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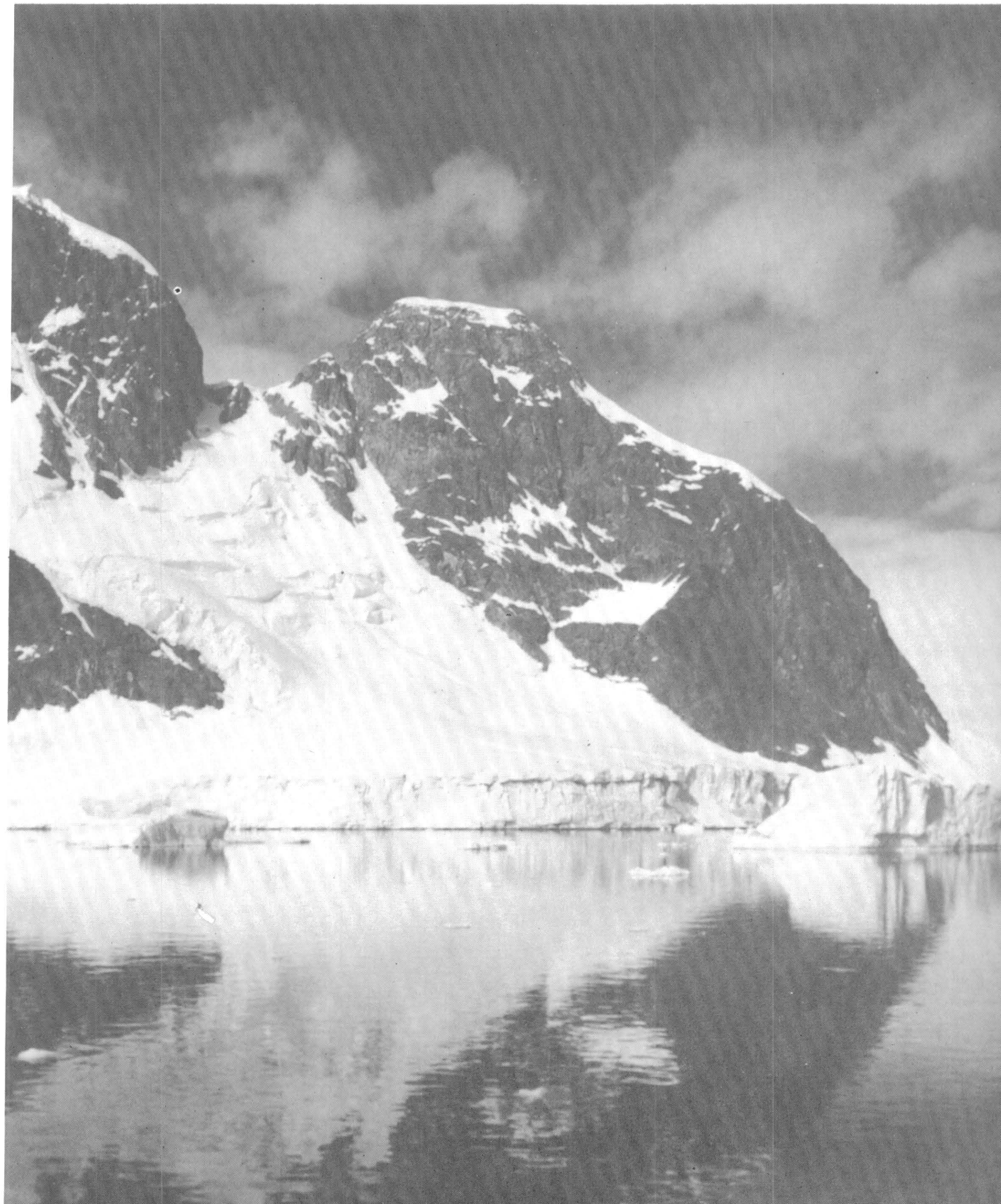

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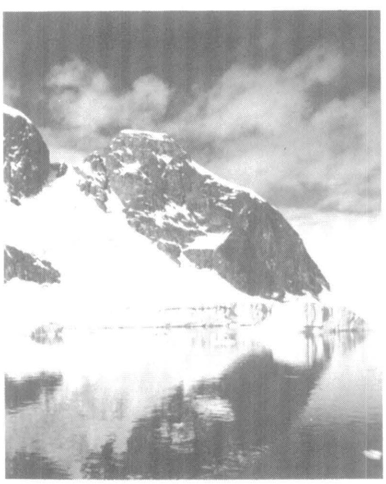

(*U.S. Navy Photo by R. J. Walinowski*)

COVER PHOTO
Wandel Peak (65° 05'S. 64° 00'W.), south of Lemaire Channel, Antarctic Peninsula.

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U. S. Antarctic Research Program, 1968—1969

Part II: Year-Round and Stateside Activities

Research

The Marine Geology of the Southern Oceans

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The Florida State University

Coring on USNS *Eltanin* since Cruise 27 has produced 132 piston cores totaling 74,426 cm (see table).

Eltanin Core Inventory

Cruise	No. Piston Cores	Core lengths (cm)			
		Longest	Average	Total	Cumulative
1—27	552	2,642	669.7	369,648	369,648
32*	46	1,590	438.5	20,170	389,818
33	20	1,591	731.7	14,633	404,451
34	17	2,260	739.5	12,571	417,022
35	15	1,218	686.0	10,290	427,312
36	34	1,226	493.0	16,762	444,075
1—36	684	2,642	649.2	444,075	444,075

*No cores taken on Cruises 28-31.

Textural and mineralogical investigations on more than 1,000 samples from the tops of these piston cores or from Phleger cores have permitted mapping of the surface sediments of the southern oceans (Fig. 1). Across the South Pacific, the Antarctic Convergence is the approximate boundary between carbonate oozes to the north and siliceous oozes to the south. East of about 110°W., this boundary disappears, except for patches of carbonate ooze in the Drake Passage and across the Burdwood Bank. In the Pacific-Antarctic Basin between the Convergence and the August 0°C. surface-water isotherm, an irregular belt of siliceous oozes constitutes the surface sediment. Along its southern margin, this deposit is only tens of centimeters thick and overlies continentally derived silts and silty clays, but it reappears repeatedly in the cores, interlayered with silts and silty clays. The siliceous ooze deposit thickens northward and interfingers vertically and laterally with the carbonate oozes.

South of the August 0°C. surface isotherm and across the Drake Passage and Scotia Sea, the sediments are dominated by glacially derived antarctic sediments which coarsen toward the Continent. West of 180° and in the Southwestern Pacific Basin, the biogenic oozes are replaced again by clayey silts and

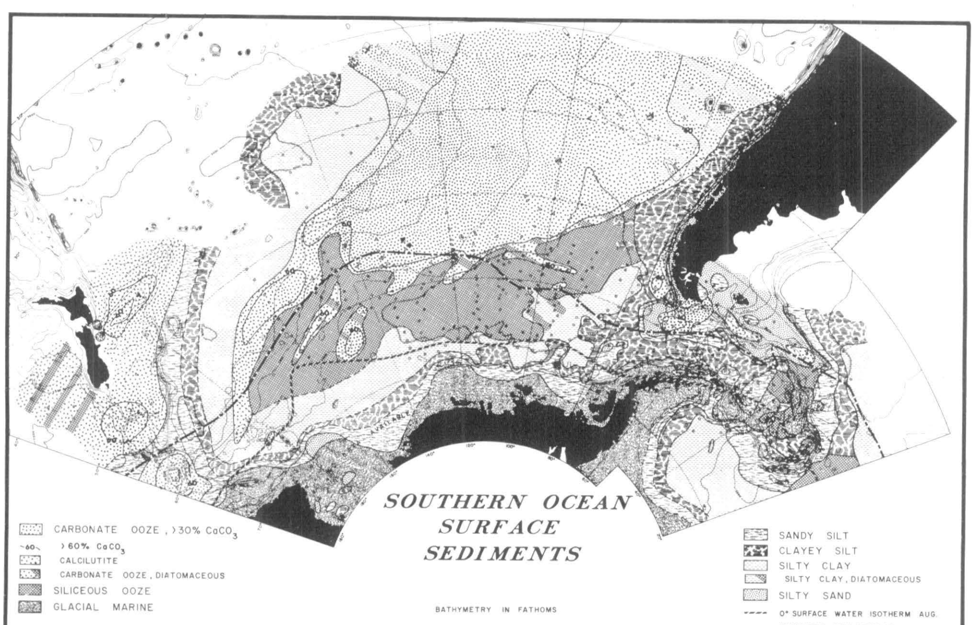

Figure 1. Surface sediments of a sector of the southern oceans.

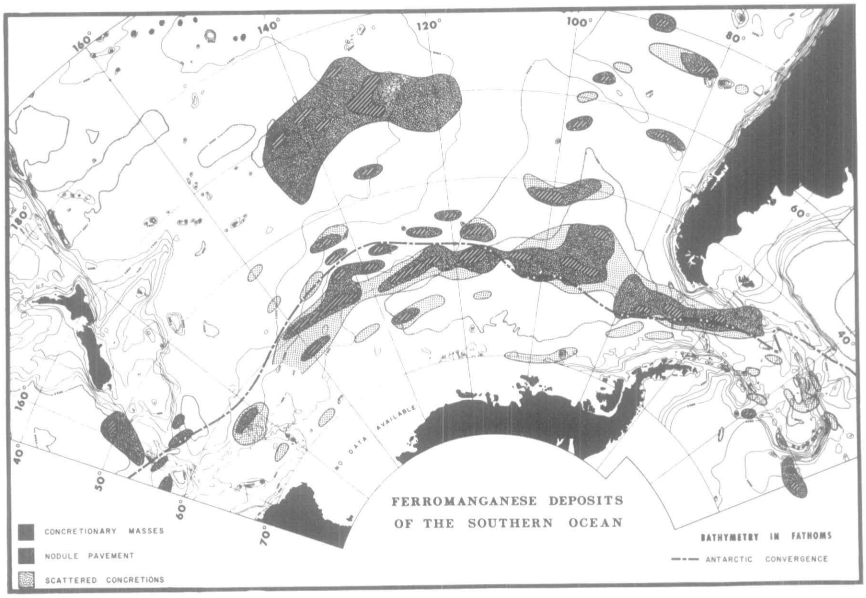

Figure 2. Ferromanganese deposits of a sector of the southern oceans.

silty clays, except across the New Zealand Plateau and the Macquarie Swell, where carbonate oozes again dominate.

Rates of deposition vary widely with the sediment type, their proximity to the Antarctic Continent, and their relationship to the bottom current regime. South of 70°S., sedimentation rates have averaged more than 20 mm/1,000 yrs. for the last 700,000 yrs., while across the center of the Pacific-Antarctic Basin under the circumpolar current, rates are less than 2 mm/ 1,000 yrs. (Goodell *and* Watkins, 1968). Over some parts of the Pacific-Antarctic Ridge swept by bottom currents, net rates are zero.

Superimposed on the sediments are fields of ferromanganese concretions (Fig. 2). These range from large masses of ferromanganese draped on volcanics, to fields of potato-size nodules hundreds of miles in diameter, to areas of scattered, irregularly shaped concretions of odd morphologies. Element suites in the concentrations of trace elements in submarine basalts co-vary directly with the same elements in adjacent concretions. In addition, definite suites of elements exist that are associated primarily with either iron or manganese. Concretions and volcanics associated with the Pacific-Antarctic Ridge are enriched in lithophile (ferrophile) elements; those in the abyssal basins, in chalcophile (manganophile) elements (Goodell *et al.*, in press).

Acknowledgement. This research is supported by National Science Foundation grant GA-4001.

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Surface Features on Sand Grains from Antarctic Continental Shelf and Deep-Sea Cores

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Investigations are in progress of *Eltanin* cores that contain sediments of Tertiary age. The sand fractions of these cores are being examined by transmission and scanning microscopy in order to identify grains of ice-rafted origin. Glacial features have been identified on quartz sand grains from sediments of Eocene age in core E13–4 (Geitzenauer *et al.,* 1968). Several other Tertiary *Eltanin* cores containing sediments of Eocene to Pleistocene age have also been found to contain evidence of ice-rafting. Sand grains known to have been transported by turbidity currents and by atmospheric means have been found to exhibit features distinctive from glacially derived grains (Figs. 1–3). By examining sand grains from *Eltanin* cores as well as cores collected by the D.S.D.P. (JOIDES) project, the Tertiary variations in sediment transport regimes and their antarctic paleoclimatological implications are being determined.

Similar examinations are being performed on sediments from the Berkner Bank in the Weddell Sea (Rex, 1964). Scanning electron micrographs (Fig. 4) show a sequence of features indicating an initial, glacially derived texture, with a superimposed pattern of both beach- and dune-sand abrasion. On top of all of these features are found triangular etch pits which suggest that the grains have undergone an extensive period of exposure to sea water. These and other

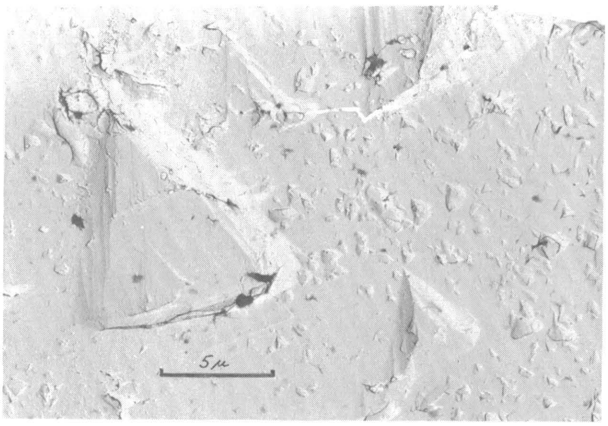
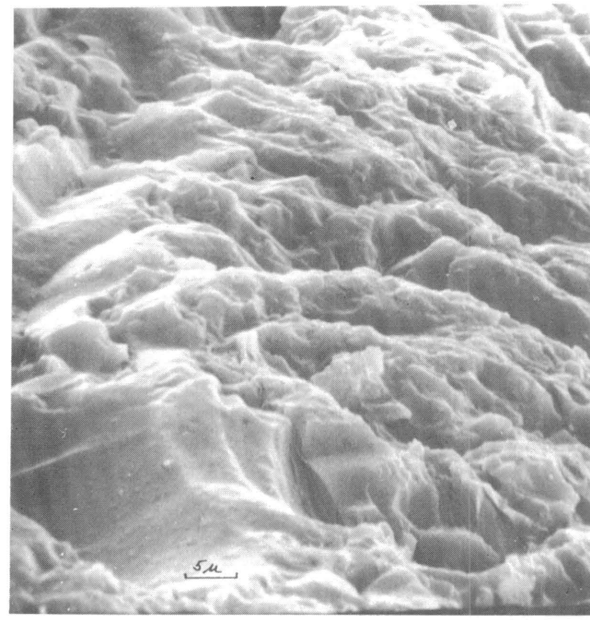


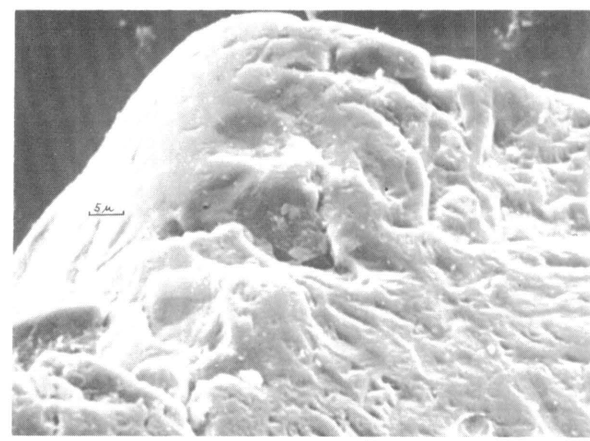
Figure 1 (above). Transmission electron micrograph of quartz sand grain from "Turbidite" sequence in equatorial Mid-Atlantic deep-sea core. V-shaped indentations are believed to have been produced by abrasion during transportation. These features are similar to those observed on sand grains from high-energy beach-surf zones. Triangular etch pits are evidence of solution of quartz by sea water.

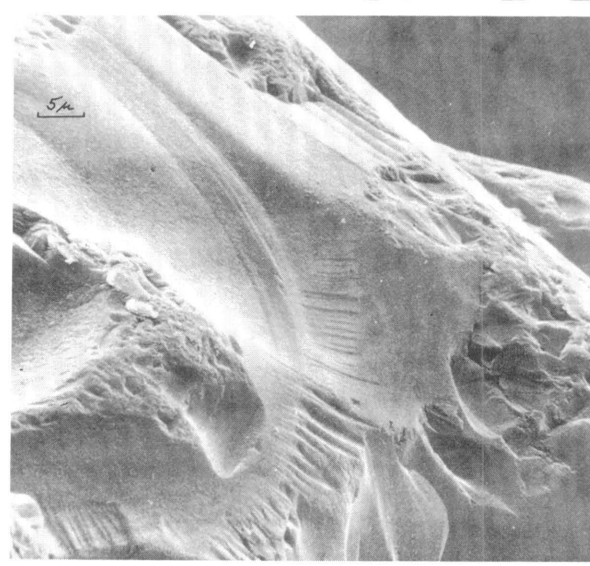
Figure 2 (top, right). Eolian surface textures, scanning electron micrograph. Sand grain from Libyan Desert showing oriented fracture patterns.

Figure 3 (center, right). Glacial marine environment, *Eltanin* core 13-4. Sand grain from sediments of Eocene age. SEM photo showing glacial scratches on smooth surfaces at top of grain and oriented triangular etch pits similar to those in Figure 1.

Figure 4 (bottom, right). Combination of glacial, eolian, and beach features. Sand grain from Berkner Bank, Weddell Sea. SEM photo shows large conchoidal fractures and chatter marks of glacial origin. Small fractures on pitted surface are similar to those found on grains from coastal dunes.







sedimentological data indicate that the Berkner Bank may have been exposed at the surface during an interglacial period when the antarctic land surface stood approximately 300 m higher with respect to sea level than it does today.

The effect of chemical solution on quartz sand grains after burial in deep-sea cores was investigated with the scanning microscope (Krinsley *and* Margolis, 1969). Fifty sand grains were sampled every 100 cm of core E13–17 from the South Pacific (Watkins *and* Goodell, 1967). Examination of these grains showed a progressive increase with depth in the percentage of sand-grain surface area covered with oriented solution features. Below a depth of 1,970 cm, however, there was an abrupt increase in the area covered by these features, possibly indicating an unconformity or perhaps a chemical change in interstitial fluids. More detailed investigations are in progress, in cooperation with Dr. N. D. Watkins, on the surface features of sand grains from *Eltanin* cores, with emphasis on possible chemical changes occurring at paleomagnetic boundaries.

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Major Late Cenozoic Planktonic Datum Planes, Antarctica to the Tropics

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Miocene-Pliocene Boundary. A significant planktonic datum plane for the later Cenozoic is the *Sphaeriodinella dehiscens Datum* (Fig. 1) of the tropics, which approximates the Miocene-Pliocene boundary (Bandy, 1963, 1964). It has been defined recently in deep-sea cores at a position within the upper part of the Gauss Magnetic Epoch (Glass *et al.,* 1967). This datum plane is essentially the boundary between Neogene zones 18 (Miocene) and 19 (Lower Pliocene) of Banner and Blow (1965). Analysis of radiolarian faunas of antarctic deep-sea cores (Hays *and* Opdyke, 1967; Bandy *et al.,* 1969) shows that the extinction datum for *Prunopyle titan* occurs within the upper part of the Gauss Normal Magnetic Epoch, a point nearly correlative with the *S. dehiscens Datum Plane* of the tropics. In California, these radiolarian and foraminiferal events are approximately coincident with the Miocene-Pliocene boundary; in Italy, the first appearance of *S. dehiscens* is near the base of the recognized Pliocene. Additional Upper Miocene radiolarians occurring just below the *Prunopyle titan Datum* include *Oroscena digitata,* verifying the Upper Miocene character of the fauna.

Pliocene-Pleistocene Boundary. A second important planktonic datum of tropical areas is that marking the origin of the keeled forms of *Globorotalia truncatulinoides,* which is also the approximate level for the extinction of discoasters in tropical and temperate regions (Fig. 1). These planktonic events mark the approximate base of the Gilsa event, formerly misidentified as the Olduvai event, which is approximately coincident with the extinction datum of *Eucyrtidium calvertense* in antarctic and temperate deep-sea cores. Similarly, the appearance of *G. truncatulinoides* and extinction of discoasters mark the base of the Wheelerian Stage in California and the base of the Calabrian in Italy (Hay *and* Boudreaux, 1968; Bandy, 1969; Bandy *et al.,* 1969).

Paleoclimatology. Major paleotemperature variations of the Antarctic consist of subtropical conditions in the lower part of the Gilbert Reversed Magnetic Epoch, indicated by tropical collosphaerids; cold-water conditions in the upper Gilbert, Gauss, and basal Matuyama Epochs as indicated by exclusively cold-water types; temperate influences in most of the Matuyama Epoch, indicated by mostly continuous occurrences of temperate species such as *Pterocanium trilobum* and *Saturnulus planetes*; colder water conditions during much of the Brunhes Normal Epoch with exclusively cold-water species; and a temperate influence near the top of the Brunhes indicated by the appearance of *Saturnulus planetes, Theoconus zancleus,* and others. The first appearance of glacial deposits in most cores occurs at or just above the disappearance of the tropical collosphaerids well down into the Gilbert Reversed Epoch (Fig. 1). It would appear that the major, coldest intervals, represented by left-coiling populations of *Turborotalia pachyderma* invading temperate areas, are those of the Upper Miocene (upper Gilbert Epoch), and the glacial Pleistocene (most of the Brunhes), with perhaps a short cooler interval in the middle Matuyama which is equivalent to the Venturian cool interval of California (Bandy, 1968) and the Astian cool interval of the Italian section (Lona, 1962).

Radiometric dating. It is clear that radiometric dates available from land sections (Obradovich, 1968; Bandy *and* Ingle, in press) are in direct conflict with those associated with the paleomagnetic scale (Fig. 1). Planktonic events and paleomagnetic data are in agreement for correlations made between high and low latitudes in deep-sea cores. Planktonic events in deep-sea cores correlate well with land-based sections. It is suggested that radiometric dates for the land-based marine sections are too high by a factor of about 3.

Acknowledgements. Support for this continuing study was provided by the National Science Foundation under grants GA–10204 and GB–8628. This is Contribution No. 216, Department of Geological Sciences, University of Southern California.

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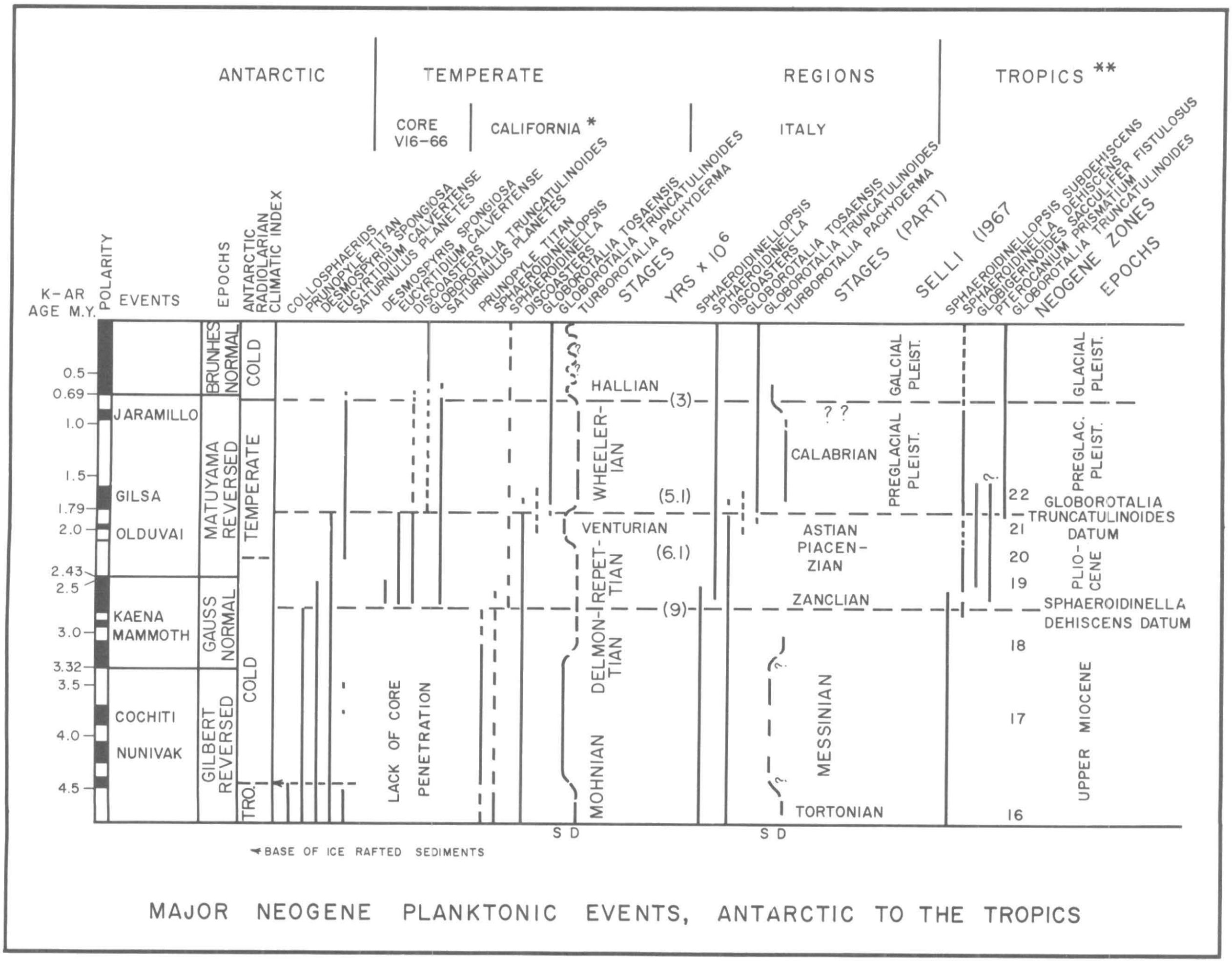

***Bandy *and* Ingle, in press.**
****Glass *et al.*, 1967.**

S=Left-coiling.
D=Right-coiling.

Figure 1. Major later Neogene planktonic datum planes. Paleomagnetic scale from Cox, 1969.

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Silicoflagellates: A New Tool for the Study of Antarctic Tertiary Climates

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A recent petrological study (Geitzenauer *et al.*, 1968) presented evidence in support of antarctic Eocene glaciation, based on examination of an *Eltanin* deep-sea core collected at 57°46.2'S. 90°47.6'W. In another deep-sea core from a site 42° further east (51°41'S. 48°29'W.), evidence was found that supports the idea of antarctic Eocene warm climate. This report presents data and interpretations, based upon a study of fossil silicoflagellates,[2] suggesting that at least one part of Eocene Antarctica had a warm climate.

The presence of the silicoflagellate, genus *Naviculopsis,* indicates that the age of the sample is Eocene (probably Late Eocene). In an independent study of the sessil benthonic diatoms in our sample, Dr. G Dallas Hanna[3] also determined that the age of the sample is Eocene.

No prior report of fossil silicoflagellates from Antarctica is available for comparison. There are earlier studies of living silicoflagellates in waters off the coast of Antarctica (*e.g.,* Gemeinhardt, 1931); however, these studies contain data that are at best distantly peripheral to Tertiary climates.

In this investigation, the ratio of two genera of silicoflagellates, *Dictyocha/Distephanus,*[4] was used to determine the Eocene ocean temperature. The relationship between the ratios of the two genera and temperatures is shown in the graph. Of 540 fossil silicoflagellates of this faunule mounted on glass slides, 150 were specimens of *Dictyocha* distributed in 11 species, and 16 were specimens of *Distephanus* distributed in 2 species. These data (150/16), when applied to the graph, indicate that in the immediate area of deposition, near-surface ocean waters were slightly warmer than 25°C. at the time of deposition. A detailed description of this ratio method was given in a prior paper (Mandra *and* Hanna, 1969), and a procedure for statistical utilization of silicoflagellates has been presented earlier (Mandra, 1968).

Further study is needed to evaluate the degree of accuracy of this conclusion; hence, no claim of precision is intended for the statement, "slightly warmer than 25°C." However, prior experience (Mandra, 1968) has demonstrated that this method is qualitatively correct. For these reasons, the term "tropical" is preferred to "slightly warmer than 25°C." in this report.

Seven papers presented at the Symposium on Tertiary Climate of New Zealand (Victoria University of Wellington, August 1967) contained data supporting our idea of Upper Eocene tropical climate at mid-southern latitudes. For the sake of brevity, reference will be made to only three of the seven.

Hornibrook (1968, p. 13) presents a graph which indicates that, during the Upper Eocene, maximum temperatures were slightly above 25°C. for the latitude of Wellington, New Zealand. Similarly, Jenkins (1968, p. 35) presents data to indicate maximum temperatures of about 28°C. These studies of planktonic and benthonic Foraminifera were substantiated by a study based upon Mollusca by Beu and Maxwell (1968, p. 72), pointing to temperatures in excess of 25°C. for South Island, New Zealand in the Upper Eocene.

The locality in the South Atlantic Ocean is close to the present Antarctic Convergence. The sample came from the interval 325–330 cm below the top of a core taken in waters 2,429 m deep. These data are important because the sample contains a tropical Eocene faunule and it is only 13° of latitude north of Graham Land, Antarctic Peninsula.

If the geographic relationship between the locality of our tropical sample and the Antarctic Continent were essentially the same in Eocene time as it is now (paleomagnetic studies by Blundell, 1962, support this assumption), then it is possible to envision at least a warm-temperate or warmer climate for the most northerly, low, coastal areas of Antarctica which are directly south of our sample site.

The climatic conclusion stated here seems to be warranted by the limited relevant post-depositional movement of our sample. Dr. Hanna[3] has demonstrated that the sample contains sessil benthonic diatoms that lived in waters less than 200 m deep. Since our material was collected in waters about 2,500 m deep, it has received considerable vertical movement. But down-dropping without a corresponding change in latitude does not weaken the data in this report.

Sea-floor spreading in the Atlantic must also be considered. Most of these movements, however, are essentially east-west or west-east with relatively little shift in latitude. Hence, there should not be much difference in the pre-drift position near-surface temperatures and post-drift position near-surface temperatures.

