Andrus	75°50′	132°40′		x		
Mathewson Pt.	74°17′	132°30′	x	x	x	x
Mt. Kauffman	75°33′	132°20′	x	x		
Mt. Flint	75°45′	129°00′		x		
Mt. Petras	75°52′	128°30′		x		
Mt. Waesche (2,700 m)	77°12′	126°57′		x		
Mt. Waesche (3,600 m)	77°11′	127°00′	no life found			
Bennett Saddle	77°05′	126°30′	no life found			
Whitney Peak	76°23′	126°05′		x		
Boudette Peaks	76°50′	126°05′		x		
Mt. Sidley	77°07′	126°00′		x		
Mt. Hampton (3,400 m)	76°30′	125°58′		x		
Mt. Hampton (3,700 m)	76°27′	125°54′	no life found			
Mt. Cumming	76°41′	125°58′	no life found			
Mt. Rees [2]	76°37′	118°15′		x		
Mt. Frakes	76°48′	117°53′		x		
Mt. Steere	76°40′	117°30′		x	x	
Boyd Ridge [2]	76°54′	116°30′	no life found			
Toney Mt.	75°48′	116°25′	x			
Toney Mt.	75°48′	115°40′		x		
Siglin Rocks [2]	74°07′	114°40′		x	x	x
Schneider Rock [2]	74°05′	114°39′		x		x
Binder Rocks [2]	74°14′	114°38′		x		x
Morrison Bluff [2]	75°05′	114°15′		x		
Leister Peak[2]	75°09′	113°50′		x	x	
Mt. Isherwood [2]	74°56′	113°30′		x		
Mt. Strange [2]	74°54′	113°20′	x	x		
Jeffrey Head [2]	74°35′	111°45′	x	x		
Dorrel Rock [2]	75°25′	111°20′		x		
Turtle Peak [2]	75°22′	111°18′	x			x
Mt. Murphy	75°22′	111°07′	x			x

[1] The coordinates given are of actual collection sites and do not necessarily agree with those given in the antarctic gazetteer (U.S. Board on Geographic Names. *Antarctica,* 2nd edition, 1966).
[2] Unofficial name.

* Unofficial name.

ing one of three agar media, and the fourth was preserved in CRAF fixative. Samples of soil, as well as of obvious algal mats, were placed on culture media. All of the living cultures were shipped frozen and are now growing at Ohio State University in a controlled-environment chamber at 4°C.

Cultures prepared with material from all algal sampling localities contain specimens of chlorococcalean algae. *Prasiola crispa* was collected at both Mathewson Point and at Jeffrey Head.* *Chlamydomonas* sp. was collected only at the latter site. Cyanophyta, the most ubiquitous of antarctic algae, were present in samples from only 6 of the 10 collection sites. Samples from Mount Murphy were unique in that they contained large numbers of filamentous and flagellated Chrysophyte cells.

Owing to a malfunctioning telethermometer, temperatures were measured only in mid-November and early January. The measured maximum differential between the temperature of the air and of rocks upon which lichens were growing was 27.5°C. (air, −16°C.; rock, +11.5°C.) at 1930 local time on November 16. The maximum water temperature measured was +5.0°C. in a pond near Turtle Peak* on January 6. The air temperature was also +5.0°C. at that time.

The animal life observed was limited to snow petrels at eight locations and Adélie penguins at Mathewson Point. Although a concerted effort was made to collect arthropods by means of Berlese funnels, none were found.

* Unofficial name.

Paleomagnetic Investigations in Marie Byrd Land

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In a continuation of the project begun last year in Marie Byrd Land by Washington University, rock samples for paleomagnetic studies were collected during the 1967–1968 austral summer. Ninety-eight oriented specimens were collected, from which approximately 500 individual cores will be obtained for paleomagnetic measurements.

In the region of the first base camp on the Hobbs Coast, samples were collected at Koerner Bluff, Mount Moulton, and Brandenberger Bluff in the Flood Range, as well as at numerous sites along the western flank of the Ames Range. In addition, samples were taken from Coleman Nunatak, providing a link-up with the termination point of the studies conducted last season. The specimens collected in these areas appear to be basalts and andesites.

The Executive Committee Range yielded oriented samples of volcanic lavas and tuffs from Whitney Peak, Mounts Hampton, Waesche, and Cumming, and a sequence of progressively older rock at Mount Sidley. Additional samples were collected at Benes Peak and Mount Galla on the USAS Escarpment north of the Executive Committee Range.

The second base camp was located near Toney Mountain on the Bakutis Coast. Oriented samples were taken from basalts and tuffs on Spitz Ridge* of Toney Mountain, Turtle Peak* at Mount Murphy, at Boyd Ridge* in the Crary Mountains, and at several sites west of Morrison Bluff* in the Kohler Range. Samples of plutonic rocks and associated dikes were collected at Early Bluff,* Mount Isherwood,* and Mount Bray* in the Kohler Range; at Hunt Bluff and Jeffrey Head* on the Bear Peninsula*; and at Siglin Rocks* on the Martin Peninsula.

Because a large percentage of the oriented samples collected are basic volcanics, it is expected that the paleomagnetic data for them will be reliable and thus yield valuable information about the relationship of East and West Antarctica. Some preliminary suggestions as to this relationship have been made by C. K. Scharnberger and I. Hsu on the basis of a study of plutonic and basaltic dike rocks collected during the 1966–1967 field season along the Saunders, Ruppert, and Hobbs Coasts.

Based on samples of basaltic rocks obtained at four sites, the mean south virtual geomagnetic pole (VGP) is at 62°S. 64°E. These results are considered to be very reliable because of the high susceptibilities and strong remanence of the samples. The granitic rocks, on the other hand, generally have low susceptibilities and weak remanence. A gneissic granite from the Fosdick Mountains indicates that the south VGP is at 28°S. 140°W., which is about the same longitude but a lower latitude than the average position of Jurassic poles for East Antarctica (53°S. 139°W.). An adamellite from the Clark Mountains indicated a VGP at 22°S. 106°E., which is quite anomalous; the result is doubtful, however, owing to the very weak intensity of magnetization. Additional measurements of plutonic rocks will be carried out with more sensitive instruments.

Our preliminary results indicate that further studies must be made in order to fully elucidate the tectonic history of West Antarctica.

*Unofficial name.

South Pole—Queen Maud Land Traverse III

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Coast and Geodetic Survey
Environmental Science Services Administration

From December 5, 1967, to January 29, 1968, South Pole–Queen Maud Land Traverse (SPQMLT) III, a USARP geophysical expedition, crossed the largest remaining unexplored region of Antarctica—central Queen Maud Land (see map). The expedition may be the last of a planned series of traverses that began late in 1964 at the South Pole and crossed, zig-zag fashion, the sector of Antarctica bounded by the 60°E. and Greenwich meridians. Starting at Plateau Station, SPQMLT III covered 1,312 km (815 miles), ending at a point about 320 km (200 miles) northeast of the Shackleton Range. The nine-man party included researchers from ESSA's Coast and Geodetic Survey, the University of Wisconsin, Ohio State University, Belgium, and Norway.

Operations

A Navy reconnaissance flight made over the proposed route of the traverse in late November 1967 revealed extensive crevasses near the end point; other areas appeared to be free of such danger, however.

As on SPQMLT I and II, three diesel-powered Sno-Cats were used for transportation. Two of the Sno-Cats were outfitted with electronic and other equipment needed for research; the third was equipped with an ice drill capable of boring 10-cm holes to a depth of 50 m. Each vehicle had a single-sideband transceiver for intervehicle communication and contact with antarctic stations.

Fuel for the engines and for personnel heaters was carried in the large rubber "tires" of two modified Rolli-transporters. Food and supplies were hauled in 10 sleds of one- and two-ton capacities.

Originally, the traverse party consisted of 10 men—8 scientists and 2 engineers. On December 8, however, when the expedition was 80 km (50 miles) out of Plateau Station, one of the scientists became ill and had to be returned to the station, reducing the number to nine.

When about 320 km (200 miles) from Plateau Station, the party came upon a large Russian sled that had been left behind by a Soviet expedition during a journey from Plateau Station to Novolazarevskaya in March 1967. The sled, which is similar to one the Russians left at the Pole of Inaccessibility early in

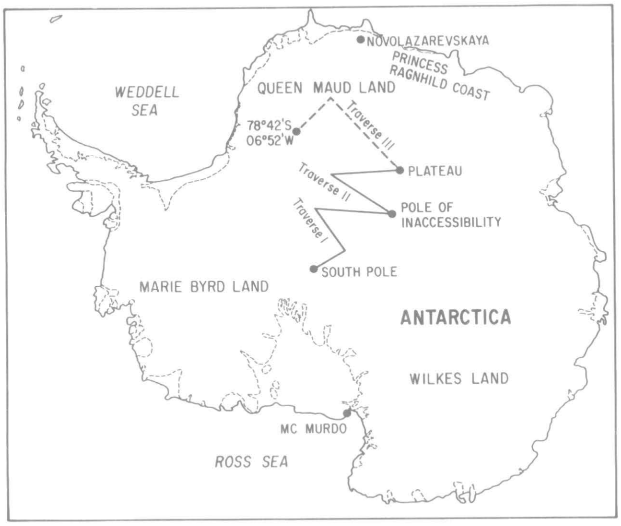
(*Photo by author*)

Rossman Smith lowers a radioactive density probe in a 50-m-deep hole.

(*Photo by author*)

Yngvar Gjessing measures surface density with a Rammsonde.

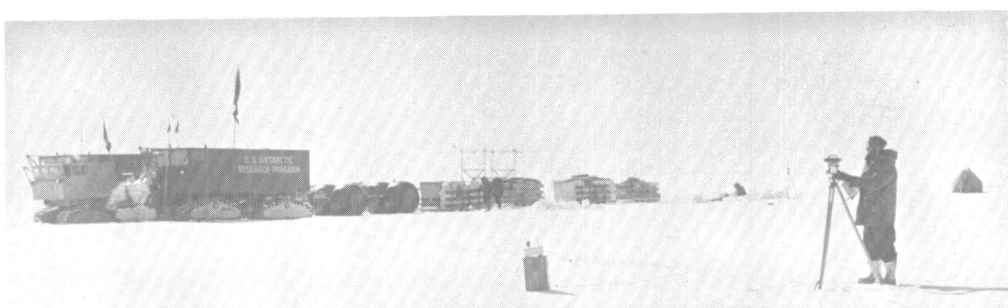
[1] Traverse leader



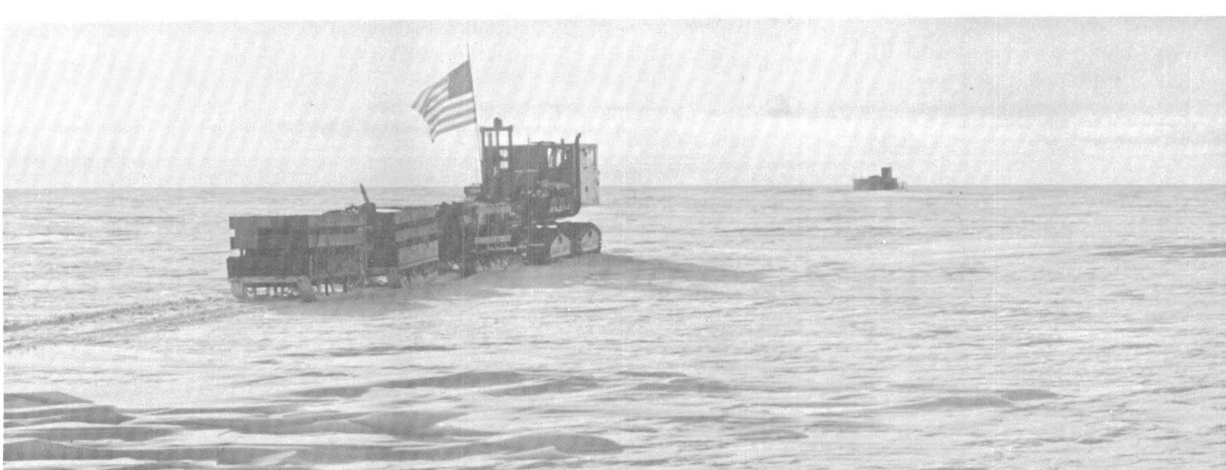
Route of SPQMLT III (indicated by dashed line). Routes of Traverse I (1964–1965) and Traverse II (1965–1966) are shown by solid lines.

(All photos by author)

Arthur Rundle makes a snow-density measurement.



The author measures the geomagnetic field with a portable flux-gate magnetometer.



Tractor approaches an abandoned Soviet drill sled.

1964, is essentially a large wooden shelter on iron runners that houses a drilling rig and sleeping quarters.

On three occasions, the expedition was resupplied with fuel and parts needed to repair equipment. The supplies were air-dropped to the party by Navy LC–130 aircraft from McMurdo Station.[2] A special radar beacon, loaned by the Navy, helped guide the aircraft to the party's location. Cairns, built of empty fuel drums, were erected at the sites of the airdrops.

No unusual topographic features were discovered. The terrain was generally flat, and its surface layer consisted of hard-packed snow. The weather was favorable, the temperature ranging from −40°C. to −10°C. and the wind rarely exceeding 10 knots. Severe whiteouts occurred during the final week of travel. Vehicle breakdowns cost considerable travel time, but outstanding work by the two engineers kept the loss as low as possible.

On January 30 and 31, SPQMLT III ended when the personnel, equipment, snow samples, and one Sno-Cat were airlifted to McMurdo Station on two flights by Navy LC–130 aircraft.

Scientific Procedures

Weather observations were made every six hours during the period of the traverse. A profile of the ice cap's thickness was obtained en route by means of a continuously recording radio-sounding device. Every 8 km (5 miles), the traverse halted for a few minutes to permit measurements of local gravity, surface elevation, snow density, and snow-accumulation rate.

Every 65 km (40 miles), a major station was established at which the following investigations were made: (1) The geographic position of the station and a true bearing were determined by celestial observations; (2) the intensity and direction of the magnetic field were measured; (3) a 50-m hole was drilled and the temperature and density of the ice at selected depths were measured; (4) the thickness of the ice cap was measured by the seismic-reflection method; (5) a 3-m-deep pit was dug to obtain snow samples for later chemical studies; and (6) the near-surface stratigraphy, density, and accumulation rate of snow were studied and measured. At one of the major stations, a difficult seismic-refraction experiment was accomplished.

The scientific programs conducted on the traverse are discussed more fully in the following articles.

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[2] *Antarctic Journal*, vol. III, no. 3, p. 72.

Snow Stratigraphy and Accumulation (SPQMLT III)

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Institute of Polar Studies
Ohio State University

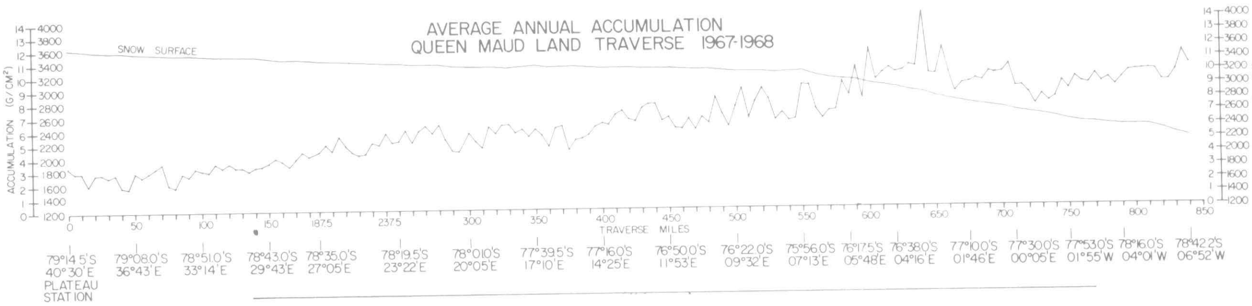
In order to establish a snow-stratification and accumulation reference for investigations to be conducted along the route of SPQMLT III, investigations of these factors were conducted during late November and early December at Plateau Station. Snow accumulation was determined by the remeasurement of the accumulation-stake network established there in February 1966.

The remeasurement of the stake network showed an average accumulation between January 21 and November 25, 1967, of 5.7 cm (Gjessing, personal communication). These stakes, when again inspected by E. E. Picciotto on January 17, 1968, showed an additional average increment of 0.3 cm (Picciotto, personal communication). At 10 snow pits, the stratigraphy revealed an extensive, hard, fine-grained (wind-packed) surface layer. This layer, which is interpreted as having been formed by high winds during mid-November 1967 (Dingle, personal communication), contrasts with the hard, summer "sintered" layer described by Koerner (1968). The density of this upper layer, which accounted for more accumulation than that precipitated during the year 1967, was determined as 0.364 g/cm^3, indicating an accumulation of 2.07 g/cm^2 for that year. Direct interpretation of the pit stratigraphy, however, revealed an accumulation of 3.39 g/cm^2, suggesting that a more extensive sampling program would have been desirable.

Along the traverse route, 168 shallow pits were excavated, one approximately every 8 km (5 miles), and examined for stratigraphic features and firn density.

The criteria used in determining the annual horizons varied along the traverse route. They consisted of hard layers, crusts, depth hoar, and texture changes (particularly in grain size and shape).

Numerous problems arose in the interpretation of the stratigraphy, the most notable being the frequent possibility of one year's layer being very thin or missing entirely as a result of erosion of the small annual increment. Thick layers, on the other hand, might be accounted for by redeposition. Frequently, the origins of the hard layers, hoar layers, and crusts were impossible to determine, and in many cases contradictory interpretations of the number of years represented in one section could be made. Periodically, however, an "indisputable" section was excavated, al-



Average annual accumulation, SPQMLT III

Mile	Accumulation (g/cm²)	Mile	Accumulation (g/cm²)	Mile	Accumulation (g/cm²)	Mile	Accumulation (g/cm²)
5	2.99	217.5	4.13	430	7.46	640	14.36
10	3.00	222.5	4.23	435	6.72	645	9.81
15	2.00	227.5	5.07	440	7.73	650	9.75
20	2.83	232.5	4.88	445	6.51	655	11.79
25	2.88	237.5	5.76	450	6.78	660	9.88
30	2.62	242.5	5.07	455	5.98	665	8.48
35	2.83	247.5	5.19	460	5.90	670	9.03
40	1.89	252.5	5.96	465	6.66	675	9.11
45	1.78	257.5	5.08	470	5.87	680	9.39
50	2.95	262.5	5.92	475	6.74	685	9.23
55	2.65	267.5	6.28	480	6.32	690	9.89
60	2.93	272.5	5.72	485	8.22	695	9.80
65	3.29	277.5	6.33	490	6.99	700	9.87
70	3.61	282.5	5.26	495	6.09	705	10.46
75	2.01	287.5	4.42	500	7.50	710	8.80
80	1.83	292.5	4.37	505	8.85	715	8.81
85	2.88	300	5.73	510	6.64	720	8.31
90	2.63	305	5.11	515	7.89	725	7.47
95	3.24	310	4.63	520	8.85	730	8.17
100	3.07	351	6.19	525	8.05	735	7.66
105	2.96	320	5.67	530	6.50	740	7.98
110	3.58	325	6.30	535	7.02	745	9.15
115	3.27	330	6.33	540	6.45	750	8.57
120	3.58	335	5.70	545	6.58	755	9.49
125	3.24	340	5.98	550	9.07	760	9.07
130	3.28	345	5.41	555	9.01	765	8.97
135	3.01	350	5.99	560	7.29	770	9.65
140	3.29	355	5.53	565	6.59	775	9.09
145	3.34	360	4.70	570	7.12	780	9.35
150	3.58	365	6.05	575	7.19	785	8.80
155	3.95	370	6.20	580	9.28	790	9.35
160	3.73	375	4.44	585	8.26	795	9.87
165	3.32	380	5.17	590	10.38	800	9.91
170	3.90	385	5.28	595	8.05	805	9.95
175	4.41	390	5.58	600	11.68	810	10.00
180	4.05	395	6.13	605	9.38	815	9.93
187.5	4.38	400	6.35	610	9.89	820	9.13
192.5	4.94	405	6.28	615	10.25	825	9.12
197.5	4.48	410	6.99	620	9.92	830	9.87
202.5	5.55	415	7.26	625	10.03	835	11.32
207.5	4.85	420	6.62	630	10.44	840	10.38
212.5	4.36	425	6.48	635	10.32		

lowing, by projection, an acceptable interpretation of the more confused sections. In this way, a value for the average accumulation over the past 2–5 years was calculated for each station (see table and figure).

These results conform with the expectation that accumulation increases with decreasing elevation and distance from the coast. The apparent levelling-off of the values toward the end of the traverse route, in spite of a continued loss of elevation, might be explained by the compensating factor of increasing distance from the coast.

The following overall conclusions have been drawn from the foregoing aspect of the glaciological program:

1. Modest reliability can be claimed for stratigraphic interpretations in this area of low annual accumulation, although the interpretations are by no means as reliable as those made at South Pole and Byrd Stations, where the accumulation is higher and the stratigraphy less complex.
2. Because of the complex stratigraphy, it is highly desirable to study several shallow pits at one site or to space the excavations more closely over the traverse route. The interpretation of deeper pits at widely spaced locations might not be possible without the shallow-pit investigations.

Acknowledgments. The author is grateful to Mr. Carl K. Poster, Geophysical and Polar Research Center, University of Wisconsin, for information on surface elevations along the traverse route. This program was supported under National Science Foundation grant GA-1076 to the Ohio State University Research Foundation.

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Ice-Thickness Investigations on SPQMLT III

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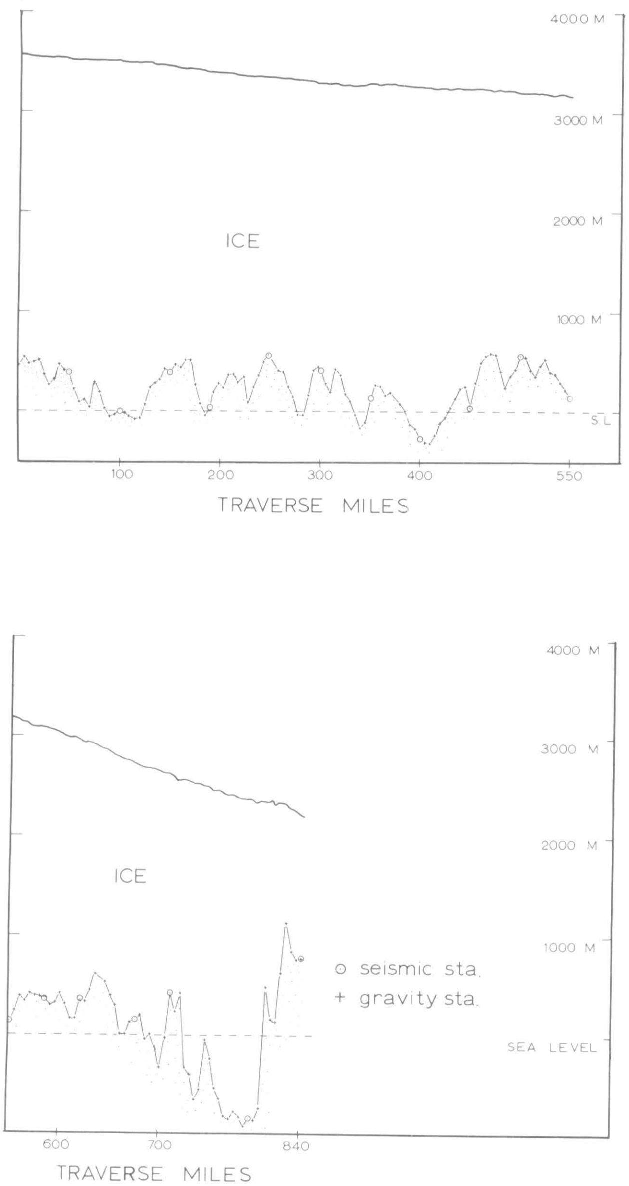
Elevations of the ice surface along the traverse route were measured with 11 temperature-corrected aneroid altimeters. Simultaneous altimeter readings were made at 8-km (5-mile) intervals, and nearly continuous readings were made with a single altimeter.



Ice-thickness profile, SPQMLT III.

Elevations ranged from 3,625 m above sea level at Plateau Station to 2,210 m at the terminal point (78°42′S. 06°52′W.) of the traverse. From Plateau Station to the turning point, the surface sloped downward at an average gradient of 1-2 m per 1.8 km. This gradient increased sharply on the southwest leg of the traverse. Two pronounced valleys, about 50 m deep and 10 km wide, and several smaller valleys were encountered near the end of the traverse.

Ice thickness was measured by both seismic- and electromagnetic-reflection methods. Vertical seismic reflections were obtained at 18 major stations to establish thicknesses, and gravity determinations were made every 8 km (5 miles) to provide detail between the major stations. The resulting profile is shown in the figure. For convenience, the profile has been divided at the turning point and presented in two portions that are roughly perpendicular to each other.

The electromagnetic sounding (EMS) system was monitored continuously, but bottom echoes were received over only one-third of the track. Strong reflections were received at Plateau Station and during the first 180 km (112 miles). From this point to mile 800, only occasional spots of thin ice yielded reflections. Three short refraction profiles and three wide-angle reflection profiles (one pair of which employed a common reflecting point) were established to determine the seismic-wave velocities in the ice. Of two long refraction profiles attempted, one yielded good arrivals for determining subglacial velocities.

Two detailed EMS wide-angle profiles were obtained in order to determine the electromagnetic-wave velocity structure in the first 1,200 m of ice. A third EMS wide-angle profile was made to determine the average vertical velocity for the ice column, the basis for all EMS profiling.

Near the end of the season, field tests were successfully carried out on a prototype digital EMS profiling system. This system was designed to record and store on paper tape the vertical travel time at selected intervals as well as to plot a chart of the ice thickness.

The strain network established during SPQMLT II in January 1966 was remeasured with Tellurometers in December 1967.

Magnetic Studies and Navigation (SPQMLT III)

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NORMAN W. PEDDIE

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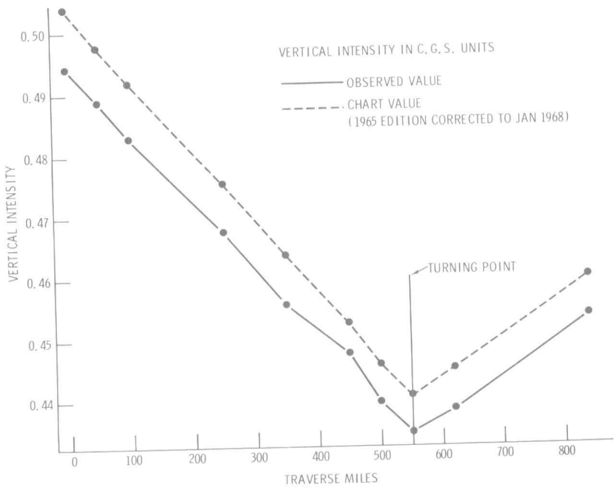
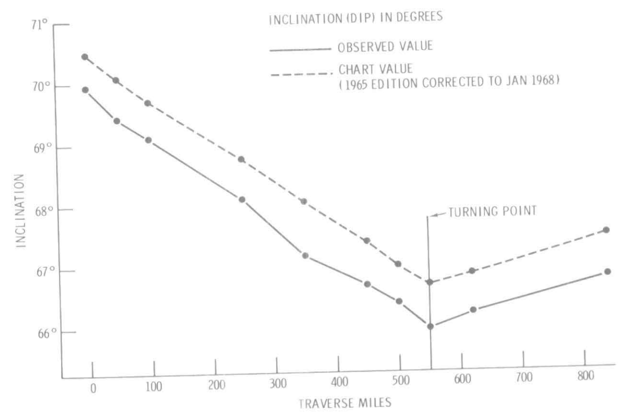
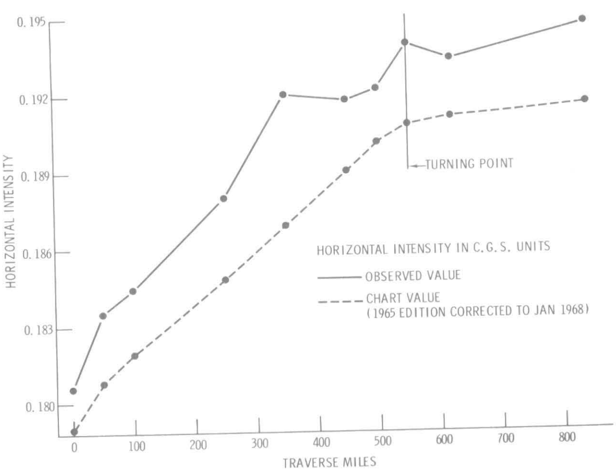
Environmental Science Services Administration

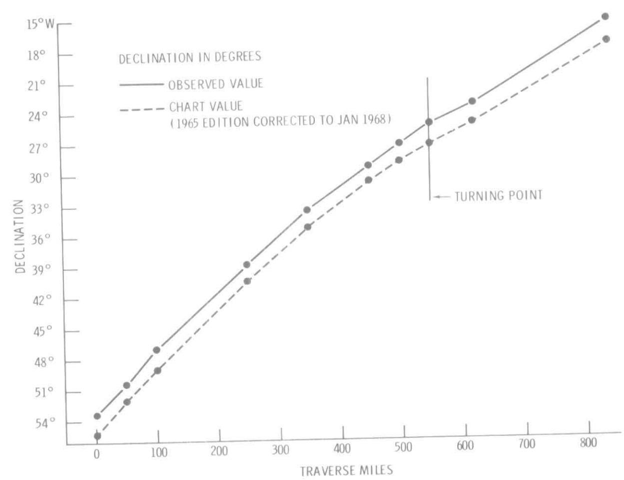
The third phase of the South Pole–Queen Maud Land Traverse has proved no less valuable than the first two phases in providing a truer description of the Earth's magnetic-field vector in vast areas of previously unexplored territory. Therefore, these data are a prized addition to the files of scientists and cartographers engaged in studying and mapping Antarctica's magnetic field. The 1970 version of the World Magnetic Charts, to be compiled by the Coast and Geodetic Survey and published by the U.S. Naval Oceanographic Office, will reflect considerably increased accuracy as a result of this traverse.

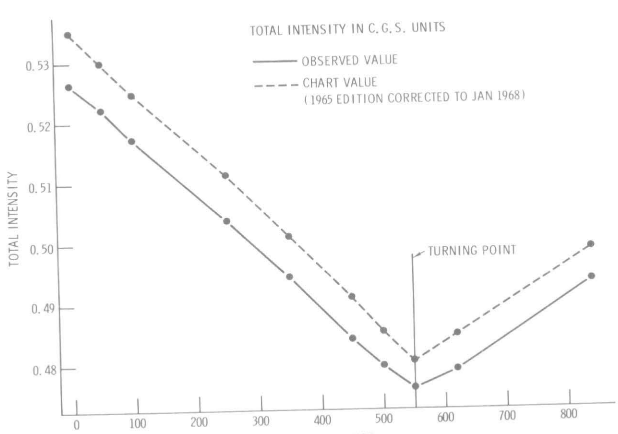
Although magnetic charts depicting the vector field to the highest degree of accuracy possible at the time of their preparation have been published at peri-











odic intervals for many years, only in recent years has the cartographer had good observational data from Antarctica on which to base scientifically sound judgment in describing the configuration and strength of the field. As with data from traverses I and II, a preliminary analysis of the SPQMLT III data indicates that significant inaccuracies have been incorporated in magnetic-charting methods applied previously to graphically portray the field (see accompanying graphs).

Two absolute instruments, the Elsec proton-precession magnetometer and the Canadian Applied Research Laboratory magnetometer, were employed for magnetic measurements on SPQMLT III. Their absolute accuracy is estimated to be within one part in 25,000 and one part in 5,000, respectively.

Geographic positions were determined approximately every 65 km (40 miles) at 20 major stations by use of a Kern DKM-2 theodolite. Severe cold, wind, and sun refraction imposed some limitation on the accuracy of azimuth and position determinations. A magnetic compass was used to point the course between major stations. No serious navigational problems were encountered at any time.