All slides of silicoflagellates used in this study will

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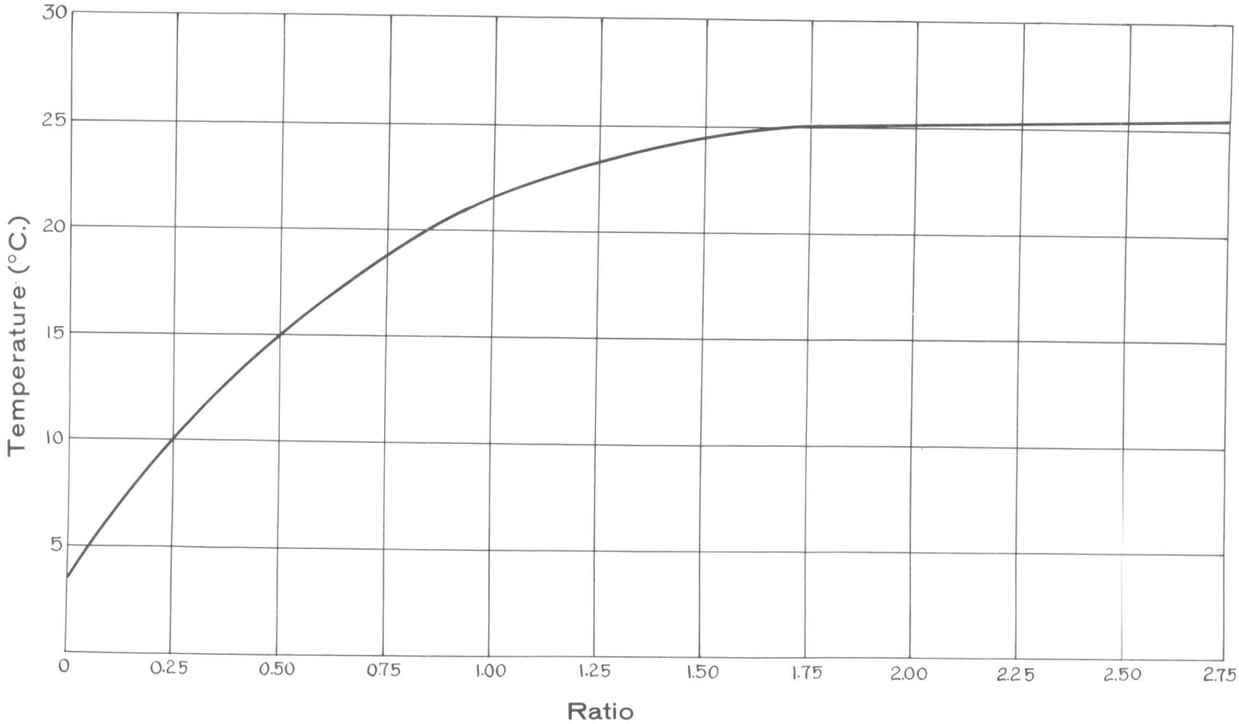
[1] Mailing address: 8 Bucareli Drive, San Francisco, California 94132.

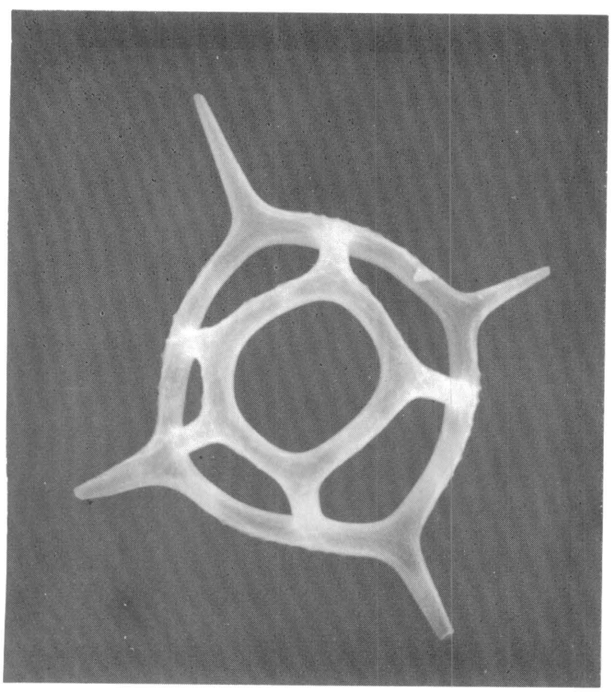
[2] Silicoflagellates are defined here as planktonic Protozoa with a flagellum, yellow or greenish-brown chromatophores, and a skeleton of hollow siliceous rods.

[3] Personal communication, May 1969.

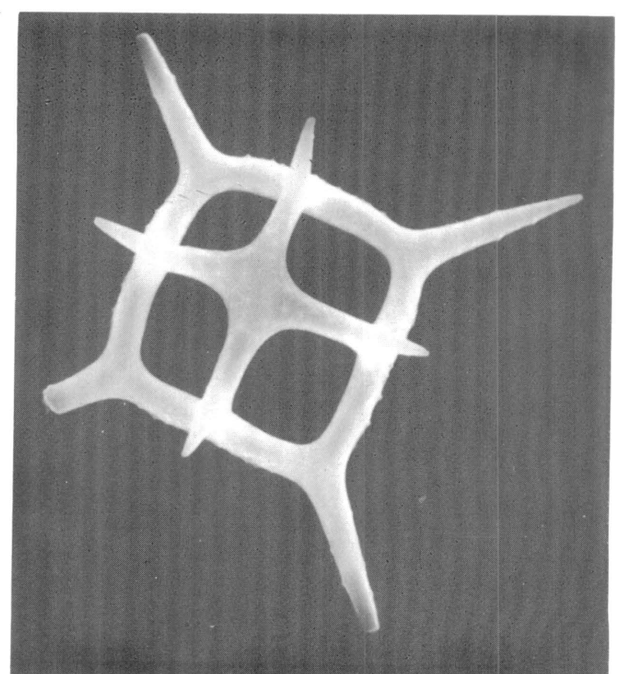
[4] Regarded by some workers as a synonym of *Dictyocha.*



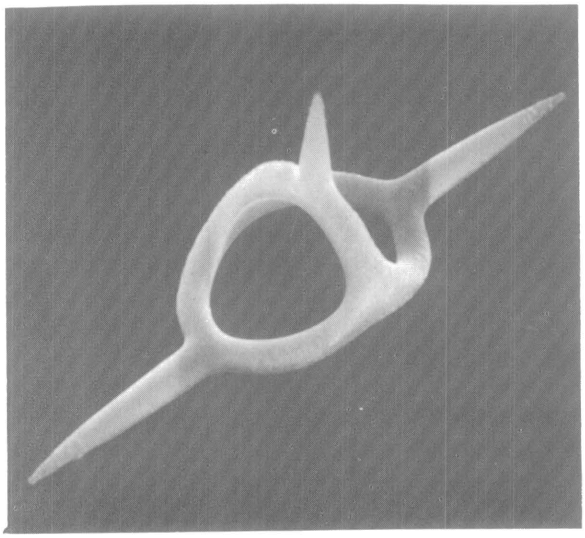
Temperature/population ratio. The graph is based on studies of present-day ratios of *Dictyocha* and *Distephanus* found in waters of different temperatures. Independent collateral evidence, in the California Tertiary, tends to confirm the validity of the relationship shown. The graph is used as follows: the number of specimens of *Dictyocha* and *Distephanus* are expressed as a fraction which indicates temperature. Example I: 150 *Dictyocha/75 Distephanus* = 2.00 = 25°C. Example II: 80 *Dictyocha*/160 *Distephanus* = 0.50 = 15°C.



Dictyocha. X 1900. Eocene silicoflagellate with four-blade, propeller-like structure. Scanning electron photograph made by Jeolco, Burlingame, California, and the California Academy of Sciences.



Distephanus. X 1500. Eocene silicoflagellate with one "window" surrounded by five other "windows." Scanning electron photograph made by Jeolco, Burlingame, California, and the California Academy of Sciences.



Naviculopsis. × 1500. Eocene silicoflagellate with one long spine on its central bridge. Scanning electron photograph made by Jeolco, Burlingame, California, and the California Academy of Sciences.

be deposited in the Department of Geology Type Collection of the California Academy of Sciences. A paper describing the fauna of silicoflagellates in this sample is in preparation.

Acknowledgements. The help of G Dallas Hanna and Mort D. Turner is gratefully acknowledged. This study was supported in part by National Science Foundation grant GA–1173.

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Grain Surface Features in *Eltanin* Cores and Antarctic Glaciation

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Eltanin deep-sea cores from the southern oceans have been evaluated throughout their length with respect to the mineralogy of the sand and clay-size material. In addition, the surface features of the quartz grains and other selected minerals have been examined optically and by electron microscope for evidence of glacial transport, environmental marks, and/or diagenetic alterations.

Krinsley and Newman (1965) suggested that the surface features of quartz grains are of value in recognizing sediments of glacial origin. Krinsley and Takahashi (1962a, b), Krinsley and Donahue (1968), and Krinsley and Margolis (1969) have postulated that grain surface features are not only diagnostic of a glacial origin of sediments, but of other environmental origins as well. The majority of this work has been accomplished utilizing the electron transmission scope, and currently the Scanning Electron Microscope (SEM). Recently, an optical technique employing interference microscopy (Warnke *and* Gram, 1968, in press) for examining grain surface replicas has been investigated.

An even simpler optical technique has now been developed for direct examination of grain surfaces using reflected dark-field illumination with the Leitz Ortholux Ultropak system. This method has been compared with electron microscopy with favorable results. The latest optical method has the advantage of enabling rapid evaluation of many grains without the necessity of plating or replica-making. A depth of field problem exists with the optical methods, particularly at higher magnifications, and some of the more minute features may, therefore, go unobserved. However, the speed of the optical techniques permits a large number of observations to be made and, therefore, increases the statistical reliability. This advantage compensates for the depth of field problem to a large degree. During the present study, no features of significance were observed electronically that were not visible using optical methods.

In an effort to more fully establish the accuracy of the surface-feature environmental criteria established by the aforementioned workers, and to validate the optical technique developed by the present author, quartz grains from numerous environments were examined. These grains were obtained from icebergs off the Antarctic Peninsula; Alaskan glaciers and their outwash plains (Slatt *and* Hoskin, 1968); Florida, California, and New York beaches; and Florida, California, and Texas sand dunes. Some Florida river samples were also examined. The results of this effort have, in general, supported the work of Krinsley and his coworkers. Consequently, the use of optically identifiable grain surface features as indicators of environmental origin is believed to be a valid technique.

Fig. 1 is a SEM photograph of a quartz grain from the 6–11 cm interval of *Eltanin* core 11–13. The photo shows the high relief, parallel steps, and breakage pattern attributed to glacier action. Fig. 2 is a reflected-light photomicrograph of a quartz grain from the same core showing similar features; the grain is from the 1,695–1,700 cm interval. Preliminary results from this study indicate that, in general, at least one-third of the sand-size quartz present throughout the core lengths show surface features resulting from glacier activity. The majority of the cores examined extend into the Gauss Paleomagnetic Epoch, four extend into the Gilbert, and one through the Gilbert. The quantity of quartz present in these cores showing direct evidence of glacial transport supports Goodell and others (1968) in their hypothesis that widespread glaciation of the Antarctic Continent was in progress at least 5 m.y. ago.

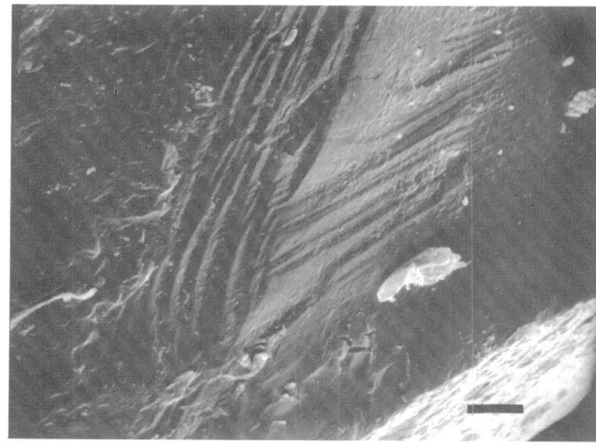

Figure 1. SEM photograph of quartz-grain surface showing features resulting from glacier or ice transport. Grain from *Eltanin* Core 11–13, 6–11 cm interval. Scale bar equals 10 microns.

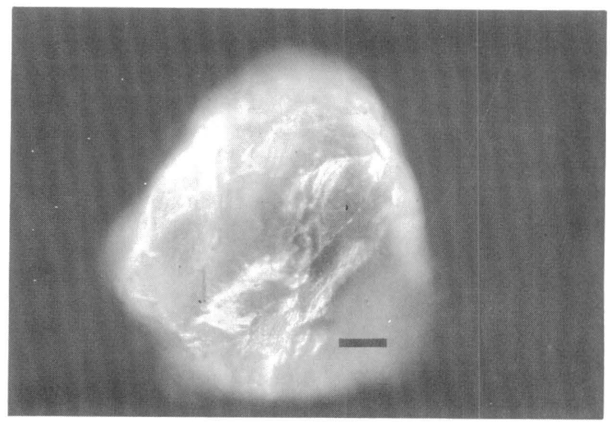

Figure 2. Light micrograph of quartz-grain surface showing features resulting from glacier or ice transport. Grain from *Eltanin* Core 11–13, 1,695–1,700 cm interval. Scale bar equals 10 microns.

A core believed to be of Eocene age (Geitzenauer, verbal communication) also contained some ice-rafted quartz throughout its length, although the percentage of such grains was considerably lower than in the other cores examined. The majority of grains in this core showed a combination of glacially derived features and diagenetic or chemical features, or were non-diagnostic. However, the presence of some grains showing evidence of glacier activity supports to a degree the evidence of Eocene glaciation of the Antarctic found in another core by Geitzenauer and others (1968).

Acknowledgements. This research was supported by the National Science Foundation under grant GA–4001 to Dr. H. G. Goodell. Drs. Biedler and Gradziedi, Florida State University, permitted the use of the SEM, and Mr. R. Parker took the SEM photograph. Grains examined during this study, other than those from *Eltanin* cores, were provided by Messrs. D A. Warnke, R. M. Slatt, E. Hopkins, F. Stapor, and the author.

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The Pleistocene Coccolithophoridae of the Southern Oceans

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The Coccolithophoridae from a number of USNS *Eltanin* carbonate cores taken in the subantarctic southern oceans have been studied over the past two years with the following objectives in mind:

1) To ascertain the stratigraphic ranges and population composition of the Pleistocene Coccolithophoridae in the southern oceans.
2) To determine the paleoecology and evolution of the Coccolithophoridae in the southern oceans during the Pleistocene.
3) Applying the above two objectives along with absolute ages, paleomagnetic data, and comparison with other microfossil groups to develop the Coccolithophoridae as paleoclimatic and biostratigraphic indicators of the Pleistocene.

Although the biostratigraphic application of coccoliths and discoasters has been used for some time and a zonal scheme established (Hay *et al.*, 1967), only a few studies have been directed toward the use of the Coccolithophoridae as paleoclimatic indicators (Cohen, 1964; McIntyre, 1967). Because of the high-latitude sources of most of the *Eltanin* cores, they should be ideal for the recognition of climatic changes during the Pleistocene.

An analysis of the coccolith populations present throughout the cores has shown that they do reflect the paleoclimates. By comparison with the data obtained from the same cores, using Radiolaria (Hays, 1967) and planktonic Foraminifera (Kennett, in press), it has been determined that, in most cases, an increase in the relative percentage of the coccolith *Umbilicosphaera leptopora* (Murray and Blackman) is indicative of an interglacial stage or warming trend in at least the Upper Pleistocene (Geitzenauer, 1969).

An attempt to apply the coccolith biostratigraphic zonation developed in the Caribbean area to the subantarctic cores was not completely successful, partly because the number of coccolith species present in the latter cores is very limited. It also appears that the worldwide correlation of biostratigraphic zones (even of planktonic forms), which apparently cross biogeographic boundaries, is indeed hazardous. Based on these studies, the subantarctic Pleistocene was divided into zones differing somewhat from those erected by Hay and others (1967) in the Caribbean.

Seven of the cores studied have been dated radiometrically by the excess Th^{230} method. The maximum absolute age obtained, 300,000 yrs. B.P., is especially useful as a base of reference in the absence of reliable paleomagnetic data. This method has been used to date the observed paleoclimatic events (Geitzenauer, 1969) and some biostratigraphic boundaries. The appearance of the coccolith species and zone fossil *Emiliania huxleyi* (Lohmann) in the subantarctic Pleistocene has been dated with the excess Th^{230} method as having occurred about 150,000 years B.P.

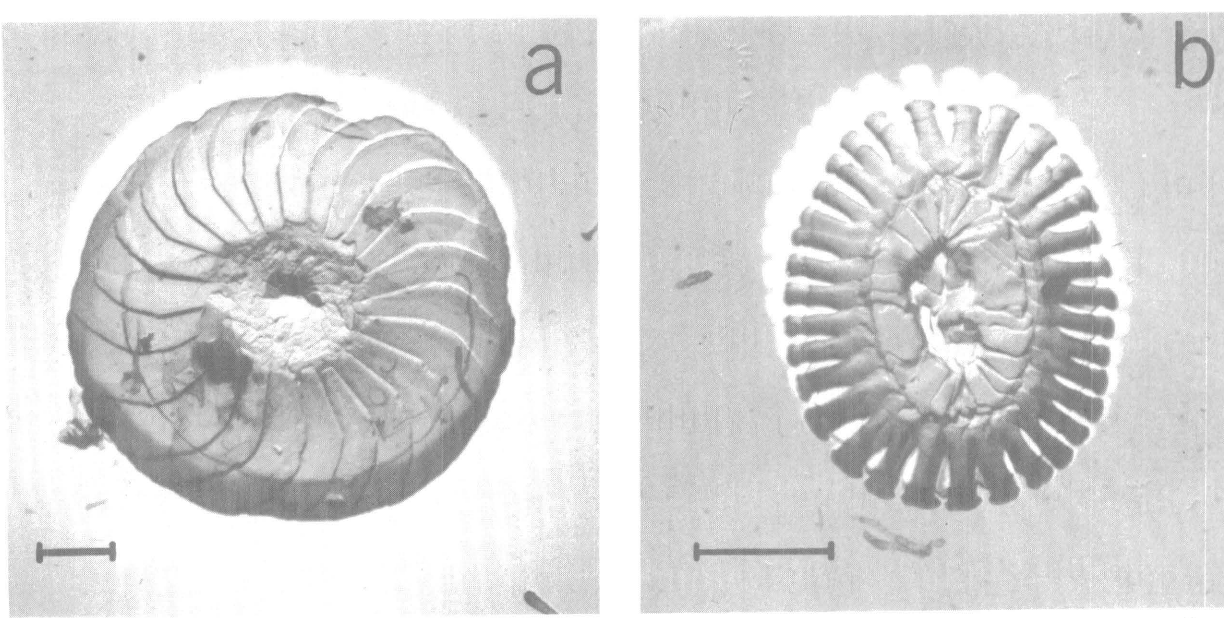

Figure 1. Electron micrographs of coccoliths of two important Coccolithophoridae species found in Recent and Pleistocene sediments of the southern oceans. a) *Umbilicosphaera leptopora* (Murray and Blackman) × 10,000. b) *Emiliania huxleyi* (Lohmann) × 18,300. A 1-micron scale is in the lower left corner of each micrograph.

Acknowledgement. These investigations have been supported by the National Science Foundation under grant GA–4001 to Dr. H. G. Goodell.

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Continuing Studies of *Eltanin* Sedimentary Cores and Dredged Rocks

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In a previous report (Watkins, 1968), mention was made of paleomagnetic observations of some *Eltanin* sedimentary cores indicating hitherto undiscovered short-period reversals of the earth's magnetic field 0.82 and 1.07 million years ago. Subsequent detailed examination of cores taken during Cruises 27 through 35 have confirmed this earlier suggestion. Fig. 1 shows the results of studies made on one of these cores. The data are to be presented at a meeting of the International Association of Geomagnetism and Aeronomy in Madrid in September, 1969.

During 1969, the paleomagnetic investigations have become integrated with the micropaleontological studies of Dr. J. Kennett. It appears probable that the paleo-oceanographic history of the area south of Australia and New Zealand will become clearer through the current application of these two disciplines to the sediment cores taken during *Eltanin* Cruises 16, 26, 27, 34, and 35.

The distribution of the dredged rocks recovered during *Eltanin* Cruises 5–9, 12, and 22 in the Scotia Sea has been examined. It has been shown that the Antarctic Continent south of the Weddell Sea and the east coast of the Antarctic Peninsula are probably the major sources of the recovered materials (Watkins *and* Self, 1969). Since an earlier regional survey of the *Eltanin* dredges from the Pacific (Watkins

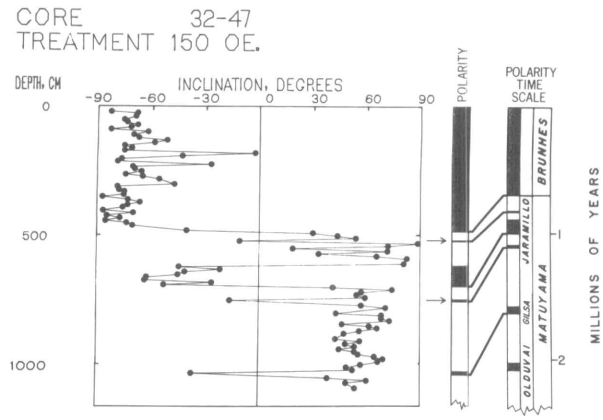

Figure 1. Inclination of remanent magnetism in specimens of core E32–47, following demagnetization at 150 oersteds. Polarity log at right; black is normal polarity (negative or upward magnetic inclination), clear is reversed (positive or downward magnetic inclination). Specimen interval 10 cm. The known polarity time scale is to the right. Added to this are the two short polarity events initially detected by examination of cores from earlier *Eltanin* cruise (Watkins, 1968). Correlation lines are included.

et al., 1968) indicated that rocks recovered during Cruises 16, 26, and 27 over the Macquarie Rise included some *in situ* materials, chemical, petrological, and magnetic analyses have been made of several of the samples, in conjunction with Dr. B. M. Gunn, University of Montreal. This research has revealed the occurrence of hartzburgites, of high intensity of magnetization, which may be relevant to the genesis of the Rise. Further analyses are intended before the data are published.

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The Antarctic Marine Geology Research Facility

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Cores obtained during USNS *Eltanin* cruises are stored in 5,200 ft^2 of refrigerated storage at 2°C., the temperature of Antarctic Bottom Water, in the Antarctic Marine Geology Research Facility of Florida State University. An additional 400 ft^2 is refrigerated to –10°C. for storage of core cuts destined for

Figure 1. Split piston cores from USNS *Eltanin* stored at 2°C. at the Antarctic Marine Geology Research Facility at Florida State University.

analysis of organic geochemistry, and 5,000 ft^2 is devoted to core and sample processing.

The Facility was completed in January 1966, and cores from Cruise 21 of *Eltanin* were the first to be accommodated directly. At present, 650 *Eltanin* cores, totaling more than 4.27 km of sediment, are shelved on about 20 percent of the available storage (Fig. 1). These cores, from *Eltanin* Cruises 2–36, represent samples from about one-third of the geographic area covered by the southern oceans.

The 3-m core sections in their plastic core-liner tubes are shipped under refrigeration when possible to the Facility from the *Eltanin* port of debarkation in New Zealand or Australia. At the Facility, the liners are cut through and the cores parted (using a nylon filament), tagged, and described. A 70-mm continuous negative is made of each core prior to initial sampling. The core halves are stored in their liners sheathed in a plastic sleeve.

Since the inception of the marine geology program on *Eltanin*, 14,774 samples have been distributed for sedimentological, mineralogical, geochemical, and paleontological investigations. In addition, 30,819 samples have been taken for paleomagnetic determinations. These samples have gone to 43 investigators representing 16 institutions in the U.S.A. Other samples have gone to researchers in Great Britain, France, Monaco, New Zealand, and Australia.

The inventory of *Eltanin* dredge haul samples, exclusive of manganese nodules, has been transferred to the Smithsonian Oceanographic Sorting Center. Prior to this transfer, 525 samples from the collection had been provided to investigators for study.

Acknowledgement. The Antarctic Marine Geology Research Facility is supported by the National Science Foundation under grant GA–4001 and contract C–564.

Foraminiferal Studies of Southern Ocean Deep-Sea Cores

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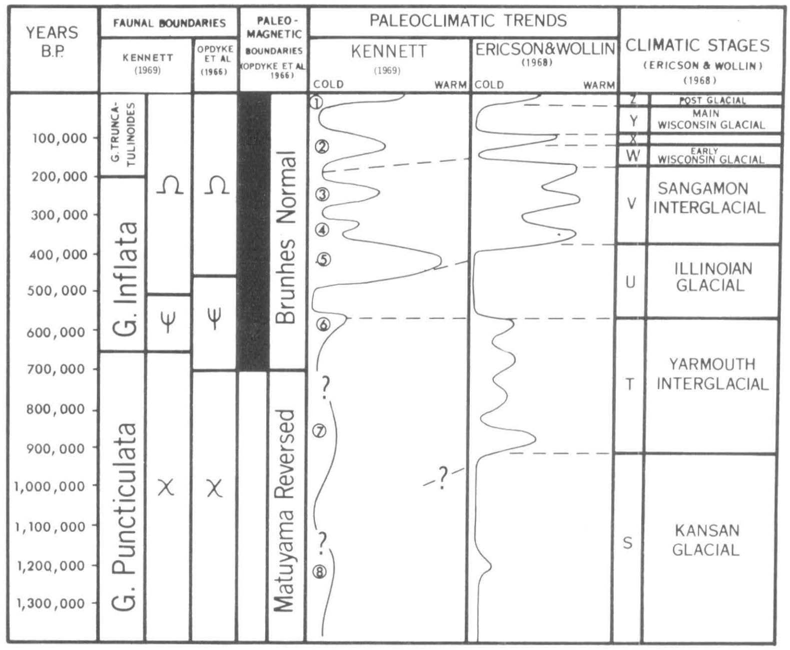
The principal objectives of foraminiferal studies of southern ocean deep-sea cores at Florida State University are to establish a foraminiferal biostratigraphy and paleoclimatic history of antarctic, subantarctic, and southern subtropical areas for as much time within the Cenozoic as the material allows.

Middle and Upper Pleistocene cores from the subantarctic region of the South Pacific (Kennett, 1969a) can be divided into three faunal zones on the basis of the upward sequential appearance of planktonic Foraminifera. Correlation of this sequence with established radiolarian zones and paleomagnetic stratigraphy are supported by radiometric dates. Alternations of cold- and warm-water planktonic foraminiferal faunas delimit 8 intervals of climatic warming during the last 1.2–1.3 m.y. B.P. The relative magnitudes of climatic warmings were considerably greater during the last 0.5 m.y. than between 0.5 and 1.2–1.3 m.y. B.P., when conditions were generally cooler. Only once were conditions significantly warmer than the Recent, *i.e.,* during the interval between 0.4 and 0.5 m.y. B.P. Paleoclimatic trends for polar areas can be correlated rather closely with those of tropical areas (Ericson *and* Wollin, 1968).

A South Pacific subtropical core (*Eltanin* 21–5; 36°41′S. 93°38′W.; length 480 cm), which has been shown by nannofossils to be Upper Pliocene to Lower Pleistocene in age, is significant in showing alternations of dominantly keeled and non-keeled populations of the *Globorotalia truncatulinoides–G. tosaensis* plexus (Kennett *and* Geitzenauer, 1969). The lower (425–480 cm) and upper (0–130 cm) core sections contain populations dominated (>78%) by keeled



Correlation of foraminiferal and radiolarian boundaries and paleoclimatic events of various authors with a Middle and Upper Pleistocene time scale (Kennett, 1969a). Ages of foraminiferal boundaries (subantarctic area), inferred positions of the radiolarian boundaries of Opdyke and others (1966), and paleoclimatic trends (subantarctic area) were based on extrapolations of mean sedimentation rates by the excess Th^{230} method. The ages of inferred radiolarian boundaries determined by Kennett (1969a) show rather close correlation with those proposed by Opdyke and others (1966) based on known ages of magnetic polarity reversals. A generalized paleoclimatic curve for the southern oceans is correlated with the generalized paleoclimatic curve of Ericson and Wollin (1968) for equatorial areas.

forms referable to *G. truncatulinoides,* while intermediate sections between 198 and 400 cm contain populations dominated (>80%) by non-keeled forms which resemble topotypes of *G. tosaensis.* Transitional populations occur between 145 and 180 cm.

Globorotalia truncatulinoides is associated in the core only with marginal tropical foraminiferal faunas including *Globorotalia menardii, Globigerinoides conglobatus,* and *"Globigerina" dutertrei,* while *Globorotalia tosaensis* is associated with a cooler-water planktonic foraminiferal assemblage lacking these species but having higher frequencies of *Globorotalia inflata* and right-coiling *Globigerina pachyderma.* Likewise, the coccolith *Umbilicosphaera leptopora,* which prefers warmer waters, exhibits marked increases in frequency in the upper and lower core sections containing *Globorotalia truncatulinoides.*

Although not decisive, this sequence suggests that during the Upper Pliocene to Lower Pleistocene, at least in this area, *G. truncatulinoides* and *G. tosaensis* were either phenotypic variants or separate subspecies or species with distinct environmental preferences. It also provokes speculation as to whether the *G. tosaensis* to *G. truncatulinoides* evolutionary bioseries reported by a number of workers near the Pliocene–Pleistocene boundary in tropical deep-sea areas, including the Gulf of Mexico, is instead the result of ecological or oceanographic change.

Comparisons have been made between antarctic and arctic populations of *Globigerina pachyderma* (Ehrenberg), the only species of planktonic Foraminifera living in both water masses. Populations of *Globigerina pachyderma* in arctic bottom sediments exhibit morphologies distinctly different from those in antarctic bottom sediments (Kennett, 1969b). Arctic populations are less heavily encrusted, more lobulate, and have a higher arched aperture and a dominance of 4½-chambered forms (umbilical view) compared with a dominance of 4-chambered forms in antarctic populations. Both exhibit dominance of sinistrally coiling forms and have similar size characteristics. Because of a shortage of morphological data on *G. pachyderma* in subarctic and Northern Hemisphere subtropical areas, it is not possible to evaluate whether these morphological differences result from phenotypic variation or subspeciation. Characteristic ranges of variation have been illustrated by scanning electron micrographs.

Studies in progress include the establishment of a paleoclimatic model for Pleistocene cores from antarctic ocean areas, one objective being to correlate this model with the one already established for subantarctic areas.

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Biolithology and Chemistry of Surface Sediments in the Subantarctic Pacific Ocean

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The region under investigation lies between 120°W.–180°W. and 30°S.–60°S. Bounded in the east by the East Pacific Rise and in the west by the New Zealand Plateau, it includes three major physiographic regions—the Southwestern Pacific Basin, the Pacific-Antarctic Ridge, and a part of the Pacific-Antarctic Basin. Most of the Southwestern Pacific Basin lies between 2,500 and 3,000 fm. The Pacific-Antarctic Ridge and numerous scattered seamounts rise more than 1,500 fm above the Basin floor. Two major oceanic west-east convergences transect the area—the Antarctic Convergence to the south and the Subtropical Convergence to the north. Most of the area lies between these convergences and is commonly referred to as the subantarctic regime. It is influenced by the tropical regime to the north and the polar regime to the south. The major physiographic features and surface currents are shown in Fig. 1.

Five different sedimentary units have been defined for the area on the basis of studies of surface sediments from approximately 100 cores collected by investigators on USNS *Eltanin* and other ships. These units are: (1) diatomaceous sediment, (2) carbonate (Foraminifera-rich) sediment, (3) brown clay, (4) mixed diatom-carbonate sediment, and (5) diatomaceous clay (Fig. 2).

Surface sediments were analyzed for major elements—silicon, iron, aluminum, magnesium, calcium, sodium, potassium, titanium, phosphorus, and manganese, and trace elements—cobalt, nickel, copper, chromium, zinc, strontium, and barium. The original data, along with contours of the second-degree trend surfaces for iron, manganese, cobalt, nickel, and chromium are shown in Figs. 3–7.

The manganese trend (Fig. 4) shows a high in the Southwestern Pacific Basin, as do the trends of cobalt, nickel, and chromium (Figs. 5, 6, 7). Iron (Fig. 3) might be expected to have a similar regional trend due to the common association of iron and manganese in micromanganese nodules, which are present in high concentrations in brown clay. Instead, iron concentration seems to increase toward the north and reflects a greater contribution of volcanic material from the seamounts in the area (Fig. 1).

From the petrologic and chemical studies, it appears that most of the brown clay is derived from volcanism in and around the Basin margin. Subma-

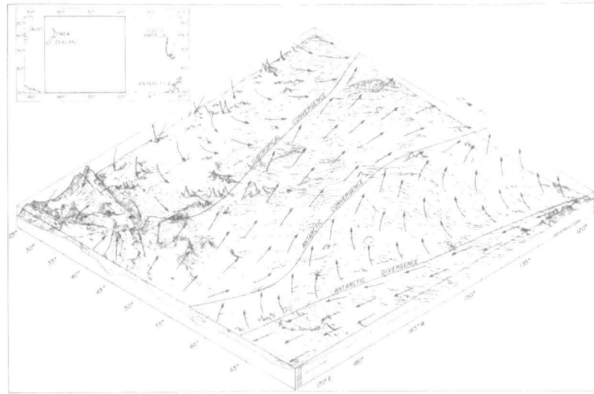

Figure 1. Physiographic diagram of the subantarctic Pacific Ocean showing surface currents.

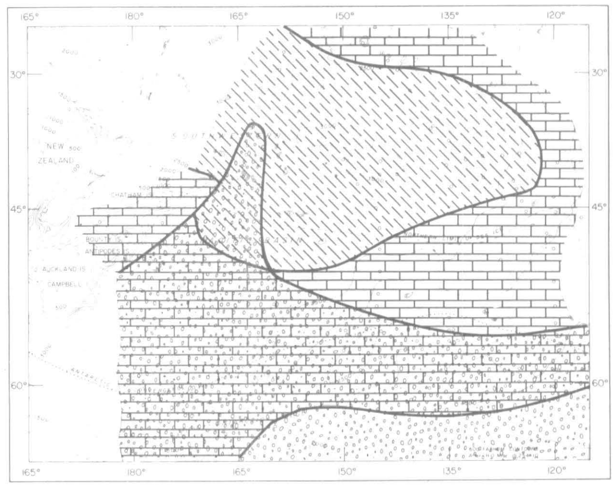

Figure 2. Surface-sediment distribution in the subantarctic Pacific Ocean. Diatomaceous sediment is shown by the open circle pattern, carbonate (Foraminifera-rich) sediment by the block pattern; the dashed pattern denotes brown clay, and areas of mixed sediment are shown by combinations of these patterns.

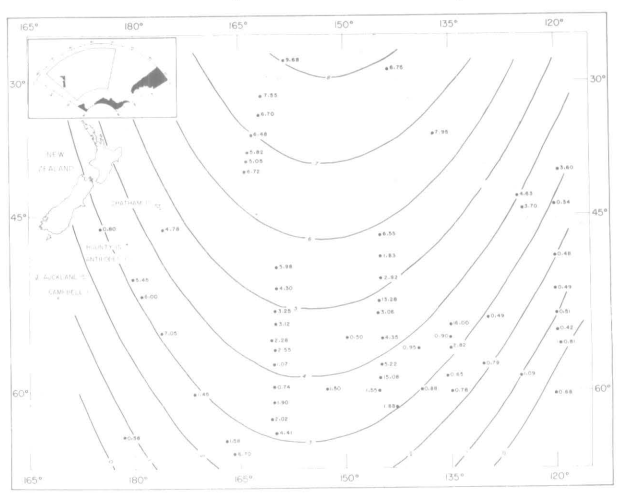

Figure 3. Iron in surface sediment of the subantarctic Pacific Ocean with contours of the second-degree trend surface. Iron values are in weight percent. Contour interval is 1.0 percent.

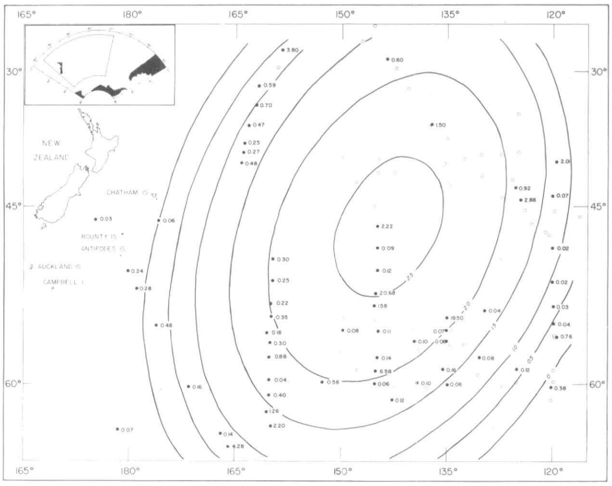

Figure 4. Manganese in surface sediment of the subantarctic Pacific Ocean with contours of the second-degree trend surface. Manganese values are in weight percent. Contour interval is 0.5 percent.

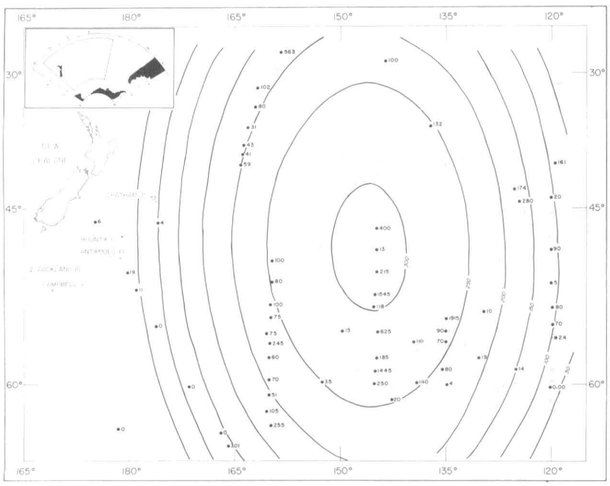

Figure 5. Cobalt in surface sediment of the subantarctic Pacific Ocean with contours of the second-degree trend surface. Cobalt values are in ppm. Contour interval is 50 ppm.

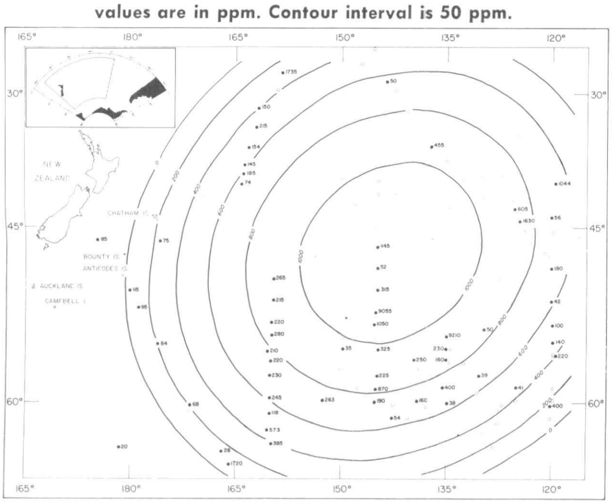

Figure 6. Nickel in surface sediment of the subantarctic Pacific Ocean with contours of the second-degree trend surface. Nickel values are in ppm. Contour interval is 100 ppm.

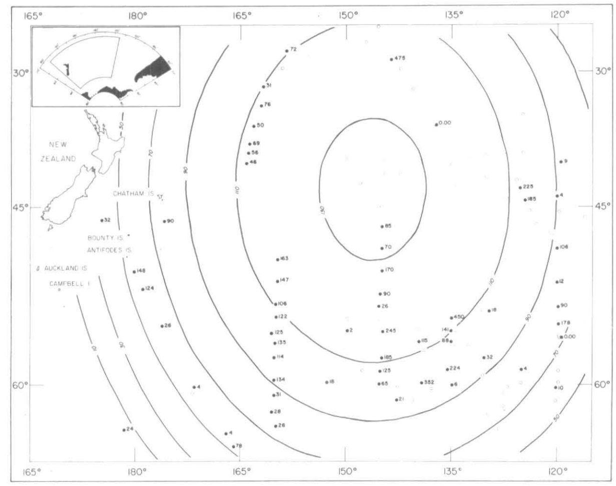

Figure 7. Chromium in surface sediment of the subantarctic Pacific Ocean with contours of the second-degree trend surface. Chromium values are in ppm. Contour interval is 20 ppm.

rine volcanism generated turbidity currents, which would flow down-slope and spread volcanic material (Nayudu, 1969). Mineral associations strongly suggest *in situ* alteration of the volcanic sediment. A detailed discussion of these units and the chemistry of surface sediments will be presented in a separate paper.

A study is in progress on significant changes at depth in these cores in order to evaluate the origin of the sediments and the paleoclimatic history and the paleocurrent regime of the region. Also, a study is being conducted of the chemistry, origin, and distribution of manganese nodules in the area.

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The Marine Geophysical Program of USNS *Eltanin*, 1968-1969

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The marine geophysics program aboard *Eltanin* during 1968–1969 consisted of several phases, including the routine collection of continuous underway gravity, magnetic, and seismic-profiler data. As part of a cooperative program, the geophysics group of the University of New South Wales provided one or two observers (generally advanced graduate students) who assisted in the data collection on Cruises 34–37. Geophysical observations made on board *Eltanin* continue to provide the bulk of geophysical information on the extreme southern oceans.

A new program of sediment-velocity determination was introduced on Cruise 37. This program utilizes the normal reflection profiling equipment in conjunction with passive, expendable radio-sonobuoys (Le Pichon *et al.*, 1968; Houtz *et al.*, 1968). Sonobuoys were made available to the program from those supplied to the Lamont-Doherty Geological Observatory by the Office of Naval Research. A commercial radio receiver (Communications Electronics No. 501A) was used to receive the sonobuoy signals. Sixteen wide-angle sonobuoy stations (Fig. 1) were made which produced useful sediment-velocity information.

Figs. 2a and 2b illustrate seismic data collected at sonobuoy station 14. Fig. 2a shows the normal, vertical-incidence seismic profiler record: the record quality is poor and sub-bottom penetration is generally less than 0.5 sec. The wide-angle reflection record, collected simultaneously with the record of Fig. 2a, is shown in Fig. 2b. The additional penetration achieved with the sonobuoy technique frequently reveals total sediment thickness in areas where basement reflections are not recorded with the vertical reflection technique. This record yields the following sediment-velocity information:

layer 1 (5.0–5.9 sec reflection time)
interval velocity $V_p = 2.26 \pm 0.10$ km/sec

layer 2 (5.9–6.6 sec reflection time)
interval velocity $V_p = 2.70 \pm 0.03$ km/sec

layer 3 (~6.6–? sec reflection time)
refraction velocity $V_p = 3.80$ km/sec

Interval velocities from wide-angle reflection data have been corrected for dip, but the refraction velocity has not been corrected. If we assume that the refracting horizon is parallel to the sea floor, the correct velocity of layer 3 is 3.50 km/sec. These records demonstrate the complementary nature of these two seismic reflection techniques. A knowledge of sediment velocities and their variations with depth will help evaluate the possible relationships of sediments of the southern oceans to those elsewhere. The sonobuoy program has now become a routine part of the *Eltanin* geophysical program.

Geophysical data reports (navigation, bathymetry, and magnetics) have been issued for *Eltanin* Cruises 16–27 (Heirtzler *et al.*, 1969; Hayes *et al.*, 1969) and are in preparation for the more recent cruises. Of particular interest are data collected on Cruises 34, 36, and 37 in the vicinity of the Macquarie Ridge–Trench complex and on numerous crossings of the mid-oceanic ridge south of Australia. Studies are in progress of these areas (*e.g.*, Houtz *et al.*, in press) and numerous others. A regional gravity map of the South Pacific compiled largely from data collected on *Eltanin* will be available shortly (Talwani *et al.*, in preparation).

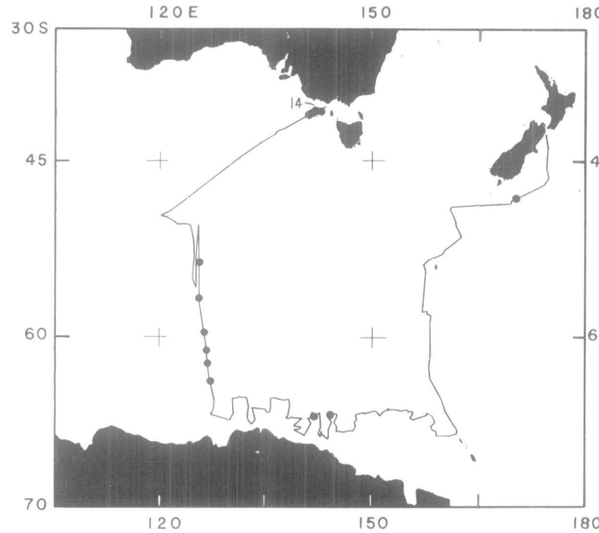

Figure 1. Index map of *Eltanin* Cruise 37 showing location of wide-angle seismic-reflection observations using expendable sonobuoys.

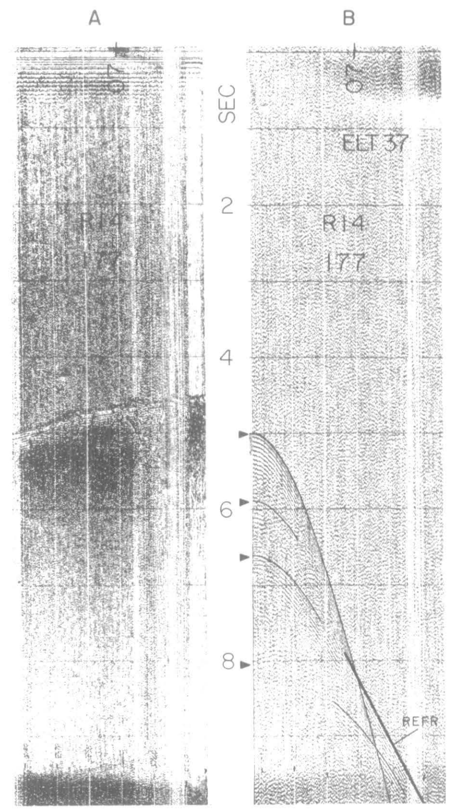

Figure 2. Sonobuoy station 14 (39°41'S. 141°12'E.), *Eltanin* Cruise 37. Reflection time for both records in seconds (1 sec=400 fm in water). (a) Vertical-incidence reflection record using normal seismic profiling technique. (b) Wide-angle reflection record using a sonobuoy. Black diamonds indicate major reflectors. Reflection line is labelled REFR.

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Physical Oceanography on *Eltanin* Cruises 32-37

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The Lamont-Doherty Geological Observatory conducted the physical-oceanography program aboard USNS *Eltanin* continuously from Cruise 32 to 37. Cruise 37 was devoted entirely to this program (see *Antarctic Journal* vol. IV, no. 4, p. 162–163). The table summarizes the data collected.

Water samples, obtained from Nansen-bottle casts and Niskin bottles surrounding the STD sensors (Gerard *and* Amos, 1968), are analyzed for salinity, oxygen (Carpenter modification of Winkler method), and micronutrients–nitrate, phosphate, and silicate (Auto-Analyzer). The temperature and depth of water samples are determined by the standard reversing thermometer. The STD sensors transmit information via sea cable to the ship, where it is recorded in analog and digital form on magnetic tape for analysis at Lamont-Doherty. Since the ship drifts during the lowering and raising of the STD sensors, and the small-scale temperature and salinity structure differs in the two traces, a separate station number is given to each descent and ascent.

The information from the Nansen-bottle casts and STD (with the calibration data of the SAMS) is fully processed at Lamont-Doherty. The data from Cruises 32–36 will appear in the 1968 report (previous reports are listed in references under Jacobs), to be distributed in late 1969. Cruise 37 data (with those of 39 and 41) will appear in the next data report.

The bottom photographs,[1] bottom-current measurements, and nepheloid measurements of the water column are accomplished by one lowering of a tripod apparatus developed at Lamont-Doherty by Drs. Ewing and Thorndike. The current-meter and nephelometer data are processed soon after completion of the cruise. Analysis of the current-meter data and correlation with evidence of currents in the bottom photographs is being conducted and the results will be published. The relation of the nepheloid data to the STD data and the form and position of the nepheloid layer in antarctic waters is also under investigation. During Cruise 35, close-up photos[1] were obtained from an elevation of 12 inches above the sea floor in addition to the regular bottom photographs.

Analysis of the hydrographic data is proceeding along various lines. Cruise 32 data, which are mostly from the Ross Sea area, combined with Cruise 27 and earlier data from that area, form the basis for a study of the oceanography of the Ross Sea with special emphasis on the sea as a bottom-water producer and the interaction of the Ross Ice Shelf with the Ross Sea waters. Evidence has been found of freezing of sea water to the bottom of the ice shelf; the resultant water, which contributes to the dense Ross Sea shelf water (salinities above 34.75°/oo), finally escapes into the deep ocean. The ice shelf also appears to be related to numerous thin filaments of cold water in the Ross Sea. A Ross Sea study cannot be fully completed until the water under the ice shelf can be investigated.

During Cruise 37, dense bottom water flowing from the northwest Ross Sea was traced as a bottom salinity maximum in the deep ocean region north of Adélie Coast. It is expected that the Ross Sea bottom water flows between the Balleny Islands and Antarctica. The Ross Sea-originated bottom water is deflected northward at 140°E. by newly formed bottom water on the continental shelf of Adélie Coast. This bottom water has lower salinities than the Ross Sea bottom water and its oxygen saturation is over 90 percent.

The microstructure of the Ross Sea STD data is also being analyzed. The power spectra of the temperature and salinity microstructures (wave numbers from 10 to 500 cycles/km) are found by averaging the spectra from individual stations. The results of this study are most interesting and will be published in the near future.

The *Eltanin* bathythermograph data consist of mechanical BT and expendable BT (XBT) information. The BT data extend to 275 m, while the XBT data

[1] Available from the Smithsonian Oceanographic Sorting Center.

Number of stations taken during *Eltanin* Cruises 32-37

Cruise	Nansen casts	STD[3]	BT	XBT	Bottom photographs[5]	Bottom current	Nephelometer	Other measurements
32	0[1]	115	334	13	32	32	29	Pack-ice observations
33	20	6	112	119	21	22	22	Surface C^{14}
34	28	0	228	43	22	22	22	
35	21	10	65	133	24	20	23	Radium
36	11	66	196	129	32	1	1	
37	10[2]	154[4]	0	144	32	24	32	Radium, uranium, core-water P_{CO_2}, radon

[1] Ten Nansen bottles were attached to the STD cable.
[2] Ten "mini-casts" were made in addition to the ten full Nansen casts. These "mini-casts" consist of 4-6 Nansen bottles attached to the STD cable.
[3] Separate numbers are given to the up and down STD trace. Occasionally an uptrace did not work, hence an odd number of stations.
[4] Forty-six of these consisted of repeated STD stations at one location (65°55'S. 139°E.) for a period of 24 hours.
[5] Numerous photographs are taken at each station.

extend to nearly 800 m. The BT data were used in a study of the polar front zone (Gordon, in press). A double polar-front zone is found to exist from the Macquarie Ridge system eastward to approximately 110°W. The transition from Antarctic to Subantarctic Surface Water and the production of Antarctic Intermediate Water is complicated in this polar front zone.

The meridional transport of water masses has been estimated in a study by Gordon (in press). The southward transport of circumpolar deep water averages 77 $\times$ 10^6 m^3/sec, of which approximately one-half becomes Antarctic Surface Water and the other half becomes Antarctic Bottom Water. The alteration of deep water to bottom water is accomplished by interaction of the sea water with ice formation, followed by entrainment of more deep water by sinking altered water. The significant ice formation may involve either or both the formation of sea ice at the surface or ice formation at depths greater than 100 m below the ice shelves.[2] It is possible that a third method of bottom-water production occurs due to the intense evaporation resulting from the action of the katabatic winds.

[2] It is possible that melting of the shelf ice may also contribute to bottom-water formation. A study discussing this process is in preparation by S. S. Jacobs and others.

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Radiocarbon From Nuclear Testing and Air-Sea Exchange of CO_2

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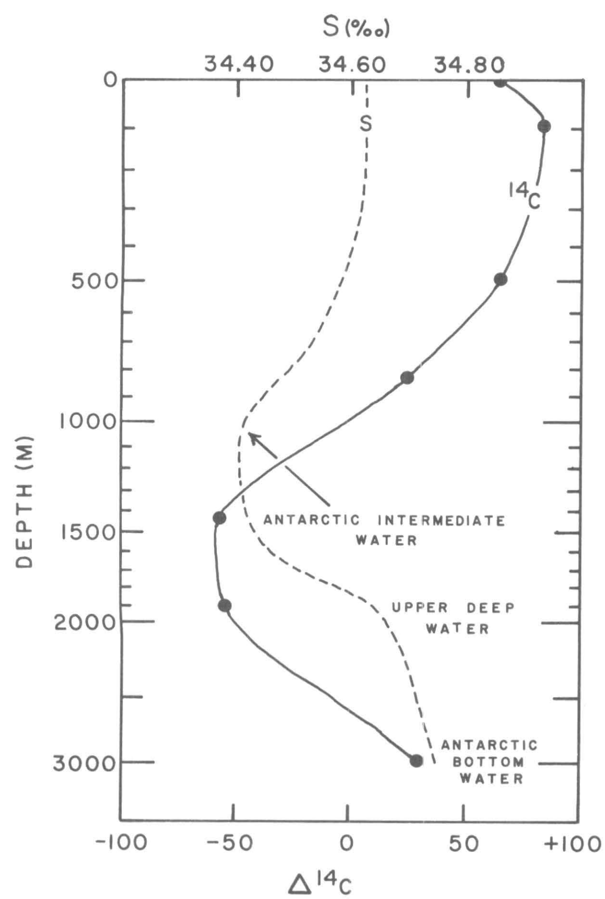
Atmospheric testing of nuclear weapons, particularly the 1961–1962 tests by the U.S.A. and the U.S.S.R., has introduced significant amounts of C^{14} into the atmosphere. Much of this C^{14} was injected into the stratosphere at high northern latitudes. As this "spike" mixed into the troposphere, C^{14}-levels in the Northern Hemisphere troposphere rose until, in the late summer of 1963, levels as high as 110 percent above pre-atomic era values were reached. C^{14}-levels in the Southern Hemisphere troposphere lagged somewhat behind, owing to the slow mixing and large volume of the troposphere in the tropics, but by mid-

1966, the entire troposphere became fairly homogeneous in C^{14} content, the level at that time being about 65 percent above pre-bomb levels.

Transfer of this C^{14} to the sea is causing the level of C^{14} in the troposphere to decline slowly, while the near-surface levels of the sea become enriched in this tracer. The rate of air-sea exchange of CO_2 is expected to be proportional to the square of the wind speed over the sea surface (Young *and* Fairhall, 1968). The large ocean areas and high wind speeds at southern latitudes mean that the bulk of the bomb-released C^{14} will probably be taken up by the oceans. We are studying this uptake by a total-CO_2 sampling program aboard USNS *Eltanin.* Sixty-liter samples of water are being collected (Young *et al.,* 1969) from various depths to 4,000 m at a number of locations south of Australia. Carbon dioxide is stripped from the water aboard ship and absorbed in molecular sieve which is later returned to our laboratory for C^{14} assay.

The accompanying figure shows some of the first data obtained. The limited data that are available on



Salinity and C^{14} profiles for *Eltanin* station no. 35, Cruise 36, at 49°45′S. 155°E., taken on November 25, 1968. The origins of the various water masses are indicated.

C^{14} levels in the southern oceans from the time that they were relatively uncontaminated by C^{14} from nuclear tests (Rafter, 1968), indicate that Δ C^{14}, the isotope-corrected deviation from the pre-atomic concentration of the terrestrial biosphere, was as low as –269. On this scale, the pre-atomic levels of most of the surface ocean is generally taken to be –50. In comparison with these numbers, the data in the figure show that significant amounts of bomb-released C^{14} have been taken up by the ocean at high southern latitudes. Although the data are as yet rather meager, the bomb-released C^{14} should serve as a useful tracer for determining the rate of air-sea exchange of CO_2 and for tracing the advection and mixing of the various ocean-water masses. For example, the Upper Deep Water, with a Δ C^{14} value of –60, corresponds to a water mass originating in the North Atlantic before the atomic era. The higher concentration of C^{14} in the water masses above and below show that these have a fairly recent origin at the surface.

The National Science Foundation has provided logistic support for this project, which is supported by the Atomic Energy Commission under contract AT(45–1)–2091. The samples were collected and processed by Dr. Burton T. Ostenson, whose assistance is greatly appreciated.

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Rn^{222} in Antarctic Near-Surface Waters

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The Lamont-Doherty Geological Observatory geochemistry program on Cruise 37 of USNS *Eltanin* included a study of the distribution of Radon-222 (Rn^{222}) in near-surface waters.

Radium-226 (Ra^{226}) in the ocean decays into Rn^{222}, which then partly escapes to the atmosphere, resulting in a deficiency in Rn^{222} in near-surface waters. Hence, by measuring both Rn^{222} on board and Ra^{226} later on in the laboratory, one can determine the Rn^{222} deficiency. As this deficiency in turn depends on the rate of near-surface vertical mixing and the rate of gas exchange between the water and the atmosphere, these measurements provide a perfect tool for determining those rates of mixing and exchange.

The shipboard operations included sampling of the water with 30-l Niskin bottles at the surface and at depths of 50, 100, 200 and 400 m. The Rn^{222} was then extracted and counted in an alpha scintillation counter.

As the Ra^{226} measurements have not yet been made, only preliminary conclusions can be drawn here. All 18 profiles measured show an increase in Rn^{222} with depth. The surface samples vary from 33 to 76 percent of the deeper values, the average being 60 percent. A general increase in Rn^{222} in near-surface waters with increasing latitude was discovered, probably reflecting an increase in Ra^{226} concentration related to upwelling of deep Pacific and Indian water in the Antarctic.

Radium and Inorganic Carbon in Antarctic Waters[1]

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The program summarized below involves simultaneous analyses of Ra^{226}, P_{CO_2}, ΣCO_2, and U isotopes in a number of profiles taken during *Eltanin* Cruises 35 to 37 along approximately a meridional trend (between 125°E. and 145°E.) extending from the antarctic continental shelf to the South Australian Basin.

Our study of the radium distribution in the antarctic region has the following objectives: (1) to establish the radium concentration level in this region of deep-water formation, the knowledge of which is essential to the understanding of the radium budget (hence the total flux from sediments) in the World Ocean; (2) to assess the role of biological transport of radium in this region of relatively high surface productivity; and (3) to collaborate with a program of shipboard Rn^{222} analyses carried out by a Lamont-Doherty group studying gas exchange across the air-sea interface in the Antarctic.

Our measurements show that the Antarctic Convergence (located around 52°S.–55°S. in the area studied) forms a remarkable boundary for the distribution of radium. South of the Convergence, the radium profiles are uniform, concentrations near the surface being close to 8×10^{-14} g/l and those of the deep waters 10×10^{-14} g/l. North of the boundary, surface concentrations drop to about 4×10^{-14} g/l, whereas bottom values remain near 10×10^{-14} g/l, the transition being at a depth of 1,000 m or more. The characteristic changes are shown in Fig. 1. The data have several implications: (1) The advection effect on the distribution of radium is strongly emphasized in this part of the ocean; (2) The sharp contrast in the surface radium concentrations across the Antarctic Convergence and the equality of surface concentrations (*i.e.*, $\sim 4 \times 10^{-14}$ g/l) north of it with those of the Atlantic and Pacific Oceans (Broecker *et al.*, 1967) may well indicate that surface

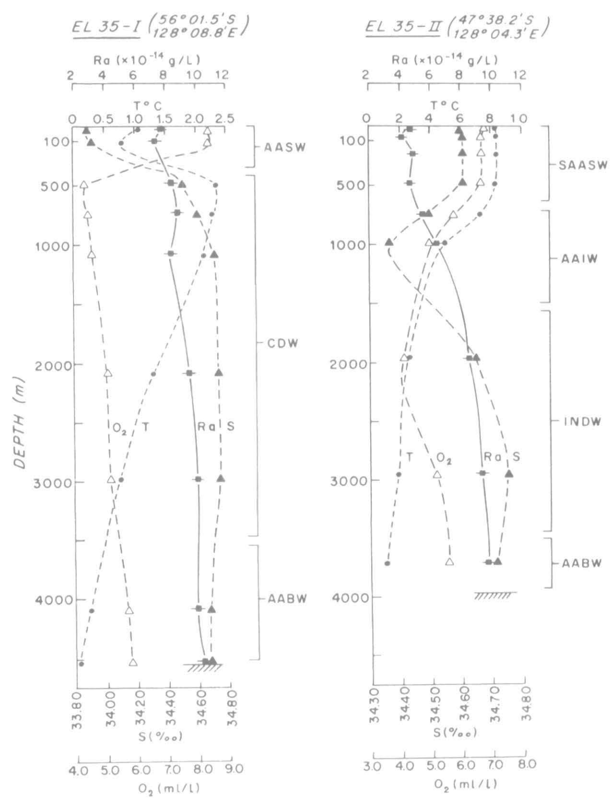

Figure 1. Radium distribution in two profiles taken from either side of the Antarctic Convergence. AASW = Antarctic Surface Water, SAASW = Subantarctic Surface Water, AAIW = Antarctic Intermediate Water, CDW = Circumpolar Deep Water, INDW = Indian Ocean Deep Water, AABW = Antarctic Bottom Water.