Other Scientific Programs

GEOLOGY

Glacial Geology and Chronology of the McMurdo Sound Region

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and

RICHARD L. ARMSTRONG

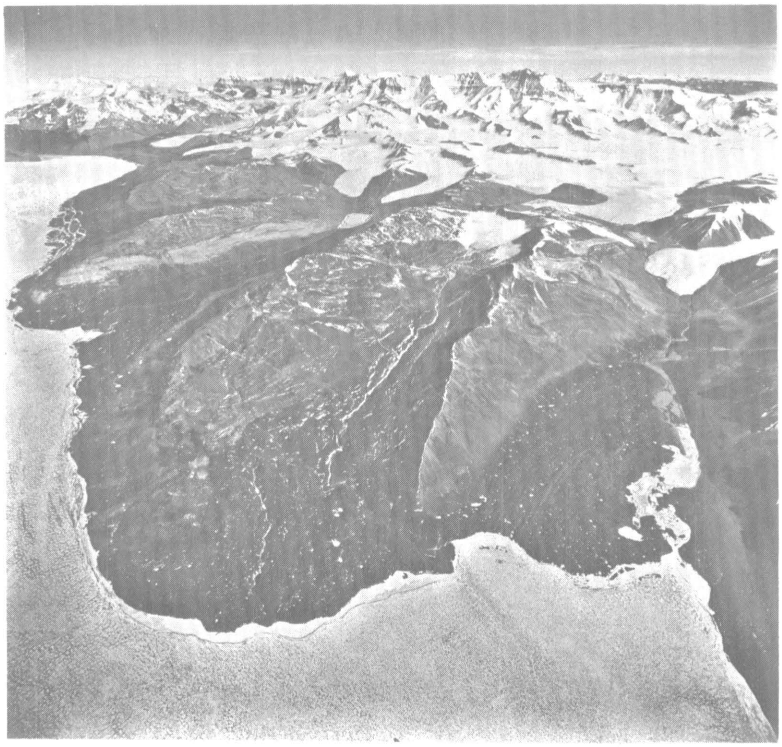
Department of Geology Yale University

The objective of this three-year program in glacial geology is to establish the configuration and chronology, by potassium-argon and radiocarbon dating, of Cenozoic glacial events in the McMurdo Sound region. The results will be used to test current theories of the history of the antarctic ice sheet and to relate antarctic glaciations to those which occurred elsewhere.

The field program was initiated during the recent austral summer and will be completed during the 1968-1969 season. The first field season was devoted mainly to detailed mapping of glacial deposits in upper Wright Valley, most of Taylor Valley, part of the ice-free valley system fronting the Royal Society Range, and part of Ross Island. In addition, more than 40 samples suitable for potassium-argon dating were collected from units of volcanic rocks interbedded with glacial drift in Taylor Valley and the Walcott Glacier area, and 11 samples were obtained for radiocarbon dating from the youngest moraine deposited by the Ross ice sheet along the west coast of McMurdo Sound. All dating results will be available in late August 1968. Detailed mapping of glacial deposits in the remaining ice-free valleys of the Royal Society Range, in the Mount Morning—Mount Discovery area, and on the volcanic islands of McMurdo Sound is scheduled for the austral summer of 1968-1969.

The ice sheet in East Antarctica is dammed to considerable thickness behind the Transantarctic Mountains in southern Victoria Land (see the American Geographical Society's 1:5,000,000-scale map of Antarctica). At present, several small glaciers fed by the upper part of this thick ice sheet spill over the mountain barrier and occupy the heads of Taylor (Taylor Glacier), Wright (Wright Upper Glacier), and Victoria Valleys. Large-scale fluctuations of these spill-over glaciers probably reflect changes in thickness of the interior of the ice sheet in this area of East Antarctica. Early stages of the glacial history of the McMurdo region are marked by repeated invasions of the ice-free valleys by thick glacier tongues, predecessors of the present spill-over glaciers (Nichols, 1961; Bull *et al.*, 1962; Calkin, 1964). Taylor Valley experienced at least three such invasions. Each was probably of composite character, and each was followed by substantial ice recession. During the second advance, ice in Taylor Valley attained a maximum thickness of about 1,200 m; thickness values were somewhat less during the first and third advances. As reported previously (Armstrong *et al.*, 1968), volcanic rocks which occur between till sheets deposited during the first and second advances have yielded potassium-argon ages of around 2.7 million years. Several new potassium-argon dates are now available. Samples of lava flows at two locations but at the same stratigraphic position in the glacial sequence of Taylor Valley have yielded ages of 3.0 $\pm$ 0.2 million years (lava flow at an altitude of about 350 m near the terminus of Sollas Glacier) and 3.3 $\pm$ 0.2 million years (lava flow at an altitude of about 1,200 m just west of the Matterhorn Glacier). In addition, a cinder cone about 1,000 m high on the valley wall immediately east of the Rhone Glacier was produced by an eruption 1.8 $\pm$ 0.2 million years ago, during the interval between the second and third advances. Basaltic cinder cones in Wright Valley have been described by Nichols (1965) as being associated with glacial features there. These cones rest on the glacially eroded floor of the valley and thus postdate extensive glaciation. One of two cones 11 km west of Wright Lower Glacier is covered by erratics of Loop age; it is 3.6 $\pm$ 0.3 million years old. One of three cones on a lateral moraine of the Bartley Glacier has been overrun at least once by the glacier; a sample from it yielded an age of 3.5 $\pm$ 0.3 million years.

More recent glacial activity in the McMurdo region has been characterized not by major advances from East Antarctica but rather by repeated ice invasions of McMurdo Sound by the Ross Ice Shelf, which, during these expansions, was transformed largely into a grounded ice sheet. There have been at least four such expansions. The younger two postdated all major invasions of Taylor and Wright Valleys by glacier tongues from the ice sheet of East Antarctica; the older two are less clearly related to events in the valleys. During each of the two younger expansions, glacier tongues from the Ross ice sheet pushed westward into lower Taylor Valley and all of the valleys fronting the Royal Society Range. Wright and Victoria Valleys were similarly invaded, either by Ross

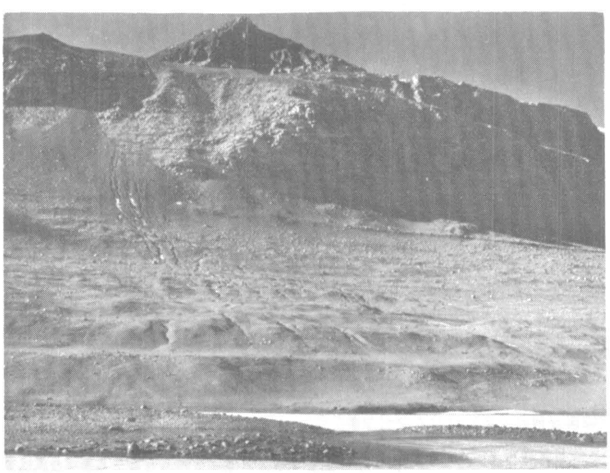


(Photo by U.S. Navy for U.S. Geologial Survey)

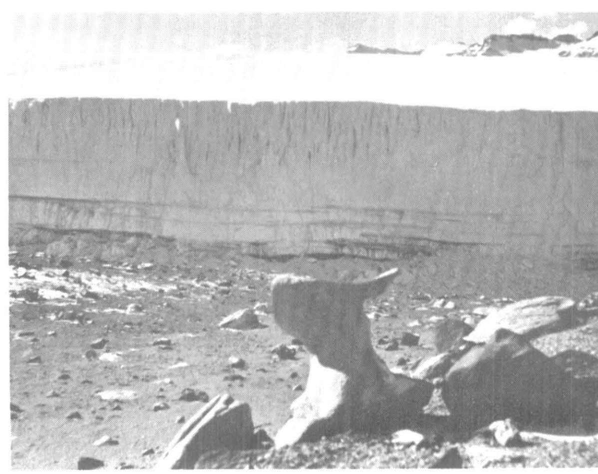
View southwestward toward ice-free valleys fronting the Royal Society Range, which is about 45 km distant. McMurdo Sound, covered with sea ice and floating ice of Koettlitz Glacier, is in foreground. The dark-colored drift on the valley floors is composed predominantly of volcanic rocks deposited by lobes of ice that pushed westward up the valleys from a former, expanded Ross ice sheet in McMurdo Sound.

Below, left: Horizontal benches, such as those shown here, line the walls of Taylor Valley to an altitude of about 310 m. They mark the former levels of a large lake dammed in the valley by the youngest body of Ross ice to occupy McMurdo Sound. Taylor Glacier advanced a considerable distance over the shoreline features after the lake drained. Lake Bonney is about 98 m above sea level. The peak in background is about 1,600 m in altitude.

Below, right: An ancient till sheet that borders Taylor Valley. This old drift contains numerous granite boulders with cavernous weathering, in sharp contrast to the youngest Ross drift, which lacks them.



(Photo by George H. Denton)



(Photo by George H. Denton)

ice bodies in McMurdo Sound or by coastal glaciers (Nichols, 1961; Calkin, 1964). The radiocarbon ages of 11 samples of algae buried in the youngest Ross moraine show that the dissipation of the last Ross ice sheet to occupy McMurdo Sound is correlative with the rapid rise of sea level which accompanied melting of late-Wisconsin ice sheets elsewhere in the world.

During the two youngest advances of the Ross ice sheet into McMurdo Sound, fluctuations of Taylor and Wright Glaciers were confined to the upper parts of the valleys and were basically unrelated to glacial events in the Sound. In fact, during the last expansion of the Ross ice sheet, Taylor Glacier was considerably smaller than it is now. Following the dissipation of Ross ice in McMurdo Sound, both Taylor and Wright Glaciers expanded to their present positions, which are more advanced than any attained throughout the time span required for at least the two major expansions of the Ross ice sheet.

The fluctuations of independent alpine glaciers in Taylor Valley and the Royal Society Range have been basically in opposite phase to expansions and contractions of the Ross ice sheet in McMurdo Sound.

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Geology of the Fosdick Mountains, Northern Ford Ranges, West Antarctica

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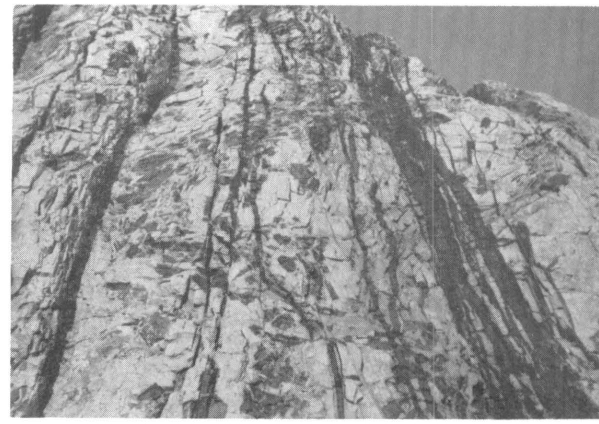
During the period from October 29, 1967, to January 15, 1968, a three-man party of geologists from Texas Technological College and Colorado College observed and mapped the geology of the Fosdick Mountains in the northern Ford Ranges of Marie Byrd Land. The party was equipped with two Polaris toboggans and worked out of a tent camp. Unfavorable weather was the major handicap to field operations. The survey was terminated in the vicinity of Marujupu Peak due to unforeseen accumulations of meltwater on the surface of Ochs Glacier.

The geologic investigations were carried out along the northern front of the Fosdick Mountains where the rock outcrops are most numerous and accessible. The mountains had been examined in less detail by Siple in 1934, during the second Byrd Antarctic Expedition; by Richardson and others in 1940, during the United States Antarctic Service Expedition; and in 1966-1967 by members of the Marie Byrd Land Survey.

In comparison with the less complex geological relations in the remainder of the Ford Ranges, the Fosdick Mountains contain rock types which are quite anomalous. The Ford Ranges are made up mainly of Cretaceous granite-granodiorite plutons and an older, thick sequence of quartzites, slates, and phyllites. The Fosdick Mountains are composed of metamorphic rocks containing mineral assemblages of the medium-to-high amphibolite facies.

There is evidence of a pervasive event of granitization followed by several periods of basic-dike injection. Some sets of basic dikes have been intensely deformed due to post-dike movement of the host migmatite (see figure). Olivine fourchites of probable Recent age crop out along an irregular but generally linear zone paralleling the west-northwest strike of the Fosdick Mountains. The linearity of this zone suggests the possible existence of a deep-seated, aligned fracture. Block faulting, which uplifted the Fosdick Mountains, may have occurred along this fracture at some obscure time.



(Photo by John R. Wilbanks)

Three generations of basic dikes exposed on the northern walls of the Fosdick Mountains.

Foliation attitudes of gneisses in the eastern portion of the Fosdick Mountains indicate the presence of a northwest-plunging antiform. At the western end of these mountains, this simple structure is obscured by gneissic flow-folding and possible horizontal transpositions along axial planes of the folds. The majority of the minor folds plunge 10° – 20° to the west.

Analyses of field data and rock specimens are proceeding at the laboratories of Texas Technological College and Colorado College. Dr. John H. Lewis of Colorado College is responsible for major structural features and relationships, and the writer for petrology and general geology.

Pedological Study in Wright Valley, Southern Victoria Land

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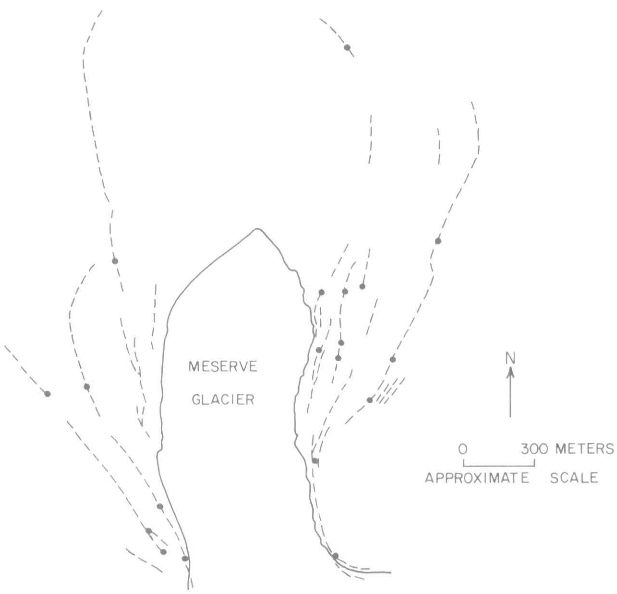
Institute of Polar Studies
Ohio State University

An extensive investigation was carried out during the past season of the moraine complex of the small, alpine Meserve Glacier (see figure). Its purpose was



Meserve Glacier, showing moraines (dashed lines) and sampling locations (dots).

to establish if the age differences of the three major moraines can be determined through studies of the morphology, chemistry, and clay mineralogy of soil profiles, of permafrost depths, and of surface-weathering characteristics of the moraines. If reliable age indicators were found and finite dates affixed to the moraines, considerable progress could be made in unraveling the overall glacial history of Wright Valley and possibly of other dry valleys of Victoria Land.

Thirty-two soil profiles were described and sampled on the Meserve moraine sequence and in adjacent areas. All but three of the pits that were dug for this purpose were 1 m or more in depth, and six extended to the ice-cemented layer. An average of eight samples was taken from each pit, and all significant textural and color horizons were described and sampled.

Marked morphological differences were observed between the profiles of the outer moraine and the two inner moraines. The most striking of these was in the depth at which completely weathered metamorphic rocks occur, the amount and degree of induration of the saline horizon, and the extent of consolidation of the material.

In general, the depth of the ice-cemented layer increases the farther one moves away from the present glacier. This depth, however, is not a reliable criterion for determining the relative ages of the deposits. Salt-indurated soil horizons tend to increase in thickness and degree of induration toward the outer moraine and in the ground moraine beyond.

Wet chemical analyses were conducted in the field on at least two horizons of each profile to determine the chloride, sodium, magnesium, calcium, sulfate, nitrite, and hydrogen-ion concentrations. Although the analyses were preliminary and crude by laboratory standards, they indicated that in each profile elemental concentrations decrease with depth, except where a deep or multiple salt-encrusted horizon occurs. The chloride-ion concentration is relatively high in all cases; however, the concentration is significantly lower in the younger moraines, both of the Meserve Glacier and of the axial, or valley, glacier. Minor differences also exist between the intermediate and inner moraines, but laboratory analysis is necessary to show their degree. Analyses of the ice-cemented mineral soil from six profiles in the intermediate and inner moraines indicate uniform, but very low, elemental concentrations.

A weathering index, based upon a comparison of labile and resistant rocks at the surface (resistant rocks, r_1) and at a depth of 50 cm (resistant rocks, r_2) at 32 sites yielded values for r_1/r_2 of 3.7 for the outer moraine, 1.7 for the intermediate moraine, and 1.2 for the inner moraine. It is hoped that these values, along with the results of the chemical and physical studies, can be related to a maximum-minimum set of finite ages for each moraine. These dates will be based on calculations of moraine volume relative to the present basal load of the Meserve Glacier as well as on values for the rate of retreat of the Meserve Glacier from its outer and intermediate moraines.

Geology of the Beardmore Glacier Area, Transantarctic Mountains

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During the 1967–1968 field season, geologists from the Institute of Polar Studies, Ohio State University, continued the investigation of the central Transantarctic Mountains (Fig. 1) started in the 1966–1967 season in the Queen Alexandra Range (Barrett *et al.*, 1967). Four and five weeks, respectively, were spent in the Marsh Glacier area, described broadly by Grindley (1963), and the area southeast of the Beardmore Glacier, described by McGregor (1965). The strata examined this season fit well into the stratigraphy determined from field work in the 1966–1967 season, in which three new formations are considered (see table) for strata that form the lower parts of Grindley's Buckley Coal Measures and Falla Formation and for a volcanic and sedimentary unit between

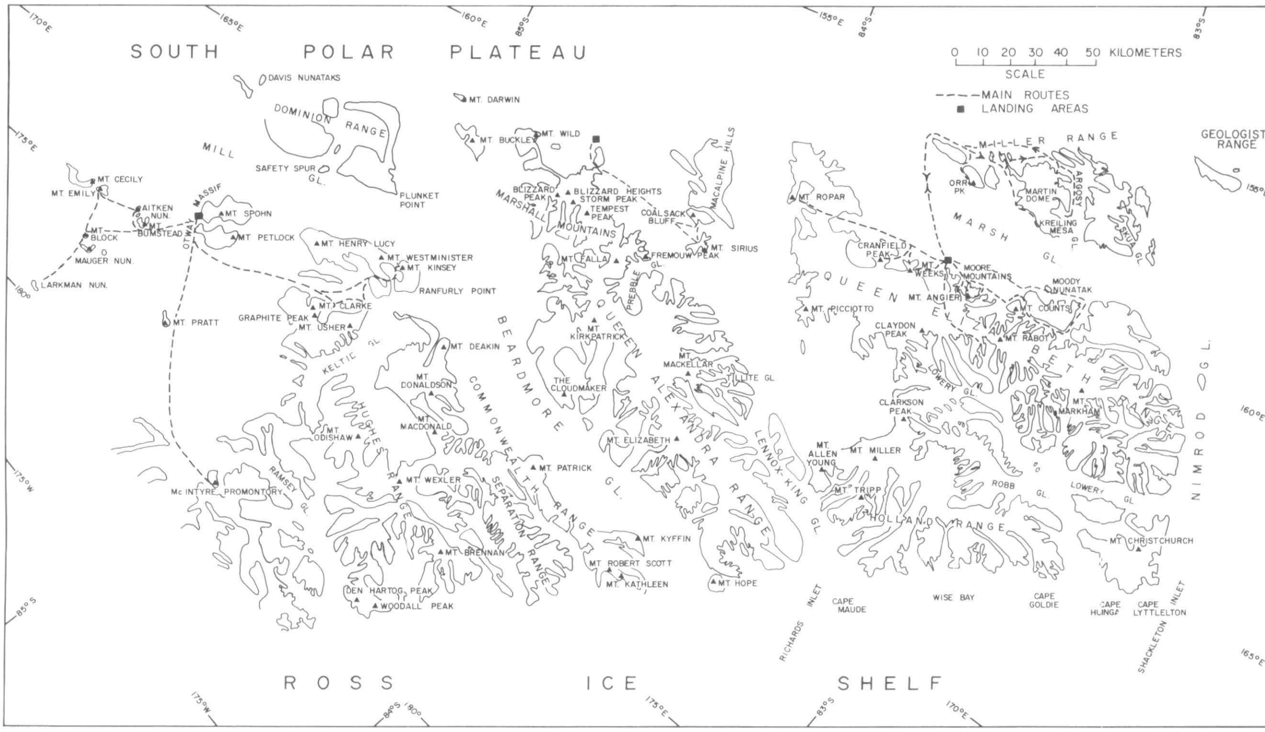

Figure 1. Beardmore Glacier area, showing landing sites and routes traveled.

the Falla Formation and Kirkpatrick Basalt. They are, respectively, the Fairchild, Fremouw, and Prebble Formations. In addition, the Lower Paleozoic and Precambrian basement of the Miller Range was examined. A midseason flight to recover the remainder of last season's samples and fossils from the southern Queen Alexandra Range and to check out some local geology was successful.

In the Miller Range (Fig. 2), the two major basement units are the Precambrian Nimrod Group of high-grade metamorphic rocks and the Lower Paleozoic granites which intrude them. The contact of these units was mapped south of the Argosy Glacier and at Orr Peak; a third outcrop of granite, macroscopically similar to those of the Martin Dome and Skua Glacier areas, was discovered. No Beacon rocks were seen in the range.

The Nimrod Group has been described by Grindley *et al.* (1964). The rocks of this group consist of pelitic, quartzo-feldspathic and calcareous metasediments that are interbanded in some areas with augen gneisses, marbles, and amphibolites. Examination of the structure reveals a complex history of strong deformation. Over a wide area around the Argosy Glacier, the foliation generally dips from 10° to 60° west to west-southwest. However, 7.5 km west-northwest of Martin Dome, two minor recumbent folds in biotite gneisses were observed. Both have an amplitude of about 1 m and axial planes that strike north-northeast. Seven kilometers northeast, an overturned, tight anticline of similar dimensions strikes northwest. While these folds may date from the intrusion of the Martin Dome granite, it is also possible that they are small-scale reflections of undetected large-scale recumbent folding. Three kilometers south of Orr Peak, evidence of at least three phases of deformation was found in a biotite gneiss-marble sequence. The north-striking axial plane of a recumbent fold has been refolded about a second coaxial axis and is characterized by intense lateral compression (Fig. 3). Nearby, another set of tight, upright folds on east-striking axes suggests a third phase of deformation.

On the northwestern spur of Kreiling Mesa, a thick sequence of low grade metasediments was observed that may prove to be younger than the Nimrod Group. The rocks, which dip almost vertically, are largely argillaceous, although interbeds of quartz arenites and two marble members 30–40 m thick are present. The argillites are intruded by the granite of Kreiling Mesa, but no contact with rocks of the Nimrod Group was found. Lithologically, the argillites compare with the Goldie Formation, which is exposed at Moody Nunatak, 22 km to the east.

The oldest Beacon Formation in the Beardmore Glacier area is the Alexandra Formation, over 300 m thick, which is exposed at the head of the Lowery Glacier and in the Queen Alexandra Range but which is absent in the central Queen Elizabeth Range,

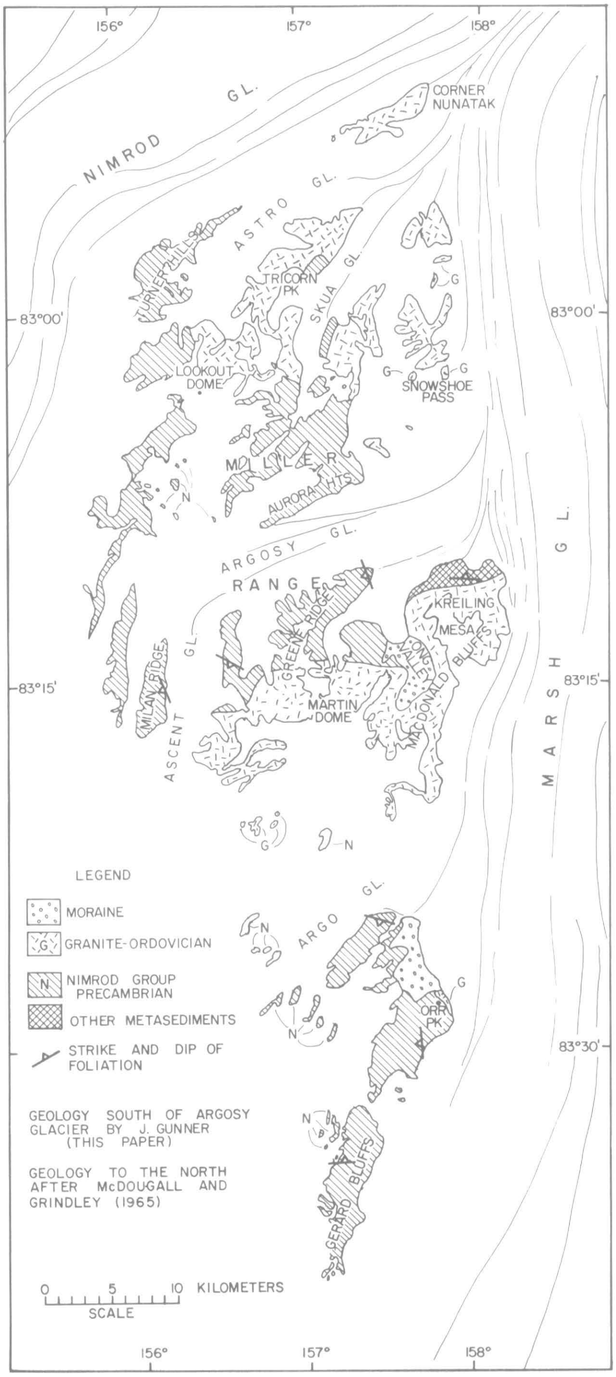

Figure 2. Outcrop map of the Miller Range, showing major geological features.

where the Pagoda Formation rests directly on the basement complex. A preglacial karst topography is present at Mount Counts, where the Pagoda Formation overlies the Shackleton Limestone. A former cave 10 m in diameter and 10 m below the erosion surface is filled with coarse green sandstone that includes large blocks of Shackleton Limestone. A broad depression, apparently the remnant of a sinkhole, leads down to the cave. Fissure fillings of sediment similar to the cave fill were found in vertical joints extending down into the limestone from the erosion surface, which is directly overlain by tillite. The only evidence for the age of the cave fill, apart from indications that it is preglacial, is the similarity of the Alexandra Formation near the head of the Lowery Glacier.

The Pagoda Formation, which consists predominantly of tillite, thickens markedly in and around the Moore Mountains to about 400 m, in contrast to the 100 m recorded in the Holland and Queen Alexandra Ranges. This local thickening appears to be due largely to a preglacial valley in which thick, massive units of poorly bedded, pebbly sediment were probably deposited from floating ice in proglacial lakes. In general, ice-movement directions, as determined from pavements and ice fabrics, are to the southeast, much as in the Holland and Queen Alexandra Ranges.

The Mackellar Formation, which conformably overlies the Pagoda Formation, is mainly dark shale in the Holland and Queen Alexandra Ranges, but fine- and medium-grained sandstone predominates at several localities in the Queen Elizabeth Range. Of particular interest is the presence of a thick (6.6 m) mudflow unit exposed on a section 7.5 km northwest of Mount Angier in the Moore Mountains. The sediment is very poorly sorted and contains large slabs, up to 20 m long, of the underlying

(Photo by J. Gunner)

Figure 3. Recumbent fold in biotite gneiss and marble exhibiting coaxial folding 3 km south of Orr Peak; the "first" fold axes are outlined in white.

Stratigraphy in the Beardmore Glacier area.

Group or Sequence	Age	Formation	Description	Thickness (m)
Ferrar Group	Jurassic	Kirkpatrick Basalt	Tholeiitic flows, rare shale lenses with conchostracans, ostracods.	600
		Ferrar Dolerite	Numerous sills and a few dikes.	about 1000
		Prebble Fm.*	Volcanic mudflows, agglomerate, tuff and tuffaceous sandstone.	0–500
Beacon Sequence	Triassic	Falla Fm.	Sandstone, shale, *Dicroidium*; tuff dominates upper part.	160–530
		Fremouw Fm.	Sandstone, greenish-gray mudstone; logs, coal, *Dicroidium* near top.	620
			Disconformity	
	Permian	Buckley Fm.	Lithic sandstone, dark-gray shale, coal, *Glossopteris*.	about 750
		Fairchild Fm.	Massive arkosic sandstone.	160
		Mackellar Fm.	Dark shale and fine sandstone.	90
		Pagoda Fm.	Tillite, sandstone, shale.	100–400
			Disconformity	
	Devonian(?)	Alexandra Fm.	Orthoquartzite, sandstone.	about 400
			Angular Unconformity	
	Ordovician(?)	Hope Granite	Porphyritic microcline-biotite-granite, granodiorite, pegmatite, lamprophyre.	
Byrd Group	Low to mid Cambrian	Shackleton Limestone	Limestone (in places with archeocyathids), shale, conglomerate.	
Beardmore Group	Uppermost Precambrian	Goldie Fm.	Graywacke, phyllite, quartzite, marble, schist, hornfels.	
Nimrod Group	Precambrian		High-grade pelitic, quartzo-feldspathic and calcareous metasediments with orthogneisses, marbles, and amphibolites.	

*Possibly Triassic.

sediments. Clast fabric studies indicate that the paleoslope dipped approximately south, which agrees well with the orientation of current structures on the underlying sandstone beds.

The Fairchild Formation, a prominent light-colored, massive sandstone overlying the Mackellar Formation, is somewhat thicker (160 to 230 m) in the Queen Elizabeth Range than in the Queen Alexandra Range to the east (120–140 m). In the former area, pebbles and cobbles, mainly of metasedimentary rocks, are scattered through the lower part of the formation; they may have been derived from the Pagoda Formation or its source, which are to the northwest. Plant stems are also common, and leaves of *Gangamopteris* (identified by Dr. J. M. Schopf) were found only 130 m above the top of the Pagoda Formation in the Moore Mountains.

The Buckley Formation, whose contact with the underlying Fairchild Formation is disconformable and generally marked by rounded white quartz pebbles, is the youngest unit known in the Queen Elizabeth Range, and it was the oldest unit seen in the later part of the season southeast of the Beardmore Glacier. No complete section of the formation was found, though exposures containing 200 m or more of strata are common. The formation is dominated by sandstone in the lower 100 m; above this level, plant-bearing siltstone and claystone are more common. Coal seams, mostly less than 3 m thick, were found throughout the formation. A number of plant collections were made, and natural graphite was found near the head of the Ramsey Glacier. The primary sedimentary structures of all of the preceding formations indicate a south- or southeast-trending paleoslope, as do those measured last season.

The boundary between the Buckley and the overlying Fremouw Formations (thought, on the basis of last season's work, to be close to the Permo-Triassic boundary) was found well exposed at three widely separated localities southeast of the Beardmore Glacier: Mount Kinsey, Graphite Peak, and McIntyre Promontory. The lower part of the Fremouw Formation is characterized by noncarbonaceous greenish-gray mudstone and, in the lower 100 m, by quartzose sandstone, in contrast to the medium-gray to black carbonaceous and plant-bearing mudstone and lithic sandstone typical of the Buckley Formation. Near Graphite Peak, a piece of a labyrinthodont jawbone, probably of Early Triassic age, was recovered from a pebbly lens in quartzose sandstone 76 m above the base of the Fremouw Formation (Barrett *et al.*, in press). The mold of a gastropod, 4 cm across, was found only a few meters away. In the upper part of the formation, the beds gradually become more carbonaceous and include impressions of roots and stems (possibly of *Neocalamites*). The upper 100 m of the formation, seen only at Graphite Peak this season, includes silicified wood, logs, and thin coal, similar to the upper part of the proposed type section at Fremouw Peak, 100 km to the northwest. Current directions from the Fremouw Formation indicate a west-dipping paleoslope, which is in contrast to the south and southeast trends obtained from Permian strata.

The Falla Formation, a cyclic sandstone and carbonaceous-shale sequence in the Queen Alexandra Range, was found only near Graphite Peak and at Otway Massif, where small areas of sandstone are exposed.

Poorly sorted volcanic conglomerates and tuffaceous beds of the Prebble Formation crop out on the west side of Otway Massif and at Mount Pratt. On Otway Massif, the minimum thickness of 460 m consists almost entirely of the poorly sorted conglomerate with doleritic boulders up to 1 m across. The 60 m at Mount Pratt also includes tuffaceous sandstone and a thin water-sorted conglomerate.

The near-horizontal lavas of the Kirkpatrick Basalt cap the succession on Otway Massif and form all of the bedrock of the Grosvenor Mountains. The maximum thickness recorded was 504 m at Mount Spohn, where there are only five flows; the flows are more numerous farther south, and 12 are present on Mount Emily, although the thickness there is only 265 m. As in the Queen Alexandra Range, the centers of the thicker flows are cliff-forming, coarse-grained rocks which have the appearance of dolerites; the thinner flows are fine-grained black basalts. All flows have thin amygdaloidal lower contact zones and much thicker, baked, amygdaloidal upper zones. Pillow lavas are conspicuous at a few localities.

Sedimentary interbeds are rare, but one, at Mauger Nunatak, yielded a few poorly preserved conchostracans. Fossil soils are present at many localities and vary from a few centimeters to 1.5 m in thickness. Most of them are derived from the underlying basalt flows, proving that some of the very thick flows are extrusive rocks and not sills. Wood fragments and rootlets are quite common in the soils, but only at one place were leaf impressions found.