[1] Research supported by NSF grants GA-4239 and GA-13895.
[2] Now at the Department of Geological Sciences, University of Southern California.

waters of the oceans intermix with each other more often than they intermix with the deep water masses (the antarctic circumpolar currents do not facilitate the surface-deep water exchange); (3) The Antarctic Intermediate Water in this region has a radium content of 6×10^{-14} g/l, indicating its formation through sinking and mixing of the Antarctic Surface Water mainly with the Subantarctic Surface Water rather than with the Deep Water (such relationship is also borne out by the T-S data); (4) A resemblance between the radium profiles and those of PO_4–P and NO_3+NO_2–N taken at the same locations is noted, hence a biologically controlled process for the radium distribution cannot be dismissed.

There appears to be no significant difference in the radium distribution across the Subtropical Convergence. This is consistent with the observation of Deacon (1937, p. 61) that a sharp convergence between the subantarctic and subtropical water is absent south of Australia owing to smallness of the northward and southward components of the two currents.

As illustrated in Fig. 2, the P_{CO_2} variations are remarkably well mirrored by those of the dissolved oxygen, and are in a more sensitive way indicative of the oxidation of organic matter in the water column. Also, surface P_{CO_2} values increase toward the south polar region. This observation, coupled with the rather sharp decrease toward the surface in the vertical profiles taken from the circumpolar ring, strongly suggests that, as a result of deep-water upwelling and intense vertical mixing, a considerable amount of CO_2 escapes to the atmosphere in the Antarctic. Measurements of ΣCO_2, currently in progress, are expected to yield valuable information on the degree of undersaturation of $CaCO_3$ in the often-quoted "corrosive" Antarctic Bottom Water, as well as on the possible downward transport of radium by biological agents.

To date, 20 analyses give a uranium concentration range of between 2.98 and 3.32 μg/l. When normalized to salinity, virtually no variations have been detected within the experimental error range of $\pm$ 2 percent. The U^{234}/U^{238} activity ratios are 1.14 ± 0.02. These results in no way differ from our measurements in other parts of the ocean. The uranium-series radioactive disequilibrium relationships in the antarctic waters are, in terms of activity ratios, $U^{234}/U^{238} = 1.14$, $Ra^{226}/U^{238} < 0.1$, $Ra^{226}/Th^{230} > 100$.

In addition to the research outlined above, work is under way or planned for barium measurements and for interstitial water chemistry of sedimentary cores.

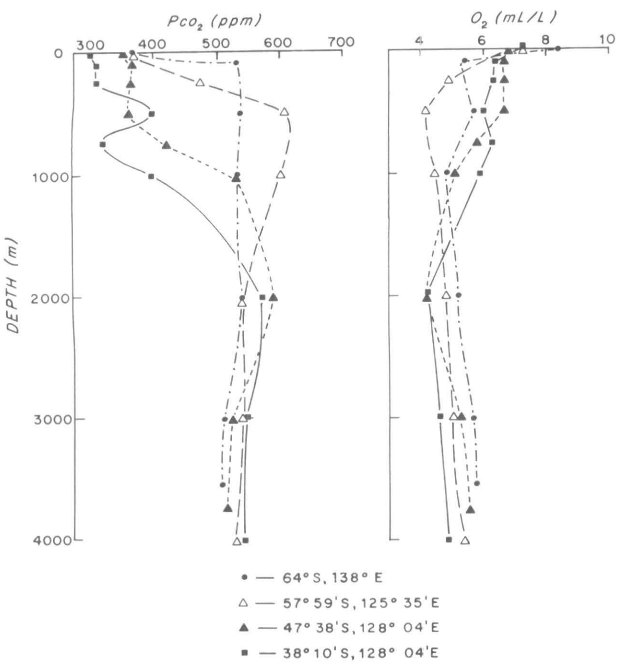

Figure 2. P_{CO_2} **and dissolved oxygen data for four profiles along an appropriate meridional direction. Variations in a remarkably mirrored fashion are shown by the two parameters.**

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Ra^{228} in High-Latitude Southern Hemisphere Waters

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Preliminary data indicate that there is a sharp drop-off in the Ra^{228}/Ra^{226} ratio of surface Indian Ocean waters as one approaches Antarctica. A probable explanation for this decrease is that the radium introduced in the more northerly regions has been in contact with continental materials more recently. Hence, the isotope Ra^{228}, with its 6.7-year half-life, has had only a relatively short time to decay. As one goes farther south, a larger component of the surface water is derived from deep water. The Ra^{228} of the deep water, which has been removed from continental material for a longer period of time, has decayed almost completely.

A total of 21 surface sea-water samples were collected on Cruises 35 and 37 of *Eltanin* along four north-south traverses. When these analyses are completed (in about a year), insight may be gained into the rates at which deep water mixes with surface water in the Australia–New Zealand area of the antarctic seas.

Metabolism of Total Water Columns

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One of the central problems of biological oceanography is the measurement of energy flux through the system of living organisms. Early efforts at such measurements emphasized the higher levels of the food web and postulated a rather direct transfer of energy from phytoplankton to fishes in two or three steps.

For several years, our group at the University of Georgia has been concerned with this problem. We have found that microorganisms account for most of the respiration in the ocean, at least in low latitudes. Cruise 38 of USNS *Eltanin* was a special-purpose one, in which we attempted to estimate total respiration in several complete water columns across the southern oceans, with emphasis on microbial metabolism. We included studies of benthos, net plankton, and the smaller nekton as well.

Abundance and respiration of microorganisms was measured following concentration of 200-liter water samples to a final volume of a few milliliters. Aliquots of the concentrate were placed in 6-ml respirometers at simulated *in situ* temperature and pressure for rapid measurements of respiration. ATP extracts were made from another aliquot as a parameter of microbial biomass. A third aliquot was used for microscopy and other microbiological studies. A specially stabilized microscope, equipped with phase and fluorescence, was used at oil-immersion magnification to examine fresh concentrates of living microorganisms and to photograph them.

Net plankton was sampled with a Clarke-Bumpus sampler, and respiration of the net plankton catches was measured at *in situ* temperature. Nekton was sampled with an Isaacs-Kidd midwater trawl. Respiration of individual specimens from the IKMWT was measured immediately after each tow. All samples were retained for both identification and biomass estimation.

Biomass and respiration of benthic organisms were estimated by a combined program of grab and camera. The smaller bethos were sampled quantitatively with multiple grabs at each location. The camera aided in the identification and estimation of mass of the larger benthos and the meiofauna. Grab and camera stations were precisely overlapped with the aid of satellite navigation.

Some other programs on Cruise 38 also contributed to the analysis of metabolic rate of complete water columns. These included the work of Sayed Z. El-Sayed of Texas A&M University and of H. R. Jitts of the Australian C.S.I.R.O., Division of Fisheries and Oceanography. Both programs were concerned with photosynthesis. El-Sayed's group also measured dissolved nutrients.

From four to nine days were spent at each of six locations between 40° and 64°S. Even so, our estimation of total respiration will be crude and preliminary. However, only by making this attempt can we hope to discover the problems to be overcome before a truly definitive measure of total metabolism of the ocean becomes possible.

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Analysis of Variance of Benthic Parameters

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A benthic grab sampling program was undertaken on *Eltanin* Cruise 38 with the primary objective of evaluating variations in the abundance of different taxa of invertebrates, the abundance of ferromanganese nodules, and various sediment characteristics within and between individual samples at different stations. A secondary objective is to obtain estimates of the abundance of infaunal and epifaunal benthos exceeding 1 mm in size and to determine the amount of skeletal material contributed to deep-sea sediments by these organisms. If obtained, this information will result in a better understanding of the macrofossil community which might be expected to occur in deep-sea sediments preserved in the geologic column.

Eltanin remained on station for periods of up to 9 days during Cruise 38, providing ideal conditions for collecting the samples required to study variations in abyssal substrates. Multiple 0.6 m^2 grab samples were taken at three stations in abyssal depths, viz: 12 covering a total area of 7.01 m^2 at station 7 (64°11′S. 150°08′E.); 10 covering 5.84 m^2 at station 8 (61°50′S. 149°50′E.); and 20 covering 11.68 m^2 at station 11 (49°45′S. 152°30′E.).

Sediment subsamples were obtained from each successful grab. A split of all such subsamples was sent to the Smithsonian Oceanographic Sorting Center for study of the meiofauna, and Petrie dish subsamples were taken from each grab in order that benthic foraminiferal distribution might be examined.

It is expected that analysis of the samples collected will result in a better estimate of what sample size is required for quantitative work on animals of different sizes from abyssal depths (clearly, larger samples are necessary to estimate bivalve abundance than to estimate benthic foraminiferal abundance).

In addition to the grab samples, a number of trawls were attempted in order to relate the ratios of different epifaunal organisms in the trawls to the more quantitative grab samples. Unfortunately, few large benthic forms were captured and it is believed that these were not entirely representative of the fauna.

A single trawl at station 8 yielded an interesting assemblage of ferromanganese nodules. The nucleating centers for many of these nodules were siliceous sponge skeletons. A complete series of sponge skeletons was collected, ranging from skeletons on which no ferromanganese material had been precipitated to some that were so heavily coated as to be barely recognizable. Since it seems unlikely that structures as delicate as siliceous sponge skeletons would remain intact on the sea floor for any substantial period of time, the occurrence of this assemblage provides supporting evidence for the belief of many geologists that ferromanganese nodules may be formed by rapid periodic precipitation.

Ontogenic Studies of Antarctic Pelagic Ostracoda

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To date, 977 *Eltanin* plankton samples containing Ostracoda from the Pacific sector of the Antarctic and the Scotia Sea (Fig. 1) have been examined to determine the seasonal quantitative distribution of the Ostracoda at four levels (0–100 m, 100–250 m, and 500–1,000 m). In addition, ontogeny studies have been carried out on the relatively unknown juveniles of *Conchoecia serrulata,* a subantarctic near-surface species found from 39°S. to 67°S. in the Pacific (*Eltanin* data) and somewhat further north in the Atlantic (Müller, 1908; Skogsberg, 1920). *C. serrulata* extends only about four latitude degrees south of the Antarctic Convergence in the Pacific. Several stations containing abundant specimens of *C. serrulata* were selected from the *Eltanin* zooplankton samples to represent the species' widespread distribution in the southern South Pacific.

Like all crustaceans, pelagic Ostracoda grow by molting their exoskeleton, expanding, and laying down a new exoskeleton. The intermittent stages between molts are called instars. Juvenile Ostracoda of the genus *Conchoecia* pass through six instars before becoming adults in the seventh (Claus, 1894; Kesling, 1961). There is no evidence that *Conchoecia* continues to molt after reaching sexual maturity. The 6 oldest instars of *C. serrulata* have been studied (instar one was not captured), and the carapaces of 1,310 specimens, including all the 6 available instars, were measured.

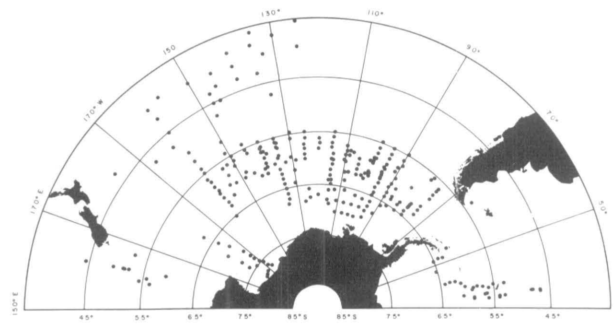

Figure 1. Map of *Eltanin* plankton stations containing Ostracoda that have been examined.

Important morphological observations from juvenile *C. serrulata* include the fact that with each molt, one additional claw on each furca is added: instar two has three claws per furca, instar three has four, etc., and the adult has eight claws per furca. Also, the instar two antennula bears two setae and adds one seta with each molt, until a total of five setae are present in instar five. Succeeding instars also bear five antennular setae.

Carapace lengths differ significantly between instars (see Fig. 2 and table), indicating that such measurements are a useful tool for identifying the instars of *C. serrulata.*

Morphological, descriptive data for *C. magna* and *C. spinirostris* (Claus, 1894) and *C. elegans* (Skogsberg, 1920) corroborate the *C. serrulata* data, and

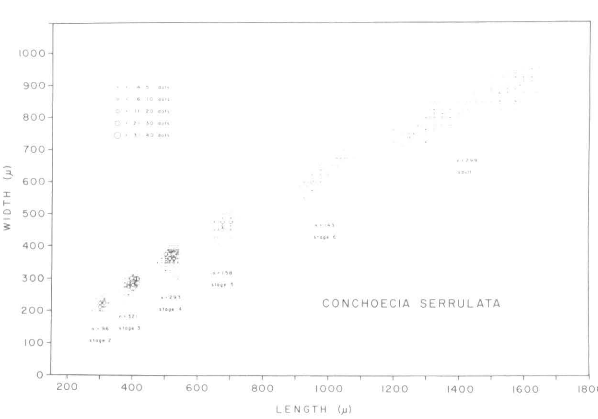

Figure 2. Carapace size relationship of *Conchoecia serrulata* instars.

Mean length and width of *Conchoecia serrulata* instars

Instar	1	2	3	4	5	6	7
Length (μ)		307.8	400.6	517.6	681.1	777.3	1,405.8
Width (μ)		202.9	286.9	366.6	465.8	635.9	825.9

indicate that the morphological features of the furcae and antennulae are consistent throughout the genus *Conchoecia*. This fact allows identification of instars even if the species is unknown. It is not known how useful a tool for instar identification the carapace length will be in species other than *C. serrulata*, because carapace lengths may overlap in instars of other species (Fowler, 1909).

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Polar Faunal Trends Exhibited by Antarctic Isopod Crustacea

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The past four years of research on antarctic Isopoda have yielded significant new data on the general features of polar and deep-sea crustacean biology, and several species and genera new to science have been discovered. Collectively, the results reveal the existence of certain salient faunal features which appear to

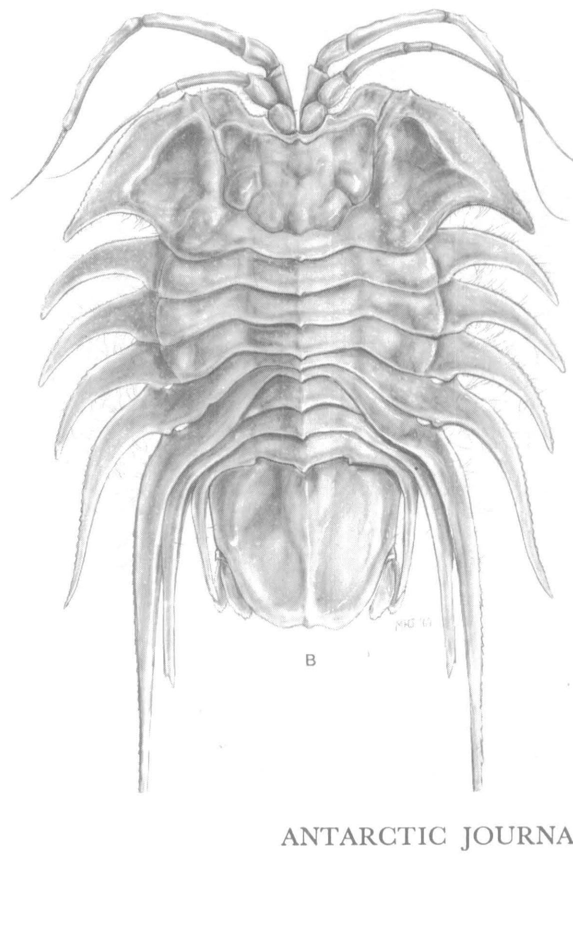

Figure 1. Dorsal view of two antarctic species of the isopod genus *Serolis*. A, Shallow-water species with large eyes; B, Deep-sea species lacking eyes. In appearance, this curiously looking, flat-bodied animal misleads the casual observer as a fossil trilobite. *Serolis* constitutes a classical antarctic faunal component with more than 90 percent of the 62 known species inhabiting the cold antarctic waters. Only two species are hitherto found to occur north of the Equator.

operate uniquely at high latitudes. One striking pattern is a tendency of shallow-water genera to penetrate deep into the abyss, and a simultaneous tendency of the abyssal genera to emerge into shallow water. These two phenomena—polar submergence and polar emergence—remain clearly distinguishable from the standpoint of taxonomic perception of the genera involved. Contrary to the situation in tropical seas, the eye-bearing, shallow genera such as *Munna, Gnathia, Antarcturus, Cirolana, Serolis,* etc. descend along the antarctic continental slope into the abyss. Most often, the deep-sea species of these genera lack eyes or bear degenerate eyes. A scanning-microscope examination of *Serolis* eye structure has provided crucial data on the minute details of retinula and lens of antarctic species from different depths (mss. in preparation). The accompanying figure illustrates a shallow-water species with very prominent eyes and a deep-sea blind species (Fig. 1A and B). This predominantly antarctic genus, *Serolis,* was subject to a monographic study (Moreira *and* Menzies, submitted to the *Antarctic Research Series*).

Polar emergence is exhibited by several blind Asellote isopod genera such as *Macrostylis, Haploniscus, Desmosoma, Eurycope, Eugerda, Munnopsis, Ilyarachna,* and *Storthyngura,* all exclusively deep-sea genera in middle and lower latitudes that emerge to moderate depths both in the Antarctic and in the high Arctic. A significant correlation is evident in the coincidence between the upper limits of these emerging abyssal genera in high latitudes and the start of the Abyssal Faunal Province, identified by a new method: the abyssal boundary determined on the basis of rate of faunal change showed tropical submergence or, in other words, polar emergence. The aspects of vertical faunal zonation in the Antarctic in comparison with other parts of the World Ocean are elucidated in a manuscript now in progress. A generic catalogue illustrating all isopod genera known within the Antarctic Convergence is being prepared with maps of distribution of antarctic species.

Data from the Scotia Sea offer evidence of a seasonal breeding cycle in the deep sea (George *and* Menzies, 1967). Further investigations of the breeding behavior of abyssal isopods provide new information confirming this cyclic reproductive activity in the physically uniform deep sea. The peak breeding period for abyssal isopods in both antarctic and North Atlantic deep-sea regions seems to be limited to four months of the year—July-November (George *and* Menzies, 1968).

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Antarctic and Subantarctic Brachiopods

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During the past year, I have been engaged in the concluding phases of my research on the brachiopods of the far South. My material consists of undescribed specimens from many earlier expeditions; however, the majority of the specimens were taken on cruises of USNS *Eltanin.* Some of my findings are summarized below.

At least 21 genera and 38 species are present in the material; two new genera are recognized. Ten new species are recognized in the genera *Compsothyris, Hispanirhynchia*(?), *Liothyrella, Eucalathis, Amphithyris, Dallina, Fallax,* and *Magellania*(?). Six other specimens which may represent new species have been described in *Compsothyris, Liothyrella,* and *Dyscolia.* Analysis of character variation in large samples has led to the placement of one genus and nine species in synonymy. This is the first time that *Amphithyris, Dallina, Fallax,* and *Dyscolia* have been reported from the far South. New subspecies have been described in *Neorhynchia, Liothyrella,* and *Gyrothyris.*

The majority of the Recent species and genera within the family Terebratellidae have been restudied. It has been concluded that the admittedly polyphyletic, but practical, genera *Terebratella* and *Magellania* should be retained in the broad sense. I also favor retaining the genera *Gyrothyris* and *Neothyris.*

The majority of antarctic brachiopod species show reduction in punctae density, shell thickness and spiculation, as well as coarsening of shell mosaic as compared with related taxa from farther north. These same changes are seen within the wide-ranging species *Liothyrella uva.* Similar trends as well as reduction in shell porosity are observed in deep-water species at various latitudes. These changes are believed to reflect the greater difficulty of maintaining and depositing calcite skeletons at locations with greater $CaCO_3$ solubility. The changes in punctae density lend support to Campbell's (1965) suggestion that Australian Permian terebratuline brachiopods with low punctae densities inhabited cool water.

Multivariate analyses suggest negative associations of foramen diameter, hinge-plate width, and beak height of the terebratellid shell with depth. I believe these associations reflect adaptations for stability in the varying current velocities at different depths.

Dissections of *Macandrevia vanhoffeni* reveal muscle arrangements quite different from those known in other genera in the same family. It is suggested that this genus be placed in a different family.

Within the Ross Sea, the greatest diversity of brachiopods occurs on the seaward edge of the shelf. This diversity is believed due to an ecotone effect caused by the junction of two different water masses at this location. Significant associations (using the chi-square test) between different brachiopod species occur in the Ross Sea only between *Crania lecointei—Compsothyris racovitzae* and *Magellania fragilis—Macandrevia vanhoffeni.* I believe these species occur together commonly only because of quite different feeding behavior.

My studies have clearly shown that brachiopods are a significant and abundant element of the marine benthos in the southern oceans. The large number of specimens available in this study has permitted close examination of species structure and its relationship to systematics in various brachiopod species.

Reference

Campbell, K. S. W. 1965. Australian Permian terebratuloids. *Bureau of Mineral Resources. Geology and Geophysics Bulletin* no. 68. 113 p.

General Physiology of the Echinoderm Body Wall with Special Reference to Asteroids and Echinoids

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As earlier observations had suggested that the body wall of the antarctic sea star *Perknaster fuscus antarcticus* had much more protein than that of the temperate species *Pisaster ochraceus* and *Patiria miniata,* a study of the biochemistry of the body walls of antarctic and temperate-zone sea stars was initiated to determine whether this high protein level was characteristic of antarctic species or whether it was a peculiarity of only one of the species examined by chance. Conversely, it was desirable to sample other temperate sea stars to determine whether some might not have a high protein level in the body wall comparable to that in *Perknaster.* It was of interest also to determine the oxygen consumption rate for both temperate and antarctic sea stars as a measure of the metabolic acitivity of the body wall.

These objectives have been fulfilled in part. It was found that the high protein level (38.3% of the dry weight) of *Perknaster* was unusual among antarctic sea stars: in *Diplasterias brucei* it was found to be 29.7%; in *Cuenotaster involutus,* 31.1%; and in *Odontaster validus,* 21.7%. In the body wall of all of these sea stars, the lipid levels were found to be about 5% and the total carbohydrate about 1%. In the temperate sea stars, the protein level for the body wall varied from 9.7% of the dry weight in *Astropecten californicus* to 34.2% in *Dermasterias imbricata* and *Pycnopodia helianthoides.* In most of the other temperate sea stars, the values were closer to those in *Astropecten* than to *Dermasterias—e.g.,* in *Pisaster ochraceus,* the common ochre star, 14.1%; *Pisaster giganteus,* 18.6%; *Pisaster brevispinus,* 13.5%; and *Patiria miniata,* the common sea bat, 12.8%. Only in *Orthasterias kohleri* do the values approximate those in *Dermasterias* and *Pycnopodia* (22.2%). In the body wall of most of these species, the lipid level per unit dry weight was much lower than in the antarctic stars—around 2%, reaching 4.3% in *Pycnopodia.* The carbohydrate level (in this case, glycogen-like material) was always less than 1%, and usually about half that amount.

Measurements of the oxygen consumption of these antarctic sea stars were planned for *Eltanin* Cruise 38, but the ship never reached the area of the continental shelf where the species are found, and none were caught.

The oxygen consumption of the body wall of the following six temperate sea stars was determined with Warburg respirometry: *Pisaster ochraceus, Patiria miniata, Pycnopodia helianthoides, Dermasterias imbricata, Orthasterias kohleri,* and *Astropecten californicus.* It ranged from 15 to 35 μl/gram wet weight/hour, the rate for *Pycnopodia* being the highest and that for *Patiria* and *Astropecten* the lowest. However, on the basis of protein level, *Astropecten* has the highest rate while *Dermasterias* has the lowest.

The possible reason for the low oxygen consumption in the high-protein body wall of *Dermasterias* may be a result of much inert protein, possibly connective tissue. The construction of the body wall in *Dermasterias* was therefore studied histologically and compared with that of *Patiria.* Preliminary examination of the material indicates that *Dermasterias* has much more connective tissue in the body wall than *Patiria.*

Oxygen consumption compared for *Patiria* (low protein) and *Dermasterias* (high protein) on the basis of DNA level of the body wall proved to be quite similar, much more so than on the basis of protein level. If DNA is taken to measure the cell content of the tissue, this finding suggests that the oxygen consumption of the body wall is related to the number of cells present, not the protein, much of which is extracellular in the high-protein type of body wall.

It is conjectured that, on the basis of protein level, the body wall of a sea star like *Perknaster* with high protein level would probably have a lower oxygen consumption than a star like *Odontaster* with considerably lower protein level, but that on the basis of DNA level, they would be similar.

In conclusion, it appears that the antarctic sea stars are variable with respect to protein level in the body wall, but so are temperate forms. The antarctic species appear to store slightly more nutrient than the temperate stars. Sea stars with much connective tissue in the body wall have a lower oxygen consumption per unit protein level than do those with little connective tissue. The oxygen consumption of the body wall is similar in sea stars with and without much connective tissue in the wall when measured on the basis of the DNA levels in the body wall.

Microbiology of Sea Ice

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During 1968, the analysis of field data and materials collected at McMurdo Sound during 1967 and in the Weddell Sea during IWSOE–1968 was completed. The raw data on hydrology, intensity and spectral composition of submarine radiation, and parameters relating to the microalgal flora of the sea ice were assembled in a technical report issued by the Institute of Marine Sciences (Bunt *and* Lee, 1969). A manuscript concerned largely with the reliability of C^{14}-uptake measurements in the laboratory as a means of predicting ultimate yields of cell carbon in the sea ice has been submitted for publication (Bunt *and* Lee, submitted). The account also provides the first documentation of the development of the ice microflora onwards from midwinter.

In the course of the field programs, algal and protozoan enrichment cultures were established, and a great deal of effort since then has been expended on the separation of pure cultures for more detailed study. The success of this endeavor may be measured by the fact that we now have in unialgal and, in some cases, axenic conditions, several green flagellates, two chrysomonads, one cryptomonad, and a number of diatoms including one centric form. Some of this material has been made available for studies of taxonomy and ultrastructure to Dr. R. O. Fournier of Dalhousie University. In addition, an elucidation of gross food needs has added to the collection one ameba, some colorless microflagellates, and several ciliates. One of these organisms has been used for comparative studies of temperature requirements for growth, demonstrating marked psychrophily and inability of the organisms to survive at temperatures above 10°C. A detailed account, supported by a companion document dealing with the taxonomy of the ciliates including one new genus recognized and described by Dr. T. Fenchel, has been prepared for publication. Preserved samples from the ice have been sent to Dr. G. Hasle at Texas A&M University for taxonomic study.

Contribution No. 1095, Institute of Marine and Atmospheric Sciences, University of Miami.

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Bunt, J. S. *and* C. C. Lee. Seasonal primary production within antarctic sea ice. Submitted to the *Journal of Marine Research.*

Ecological Studies of Antarctic Marine Phytoplankton

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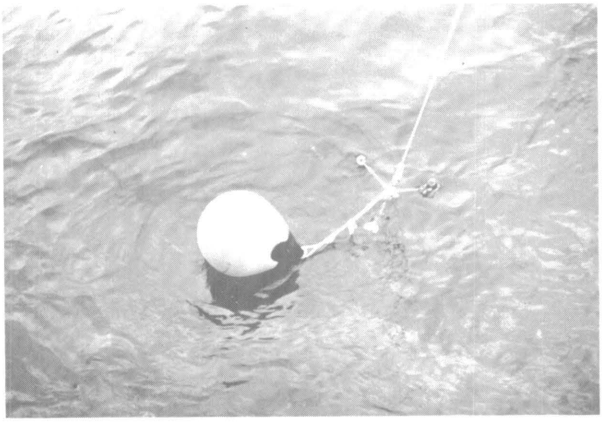
Folio 10 of the *Antarctic Map Folio Series*, published recently by the American Geographical Society, summarizes our present knowledge of marine plant life in antarctic and subantarctic waters. In this Folio, the author discusses the distribution and abundance of the phytoplankton standing crop (in terms of chlorophyll *a*) and primary productivity (in terms of C^{14} uptake), on the basis of collections made at different depths during 18 cruises in the Atlantic and Pacific sectors of the southern oceans. Seasonal and year-to-year variations in productivity parameters are also discussed, and data are presented on the concentrations of nutrient salts (phosphates, silicates, nitrates, and nitrites) and particulate and dissolved organic carbon. Contributions to the Folio by other authors include texts and plates showing the circumpolar distribution of selected species of diatoms (G. Hasle) and dinoflagellates (E. Balech). Ecology and distribution of benthic marine algae are discussed by M. Neushul and J. S. Zaneveld.

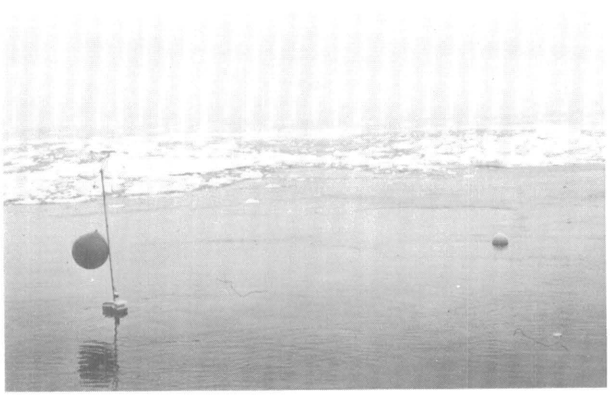
Since publication of Folio 10, additional data have been compiled on phytoplankton dynamics in the region south of Australia and New Zealand during *Eltanin* Cruises 35, 36, and 38. Of special interest during Cruise 38 was the success in measuring the photosynthetic activities of phytoplankton by means of *in situ* experiments (using C^{14} as a tracer) at all the stations occupied in the antarctic, subantarctic, and convergence regions (see photograph). These productivity experiments were conducted simultaneously with "simulated *in situ*" experiments using a deck incubator. Also of special significance on Cruise 38 were studies of the day-to-day variability in phytoplankton standing crop, primary production, dissolved



Above: Close-up photograph showing the lowering of light and dark bottles used in conducting *in situ* primary productivity experiments during *Eltanin* Cruise 38 (March—May, 1969).

Photos by George H. Weissberg

Below: Buoy used in conducting *in situ* primary productivity experiments during Cruise 38.



and particulate organic carbon, and nutrient salts during on-station periods lasting up to 7–9 days.

Analysis of the data collected on recent *Eltanin* cruises and during the 1968 International Weddell Sea Oceanographic Expedition aboard USCGC *Glacier* has resulted in the following manuscripts:

Phytoplankton Production of the South Pacific and the Pacific Sector of the Antarctic, by S. Z. El-Sayed. Presented at the Symposium on the South Pacific held at Scripps Institution of Oceanography in June 1968 (in press).

On the Productivity of the Southern Ocean, by S. Z. El-Sayed. Presented at the Symposium on Antarctic Biology held at Cambridge University in August 1968 (in press).

Dynamics of Trophic Relationships in the Southern Ocean, by S. Z. El-Sayed. Presented at the Antarctic Research Symposium at the AAAS Meeting in Dallas, Texas, December 1968 (submitted for publication).

Observations on Phytoplankton Bloom in the Weddell Sea, by S. Z. El-Sayed.

Studies of Antarctic and Subantarctic Phytoplankton (Pacific Sector), by R. Marumo.

Thalassiosira tumida *(Janisch) comb. nov., Antarctic Marine, Centric Diatom of Unusually Great Morphologic Variability,* by G. Hasle, B. R. Heimdal, and G. A. Fryxell.

Arctic Invertebrate Studies*

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During August 1968, we conducted invertebrate studies in the Labrador Sea and the Davis Strait as part of the arctic shakedown cruise of the National Science Foundation's new antarctic research vessel, *Hero*. We were assisted on the cruise by James A. Blake and Robert C. Bullock. Although the biological program was second in priority to the testing of the vessel in polar waters, we were able to make a total of 33 stations—5 benthic, and the remainder for plankton collections and hydrographic work. A variety of collecting gear and laboratory equipment was tested in an attempt to evaluate *Hero* as a research vessel.

Our first objective was to obtain specimens of adult and larval polychaetes and echinoderms for taxonomic studies and for determination of the reproductive condition or stage of development. This work was part of a continuing investigation of the reproductive biology of polychaetes and echinoderms in polar and cold-temperate seas. Our primary concern was with the differences in timing of reproductive events in widely distributed intraspecific populations. We are especially interested in species of polychaetes and echinoderms which occur both in the Davis Strait and farther north, and in the Gulf of Maine. The asteroids *Ctenodiscus crispatus* (Fig. 1), *Solaster papposus,* and *Solaster endeca* are examples of such echinoderms that were obtained during the cruise. Histological and other analyses of the resulting collections are under way.

Three benthic stations were occupied in the western Davis Strait in depths from 132 to 1,920 m. At two of these stations, successful hauls were made with a Beyer epibenthic sled (Holme, 1964) and with a "mouse-trap" sampler (Muus, 1964). The modified epibenthic sled consisted of a 0.5-m plankton net combined with a Clarke-Bumpus closing device mounted in a sled frame (Fig. 2). The instrument was towed along the bottom and collected a plankton sample from about 0.5 m above the bottom. The "mouse-trap" is a special device used to collect a 225 cm^2 sample of the top centimeter or two of substrate, where recently settled larvae are found (conventional grabs or cores cannot be used to sample this rather flocculent layer adequately). The successful use of these instruments during the *Hero* cruise demonstrated that delicate larvae can be obtained from or very near the bottom at depths of at least 1,900 m.

* Contribution No. 3 of the Ira C. Darling Center, University of Maine.

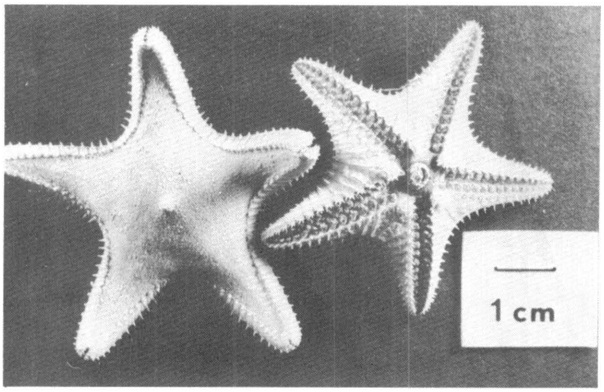

Figure 1. Abactinal (left) and actinal views of the mud star, *Ctenodiscus crispatus* (Retzius) from *Hero* Station 20. This is a common subtidal species from the Davis Strait to the Gulf of Maine. The reproductive biology of this sea star is currently being investigated.

The qualitative zooplankton collections will be used by Bernard J. McAlice to describe the latitudinal distribution of species in the surface waters of the Labrador Sea. Morphometric data for copepod species will be analyzed to see whether geographic variation exists. The population structure (age and sex) of the more abundant copepod species will be determined.

Twenty-four phytoplankton samples were obtained by utilizing the vessel's uncontaminated sea-water system at regular intervals between 49°N. and 67°N. These and samples from vertical tows will be analyzed to ascertain species and community distributions. It is hoped that such data can be correlated with the hydrographic data. Preliminary examination of zooplankton and phytoplankton collections has revealed a profound change in the species composition of the plankton between southern Labrador and the western Davis Strait.

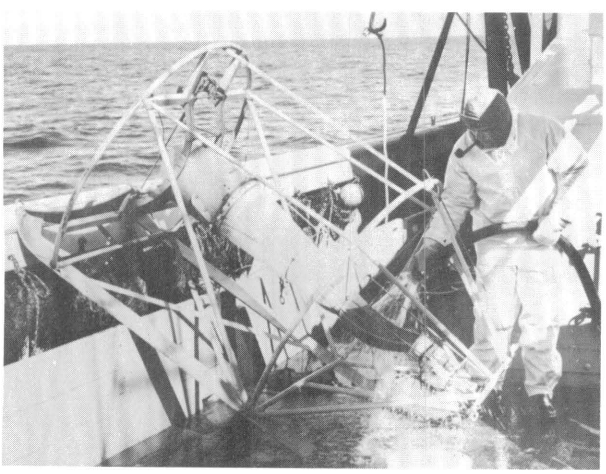

Figure 2. Modified Beyer epibenthic sled being hosed down after sampling plankton about 0.5 m above the bottom at 245 m depth east of Angijak Island (65°41'N. 62°05'W.).

Systematic or ecological reports on selected groups of invertebrates are in preparation by Blake and Dean (polychaetes), Bullock (mollusks and brachiopods), Dearborn (echinoderms), and McAlice (phytoplankton and zooplankton). Preliminary work has shown that a number of species of polychaetes and mollusks previously recorded only from west Greenland also occur off the coasts of Baffin Island and northern Labrador.

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Participation in Antarctic Expeditions

I. Eugene Wallen

Office of Oceanography and Limnology
Smithsonian Institution

Funds for field expenses from the National Science Foundation made it possible for four scientists from the Smithsonian Institution to work in the southern Chile–Antarctic Peninsula area during fiscal year 1969. This continuing program attempts to insure that all USARP cruises have someone on board to take biological samples and preserve them properly for shipment to the U.S.A. and further study.

Dr. John C. McCain, after joining the Smithsonian Oceanographic Sorting Center (SOSC) staff as Assistant Supervisor for Benthos on March 1, 1969, continued for a few days research and collections begun with Dr. Joel W. Hedgpeth of Oregon State University. Specimens collected by Dr. McCain near Palmer Station were processed at SOSC and distributed for study to scientists on the SOSC specialist lists.

Dr. H. A. Fehlmann and Messrs. Ernani Meñez and Victor Haley worked with a Bureau of Commercial Fisheries party on *Hero* for two months in March–May, 1969. The principal effort was midwater trawling, which yielded few organisms. A few benthic samples were taken and the SOSC personnel participated in fixing, preserving, packaging, and shipping this material. Samples were obtained from a total of 28 locations including 5 terrestrial, 1 stream, 4 shore, 10 pelagic, and 4 benthic stations, as well as 4 purchases of specimens from fishermen. In all, 69 gallons of collections were taken, consisting of lichens, bryophytes, angiosperms, algae, invertebrates, and fishes.

In addition to the collections for SOSC, duplicate material (19 samples) was collected during the *Hero* cruise for the National Institutes of Health (NIH). These samples, preserved in alcohol and shipped to NIH via the Smithsonian Institution, were expected to include at least 1 kg wet weight of each species of marine organism. They are to be analyzed for the kinds of individual chemicals present in each of the species, and a search will be made for possibly interesting marine-derived drugs.

Cooperative Systematic Studies in Antarctic Biology

I. Eugene Wallen

Office of Oceanography and Limnology
Smithsonian Institution

Since 1962, the NSF research vessel *Eltanin* has made 35 cruises into antarctic waters, generally using nets, trawls, and dredges to sample the biota. Additional collections have been taken by *Hero,* by Coast Guard and Navy vessels, and occasionally by vessels of oceanographic institutions. Collections, or parts of them, have also sometimes been made available to U.S. scientists from foreign-flag vessels.

An active NSF support program for U.S. investigators has resulted in significant research being accomplished on the biology of many antarctic plants and animals. However, an acute shortage existed of biologists with the training and time to do good systematics. An important accomplishment of NSF would be to develop a biological resource evaluation of the Antarctic; however, such an evaluation is dependent on knowledge of the identities, populations, and distributions of the antarctic biota. It appeared unlikely that many of the taxa would be identified and studied unless special attention were given to them. For this purpose, the Smithsonian Institution agreed with NSF to arrange for service contracts with specialists to study and provide publishable reports on antarctic specimens not under active study.

During the first 3 years of this specialist project, agreements have been reached with 12 scientists to produce 16 manuscripts on groups of organisms. Manuscripts have been forwarded to the *Antarctic Research Series* from Patricia Mather, Ryuzo Marumo, Robert Moreira, William A. Newman, Thomas E. Bowman, and George A. Schultz. Several other manuscripts have been examined and are being revised for presentation.

Publications have been completed or are under way on antarctic gorgonaceans, diatoms, ascidians (2 groups), benthic isopods, pelagic isopods, amphipods, holothurians, asteroideans (2 groups), barnacles (2 groups), copepods (2 groups), aplacophorans, and lichens.

Through the Smithsonian Oceanographic Sorting Center, the archives of the National Museum of Natural History and other museums, and the collections at several universities, there still exists a large series of unworked taxa of antarctic organisms. Additional specimens being accumulated by current antarctic expeditions are also available.

Substantial numbers of specimens in several groups not committed for study are available from the Smithsonian Oceanographic Sorting Center. Qualified scientists are encouraged to make requests for this material if it can be studied in sufficient depth to produce good monographic papers. The following groups are available in sizable numbers:

Actinaria	Mollusk eggs
Antipatharia	Mysida
Bryozoa	Porifera
Cladocera	Pyrosomidae
Copepoda	Radiolaria
Doleodidae	Rhynchocoela
Echinoderm larvae	Salpidae
Euphausiacea	Sessilia
Galatheidae	Turbellaria
Hydroida	Zoanthidea

A Handbook to the Birds of the Antarctic

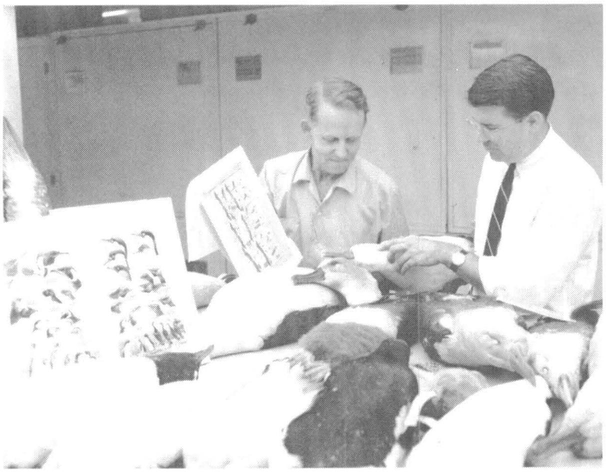
George E. Watson

National Museum of Natural History
Smithsonian Institution

At present there exists no comprehensive guide or handbook to the birds of the Antarctic. Research scientists and travelers, who are invading the Antarctic in increasing numbers, have to rely on an outdated field guide with poor illustrations, or several regional guides of which no one covers all species. To meet this need, the Smithsonian Institution has undertaken production of a manuscript for a handbook on antarctic birds to be illustrated in color. J. Phillip Angle and Peter C. Harper have been collaborators on the text.

The area covered includes the Antarctic Continent and Peninsula, all unequivocal antarctic islands south of the Convergence and 60°S., as well as Tristan da Cunha, Gough, Marion, Crozet, Amsterdam, St. Paul, Kerguelen, and Macquarie Islands. Species regularly occurring in the area are covered as well as vagrants, but the land birds of Tristan and Gough are omitted.

Information on each regular species consists of identification, flight and habits, voice and display, food, reproduction, molt, parasites, predation and mortality, habitat, and distribution. Only identification characters and distribution documented by literature citations are given for vagrant records. Refer-



Author and artist discuss plates for the handbook of antarctic birds.

ences are included for each antarctic bird family represented.

Research on distribution of the birds has resulted in preparation of maps for 51 species to be published in the *Antarctic Map Folio Series.* Roberto Schlatter, John Boyd, and W. L. N. Tickell have collaborated on various maps.

A preliminary draft of the species accounts section of the handbook was sent last year to 30 specialists. On the basis of their comments, this 250-page section has been revised and is now completed, and present work is centered on the introduction. Ten color plates illustrating 69 species have been completed by Bob Hines, who is currently working on black and white sketches of the numerous vagrants. The manuscript and illustrations, which should be finished early in 1970, will be submitted for publication in the *Antarctic Research Series.*

Antarctic and Circum-Antarctic Palynological Contributions

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Assemblages from the Snow Hill Island Series, the McMurdo–Ross Sea matrices, and correlative sequences of the South Chilean flysch have been the chief subject of study during the past year. The antarctic samples have yielded provocative evidence of regional warmth and aridity through the recovery of *Sesame*-type pollen belonging to the Pedaliaceae, a family now restricted to hot, dry habitats from Africa and India to northernmost Australia. The climatic and latitudinal significance of these finds was explored in a paper given at a meeting connected with the SCAR Symposium held in Cambridge, England, in 1968. This paper will appear in *Palaeoecology of Africa and Antarctica* (*ed.* E. M. van Zinderen Bakker).

Antarctica: Samples from both areas lack stratigraphic data; moreover, corrosion is prevalent, so that some of the most significant forms occur only as rare fragments. A few redeposited grains occur, all of which appear to be Triassic. Deposition has clearly been in inshore or lagoon environments, as indicated by *Botryococcus* and *Pediastrum* colonies and by high frequencies of fern, conifer, and angiosperm microspores. Matrices from Snow Hill and Seymour Island containing corals or the serpulid worm *Rotularia callosa* supplement Howarth's ammonite-based Campanian datings. Others promise exact datings for younger Seymour Island material, which now appear to be Maastrichtian to Paleocene, rather than Oligocene or Miocene in age, as generally held.

The McMurdo erratic assemblages, coeval with that of the Leña Dura (S. Chile), are characterized by *Cordosphaeridium diktyoplokus, C. filosum, Aiora fenestrata,* and *Deflandrea* spp. I believe them to be of Upper Eocene age.

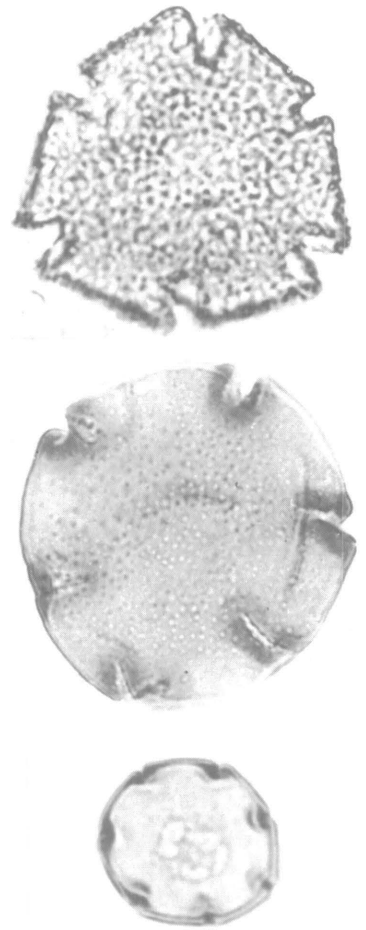
The pedaliaceous pollen more than any other seems to lock West Antarctica most securely into Gondwanic union with Madagascar and Australia in particular, at least as late as the Upper Cretaceous.

Circum-Antarctic: The most striking results obtained have been as follows:

I. A preliminary study of South Georgia peats, provided by the British Antarctic Survey, has traced the history of *Sphagnum* moss and has shown that (a) endophytic "fly speck" fungi (Microthyriaceae) occur freely in grass-peat layers; (b) thin, volcanic

Photomicrograph by L. M. Cranwell

***Botryococcus* colony from an Upper Cretaceous sediment, Snow Hill Island.**



Photomicrographs by L. M. Cranwell

Fossil pollen grains of *Nothofagus fusca*-type. *Top:* Upper Cretaceous from Snow Hill Island. *Center:* Lower Tertiary from South Chile coal. *Bottom:* Fresh pollen wind-blown south of New Zealand.

ash lenses favor preservation of all microspores; (c) *Ephedra* and *Nothofagus* pollen, blown from South America, occurs sparingly in the peats; and (d) almost all genera of the island flora, apart from ferns, have left their microspore record throughout the period of peat growth—over 5,000 years.

II. Some progress has been made with atmospheric slides (New Zealand/McMurdo collections) submitted by Dr. J. L. Gressitt of Bishop Museum, Honolulu. For instance, *Nothofagus fusca*-type pollen has been found south of the Auckland Islands. Most of the catches, however, represent microspores freshly shed near Harewood.

III. Older Kerguelen sediments, previously considered Oligocene to Miocene, now appear to be at least Lower Oligocene to Eocene, with the same rich conifer component as in Tasmanian and New Zealand deposits of this age. Distinctive spiny palm pollen occurs, as in the Australasian sediments, and is now reported for the first time from Kerguelen.

Antarctic Paleobiology: New Fossil Data and Their Significance

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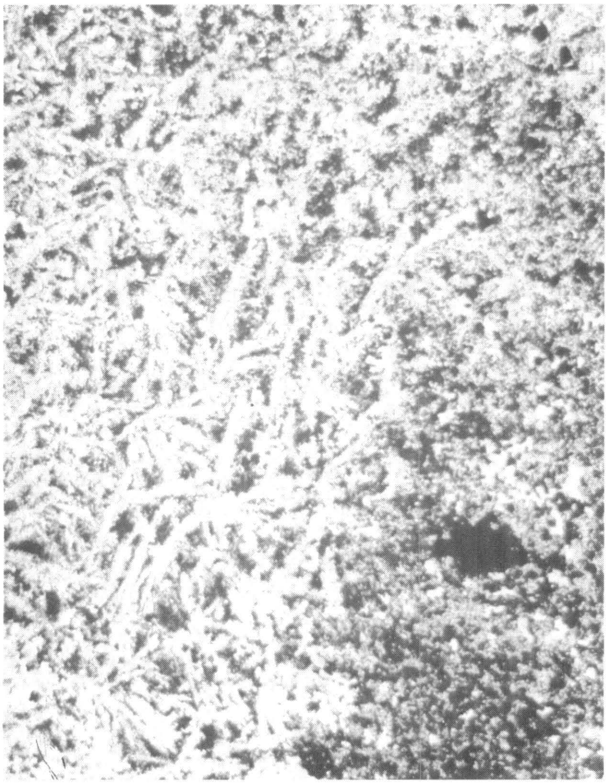
Three Polarstar Formation samples from the Sentinel Mountains have yielded new and important biotic data. Sample S–10, from the east slope of Polarstar Peak, near the 2,000-m contour, contains a homopterous insect wing, family Stenoviicidae(?), in a slab taken from a dense spoor zone (Tasch *and* Riek, 1969). An acetate peel study of sample S–14, from a nonfossiliferous slab near the contact of Polarstar and Whiteout Conglomerate, disclosed a trace fossil (algal? mat) (Fig. 1 and Tasch, 1969a). In sample S–17, from a ridge north and west of Mount Weems, several trace fossils were exposed on a slab showing graded bedding (Tasch, 1968a).

These data establish two new fossil zones in the Polarstar Formation and hint at the probable equivalence of the fossil spoor zones at S–10 and S–17—both well below the *Glossopteris* beds. Furthermore, the Polarstar insect wing has equivalents in the Permian and Triassic of eastern Australia (Newcastle Coal Measures and possibly the Bowen Basin, Queensland) and elsewhere (Russian Permian). Both of the Australian localities contain Permian ribbed conchostracans that are also found in the Ohio Range *Leaia* zone. Such evidence favors two different yet related postulates: (1) proximity of Antarctic–Australia during Permian time (Tasch, 1969b) and (2) the validity of du Toit's Samfrau geosyncline concept (Craddock *et al.*, 1965), the former originally derived from fossil conchostracan data only, and the latter from compelling evidence (folded belt, *Glossopteris* flora, etc.) exemplified in the Sentinel Mountain sequence. The fossil homopteran from the Sentinels provides a Paleozoic reference point in the Antarctic lacking in past discussions of a transantarctic migratory route for Gondwana insects (Tasch, 1969b).

Acetate peel studies of a sample (0–19) from the Ohio Range uncovered one new fossil zone not seen in the field. The sample, collected on Mercer Ridge, about 3.0 m above sample 0–18, bears a vermiform trace fossil (ref. cit. Tasch, 1968b). The fossils consist of shells, chiefly molluscan, and some impressions on them appear ostracodal in dimensions and configuration. These were obviously brackish-water forms (salinity 29.0 ppt, corrected to 25.0 ppt), and recur in successive peels (Tasch, 1969a).

Exclusive of the basal spoor zone (Long, 1965) and the *Leaia* zone, there are now two additional faunal zones in the Mount Glossopteris Formation exposed at Mercer Ridge: 0–18 and 0–19.



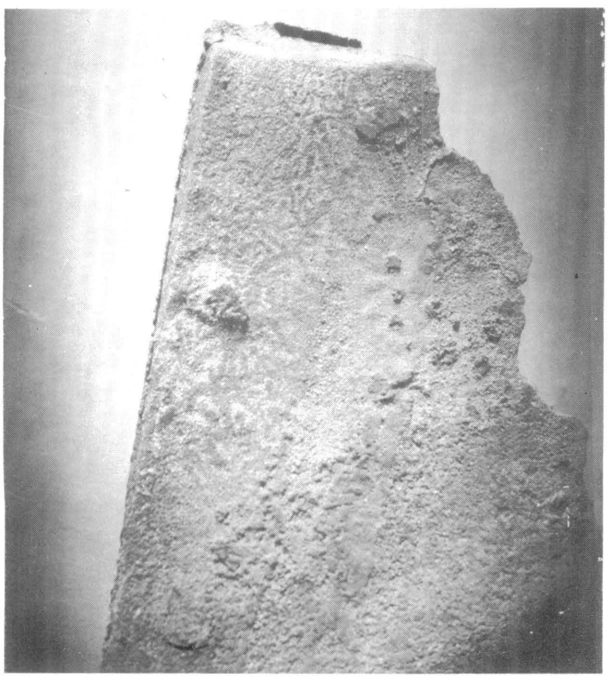


Figure 1. Polarstar Formation (Whiteout Nunatak) trace fossils. *Top:* Acetate peel No. 35 (locality S–14), transmitted light, × 15. Taken 9.4 mm below top of slab. Note matted pattern and trifid ends of fibrous elements. *Bottom:* Surface of rock slab (S–14), acid-etched and ready for next acetate peel (No. 36, × 2.6). The intricate pattern in the upper left sector is a continuation of that seen in the top photograph.

David Elliot's collections from Mauger Nunatak (Tasch, 1968b) contain, along with lioestherid conchostracans, some small specimens of the conchostracan genus *Paleolimnadia*. Since this genus was first described from some Triassic estheriids from New South Wales, the further significance of this find to continental drift theory is being studied.

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Fossiliferous Boulder of Early Tertiary Age from Ross Island, Antarctica

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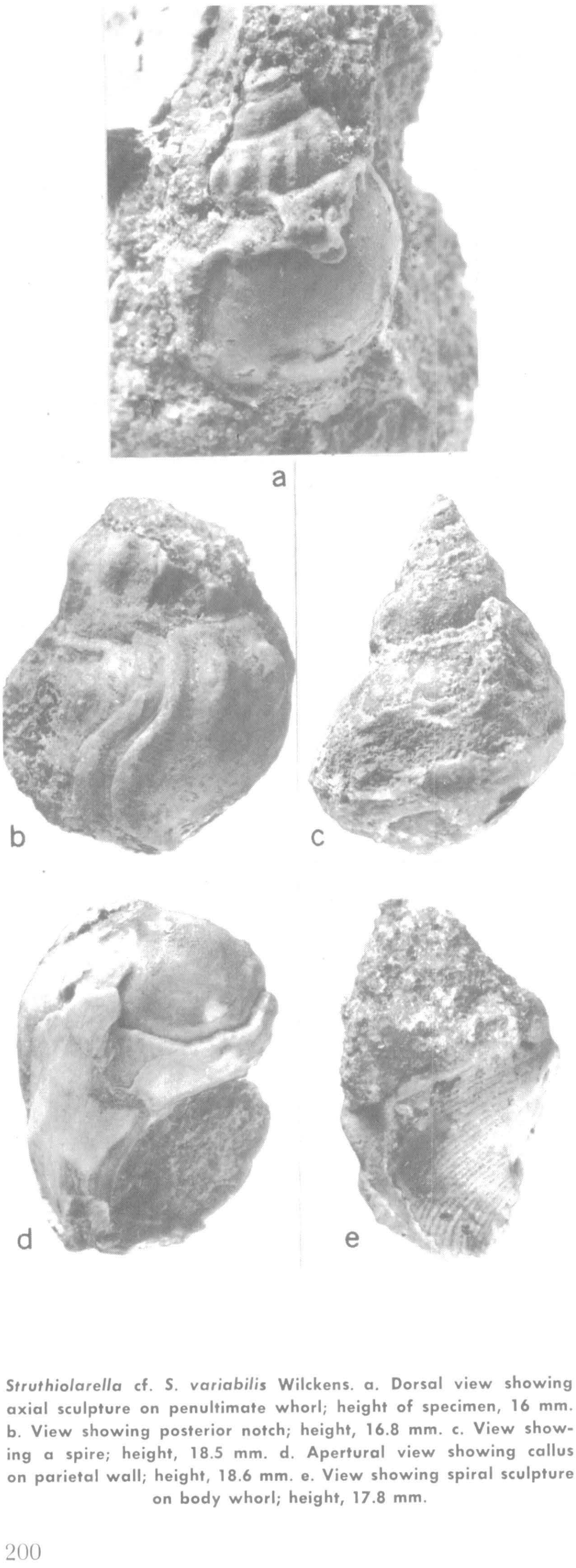
During the summer of 1968–1969, Robert C. Wood, of Johns Hopkins University, collected a boulder, almost certainly a glacial erratic, in the vicinity of Cape Crozier, Ross Island. This boulder, approximately 25 cm long, 20 cm wide, and 7.5 cm thick, is a hard graywacke containing a layer of fossil mollusks. Mr. Wood, with admirable foresight, shipped the boulder to the National Science Foundation, and from there it was sent to me with a request for information concerning age assignment and condition of deposition on the basis of the fossils and sedimentary matrix.

The individual fossils are oriented in various directions within the single layer, from which it may be inferred that the assemblage of empty shells lay in a mass upon the bottom before becoming embedded in sediment. The top of the fossil layer is eroded and most of the fossils are imperfectly preserved, but portions of the marginal outline and ornamentation can be observed on individual specimens. The hard matrix makes the extraction of individual fossils difficult. Those extracted do not exceed 20 mm in length, but there are others in the matrix which are somewhat larger.

Most of the fossils apparently belong to the same genus and probably to the same species. The shell characters of the fossils in the block, as well as of those extracted from the matrix, are referable to the Struthiolariidae, a family of marine Gastropoda reported to range from late Cretaceous to Recent. The specimens bear a strong resemblance to a species of Tertiary age from Seymour Island, off the eastern coast of the Antarctic Peninsula, described by Wilckens (1911) as *Struthiolarella variabilis*. A comparison of the fossils with this and other species assigned to *Struthiolaria* or its subgenera (or related genera in this family), described from strata of late Cretaceous or Tertiary age in New Zealand, Patagonia, and Chile, reveals similarity with species of early Tertiary (Eocene and Oligocene) age.



Struthiolarella cf. _S. variabilis_ Wilckens. a. Dorsal view showing axial sculpture on penultimate whorl; height of specimen, 16 mm. b. View showing posterior notch; height, 16.8 mm. c. View showing a spire; height, 18.5 mm. d. Apertural view showing callus on parietal wall; height, 18.6 mm. e. View showing spiral sculpture on body whorl; height, 17.8 mm.

Some of the specimens in the present collection were examined by Dr. C. A. Fleming and Dr. John Marwick, New Zealand Geological Survey. Fleming (written communication dated June 9, 1969) believes that these "agree better with Magellanian (?Eocene) than Patagonian (?Miocene) species." I agree completely with this appraisal of the relationship and age.

This age assignment is in general accordance with that of microfossils from erratics from Minna Bluff and Black Island, McMurdo Sound, which are believed to be probably of Eocene age (see Cranwell *et al.*, 1960; McIntyre *and* Wilson, 1966; Wilson, 1967).

Recent members of the Struthiolariidae now live in the cold waters of New Zealand, southeastern Australia, South Georgia, and Kerguelen Islands. However, some of the extinct genera and species in this family evidently lived under more temperate conditions. Depth records reported for this family in the literature indicate comparatively shallow water, 5 to 218 m (3 to 120 fathoms).