Dolerite sills are conspicuous in the Queen Elizabeth Range and south of the Beardmore Glacier, where the total thickness may exceed 600 m. A very prominent circular feature on the northwest side of Otway Massif is a sill that dips gently outward and is cut by several dikes which radiate from a small, central spine of basalt and dolerite. The elevation of the lowest adjacent basalt flow on Otway Massif is 110 m higher than the highest point on this feature; as there is no evidence of faulting, this circular feature is probably the sub-Jurassic surface remnant of a Jurassic central vent.

Gravity measurements were taken at six rock outcrops and five snow stations at campsites southeast of the Beardmore Glacier. The station gravity has been calculated for all localities, but the data have not yet been interpreted.

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Patterned-Ground Studies in Victoria Land

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Patterned-ground investigations on Ross Island and in the dry valleys of Victoria Land were begun in 1960 to establish the conditions under which sand wedges and ice wedges form and to determine their rate of growth for the dating of various surfaces. Near-surface ground temperatures are being monitored continuously by thermal recorders at McMurdo Station and in Taylor Valley. During the 1967–1968 field season, Twomey and one assistant serviced these recorders.

Large thermal stresses produced each fall by rapid cooling at low temperatures cause cracking along ice wedges. Twomey installed an apparatus near McMurdo to record the time of cracking of several ice wedges for which growth rates had been established. Simultaneous field recording of the thermal regime and the cracking of wedges in a single polygon should provide a partial check of Lachenbruch's (1962) theory of ice-wedge formation. In it, he calls for velocities of crack propagation sufficient to cause bifurcation and, hence, nonorthogonal intersections in the normal hexagon.

Probing perennially frozen morainic material with pick and shovel, auger, or other mechanical means to determine its thickness and other physical properties

(Photo by Arthur A. Twomey)

Seismic refraction shot on the "Trilogy" moraine, lower Wright Valley.

is inefficient when a depth of more than a few feet is involved. Therefore, Twomey employed seismic-refraction techniques to investigate the subsurface at contraction sites on moraines in Taylor, Wright, and Beacon Valleys (see figure). A portable Geospace GT-2a multichannel seismograph was used to provide a Polaroid record of the shot and of reflection traces. Explosive charges varied in size with the material being tested. Twomey is reducing the data and preparing a thesis to be submitted this summer to the University of Wisconsin in partial fulfillment of an M.S. degree.

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Geological Studies in the Dry Valley Area of Victoria Land

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The area investigated during the 1967–1968 field season extended from Granite Harbor to Taylor Valley in southern Victoria Land; detailed mapping was undertaken in Victoria and Wright Valleys. Regional mapping was conducted at a scale of 1:12,000, and detailed mapping of well-exposed key areas was carried out at a scale of 1:3,000. On the valley walls, the amount of exposure is highly variable. A typical sequence of metasedimentary rocks in this region is rich in calcium and is composed of marble (commonly graphitic), diopside granofels, plagioclase granofels, tremolite schist, quartzofeldspathic gneiss, amphibolite, and some pelitic schist.

The metamorphic grade in Victoria Valley is represented by sillimanite-almandine-orthoclase subfacies. Augen gneiss (pretectonic granite) is the same metamorphic grade as the metasedimentary rocks with which it interfingers on both large and small scales. It shows isoclinal folds in places and contains boudins of schist, marble, and diopside granofels that range in size from 10 cm to tens of meters. No intrusive contacts were observed between augen gneiss and metasedimentary rocks, although the two rock types grade into each other in places.

Rocks shown as Larsen Granodiorite (syntectonic granite) on preexisting maps are highly variable. The rock types include augen gneiss, porphyroblastic granite gneiss, migmatite, fine-grained granodiorite, porphyritic granodiorite, and porphyritic quartz monzonite, most of which cover relatively large areas. In places, the Larsen Granodiorite closely resembles the augen gneiss, except that the large K-feldspars tend to be euhedral rather than lenticular. Although more work needs to be done, the Larsen Granodiorite is not easily visualized as a huge synkinematic batholith because of its extreme variability.

Fine-grained gray granodiorite (Theseus Granodiorite in Wright Valley) is found throughout the area in dikes that range from 1 m to more than 10 m in width and that cut all of the previously mentioned rock types. South of Lake Vida, however, the dikes are deformed. Microdiorite dikes (Loke Microdiorite in Wright Valley) occur sporadically in the area, except in eastern Wright Valley where they are found in swarms. The Vida Granite (Irizar Granite), a distinctive pink rock with prominent quartz grains, is a quartz monzonite petrographically. It is a postkinematic intrusive that has crosscutting near vertical contacts and that has a roof exposed in Mount Cerberus, south of Lake Vida. Tabular mafic inclusions that are commonly partly assimilated and that resemble microdiorite in places are scattered throughout the Vida Granite. Although the granite appears homogeneous, compositional studies of the pluton are being carried out to test particularly for vertical variations in composition. The contact of the Vida Granite with metasedimentary rocks is just north of Lake Vida. In the ridges 7 km to the north, a different kind of medium-grained biotite quartz monzonite is exposed.

At least two periods of deformation are recognizable in the area. Earlier isoclinal folds have been refolded around tight folds with northwest-trending axes.

Bouguer gravity anomalies range from −10 mgal along the coast to −150 mgal 70 km inland. The anomaly values reach −100 mgal at Lake Vida and just west of The Flatiron at Granite Harbor. A large gravity gradient of 6 mgal/km parallels the coast just inland from McMurdo Sound. The high gradient suggests a shallow source, but the source has not been found in the surface exposures.

Volcanic Rocks of the Ross Island Area

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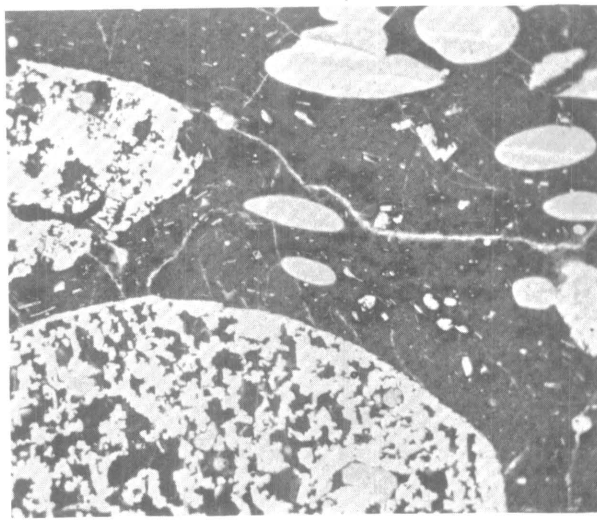
During the 1960–1961 and 1961–1962 field seasons, the volcanic rocks of the Capes Evans and Royds and McMurdo Station areas were studied and mapped (Treves, 1962). During the 1964–1965 season, a study of the entire Ross Island Volcanic Province was started; for that study, the author had proposed that sequential relationships, geologic history, mineralogy, petrography, chemistry, and petrology of the volcanic rocks be investigated. Rocks were studied, mapped, and collected for petrographic, chemical, and isotopic analyses near McMurdo Station, at Capes Evans, Royds, Bird, and Crozier, and at Minna Bluff, Black Island, White Island, Marble Point, Taylor Valley, Heald Island, Brown Peninsula, the Dailey Islands, Tent Island, Inaccessible Island, the Dellbridge Islands, Cape Barne, Turks Head, Tryggve Point, Big and Little Razorback Islands, Mount Discovery, and Hut Point. During the 1967–1968 field season, additional work was done on the volcanic rocks at Capes Royds, Evans, and Crozier, Black Island, White Island, Brown Peninsula, Minna Bluff, Miers Valley, and in the general area of the Royal Society Range.

In general, field results obtained last season agree with those of earlier years. Almost everywhere, an older olivine basalt-basalt-trachyte series and a younger olivine basalt-basalt series occurs. The author believes that the antarctic kenyte (Treves, 1962) is a trachyte equivalent and that it should be called an anorthoclase trachyte, an opinion that is apparently shared by Boudette and Ford (1966). A radiometric age determination of the anorthoclase trachyte at Cape Royds gave a value of 0.68 ($\pm$0.14) $\times 10^6$ my.



Photomicrograph of anorthoclase trachyte from Cape Royds.

Photomicrograph of plagioclase basalt from Cape Royds.

Field and petrographic data indicate that older and younger basalts occur at Cape Royds. The relationship of the trachyte at Mount Cis* (which is really only an ice-cored mound) to the anorthoclase trachyte is not clear.

Chemical, isotopic, and petrographic studies of the rocks are continuing. Future investigations should be concerned with the geology of the high peaks of Ross Island, the volcanic rocks of Mounts Discovery and Morning, the subprovinces of the McMurdo volcanic area, the relationship of the volcanic rocks to the crustal structure of the area (especially to the structure indicated by recent gravity maps), and the relationship of volcanic vents to the gross structural features of the nearby Transantarctic Mountains.

*Unofficial name.

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Sedimentological Aspects of the Darwin Tillite in the Darwin Mountains

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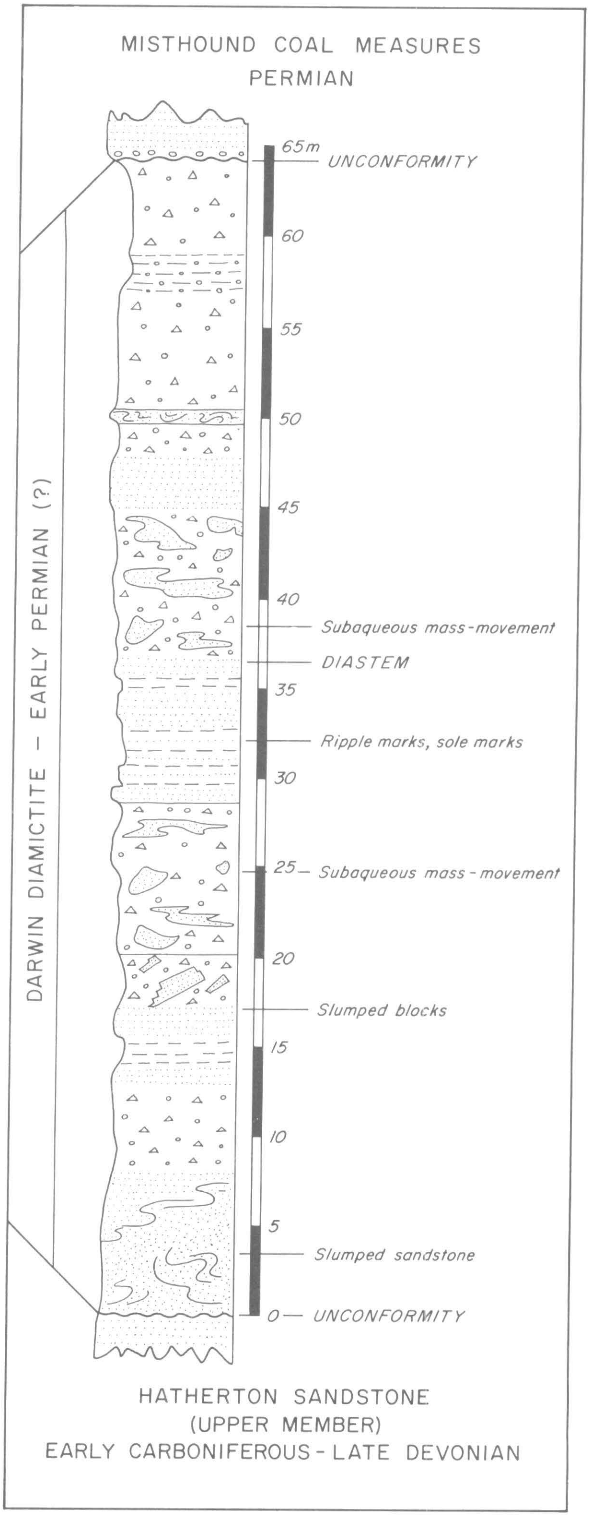
The sedimentology of the Darwin Tillite was studied during a visit to the Darwin Mountains of southern Victoria Land in December 1967. The examination of exposures there is critical to our understanding of the Late Paleozoic glaciation of Antarctica because the rocks are the northernmost ones known to crop out in the Ross Sea sector, with the exception of thin diamictite of the dry-valley region (Pinet *et al.,* 1967). The purpose of the work was to determine the facies of the glacial rocks, as well as the direction of glacial transport.

The stratigraphy of the Darwin Tillite and its relationships to adjoining rocks are shown in the figure. As noted by Haskell *et al.* (1965), the Darwin Tillite unconformably overlies the Devonian(?) Hatherton Sandstone. The relationship is well exposed on Colosseum Ridge near 79°45′S. 156°30′E., where gray sandstone containing abundant slump structures overlies quartz sandstone which weathers to a light brown color. As in other areas, angularity at the contact is not observable. The top of the Darwin Tillite is sharply truncated by an erosional unconformity on which rests the basal quartz sandstone and conglomerate of the Misthound Coal Measures. Fossils were not observed in these units during the present study, with the exception of trace fossils in the Upper Member of the Hatherton Sandstone. Haskell *et al.* (1965) reported *Gangamopteris* and other plant remains from the Misthound and assigned the unit a Permian



age on the basis of regional correlations. They considered the Darwin to be Carboniferous–Early Permian in age, which is probably as close an estimate as is possible at present in view of the scarcity of fossils.

The Darwin Tillite comprises slightly more than 60 m of poorly sorted, pebbly, sandy mudstone or diamictite; lenticular medium-grained sandstone bodies; and thin interbeds of siltstone and shale. Four units of diamictite occur: a varicolored lower one, 5 m thick; two very sandy ones, both 8 m thick in the central portion of the section; and a fourth which marks the top of the Darwin. The uppermost diamictite is medium-gray, nonstratified, pebbly mudstone, 17 m thick, containing rare interbeds of sandstone and one pebbly shale unit. Whereas this diamictite has the appearance of typical Late Paleozoic tillites seen elsewhere in Antarctica, the lower diamictites are atypical in that generally they contain more sand and display evidence of soft-sediment deformation. Throughout the lower diamictites are scattered bulbous masses and blocks of well-sorted sandstone, some apparently in-place but others probably allochthonous in that they are canted at all angles to nearby stratification. The bulbous masses are interpreted as load-casts of sand which sank into the diamicton substrate, causing a sizable portion of sediment to become unstable and move in response to gravity, as does a mudflow. Tabular sandstone bodies, which could not flow like the diamicton envelope, ruptured into blocks and were moved along by the diamicton.

The youngest diamictite, on the other hand, may have been deposited as till beneath a glacier. This unit contains striated clasts up to 40 cm in maximum dimension; the largest clast observed measured 1.4 m. Striae on the clasts are randomly oriented. The pebbly shale near the top of the unit is highly fissile, poorly laminated, and dark gray. It contains sparsely scattered, subrounded to well-rounded, up to pebble-size clasts, most of which are of sedimentary origin. This shale must have formed in a subaqueous environment because of its high degree of sorting; the presence of isolated clasts suggests that a rafting material was involved—probably ice, in view of the associated diamictite. Whether the underlying diamictite formed underwater cannot yet be determined, but the older diamictites are interpreted as having formed underwater because the substrata appear to have been wet when the load-casts formed. The few sandstone and shale interbeds also appear to have originated in a subaqueous environment. Because of the lack of fossils, it cannot be determined at this time whether the water was saline, brackish, or fresh.

In two clast counts involving a total of 82 clasts in the upper diamictite, granite constituted the most abundant rock type (50 percent). Only 5 percent of the clasts were of other igneous and metamorphic types, and the remaining 45 percent were of various sedimentary types, including quartz-sandstone similar to the Hatherton Sandstone. A count of clasts in the basal lag gravel of the overlying Misthound Coal Measures gave a similar result, except that granite made up only 20 percent. On the basis of this information, the provenance of the Darwin Tillite is considered to have been a mixed igneous and sedimentary terrane, probably containing granite similar to the Mount Rich Granite of the nearby Brown Hills (Haskell *et al.*, 1965) and some Hatherton Sandstone.

A total of 25 indicators of transport direction were measured, including 21 sets of asymmetric ripple marks, 2 sets of parting lineation, and 2 asymmetric slump folds. These data yield a resultant vector direction of S.25°E. and vector magnitude of 80.4 percent. This determination is in agreement with that of Haskell and others (1965) that the direction of transport for the Misthound Coal Measures was toward the east. Striated floors and boulder pavements were not observed, so it is not possible to substantiate that ice moved in the same direction as paleocurrents. However, a diamictite fabric measured on 32 clasts larger than 2 cm in diameter gave a vector resultant oriented S.71°E.–N.71°W. with a magnitude of 65.6 percent.

The Darwin Tillite was probably deposited in a subaqueous basin that stretched southward to include portions of the Queen Maud Mountains and perhaps the Horlick Mountains. The original extent of the unit cannot now be determined because deposition was evidently soon followed by erosion, which removed much of the glacial sediment. Some erosion was probably associated with the retreat of the glaciers which laid down the diamictite, as fluvial-glacial deposits are common in the Queen Maud Mountains. The extent of the basin to the east and west is not known either, but it is speculated that the source area at the north end of the basin lay not far from the Darwin Mountains because of the common large granite clasts found intact in the Darwin Tillite. Perhaps much of northern Victoria Land, where Late Paleozoic glacial rocks seem to be absent, was a high region which nurtured glacial ice.

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CARTOGRAPHY

Topographic Mapping Field Operations, 1967-1968

RUPERT B. SOUTHARD, JR.

Topographic Division
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During the 1967–1968 season, eight engineers from the U.S. Geological Survey were assigned to Antarctica to establish control for topographic mapping, remeasure the Byrd Station ice-strain network, and contribute to other USARP programs.

For the eighth consecutive season, a Survey mapping specialist was assigned to Antarctica to provide visual navigational assistance to Air Development Squadron Six (VX–6) during photographic missions and to inspect all developed photographs to ensure that they met mapping specifications.

A four-man party working in Marie Byrd Land completed a total of 1,230 km (850 mi) of traverse by means of electronic distance-measuring instruments. The helicopter-supported survey was tied to last season's control network at stations located on Poindexter Peak and Holmes Bluff (northeast of the Ames Range) and extended eastward approximately 650 km (400 mi) to 110° W. in the vicinity of Mount Murphy. In conjunction with this work, two stellar astronomical stations were established—one approximately 16 km (10 mi) southeast of Mount Andrus, in the Ames Range, and the other about midway between Toney Mountain and the Kohler Range. A combination stellar and solar astronomic position was established on the north side of Carney Island. This work furnished control for approximately 130,000 km² (50,000 mi²) of topographic mapping.

Another four-man party remeasured the 163-km (101-mi) ice-strain network northeast of Byrd Station for Ohio State University, reobserved astronomically the position of South Pole Station, and remeasured the ice-movement stakes on the annual and fast ice between Hut Point and the Koettlitz Glacier for the Naval Civil Engineering Laboratory. In addition, the party determined azimuths for the geomagnetic tunnels at Byrd and South Pole Stations for the Coast and Geodetic Survey.

On one flight by a photoconfigured LC–130F Hercules, VX–6 obtained approximately 414,000 km² (160,000 mi²) of mapping photography, which represented 85 percent of the summer's photography requirement. The Geological Survey had planned and prepared detailed specifications for obtaining mapping-quality aerial photography of about 1,039,000 km² (401,000 mi²). It also prepared visual navigation photo packets for use by VX-6 pilots. However, based on information developed by Survey in-flight observers during a reconnaissance flight made early in November 1967, areas totaling about 594,000 km² (229,200 mi²) where eliminated from the program. These areas are basically featureless and do not warrant mapping at a scale of 1:250,000.

For the second consecutive year, pictures received from the Nimbus and ESSA satellites by the Automatic Picture Transmission receiver at McMurdo Station contributed to the success of the aerial-photography program. Using these pictures, meteorologists were able to predict weather more accurately over distant areas than had been possible previously. This weather information made it possible to obtain the 414,000 km² (160,000 mi²) of photography with a minimum of aircraft flight hours. Because of the remoteness of the areas covered, the photographic aircraft had to stop for refueling at either Byrd or Pole Stations.

Experimental color photography was taken of about 5,000 km² (2,000 mi²) of the Shackleton Range, and reconnaissance photography was obtained of about 52,000 km² (20,000 mi²) of the Filchner Ice Shelf, Coats Land, and the Kraul Mountains and Heimefront Range (Kottas Mountains) in Queen Maud Land.

GLACIOLOGY AND GEOPHYSICS

Deep-Core Drilling Program at Byrd Station (1967-1968)

H. T. UEDA *and* D. E. GARFIELD

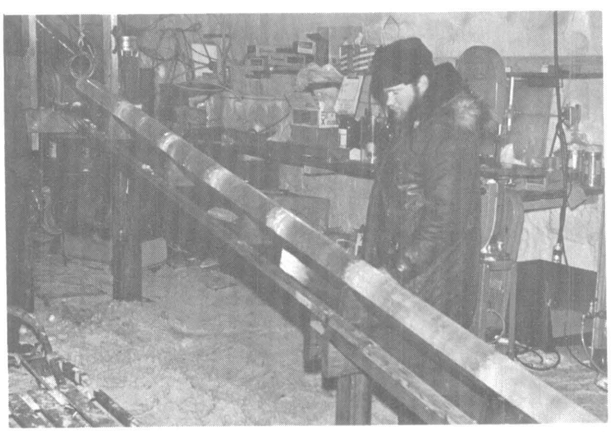
U.S. Army Cold Regions
Research and Engineering Laboratory

The deep-core drilling program at Byrd Station was begun under the direction of B. L. Hansen of the Cold Regions Research and Engineering Laboratory (CRREL) during the 1966–1967 austral summer with the installation of equipment and the penetration of 220 m of ice (Ueda *and* Hansen, 1967). Operations were resumed on October 23, 1967. The equipment showed no adverse effects of the winter shutdown period. The only modification made to the drill was the addition of an inclinometer to measure deviations from the desired vertical course of the drill hole. Five people were trained to operate the equipment.

Drilling was resumed on November 1, 1967, at the 220-m depth, and a two-shift, 24-hour-per-day schedule was started on November 3. By the end of November, a depth of 770 m had been attained. The hole began to deviate from the vertical at 330 m, and at 770 m the inclination was 4.5°. Efforts to correct the deviation were not successful. The penetration rate for the month was 18.3 m per day.

By December 31, the hole depth had been advanced to 1,400 m, with the inclination reaching 11°. One gear section of the drill had to be replaced because of wear, and one drill motor was burned out. Problems with the winch resulted in a 40-percent reduction in rated hauling speed. This condition prevailed for the remainder of the season. Despite the delays, a penetration rate of 20.3 m per day was achieved for the month.

The penetration rate increased considerably during January, when a higher drilling speed was achieved; a maximum core length of 6.1 m per run was cut (Fig. 1). On January 28, at a vertical depth of 2,160 m, the first cores containing rock were obtained. The following day, a layer of water estimated to be less than 0.3 m thick was encountered at 2,164 m. Several attempts to recover a core below this depth were unsuccessful. Damage caused by the freezing of entrapped water in various drill sections forced the termination of drilling on February 2.



(Photo by Herbert T. Ueda)

Figure 1. Six-m ice core from 2,000-m depth.

The overall penetration rate for the season was slightly more than 20 m per day. Drilling rates varied from 3.5 to 19.8 cm per minute. Power input was 7.5–9.0 kw with a 225-rpm cutter. Steel and diamond cutters with 6⅛-inch (15.6-cm) OD and 4½-inch (11.4-cm) ID blades were employed. Cores averaged 10.8 cm in diameter and were recovered in 3.0- to 6.1-m lengths. More than 99 percent of the ice drilled was recovered.

Deviation measurements were made every 15-30 m. A maximum inclination from the vertical of 15° was measured at the bottom. Temperatures in the hole were recorded after completion of drilling. The minimum temperature was −28.85°C. at a depth of 800 m, beyond which the temperature steadily increased (Fig. 2). Temperatures at the bottom could not be measured owing to the presence there of heavy slush resulting from the accumulation of ethylene glycol, used to dissolve ice chips produced by drilling. Circumstances did not permit the removal of the slush this season.

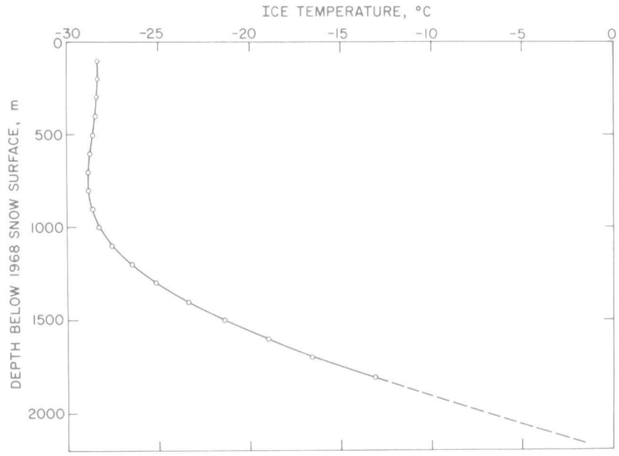


Figure 2. Depth-temperature profile, Byrd Station drill hole.

Extrapolating the temperature curve from a depth of 1,800 m to an estimated pressure melting point of −1.6°C. at the bottom gives a gradient of 3.25°C. per 100 m. The average temperature of the ice in this region is −9.0°C., and the thermal conductivity at this temperature is 0.00553 cal./sec-cm-°C. (Ratcliffe, 1962). The heat flow in this region is calculated to be 1.8×10^{-6} cal./cm^2-sec. Part of this heat flow may be due to the flow of the ice.

Thermal Drill. CRREL's thermal drill was used to make holes at five locations during the season. Four holes, 57–61 m in depth, were drilled within an 8.5 km radius of Byrd Station to aid in the establishment of an acoustic array for a Stanford Research Institute experiment. A fifth hole, 335 m deep, was drilled in the main tunnel, 44 m south of tunnel L–4, for future testing of a C^{14}-dating instrument.

Acknowledgments. Many people contributed their efforts toward the success of this project. The following individuals made significant contributions during the past season: Mr. Edward Parrish, SP5 Roger Doescher, SP4 Dominic Gianola, SP5 William Strange, SP4 Lawrence Strawn, and SP4 William Trenholm.

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Preliminary Analysis of Ice Cores from Byrd Station

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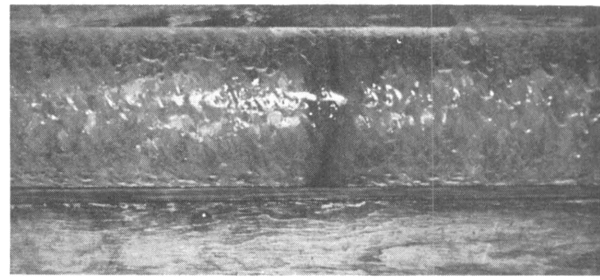
On January 29, 1968, a team from the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) completed drilling to the bottom of the antarctic ice sheet at Byrd Station—the first penetration of the thick inland ice of Antarctica (cf. preceding article). The vertical thickness of the ice was 2,164 m. With the exception of a zone of brittle and badly fractured ice between 400 and 900 m, the condition of the core varied from good to excellent. Core recovery exceeded 99 percent of the footage drilled.

All of the core was examined for significant stratigraphic markers (*i.e.,* signs of melting, dirt layers, etc.), and spot checks were made of the bulk density, bubble structure, crystal growth, crystal fabric, and electrolytic conductivity of the cores. Highlights of these studies were as follows:

1. Abundant dirt was observed in the bottom 4-5 m of core, including layers of silt, sand, and pebbles, and some large fragments of pink and white granite.

2. The rock bed of the ice sheet was cut to a depth of 1.3 m, but all attempts to retrieve the core were unsuccessful. This may have been due to the fact that the ice sheet beneath Byrd Station is underlain by unconsolidated material (glacial till rather than solid rock).

3. Water was encountered at the ice-rock interface, clear evidence that the basal ice is at the pressure melting point.



(Photo by Anthony J. Gow)

Figure 1. Thin layer of dirt (volcanic ash?) in ice from a depth of 1,301.6 m. Younger end of ice core is at right.

4. Several thin layers of dirt (0.5 mm thick) were observed between depths of 1,300 and 1,700 m. Tentatively identified as volcanic ash (Fig. 1), these layers are estimated to have been deposited between 15,000 and 25,000 years ago from nearby volcanoes, such as those of the Executive Committee Range.

5. The dramatic improvement in the condition of the ice cores below 900 m can probably be correlated with the gradual disappearance of air bubbles in the ice and the onset of oriented crystal fabrics (Fig. 2). No trace of air bubbles was observed in freshly cored ice from below 1,200 m, at which depth the majority of the basal glide planes of crystals were oriented within 15° of the horizontal plane of the ice sheet. This zone of oriented ice crystals, which also contains numerous cloudy bands of very small crystals that might be attributed to shear, persisted to a depth of about 1,800 m. A very rapid growth of crystals (with cross-sections frequently exceeding 30 cm^2) was observed between 1,800 m and the bottom. Some "exsolving" of bubbles has been observed in deeper ice that was originally devoid of bubbles.

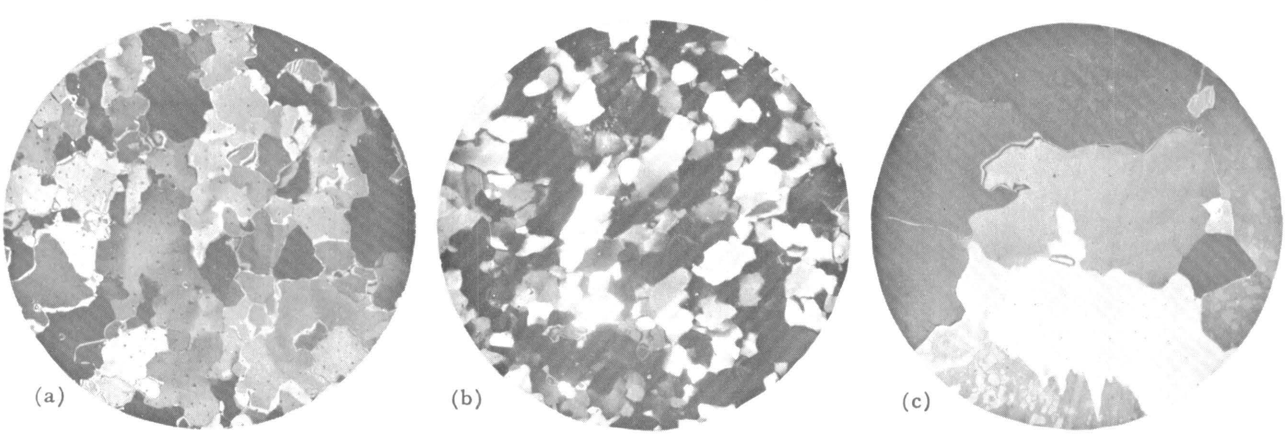


Figure 2. Thin sections of ice from depths of (a) 340 m, (b) 1,576 m, and (c) 2,138 m. Photographed natural size and between crossed polaroids to reveal crystal structure.

6. A maximum *in situ* ice density of 0.9206 g/cm^3 was measured at a depth of about 1,000 m. The density then decreased progressively to 0.9170 g/cm^3 near the bottom. Gradual but significant expansion of the ice is following its release from high confining pressure, as evidenced by the decrease in density of cores remeasured as little as two months after they were drilled.
7. Measurements of the electrolytic conductivity of melted samples have indicated very low levels of dissolved solids at all depths in the ice sheet. The median value of the 45 samples of dirt-free ice tested is 2.1 μmho/cm, which is equivalent to a dissolved ion content of less than 1.0 ppm.

A total of 59 tubes of 1.5-m cores, including the bottom 5 m of dirty ice and samples used for random checks of density, crystal structure, and other features, were returned to CRREL for further studies.

Additional field studies in Antarctica included (1) remeasuring ice movement and ablation of the Koettlitz Glacier ice tongue, (2) further measurements of deformation in the 10-year-old drill hole at the old Byrd Station, and (3) resurveying and remeasuring the two long accumulation-stake lines at Byrd Station.

Ice-Flow Studies on Roosevelt Island

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During the 1967–1968 austral summer, the third season of intensive study of ice flow was completed on Roosevelt Island. During the first two seasons, a strain-rate network was established and the depth, subsurface conditions, and accumulation of the ice were determined.

The field work during the 1967–1968 season was conducted by the author and two associates, John C. Albright and James D. Gruendler. The work included determination of the surface configuration of the ice cap at the boundary between the grounded ice and the Ross Ice Shelf, remeasurement of approximately 700 km of strain network, determination of the change in azimuth of the network due to ice flow, and extension of precise vertical control over approximately 300 km of the ice cap.