The fossil specimens, here identified as *Struthiolarella*[1] cf. *S. variabilis* Wilckens, were found above sea level on the eastern tip of Ross Island, an active volcanic pile in the western Ross Sea made up of three major basaltic cones, with numerous small parasitic cones. Craddock and Splettstoesser (personal communication, John Splettstoesser to M. D. Turner, 1969), in a reconnaissance survey of the area February 1961, found numerous boulders of mixed provenance scattered in areas over both the flat and rolling topography at Cape Crozier. These are not related to the underlying volcanics, but are similar, in part, to rocks south and west of the Transantarctic Mountains, rein-

[1] *Struthiolarella* Steinmann and Wilckens, 1908, was relegated to the synonymy of *Perissodonta* von Martens, 1878, by Marwick, 1960.

forcing the conclusion that they are glacial erratics. Despite a specific search for fossils, none was found at that time.

Tertiary macrofossils were unknown in the Ross Sea area before the present finding; however, sparse Tertiary microfossils in erratics in glacial moraine and glacial material are distributed in a pattern indicating the probable presence of a Tertiary sedimentary sequence under the floor of the Ross Sea. The previous work on these Tertiary sediments and their significance in antarctic geologic history has been summarized by Harrington (1969).

Appreciation is expressed to Mort D. Turner of the Office of Antarctic Programs, National Science Foundation, for the opportunity to study these fossils and to G D. Hanna, California Academy of Sciences, for extracting some of the fossils from the matrix and for offering constructive criticism concerning the manuscript. I am also grateful for advice received from Dr. C. A. Fleming and Dr. J. Marwick, New Zealand Geological Survey, who examined specimens and called my attention to some of the literature relevant to this study. Photographs used to illustrate the fossils were prepared by Mr. Maurice Giles. Acknowledgement also is due Mrs. G Dallas Hanna for retouching the photographs and to Mr. Barry Roth for their arrangement.

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Late Paleozoic Glacial Geography of Gondwanaland

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This year has been the penultimate in a long-range study of Late Paleozoic glacial deposits of Antarctica and the other continental fragments of Gondwanaland. The field work was concluded with investigations of these rocks in Australia, including Tasmania, and peninsular India and West Pakistan. A total of about 12 man-months was spent overseas, during which time we attempted to view most of the significant exposures.

Upper Carboniferous and Lower Permian strata of glacial aspect are widely distributed in New South Wales and less abundantly in Victoria, South Australia, Western Australia, and the Northern Territory (*see* Brown *et al.,* 1968). In the east, the strata are intercalated with both marine and volcanoclastic rocks and attain the youngest age known anywhere for Upper Paleozoic glacial rocks—into the Middle Permian. A striking feature of Tasmanian glacials is the fact that they are interlayered with biostromal and clastic limestones. In South Australia, esker-like sandstone bodies were discovered among the subaqueously deposited diamictites of the Bacchus Marsh region. Western Australia and the Northern Territory display mostly discontinuous units of diamictite, locally highly deformed in a soft-sediment state. Directions of ice transport as deduced from striated floors and other structures are eastward and northeastward in New South Wales and Tasmania, westward and northwestward in Western Australia, and generally northward from the Great Australian Bight in South Australia. The suggestion is that major centers of ice dispersal were located in western New South Wales and inland Western Australia. However, the flow directions in Tasmania and South Australia require an ice center off the south coast of the continent. We suggest tentatively that this center may correspond to that located in northern Victoria Land, Antarctica (Frakes *and* Crowell, 1968). Thus, a reconstruction of Gondwanaland in which Tasmania lies in the eastern Ross Sea and the Great Australian Bight lies along George V Coast of Antarctica fits the data well.

Several critical exposures in peninsular India and the Salt Range, West Pakistan contribute to an understanding of the glacial geography there in Late Carboniferous time. Ice and current transport was generally parallel to the post-glacial graben structures of the shield—Godavari Valley, Mahanadi and Namada rifts—and from southeast to northwest. In the Salt Range, the glacials were derived from an ice center located in the Indus plain to the southeast. Glacial effects are neither widespread nor intensive here on the northern boundary of Gondwanaland and adjacent to the Tethys Sea.

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Chemical Trends in the Dufek Intrusion, Pensacola Mountains*

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Major and trace element concentrations in the layered cumulate rocks of the immense post-Permian Dufek intrusion (Ford *and* Boyd, 1968) vary more or less systematically with stratigraphic position. The trends of most elements generally parallel those of the better known, highly differentiated mafic intrusions of the stratiform type elsewhere in the world. Conspicuous chemical and mineralogical differences exist, however, between the Dufek and other stratiform bodies, believed due largely to important differences between parental basaltic magmas (Ford, in press). Dufek chilled border rocks, where exposed, are highly Fe-enriched and so probably do not represent parent magma, but rather a later, differentiated daughter. Parental Dufek magma, inferred from contact facies of little differentiated Mesozoic diabase and basalt sills and dikes nearby, is believed to have been Si-rich hypersthene tholeiite.

The chemically and mineralogically varied rocks are believed to form a single comagmatic series. Two distinct chemical trends, one mafic and the other felsic (Ford, in press), lead rather smoothly through the main layered series into and through a 300-m thick granophyre cap (Figs. 1–2). The smooth trends

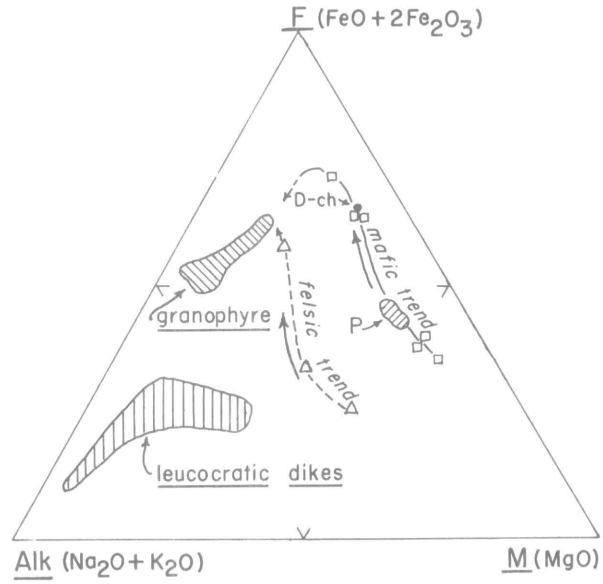

Figure 1. Dufek rocks and their chemical trends plotted on a triangular "Alk-F-M" diagram. Triangles and dashed line show averaged rocks and "felsic" trend for anorthosite and leucogabbro from interlayers in gabbro. Squares and solid line show averaged rocks and "mafic" trend for gabbro of main layered series. Arrows show direction of increasing stratigraphic height (see Figure 2). "D-ch" marks Dufek chilled contact rocks. Lined regions show fields of (1) leucocratic dike rocks including aplite, alaskite, and pegmatite; (2) granophyre from capping layer; and (3) chill phases, "p", of Mesozoic dikes and sills elsewhere in the Pensacola Mountains.

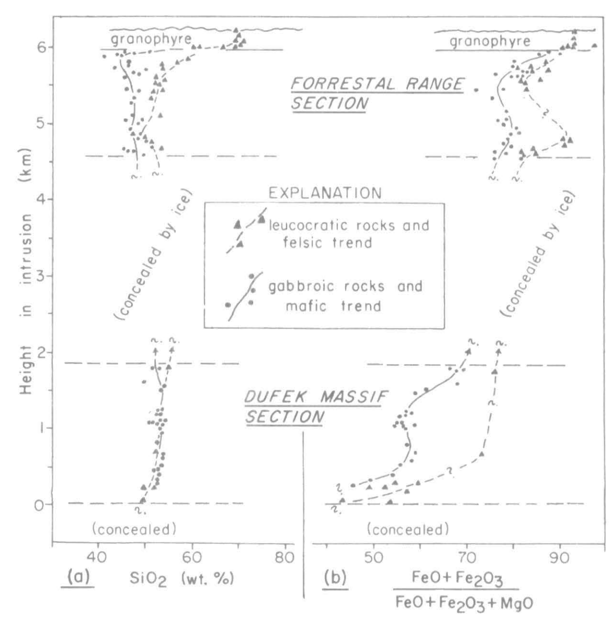

Figure 2. Silica (a) and ratio of total iron/total iron plus magnesia (b) plotted against stratigraphic height in the Dufek intrusion. See report by Ford and Boyd (1968) for terminology of major stratigraphic subdivisions.

* Publication authorized by the Director, U.S. Geological Survey.

point to a close genetic tie between all the contrasted rocks of the intrusion.

SiO_2 abundance shows a slight negative slope upward through the intrusion (Fig. 2a). This decrease is especially marked in higher rocks of the mafic suite that are strongly enriched in FeO + Fe_2O_3. The presence of at least minor amounts of modal and normative quartz in rocks from all levels indicates that the magma remained saturated with SiO_2 at all stages of the differentiation process, even during the production of rocks with SiO_2 as low as about 45 percent.

The extreme Fe enrichment of higher rocks of the mafic suite is seen in the triangular plot of Fig. 1. The general upward increase of total iron relative to iron plus magnesium through the body is shown in Fig. 2b. Steepenings and even slight reversals in the trend lines are thought to be more likely the result of some indigenous mechanism (such as variations in maintenance of crystal-liquid equilibrium) than of an extraneous one (such as periodic multiple intrusion of fresh magma). Laboratory work is presently under way on this and many other aspects of this major stratiform mafic igneous body which was discovered only as recently as 1957 (Aughenbaugh, 1961), and which was mapped and sampled in its exposed entirety in the summer of 1965–1966 (Schmidt *and* Ford, 1966).

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Precambrian and Lower Paleozoic Igneous Rocks, Pensacola Mountains, Antarctica*

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Three major igneous rock suites have been mapped in the Pensacola Mountains by the U.S. Geological Survey during 1962–1966. Each suite is significantly related to different sequential parts of the geologic history (Schmidt *et al.,* 1965; Nelson *et al.,* 1968). The oldest suite of Precambrian age consists of spilitic and keratophyric volcanic rocks and related diabase occurring in dikes and sills; the suite is associated with a thick eugeosynclinal subgraywacke and slate sequence. The second suite of early Paleozoic age consists of rhyolitic and dacitic volcanic rocks and related granitic plutonic rocks and is closely associated with widespread mountain building (orogeny) in the Transantarctic Mountains. The third and youngest suite of Mesozoic age consists of quartz diabase occurring in dikes and sills and the Dufek stratiform gabbroic intrusion; this suite is associated with orogeny in the areas bordering the Weddell Sea (see note by A. B. Ford and W. W. Boyd, Jr., in this issue).

The Precambrian igneous rock suite contains a large volume of spilitic basalt flows and pillow lavas and a relatively small volume of quartz-keratophyric tuffs and volcanic breccia. A large volume of diabase was penecontemporaneously intruded as dikes and sills into interbedded subgraywacke and shale. Study of the diabase by W. W. Boyd, Jr., indicates an initial olivine-bearing, augite-plagioclase (An_{50}) diabase; the coarse-grained interiors of thick sills are well differentiated. Alteration to chlorite and relatively sodic plagioclase is extensive, but no distinction has yet been made between a primary (spilite) and a metamorphic origin. Rb-Sr whole-rock dates of quartz-keratophyric pyroclastic rocks suggest a 953 ± 175 m.y. isochron age (Eastin *et al.,* 1969).

The lower Paleozoic rhyolites and dacites—the Gambacorta Formation—occur as a volcanic pile more than 1,500 m thick in the southern part of the Neptune Range. The Gambacorta Formation is divided into six distinctive members containing many ash-flow tuff units. The central area is an elliptical caldera, measuring 15 by 25 km, bounded by concentric border faults and filled with more than 1,000 m of rhyolite ash-flow tuff, the Hawkes Member. Away from the caldera, the Hawkes Member is a well-defined, relatively thin ash-flow tuff in the middle part of the volcanic sequence; it extends about 40 km to the present limit of outcrop of the Gambacorta Formation. Rb-Sr whole-rock dates of the Gambacorta volcanics (8 dates) indicate a 500 ± 10 m.y. isochron age (Gunter Faure and René Eastin, written communication). Postkinematic granite in the Neptune Range is dated 510 ± 30 m.y. by the Rb-Sr whole-rock method (Z. E. Peterman, written communication). The associated mountain building event corresponds to the Ross Orogeny that is recognized throughout the 3,500-km extent of the Transantarctic Mountains.

* Publication authorized by the Director, U.S. Geological Survey.

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Age of the Basement Complex of Wright Valley, Antarctica

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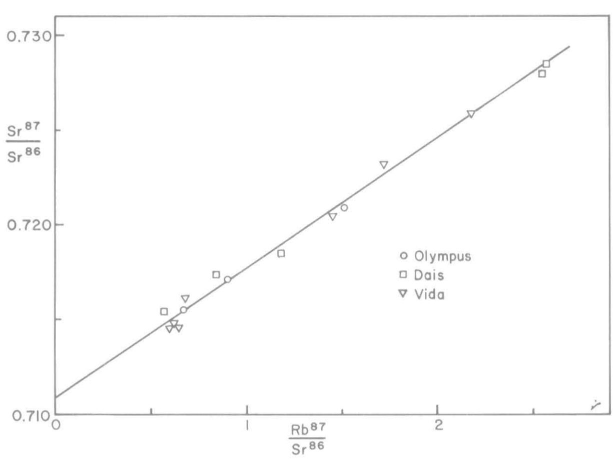
The rocks of the basement complex of Wright Valley can be divided into four major units: Asgard Formation, Olympus granite-gneiss, Dais granite, and Vida granite and minor associated dikes. The oldest rocks of the basement complex are the tightly folded metasediments of the Asgard Formation, which is the equivalent of the Skelton Group elsewhere in Victoria Land (Gunn *and* Warren, 1962; McKelvey *and* Webb, 1962). The Asgard metasediments are flanked by the Olympus granite-gneiss, which may be a metamorphic equivalent of the Asgard Formation. McKelvey and Webb (1962) consider it to be intrusive because inclusions of Asgard schist occur within the gneiss, and the alignment of these inclusions is parallel to the schistosity.



Isochron diagram for rocks from the basement complex of Wright Valley. The age of these rocks is 490 ± 14 m.y. and the initial Sr^{87}/Sr^{86} ratio is 0.7109.

The Asgard Formation and the Olympus granite-gneiss are in turn flanked by the Dais granite. It has a coarse foliation generally parallel to that of the Asgard and Olympus rocks. The last major intrusive of the basement complex is the Vida granite, which is the equivalent of the Irizar granite of Taylor Valley and elsewhere (Haskell *et al.,* 1965).

Several dates have been reported for samples of the basement complex in the vicinity of Wright Valley (see age compilations by Picciotto *and* Coppez, 1963 and 1964; Webb, 1962; Webb *and* Warren, 1965). Most of the dates were obtained by the K-Ar method and range from 425 to 525 m.y., with the majority of the dates in the interval 470–500 m.y. Deutsch and Grögler (1966) reported a U-Pb date of 610 m.y. for a zircon from the Olympus granite-gneiss in Victoria Valley, north of Wright Valley. The Vanda porphyry dikes, which are apparently the youngest rocks of the basement complex, are 470 ± 7 m.y. old according to Jones and Faure (1967). One sample of these dikes had been dated previously by Deutsch and Webb (1964), who reported an anomalous date of 1000 m.y. Work by Jones and Faure (1967), however, indicated that the 1000 m.y. date may be the result of contamination of the dikes during intrusion.

Suites of samples of the Olympus granite-gneiss, the Dais granite, and the Vida granite have been analyzed for an age determination by the whole-rock Rb-Sr method. In addition, several feldspar concentrates have been analyzed. The Sr^{87}/Sr^{86} and Rb^{87}/Sr^{86} ratios for the rock and mineral samples have been plotted as points in the figure using different symbols for identification. It is apparent that the samples form a single straight-line isochron whose slope and intercept can be determined by a linear regression analysis. From the best estimate of the slope of the isochron, one obtains an age of 490 ± 14 m.y. for all of the rocks in this suite, using a value of 1.39×10^{-11}/yr for the decay constant of Rb^{87}. The initial Sr^{87}/Sr^{86} ratio for these rocks is 0.7109.

The result of this age determination has two possible geologic interpretations. First, all three rock units could have been emplaced within a period of time of the order of 30 m.y., which is not resolvable on the basis of these data. Second, the Olympus granite-gneiss and the Dais granite may have been thermally metamorphosed by the igneous activity accompanying the intrusion of the Vida granite during and after the Ross Orogeny. The thermal metamorphism may have been sufficient to cause complete isotopic homogenization of strontium in the Olympus granite-gneiss and the Dais granite. The U-Pb date of the zircon from the Olympus granite-gneiss of 610 m.y. reported by Deutsch and Grögler (1966) suggests that this rock is in fact older than 490 m.y. On the other hand, it is possible that the zircons are detrital and that they therefore indicate the time of their original crystallization and set only an upper limit for the age of the Olympus granite-gneiss.

On the basis of available information, we conclude that the igneous and metamorphic rocks of the basement complex in Wright Valley either crystallized 490 ± 14 m.y. ago or that they were extensively recrystallized and isotopically homogenized at this time. The event dated by the Rb-Sr isochron method occurred in the Late Cambrian to Early Ordovician Periods and is generally referred to as the Ross Orogeny.

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Jurassic Tholeiites of the Beardmore Glacier Area

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Tholeiitic basalts which cap the flat-lying Late Paleozoic–Early Mesozoic Beacon rocks and crop out in several distinct areas in the Transantarctic Mountains are the remnants of a formerly much more extensive lava field. Conchostracans (Elliot *and* Tasch, 1967) present in sedimentary interbeds within the basalts (called the Kirkpatrick Basalt in this and most other areas) and potassium-argon age determinations on the basalts and the correlative Ferrar Dolerite sills, give Jurassic ages (McDougall, 1963; Wade *et al.,* 1965; Compston *et al.,* 1968).

The Kirkpatrick Basalt of the Beardmore Glacier area rests without angular discordance, where the contact is exposed, on the Prebble Formation (Barrett *et al.,* 1968), which is a pyroclastic and volcanic mudflow unit of intermediate to acid composition. The Prebble Formation is the culmination of a long period of volcanicity first recorded in the Permian Buckley Formation (Barrett, 1969) and present throughout the succeeding Triassic rocks. Considerable topographic relief is implied by the accumulation of mudflows, including one apparently unstratified 240-m-thick unit on the Otway Massif. Other evidence of relief is present at Buttress Peak, where 270 m of basalts are in juxtaposition to Triassic Falla Formation sediments and the near-vertical contact is not a fault contact. Correlation of the basalt flows also suggests relief of some 80 m, and the extreme thickness of some flows—more than 200 m in one instance—implies the formation of huge lava ponds which must have been confined topographically. This is in marked contrast to the conditions under which the flood plain deposits of Permian and Triassic age accumulated, and implies the presence of a major disconformity below the Kirkpatrick Basalt.

The basalts are typical tholeiites with two pyroxenes, augite and pigeonite, labradorite, opaque minerals, and varying amounts of glass, devitrified glass or a quartzo-feldspathic groundmass. The diabase sills differ only in the absence of glass, a coarser grain size, and, in many of them, the presence of orthopyroxene crystals. Two of Gunn's (1966) magma types can be recognized mineralogically, and there is also a clear distinction chemically, although comparison with Gunn's data shows considerable chemical differences in the case of the pigeonite tholeiites. The percentage of silica, > 58 percent on a water-free basis, of the pigeonite tholeiites is remarkably high and it is reflected in more than 18 percent normative quartz. This high silica content is present mainly in the glassy or microcrystalline groundmass of the basalts, but it is not caused by local contamination. Although the Ferrar group of the Beardmore Glacier area is undoubtedly part of the same magmatic province as that of the McMurdo Sound area because of the consistently high and anomalous Sr^{87}/Sr^{86} ratio (Faure *et al.,* 1968), the parent magmas of these basalts and diabases are likely to have been derived from a slightly different source and to have had different crystallization histories. Crustal contamination might at first sight account for the high silica content and the anomalous strontium-isotope ratios, but there are difficulties with this interpretation (Heier *et al.*, 1965; Compston *et al.*, 1968) which the accumulation of more data may resolve.

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Sr^{87}/Sr^{86} Ratios of Ultramafic Nodules and Host Basalt from the McMurdo Area and Ford Ranges, Antarctica*

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The Sr^{87}/Sr^{86} ratios of basalt and ultramafic nodules from McMurdo and the Mount Perkins area of the Fosdick Mountains, Ford Ranges, were measured to identify the source region of the basaltic magma and the nodules. Slabs of total ultramafic nodule and total basalt were washed in purified 6N hydrochloric acid before crushing and elution of strontium to eliminate possible strontium contamination, especially in the McMurdo samples which were subject to contamination from sea water. The Sr^{87}/Sr^{86} ratio of McMurdo Sound sea water is 0.7094 (Jones *and* Faure, 1968).

The present Sr^{87}/Sr^{86} ratios of the analyzed nodules and basalt are as follows:

Sr^{87}/Sr^{86} ratios of ultramafic nodules and basalt, McMurdo area and Ford Ranges

Material and Locality	Sr^{87}/Sr^{86}*
Ultramafic nodule A, Mt. Perkins	
Dissolution 1	0.7035
Dissolution 2	0.7029
Ultramafic nodule B, Mt. Perkins	0.7030
Ultramafic nodule, McMurdo	0.7034
Host basalt, McMurdo	
Dissolution 1	0.7030
Dissolution 2	0.7029
Dissolution 3	0.7028

* Normalized to Sr^{86}/Sr^{88} ratio of 0.1194.

At the time of these analyses, the Sr^{87}/Sr^{86} ratio of the Massachusetts Institute of Technology standard Eimer and Amend $SrCO_3$ was measured as $0.7080 \pm 0.0002_6$ (mean of 7 analyses).

The McMurdo Volcanics are Late Tertiary and Quaternary (Harrington, 1958); the volcanic rocks which contain the analyzed ultramafic nodules in the Mount Perkins area are no older than Tertiary (Wade, 1967). The nodules have less than 5 ppm Sr and less than 5 ppm Rb; their host basalt contains about 1,000 ppm Sr and about 20 ppm Rb, as determined by atomic absorption spectrophotometry. The young age of the rocks, their low Rb content, and low Rb/Sr ratio of the basalt support the assumption that their measured and initial Sr^{87}/Sr^{86} ratios could not have differed significantly.

Sr^{87}/Sr^{86} ratios of about 0.7030 to 0.7034 for both the ultramafic nodules and their basaltic host material indicate that they are isotopically homogenous with respect to strontium, and probably cogenetic. However, because of the low strontium content of the nodules and high strontium content of the basalt, it is possible that isotopic strontium equilibration occurred during emplacement of these rocks. The values are consistent with those determined for basaltic rocks from islands on the Mid-Atlantic Ridge (Gast *et al.*, 1964), which have been interpreted as having an upper-mantle source.

Acknowledgements. I sincerely thank Professor F. Alton Wade for providing the samples from the Mount Perkins area of the Ford Ranges. This research was completed during the course of Rb-Sr dating of rocks from the Ford Ranges (Halpern, 1968). Support for this work was provided by the National Science Foundation through grant GA–1428.

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Petrographic and Field Characteristics of Marie Byrd Land Volcanic Rocks

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Preliminary petrographic studies of samples collected during the Marie Byrd Land Survey of 1967–1968 indicate that the lavas in this entire region are alkaline. Alkalinity is indicated petrographically by the presence of alkali pyroxenes in virtually all rocks except basalts, and by the predominance of alkali feldspar as phenocrysts in the andesites and the more acid rocks of the region. Similar observations were made by petrographers that accompanied the earlier oversnow traverses to various parts of this area (Anderson, 1960; Doumani *and* Ehlers, 1962).

The basaltic rocks in central Marie Byrd Land are characterized mineralogically by olivine and titanaugite in the groundmass, and by plagioclase phenocrysts and groundmass grains with broad, soda-rich rims. These rocks are found principally in two geologic occurrences: (1) a basal sequence of horizontal flows or hyaloclastite beds, and (2) parasitic cones on the flanks of stratovolcanoes. The basal sequence rests on a nearly flat bedrock erosion surface which is exposed in various nunataks along the Hobbs Coast, at Mounts Aldaz and Murphy, and in the Kohler Range. In the Crary Mountains, and apparently also at Toney Mountain, a basalt sequence forms a foundation upon which the stratovolcanoes of these ranges were built. The basaltic character of hyaloclastites in the basal sequences is recognizable in clasts that are composed of sideromelane or tachylite, with phenocrysts of olivine, titanaugite and labradorite.

The parasitic cones are composed of beds of cinders and bombs, interbedded with basalt flow rock. The flows are petrographically indistinguishable from flows in the basal sequences, but ultramafic nodules are much more common in the parasitic cones. Most of the nodules examined contain about 50 percent olivine, plus variable proportions of orthopyroxene, clinopyroxene, and a brown garnet tentatively identified as melanite.

Stratovolcanoes, many exceeding 4,000 m (13,000 feet) in height, make up most of the Flood, Ames, and Executive Committee Ranges, Mount Takahe, Toney Mountain, and the Crary Mountains. They are composed of trachyandesite flows and tuff breccias, and apparently lesser amounts of trachyte and rhyolite. Mounts Waesche and Hartigan are stratovolcanoes that are exceptional in that each is composed of a large proportion of basalt. The trachyandesites are rich in olivine and soda-iron pyroxene, which may be found in the groundmass or as phenocrysts. Some of these rocks carry modal nepheline and sodalite. Feldspar phenocrysts in the trachyandesites are most commonly anorthoclase, similar to that described by Boudette and Ford (1966).

The more acid rocks are marked by the disappearance of olivine, the appearance of alkali amphibole in some samples, and by sanidine as phenocrysts in place of anorthoclase. Aegerine-augite appears as phenocrysts in even the most acid rocks, and quartz phenocrysts are found in some of the rhyolites.

The trachytic and rhyolitic rocks all appear to be peralkaline, and the entire petrographic province is unusual in that both silica-undersaturated and silica-oversaturated varieties of peralkaline rock are found.

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Volcanic Rocks of the Ross Island Area

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During parts of 1968 and 1969, the data and rocks collected during the 1967–1968 field season in the Ross Island area were studied. The field observations and mapping and subsequent work on specimens and thin sections indicate the following at this time:

Cape Crozier consists primarily of trachyte plugs and younger basalt and scoria vents. Basaltic units older than the trachyte may be present. Pyroclastic units of various ages are found, and some large pillows (?) occur in the bedded pyroclastic rocks.

White Island appears to consist primarily of pyroclastic units, olivine basalt, and scoria. The cones and rib-like ridges that partially connect all of the outcrop areas are constructed essentially of pyroclastic rocks that are partially covered by a thin mantle of basalt and scoria.

Black Island consists of trachyte plugs, olivine basalt, and scoria. Some green, trachytic glass and breccia occur at Mount Aurora.

Additional field work was done at Cape Royds, Cape Evans, Brown Peninsula, and Minna Bluff, and in the McMurdo area. In general, the results of this work are similar to those reported earlier by the author. Work on specimens collected by Dr. G. Denton and M. Alford from Mounts Erebus and Terror indicate that the trachyte (Kenyte) high on the flanks of Mount Erebus is the same as the rocks that occur at Capes Royds and Evans. A specimen from Mount Terror rocks consists of olivine and iddingsite.

Mount Cis appears to be a pingo rather than a vent. Remnants of a yellowish trachyte flow (?), 1–1½ m thick, cap this feature.

Miers Valley and the "Brando" vent in the Radian Glacier area were studied. The unit identified as a Kenyte by earlier workers in Miers Valley appears to be a porphyritic (plagioclase-phenocryst) basalt.

Pedology of Enderby Land, Antarctica*

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Although the ice-free portions of Antarctica comprise only about 4 percent of the present-day continental surface, pedologic investigations are yielding data important in the understanding of periglacial environments and weathering processes. With few notable exceptions, detailed pedologic studies in Antarctica have been conducted in West Antarctica, mainly in Victoria Land. As the USARP exchange scientist to the 12th Soviet Antarctic Expedition, the author collected field data and soils from the ice-free areas (oases) of coastal Enderby Land. The data derived and reduced to date indicate that these soils differ measurably in many parameters from the soils of Victoria Land. The present postulate is that the coastal Enderby Land soils more closely resemble arctic soil conditions than the soils of Victoria Land.

Soil morphology and moisture dynamics of a soil group tentatively designated red and brown ahumisolic have been described (MacNamara, 1969). In contrast to the ahumic soils of Victoria Land (Jensen, 1916; Tedrow *and* Ugolini, 1966; Claridge, 1965; Ugolini, 1963, 1964, 1967; Campbell *and* Claridge, 1969; Ugolini *and* Bull, 1965; McCraw, 1967), these soils of coastal Enderby Land have well-developed horizonation, bright colors, visible structural elements, and are deep and moist. The average soil moisture contents throughout the profile are three to four times greater than those reported from Victoria Land. Figs. 1 and 2 present soil-moisture data from two soil sites monitored over a 12-month period. The term "impeded drainage" is used to describe the moisture content when all the overlying soil is thawed but the underlying material is frozen. In general, zones of continuous high moisture content are finer textured and exhibit structural reorientations. These are the zones of maximum weathering, color development, structure development, etc., approximating the B horizons of the classical soil.

Further laboratory investigations have shown that the Enderby Land soils have acid soil environments with greater cation exchange capacities, lower quantities of water-soluble salts, and differing ratios of exchangeable cations than formerly reported in Antarctica.

The composition of water-extractable ions from a representative ahumisolic soil profile, as sampled in the late-summer or dry period, is presented in the table. The concentration of the more mobile ions in the surface layers is the result of two processes: vertical migration of soil solutions in response to thermal gradients with subsequent deposition of soluble salts when the phase transformation from liquid to vapor occurs and minor additions of wind-borne salts (aerosols) from the nearby open sea. Local on-shore breezes (upslope winds) develop during the summer periods as a result of the intensive heating of the exposed rock and soil surfaces. The surface-deposited salts are, to a large extent, stripped and blown to sea during infrequent summer storms and the first major storms of autumn, for these are associated with strong katabatic (downslope) winds.

The effect of the stripping during the early fall storms has been shown by analysis of wind-driven snow captured at the 1-m level. This snow had high (2–7 ppm) concentrations of water-soluble silica,

* The field and laboratory studies upon which this report is based were supported by the Office of Antarctic Programs, National Science Foundation. Logistic support was furnished by the 12th and 13th Soviet Antarctic Expeditions.