Data on the surface configuration were taken in order to study the possible relationship of surface characteristics to small variations in the bedrock formation and the pressure of the adjacent ice shelf. The strain network was remeasured to determine the surface strain rates. The determination of the absolute change in azimuth of the strain network was made to permit the calculation of displacement vectors for the strain-network control points, which, in turn, will facilitate an evaluation of the influence of the surrounding ice shelf upon the Roosevelt Island ice cap. The vertical control was extended to define more precisely the step-like surface profile near the edges of the ice cap and to relate all measurements to a common datum.

Field operations were conducted in four phases. First, a reconnaissance was made to relocate and remark the control points on the strain network. Second, measurements were taken on the network lines with an MRA-2 Tellurometer system mounted on a Trackmaster. Third, three wire levels were run with a Zeiss Ni2 automatic level to establish vertical control on the network. (Small networks at the north and south edges of the ice cap were tied in by barometric leveling.) Fourth, astronomic observations were taken to determine the true azimuth of critically located lines.

All instruments and systems proved reliable, and the party was fortunate in having uniformly good weather.

Geophysical Studies along the Byrd Station Strain Network

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Seismic and gravity observations were made along the strain-measurement network northeast of Byrd Station from November 1967 until January 1968. The array of stakes parallels the ice-flow line from the Ross Sea—Amundsen Sea ice divide to Byrd Station, a distance of approximately 150 km. The main objective of the field investigations was to determine the subglacial topography in this region, with the ultimate goal of establishing an ice-flow relationship that will explain the measured strain rates and morphology of the glacier surface. Another objective was to find if any correlation exists between events revealed on the seismic-reflection records and major changes in the physical properties of the ice disclosed by cores obtained by the deep-drilling program at Byrd Station.

Reflection shots to determine the ice thickness and the strike and dip of the glacier bed were made at several points along the network. Wide-angle reflections were recorded to determine the average vertical seismic-wave velocity, and up-hole and short refraction measurements were made for the calculation of compressional- and shear-wave velocities in the snow-firn layer.

Gravity observations were made at all stakes of the strain network with a Worden gravimeter in order to provide more detail on the subglacial topography than would be available from the seismic sounding alone. The gravity survey was carried out in a series of loops, with frequent reoccupation of stations. A new gravity base was established at Byrd Station and tied to the base station at McMurdo.

Preliminary results indicate that the bedrock topography beneath the Byrd strain network is fairly irregular. The ice thickness increases irregularly from about 2,400 m near Byrd Station to more than 3,000 m at the end of the network, indicating that the glacier bed is several hundred meters lower beneath the ice divide than it is under Byrd Station. Relatively small reflections preceding and following the main bottom reflection have been noted on the seismic records. The relationship, if any, of these events to the deep-core record will be investigated.

UPPER ATMOSPHERE PHYSICS

Magnetospheric Studies Using Balloon-Borne Instrumentation

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University of Denver

In continuation of our previous summer's investigation of the precipitation of energetic electrons out of the magnetosphere (Barcus *et al.*, 1967), a second series of high-altitude balloon flights was conducted from Byrd Station during January and February 1968. During the same period, a similar series of flights was carried out in an area that is magnetically conjugate to that of Byrd Station—near Hudson Bay in northern Canada. Polyethylene balloons of 100,000 cu-ft capacity and payload instrumentation consisting of energetic-particle and X-ray detectors, associated pulse-analysis circuitry, and telemetry gear were similar to those used previously.

The surface winds and weather conditions at Byrd Station were generally quite favorable for balloon inflation and release; on only two occasions were surface conditions so severe as to force postponements of planned releases. Extremely light stratospheric winds over Byrd Station and excellent balloon and payload performances combined to yield an average of about 40 hours of useful data per flight. Unfortunately, meteorological conditions in the vicinity of Hudson Bay were most unfavorable, both at the surface and in the stratosphere. As a result, only a limited amount of new information relating to conjugate features of electron precipitation was obtained.

Two intervals of enhanced solar activity occurred during the flight series although the resulting levels of geophysical disturbance were not particularly outstanding. Nevertheless, typical auroral-zone activity was frequently encountered, and a number of new and significant observations were recorded by our instruments in both hemispheres. While the analysis of the observations is incomplete at this time, some preliminary results concerning two special types of electron precipitation observed over Byrd Station will be noted briefly here.

Sudden Commencement Precipitation

Geomagnetic sudden commencements or sudden impulses are believed to be the result of the impact of solar plasma on the Earth's magnetosphere or of violent but transient readjustments of the magnetic intensity in the extended geomagnetic cavity. On only a few occasions have observations been reported of energetic electron precipitation accompanying these unusual perturbations. Thus, there is considerable current interest in examining such occurrences in detail in order to establish better the character of the radiation, its origin, and its relation to the more common forms of electron precipitation observed in the auroral zones.

At 1440 UT (0640 Byrd local time) on January 26, a very rapid and pronounced increase in bremsstrahlung X-radiation was observed by our instruments at 8 g/cm² residual atmospheric depth (Fig. 1). This increase was due to the bombardment of the upper atmosphere by electrons with energies exceeding 20 kev. The radiation enhancement was

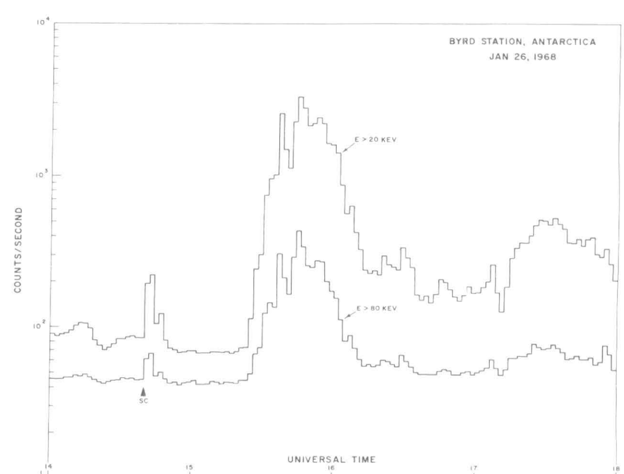

Figure 1. Enhancement in bremsstrahlung radiation due to the precipitation of energetic electrons accompanying and following a geomagnetic sudden commencement disturbance on January 26, 1968.

simultaneously accompanied by a similarly sudden and pronounced increase in the horizontal component of the Earth's magnetic field at Byrd Station as well as at low-latitude magnetic observatories, such as those at Honolulu and San Juan. Although the sudden commencement feature was quite clear, the subsequent disturbance did not reach storm proportions.

The electron precipitation coincident with the sudden commencement was highly structured in time (Fig. 2), with significant variations extending to a time scale of less than one second. On the other hand, the more intense and enduring precipitation, which was observed to follow the sudden commencement by about 40 minutes, was quite different. Although significant variations, on the order of minutes in duration, occurred in this latter event, the precipitation was otherwise exceedingly smooth and exhibited no tendency towards more rapid fluctuations.

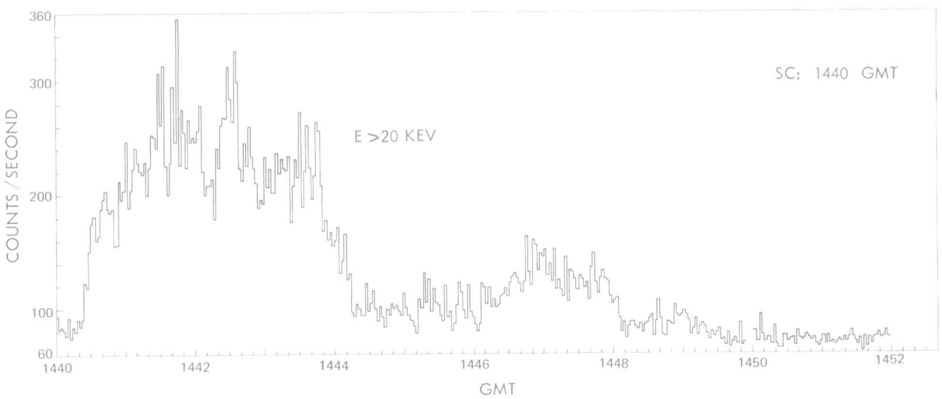

Figure 2. Higher time resolution of the radiation accompanying the sudden commencement.

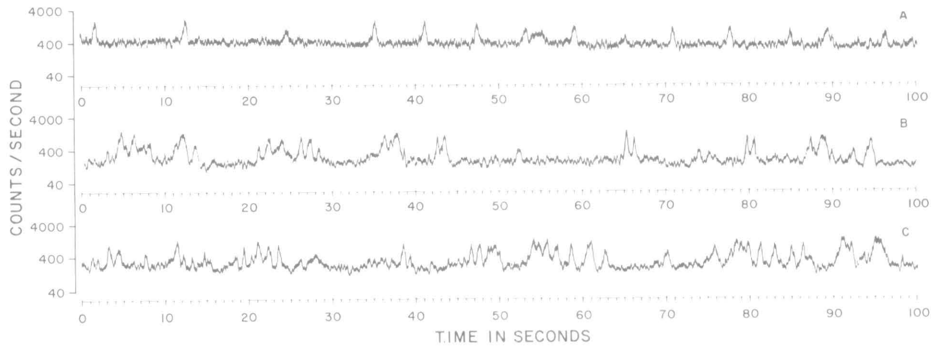

Figure 3. Selected samples of microburst activity observed at Byrd Station between 1500 UT and 1600 UT on February 3, 1968: (a) single, isolated bursts, (b) double- and triple-burst groups, and (c) more complicated structures.

These results are somewhat different from those we obtained last year at Byrd Station for a sudden-commencement event (Barcus, 1968). Also, the present results are quite dissimilar to those obtained by Brown (1967) for a sudden-impulse event; his observations (taken near local noon) showed that the sudden-impulse radiation was rather smooth, whereas the auroral-type precipitation preceding it was highly structured in time. As has been pointed out before, the resolution of this seemingly paradoxical behavior may simply reflect the local-time dependence which is known to exist for certain types of auroral-zone precipitation (Barcus *and* Rosenberg, 1966; Parks *et al.,* 1968) rather than specific magnetic-impulse mechanisms. Further observations and theoretical study are needed to clarify this interesting and important feature of auroral-zone phenomena.

Periodic Microburst Precipitation

Observation has established that energetic electron precipitation in the auroral zones is far from steady; rather, it is highly dynamical, exhibiting a temporal structure from 10^{-2} to 10^{3} seconds. These observations have come principally from experiments carried out by means of balloon platforms, which are relatively steady and thus admirably suited to this task. Anderson *and* Milton (1964) investigated rapid temporal variations and introduced the term "microbursts" for transient enhancements ($\approx$0.25 seconds full width at half maximum) of bremsstrahlung X-rays. As with other types of precipitation that await satisfactory quantitative explanation, empirical periodicities contain a wealth of information pertaining to the acceleration and/or release mechanisms at work in the magnetosphere.

Between 1500 and 1600 UT on February 3, we were fortunate to record an interesting microburst event. Some of the observations are shown in Fig. 3.

In the early part of the event, the microbursts occurred principally as single, isolated structures (Fig. 3a). Approximately midway through the event, double- and triple-burst structures predominated, with a well-resolved temporal separation of 1-2 seconds within a given group (Fig. 3b). Finally, towards the end of the event, more complicated structures were seen, but still with a similar intragroup spacing (Fig. 3c).

We wish to call attention to three largely qualitative facts: (1) for an interval of about one minute, a striking 6-second periodicity appeared in the occurrence of isolated microbursts (Fig. 3a); (2), a persistent intra-group spacing of 1 to 2 seconds frequently appeared; and (3), commencing with the microburst activity and continuing throughout its duration, there were recorded similarly structured VLF emissions at Byrd Station and its magnetic conjugate, Great Whale River, Canada. We are presently studying these features, as well as others, in greater quantitative detail and will report on them at a later time.

Acknowledgments. Once again we express our indebtedness to the many USARP and naval personnel who generously contributed their time and talents in support of this program. The work was supported under NSF grant GA–1132.

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Conjugacy of Visual Auroras During Magnetically Disturbed Periods

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Optical measurements of auroras near magnetically conjugate points provide information on distortions of the geomagnetic field caused by solar-wind pressure and electric currents within the magnetosphere and on the source and trajectories of the auroral particles. In March 1967, conjugate-point observations were made simultaneously aboard two NC–135 aircraft equipped with all-sky cameras on three round trips each across the northern and southern auroral zones (Belon *et al.,* 1967). Magnetic activity was very slight during all three flights, with the College *K*-index remaining between 0 and 2. Nevertheless, auroras were recorded between dipole (dp) latitudes 65° and 71°. They displayed a striking similarity in shape and intensity, at times being nearly mirror images of each other. Within the accuracy of the measurements, these auroras were found to be magnetically conjugate according to a model of the geomagnetic field that takes into account only sources of magnetism within the Earth (Hendricks *and* Cain, 1966). A tendency of the southern auroras to be slightly eastward of the northern conjugate auroras was ascribed to a slight asymmetric distortion of the geomagnetic field due to solar-wind pressure and Earth-sun geometry.

To investigate the conjugacy of auroras over a wider range of latitudes and, hopefully, during periods of greater magnetic activity, a series of five NC–135 conjugate flights was made during the new-moon period of the 1968 spring equinox. The instrumentation installed aboard the two aircraft was more sophisticated than that used during the 1967 flights and was intended to provide good spatial and temporal resolution as well as spectral information. It included an all-sky camera that takes photographs every 5.0 seconds with an exposure duration of 3.0 seconds, an image orthicon television camera that has a field of view of 40° at the zenith and that records auroras at 30 frames per second, a meridian-scanning photometer (on the northern aircraft only) that measures 8 prominent auroral emissions continuously, and a riometer to provide information on the precipitation of auroral particles having energies greater than 30 Kev. Several narrow-field cameras, zenith photometers, and a magnetometer were also operated on each aircraft.

The flight paths were approximately the same as those flown in March 1967, except that the range of both aircraft was extended to approximately dp latitude 72° (from 67° in March 1967).

The flights were made during a magnetically disturbed period with College K-indices of 5 and 6 on March 24, of 2 and 6 on March 26, of 3 and 3 on March 28, of 4 and 4 on March 29, and of 5 and 5 on April 1.

At the time of this writing, the data had been available for less than a week, and only a cursory examination of the all-sky-camera and television observations had been made, resulting in the selection of six pairs of all-sky camera photographs (see figure) to accompany this article. Rather than discussing details at this time, it seems preferable to present an average qualitative description of the latitudinal variation in conjugacy based on the preliminary examination of the data obtained on all five flights.

As the aircraft proceeded poleward during each flight, the first auroral form was encountered between dp latitudes 62° and 64°; in each instance, the scanning photometer identified it as a widespread and diffuse hydrogen arc. The all-sky-camera photographs showed it to be closely conjugate and very similar in shape and intensity in both hemispheres. Immediately poleward of the hydrogen arc, weak striated arcs, followed by more discrete and brighter auroral bands, were encountered. These arcs and bands were grossly conjugate, but the detailed features of the auroras appeared to become less similar with increasing latitude. Above dp latitude 67°, auroras which exhibited a degree of similarity were often displaced by several tens of kilometers from conjugate locations calculated on the basis of an internal geomagnetic field. This deviation from conjugacy did not appear to manifest itself consistently in the same direction at all times and latitudes, although there was an average tendency for the southern auroras to be located poleward and eastward relative to the conjugate northern auroras. The auroras observed at these latitudes (above dp latitude 67°) often differed greatly in intensity—the intensities of the northern auroras being on the average greater than those of the southern auroras. In this range of dp latitudes, a high degree of conjugacy in position and brightness occurred on several occasions for a few minutes within auroral displays which previously had appeared dissimilar.

One striking example of a breakdown in auroral conjugacy was observed on the last flight near the turnaround points of the two aircraft at about dp latitude 72°. At that time, a moderately bright, rayed arc was present overhead in the Northern Hemisphere. For a period of 20 minutes at the corresponding time and conjugate location in the Southern Hemisphere, no aurora appeared in the field of view of the all-sky camera. If this apparent nonconjugacy were due to an intensity difference between hemispheres, the southern aurora would have been at least 100 times weaker than the northern aurora.

The situation encountered on the return flights was generally similar, but more complex structures were observed. As the aircraft proceeded equatorward, a fair degree of conjugacy reappeared at latitudes below dp 65°. This was usually the region where pulsating auroras and the hydrogen arc were observed, often mixed. These auroras were again similar in structure and intensity.

The recording of pulsating auroras with the image orthicon television systems has revealed that when the pulsations are clearly identifiable, they are simultaneous in both hemispheres to within 0.1 seconds. Such a result is compatible with a particle-injection mechanism located near the equatorial plane.

In summary, it is evident, even at this early stage in the analysis of the data, that substantial deviations from the magnetic conjugacy (computed on the basis of an internal field) have been observed above auroral-zone latitudes. At least one instance of nonconjugate auroras was observed. It appears that the hydrogen arc and the region immediately poleward of it are always within the domain of closed field lines, while auroras above dp latitude 65° are in a transition domain where large stretching and perhaps opening of the field lines occurs (in that auroral particles are not guided directly across the equatorial plane).

Acknowledgments. This project was made possible only through the excellent cooperation of Mr. Ray R. Heer of the National Science Foundation; Messrs. T. J. Hallinan, L. R. Sweet, and G. LaPoint of the Geophysical Institute; Messrs. George Hughes, Mal Kennedy, Jack Ritchey, and their associates at the firm of EG&G, Inc.; Dr. R. E. Donaldson of the Lawrence Radiation Laboratory; Dr. M. M. Robertson and Mr. A. F. Huters of the Sandia Corporation; and Lt. Cols. Neil Garland and James Wells, USAF, and their personnel on each aircraft. The Geophysical Institute's participation was funded by the National Science Foundation through its Office of Antarctic Programs. The aircraft were operated by the U.S. Air Force and were funded by the Nevada operations office of the Atomic Energy Commission. The participation of the Los Alamos Scientific Laboratory, Lawrence Radiation Laboratory, Sandia Corporation, and EG&G, Inc., was under the auspices of the Atomic Energy Commission.

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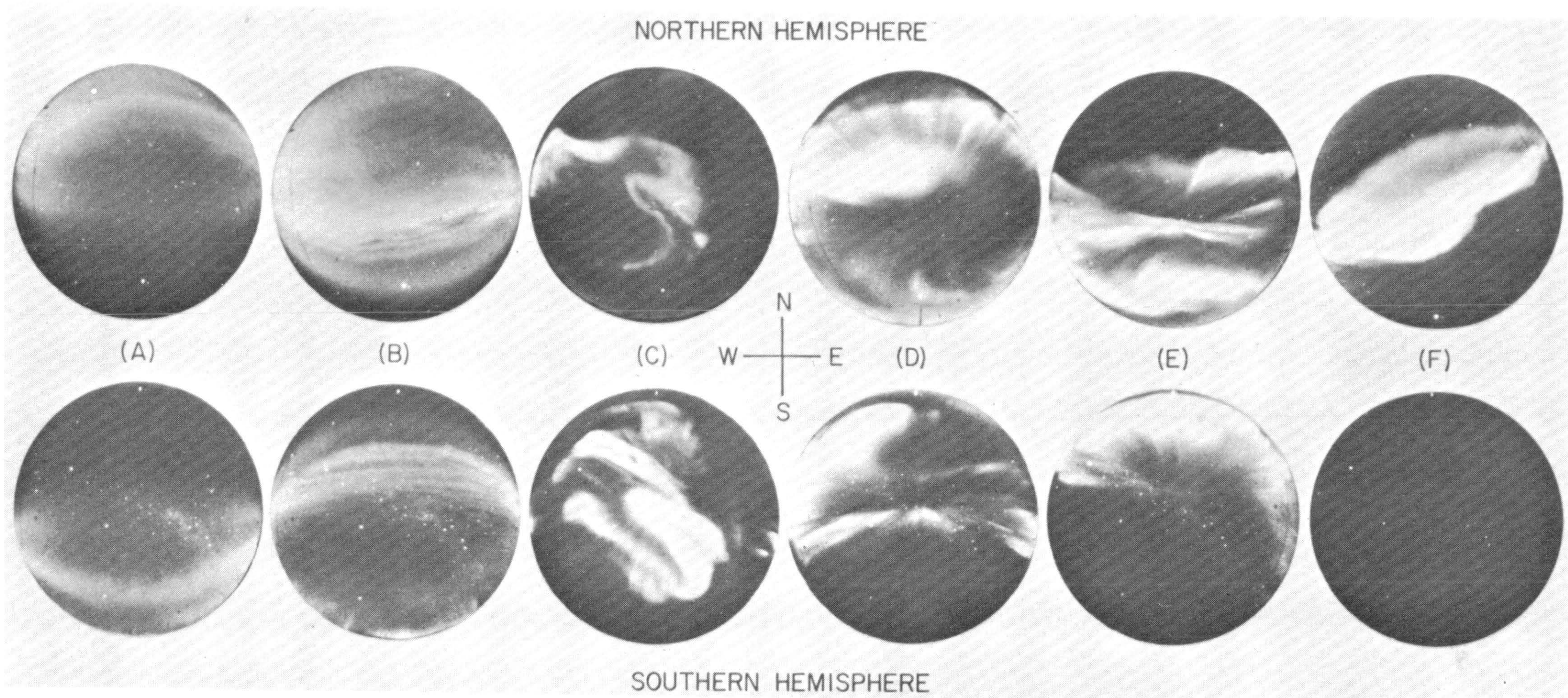

Examples of all-sky-camera photographs taken March 29-April 1, 1968, showing the degree of conjugacy of auroras in Northern and Southern Hemispheres.

A—March 29, 0845 UT (dp lat. 63°): Conjugate hydrogen arcs (zenith) at the equatorward boundary of the auroral display.

B—March 29, 0855 UT (dp lat. 63°): Conjugate striated arcs on the poleward side of the hydrogen arc.

C—March 29, 0925 UT (dp lat. 67.5°): Conjugate auroral bands in which the similarity of small-scale structure and brightness has greatly deteriorated.

D—March 29, 0930 UT (dp lat. 68°): Similar auroras which are displaced in latitude from conjugate locations calculated on the basis of an internal model of the geomagnetic field.

E—March 29, 1010 UT (dp lat. 67.5°): Conjugate auroral bands near dp lat. 65° accompanied by nonconjugate overhead auroras in the Northern Hemisphere.

F—April 1, 1000 UT (dp lat. 69°): Striking example of a breakdown in auroral conjugacy. As the aircraft flew from dp lat. 72° to 69°, there was no sign of an aurora in the Southern Hemisphere field of view (500 km).

REMOTE SENSING

Infrared Survey in Antarctica

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In December 1967, infrared imagery, radiation-temperature records, and aerial photographs were acquired over the volcanoes Mounts Erebus, Terror, Discovery, and Melbourne; the volcanic Balleny Islands; portions of the Scott Coast; some of the dry valleys of Victoria Land; and parts of the Ross Ice Shelf, McMurdo Sound, and the Wood Bay coast.

The equipment used included a Bendix Thermal Mapper (infrared scanner), a Barnes Airborne Radiation Thermometer (ART), and a T–11 tri-camera system. The survey aircraft was a C–121J operated by Air Development Squadron Six.

Evaluation of the data has not yet been completed, but some preliminary findings are noteworthy. Infrared imagery of Mount Erebus defines the geothermal activity associated with the summit crater (see figure). The Ektachrome Infrared photographs reveal incandescence in the central vent, indicative of molten lava. The upwelling of lava was not sufficient to cover the central crater floor.

Correspondence with Nathan (1967) of the New Zealand Geological Survey confirms that one anomalously warm area on the infrared imagery of Mount Melbourne coincides with a geothermal area discovered by his party in 1966.

Analyses of the infrared imagery and aerial photographs of the Balleny Islands have not revealed indications of present-day volcanic activity. An interesting aside to the Balleny Islands survey was the measurement of the altitude of the summit of Sturge Island—named Brown Peak by Balleny. L. B. Quartermain (1964) gives the elevation as 3,830 feet (1,167 m), and U.S. Navy Air Navigation Chart no. V30–SP7 lists it as 5,000 ± feet (1,524 ± m). An accurate measurement made with the SCR–718 radar altimeter indicated that the elevation is 7,150 feet (2,179 m).

Infrared image of Mount Erebus.

The infrared imagery differentiates many snow and ice features, such as crevasses, icefalls, sastrugi, and surface patterns caused by past and present meteorological conditions. Thermal anomalies have been found in the infrared imagery of ice- and snow-covered areas in locations where no visible break in continuity can be noted on panchromatic photographs. These anomalies are attributed to variations in the properties of the ice and snow caused by internal forces, meteorological or climatic factors, and the presence of near-surface features such as rocks, moraines, or snow-bridged crevasses. Thermal patterns known as "wind shadows," caused by the wind blowing across the snow surface, abound in the imagery and are particularly striking in the Mount Melbourne area. These may be useful in studies of prevailing surface winds, especially of local winds around major land forms.

Seals have been seen in the Ektachrome Infrared and panchromatic photographs and have been identified in the infrared imagery. Patches of lichens and/or mosses have not as yet been detected in the Ektachrome Infrared photographs. If they were present in the areas surveyed, they may have been too small to be resolved from aircraft altitudes.

The ART charts give a continuous record of radiation temperatures of features along the flight line. They can be correlated with identifiable objects in the infrared imagery and the photographs and thus provide approximations of surface temperatures. There are many applications of this information.

In summary, the results of the survey are quite encouraging. The infrared and photographic sensors show great promise for providing useful information to the various disciplines concerned with research and engineering in Antarctica.

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BIOLOGY

Soil Microbial and Ecological Studies in Southern Victoria Land [1]

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Since 1961, the Jet Propulsion Laboratory (JPL) has conducted a desert-microflora program involving investigations on several continents of desert environments, soils, and microorganisms relevant to the detection and quarantine of life on Mars. The objectives are to study and identify basic groups of microorganisms of extreme environments, especially those of desert soils, and to correlate the environmental parameters with the distribution, abundance, and kinds of microorganisms and their activities.

Antarctic dry valleys have been studied during the austral summers of 1966–1967 (Cameron, 1967) and 1967–1968. Five field sites were established for approximately one-week periods, some in cooperation with the Virginia Polytechnic Institute (VPI) (Benoit *and* Cameron, 1967). Soil samples were collected aseptically from the surface to a level a few inches below the upper surface of permafrost at selected sites throughout the valleys. Measurements or observations were made either continuously or every three hours of soil temperature, solar-radiation flux, net thermal exchange, ultraviolet-radiation flux, light intensity, wind direction and velocity, barometric pressure, evaporation rate, relative humidity, dew point, and gas concentration.

During the past season, 58 surface and subsurface soil samples were collected. Twelve of them were obtained with Dr. James Turnock of NASA, Washington, D.C., for testing at the Lunar Receiving Laboratory. Microbiological analyses of 45 samples from 22 sites were made at the McMurdo biological laboratory. More than 1,000 pounds of frozen samples were sent to JPL's Soil Science Laboratory for further processing and analysis. Sandy, saline soils that are sometimes high in chlorides, nitrates, and sulfates, but quite low in organic matter, yielded few microorganisms.

For the first time in the study of desert-soil microbial ecology, it was found that the abundance and diversity of microorganisms was greatly dependent upon variations of specific ecologic factors. Unfavorable environmental conditions, such as east-west valley orientation, south-facing slopes, low solar-radiation flux, high southerly winds, low humidities, short duration of available water, and salty soils, were observed to restrict greatly the existence and activity of microorganisms. A comparison of favorable and unfavorable ecologic factors important for determining the distribution of life in the antarctic dry valleys is shown in Fig. 1. Under the least favorable conditions, either no microorganisms or only a single population of heterotrophic, aerobic, nonpigmented bacteria was observed. For example, such conditions were observed

FAVORABLE

N-S ORIENTATION
NORTHERN EXPOSURE
GENTLE, NORTH-FACING SLOPES
HIGH SOLAR RADIATION
MICROCLIMATE ABOVE FREEZING
ABSENCE OF WIND
NORTHERLY WINDS
HIGH HUMIDITIES
SLOW OR IMPEDED DRAINAGE
LENGTHY DURATION OF AVAILABLE H_2O
(PRESENCE OF GLACIERS, LAKES, STREAMS, SNOW AND ICE FIELDS)
TRANSLUCENT PEBBLES
NON-SALTY SOILS, BALANCED IONIC COMPOSITION
APPROX NEUTRAL pH
ORGANIC CONTAMINATION
(SKUAS, SEALS, ETC)

UNFAVORABLE

E-W ORIENTATION
SOUTHERN EXPOSURE
FLAT OR SOUTH-FACING SLOPES
LOW SOLAR RADIATION
MICROCLIMATE BELOW FREEZING
HIGH WINDS
SOUTHERLY WINDS
LOW HUMIDITIES
RAPID DRAINAGE
SHORT DURATION OF AVAILABLE H_2O
(ABSENCE OF GLACIERS, LAKES, STREAMS, SNOW AND ICE FIELDS)
OPAQUE PEBBLES
SALTY SOILS, UNBALANCED IONIC COMPOSITION
HIGH (OR LOW) pH
NO ORGANIC CONTAMINATION
(NO LARGE INCREMENTS OF ORGANIC MATTER)

Figure 1. Ecological factors determining distribution of life in antarctic dry valleys.

[1] This paper presents the results of one phase of research carried out by the Jet Propulsion Laboratory, California Institute of Technology, under contract NAS 7–100, sponsored by the National Aeronautics and Space Administration. Logistic support and facilities for the investigations in Antarctica were arranged by the Office of Antarctic Programs, National Science Foundation.

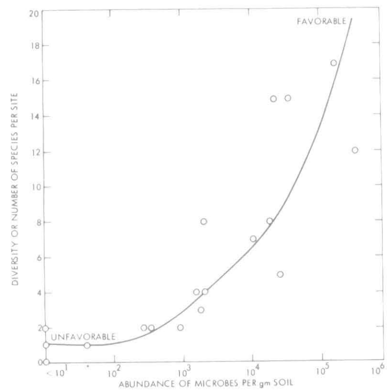

Figure 2. Diversity vs. abundance for surface samples at each soil-collection site in the Asgard Range.

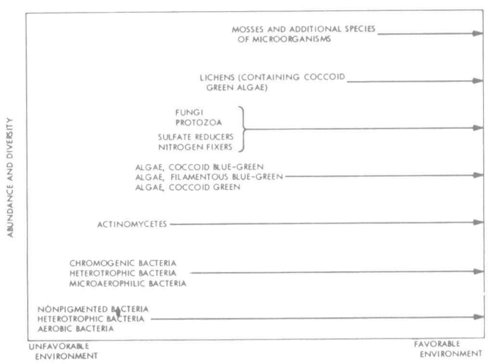

Figure 4. Variability of population density and diversity with variability of ecological factors in antarctic dry valleys.

SAMPLE No.	SAMPLE DEPTH, in.	AEROBIC BACTERIA + ACTINOMYCETES				ANAEROBES	FUNGI	ALGAE	MICROAEROPHILES
		+ 2°C	+ 20°C	+ 2°C	+ 20°C	ROOM TEMP	+ 20°C	ROOM TEMP	+ 20°C
661	SURF. 1	3.7×10^2	3×10^3	3.2×10^2	1.8×10^4	0	2.5×10^2	2×10^2	10^3
662	1 → 4	20	4×10^4	< 10	1.7×10^5	0	3×10^3	20	10^4
663	SURF. 1	0	1.6×10^2	~ 10^2	2×10^3	0	0	20	10^2
664	SURF. 1	0	< 10	0	< 10	0	0	0	0
665	SURF. 1	< 10	2.8×10^3	< 10	2.5×10^4	0	0	0	10^3
666	1 → 4	< 10	2.7×10^3	< 10	1.1×10^3	0	0	20	10^3
667	SURF. 1	< 10	30	0	40	0	0	0	10^2
668	1 → 4	< 10	< 10	0	< 10	0	0	0	10
669	SURF. 1	180	90	< 10	2.7×10^2	0	0	0	10^2
670	1 → 4	3.5×10^4	1.4×10^4	< 10	4.4×10^2	0	0	0	10^3
671	SURF. 1	1.6×10^2	30	0	3.1×10^2	0	2	0	10^2
672	1 → 4	2.5×10^2	90	0	30	0	2	0	10^2
673	SURF. 1	1.2×10^2	10^2	40	1.8×10^3	0	0	20	10^2
674	1 → 4	3.5×10^2	10^2	50	5.5×10^2	0	0	0	10^2
675	SURF. 1	10^2	1.8×10^2	10	9×10^2	0	0	0	10^2
676	1 → 4	2.4×10^3	1.2×10^3	2×10^2	2.4×10^3	0	0	0	10^2
677	SURF. 1	< 10	90	0	< 10	0	0	0	10
678	1 → 4	< 10	< 10	0	< 10	0	0	0	10^2
MEDIA		TRYPTICASE SOY AGAR		SALTS (SIMULATED TAYLOR VALLEY SOIL EXTRACT) + YEAST EXTRACT + NEOPEPTONE		TSA IN CO_2	ROSE BENGAL AGAR (5 gm INOCULUM)	THORNTON'S SALT MEDIUM (10 gm INOCULUM)	FLUID THIOGLYCOLLATE (POSITIVES RECORDED FOR HIGHEST DILUTION)

Figure 3. Microorganisms in Asgard Range soil samples (per gram of soil).

at all locations examined by the authors and Prof. Robert Benoit of VPI during a traverse they made cooperatively along the west side of the Matterhorn Glacier from the glacier's head to Lake Bonney in Taylor Valley.

The abundances of microorganisms determined for 18 samples are shown in Fig. 3. The maximum total abundance did not exceed 10^5/g of soil, and some samples contained few or no microorganisms as determined by culture techniques.[2] In three out of every four sites investigated, the subsurface microflora was more abundant than the surface microflora. Nonpigmented bacteria were generally more abundant than pigmented species and had the ability to grow in a wider variety of culture media. Most of the bacterial isolates were *Bacillus* spp., soil diptheroids, *Micrococcus* spp., and *Mycococcus* spp. The algae were primarily oscillatorioid and coccoid blue-green forms, including *Oscillatoria* spp., *Microcoleus* spp., *Schizothrix* spp., *Anacystis* spp., and *Coccochloris* spp. The fungi included a number of ascomycetous molds and some yeasts. Protozoa were of the flagellated or amoeboid forms. No bacteriophages were found. The absence of anaerobes is especially significant since they have not been found in the harshest of other desert soils (such as those of the Sahara and Atacama Deserts) investigated by JPL.

The relationship of population diversity and abundance of microorganisms in samples obtained from a valley in the Asgard Range is shown in Fig. 2. As indicated in this figure, species diversity and abundance increase with the favorableness of ecological conditions. For this valley, as well as for other valleys investigated, it was predicted and then substantiated that, with a given set of environmental conditions, there would be an ecologic succession as well as a numerical increase in organisms as the environment became more favorable (Fig. 4).

Additional antarctic soil samples will be analyzed and attempts made to correlate the abundance, distribution, and kinds of microorganisms according to pertinent ecological factors operative in the dry valleys. For life-detection purposes, whether terrestrial or

[2] Fifteen antarctic soils were studied by Dr. Jerry Hubbard of the JPL Bioscience Section. Soils were incubated with a substrate mixture containing ^{14}C–glucose and ^{14}C–amino acids. Metabolic $^{14}CO_2$ was then determined. The net CPM was found to correlate to a considerable extent with the absence or presence of microorganisms as determined by culture techniques.

extraterrestrial, it is becoming more evident that the environmental conditions, especially the duration of availability of nonsalty moisture, are extremely important for the existence of life in a harsh environment.

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Entomological Studies at Hallett Station

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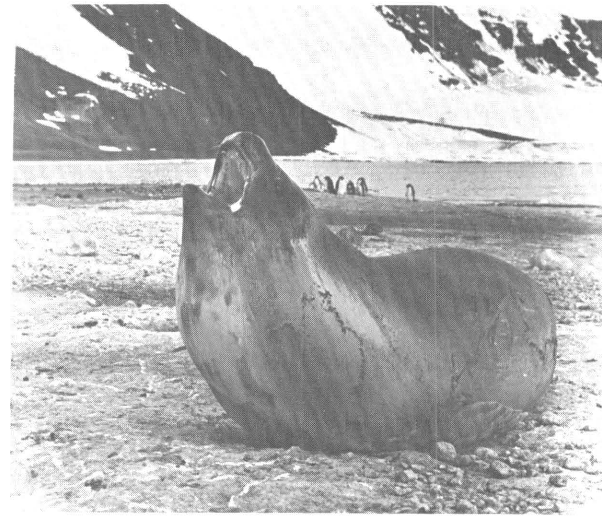
The end of the 1967–1968 austral summer brought to a close a third season of intensive study at Hallett Station of mites' life cycles. Tritonymphs of *Eupodes wisei* Womersley and Strandtmann were reared to adulthood *in vitro.* Offspring of these adults were then reared through all immature stages to adulthood of the second filial generation. This species of antarctic mite is the second one to have completed an entire life cycle in the laboratory, following success with *Stereotydeus belli* Womersley and Strandtmann during the 1966–1967 season, when techniques for *in vitro* culture were perfected. In both cases, the natural habitat was suitably duplicated by culturing algae and mosses upon an artificial medium. A golden-brown diatomaceous alga was found to be a primary source of food.

Attempts to rear *Protereunetes* sp. n. and *Coccorhagidia gressitti* to the second filial generation failed a second time. Mold in the cultures was a continuing problem.

Additional microclimatological data were accumulated in an effort to describe more accurately the terrestrial ecology of the study area. Algae and mosses were found to be secondarily dependent upon wind for an adequate water supply. Water was carried in the form of drifting new snow, and humidity was sublimed from existing snow fields. Most terrestrial arthropods of the area were dependent upon vegetation for food.

An interesting sidelight was the collection of 13 specimens of *Antarctophthirus lobodontis* Enderlein, 1909 (Anoplura), from two crabeater seals. The seals had been collected by Messrs. Terrance M. Wilson of Harvard University and Ian Stirling of Canterbury University, Christchurch, New Zealand. On January 31, a large male Ross seal wandered into the penguin rookery and was captured. It was inspected for lice, but none were found.



(Photo by E. E. Gless)
Large Ross seal in penguin rookery at Hallett Station

Recordings were made of the Ross seal's vocalizations. In addition to guttural thumping, it emitted a very high-pitched combination of whistling noises similar to high-frequency sounds recorded underwater from other seals. High-fidelity recordings of all sounds were made by Mr. D. H. Thompson of the University of Wisconsin's penguin behavior program. Additionally, many photographs were taken.

Ecology of Antarctic Protozoa

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Recent research in temperate regions of the United States has emphasized the importance of community structure, succession, and microhabitat in the ecology of free-living Protozoa. In addition, Bamforth (1958) emphasized the need in this regard for systematic, closely spaced observations over a long period of time. Following a preliminary survey near McMurdo Station during the 1966–1967 season (Dillon, 1967), the senior author planned a systematic study of protozoan ecology at Cape Royds on Ross Island. This study was conducted by the junior authors while the senior author extended the 1966–1967 observations to Palmer Station on the Antarctic Peninsula.

Beginning on December 10, 1967, and ending on February 5, 1968, visits were made about every five days to Coast Lake* at Cape Royds to obtain environmental and biological data, the former including maximum and minimum air and water temperatures, temperatures at the times of visits, cloud cover, and wind conditions. The types of lake-water data obtained are lisited below.

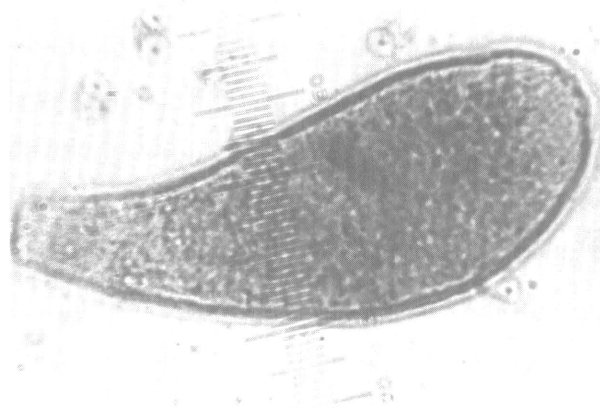
pH	Fe^{++}/Fe^{+++}	Cl^-
Dissolved oxygen	Mg^{++}, Mn^{++}	NO_2-N
Turbidity and color	K^+	NH_3-N
Conductivity	Na^+, Li^+	Ca^{++}
Total hardness	SO_4^{--}	NO_3-N
Alkalinity	PO_4^{--}, ortho and meta	

The quantitative biological data consisted of surface and bottom samples from nine stations arranged in transects across the lake. The samples were collected on millipore filters, then fixed and mounted on slides. Total species counts are being made of the Protozoa, primarily of ciliates. In addition, rotifers, tardigrades, nematodes, and algae are being counted because of their importance in understanding the nutritional and competitive roles of Protozoa.

Generally, the lake water is characterized by low temperatures (0°C.–5°C.), dissolved oxygen saturation, very high pH (9.2–9.9), and variable ionic content. Tentative results of the biological investigations reveal the presence of about 29 species of ciliate Protozoa, several flagellates and amoebae, 3 species of rotifers, and some tardigrades, nematodes, and filamentous algae. The tentative count of a bloom of the red rotifer (*Philodina* sp.), which peaked on about January 3, 1968, was about 5,000/cm² of bottom surface, while the count of the total ciliates in the same sample was nearly 9,000/cm² of bottom surface. Surface waters, although containing very few organisms, included an unidentified green flagellate that numbered about 50,000 to 100,000 cells/ml. The predominant ciliates belong to the following genera: *Nassula, Pleuronema, Vorticella, Oxytricha, Trachelophylum, Euplotes,* and *Paramecium.* Fixed samples, stained preparations, cultures, and photographs are being studied at the laboratories of the University of South Dakota for further identification of the Protozoa. Total and species counts of Protozoa from Cape Royds are also being continued, with the hope that they will provide information on the succession, nutrition, and other features of these organisms.

The remainder of the work at McMurdo consisted of the collection of freshwater and soil samples from about 25 areas.

The senior author made about 100 collections of flora from soils and meltwater ponds in the vicinity of Palmer Station, the British stations on Adelaide Island and the Argentine Islands, and near Argentina's Almirante Brown base and the Chilean refuge near Adelaide Island. Near Palmer Station, collections were made on Norsel and Bonaparte Points and on Cormorant, Humble, and Litchfield Islands.



Spathidium spathula, *from a meltwater pond near Palmer Station.*

Smears were made of blood collected from 17 fish, and special slides were made of free-living and cultured Protozoa. Data on communities of Protozoa and freshwater crustaceans were obtained from freshwater ponds. Amoebas similar to those gathered from soil at McMurdo (Dillon *et al.*, 1968) were found near Palmer Station. The culturing and identification of these organisms (particularly the protozoans) and the development of a checklist and pictorial set of drawings of antarctic Protozoa continue at the laboratories of the University of South Dakota.

*Unofficial name.

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Arthropods of the Convoy Range

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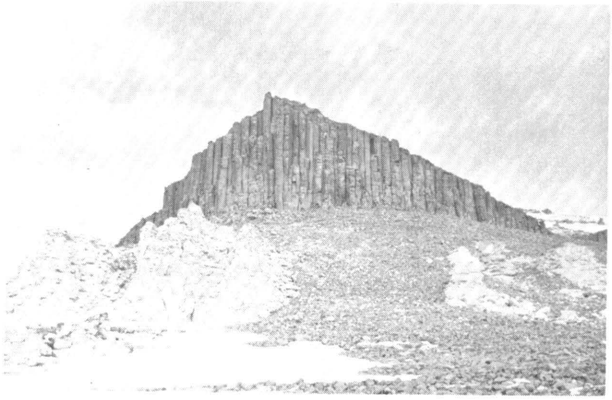
During the 1967–1968 austral summer, a search for arthropods was made in the previously unexplored Convoy Range, a series of small mountains and inter-



(Photos by authors)

Views of the Convoy Range; left, an outcrop of massive sandstone; right, the authors' camp.

vening dry valleys located about 160 km north of Taylor Valley and about 48 km inland from the Ross Sea.

The dominant geologic formation of the Convoy Range is a dense igneous rock that is red on exposed surfaces and gray within. Massive sandstone outcrops occur along the valley walls. The valleys are short (3–8 km), steepsided, and boulder strewn, and they contain scattered snowbanks. The glaciers are retreating but have not yet reached the stage of producing floodplains. Plant life is very sparse. A few orange-yellow and grey-black lichens were found on the slopes at an altitude of about 250–400 m. Green algae were noticeable on the margins of stones in areas moistened by melting ice and snow. Apparently there are no mosses. Mites were found only in areas where meltwater was present.

Camp was established on December 27, 1967, at about 76°40′S. 160°40′E. in the valley draining into the Towle Glacier.

We collected intensively for six days over an area of approximately 130 km^2 extending from the foot of the glacier (at an altitude of about 250 m) to the top of Elkhorn Ridge (at about 600 m). We found mites almost everywhere that the rocks were moist. Although the mites were widely distributed compared with those of such areas as Cape Roberts, Spike Cape, and Miers Valley, they were scarce. Generally, algae were obvious wherever mites were found, but sometimes mites were found where no trace of algae was visible. Collembola were present, but not in as many places as the mites.

We found two species of Collembola and two of mites in about equal abundance. The mites were *Stereotydeus mollis* and *Nanorchestes antarcticus*. Intensive collecting in certain areas of Victoria, Wright, and Taylor Valleys to the south also revealed the presence of only these two species of mites, whereas along the coasts—at Cape Roberts, Spike Cape, and Hobbs Glacier on the mainland and at Capes Royds and Crozier on Ross Island—an additional species (*Tydeus setsukoae*) occurs. North of Towle Glacier, at about 76°10′S., a predatory mite (*Coccorhagidia kiethi*) has been found.

I think we are now in a position to make the following general statement regarding the distribution of mites in the areas mentioned: Two species of mites (*Stereotydeus mollis* and *Nanorchestes antarcticus*) are ubiquitous in all of the areas; a third species (*Tydeus setsukoae*) is restricted to the coast; and the southern limit of the predatory mite is approximately 76°10′S. It is true that along the Kirkwood Range between Towle Glacier and Mount Murray there are a few isolated exposures, but they appear to be most inhospitable.

The authors are grateful to Lt. Donald Chider for his keen interest in their project and welfare.

Physiological Studies of Antarctic Mosses, 1967-1968

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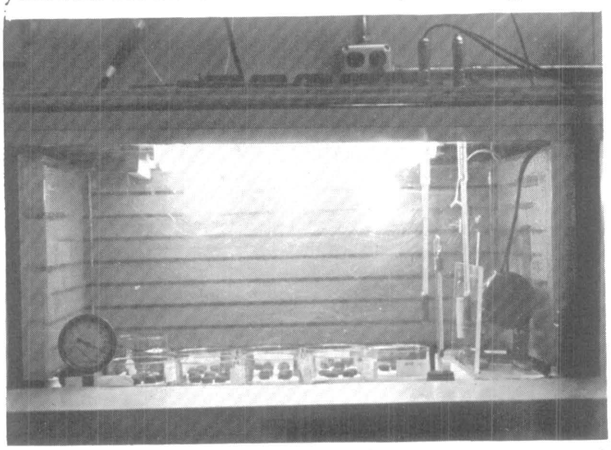
Preliminary studies of the physiology of antarctic mosses were completed during the past austral summer at McMurdo Station. They included culturing, pigment assaying, and measurements of photosynthesis and respiration of two species. Collections of *Bryum argenteum* and *B. antarcticum** served as

*The collection of this species often included some other *Bryum* spp.

the principal study materials because reconnaissance trips revealed them to be the most abundant mosses in the coastal regions of Victoria Land. Gametophytes of *B. argenteum* were collected at Cape Hallett, whereas those of *B. antarcticum* were collected at Marble Point, Miers Valley, and near the Hobbs Glacier. Although both species and other mosses were found elsewhere in Victoria Land, as well as on Ross and Black Islands, the Victoria Land localities provided a better supply of material for laboratory use.

Portions of the moss colonies were grown in a modified aquarium under laboratory-controlled temperatures of 10°C.±2°C. and light of 150 ft-c (with a 6-hour dark period per 24 hours). The plant samples had new growth within a relatively short time and were a much richer green than plants in the field. Leaves of *B. antarcticum*, which are a characteristic yellowish-brown color in the field, turned green in the laboratory owing to an increase in chlorophyll. The chlorophyll contents of both field and laboratory plants were determined spectrophotometrically. These studies indicate that the high solar radiation during the austral summer is superoptimal in adversely affecting chlorophyll content.

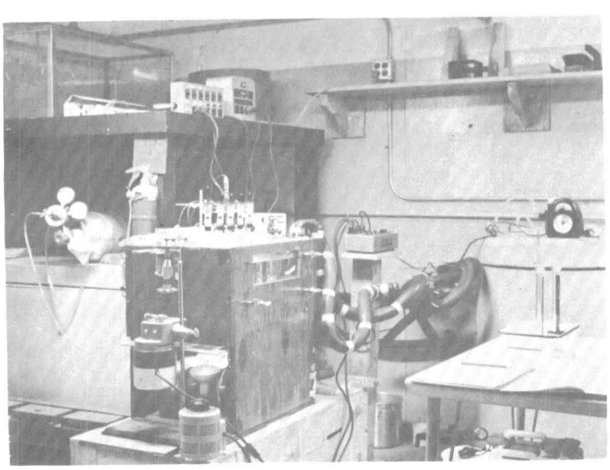


(Photo by J. R. Rastorfer)

Figure 1. Modified aquarium that served as a temperature- and light-controlled growth chamber for antarctic mosses.

One of the initial laboratory projects involved the construction of a temperature-controlled water bath equipped with lights to accommodate five Gilson all-glass volumometers (differential respirometers). This apparatus was used to determine net photosynthetic and respiratory rates by measuring oxygen exchange in air containing 1 percent CO_2 by volume. The tests were made over a wide range of temperatures and light intensities— from −2°C. to +38°C. and from 0.31 to 11.0 mw/cm², respectively. A preliminary evaluation of the results indicates that the photosynthetic and respiratory responses to temperature and light intensity are similar to those expected for mosses in temperate zones. It appears that the antarctic mosses studied do not require cold temperatures or high light intensities for survival, but that they have the capacity to endure them. It also seems apparent that at least minimal requirements for growth are met during the austral summer. The determination of these requirements will be given further consideration.

Other activities included the preparation of specimens of frozen and dried moss and soil for shipment to Ohio State University for further analyses. About 300 mineral agar cultures of mosses were initiated in the biology laboratory and shipped to the university. Although these cultures arrived in an impoverished condition, it now appears that there will be a high percentage of recovery.



(Photo by J. R. Rastorfer)

Figure 2. Apparatus used to measure photosynthesis and respiration of antarctic mosses.

Factors Determining the Distribution of Terrestrial Plants

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During the 1967–1968 austral summer, the groundwork was laid for a study of the distribution of terrestrial plants near McMurdo Station. It consisted of selecting five sites at which relatively large numbers of lichens, mosses, and algae occur, and of making initial ecological observations. Sites were chosen according to the assumed presence or absence in the substrate of different classes of nitrogen compounds. One site was in a skuary at Cape Royds, another was in a skuary near Cape Crozier, one was south of Miers Valley (about 500 m above Lake Miers), and two were on the Kar Plateau near Granite Harbor. A 400-m^2 quadrat was laid out for detailed investigation at each site. Small ponds, one each near three of the quadrats, were included in the studies because they contained lush growths of blue-green algae.

Soil and water samples were taken and preliminary analyses made of them. Nitrate and ammonium were detected in a very wide range of concentrations. Large quantities of urea were found in guano taken from the Cape Crozier Adélie penguin rookery.

Air, soil (surface and subsurface), and rock-surface temperatures, relative humidity, soil moisture, wind speed and direction, light intensity, and total sky radiation were measured. Maximum and minimum temperatures were recorded near the soil surface at various intervals of time during the summer; such readings for the winter will be determined early next season by thermometers presently in the field. In the 1968–1969 field season, all observations will be continued on a more intensive basis and additional parameters will be monitored.

Preliminary results suggest that moisture and type of nitrogen source are the primary determinants of plant distribution, with moisture probably being the more significant because it enables biological activity to occur in the first place and because the presence of moisture modifies a number of other soil and microclimatic factors, including the quantity and type of nitrogen source. Related to soil moisture, and to a large extent influencing it, are the soil's orientation with respect to the noon sun and exposure to wind. Small topographic features, such as knolls, can combine with the last two factors to determine the availability of soil moisture and thus the distribution of plants. Numerous examples of such environmental interactions were observed in various permutations and combinations at Cape Royds, Cape Crozier, and Kar Plateau.

Lichens, algae, and mosses were collected at each site. When they have been identified and enough observational data have been obtained, their distributions will be correlated with the environmental factors studied in the field. A number of species from each area will be isolated into pure culture to determine their nitrogen-source preferences, temperature requirements, and ability to fix atmospheric nitrogen. Observations made during the first season indicate that there are definite associations of lichen, algae, and moss species. Laboratory and field studies will be undertaken to detect interactions among these plants.

Next season, most work will be done in the field. As much weather and microclimatic data as possible will be collected to permit a comparison of the climates of the study areas. Additional soil, water, and plant collections will be made for the correlation analyses. Radioisotopes will be employed to study ion and nutrient uptake. The acetylene-reduction technique will be used to detect nitrogen-fixing systems in soil and water samples, and the plants themselves will be tested for nitrogenase activity.

Mr. Paul R. Theaker assisted in all phases of the field and laboratory studies.

Sub-Ice Observations of Ross Sea Benthic Marine Algae

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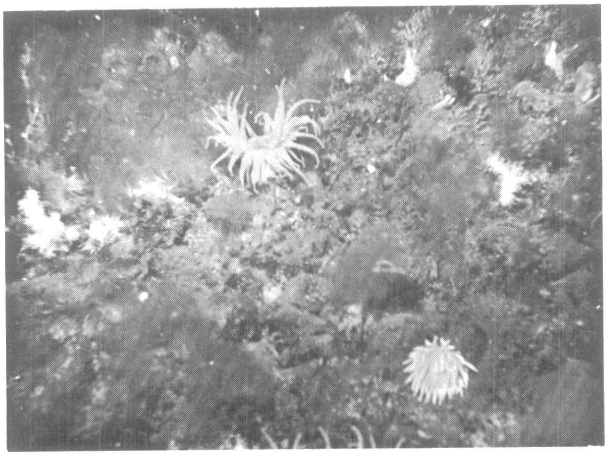
Sub-ice and submarine studies carried out during the austral summers of 1963-1964 and 1964-1965 revealed the presence of benthic marine algae with both stenobathic and eurybathic sublittoral and elittoral distributions (Zaneveld, 1966a, b, c, and 1968). In these papers, the author suggested that at least some of the Ross Sea algae might continue their growth throughout the year.

In order to check this theory, new investigations were made during the austral winter of 1967. Transportation to McMurdo Station was provided aboard the first regularly scheduled antarctic midwinter flight (Abbot, 1967). Sub-ice observations and collections made near Hut Point (77°51′S. 166°38′E.) showed that at least two species of Rhodophyta, *i.e. Phyllophora antarctica* A. et E. S. Gepp (Fig. 1) and *Iridaea obovata* Kützing (Fig. 2), continued to grow during the period of total darkness. All specimens collected not only had their natural color and shape, but were actively growing (some individuals even fructificating). These algae thus demonstrated that they are able to tolerate the stresses of such an extreme biotope as the Antarctic during the austral-winter months. Some as yet unidentified crustose and corallinaceous algae were also collected, similarly indicating adaptation to these extreme conditions.

All collections were made by means of scuba diving, carried out with the regular ¼-inch neoprene suit. The divers, students L. L. Nero and D. M. Bresnahan of Old Dominion College, used a 1,000-w, 115-v AC light of 65,000 centerbeam candlepower, which was found to give an excellent output in the total darkness under the ice. The duration of the dives was from 38 to 10 minutes at depths of 7 to 36 m, respectively. (See Fig. 3.)

The collection of algae in the winter confirmed the earlier assumption (Zaneveld, 1966c) that benthic



(Photo by L. L. Nero)

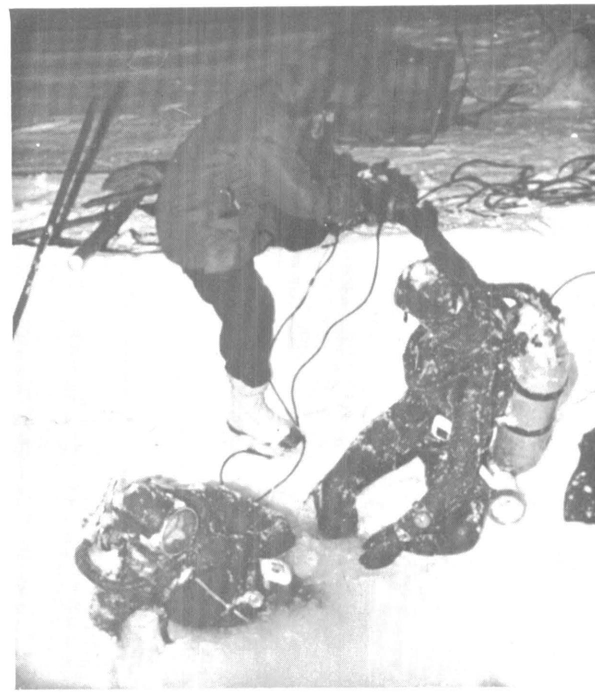
Figure 1. Midwinter (July 25, 1967) sub-ice flora and fauna at 30-m depth in McMurdo Sound.

Figure 2. An immature specimen of Iridaea obovata *Kützing collected on July 14, 1967, near Hut Point.*

(Photo by L. L. Nero)

marine algae are present in the Ross Sea throughout the year and are able to tolerate extreme environmental stresses of temperature and light. However, certain unforeseen limitations were placed upon the study. As fast ice did not form in the Ross Sea until the end of August, access was denied to the large beds of algae that had been found near Capes Royds and Evans during the austral summers of 1963-1964 and 1964-1965. Also, complete darkness was observed only between June 12 (the time of arrival) and July 22.

Apart from the limitations imposed by the various substrates, the main ecological parameters (low light intensity and temperature) decrease the rate of algal metabolism in the Ross Sea, particularly during the winter. During the summer months, when photosynthesis continues 24 hours per day, the algae must store a large amount of reserve substances. Though heterotrophic feeding of macroscopic deep-sea algae is not impossible, the more probable sources of energy for growth come from reserves accumulated the previous summer and possibly through reduced photosynthesis during the semi-darkness of winter. Certainly the balance of the metabolic processes is such that growth can continue throughout the year.



(Photo by W. J. Boggs)

Figure 3. Dr. Zaneveld hands the sub-ice light to Mr. Nero. Mr. Bresnahan is in the "water."

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Investigations of Isopod Crustaceans of Erebus Bay, McMurdo Sound

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Recent studies by the authors of isopods at generic and species levels, primarily on the basis of *Eltanin* data, have adequately documented the existence of a large and diverse benthic taxa in the cold antarctic seas. More than 200 isopod genera and approximately 350 species have been encountered within or south of the Antarctic Convergence, a great majority of them in the Scotia and Weddell Seas. In the less-known Ross Sea sector, field research was carried out during the 1967–1968 austral summer at McMurdo Station to obtain data on metabolic-response patterns and postembryonic growth rates of the antarctic stenothermal isopods, with particular emphasis being placed on the giant valviferan *Glyptonotus.*

Several specimens of isopods were collected by means of scuba diving through holes 1½–3 m in depth blasted or opened by seals in the shelf ice near Cape Armitage, Hut Point, and Cape Evans. They were kept alive in aquaria maintained at a near freezing temperature. Examination of three benthic samples of sponges revealed the presence of 15 isopod species belonging to the following genera: *Antias, Austrofilius, Austrosignum, Austroniscus, Austrogonium, Astacilla, Antarcturus, Cirolana, Coulmania, Gnathia, Iathrippa, Munna,* and *Paramunna.*

Studies of oxygen consumption were made of *Glyptonotus antarcticus* from the Erebus Bay area to determine the metabolic-response patterns of the whole organism as well as of tissue at different temperature levels (from $-1.8°$ C. to $+12.0°$ C.) by direct transfer from the habitat temperature (which remains within $-1.8° \pm 0.2°$C. throughout the year) and also after 48 hours of acclimation at the experimental temperature. The data suggest that this species is capable of metabolic compensation, the elevated rate of metabolic activity being reflected in the tissues studied *in vitro.* The R-T curve indicates shifts to alternate enzymatic pathways at definite temperature levels. Observations of thermal death points suggest that juveniles have better temperature tolerance than adults. However, the upper incipient lethal temperature is low, the average adult survival time being 13 hours at 6° C. and 6 hours at 12° C.

Observations of the feeding behavior of *Glyptonotus antarcticus* were made under laboratory conditions. This species was found to feed on a variety of dead and living invertebrates, including sponges, polynoid polychaetes, a gastropod (*Margarella* sp.), an amphipod (*Orchomenella* sp.), an isopod (*Cirolana* sp.), pycnogonids (*Ammothea* and *Collossendeis* spp.), and echinoid and crinoid echinoderms, including an ophiuroid (*Ophiacantha* sp.). This carnivorous giant isopod seems to be a predator and scavenger as well as a cannibal. Feeding movements were studied and photographed.

The reproduction and post-embryonic growth of *Glyptonotus* were also studied. This genus has a large reproductive capacity, an average of 900 eggs being found in its brood pouches. One ovigerous female collected in October released 940 juveniles on November 20–21; the newly hatched young were isolated and kept alive for periodical observations. Post-embryonic growth rates and data on molting frequency reveal some interesting patterns, including an unusual new mode of molting by this species.

Pycnogonid Studies

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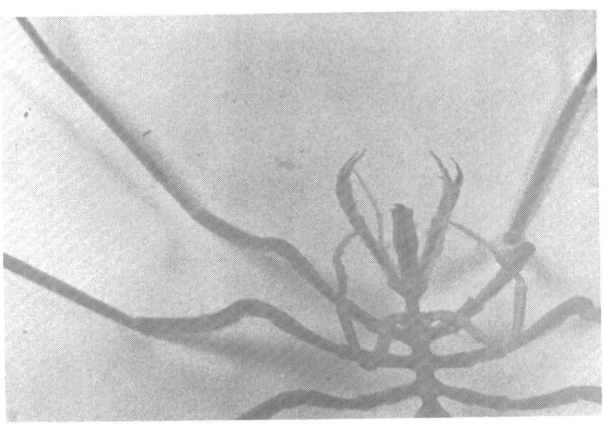
Living specimens of several species of the larger pycnogonids were collected in McMurdo Sound for studies of their activity and for fixation for later histological examination. In addition, voucher specimens were provided for ecological and respiratory-pigment studies. Most of the specimens were collected by Dr. John C. McCain by scuba diving. The common large pycnogonids that were observed and captured during November-December 1967 were *Colossendeis megalonyx, Ammothea clausi, A. striata,* and *Pentanymphon antarcticum.* Less common species were *Pallenopsis* cf. *patagonica, Colossendeis scotti* (one of the largest of all pycnogonids in terms of bulk), and *Nymphon charcoti.* Some idea of the size of *Colossendeis megalonyx* and *Nymphon charcoti* is given in Fig. 1.

The motion and coordination of these large pycnogonids are somewhat reminiscent of those of opilionids ("daddy longlegs"). In an aquarium, they walk in a leisurely, somewhat tentative fashion and, like their smaller relatives in temperate seas, seek out stones and sessile organisms to attach or cling to, or they entangle themselves with each other. A specimen of *C. megalonyx* walked across the disc of an expanded anemone without causing any perceptible reaction, but the anemone did retract slightly when similarly trod upon by *Ammothea striata;* this difference may be attributable to the stronger, more spinose toenails of the latter species. The motion pictures indicate that *Nymphon charcoti,* which has large, functional chelae, carries these appendages forward and open

(Photo by Joel W. Hedgepeth)

Figure 1. A dish of live pycnogonids (Colossendeis megalonyx *and* Nymphon charcoti) *at the McMurdo biological laboratory. The pan is about 14 inches wide.*



(Photo by John C. McCain)

Figure 2. Nymphon charcoti *moving forward, chelae open.*

at the "ready" position, in the manner of scorpions and pseudoscorpions. (In these terrestrial arachnids, however, the appendages so involved are actually modified pedipalps.) Perhaps the chelae serve both as sensory and defensive or offensive appendages (Fig. 2).

Studies now in progress indicate that the deep-sea genus *Pantopipetta,* represented in *Eltanin* and *Vema* samples from antarctic waters, may be closely related to the genus *Austrodecus.* The species of *Austrodecus* are among the smallest of pycnogonids. One of them is characteristic of the benthic mat of the Ross Sea. Species of the genus *Pantopipetta* are very slender, attenuated organisms having proboscises that are remarkably similar to those of *Austrodecus,* suggesting ecological as well as morphological likenesses between the two genera. Superficially, the species of *Pantopipetta* resemble certain species of the genus *Colossendeis,* which may have an antarctic origin but are possibly more closely related to *Austrodecus* and the ammotheids than to the colossendeids, suggesting one more aspect of the biological continuum of the Pycnogonida that makes ordinal divisions untenable. It is of interest to note that the pycnogonids are the only arthropods whose classification depends on the presence, absence, or various combinations of anterior appendages. Consequently, familial lines are also difficult to establish.