Chemical composition of 1:1 (soil:water) extracts from red ahumisolic soil from coastal Enderby Land, Antarctica

Depth (cm)	Na (ppm)	me/100g	K (ppm)	me/100g	Ca (ppm)	me/100g	Mg (ppm)	me/100g	Cl (ppm)	me/100g	SO_4 (ppm)	me/100g	pH	E.C.* (micro-mhos)
0/5	344	14.96	101	2.59	0.9	0.05	.5	0.04	404	11.38	27.2	0.57	7.0	325
5/10	54	2.48	9	0.23	0.9	0.05	.5	0.04	367	10.34	19.0	0.40	6.9	56
10/15	66	2.87	15	0.38	1.1	0.06	.8	0.07	226	6.37	29.6	0.62	6.9	50
15/20	47	2.04	12	0.31	1.2	0.06	1.3	0.11	222	6.25	22.8	0.48	7.0	45
20/25	56	2.43	10	0.26	2.4	0.12	1.3	0.11	226	6.37	28.4	0.59	4.9	50
25/30	46	2.00	14	0.36	2.6	0.13	1.6	0.13	194	5.46	24.5	0.51	5.5	43
30/35	46	2.00	14	0.36	2.8	0.14	1.7	0.14	197	5.54	24.4	0.51	6.0	56
35/40	52	2.26	13	0.33	2.9	0.15	1.5	0.13	206	5.80	25.8	0.54	5.2	44
40/50	52	2.26	13	0.33	11.7	0.59	1.5	0.13	230	6.48	24.9	0.52	5.0	58
50/60	50	2.16	13	0.33	12.1	0.61	1.4	0.12	230	6.48	25.9	0.53	5.0	61
70/80	28	1.22	22	0.56	14.8	0.74	1.3	0.94	230	6.48	20.5	0.43	4.8	72

* 1:10 (soil:water) extract used for electrical conductivity measurements. Small amounts of soluble silica were detected in most samples.

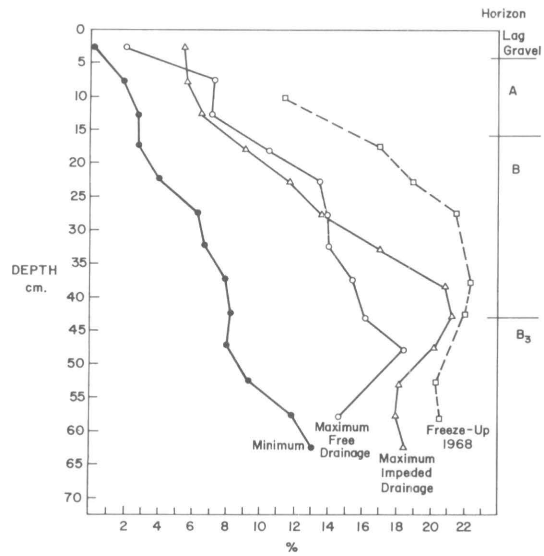

Figure 1. Annual soil-moisture dynamics of brown ahumisolic soil from coastal Enderby Land. Horizon terminology is tentatively assigned, as determined from soil morphological criteria. Moisture-content terminology is discussed in text.

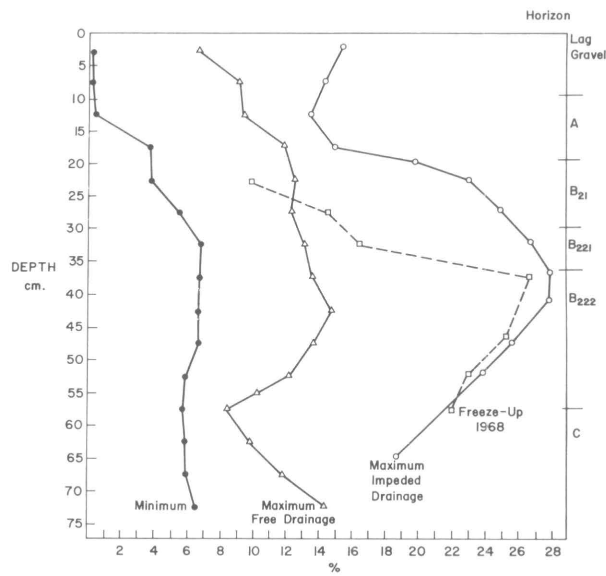

Figure 2. Annual soil-moisture dynamics of red ahumisolic soil from Molodezhnaya oasis, coastal Enderby Land. Detailed profile morphology has been reported previously (McNamara, 1969).

which obviously had originally been on weathered rock and soil surfaces. Additionally, the sodium and chloride ion contents of captured wind-blown snow were 3–8 times greater during March storms (autumn) than during July storms (mid-winter). Soluble salt profiles from the same site as presented in the table, determined during the early spring period, do not show the marked concentrations of sodium, potassium, chloride, or sulfate at the surface revealed in the mid-summer study.

Preliminary soil micromorphological investigations have shown similarities between Enderby Land soil conditions and northern Alaska soil conditions (personal communication, W. L. Kubiena, June 25, 1969). Further studies into these similarities will form the major part of laboratory studies in 1969–1970.

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Volcanic Eruption on Deception Island*

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The volcanic eruption of February 21, 1969, on Deception Island off the northern coast of the Antarctic Peninsula (Fig. 1) was preceded by earth tremors which began on February 14. The tremors increased in intensity until the 21st, when volcanic activity began as a cloud of steam rising to an estimated height of 3,000 m. Ash, pumice, and scoria were then ejected from a fissure about 4.5 km long and 120 m wide, trending about N.20°W. in the eastern part of the island. The ejecta and gases were erupted through the permanent ice cap, a hundred meters or so thick, that crowns the mountainous, horseshoe-shaped island caldera. Several hundred thousand cubic meters of bombs and blocks up to 3 m in maximum dimension were discharged and came to rest adjacent to the vent near its northern extremity; elsewhere, only ash and scoria appear to have been erupted. Areas that had been active during the December 1967 eruption, such as "Yelcho Island," which was built during that eruption, and the smaller eruptive center east of Telefon Bay, were inactive. Considerable gas was emitted in Fumarole Bay before the recent event (Kaye R. Everett, as quoted in Anonymous, 1969).

Although the eruption was minor in duration and amount of ejecta, it resulted in total destruction of the Chilean base (Fig. 2), previously damaged in 1967 (Valenzuela *et al.*, 1968), and also in partial destruction and abandonment of the British base (Fig. 3). Both base facilities were built on alluvial slopes near

* Publication authorized by the Director, U.S. Geological Survey.

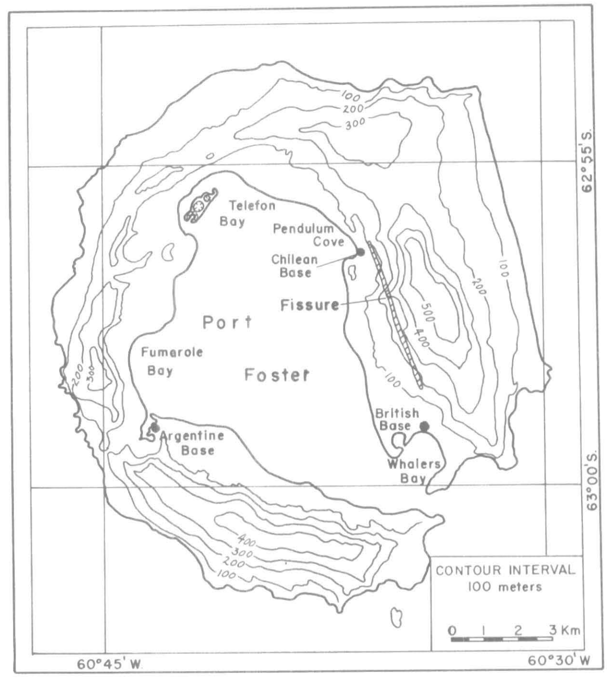
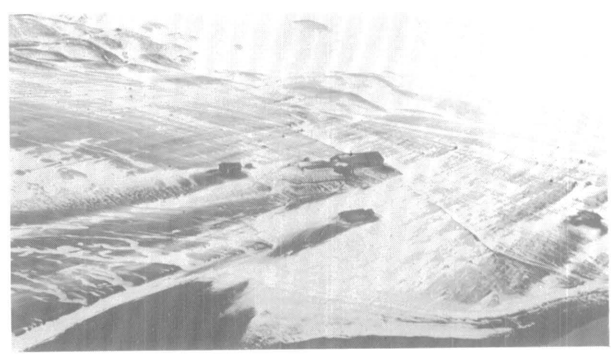


Figure 1. Deception Island. Base map modified from Valenzuela and others (1968).

Figure 2. Remains of living hut at Chilean station destroyed by eruption on February 21, 1969. Ash and scoria mantle surface in foreground. Fissure, mostly concealed by steam, lies on far side of bomb-covered slope behind station.



U.S. Coast Guard Photo

Figure 3. The British station after the eruption. Meltwater floods rushing from the fissure in the ice cap (just beyond upper left corner) to the sea (lower right) severely damaged the huts.

sea level, directly downslope from the fissure. Eruption of hot gases and ejecta through the ice cap produced floods of meltwater charged with ice blocks and ash which rushed downslope and damaged or destroyed the buildings in their path. Fortunately, there was no loss of life or serious injury to personnel, who were heroically evacuated by helicopters from the Chilean naval vessel *Piloto Pardo*.

The results of the eruption emphasize the danger of establishing permanent bases on alluvial slopes at the base of ice-covered, active (or even apparently dormant) volcanic mountains. Flood damage could be avoided or minimized by constructing bases on rocky promontories.

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Antarctic Sodium Sulfate and Recent Geomorphic History

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Beds of essentially pure mirabilite ($Na_2SO_4 \cdot 10H_2O$), usually with a thin coating of powdery thenardite (Na_2SO_4), are known from three areas in Antarctica. At Skarvsnes Foreland on the Prince Olav Coast, thin beds of mirabilite interlayered with sand and silt are exposed on the shore of a highly saline lake that is separated from the ocean by a narrow rock ridge. The surface of the lake is now about 10 m below sea level, but a gravel terrace about 45 m higher up indicates that, prior to isostatic uplift of the coast, this basin was occupied by an arm of the sea. The lake is composed of relict sea water, trapped by the uplift, from which the mirabilite crystallized. The presence of additional saline lakes and numerous remains of marine organisms show where other bays existed in the Skarvsnes area prior to the uplift.

A similar situation occurs in the Vestfold Hills, where several saline lakes are present near the coast. Although a marine terrace is not as well developed as at Skarvsnes, remains of marine organisms indicate the former extent of the sea, and show that the lakes contain relict sea water. Several small deposits of mirabilite occur here.

Mirabilite is the first solid after ice to crystallize as sea water is cooled. It does not begin to form, however, until 88 percent of the original volume of water has become ice. Many of the lakes at Skarvsnes Foreland and the Vestfold Hills are deep, at least one exceeding 100 m, and it is unreasonable to postulate that more than 88 percent of their volume froze. Rather, part of the water that was originally trapped by the uplift was lost from these basins by evaporation in summer and sublimation from an ice cover in winter. When consequent concentration of salts and water temperature reached a critical relationship, mirabilite began to crystallize.

Thicker, more extensive beds of mirabilite crop out in morainic debris in front of the Hobbs Glacier and in Miers Valley, southern Victoria Land. The high purity and faintly laminated structure of the deposits suggest periodic accumulation in bodies of water even though the locations are in open valley ends facing the ocean. It is probable that these valleys, and others along this part of the coast, were dammed by a higher-level stage of the Koettlitz Glacier, the former existence of which is indicated by moraines. The sodium sulfate was deposited in water ponded against the glacier and its moraine. Apparently the Hobbs Glacier has since advanced over some of these deposits.

Some sodium sulfate could accumulate where efflorescent deposits were washed into a basin. However, the drainage areas of these valleys are so small that such an explanation appears to be untenable. Therefore, the beds must have been deposited from trapped sea water. The fact that they are now as much as 200 m above sea level suggests that there was a considerably higher stand of the sea against the land before isostatic uplift occurred as a result of partial deglaciation of the coastal area. The higher level of the Koettlitz Glacier that blocked the valley mouths was floating on this higher stage of the sea and may have been no thicker than the present glacier.

It is probable that sea water was also ponded in other valleys between and near the Hobbs Glacier and Miers Valley, but any resulting beds of mirabilite are still concealed beneath younger debris. Furthermore, a stand of the sea somewhat in excess of 200 m above the present strand would result in inundation of Taylor Valley to above Lake Bonney and Wright Valley to above Lake Vanda, provided there is a low-level continuation of Wright Valley beneath the Wilson Piedmont Glacier. Victoria Valley would still have been above sea level. This, in turn, provides additional support for the proposal that all of the lakes in the lower and middle reaches of Taylor and Wright Valleys contain relict sea water and marine salts now modified to varying degrees by fractional crystallization and mixing with terrestrial salts.

Bibliographic references applicable to this report, the result of two years of work, will appear in a paper now in press in the proceedings of the Third Salt Symposium.

Colored Geologic Maps of the Beardmore Glacier Area

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The idea of producing colored geologic maps of the Beardmore Glacier area developed after a very successful field program was carried out there in 1966–1967 by an Institute of Polar Studies field party that included the writers and Dr. David H. Elliot. The work of the party showed that the Beardmore area has an unusually thick section of Beacon strata, that rock exposures are widespread, and that most of the area is accessible by motor toboggan. Discoveries during the season, such as grooved pavements in the Permian glacial beds, volcanic ashfalls and well-preserved plant remains in the Triassic, and several fossil localities within the Jurassic basalts, all suggested that the area would be of continuing geologic interest.

In the summer of 1967, a manuscript was prepared for a geologic map of the area between the Beardmore and Nimrod Glaciers at a scale of 1:125,000. It was apparent from this preliminary work that the areas of exposure were relatively small and that some small exposures included as many as five formations. Clearly, patterning was not going to show the geology adequately, but colored maps might.

On the advice of the U.S. Geological Survey (USGS), it was decided to publish at a scale of 1:250,000. By scribing, instead of using conventional drafting techniques, the geology could be portrayed in adequate detail, and the plates used in producing the USGS 1:250,000 reconnaissance series could be used for the topography.

Following the 1967–1968 field season, information was either available or could be obtained from aerial photos for most of five 1:250,000 reconnaissance topographic sheets covering the Beardmore Glacier area. It was hoped that the USGS would undertake color separation and printing because of its long experience in color map reproduction and so that if other geologic maps were prepared in the future, standardization of format and color would be easier to achieve.

In March 1969, the authors spent seven days learning about the techniques used in color-map production, especially scribing, at various branches of the USGS in Washington, D.C. Some agreement was also reached on line width, colors to be used on the final product, and the general layout of the map sheets. The main outstanding problem is whether the shaded relief as used on the topographic sheets should be retained on the rock exposures as well as the snow. It adds topographic detail on the areas of snow but it will vary the color on areas of rock outcrop.

The first sheet of a new antarctic map series, the Mount Rabot Quadrangle, has been scribed and submitted for publication by the USGS, and work is well under way on the Buckley Island and Mount Elizabeth Quadrangles. Publication of the Mount Rabot sheet is expected by June 1970, and the other four sheets will be completed following a further field season in the Beardmore Glacier area by an Institute of Polar Studies party led by Dr. Elliot.

Regional Earthquakes Recorded at Byrd and South Pole Stations

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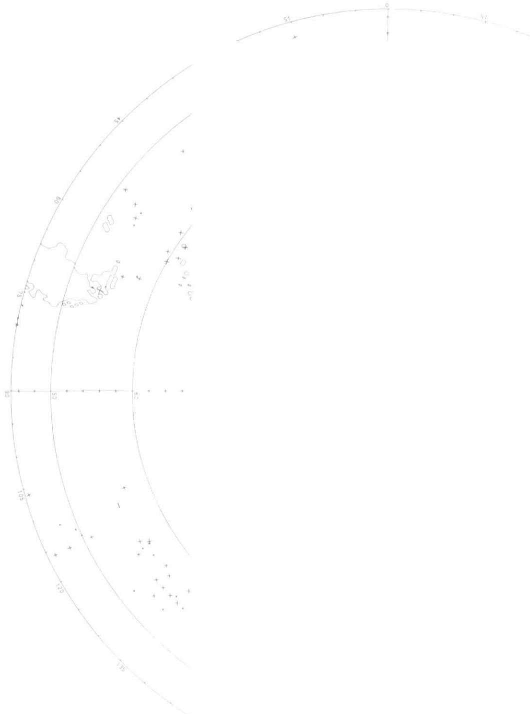
In the period 1957 through 1968, 1,058 epicenters were located south of 45°S. latitude, mostly in segments of the mid-oceanic belts which, together, form a circum-antarctic belt. Of the total, 149 epicenters were located in 1967 and 130 in 1968. The increasing density of data points clarifies the existence of zones of low seismic activity and brings out a fine structure within the more active zones. The seismicity of these mid-oceanic ridges, currently under study, plays an important role in validating theories of global tectonics and continental drift.

Figs. 1–2 show centers located before and since 1957, the beginning date of records from seismological stations on the Antarctic Continent. Among the many interesting observations is the trend of hypocenters from the southern end of the Scotia Arc across the South Atlantic Ocean. Such trends are associated with the system of the mid-oceanic ridges elsewhere, and it is expected that they define the location of a ridge not yet mapped. No earthquake has been located south of 65.8°S. in this time period.

Three separate earthquake episodes occurred at Deception Island during 1967–1969 that were recorded at South Pole and Byrd Stations. The first shock large enough to be located occurred on December 4, 1967 at 19 hr 00 min 22.6 sec at 63.0°S. 60.5°W. with a magnitude of 4.7 on the Richter scale. This shock was also reported by the seismological stations at Argentine Islands and Scott Base, as well as by stations in South America and Africa. A second event, about magnitude 4.5, occurred two hours later, at 20 hr 28 min 30.5 sec and was located at 63.2°S. 60.3°W. Four other events, all above magnitude 4, were reported by Argentine Islands, Byrd, and South Pole Stations with indicated times of origin at 19 hr 32 min 44 sec, 19 hr 48 min 46 sec, 19 hr 52 min 57 sec, and 21 hr 28 min 42 sec.

Figure 1 (right). The seismicity of the antarctic region as known prior to the IGY. The epicenters plotted were selected from data obtained before 1950 by B. Gutenberg and C. F. Richter and published in their *Seismicity of the Earth and Associated Phenomena*, and those since 1950 from the *International Seismological Summary* and the *Bulletin du Bureau Central International de Seismologie.*

Figure 2 (right, below). The seismicity of the antarctic region since the IGY. The X symbols are hypocenters located graphically before 1961 from the *International Seismological Summary* or listed in the *Bulletin du Bureau Central International de Seismologie*. The * are computer-determined solutions by the Coast and Geodetic Survey beginning with 1961. Despite some apparent spread in the older data, this plot shows great improvement in quality of data and resolution of seismic zones.



The second episode, apparently a solitary event, occurred on September 17, 1968 at 20 hr 47 min 26.4 sec at 63.0°S. 60.8°W. with a magnitude of 4.9. At this time, no other events could be identified from the reported data as originating from this source, nor were there any reports of volcanic activity.

The third episode was marked by a large earthquake on February 21, 1969 at 06 hr 32 min 23.5 sec at 62.9°S. 60.2°W. with magnitude 5.2. Antarctic stations have not reported seismic signals consistent with any other seismic events in this episode. Reports from the British and Argentine bases on Deception Island, which had been reoccupied this austral summer, indicated that the tremor began on February 14, increasing in intensity until eruption occurred on February 21 at 00 hr 43 min. This earthquake was recorded by stations in all parts of the world.

The earthquake occurred on a poorly defined zone that extends down the embayed coast of Chile and across the southern limb of the Scotia Arc to the mid-Atlantic seismic zone. It may have been large enough to have produced usable Rayleigh waves at several antarctic stations from which average structure may be inferred from the group velocity.

The Long-Period Earth Tide at South Pole

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and

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During January 1967, C. L. Hager installed two LaCoste-Romberg gravimeters at South Pole for the purpose of recording long-period earth tides and the free vibrations from a great earthquake, should such occur somewhere in the world. R. V. O'Connell then took over the unexpected job of operating these complex instruments, which were new and quite unfamiliar to him. The observations discussed here are the result of the joint efforts of Hager and O'Connell at a spot where the conditions of observation are difficult and the requirements for precision are unusually severe. For geophysical significance, the aim in measuring the amplitude of long-period gravity tides is a precision of ¼ microgal, which is one percent of the tidal amplitude, seven percent of the geophysically significant residual, but only ¼ part per billion of total local gravity.

For the observation of long-period earth tides, the Pole location has unique advantages, viz:

(a) The recordings are free from the large semi-diurnal and diurnal tidal variations present in mid-latitudes;

(b) The amplitude of the long-period tides is maximal and twice that at the other extremum, on the Equator;

(c) Because of the station's mid-continental location, the required correction for distant oceanic tides is both extremely small and reliable of estimation (at other stations, oceanic corrections may be both large and uncertain);

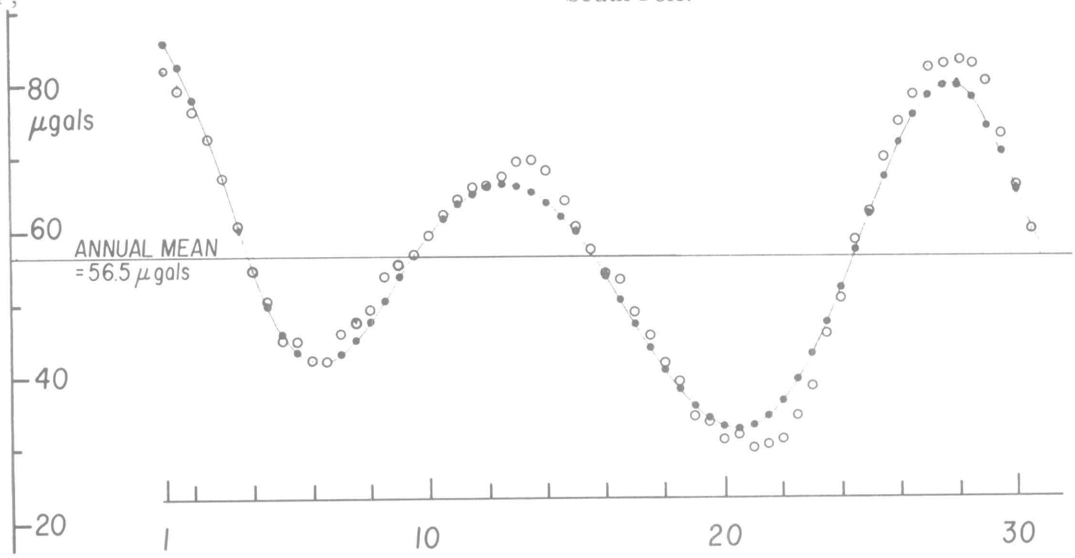
(d) From the Pole, a global mean, independent of longitude, is obtained for the gravity-tide yielding factor.

Because it is impossible with present instruments to detect a small phase lag in the long-period tides, the present objective has been to measure tidal amplitude only and, in particular, to determine the ratio of the observed gravity amplitudes to those which would occur on a perfectly rigid globe. This ratio is usually designated by δ. For the long-period fortnightly and monthly tides, it is assumed that the ratio δ is independent of the tidal period, so that the following relation may be written:

$$(g-g_o)=\delta(y-y_o)$$

where g represents an observed gravity value, y the corresponding value on a rigid earth, and $g_o=y_o$ is a reference level.

Because the records were interrupted by power failures or other causes after a month or two of satisfactory operation, it was necessary to analyze short segments of about a month's duration. A sample record is shown in the graph: the open circles represent observations, the solid circles the theoretical tide for a rigid earth. The readings have been corrected for instrumental drift to produce coincidence at a chosen mean level (here 56.5 μgals) at each intercept at this level. There is obviously room for improvement in the quality of the readings, but these initial results offer hope for precise measurements of the earth tide at South Pole.



Gravity tide at the South Pole, November 1967.

Ross Ice Shelf Studies, 1969

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Knowledge of the Ross Ice Shelf has increased steadily since the historic IGY traverses (Crary *et al.*, 1962). Ice thickness measurements by Crary using standard seismic techniques, along with accumulation studies (Heap *and* Rundle, 1964), strain measurements (Zumberge, 1964), ice velocity determinations (Hofmann *et al.*, 1964; Dorrer *et al.*, 1969), and data on the discharge of outlet glaciers into the Shelf from the western part of the drainage system (Giovinetto *et al.*, 1966) provided the basis for an assessment of the mass balance of the drainage system by Giovinetto and Zumberge (1968). The results showed a positive net budget for the entire Ross Ice Shelf drainage system even though the values used for accretion and ablation at the bottom are questionable.

Because the gain or loss of mass by bottom freezing or melting is calculated by indirect methods involving, among other things, the rate of change of shelf-ice thickness along flow lines, it is important to know the thickness of the shelf ice with greater precision and at more closely spaced points than was available to Giovinetto and Zumberge in their mass balance studies. The development and refinement of the airborne radio echo sounding technique by Evans and Robin (1966) provided the means whereby continuous ice-thickness profiles could be measured along predetermined flight lines.

Scientists from the Scott Polar Research Institute (SPRI) in cooperation with the U.S. Navy flew several flight lines across the Ross Ice Shelf in December 1967 making continuous ice-thickness profiles. These profiles, recorded on 35mm film negatives from which ice thicknesses were later measured at each half-minute of flying time using a calibrated scale under a microscope at SPRI, resulted in well over 1,000 spot ice-thickness measurements.

The flight lines were first calculated as a dead reckoning course and then corrected for wind drift and checked against a few points of known geographic coordinates. The corrections were programmed for computer analysis which resulted in computer plots of all flight lines. Fig. 1 shows the computer-corrected flight lines plotted on a base map.

The senior author spent part of February and March 1969 at SPRI working on this project. The ultimate goal was to produce an isopachous map of ice thickness for the Ross Ice Shelf between the 165°W. and 170°E. meridians and from about 82°S. to the ice front.

The ice-thickness values recorded at each minute along the flight paths were used as a basis for drawing isopachous lines on a trial and error basis with an isopachous interval of 25 m until a best fit was obtained. Some navigational errors are known to exist in the flight lines even after correction by the computer, because ice-thickness values at points of intersection of different flight paths did not agree in every case. Also, since the measurements of ice-thicknesses from the photographic record were probably accurate only to within $\pm$ 10 m, a 25-m isopachous interval was not considered warranted, and an interval of 50 m was employed in the final compilation.

After the best-fit method of drawing isopachous lines was used, ice-thickness values along flight lines were plotted on a graph and connected by a smooth line in order to refine the location of isopachous lines (Fig. 2).

The isopachous map itself will be published in connection with a further analysis of bottom melting and freezing. Future airborne radio echo soundings will be made for the Ross Ice Shelf south of 82°S., thereby providing data for the compilation of an isopachous map of the entire Ross Ice Shelf.

Acknowledgements. The senior author wishes to acknowledge the many courtesies extended to him while he was working at SPRI. Dr. Gordon de Q. Robin, Director, and Dr. Charles W. M. Swithinbank were especially helpful and provided many useful suggestions as the work progressed. Dr. Stanley Evans was helpful in discussions of the radio echo sounding techniques. The work was facilitated by the spirit of international cooperation that pervades the atmosphere at SPRI. Finally, the senior author is grateful for the support of the National Science Foundation under grant GA–198, and wishes also to express his thanks to the University of Arizona for allowing him to be absent from the campus while this work was in progress.

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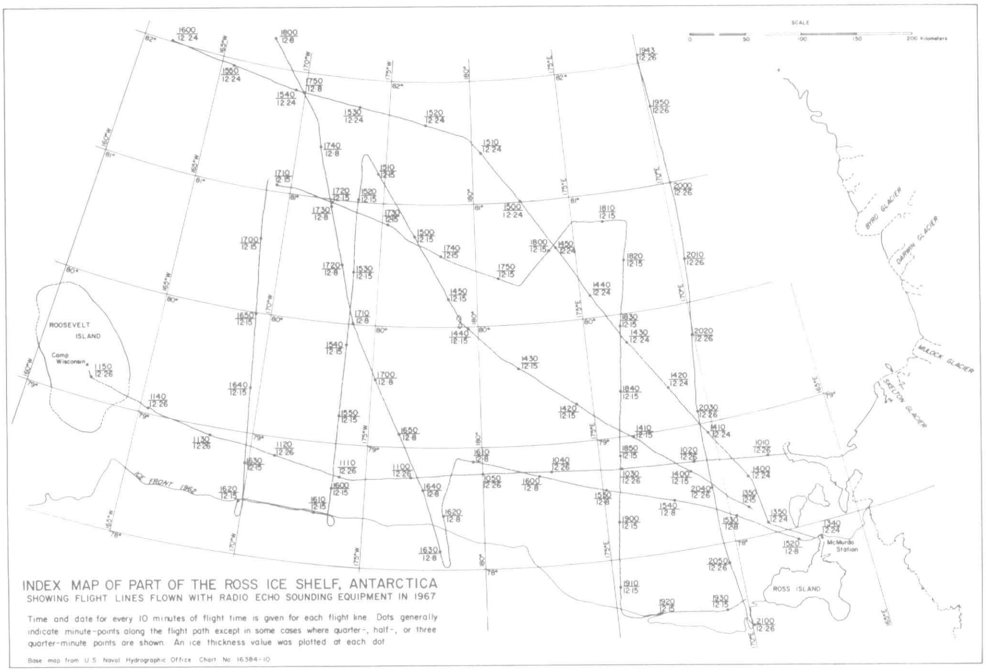

Figure 1. Computer-corrected flight lines over the Ross Ice Shelf.