Preliminary Studies of the Physiology of the Pycnogonida

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The Pycnogonida are inhabitants of all of the world's oceans and, in certain regions, such as the Antarctic, play an important role in the biological community. Despite their wide distribution, practically nothing is known of their physiology. This shortcoming is probably a result of the small size of most species. The unusually large size of many antarctic pycnogonids makes possible physiological studies that would otherwise be extremely difficult to carry out.

Specimens of *Ammothea striata,*[1] collected by scuba divers[2] in McMurdo Sound on both sides of Hut Point, were maintained in refrigerated aquaria in the biological laboratory at McMurdo Station. Blood samples were taken from the legs by inserting fine-glass capillaries at the joints. The legs of *Ammothea* are very slender, the cuticle is thick, and gut diverticula extend almost to the tips of the legs. The total blood space is small; at best, only about 0.5 ml of blood could be obtained from a large individual. These samples almost certainly included some fluid from gut diverticula. The blood tended to clot quickly into a sticky gel, further complicating the collecting procedure. The blood samples were centrifuged and the supernatant taken to Iowa State University for analysis of sodium, potassium, calcium, magnesium, and chloride content. Concentrations of the metallic elements and of chloride were determined by atomic-absorption flame spectophotometry and

[1] Species identifications were made by Drs. Joel Hedgpeth and John McCain of Oregon State University.

[2] Mr. Gordon Robilliard, Mr. Paul Dayton, and Dr. John McCain performed this service. Without their help it would not have been possible to obtain specimens for study.

automatic chloride titration, respectively. Samples of seawater were collected and analyzed in the same fashion. The results for two specimens from which adequate blood was obtained are shown in the table. Values are expressed in mmole/l and as the percentage of the corresponding element in seawater.

Amounts of various elements and water in two samples of pycnogonid serum and in associated seawater.

Samples	Elements present					
	Ca	Mg	Na	K	Cl	H_2O (gm/l)
1. Serum (mmoles/l)	15.6	67.6	599	22.8	814	847
Seawater (percent)	153	126	116	254	119	—
2. Serum (mmoles/l)	—	66.9	542	25.7	664	938
Seawater (percent)	—	125	120	226	94	—

The chloride content of the first serum sample appears to be much too high. A third serum sample gave a chloride value of 624 mmoles, which is much closer to that of the second. The collecting and handling of such small volumes of fluid resulted in the loss of water by evaporation. Consequently, all absolute concentration values are somewhat too high, although the ratios of elements in a given sample should be correct.

Despite this uncertainty, the data show unusually high concentrations of potassium and magnesium in the blood samples. The extremely sluggish nature of these animals is in keeping with the presence of large amounts of these elements, but another possibility must be considered. The preceding data are indicative of ionic regulation, but the Pycnogonida lack discrete excretory organs. Since it was difficult to obtain blood without puncturing the gut wall, it cannot be stated definitely that the high values of potassium and magnesium are normal for pycnogonid blood. If they are not, they must be due to contamination from gut fluids, which would strongly suggest that the gut epithelium is an important site of ionic regulation. This question merits further investigation.

The blood appeared to contain large quantities of protein, but the small sizes of the samples precluded its measurement. Spectral-absorption curves of the blood showed no evidence of a blood respiratory pigment.

Phase microscopy of living material revealed the presence of only one distinct kind of blood cell—a small, elongate, granular cell with an indistinct nucleus. This cell is about eight microns in length and six microns in width. Fixed and stained preparations, for light and electron microscopy, suggest that there may be other cell types present, but this examination has not been completed.

A preliminary histological examination of the legs showed the epithelium beneath the cuticle to be one cell-layer deep, columnar near the joints, and more complex in structure away from the joints. Projecting from the epithelium into the cuticle are many structures (presumably sensory in function) of three types. The first type, the smallest and most numerous, consists of spindle-shaped organs that penetrate almost to the surface of the cuticle but not beyond it. The second type is made up of structures, broadest at their bases, which pass through the cuticle and possibly into the bases of cuticular bristles. The third type is similar to the second but of broader dimensions; its external projection is capped by a dome-like swelling on the surface of the cuticle, giving it an appearance similar to that of the campaniform sensilla of insects.

This research was supported by National Science Foundation grant GA–1105.

Metabolism in Three Species of *Notothenia*

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and

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Extensive fish collecting and laboratory experiments were carried out at Palmer Station during the past austral summer. Metabolic studies were conducted of three species of *Notothenia* that are abundant in Antarctic Peninsula waters: *N. coriiceps, N. nudifrons,* and *N. gibberifrons.* The preliminary analyses revealed no unusual metabolic features as compared with those of other cold-water fishes examined earlier. The resting oxygen consumption at 0°C. ranged from 0.03 to 0.06 ml of O_2/g/hr in specimens weighing from 45 to 283 g. The oxygen capacity of the blood ranged from 4.5 to 8.8 volume percent. In spite of these low oxygen capacities, the fishes sustained a normal oxygen consumption even at low oxygen tensions; the critical oxygen tensions at 0°C. were from 10 to 20 mm Hg. Blood samples from the three species were collected and preserved for studies of their osmotic properties. The project will be continued and expanded during the next austral summer.

Parent-Chick Individual Recognition in the Adélie Penguin

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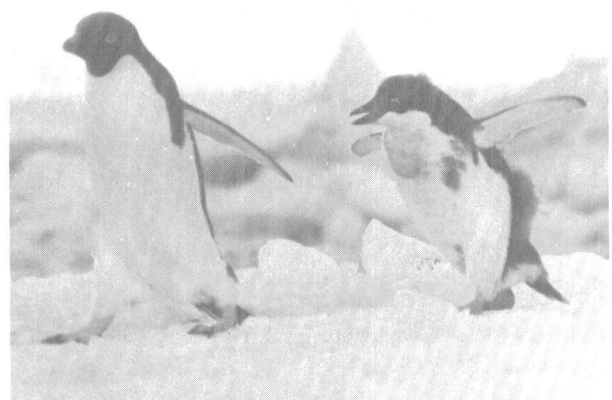
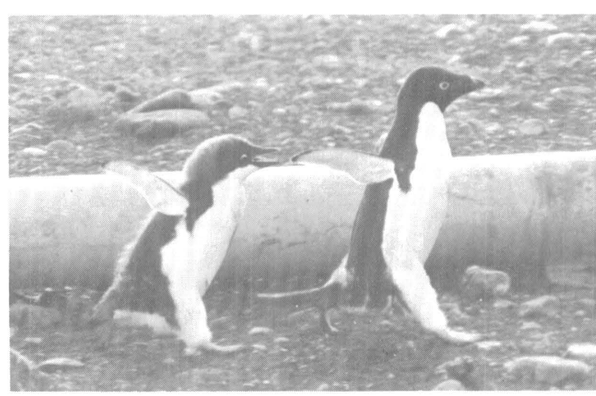
During the 1965–1966 and 1967–1968 austral summer seasons, studies were undertaken at Hallett Station to determine how Adélie penguin chicks and their parents establish contact under the crowded conditions and confusion of a crèche-stage Adélie penguin colony. Attention was focused on the development of the ability to discriminate at the individual level in both adults and chicks.

Various forms of cross-fostering experiments demonstrated that individual recognition begins to develop during the three weeks after hatching, when the chicks are confined largely to their nests and are attended continually by one or the other of their parents. During the first week after hatching, the chicks are inactive, and the parents are quite indiscriminating. The first rejection of foster chicks, indicative of a parent's ability to identify its own young, occurs at approximately eight days of age. The incidence of such rejections increases subsequently until, by the 17th day, nearly all experimental introductions are rejected. Fear, aggression, and vocal displays appear in penguin chicks during this stage of their development and figure importantly in the formation of exclusive family bonds.

Chicks leave their nests permanently when they are about 21 days old, and for the next five weeks congregate with neighbor chicks in clusters or crèches during the long hours when their parents are away at sea. The return of an adult to the colony during the crèche stage is followed by a series of interactions before the food is finally delivered to the proper chick or chicks. The stages of interaction are as follows:

1. Upon arrival, the parent goes to its now abandoned territory and vocalizes.
2. The chick or chicks belonging to the vocalizing adult immediately approach the site.
3. The parent initiates mutual vocal display with any chicks that approach it, then drives away chicks other than its own.
4. The parent runs off, with the persistent chick or chicks in pursuit. The vigorous "feeding chases" (so named because most feeding occurs during intervals in the chase) loop back and forth, often covering several hundred meters. Less persistent chicks, including strange individuals, generally drop behind and are lost.





(Photos by John T. Emlen)

The vigorous feeding chases loop back and forth, often covering several hundred meters.

5. Should the parent and persistently pursuing chicks loose contact with one another, both return to the nest site, where contact is reestablished by some of the steps outlined above.

This rather complex sequence of behaviors apparently ensures, by means of redundancy, that an adult will deliver food only to its own young.

Early Embryology of the Adélie Penguin

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The object of this study was to compare the early development of the Adélie penguin (*Pygoscelis adeliae*) incubated under extreme environmental conditions with that of the domestic chicken incubated under ideal conditions. "Early embryology" here means those stages between the featureless unincubated blastoderm and the formation of the first recognizable vertebrate structures (somites, neural tube, and notochord). The following questions were among those considered: In what stage of development (compared with the normal stages of the chicken embryo) is the penguin embryo when the egg is laid? Does the unexpectedly long incubation period of the Adélie penguin (about 35 days) result from retardation in the early part of the incubation period?

This study was made at Hallett Station, near which was a large group of nesting Adélie penguins. The first penguins arrived on October 16, 1967, and the two embryologists (my able assistant was Mr. Nels H. Granholm) came on October 21, 1967. The first eggs were laid November 2. From then until November 9, several colonies close to the biology laboratory were searched for eggs at 8-12 hour intervals, and all of the eggs found were marked with the date and time. Eggs of approximately known age were taken into the laboratory, where the embryos were removed and examined.

Although we did not obtain any eggs as soon as they were laid, we could determine that the Adélie penguin embryo is probably in a stage corresponding to the unincubated chicken blastoderm when the egg is laid. The unincubated penguin blastoderm is about the same size (3 mm in diameter) as the unincubated chicken blastoderm. Adélie penguin embryos incubated by the penguins required 3-4 days to reach a definitive streak stage that the chicken embryo attains in 18 hours. A comparison of the ratios of the time required to reach the definitive-streak stage with the total incubation period for each species indicates that the penguin embryo remains proportionately longer in this early stage of development than does the chicken embryo. Whether this retarded early stage of development is due to a lower incubation temperature or to egg exposure, or whether this would be the rate of development at any constant physiological temperature, remains to be investigated.

In our small sample of embryos, we found that about 33 percent were dead or had been so arrested in development that hatching would have been unlikely, indicating that a large proportion of the natural breeding mortality occurs even before the embryo proper is formed. Most of this mortality is probably caused by poor brooders—birds who do not sit tightly on their eggs.

Comparative Biochemistry of Proteins

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University of California (Davis)

During the past antarctic summer, two graduate students from the University of California (Davis) carried out biochemical research and collected specimens on Ross Island. These students, Richard G. Allison and Stanley K. Komatsu, had participated in the biochemistry program at Davis for several years and had conducted field work at McMurdo Station and elsewhere on Ross Island during a previous summer. The 1967–1968 field work was a continuation of the Davis laboratory's study of the physical and chemical properties of proteins, including enzymes, of antarctic species. This project has concerned two major subjects: (1) the egg and blood proteins of penguins and (2) the blood proteins and muscle enzymes of several of the cold-adapted fish of McMurdo Sound. Both of these subjects involve evolutionary adaptations at the molecular level, and the second one involves particularly the effect of cold adaption on the molecular parameters of the purified proteins and enzymes.

During the fall of 1967, our attention was directed primarily to obtaining biologic material, partially processing it, and freezing it for return to the University of California. This work included collecting eggs and blood samples from approximately 25 Adélie penguins, some of which had been injected with antigens of bovine serum albumin and chicken ovotransferrin. These birds were injected and banded at Cape Crozier in the 1966–1967 season and then recaptured last season. Approximately 100 specimens of the fish *Trematomus borchgrevinki* were obtained, and samples of their blood and muscle were prepared. A preliminary study was conducted on the effect of temperature on the rate of blood clotting in one cold-adapted fish. In addition to the collection of samples for return to the U.S., certain chemical and physical examinations of the material were made at the McMurdo biological laboratory, including gel electrophoretic patterns of blood-serum proteins and initial fractionations of some of the muscle enzymes.

The more definitive phases of the characterization of the proteins is being continued in the laboratories of the University of California (Davis).

Cardiovascular Adaptation of Diving Weddell Seals

ROBERT ELSNER *and* GERALD L. KOOYMAN

Scripps Institution of Oceanography
University of California (San Diego)

CLAUDE LENFANT

Department of Medicine and Physiology
School of Medicine, University of Washington

and

CHARLES M. DRABEK

Department of Zoology
University of Arizona

A two-season project involving studies of the physiological reactions of diving Weddell seals (*Leptonychotes weddelli*) was initiated in mid-October 1967 with the placement of huts over man-made holes in the sea ice near Castle and Turtle Rocks in McMurdo Sound.

The studies are of three types: (1) the determination of natural diving times of pregnant seals, (2) investigation of properties of seal fetal and maternal blood, with particular reference to oxygen transport mechanisms, and (3) the elucidation of circulatory changes through data obtained from instrumented pregnant seals. These data are being compared with similar data obtained in this laboratory on nonpregnant adult seals, newborn seals, and pregnant and fetal sheep.

The general features of the adaptive responses to diving are now well known. Conservation of oxygen stored in blood is effected by circulatory redistribution, which causes the oxygen to bypass organs of high anaerobic capacity and selectively perfuse those organs (heart and brain, for example) which require a steady oxygen supply. The consequent decrease in the total cardiovascular outflow results in lowered heart rate, although arterial pressure is maintained. In recent studies at the Scripps Institution of Oceanography (Elsner *et al.*, 1966), implanted blood-flow meters were used to provide direct evidence of the circulatory changes that occur during dives. It was also discovered that a similar adaptive pattern was elicited by asphyxia in dogs, humans, pregnant ewes, and fetal lambs. While pregnant ewes experienced drastically reduced kidney circulation during asphyxia, as did diving seals and asphyxiated dogs, their uterine-artery blood flow was sustained. After a delay of about 30–45 seconds, a lowering of both heart rate and abdominal aorta flow in the fetal lamb was observed.

What, then, happens to the uterine-artery flow and fetal circulation in a pregnant seal during a long dive? Kooyman (1966) has shown that the Weddell seal can remain submerged for as long as 43 minutes and can reach a depth of 600 m. It is, therefore, the best of the pinniped divers—at least of those for which information is available. In Antarctica, experimentation on instrumented, free-swimming seals can be carried out more advantageously than elsewhere because the animals can be released in man-made holes in the sea ice at locations that are distant from other openings, thereby assuring that they return to the same holes.

During the austral spring at McMurdo Sound, it was possible to obtain measurements of the free-diving time of and depth attained by Weddell seals that were in late pregnancy. These data were then compared with Kooyman's earlier corresponding measurements of nonpregnant seals at the same site. Four animals were used in last season's study, and several diving times and depths were recorded. There was no indication that an advanced state of pregnancy was a disadvantage for natural diving. In fact, the longest diving times that have ever been measured (40–50 minutes) were those of seals in an advanced state of pregnancy.

The respiratory properties of blood drawn from four adult and four fetal animals were determined. The fetal blood of the seals was found to be similar to that of terrestrial species in that it has a greater affinity for oxygen than maternal blood, as indicated by a shift of the oxygen dissociation curve to the left. The oxygen capacity of fetal blood, however, was less than that of maternal blood.

Studies dependent upon the surgical implantation of blood-flow measuring devices were initiated also. Flow measurements of the maternal circulation are expected to establish whether or not blood supply to the fetus is preferentially maintained or reduced during severe asphyxial stress. It was established that

(Photo by Gerald Kooyman)

Dr. Elsner, assisted by Mr. Wulf Massell, surgically implanting blood-flow meter on the uterine artery of a Weddell seal.

drugs could be used safely for tranquilization and immobilization. The animals were transported in this state to a hut on the sea ice, where they were intubated and anesthetized with halothane gas. Doppler ultrasonic blood-flow meters were implanted on the uterine arteries of pregnant seals under aseptic conditions and anesthesia, and blood flow was successfully measured. This aspect of the investigation will be continued.

The study is being supported by NSF grant GA 1215, NIH grants HE 08323 and HE 08405, and NIH Research Career Development Award 5 K03 HE 07469.

References

Elsner, R., D. L. Franklin, R. L. Van Citters, *and* D. W. Kenney. 1966. Cardiovascular defense against asphyxia. *Science*, 153: 941–949.

Kooyman, Gerald L. 1966. Maximum diving capacities of the Weddell seal, *Leptonychotes weddelli*. *Science*, 151: 1553–1554.

Other Biological Projects Active During the 1967–1968 Summer

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

Lichens and Bryophytes of the Falkland Islands. Michigan State University; Henry A. Imshaug, Principal Investigator.

Identification and Physiology of Antarctic Microorganisms. Virginia Polytechnic Institute; Robert E. Benoit, Principal Investigator.

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

USARP Field Personnel, Summer 1967-1968

Byrd Station

Barcus, James R., Ionospheric Physics, Univ. of Denver
Brush, Bernard E., Station Engineer, Univ. of Wisconsin
Garfield, Donald E., Glaciology, CRREL
Gianola, Dominick J., Glaciology, CRREL
Gow, Anthony J., Glaciology, CRREL
Hansen, B. Lyle, Glaciology, CRREL
Hobart, H. David, Meteorology, Weather Bureau, ESSA
Jones, John E., Ionospheric Physics, ESSA Research Labs.
Jones, Robert M., Meteorology, Weather Bureau, ESSA
Keyes, Gordon, Ionospheric Physics, Univ. of Denver
Koons, Robert W., Asst. to Sta. Scientific Leader, AINA
Parrish, Edward N., Glaciology, CRREL
Pitts, John J., Ionospheric Physics, ESSA Research Labs.
Reynolds, Donald K., Ionospheric Physics, Univ. of Wash.
Say, Howard R., Jr., Meteorology, Weather Bureau, ESSA
Smith, Carl W., Seismology, Stanford Research Inst.
Spitz, A. Lawrence, Ionospheric Physics, AINA
Strange, William B., Glaciology, CRREL
Strawn, Lawrence W., Glaciology, CRREL
Trenholm, William L., Glaciology, CRREL
Trimpi, Michael L., Ionospheric Physics, Stanford Univ.
Ueda, Herbert T., Glaciology, CRREL
White, Franklin E., Ionospheric Physics, Univ. of Denver
Willard, Harrison R., Ionospheric Physics, Univ. of Wash.
Williamson, Paul R., Ionospheric Physics, Univ. of Denver
Young, Durward D., Jr., Seismology, Stanford Res. Inst.

Byrd Strain Network

Brecher, Henry H., Glaciology, Ohio State Univ.
Brockamp, Bernhard, Glaciology, Univ. of Munster, Ger.
Dewart, Gilbert, Glaciology, Ohio State Univ.
Kane, H. Scott, Glaciology, Ohio State Univ.
Marshall, William F., Topographic Engineer, USGS
Mathis, Terry R., Traverse Engineer, Univ. of Wisconsin
Reed, David E., Topographic Engineer, USGS
Schwartz, Bruce L., Topographic Engineer, USGS
Southern, Merle E., Topographic Engineer, USGS

Marie Byrd Land Survey II

Early, Thomas O., Geophysics, Wash. Univ., St. Louis
González, Oscar, Geology, Univ. of Chile
Greegor, David H., Biology, Ohio State Univ.
Harry, Jack L., Topographic Engineer, USGS
Henkle, Charles R., Topographic Engineer, USGS
Hill, Lennie J., Topographic Engineer, USGS
Koob, Derry D., Biology, Ohio State Univ.
LeMasurier, Wesley E., Geology, Texas Technol. Col.
Mackey, Steven, Field Assistant, AINA
Maigetter, Robert Z., Biology, Ohio State Univ.
Neptune, Gary R., Geology, Texas Technol. Col.
Taylor, Thomas E., Topographic Engineer, USGS
[1] Wade, F. Alton, Geology, Texas Technol. Col.

Fosdick Mountains

Bitgood, Charles D., Geology, Texas Technol. Col.
Lewis, John H., Geology, Texas Technol. Col.
Wilbanks, John R., Geology, Texas Technol. Col.

Hallett Station

Baker, John R., Biology, Iowa State Univ.
Gless, Elmer E., Biology, Iowa State Univ.
Granholm, Nels H., Biology, Iowa State Univ.
Tenaza, Richard R., Biology, Univ. of Wisconsin
Thompson, David H., Biology, Univ. of Wisconsin

Central Transantarctic Mountains

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Barrett, Peter J., Geology, Ohio State Univ.
Elliot, David H., Geology, Ohio State Univ.
Gunner, John D., Geology, Ohio State Univ.
Johnston, David P., Geology, Ohio State Univ.
Lindsay, John F., Geology, Ohio State Univ.

McMurdo Station

Adie, Raymond J., Geology, Univ. of Birmingham, U.K.
Alford, Montague, Geology, Yale Univ.
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Armstrong, Richard L., Geology, Yale Univ.
Behling, Robert E., Geology, Ohio State Univ.
Benoit, Robert E., Biology, Virginia Poly. Inst.
Bierle, Donald A., Biology, Univ. of South Dakota
Boggs, William J., Biology, Univ. of Miami

[1] Chief Scientist and USARP Representative, Marie Byrd Land Survey II.

[2] Bresnahan, David M., Biology, Old Dominion Col.
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Burris, James M., Assistant to USARP Rep., AINA
Cameron, Roy E., Biology, Calif. Inst. of Technol.
Carrick, Robert, Biology, Univ. of Adelaide, Australia
Church, Brooks D., Lab. Mgmt, North Star R&D Inst.
David, Charles N., Biology, Calif. Inst. of Technol.
Dayton, Paul K., Biology, Univ. of Washington
De Goes, Louis, Visitor, NAS
Denton, George H., Geology, Yale University
DePuy, John A., Geodesy, Geodetic Survey Sq., USAF
Dodd, Walter H., Public Information, NSF
Doescher, Roger L., Glaciology, CRREL
Drabek, Charles M., Biology, Univ. of Calif. (San Diego)
Edwards, Lloyd N., Geology, Univ. of Calif. (L. A.)
Elsner, Robert W., Biology, Univ. of Calif. (San Diego)
Everett, Kaye R., Geology, Ohio State Univ.
Fikkan, Philip R., Geology, Univ. of Wyoming
Fisher, Dean F., Geophysics, Univ. of Michigan
Forsythe, Warren L., Geology, Univ. of Wisconsin
Frakes, Lawrence A., Geology, Univ. of Calif. (L. A.)
Gadsden, Michael, Ionospheric Physics, ESSA Res. Labs.
George, Robert Y., Biology, Florida State Univ.
Gevers, T. W., Geology, Univ. of Witwatersrand, S. Africa
Hall, Caleb L., Jr., Biology, Virginia Poly. Inst.
Hamlin, David G., Geodesy, Geodetic Survey Sq., USAF
Hand, Cadet H., Jr., Biology, Univ. of Calif. (Berkeley)
Harrison, William R., Biology, Johns Hopkins Univ.
Hedgpeth, Joel W., Biology, Oregon State Univ.
Heer, Ray R., Jr., Research Administration, NSF
Huffman, Jerry W., USARP Rep. Antarctica, NSF
Johannessen, Karl R., Meteorology, Weather Bureau, ESSA
Johnstone, C. Raymond, Assistant to USARP Rep., AINA
[3] Johnstone, Graeme N., Assistant to USARP Rep., AINA
Jones, Thomas O., Research Administration, NSF
King, Jonathan A., Biology, Calif. Inst. of Technol.
Komatsu, Stanley K., Biology, Univ. of Calif. (Davis)
Kooyman, Gerald L., Biology, Univ. of Calif. (San Diego)
Lawson, Gerald J., Biology, Ohio State Univ.
Lee, Chun Chi, Biology, Univ. of Miami
Lenfant, Claude J. M., Biology, U. of Calif. (San Diego)
LeResche, Robert E., Biology, Johns Hopkins Univ.
Long, Jack B., Station Engineer, Univ. of Wisconsin
Lowman, Henry R., III, Biology, Virginia Poly. Inst.
Luhrsen, Richard H., Assistant to USARP Rep., AINA
McCain, John C., Biology, Oregon State Univ.
McDonough, John W., Ionospheric Physics, Douglas Aircraft Co., Inc.
MacPherson, Ronald K., Biology, Univ. of Sydney, Aus.
Marzolf, John E., Geology, Univ. of Calif. (Los Angeles)
Miller, Carl D., Geophysics, Univ. of Michigan
Milles, David B., Biolab Tech., North Star R&D Inst.
[2] Nero, Leonard L., Biology, Old Dominion Col.
Olson, Richard D., Research Administration, NSF
Parker, Dana C., Geophysics, Univ. of Michigan
Paul, David, III, Visitor, NASA
Pittard, Donald A., Biology, Bernice P. Bishop Mus.
Pitzman, Frederick J., Biology, Johns Hopkins Univ.
Prochnik, Martin, Research Administration, NSF
Quam, Louis O., Research Administration, NSF
Rastorfer, James R., Biology, Ohio State Univ.
Redmond, James R., Biology, Iowa State Univ.
Rinehart, Floyd J., Geophysics, Univ. of Michigan
Robilliard, Gordon A., Biology, Univ. of Washington

[2] Arrived on first winter flight; departed on second winter flight.
[3] Wintered over in 1967.

Robin, Gordon de Q., Geophysics, Scott Polar Res. Inst., U.K.
Schofield, Edmund A., Biology, Ohio State Univ.
Schroeder, Lauren A., Biology, Univ. of South Dakota
Send, Raymond F., Geophysics, Univ. of Michigan
Serrat, Javier, Electrical Engineering, Univ. of Chile
Sladen, William J. L., Biology, Johns Hopkins Univ.
Smith, Beverley M. E., Geophysics, Scott Polar Research Inst., U.K.
Smith, Philip M., Research Administration, NSF
Smithson, Scott B., Geology, Univ. of Wyoming
Solandt, Omond M., Visitor, Science Council of Canada
Stevenson, Robert G., Geology, Univ. of Wyoming
Strandtmann, Russell, Biology, Bernice P. Bishop Mus.
Svendsen, Kendall L., Geomagnetism, C&GS, ESSA
Swanson, Charles D., Biology, Iowa State Univ.
Swithinbank, Charles, Geophysics, Scott Polar Research Inst., U.K.
Theaker, Paul R., Biology, Ohio State Univ.
Toogood, David J., Geology, Univ. of Wyoming
Treves, Samuel B., Geology, Univ. of Nebraska
Turnock, James H., Visitor, NASA
Twomey, Arthur A., Geology, Univ. of Wisconsin
Van Veen, Richard C., Geology, Ohio State Univ.
Wagner, John E., Glaciology, CRREL
Wilson, Terrance M., Biology, Harvard Univ.
Womochel, Daniel R., Biology, Bernice P. Bishop Mus.
Wood, Robert C., Biology, Johns Hopkins Univ.
[2] Zaneveld, Jacques S., Biology, Old Dominion Col.

Palmer Station

Dillon, Raymond D., Biology, Univ. of South Dakota
Douglas, Everett L., Biology, Univ. of Calif. (San Diego)
Hemmingsen, Edvard A., Biology, Univ. of Calif. (San Diego)
Morrow, Melvin, Geodesy, Army Map Service
Yarbrough, Leonard, USARP Representative, NASA

Plateau Station

Bentley, Charles R., Geophysics, Univ. of Wisconsin
Hanappe, Francis, Glaciology, Free Univ. of Brussels
Picciotto, Edgard E., Glaciology, Free Univ. of Brussels
Stroschein, Leander A., Meteorology, U.S. Army Natick Labs.
Weller, Gunter E., Meteorology, Univ. of Melbourne
Wishart, Edward R., Meteorology, Univ. of Melbourne

South Pole Station

Brooks, Robert E., Physiopsychology, Univ. of Oklahoma
Dziura, Charles S., Meteorology, Weather Bureau, ESSA
Guenter, Clarence A., Physiopsychology, Univ. of Okla.
Hager, Clarence L., Geophysics, Univ. of Calif. (L. A.)
Helfferich, Merritt R., Ionospheric Physics, Univ. of Alaska
Howell, Kenneth R., Meteorology, Weather Bureau, ESSA
Shurley, Jay T., Physiopsychology, Univ. of Oklahoma
White, Russell F., Meteorology, Weather Bureau, ESSA

South Pole—Queen Maud Land Traverse III

Clough, John W., Geophysics, Univ. of Wisconsin
De Breuck, William A., Glaciology, Ohio State Univ.
[5] Freytag, John, Geophysics, Univ. of Wisconsin
Gjessing, Yngvar T., Glaciology, Norsk Polarinstitutt, Norway

[2] Arrived on first winter flight; departed on second winter flight.
[5] Evacuated prior to completion of traverse.

[3] Galan, Michael P., Traverse Engineer, Univ. of Wisconsin
[4] Peddie, Norman W., Geomagnetism, C&GS, ESSA
Poster, Carl K., Geophysics, Univ. of Wisconsin
Rundle, Arthur S., Glaciology, Ohio State Univ.
[3] Smith, Rossman W., Glaciology, Ohio State Univ.
Tenney, Phillip J., Traverse Engineer, Univ. of Wisconsin

Roosevelt Island

Albright, John C., Glaciology, Univ. of Wisconsin
Clapp, James L., Glaciology, Univ. of Wisconsin
Gruendler, James D., Glaciology, Univ. of Wisconsin
[3] Line, Kenneth, Traverse Engineer, Univ. of Wisconsin
MacDonald, William R., Cartography, USGS
Standifer, J. N., Cartography, USGS
Wilhelm, Robert C., Assistant to USARP Rep., AINA

Almirante Brown Station

Boyd, William L., Biology, Colorado State Univ.
Rothenberg, Irwin, Biology, Colorado State Univ.

International Weddell Sea Oceanographic Expedition—1968

[6] Boggs, William J., Biology, Univ. of Miami
Clark, Kerry B., Biology, Univ. of Connecticut
Cline, David R., Biology, Univ. of Minnesota
Dale, Robert L., USARP Representative, NSF
El-Sayed, Sayed Z., Oceanography, Texas A&M Univ.
Found, Bruce W., Biology, Univ. of Connecticut
Kvinge, Thor, Oceanography, Univ. of Bergen, Norway
[6] Lee, Chun Chi, Biology, Univ. of Miami
Rankin, John S., Biology, Univ. of Connecticut
Siniff, Donald B., Biology, Univ. of Minnesota
Soto, Luis R., Oceanography, Texas A&M Univ.
Strømme, Jan A., Oceanography, Univ. of Bergen, Norway

Falkland Islands

Engel, John, Biology, Michigan State Univ.
Harris, Richard, Biology, Michigan State Univ.
Imshaug, Henry A., Biology, Michigan State Univ.

Showa

Sponholz, Martin P., Meteorology, Weather Bureau, ESSA

Vostok

Hessler, Victor P., Ionospheric Physics, Univ. of Alaska
Taylor, John H., Ionospheric Physics, ESSA Res. Labs.

Mawson-Wilkes

Yeager, James A., Geodesy, C&GS, ESSA

Macquarie Island

Annexstad, John O., Ionospheric Physics, Univ. of Alaska

Halley Bay

Bailey, Dana K., Ionospheric Physics, ESSA Res. Labs.

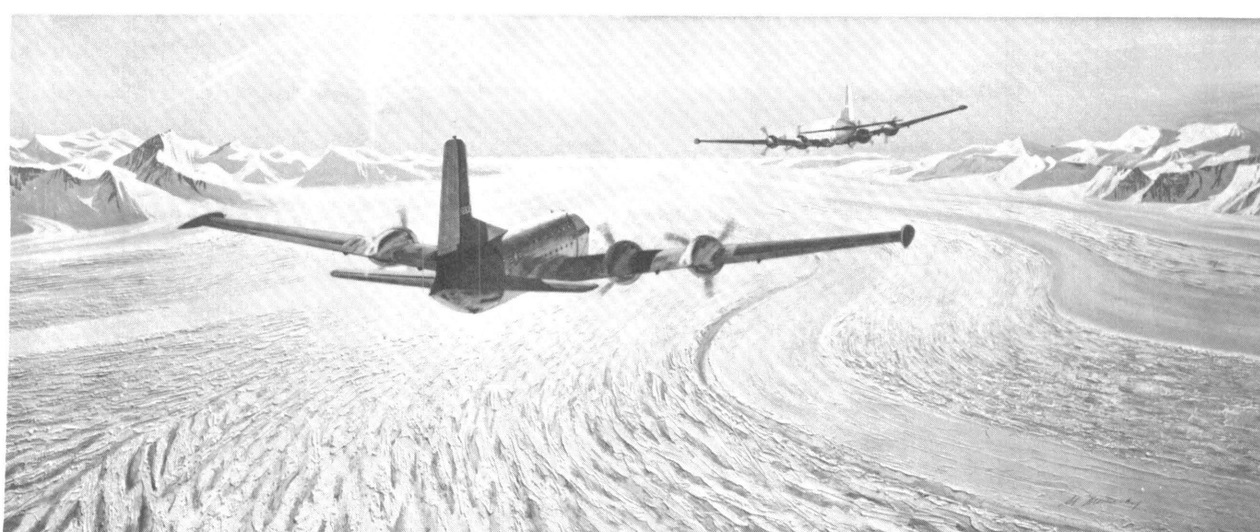
Christchurch, New Zealand

Galey, John T., Jr., Assistant USARP Rep., AINA
Goodale, Edward E., USARP Rep., New Zealand, NSF

Abbreviations:

AINA = Arctic Institute of North America
C&GS = Coast and Geodetic Survey
CRREL = Cold Regions Research and Engineering Laboratory
ESSA = Environmental Science Services Administration
NAS = National Academy of Sciences
NASA = National Aeronautics and Space Administration
NSF = National Science Foundation
USGS = U. S. Geological Survey

[3] Wintered over in 1967.
[4] Traverse leader.
[6] Arrived at McMurdo on first winter flight; listed also under McMurdo Station.



(Air Force Art Collection)

The Antarctic Scene: CLIMBING THE BEARDMORE. (Casein by A. Muenchen.) *Through* Deep Freeze 63, *U.S. Air Force C–124 Globemasters made many flights to drop supplies to inland stations.*

Deep Freeze 68 in Retrospect

J. LLOYD ABBOT, JR.

Rear Admiral, USN
Commander, U.S. Naval Support Force, Antarctica

In terms of aggregate amounts of material handled and numbers of people transported, our operations in logistic support of the United States Antarctic Research Program have developed a very uniform pattern. Figure 1 shows overall lift statistics for *Deep Freeze 68* in a simplified manner. Petroleum products, construction materials, provisions, and all other types of supplies have been reduced in this illustration to a common measurement, *i.e.*, short tons. A glance at the figure will show how utterly dependent we are on sea transport for the overwhelming bulk of our annual resupply: little more than two percent of the total was flown to Antarctica. Also shown in short tons in Figure 1 is the total weight of supplies flown to the inland stations.

The point of uniformity is illustrated in Figure 2, which presents the corresponding statistics for *Deep Freeze 67* and *Deep Freeze 66*. It would seem that, overall, the United States program in Antarctica requires somewhere around 25,000 short tons of various products to be delivered to the Continent each year.

Highlights of the Season

Such a sweeping look at cargo statistics does not, however, tell very much about "How did it go?" For an answer to this question we must look to highlights, to specific accomplishments, and to opinions and attitudes. To me, the most gratifying highlight of the season is that Air Development Squadron Six (VX-6) had its second accident-free year of air operations. Moreover, it was the first accident-free season for all U.S. aviation units flying in the Antarctic, and not a single life was lost during the entire season to any cause.

Another "first" was that *Westwind* and *Burton Island* completed cutting a channel into Winter Quarters Bay at McMurdo (Fig. 3) on December 2, 1967, the earliest seasonal ship arrival on record. On December 5th, Commander A. F. Schneider completed a daring and unprecedented flight to evacuate the seriously injured doctor of the U.K. station at Halley Bay. The 3,500-mile round trip between McMurdo and Halley Bay involved staging through South Pole for refueling and required 14 hours and 9 minutes. I am happy to report that Commander Schneider has been awarded the Distinguished Flying Cross for that demonstration of skill and determination, and each member of his crew has been awarded the Air Medal.*

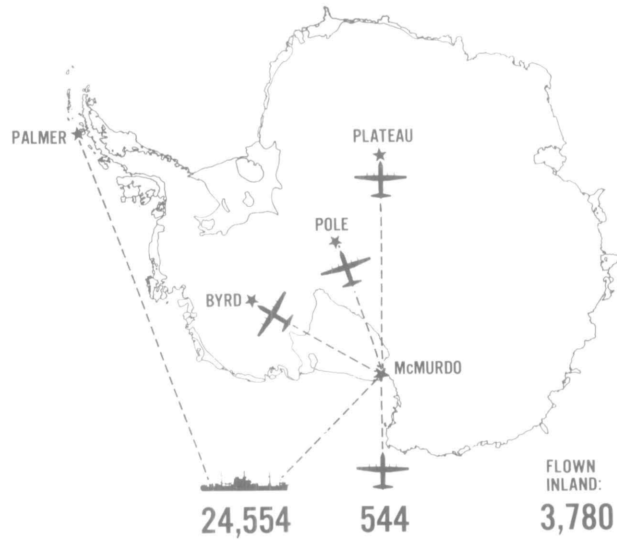


Figure 1. Cargo movement to the Continent and inland stations during Deep Freeze 68 *(in short tons).*

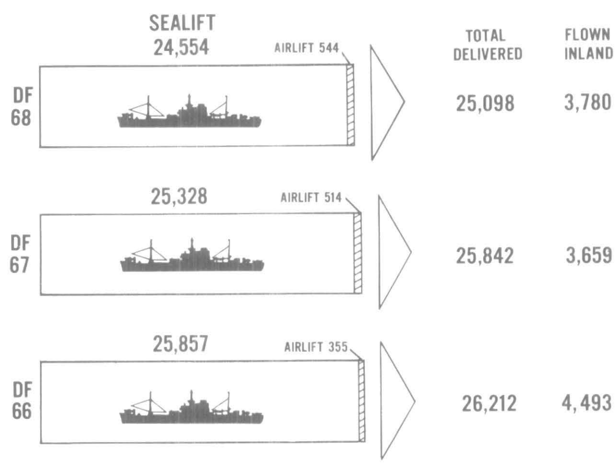
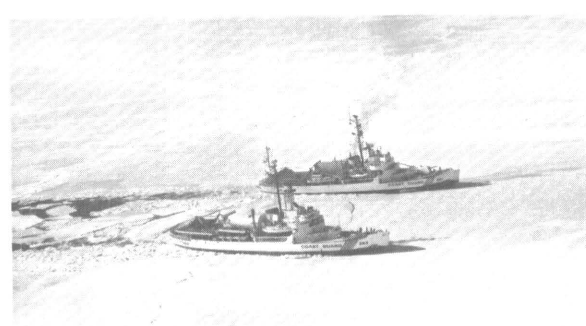


Figure 2. Deliveries to Antarctica and inland stations during the last three seasons (in short tons).



(U.S. Navy Photo)

Figure 3. Burton Island *(foreground) and* Westwind *working in tandem to cut a supply channel to McMurdo.*

Nostalgic Milestones

At least one milestone of *Deep Freeze 68* is nostalgic: the last flight by our ski-equipped DC-3s took place this past season, and the LC-117s remaining in the VX-6 inventory were backloaded to a cargo ship in January 1968 for return to the continental United States. These four old "gooney birds" will be replaced in next season's operations by one new LC-130, raising to five the number of Hercules aircraft in VX-6's stable.

Similarly, *Deep Freeze 68* was the last season during which two destroyer escorts will take turns maintaining an ocean station beneath the air route between Christchurch and McMurdo. For 12 consecutive seasons, such ships have maintained this station in the world's worst sea conditions, acting as meteorological observation platforms, as radio relay stations, and as potential search and rescue vessels. With the advent of increasingly reliable weather satellites, the effectiveness of these gallant little ships dropped below the margin of worth, and their service was terminated.

Scientific Rewards

Knowledge of our environment is the reason and the reward for *Operation Deep Freeze*, and there were many significant scientific achievements this past season. Their telling will be left to other parts of this forum and better-qualified authors, but I must mention two. First, the deep-drilling project on the ice plateau at Byrd Station penetrated to the underlying rock at 7,101 feet, a depth of ice the scientists reckoned represents nearly 50,000 years. Another significant scientific milestone—to me the most exciting of all—was the success of the airborne sensing project in poviding a continuous trace of below-the-ice ground elevations along an aircraft flight track. This breakthrough opens the possibility that man may actually know and depict, within our lifetime, the true contours of that huge continent sleeping under her gigantic ice blanket.

Finally, it has been especially gratifying to hear from a number of different sources that *Deep Freeze 68* has been the "best season ever" in terms of scientific accomplishment. I am inclined to believe this was due far more to natural circumstances—especially weather that was much better than average—than to exceptional logistic support. Nonetheless, it is good music to hear, and it encourages the Support Force's determination that *Deep Freeze 69* shall be even better.

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*On June 14, 1968, Comdr. Schneider was relieved as commander of VX-6 by Comdr. Eugene W. Van Reeth, USN. The evacuation flight was described in the *Antarctic Journal*, vol. III, no. 1, p. 14–15.

Construction Report Deep Freeze 68

DON W. BARBER

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

The construction program this past season was the most ambitious yet undertaken by *Operation Deep Freeze*. Most of the effort was concentrated at McMurdo Station, which is undergoing a virtually complete reconstruction, while much of the remainder was made on Anvers Island, where a permanent Antarctic Peninsula research station has been under construction for two years. To carry out the program, Naval Construction Battalion Unit 201 (NCBU 201), under Lt. J. R. Finn, deployed a total of 5 officers and 197 enlisted personnel, including a platoon of 1 officer and 32 men to work on Palmer Station. At McMurdo, the Seabees were aided by a special Air Force detachment whose 1 officer and 29 enlisted men were integrated into NCBU 201.[1]

Major McMurdo Projects

McMurdo Station is steadily being redeveloped into a modern, efficient base by the replacement of temporary and obsolete facilities. Projects carried out there last season included work on the second increment of the personnel building, a second (unheated) supply warehouse for Air Development Squadron Six (VX-6), the shell of a building to house VX-6 shops and offices, the shell for the USARP field-party equipment and processing center, major modifications to the petroleum system, a new road to Scott Base, a 12-foot extension of the communication receiver building, the relocation of electrical switching station number 2 to the inside of the diesel generator plant, the installation of a second water-distillation unit, and the enlargement of the helicopter landing area. Three old buildings were razed, while foundation pads were prepared at three new building sites. Several other minor projects and preparatory work for *Deep Freeze 69* rounded out the season's schedule.

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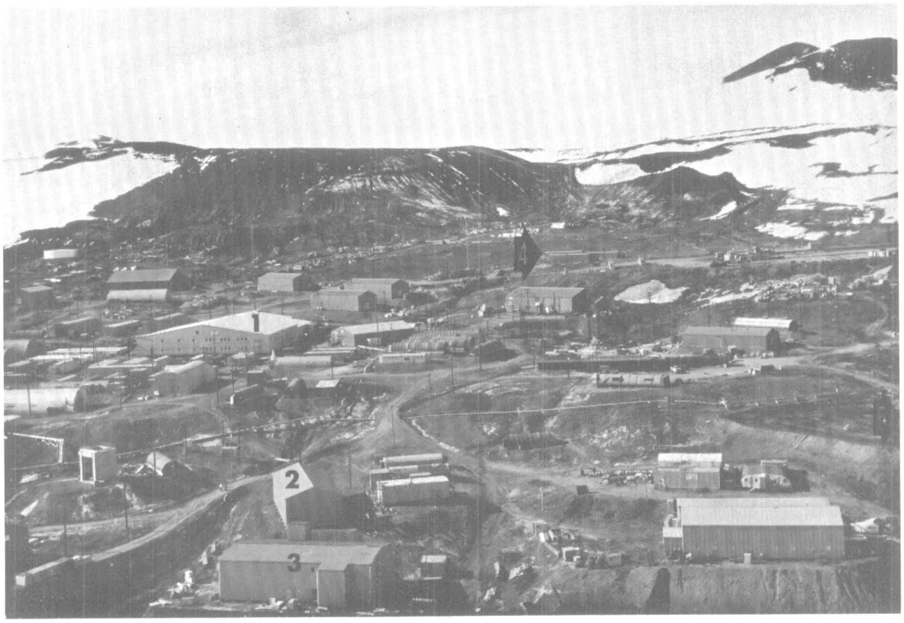
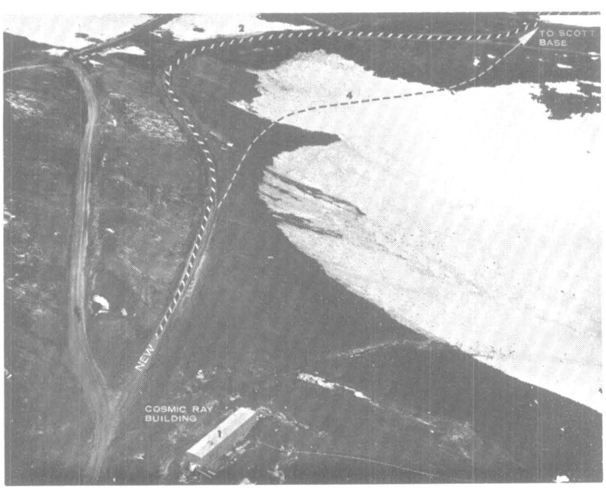
[1] This was the first direct participation by the Air Force in the antarctic construction program. It proved quite successful, and the U.S. Naval Support Force, Antarctica has requested similar future assistance of the Air Force's Chief of Civil Engineering, who has approved such for *Deep Freeze 69*.

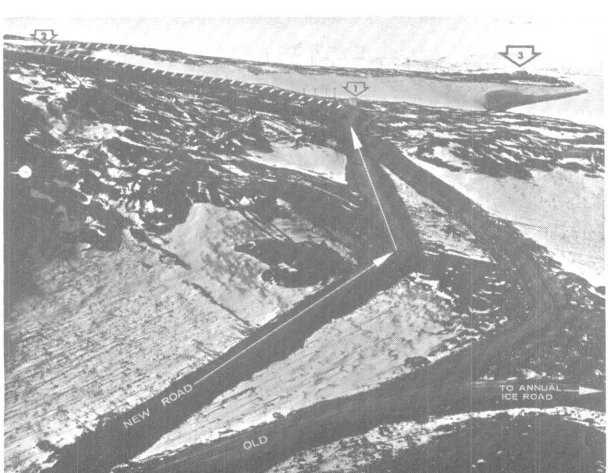


(U.S. Navy Photo)

Major McMurdo projects included additional work on the personnel building (1), erection of an unheated warehouse for VX–6 (2), the VX–6 shops and offices building (3), an addition to the communications receiver building (4) and enlargement of the helicopter pad (5).



Viewed in the lower picture from the pass beside Observation Hill, the new road to Scott Base (3) parallels the old one until the cosmic ray building (1) is reached. There they merge and cross over, the new road continuing uphill (striped line) to cross the snow field at a lower point (2) than the old route, as is seen in the upper picture. The dashed line (4) indicates future construction that is intended to further reduce the gradient.



(U.S. Navy Photos)

Work was done on both the berthing and subsistence sections of the new personnel facility. The building shell for the berthing area was erected, and utilities and interior partitions were installed in the galley, utilities room, and laundry, which comprise the subsistence portion of the structure. Present plans call for the subsistence section to be opened by January 1, 1969, and for occupancy of the berthing area by February 20 of that year. If this schedule is met, and if all systems remain functional after shakedown tests by NCBU 201 and Antarctic Support Activities (ASA), McMurdo's next winter-over party will spend the dark season in the new structure.

The VX-6 warehouse is a 40- by 100-foot two-story Robertson building, similar to the six permanent warehouses constructed previously. It is, however, unheated, and therefore has uninsulated building panels instead of the standard Galbestos panels[2] used in the other structures to minimize heat loss.

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[2] Galbestos panels consist of two metal sheets with an intervening layer of insulating fiber glass. The trade name derives from the treatment of the metal surfaces, which by a special process are galvanized and impregnated with asbestos fibers.

The new road from McMurdo Station to Scott Base follows a considerably easier route than the old road between those sites, and it undoubtedly will improve the transportation of people and goods between McMurdo and Williams Field. (Each season, after the annual ice deteriorates along the more direct route to Williams Field, vehicles travelling to the runway complex must use the inter-base road to gain access to the permanent ice shelf.) The improved horizontal and vertical grades of the new road also should cut down vehicle maintenance requirements, some of which have been caused by the steep grades of the former route. During *Deep Freeze 69* or *70*, the present maximum vertical grades of 17 and 15 percent will be decreased to a maximum of 12 percent through relocation of a portion of the road.[3]

Another major earth-moving project was the first-stage modification of the helicopter pads to provide a landing and takeoff area of approximately 200 by 500 feet. During *Deep Freeze 69*, this project will be completed and buildings 47 and 75 will be removed. These improvements will allow the critical landing and takeoff phases of flight to be executed along a route that avoids both the numbing waters of McMurdo Sound on one side and the rising terrain and elevated power lines on the other, thereby improving helicopter operations at McMurdo from what could be classified as marginal to safe. Although flight safety no longer requires lowering the power lines on the side of Observation Hill, this will still be done, but incidental to encasing them in conduits to protect them from wind stress and frost accumulation.

Fuel System Improvements

A design for extensive modification of McMurdo's fuel-handling facilities was prepared in 1967 and scheduled for completion during *Deep Freeze 69*. Last season's accomplishments in this area included replacing the flexible hose used to carry aviation gas with a 6-inch steel pipe, relocating tank 100 from the antenna farm[4] to Hut Point and converting it to store aviation gas instead of diesel fuel arctic (DFA), converting tank 97 to DFA storage, adding an 8-foot ring to tank 101 to increase its capacity by 250,000 gallons (thus making up the deficit of JP-4 storage incurred in converting tank 97), installing the first portion of a JP-4 and a DFA pipeline to Scott Base, and replacing with steel pipe the flexible hose that serviced tanks 101, 102, 103, and 104. Completing the original plan will involve the following work during *Deep Freeze 69*: replacing pumps and relocating strainers; installing a carbon dioxide fire-suppression system in the Hut Point pump house; installing pressure-relief valves throughout the system; completing the JP-4 and DFA pipelines to Scott Base; adding 8-foot rings to tanks 93 and 94 to increase DFA storage by 500,000 gallons; adding 8-foot rings to tanks 96, 122, and 123 to increase JP-4 storage by 750,000 gallons; constructing a new all-weather truck-loading stand with overhead arms, service station-type pumps, and ready-issue tanks; installing pipelines to the helicopter pads, and erecting there two 15,000-gallon ready-issue tanks for helicopter refueling; installing ship-unloading connections at the Hut Point pump house; and preparing calibration tables for all modified tanks.

By eliminating temporary connections and pumps and by generally streamlining fuel-handling operations, these modifications will create a safer, more modern and efficient, and larger capacity (6 million gallons) system. Already under consideration, however, are plans to expand storage capacity to 8.5 million gallons by *Deep Freeze 70*. This would permit use then of a giant tanker of the T-5 type, one trip by which could take the place of six runs (as were made last season) by the tankers presently used.

Other Work at McMurdo

Storms and extremely low temperatures during the 1967 winter caused failures in the saltwater intake, sewage effluent line, and primary water-distribution lines. NCBU 201 repaired the primary distribution line from its origin at the PM-3A complex to the bottom of the hill (in the vicinity of the USARP quarters buildings), while the saltwater intake and sewage effluent line were repaired by the Public Works Department of ASA. ASA's Public Works Department also installed a prefabricated lavatory at Williams Field to replace a similar structure that was destroyed by fire just prior to the second winter flight of 1967.

Some of the work done at McMurdo was in preparation for future facilities. Foundation pads were constructed for the administration-operations building and a fuel-truck loading stand, and both pad and footings were prepared to support a cold-storage warehouse.

Construction at Inland Stations

The major inland project was the rehabilitation of South Pole Station, intended to extend the station's life until a replacement is provided. This project in-

[3] The road's history is reviewed in *Antarctic,* vol. 5, no. 1 (March 1968), p. 6–7.

[4] Although this tank interfered somewhat with communications, the main reason for relocating it was safety: the former site being uphill from McMurdo's center, rupturing of the tank would have presented a serious threat to the station.

(U.S. Navy Photo)

To rehabilitate this tunnel at Pole Station, accumulated snow was removed and roof rebuilt. Considerable work also was done on the generator building (seen at left) to increase its structural strength and ventilation and to allow easier access to the generators.

volved extensive repairs to the electrical distribution system, tunnel walls, and portions of some tunnel roofs.

Byrd Substation again experienced differential settlement during the past winter. In an effort to prevent further problems of this nature, spread footings were installed beneath all of the major load-transmitting members of the building complex.

Work at Byrd Station proper included installation of a system to vent vehicle fumes from the garage/entrance tunnel, completion of most of the ducting for the cold-air plenum, and installation around the escape ladders leading to the surface of "safety cages"—lattices of metal strips to prevent serious falls.

Palmer Station

At Anvers Island, Platoon Alpha of NCBU 201, led by Lt. (jg.) Harry Anderson, completed the three-story structure that is the main building of the replacement station. Station operations were shifted to the new site in mid-March, and winter personnel are presently residing and working in the new complex. Other work at Palmer included blasting for the pad of a second building—a combination recreation/garage/warehouse facility to be built next summer, constructing a small-boat landing ramp, making a complete topographic survey of the new station site, and installing communications antennas.

Next Season's Plans

The construction program for *Deep Freeze 69* promises to be even more productive. In addition to the projects that already have been mentioned as proposed for McMurdo are the construction of 300 feet of protective facing along Elliott Quay,[5] the completion of the USARP field-party equipment and processing center, erection of a new USARP administration building, the relocation of switching station number 1 into building 89, and the erection of as much as possible of a new 40- by 100-foot, two-story USARP dormitory. With the completion of the structures listed above, several existing buildings can be razed. Furthermore, a renewed effort will be made to produce a dependable water-distribution system that will operate year-round. A completely new system with a remote electrical-sensing alarm will be installed.

Work at Byrd Station will consist of completing the cold-air plenum, which will cool some of the station's tunnels in order to inhibit ice-flow and consequent deformation, and installing an energy-recovery system that will use waste heat from the exhaust and water-jacket systems of the diesel generators to warm certain of the station's buildings. Currently under reexamination is a possible extension of the entrance tunnel. (To prepare for such a need, all three Peter snow-milling machines were returned last season to the United States for overhaul. It is hoped that by "cannibalizing" one for parts, two can be made ready for return to Antarctica at the beginning of *Deep Freeze 69*.)

Stockpiling for *Deep Freeze 70*

The materials for other McMurdo Station structures will be procured and delivered to Antarctica during *Deep Freeze 69* for use during the following season. On the design-and-procurement list are interior elements for the administration-operations building and shells for the following structures: the USARP garage and storage building; a 16,000-square-foot, one-story warehouse for ship's store items and dry stores (*i.e.*, unrefrigerated provisions); a flammable-stores building; a replacement communications-transmitter building; a utilities and ground-maintenance building; an ASA warehouse; and a mobile, 180-man quarters complex for Williams Field.

Two of these structures—the USARP administration building and the ship's store warehouse—will be unique in the McMurdo redevelopment plan. For reasons of economy, both will be primarily wooden structures, and the USARP administration building, as a concession to tradition set by the present building, will have the appearance of a Swiss chalet.

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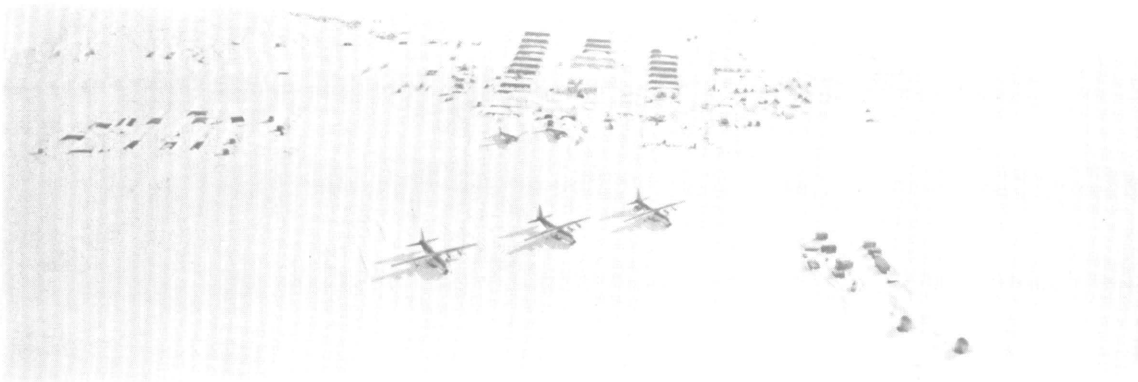
[5] Originally to have been started this past season, this project was delayed by the late arrival of some materials.



(U.S. Navy Photo)

LC–130Fs in parking area at Williams Field

Deep Freeze 68 Air Operations

A. F. SCHNEIDER[1]

Commander, USN
Naval Air Systems Command

Deep Freeze 68 was the thirteenth consecutive season in which Air Development Squadron Six (VX–6) has contributed to the geographic and scientific exploration of the Antarctic. Although, according to superstition, the number 13 is accompanied by misfortune, this season was highly successful. Planned objectives were met or exceeded, and the Squadron recorded its second consecutive accident-free year. Also enjoying an accident-free season was the U.S. Army Aviation Detachment (Antarctica Support). These successes reflect the dedication and professionalism of the personnel in all four components of the Antarctic Air Group: the main portion of the squadron deployed in Antarctica, the Aviation Maintenance Support Element (a VX–6 detachment at Christchurch), the Aviation Support Element (a VX–6 detachment at Quonset Point, Rhode Island), and the Army helicopter unit.

Stations Opened Promptly

Two of the squadron's LC–130s and its two C–121s were assigned to make the initial flights to McMurdo, which were scheduled to arrive at the station on October 2. The two other LC–130s were to arrive at Christchurch on October 8 and at McMurdo on October 15. Events went very much according to plan.

Only those personnel directly involved with activating support functions were included in the initial fly-in, along with critically needed material, but the reactivation of shops and relief of winter-over personnel proceeded quickly. With the arrival of the remaining aircraft, additional personnel, and the first scientists, operations soon reached full tempo. Deployment of squadron personnel to McMurdo was completed on October 18.

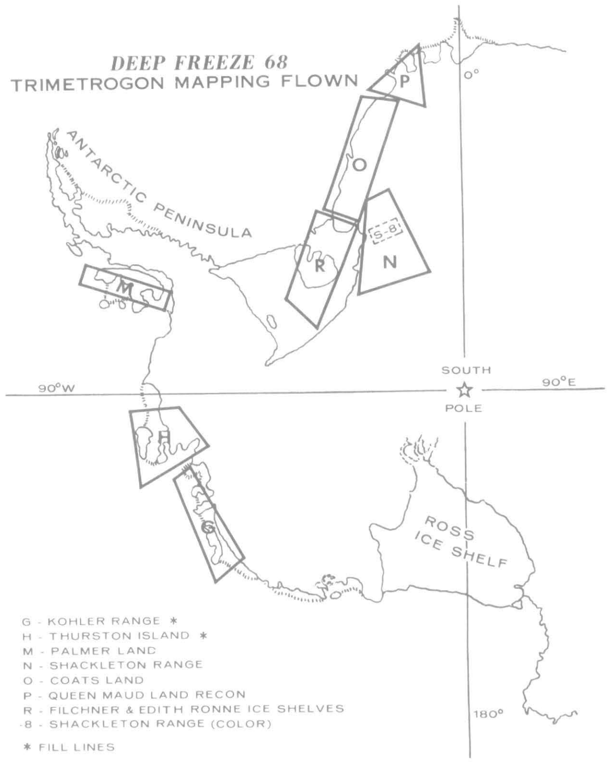
Brockton Station was reopened and Hallett Station reactivated on October 3. Byrd Station was reached on October 20, and the initial flight to Pole Station was completed on November 1. Though extremely strong upper-air winds turned back the first aircraft dispatched to Plateau Station, its arrival there was delayed only one day beyond the November 15th date set in the original schedule. These initial flights to the inland stations were but the heralds of many resupply flights that followed. During the entire season, this phase of air operations encountered no significant problems.

Aerial Photography and Special Projects

Aerial photography is a major and direct contribution of VX–6 to the antarctic research program. All of this season's photographic requirements of the U.S. Geological Survey were met with the exception of the "fill lines" (*i.e.,* photo-flight lines which had not been completed the previous year) in Palmer Land.

Photomapping operations were conducted differently this year in that all flights originated at McMurdo. Though the location of the areas to be photographed (see map) required most flights to stage through Pole Station, the new staging concept offered several advantages: (1) aircraft maintenance could be performed at McMurdo; (2) when not assigned to a photo mission, the plane could cache fuel at Byrd and South Pole Stations for future flights; and (3) when poor weather prevailed in the photo areas,

[1] Commanding Officer, Air Development Squadron Six from April 26, 1967, to June 14, 1968, with prior service as VX-6 Maintenance Officer and Executive Officer.



(U.S. Navy Photo)

(U.S. Navy Photo)

An Army UH–1 helicopter is loaded aboard a Hercules for delivery to Marie Byrd Land survey site.

the aircraft would be immediately available for other missions. The revised procedure also reduced the requirements for aviation personnel and facilities at outlying stations. As was true last year, satellite-transmitted photography of antarctic weather conditions proved a great aid in determining when to dispatch the photo aircraft.

VX–6 also provided the flying platform for two special projects that should reveal features of Antarctica that are hidden from conventional aerial photography. One was the Scott Polar Research Institute's measurement of ice thickness by radar sounding, and the other was the University of Michigan's infrared sensing program.[2]

Field Support

A number of parties were placed in the field, resupplied, and picked up at distant investigation sites in various regions without difficulties, and two major field operations were supported—the Marie Byrd Land Survey and South Pole-Queen Maud Land Traverse (SPQMLT) III.

The opening of Marie Byrd Land camp 1 on October 23, 1967, was significant in that two new support procedures were introduced. First, the Army helicopters were airlifted directly to the campsite to minimize the damage suffered during loading and unloading. The first helicopter arrived at camp 1 on November 2, and all three were there by November 9.

Second, the camps were erected this year by a Navy crew prior to the move, rather than by camp personnel, as was done last season. This method provided the scientists with more time to pursue their studies and eliminated the requirement for flight crews to provide assistance in establishing camps. It is believed that after this procedure is perfected, it will expedite moves from campsite to campsite.

Weather in the survey area was again a problem, being suitable for flight operations only about 40 percent of the time. Camp 1 became operational on November 5, and the helicopters provided the scientists with 196.3 hours of support in 36 flights. Camp 2 was a temporary tent camp with a fuel cache for limited operations, while camp 3 resembled camp 1. The Marie Byrd Land Survey party was recovered from the field on January 25.

Operating on the other side of the Continent was SPQMLT III. Though a surface-travel venture, it required a certain amount of aerial support. Prior to the traverse party's December 5th departure from Plateau Station, an LC–130F reconnaissance flight was made over the proposed traverse track so that major areas of disturbed ice could be avoided. Be-

[2] *Antarctic Journal*, vol. III, no. 2, p. 42–43.

tween the traverse party's departure and the time it was picked up at the terminal point on January 30, three flights were made to drop supplies.[3]

Busy McMurdo Helicopters

In sharp contrast to the long-ranging flights for traverse support and photomapping were the many flights by the LH–34 helicopters of VX–6 based at McMurdo. These aircraft aided 20 scientific projects within a 200–mile radius of McMurdo, logging approximately 700 hours—an increase of 20 percent over previous seasons. Three projects in particular illustrate the quality and variety of helicopter support.

First, New Zealand established a new camp near Lake Vanda; a C–130 of the Royal New Zealand Air Force dropped the components on the frozen lake, following which the LH–34s moved approximately 25,000 pounds of materials to the actual campsite. This task would have been virtually impossible for any other kind of vehicle, but the helicopters completed it in only a few hours.

The helicopters further displayed their versatility in connection with a University of California study of tillites in the Darwin Glacier area. Originally, it had been planned to fly the party to the location by LC–130 Hercules, which would have involved an open-field landing miles from the study area and forced the scientists to toboggan back and forth between their camp and study sites. The helicopters proved able to land the investigators in the immediate vicinity of their chosen site, thus reducing field time by at least a week and avoiding the ever-present dangers of open-field landings in a Hercules.

Just how much helicopters can conserve research time is most evident in the case of the University of Wyoming party that was working by Lake Vida in Victoria Valley. During the three months this group was in the field, the LH–34s provided 122 hours of support, which allowed studies to be undertaken that would have required years on foot.

The preceding paragraphs have made it all sound rather easy, but there are few places in the world that pose the hazards to air operations that Antarctica does. The accomplishments of the Antarctic Air Group during *Deep Freeze 68* are primarily the result of a high degree of interest and dedication on the part of pilots and crews.

(*U.S. Navy Photo*)

LH–34 helicopters were used extensively to support field parties and other activities in the McMurdo area.

[3] *Antarctic Journal*, vol. III, no. 3, p. 72.

Aviation Statistics, *Deep Freeze 68*

The U.S. program in Antarctica is heavily reliant on aerial logistics, as is impressively demonstrated by the statistics for the 1967–1968 operating season. The Antarctic Air Group—numerically designated Task Group 43.3—flew a total of 7,420 hours, of which 7,047.6 were by Air Development Squadron Six, and 372.4 by the U.S. Army Aviation Detachment (Antarctica Support), the Group's other flying unit. Another 550 hours were contributed by icebreaker-based helicopters, which operate as part of the ship groups. Much additional flying was performed by the Air Force's Military Airlift Command and by chartered commercial aircraft that operated on routes between New Zealand and the United States, primarily to transport personnel.

While most cargo is delivered to Antarctica by ship, and one station—Palmer—is supported entirely in this manner, the inland stations are completely dependent on the aerial supply line from coastal McMurdo. Their situation is analogous to that of isolated island outposts in that personnel and high-

Intra-antarctic cargo and passenger statistics.

Station	Number of flights	Tonnage delivered[1]	Tonnage backhauled[1]	Passengers transported
Amundsen-Scott South Pole	139	1,371	151	1,041
Brockton	13	36	8	76
Byrd	167	1,426	151	821
Byrd Substation	12	107	2	25
Hallett[2]	16	44	114	246
Plateau	25	198	34	113
Vostok	2	11	4	52
Byrd Land Camps	64	272	58	268
Field Parties	44	80	41	104
Totals	482	3,545	563	2,746

[1] Includes passenger weights.
[2] Includes LC-117 flights.

priority cargo may be delivered by air, but differs in that even the most bulky commodities are received in the same fashion. The delivery figures presented in the accompanying table include 1,080 tons of fuel for Pole Station, 960 for Byrd, 108 for Byrd Substation, and 92 for Plateau.

Helicopters play many roles, not all of them planned in the program. For example, *Westwind*'s helicopters were used for ice reconnaissance, cargo movement, photographic work, and specimen collection that included seal hunting near Hallett Station. In addition, one of *Westwind*'s helicopters conducted a rescue operation: on October 5, while the ship was 100 miles west of Panama, a helicopter was launched to evacuate to a Canal Zone hospital a Korean fisherman taken aboard from F/V *Nam Hae* with a preliminary diagnosis of spinal meningitis.

Nuclear Power Operations, *Deep Freeze 67-68*

ROBERT E. FORT

Chief Warrant Officer (CWO-2), CEC, USN

and

TOMMY R. EVANS

Senior Chief Utilities Man, USN

Naval Nuclear Power Unit
Fort Belvoir, Virginia

Operation of the PM–3A nuclear power plant at McMurdo Station during the 1967 winter and the *Deep Freeze 68* summer season was highly successful. Increased availability provided the station with a greater quantity of electrical energy than in any previous year, and the water-distillation plant, powered by nuclear-generated steam, completed its first winter of successful operation, supplying the station with plentiful amounts of fresh water. Major summer-season projects included reactor refueling, overhaul of the main turbine-generator, and the installation of a second water-distillation unit of the flash-evaporator type.

PM-3A Operating Data

The nuclear power plant was able to respond to McMurdo Station's heat and power requirements 86.24 percent of the time during calendar year 1967, up almost 9 percent from the previous year (see figure). During 1967, the PM-3A produced 9.55×10^6 kilowatt-hours of electrical energy, of which 7.4×10^6 kwh were exported to and consumed by McMurdo Station. Production of the latter net amount of energy by conventional means would have required approximately 550,000 gallons of diesel fuel arctic (DFA), as shown in Table 1. The plant's gross production from the time of its installation to February 1968, the end of the *Deep Freeze 68* summer, amounted to 3.62×10^7 kwh.

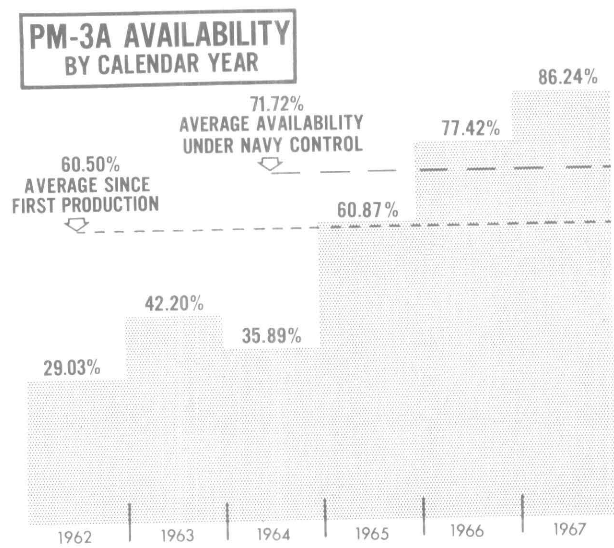


Table 1. Summary of electrical energy production

Calendar Year	Kilowatt-hours Produced		Diesel-Fuel Equivalent of Net Production (Gallons)[2]
	Gross[1]	Net	
1967	9,550,000	7,400,000	548,961
1966	8,690,000	6,780,000	502,967
1965	6,916,000	5,240,000	272,774
1964	3,240,000	2,410,000	178,783
1963	4,123,000	3,267,600	242,403
1962	2,336,000	1,803,040[3]	133,753
TOTALS:	34,855,000	26,900,640	1,879,641

[1] Taken from PM-3A weekly operating reports.
[2] Computed with a conversion factor (13.48 kwhrs/gallon of DFA) derived from actual White diesel operation in 1967.
[3] Estimated.

Water-Distillation Data

With 1967, the water-distillation plant completed its first full calendar year of continuous operation. Production was adequate to meet the station's needs for fresh water during the winter, but was augmented by water from other sources during the summer. From July 1967 through February 1968, the plant produced 1,903,236 gallons of fresh water. Nuclear-generated steam was used to produce 1,207,-639 gallons of that amount, while the remaining 695,597 gallons were produced by an oil-fired boiler. Corresponding data for calendar year 1967 are shown in Table 2.

Table 2. Water production in 1967

Total production	2,459,781 gals.
Total steam exported from PM-3A	3,965,569 lbs.
Total diesel fuel used	37,356 gals.
Water produced by nuclear energy	1,860,129 gals.
DFA equivalent of nuclear power*	54,263 gals.

* Computed with a conversion factor (34.28 gals water/1 gal DFA) derived from Cleaver-Brooks usage of 17.5 gal/hr of DFA and the distillation unit's normal water output of 600 gals/hr.

Crew Relief and Reactor Refueling

A 30-day or longer overlap of crews is customarily scheduled each year to permit the veteran crew to conduct for its relief a program of operational and maintenance training, after which the new crew is given an oral examination by a qualification board. The training of Crew VII personnel, begun during October 1967, was complicated by a concurrent refueling of the reactor, but this was offset by the advantage of providing the new crew with experience in nuclear fuel handling procedures.

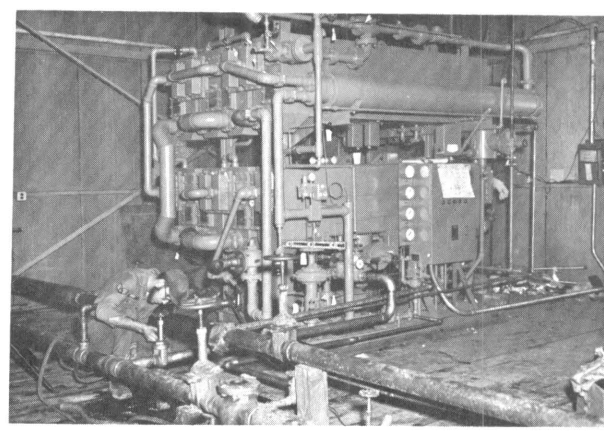
The plant was shut down for refueling on October 12. Removal of the expended core and installation of a fresh one in the reactor's pressure vessel were done in accordance with procedures previously prepared in detail. Initial criticality with the new core was achieved on October 23, and a series of core physics tests were performed to insure safe, predictable operation of the reactor. The plant assumed the McMurdo Station load on November 4. On November 14, 1967, Lt. Comdr. Arthur D. Kohler, Jr., CEC, USN, relieved Lt. Comdr. Lawrence K. Donovan, CEC, USN, as officer-in-charge, and Crew VII began its 12- to 14-month tenure. The total plant downtime attributed to reactor refueling, annual preventive maintenance, crew overlap training, and core physics testing was 24 days.

Main Turbine-Generator Overhauled

On January 2, 1968, the PM-3A was shut down to permit an inspection and repair of the main turbine-generator set and its auxiliary equipment. (This overhaul could not have been accomplished coincidentally with the refueling in October due to the limited number of personnel available and the emphasis then upon crew training.) The turbine and generator were thoroughly inspected and cleaned, main bearings were carefully examined and replaced as necessary, the shafts of the turbine, the generator, and the exciter were realigned, and the steam chest valves, turbine throttle, trip valve, the main lubrication and control oil pump, and the turbine-speed governor were overhauled and adjusted. Following reassembly of the turbine-generator set, the plant again assumed the McMurdo Station load on January 19.

New Water-Distillation Unit

A second flash evaporator, similar to the original unit, arrived at McMurdo on USNS *Towle* in late December 1967. This unit was installed in the water-distillation building by Naval Construction Battalion Unit 201 in January 1968. After satisfactory operational testing, the new unit was accepted, increasing the plant's freshwater production capacity to 28,800 gallons per day. Subsequent to installation of the second unit, the number one evaporator was completely overhauled and descaled. New water pumps were installed, and piping modifications and design improvements developed since the installation of the first unit were completed. Instrumentation and alarm circuitry necessary for remote operational monitoring of the two units were installed in the PM-3A control room.



(U.S. Navy Photo)

A second water-distillation unit was installed by NCBU–201 with assistance of Air Force personnel.

Summer Maintenance and Other Activities

An extensive summer maintenance program was conducted in order to insure continued high availability and reliability of the PM-3A during the winter of 1968. Similarly, the reboiler and the water-distillation plant's auxiliary boiler were completely overhauled and cleaned to insure that they would serve as reliable sources of steam for water production.

The officer-in-charge of the PM-3A has agreed to assist Antarctic Support Activities with maintenance and repair of all McMurdo Station high-voltage protective relays and switchgear. In discharging this new responsibility, all 4,160-volt transmission and distribution protective relays were repaired, adjusted, and set in accordance with a relay coordination program that is designed to prevent—by selective tripping of protective circuit breakers—extended gross power outages that might otherwise result from the failure of an isolated or minor electrical feeder in the transmission or distribution lines.

Meritorious Unit Commendation Received

The Secretary of the Navy has approved the presentation of the Meritorious Unit Commendation to the Naval Nuclear Power Unit, as set forth in the following citation:

> For meritorious service from 1 May 1964 to 1 March 1967 in the operation, modification, and support of the Nuclear Power Plant Unit (PM-3A) at McMurdo Station, Antarctica. The PM-3A is the Navy's prototype shore based nuclear power plant, and is the only plant of this nature which operates in such an isolated environment and replaces each crew each year. During this period, the Naval Nuclear Power Plant Unit effected extensive plant modifications, plant redesign work, and changes in operating procedures, to achieve the operational reliability and availability required. These efforts involved such complex nuclear-engineering applications as whole-core refueling, control-rod drive mechanism modification, nuclear instrumentation improvements, identification and solution of the tritium problem, radioactive waste disposal system modification, and broken control rod replacement. Due to these plant improvements and a high degree of technical competence and training of the PM–3A crews, the plant established a military record of 141 days of continuous power operations, and completed the first United States land water desalting system operating with a nuclear plant. The initiative, professional competence, and devotion to duty displayed by the officers and men of the Naval Nuclear Power Plant Unit were in keeping with the highest traditions of the United States Naval service.

Plans for Plant Modifications

Presently in the planning stage are three major changes to the plant and its auxiliary systems. One is the relocation of the high-pressure demineralizer to a point outside the primary system containment vessel. This will permit routine recharging of the demineralizer resin without interrupting reactor operations. (The demineralizer maintains the purity and proper water chemistry of the primary coolant.)

The second planned change involves moving high-voltage switching station number one, now located in an outbuilding adjacent to the PM-3A's maintenance and supply building, to the inside of that building. Coupled with the shielding in a conduit of the transmission line from the PM-3A complex to McMurdo,[1] this will improve the reliability of power-transmission facilities by affording them greater protection from wind loading and other severe weather conditions.

The third of the planned major modifications is the installation of a resistor in the neutral bus of the PM-3A's main generator. This device will balance the plant's electrical characteristics so as to facilitate operation of the PM-3A in parallel with the diesel-electric generating plant. At present, should certain transmission-line faults occur while the two plants are sharing McMurdo's electrical load, the fault over-current would be felt only by the PM-3A, which might damage components of the plant's main generator system.[2]

It is expected that these modifications, like previous hardware changes, will go far toward correcting problems and increasing the reliability of PM-3A's service to Antarctica's largest station.

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[1] Described in the construction report in this issue.

[2] Parallel operations between the PM–3A and the diesel generators take place only for a short time while the station load is being shifted from one to the other.

(Air Force Art Collection)

The Antarctic Scene: MISSED BY INCHES. (Acrylic by A. Muenchen.) *Storm-blown snow and a crosswind at Williams Field brought this Air Force C–130E close to disaster during a December 1963 emergency landing.*

Antarctic Peninsula Tourism in 1968

JOHN CADWALADER*

Captain, USNR (Ret.)

Two tours sponsored by Lindblad Travel, Inc., of New York were scheduled to transit the Chilean inland passages and visit the Falkland and South Shetland Islands and the Antarctic Peninsula during January and February of 1968. For this purpose, the motor vessel *Navarino* had been chartered from the Chilean government. Though a steering-engine casualty off Cape Horn caused the first tour to be cancelled before it got out of sight of South America, the second was carried out as planned.

These tours were intended to attract people with an intelligent interest in the Antarctic, the history of its exploration, the scientific activities carried out there, and particularly its natural history. Accordingly, two noted ornithologists were obtained as tour leaders: Dr. Roger Tory Peterson for the first trip, and Mr. Peter Scott, son of the explorer, for the second. Also on each trip was a marine biologist who made a series of water-temperature and salinity tests, took plankton tows, and lectured on the marine environment illustrated by these investigations. Lectures on antarctic history were conducted with the aid of films and slides. Mr. Ian Strange, a conservationist and expert naturalist, was engaged to act as guide during the time spent in the Falkland Islands, where he resides.

Forty-two tourists took part in the first cruise, and 60 in the second. Most of them had a keen interest in ornithology or other branches of natural history, or a considerable literary background in antarctic matters. There were many—particularly among the Britons, who made up more than half of the second tour—who had been brought up on the stories of Scott and Shackleton. While some of the tourists were world travelers and others had scrimped and saved for what would be the trip of a lifetime, nearly all were united in their desire to view the area in which they had a special interest, and which these tours opened up to them.

The first cruise started at Puerto Montt and went south to the western end of the Strait of Magellan, where it turned east and then south into the Beagle Channel and around Navarino Island to Cape Horn, where the accident occurred that cut short the trip. The planned route had been south across the Drake Passage to the South Shetlands and the Antarctic Peninsula, thence north to the Falklands, and finally west into the Strait of Magellan and on to Punta Arenas. There, the first group would have disembarked and a second group come aboard. As it happened, the ship limped back to Punta Arenas two weeks early, and the first group flew home. The time until the second group arrived was spent in ship repairs and sea trials.

The second cruise followed the reverse course of that planned for the first. Departing Punta Arenas, the ship entered the South Atlantic through the eastern entrance to the Strait of Magellan, proceeded to Port Stanley for clearance to visit the Falklands, and thence to Westpoint and Carcass Islands in the West Falklands. A half day was spent at each of these islands observing the fascinating and abundant wildlife which the inhabitants—though predominantly interested in sheep grazing—are taking intelligent and effective steps to conserve.

Navarino then steamed south to the South Shetlands, where stops were made at King George, Half Moon, and Deception Islands. None of the bases or *refugios* here were occupied, those on Deception having been evacuated because of the recent volcanic eruption. The entire island was found to be covered with a heavy layer of volcanic ash, and much fumerole activity was still in evidence. Water at the north end of the lagoon, near the two craters formed during the eruption, was too hot to put one's hand in.

From Deception, the course led southwest, passing between Brabant and Anvers Islands, to the Chilean station at Paradise Harbor. This was the only stop actually on the antarctic mainland. The Chilean base personnel were very hospitable, though the station routine was somewhat disorganized by the absorption of personnel and equipment from the evacuated base at Deception Island. From here the ship crossed the Gerlache Strait to Anvers Island, site of Palmer Station.

Upon arrival at Palmer the tour leaders went by boat to the new station, then still under construction. The station's officer-in-charge and the scientists were extremely friendly and hospitable, Dr. Theodore Gannutz being particularly helpful in explaining his work on lichen physiology. In the evening, the scientists and officers were entertained aboard *Navarino*.

From Palmer, the ship headed south and entered Lemaire Channel, where a number of bergs and some pack ice, the only ice of this type encountered on the cruise, slowed progress considerably. The ice, although light—about two-tenths coverage consisting of brash and small floes—was an appreciable hazard for the completely uniceworthy *Navarino*. Having arrived off the British base at the Argentine Islands, the captain was reluctant to remain because the pack

* Formerly on the staff of the U.S. Naval Support Force, Antarctica (1955-1959), and of the U.S. Antarctic Projects Officer, he served as the tours' antarctic expert.

was moving in, and only a token visit by Peter Scott and a few others was made to the base. This was a deep disappointment to all, but particularly to those English tourists who could not get ashore and to the base personnel, who had made great preparations for the visit. Leaving this scene of the only real setback on the whole cruise, the ship picked her way carefully through the pack to open water and steamed southwestward towards the northern end of Adelaide Island. When in sight of Adelaide and just south of the Antarctic Circle, *Navarino* turned west and then due north towards Cape Horn.

Upon arrival off the Cape Horn islands, the ship anchored in the lee of Grévy Island, and the tourists spent a day ashore. The ship then entered the Beagle Channel and retraced her outward course, with a short stop at Puerto Eden to visit the Alacaluf Indian village, and a day at Puerto Natales that was spent touring the Paine National Park. The passengers disembarked at Puerto Montt and, after a day visiting the nearby lake district, flew home by way of Buenos Aires.

Notes

Edward E. Goodale Retires

Edward E. Goodale retired from the National Science Foundation on April 30, 1968, ending a career of polar work that extended over a period of more than 40 years.

Mr. Goodale was born on April 7, 1903, in Boston, Massachusetts. At the age of 19 he went to Labrador to work for a year with the hospital missions of Sir Wilfred Grenfell. He entered Harvard University in 1924, but was lured from academia by the call of Admiral Byrd for volunteers for his first antarctic expedition.

With two Harvard classmates, Mr. Goodale spent the 1927-1928 winter in the New Hampshire hills training dog teams for the expedition. The young men, called "The Three Musketeers" by Admiral Byrd, formed part of the six-man Southern Geological Party, led by Dr. Laurence M. Gould, which surveyed the Queen Maud Mountains and acted as an emergency support party and weather observation post for Byrd's flight to the South Pole.

For a short time, Mr. Goodale had the distinction of having discovered the most southerly form of life, a lichen growing on Mount Fridtjof Nansen at 85°21′S. Mount Goodale, discovered by the party, rises to an altitude of 7,000 feet nearby. When the six men reached Little America on January 19, 1930, they had sledged more than 1,500 miles in 77 days. Upon his return home, Mr. Goodale received the special medal awarded by the U.S. Congress to members of the expedition.

In September 1941, he became a special consultant for arctic operations to the Chief of the Army Air Corps, advising on the establishment of bases that supported the ferrying of aircraft to Great Britain across arctic Canada and Greenland. He participated in the installation of a base on Baffin Island and wintered there in 1941-1942. In February 1943, he received a commission in the Army Air Corps and took charge of search-and-rescue operations in the North Atlantic for the Air Transport Command. He was discharged a Lieutenant Colonel in July 1946.

Upon resuming civilian life, Mr. Goodale joined the U.S. Weather Bureau, which was developing an active interest in arctic weather observations. He supervised the establishment of a joint Danish-U.S. station at Thule, Greenland, in the summer of 1946 and spent the ensuing year as officer in charge at the station. During the winter, he participated in an air rescue of the crew of a B29 that crashed in northern Greenland, for which he received the Air Medal and a citation from President Truman. Until 1963, as the Deputy Chief of the Polar Operations Project of the Weather Bureau, he was engaged in planning and supervising the installation and operation of a network of Canadian-U.S. stations across the Queen Elizabeth II Islands.

With the advent of the IGY, the Weather Bureau's arctic experience was called upon to aid in planning the U.S. antarctic program. Mr. Goodale coordinated much of this preparatory work. He also spent the austral summer of 1955-1956 at Little America Station as the IGY representative to the U.S. Naval Support Force, Antarctica, and participated in the icebreaker reconnaissance of the Budd Coast to select a site for Wilkes Station. In the 1956-1957 summer, he oversaw the erection of buildings and installation of equipment at Byrd Station.

During each succeeding Southern Hemisphere summer, Mr. Goodale was assigned to the Advanced Headquarters of the Naval Support Force in Christchurch, New Zealand, at first on loan from the Weather Bureau and, since May 1963, as a member of the National Science Foundation staff. There, he dealt effectively with the stream of scientists and scientific equipment bound for Antarctica and with the data and specimens being returned from the Continent to stateside laboratories. He also aided in the coordination of U.S. and New Zealand antarctic programs.

Upon retiring after almost 27 years with the Government, Mr. Goodale received the Antarctic Medal and the Harvard Travellers Club's gold medal.

Visitors During *Deep Freeze 68*

Between October 17, 1967, and February 21, 1968, 104 individuals visited Antarctica as official guests of the U.S. Naval Support Force, Antarctica, and the National Science Foundation. The time spent "on the Ice" ranged from four days to two months, with the usual duration of a visit being one week.

Itineraries typically included a day devoted to Support Force briefings and touring McMurdo Station, a day of science briefing that included a tour of McMurdo's scientific facilities, a one-day trip to South Pole Station via ski-equipped C–130 Hercules aircraft and a similar visit to Byrd Station, a half-day at McMurdo's nuclear power plant, a half-day at Scott Base, and helicopter journeys to Capes Evans and Royds.

This season's visitors included three congressmen: Rep. Jerry L. Pettis (R-Calif.) of the Science and Astronautics Committee; Rep. Richard C. White (D-Texas) of the Interior and Insular Affairs Committee; and Rep. Howard W. Pollock (R-Alaska) of the same committee. They were accompanied by Rear Admiral J. L. Abbot, Jr., commander of the U.S. Naval Support Force, Antarctica, and by Dr. T. O. Jones, Special Assistant for Antarctic Affairs to the Director of the National Science Foundation.

Representatives of 10 nations signatory to the Antarctic Treaty viewed U.S. activities in Antarctica at the invitation of the State Department. They were Dr. Juan Carlos Beltramino of Argentina, Arthur Doubleday of Australia, Ambassador Baron Louis Scheyven of Belgium, Lt. Comdr. Sergio Sanchez Luna of Chile, Dr. Daniel Frerejacque of France, Dr. Kou Kusunoki of Japan, R. J. Lawrence of New Zealand, Ambassador Knut B. Aars of Norway, Dr. Ronald E. Shuttleworth of the Republic of South Africa, and David H. Anderson of the United Kingdom.

Another visiting party included the U.S. Ambassador to New Zealand, the Hon. John F. Henning, and five New Zealand guests: Sir Richard Wild, Chief Justice of the New Zealand Supreme Court; R. L. G. Talbot and C. J. Moyle, members of Parliament representing the National and Labor Parties, respectively; Sir Arthur Tyndall, President of the New Zealand-American Association; and Brian Lochore, captain of the championship All Blacks football team.

A second party of special visitors from New Zealand included A. B. Cole, Deputy Secretary of Defense; Major General R. B. Dawson, Chief of General Staff; Commodore J. P. S. Vallant, New Zealand Naval Board; Air Commodore S. G. Quill, Royal New Zealand Air Force; and Wing Commander D. E. Jamieson, RNZAF.

In addition to the 24 visitors mentioned above, there were 8 other special visitors; 4 USARP visitors, namely, Louis De Goes of the National Academy of Sciences, James H. Turnock and David Paul, III, of the National Aeronautics and Space Administration, and Omond M. Solandt from the Science Council of Canada; 5 instructors to set up college courses for McMurdo winter-over personnel;* 41 working visitors (including Master Chief Petty Officer of the Navy, Dalbert Black); and 22 newsmen.

CRREL Redesignated

Effective July 1, 1968, the U.S. Army Cold Regions Research and Engineering Laboratory was redesignated the U.S. Army Terrestrial Sciences Center. The Center's mail address is P.O. Box 282, Hanover, New Hampshire 03755.

Future International Meetings

The Fifth Antarctic Treaty Consultative Meeting will take place in Paris, France, during November 18-December 2, 1968.

The Scientific Committee on Antarctic Research will hold its Eleventh Meeting in Norway in August 1970.

Hero to Visit Washington

Hero, the new antarctic research ship described in the last issue of the *Antarctic Journal* (vol. III, no. 3, p. 53–60) will be at the Washington (D.C.) Navy Yard September 4–10. She will be open for public visits on September 7.

New Publications

Three new publications dealing with antarctic research and sponsored by the National Science Foundation have been issued. They are available from the American Geophysical Union, Suite 435, 2100 Pennsylvania Avenue, N.W., Washington, D.C. 20037.

Volume 11 in the *Antarctic Research Series*, entitled *Biology of the Antarctic Seas III* and edited by George A. Llano and Waldo L. Schmitt. The 261-page volume costs $13.50.

Volume 6, issues 4 and 5 of the *Soviet Antarctic Expedition Information Bulletin*. These issues ($7.50 each) contain English translations of *Bulletins* nos. 61-62 and 63-64, respectively, all of which were originally published in Russian in 1967. The entire sixth volume, which will include *Bulletins* 55 through 66, is available on subscription for $40.

**Antarctic Journal*, vol. III, no. 3, p. 73.

Research at U.S. Antarctic Stations During March and April

McMurdo Station

The transition to winter activities was smooth as mild weather in April permitted completion of outdoor work. The forward-scatter circuits, which had not been functioning properly, were back in operation, but the micropulsation equipment was still out of order at the end of April. Aided by exceptionally clear weather, observations were made on 25 nights in the newly established polar-glow program. Operations in the other research programs were normal.

Palmer Station

The move to the new buildings (cf. *Antarctic Journal,* vol. III, no. 3, p. 58) caused some disruption of research in March. An information-exchange program was established with Argentine, British, and Chilean stations in the Antarctic Peninsula region.

The study of photosynthesis and respiration of lichens proceeded well, with rapid accumulation of microclimatic and metabolic data. Many sites within 11 miles of Palmer were visited while helicopter support from the icebreakers *Southwind* and *Glacier* was still available. Metabolic studies of six lichen species continued in April; the plants were exposed to a number of combinations of light, temperature, and moisture, some of which were found to produce high rates of photosynthesis.

Work continued on the installation and organization of instrumentation in the well-equipped biological laboratory. Some problems that developed at the new building, including a generator breakdown, had only transient effects on the research program.

Byrd Station

Progress in the research programs at both the main station and the substation was satisfactory except for some equipment problems.

South Pole Station

Scientific-program leaders in all disciplines reported successful operations. One phase of the sleep and activity studies of the station personnel was completed in April, all personnel having participated. An attempt was made to analyze qualitatively the carboxyhemoglobin in 16 subjects,

The micropulsation equipment, inoperative since the summer, was repaired and put back in operation. The ionospheric sounder was secured to prevent interference with the gravity program.

Plateau Station

An oil-pressure drop in a generator on February 9 precipitated a series of power shortages that necessitated the curtailment of all research programs until March 14. On March 19, a fire destroyed the garage containing three generators, a Traxcavator, and other equipment. The effect of the power loss was greatest on the very-low-frequency and micrometeorological programs, both of which had to be suspended for a considerable length of time. Variable power supply continued to hamper many programs throughout April. A new record low temperature of −78°C. (−108.4°F.) was set for April.

New Member on OAP Advisory Panel

A new member has been appointed to the National Science Foundation's Advisory Panel for Antarctic Programs. He is Dr. Heinz H. Lettau, Professor of Meteorology at the University of Wisconsin. Dr. Lettau replaces Dr. Richard M. Goody of Harvard University.

The other members of the panel are Dr. Laurence M. Gould, University of Arizona (chairman); Ambassador (Ret.) Paul C. Daniels, Lakeville, Connecticut; Dr. Laurence Irving, University of Alaska; and Dr. Ernst Stuhlinger, National Aeronautics and Space Administration.

The panel was established in 1963, under the name "Advisory Committee for the Office of Antarctic Programs," to consider broad aspects of the U.S. Antarctic Research Program. Since then, it has held six meetings, the latest on April 26, 1968.

Results of *Ob'* Cruise Available

Volume 39 of the Transactions of the Soviet Antarctic Expedition, *The Sixth Voyage of R/V Ob', 1960-1961,* has been translated and published for the National Science Foundation. The 228-page monograph, edited by A. F. Treshnikov, was originally published in Russian in 1963. Topics discussed include bottom sediments, currents, ice conditions, hydrography, meteorology, and biological observations.

The volume (TT 68-50311) is for sale at $3.00 a copy from the Clearinghouse for Federal Scientific and Technical Information, U.S. Department of Commerce, Springfield, Virginia 22151.

Antarctic Glaciation During Eocene

Evidence consistent with Eocene glaciation has been found in a deep-sea sediment core from the South Pacific, according to an article by Kurt R. Geitzenauer, Stanley V. Margolis, and Dennis S. Edwards of Florida State University in a recent issue of *Earth and Planetary Science Letters* (no. 4, 1968, p. 173-177).

The authors reported that two independent micro-paleontological examinations of an *Eltanin* core from 57°46.2′S. 90°47.6′W. showed Eocene sediments in the lower 4 m. Electron-microscope examination of quartz grains from this portion of the core revealed surface features that several authors have attributed to glacial action, suggesting that antarctic glaciation existed during the Eocene.

Philatelic Mail for *Deep Freeze 69*

Philatelic covers will be accepted by two U.S. stations in Antarctica and by four *Deep Freeze* ships that will operate post offices during the 1968–1969 season. Byrd Station and South Pole postmarks may be obtained by placing two addressed covers, each bearing U.S. postage at the 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 submitted cover should have either "Byrd" or "Pole" written in the lower left corner. Covers must arrive at Davisville by September 1, 1968, 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 1969 and March 1970.

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 1968 deadlines for receipt of covers are:

USCGC *Southwind* (WAGB–280), FPO New York 09501, October 4.

USCGC *Burton Island* (WAGB–283), P.O. Box 20820, Long Beach, California 90801, October 12.

USCGC *Glacier* (WAGB–4), P.O. Box 20900, Long Beach, California 90801, October 15.

USCGC *Edisto* (WAGB–284), Boston, Massachusetts 02109, November 5.

* Foreign collectors may use International Reply Coupons to defray postal charges.

Collectors are limited to one cover from each of the stations and ships mentioned above. Philatelic covers will be returned unprocessed when more than the authorized number is submitted, if insufficient or foreign postage is provided, or if it appears that a commercial motive is involved.

Climatological Data for Antarctic Stations

Number 9 in a series of publications entitled *Climatological Data for Antarctic Stations* has been issued. Compiled at the National Weather Records Center, Asheville, North Carolina, and published by the Environmental Data Service of the Environmental Science Services Administration, the 206-page volume of tabulated data covers the period January-December 1966 at South Pole, Byrd, and Plateau Stations and of USNS *Eltanin* operations. The first number in this series, issued in 1962, covered the period July 1957–December 1958 at U.S. stations then in operation.

Index to Topographic Maps, Antarctica Accompanies this Issue

Included with this issue of the *Antarctic Journal* mailed on the free distribution list is an up-to-date index to topographic maps of Antarctica published by the U.S. Geological Survey. The 1:10,000,000-scale index base map was prepared from plates currently being compiled for publishing a two-piece plastic relief model. The original model was jointly produced several years ago by the Geological Survey and the National Science Foundation.

The index to published maps identifies 45 1:250,000-scale and 11 1:500,000-scale topographic maps with contours, and 4 sheets in the new uncontoured interim 1:500,000-scale shaded-relief sketch-map series. Not shown are an additional 36 maps in the 1:250,000-scale series, and 3 in the sketch-map series, all of which are in compilation stages. The index map graphically points up the availability of continuous map coverage along the Transantarctic Mountains from the Thiel Mountains to the Convoy Range.

Additional copies of *Index to Topographic Maps, Antarctica* may be obtained free from the Map Information Office, U.S. Geological Survey, Washington, D.C. 20242. Copies of published maps may also be ordered from that office. Information on maps in preparation can be obtained from the Chief Topographic Engineer, U.S. Geological Survey, Washington, D.C. 20242, attention Chief, Branch of International Activities.

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