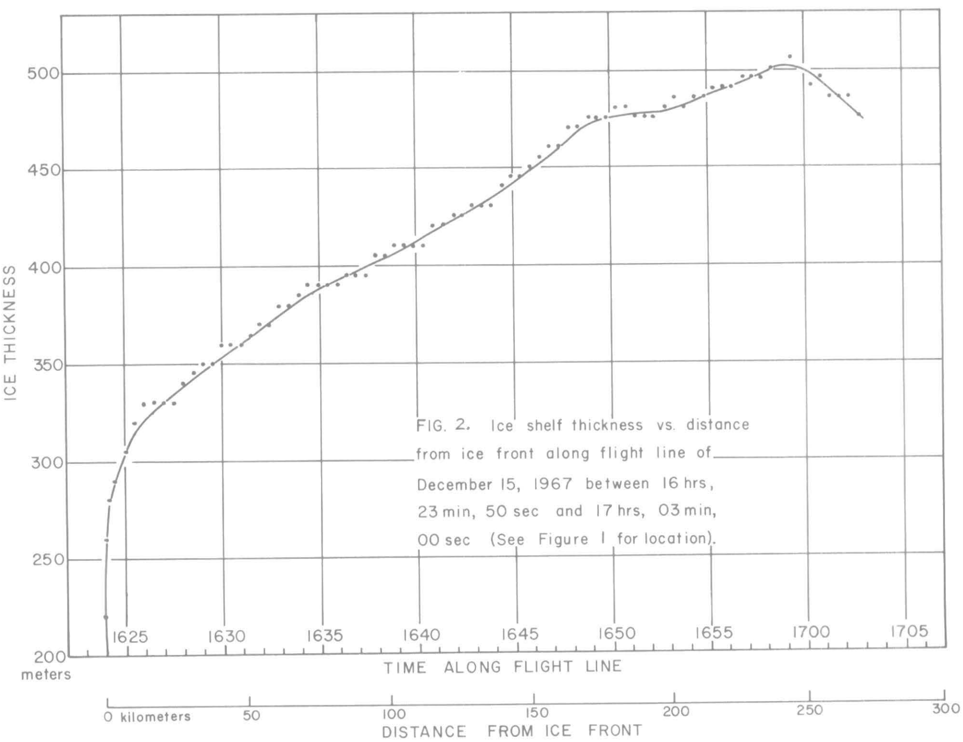

Figure 2. Ice-shelf thickness vs. distance from ice front.

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Glaciology of the Greenland and Antarctic Ice Sheets[1]

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Our present scientific maturity and logistic capabilities permit us to treat the polar regions as laboratories, and to make comparative studies on selected problems simultaneously in the North and South. We are steadily increasing our ability to do this and to make more meaningful observations on "experiments" which are under way in these laboratories. These experiments are run by nature on a continuing basis—they span an unlimited number of years and cost nothing to operate. In glaciology, the variability in critical "experimental conditions," such as mean annual temperature, range of temperature, rate of snow accumulation, frequency of storms, and extent of wind action, is very great and, although we cannot physically control these conditions, we can select the places, and thereby the conditions, that we wish to study.

A comparative study has been carried out of snow stratigraphy at selected points on the antarctic and Greenland ice sheets. The points were selected by seeking places on the two ice sheets which have nearly identical values of mean annual temperature and rates of accumulation. In this first attempt at "conjugate point glaciology," Byrd Station in Antarctica was compared with six stations in northern Greenland (see table). These stations, with comparable rates of accumulation and mean annual temperatures, have similar stratigraphic features, especially in the annual variation of snow-density values in the top 10 m of snow. However, Byrd Station has denser snow than that at the selected Greenland stations.

The difference between the average density values is significant and requires an explanation. Indeed, the Byrd Station density and load values, considered by themselves, would not even fit into the dry-snow facies of the west slope of the Greenland ice sheet. Clearly, the snow at Byrd Station belongs in the dry-snow facies because of the absence of melting and the low mean annual temperature.

Two factors seem to be involved in producing this situation—wind action and range of temperature. Because these factors vary only slightly from place to place on the west slope of the Greenland ice sheet, where the facies were originally defined, they were not treated as variables (Benson, 1962). However, they vary significantly between Byrd Station and these Greenland stations. The greater wind action and the smaller annual range of temperature at Byrd Station act together to produce the denser, harder snow.

The comparison of selected points in the north and south polar regions has just begun (Benson, 1967). However, it seems like a promising approach, both between the two polar regions and within each one by itself.

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Station	Latitude	Longitude	Elevation (m)	Average rate of accumulation ($g/cm^2/yr$)	Mean annual temperature (°C.)	Average density in top 5 m of snow (g/cm^3)	Load at 5 m depth below snow surface (g/cm^2)
Byrd Station	80°00′S.	120°00′W.	1,500	17.3	−28	0.418	209
*Station 4-50	76°19′N.	45°06′W.	2,720	17.5	−31	0.356	178
*Station 4-25	76°38′N.	45°42′W.	2,674	17.5	−31	0.356	178
*Station 4-0	76°58′N.	46°59′W.	2,616	16.5	−31	0.350	175
*Station 2-225	77°04′N.	48°01′W.	2,536	18.5	−31	0.356	178
*Station 2-200	77°10′N.	49°46′W.	2,460	22.0	−29	0.370	185
*Station 2-175	77°03′N.	51°20′W.	2,390	24.0	−28	0.372	186

* Traverse stations (Benson, 1962).

Studies on Deep Ice Cores from Greenland and Antarctica

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Last season, arrangements were made to transport from Antarctica to New Hampshire about one-half (1,000 m or 14 tons) of the Byrd deep-ice core recovered in January 1968. The U.S. Navy provided transportation by LC–130 aircraft from Byrd Station to McMurdo, from where the cores were shipped to Davisville, Rhode Island, aboard USNS *Wyandot*. All cores arrived safely in New Hampshire on March 17, 1969. These cores will provide the material needed to continue CRREL's studies of geochemical and physical properties of ice and will supply samples for other researchers involved in the NSF core-studies program.

The Camp Century, Greenland deep-ice core has been sampled at approximately 10-m intervals over its 1,380 m length and analyzed for dissolved solids. The objective of these investigations is to measure concentrations and variations in the chemical composition of the ice sheet as a function of depth in order to determine whether these small but detectable variations reflect changing climatological conditions. Replicate cation (Na^+, K^+, Ca^{++}, Mg^{++}) and anion (Cl^-, SO_4^{--}) measurements have been made on over 100 samples using atomic-absorption and ultraviolet-spectroscopy techniques. Conductivity and pH measurements have also been made on each sample. The results reveal 10 concentration maxima spaced between 73 and 1,360 m depths, which correlate favorably with climatic changes revealed in a complementary stable-isotope investigation. The ionic ratios differ considerably from sea-spray values, suggesting that the ocean is not the only source of the nuclei or fallout substances found in the ice cores. Ca^{++} and Mg^{++} show strong covariance over the entire vertical profile (correlation coefficient 0.97). Poor correlation exists between electrolytic conductivity and total (as measured) cationic content. Detailed reports of these results are being prepared by S. Leung, A. Wolf, and S. Ragone. Segments of the deeper ice core (below 500 m), the high silt-content dirty ice (the bottom 16 m), and the sub-ice material (3.5 m) have been prepared and measured for density, thermal conductivity, and creep properties. Samples of the high silt-content ice are being prepared for index analyses and mineralogical and chemical studies.

Over 2,000 small-increment samples from the Camp Century core have been measured for their O^{18}/O^{16} ratios by W. Dansgaard and associates at the University of Copenhagen. The results of these measurements are the basis for several reports, published or in press, relating to the physical, chemical, and climatic interpretations of the stable-isotope data. Four Danish scientists accompanied a CRREL team on a short revisit to Camp Century in June 1969 to collect several hundred additional samples from the surface to the 1954 stratigraphic horizon for O^{18}/O^{16} measurements. This profile will permit a tie-in to the present surface of the temperature and chronology profile obtained earlier. Six large-volume firn samples were also collected and processed for Si^{32} measurements. An additional 4,500 samples of the Century core stored in New Hampshire have been prepared for O^{18}/O^{16} measurements to obtain greater detail in the Pleistocene chronology and to refine the temperature curve.

Several laboratory studies involving measurements of the physical properties of the Byrd core as a function of depth have been completed by A. Gow. These studies include measurements of density and its changes with depth and time (after recovery from the borehole); visual stratigraphy; the effects of core relaxation on physical properties, crystal size, and orientation of the ice; and a comprehensive study of bubble shape, size, and pressure.

Samples of cores from Site 2, Camp Century, Little America, and old Byrd Station have been provided to C. Lorius, Centre d'Études Glaciologiques, France, for gas analysis. Samples of the new Byrd core have been provided to S. Epstein, California Institute of Technology, for O^{18}/O^{16} analysis. Various other ice-core samples from Greenland and Antarctica have been distributed to interested researchers for neutron activation analyses, air pollution studies, and microscopic and sub-microscopic dust investigations.

Lead, Dust, and Salt in Firn and Ice from Camp Century and Byrd Station

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The upper layers of the oceans seem to be polluted with industrial lead. Offshore from industrial areas, surface waters show much higher lead concentrations than deep waters; this effect diminishes in the open ocean. Although lead seems to be entering the oceans through rivers at greater rates today than ever before, a major fraction of pollutant lead in the oceans probably originates from the direct washout by rain of industrial lead aerosols injected into the atmosphere by the burning of lead alkyls in automotive fuels. The use of automotive fuels began in the U.S.A. in 1924; if today it serves as an important means of introducing lead into the oceans, then the lead content of the atmosphere of the Northern Hemisphere should have increased markedly after 1924.

One way of finding out whether lead pollution in the atmosphere has increased with time is to analyze the precipitated lead in successive annual layers of preserved snow. Towards this end, investigations were made of salts, dusts, and lead in firn and ice at Camp Century, Greenland and at Byrd Station, Antarctica. Block samples were sawn from the inclined shaft at Byrd and a remote site northeast of Byrd during the 1965–1966 summer.

Analysis of the samples show that lead concentrations have increased from < 0.001 γ Pb/kg ice in 800 B.C. to > 0.200 γ Pb/kg ice today in north polar ice sheets, the sharpest rise occurring after 1940. The levels of lead in south polar ice sheets are generally below our detection limits before 1940 and rise only to about 0.020 γ Pb/kg ice after 1940. The increase of lead with time in north polar snow is ascribed mainly to contamination from lead smelteries before 1940 and to burned lead alkyls after 1940. The difference between the concentrations of lead in north and south polar snow is ascribed to barriers to north-south tropospheric mixing which hinder the southward migration of aerosol pollutants from the Northern Hemisphere.

Our observations of the concentrations of the common chemical elements in ice from the interior of Greenland and Antarctica can be explained in terms of simple relations among sea salts and terrestrial dust. Dust concentrations are about 15–20 times higher in Greenland interior ice (35 γkg) than in antarctic interior ice ($\sim$ 2 γkg), but twice as much sea salt exists in antarctic interior ice (110 γkg) as in Greenland interior ice (67 γkg). The proportions of sodium, chlorine, magnesium, calcium, and potassium adhered closely to sea-salt ratios in ice that was relatively free of silicate dust, even when the concentrations of sea salts decreased from 1100 γ/kg in northwest coastal Greenland ice to 110 γ/kg in Rockefeller Plateau ice in the antarctic interior. The amounts and chemical composition of silicate dusts in Greenland were no different in coastal and interior ice, averaging 3 γ Mg, 5.6 γ Ca, 2.0 γ K, 0.1 γ Ti, and 6.8 γ Si per kg ice, respectively, in the interior. We found that there are seasonal variations in the amounts of pollutant lead, sea salts, and silicate dust in the snow, the concentration of pollutant lead and sea salts being two or three times higher in winter than in summer snow, and that of silicate dusts three times higher in spring than in winter snow.

Contrary to observations of a number of other investigators, we found that the purity of polar ice nearly equals that of the purest laboratory water. Other investigators who have studied polar ice have found values for common-element concentrations that are either much higher than ours or are so different that they cannot be explained by the simple relations mentioned above. Such data have been interpreted in a variety of ways, invoking gross chemical fractionation of sea salts or the gross addition of either silicate dusts or sea salts, but most of the conflicts among chemical data published by different investigators can be explained by contamination. It appears that the single most important factor affecting contamination is the manner of collecting the ice samples. The extreme precautions necessary to avoid lead contamination and the huge size of the samples required for the lead analyses dissuaded us from using drill-core material (which is highly contaminated). The mining procedures used seem to have provided unusually clean ice samples that were well suited for analyses of common salts and dusts.

A complete report of this work will be published in *Geochimica et Cosmochimica Acta*, vol. 33 (October 1969).

Analysis of Antarctic Geophysical Data, 1968-1969

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During the past year, the emphasis of our analysis has continued to be on the glaciological significance of geophysical data. From seismic-wave velocities in the ice sheet of West Antarctica, we have concluded that there is almost everywhere a pronounced concentration of crystal c-axes around a single mean direction which varies from place to place. Anisotropic ice composes more than half, even as much as 90 percent, of the ice column. At most observing points, the indicated mean axial direction is inclined 30° or more to the vertical, and lies in or near the flow plane, although it is nearly vertical at four locations in the West Antarctic interior, including Byrd Station. At many stations, there is clear evidence of a variation in axial orientation with depth.

Analysis of refracted wave velocities has yielded a temperature coefficient of *P*-wave velocity, 2.3 m/sec °C., in exact agreement with Robin's laboratory determination[1], and a relationship between *P*-wave time intercept and accumulation rates which might provide a more accurate determination of long-term mean accumulation rates than observations in shallow pits.

Data from three traverses in Queen Maud Land have provided ice-thickness and surface-elevation data, as well as some information concerning the subglacial terrain. A large ice stream flows from the center of the ice sheet toward Recovery Glacier. Using detailed electromagnetic sounding data, it was found that much of the ice-surface topography is related to the subglacial relief in accordance with the mechanism described by Robin,[2] wherein the effects of longitudinal stress variations are taken into account.

The subglacial surface, with a total relief of about 2.5 km, displays a strong, roughly north-south grain, and is dominated by a large high at about 30°E. and a valley below sea level to the west. Magnetic measurements suggest that the rock beneath the ice is part of a crystalline complex. The ice sheet and subglacial relief together were found to be in isostatic equilibrium throughout most of the area.

Several measurements of electromagnetic wave velocity in the ice of Queen Maud Land have been made by means of wide-angle reflection profiling and comparison of electromagnetic and seismic echo times. The mean velocity has been found to be 171 ± 2 m/μsec, corresponding, for a temperature of -10°C., to a dielectric constant of 3.08 ± 0.06. This value agrees with some field measurements made elsewhere on polar ice, but is significantly different from some others. Echo-time comparisons indicated that a major portion of the ice sheet is strongly anisotropic. The existence and horizontal continuity over at least a few hundred meters of 15 or more internal reflectors at depths between 250 and 1,250 m has been confirmed.

Further analysis of the sinking rate of South Pole Station has resulted in a quantitative model which is in satisfactory agreement with the observed secular gravity increase and topographic profiles.

Mathematical analysis leading to formal expressions for vertical and horizontal elastic displacement due to an impulsive point source in the upper, inhomogeneous part of the ice sheet has been completed. Although different wave fronts cannot be separated analytically, synthetic seismograms have been produced by numerical solution. Comparison of computed and observed Rayleigh-wave dispersion suggests anisotropy of 8–10 percent in the upper firn layers.

The following manuscripts have resulted from the current studies:

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Acharya, H. K. Propagation of a seismic pulse in the inhomogeneous antarctic ice cap. *Geophysics* (in press).

Beitzel, J. E. Geophysical exploration in Queen Maud Land, Antarctica. *Antarctic Research Series* (in press).

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Bentley, C. R. On the secular increase of gravity at South Pole Station. *Antarctic Research Series* (in press).

Bentley, C. R. Seismic anisotropy in the West Antarctic ice sheet. *Antarctic Research Series* (in press); also extended summary in *SCAR ISAGE Symposium, 1968. Proceedings* (in press).

Bentley, C. R. Seismic evidence for moraine within the basal antarctic ice sheet. *Antarctic Research Series* (in press).

Clough, J. W. *and* C. R. Bentley. Measurements of electromagnetic wave velocity in the east antarctic ice sheet. *SCAR ISAGE Symposium, 1968. Proceedings* (in press).

Further Testing for Antarctic Ice Surges

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The search for stratigraphic evidence of surges of a major ice sheet has continued in Great Britain and New Jersey. Identification of the Mollusca indicates that the three interglacial sites at 5–10 m in the Thames estuary, England, mentioned in last year's report (Judson *and* Hollin, 1968), are freshwater, although they may be within the physical range of the tide. So far, pollen counts on two of them suggest that they stem from the first half of an interglacial period, probably the Ipswichian or Hoxnian. Thus, if the sea level ever did reach the 15 and 30 m levels previously attributed to these last two interglacial periods in England (Zeuner, 1959), it must have done so in the second half of them, and to this extent the results favor Wilson's theory of late interglacial antarctic surges as the cause of ice ages. However, no actual marine deposits near these levels have come to light in the Thames estuary, perhaps because they have been removed by erosion or else because they never existed, in which case Zeuner and Wilson are wrong. On the other hand, as was mentioned in last year's report, such marine deposits have been found elsewhere in England. Hollin is continuing his search and count in

[1] Robin, G. de Q. 1959. *Seismic Shooting and Related Investigations.* Norwegian-British-Swedish Antarctic Expedition, 1949-1952. Scientific Results V, Glaciology III.

[2] Robin, G. de Q. 1967. Surface topography of ice sheets. *Nature,* 215: 1029-1032.

the Thames area, and a full report will be submitted to the *Antarctic Journal* next year.

In New Jersey, Brush has obtained a pollen profile from sediments of the Cape May formation of Sangamon age near Neptune City. The vegetation represented is temperate, similar to that of the present. The profile is terminated upward at about 2 m above mean high tide by congeliturbation features of Wisconsin age. The polleniferous sediments appear to be lagoonal and similar to the modern sediments in the adjacent lagoon of the Shark River.

Hollin presented two papers on ice sheet surges at conferences held in 1968. In one (Hollin, 1969a), he reviewed in particular the evidence for and against his earlier suggestion that Gondwanaland ice surges may be a cause of the rapid marine transgressions involved in many of the Pennsylvanian coal cyclothems. (This suggestion says merely that surges occur, not that they cause ice ages as well.) In another (Hollin, 1969b), he reviewed the evidence—chiefly based on antarctic mass-balance data and worldwide postglacial sea-level data—for and against a current buildup of the antarctic ice sheet.

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Ice Crystal Precipitation on the Antarctic Plateau

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The dominant features of the atmospheric circulation in the high southern latitudes are the outflow of cold air from the interior in the lowest layers, sinking motion over the highest and coldest part of the continent and, above approximately 600 mb, a flux toward this central area. The annual average sinking motion through the 500 mb surface has been estimated between 0.4 and 0.8 cm/sec, depending upon the assumed areal extent of the pronounced sinking motion (an idealized circular area centered at, say, 83°S. 90°E. with a radius between 1,400 and 1,000 km). In the following, 0.6 cm/sec will be accepted as a representative value.

Direct cloud observations at the South Pole, Plateau Station, and Vostok suggest that "snowfall" proper may account only for a fraction of the total accumulation. Measureable amounts of precipitation are seldom found, while "traces" are recorded almost every day, also when there are no clouds in the area. This is well compatible with the fact that the average and most frequent flow conditions over the interior of Antarctica are characterized by sinking motion in the troposphere.

Therefore, it is appropriate to examine another process—the settling of ice crystals formed by the radiative and conductive cooling of relatively moist air which is slowly subsiding from the mid-troposphere. Obviously, the crucial point for an estimate of the efficiency of this process is the vertical profile of the mixing ratio (or specific humidity). Contrary to the normal state of the atmosphere in other latitudes, over the interior of Antarctica the maximum water vapor content is not found in the surface layer, but rather in the relatively warm air above the surface inversion, that is, between 500 and 1,000 m above ground. In the South Pole area, that is the 650 to 600 mb layer. In the month of March, for instance, the maximum mixing ratio, $r(max)$, varies between 0.1 and 0.5 g/kg, while the ice-saturation mixing ratio in the lowest 200 m, where the outflow is strongest, $r_{si}(out)$ exceeds the value of 0.1 only on a few exceptionally warm days. The difference $r(max)/r_{si}(out)$ is positive on all days, the average amounting to 0.25 g/kg.

When thus the vertical gradient of the mixing ratio is directed downward during most of the year, sinking motion as well as eddy diffusion produce a downward transport of water vapor. In the near-isothermal layer above the inversion, there is little wind shear and hence little eddy diffusion. In the inversion itself, the vertical motion must decrease as the air approaches the surface. In this layer, however, there is a strong wind shear (Lettau *and* Schwerdtfeger, 1967) and, therefore, considerable eddy diffusion in spite of the extremely stable stratification of the air. Furthermore, once an ice crystal has formed, it must slowly sink under the effects of gravity and viscosity. For an estimate of the efficiency of the downward transport of H_2O, it may suffice to refer to the layer above the inversion. With a downward motion of 0.6 cm/sec and the density of the air on the order of 10^{-3} g/m^3, the supply of water vapor for ice crystal formation in the surface layer becomes 10^{-2} g of H_2O per cm^3 per day. If such a supply exists on 300 days per year, the mass of the ice crystals formed by this process in the inversion layer and eventually sinking to the surface amounts to 3 g/cm^2/year.

This kind of ice crystal precipitation can account for a substantial part of the total annual accumulation on the high Plateau, and might well be the most productive of the three possible precipitation processes over wide areas. The process is not an adiabatic one. Radiometer soundings at the South Pole have indicated that, above the inversion, the radiative cooling rate amounts to 4°/day, on cloudy as well as on clear days (Schwerdtfeger, 1968).

Deposition, or hoarfrost formation on the ground, is the third process contributing to the observed accumulation. Estimates of its efficiency in the South Pole area were given by Dalrymple *et al.* (1966) by three different methods. Two of them lead to deposition rates on the order of 10^{-3}g/cm^2/day, or 0.3 g/cm^2 for the 200 days per year with none or insignificant incoming solar radiation. The third method, based on surface heat budget considerations, does not appear appropriate to determine the deposition as long as all other terms in the budget equation are not known with much higher precision.

It must be concluded, then, that a considerable part of the total annual amount of accumulation on the antarctic plateau is produced by ice-crystal precipitation. In contrast to the normal precipitation process in clouds, it is a change from the gaseous to the solid phase of H_2O in *sinking*, not in rising air. A small fraction, less than 1/10, of the total accumulation may be hoarfrost on the snow surface itself, and only the rest would be the product of precipitation proper due to synoptic processes in the conventional sense.

The observations show that ice crystal formation in the cold surface layer occurs at temperatures above and below –40°C., a critical limit for ice nucleation. It would, therefore, be of great interest to make exact measurements of the gaseous and solid H_2O content of the inversion layer by means of absorption or filter methods, in order to determine the degree of supersaturation with regard to ice and to examine the growth of the ice crystals under natural conditions. Considering the available temperature range, which coincides with that of cirrus clouds at other latitudes, the South Pole would be the ideal location for such an investigation.

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A Satellite Study of the Ice in Antarctic Coastal Waters

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Large, Stationary Polynyas

Television and infrared observations from Nimbus I and II have been used to study large antarctic polynyas (ice-free areas in the midst of ice-covered waters) during the winter months of September 1964 and August 1966. The satellite data show that large, stationary polynyas are both more numerous and more widely distributed during the winter season than had previously been recognized.

The origin of the polynyas, which may cover an area of 5,000 km^2 or more, is primarily due to surface wind stress which removes the annual sea-ice cover from the vicinity of fast-ice, ice-shelf, or continental boundaries. Substantial, often dramatic, short-term changes are commonly observed in the size and configuration of the open-water areas. There is considerable evidence that these changes are closely linked to synoptic developments which affect the antarctic coastal region.

An example of the striking changes that can occur in little more than 25 hrs. is illustrated in Fig. 1. This previously unreported polynya north of Mac.Robertson Land is adjacent to northward-extending fast-ice projections which are stabilized by large icebergs grounded on the Fram Bank. Precise photogrammetric analysis of the Nimbus television images indicates that the fast-ice configuration mapped in Figs. 1b and 1d is a quasi-permanent feature of the winter ice regime along this portion of the antarctic coast. An analysis of meteorological conditions prevailing at the time of the observations shown in Figs. 1a and 1c indicates that westerly surface winds on the 15th were replaced by a strong easterly wind regime associated with a cyclone traveling eastward with its center a few degrees of latitude north of the coast. Theoretical considerations and available evidence suggest that the size and position of the open water areas with respect to the fast ice or other fixed boundaries at any given time depends primarily on the intensity of the surface pressure gradient, the speed and direction of translation, and the location of the center track of the prevailing synoptic system relative to the polynya.

Movement of the Amery Ice Island, 1964-1966

As a by-product of the analysis of Nimbus I observations of the Mac.Robertson Land coastal region, new information has been obtained concerning the movements of the huge section of the Amery Ice Shelf that was calved in 1964. The satellite observations

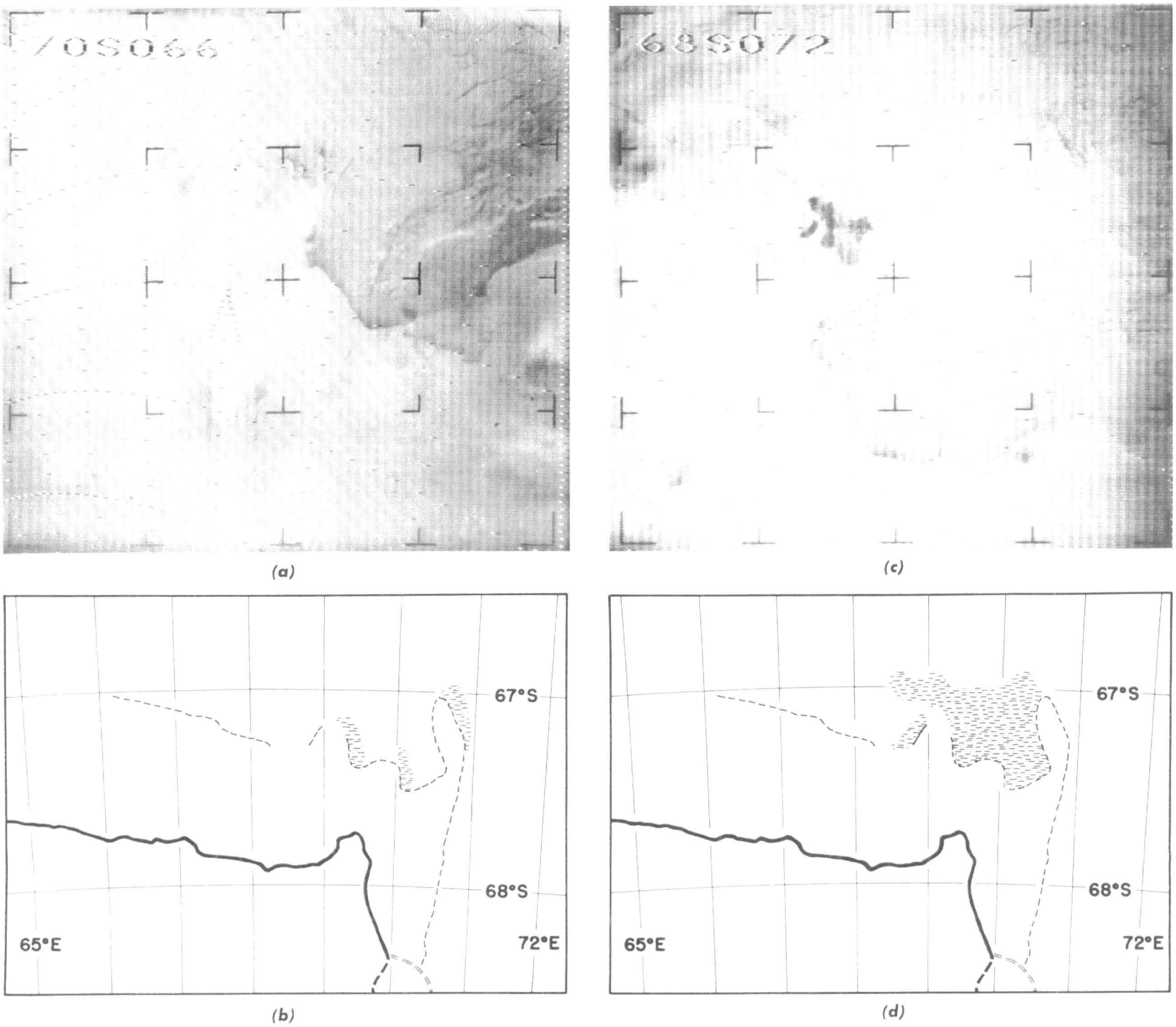

Figure 1. Nimbus II observations of short-term changes in the sea-ice regime along the coast of Mac.Robertson Land. (a) Nimbus II AVCS, Camera 1, Orbit 1225, 07:17:47 UT, August 15, 1966. Polynya located adjacent to fast-ice projections in upper center of image. (b) Map of principal ice features and open water areas seen in (a). Heavy, solid line represents continental coast line, dashed line offshore is winter-season fast-ice boundary, and shading denotes relatively ice-free areas. (c) Nimbus II AVCS, Camera 2, Orbit 1239, 08:52:58 UT, August 16, 1966. Polynya has increased markedly in size during the preceding 25 hrs. and is now located west of the north-south-oriented fast-ice projections. (d) Map similar to (b) except shading corresponds to open water areas seen in (c).

show clearly that in mid-September 1964, the missing portion of the ice shelf was located almost due north of the Australian coastal station Mawson. At the time, this gigantic island of ice was oriented with its longest dimension approximately north-south and its southern end about 90 km from the coast. These observations refute a previously expressed opinion (Ledenev *and* Evdokimov, 1966) regarding the date when the broken section of the ice shelf began its drift. They also provide a unique opportunity to estimate the integrated current between the surface and about 200-m depth in the waters north of Mac.Robertson Land.

Acknowledgements. This study was initiated while the author served as U.S. representative at the International Antarctic Meteorological Research Centre, Melbourne, Australia, from October 1965 to September 1966, through the support of NSF grant GA–267. The work was completed with the support of grants GA–515, 1251, and 10422 under the guidance of Professor Werner Schwerdtfeger at the Department of Meteorology, University of Wisconsin.

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Plateau Station Micrometeorology

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On January 20 of this year, the data acquisition system used at Plateau Station to collect and record wind and temperature profiles from the Natick Laboratories' 32-m high tower was shut down for the last time, concluding a 3-year study in micrometeorology and radiation climatology. In the following days, the tower instrumentation was removed and shipped back to the U.S.A. for calibration, and the paper tapes were sent back for data reduction and analysis.

Instrumentation used during 1968, the final year of operation, and the sought-after parameters are reviewed briefly below. The lower portion of the great inversion was investigated by monitoring the air temperature at the surface and at 0.25, 0.50, 1.0, 2.0, 4.0, 8.0, 12.0, 16.0, 20.0, 24.0, and 32.0 m above, as well as wind speed and direction at the same levels from 0.5 m upward. In addition, platinum-wound resistors were buried at 0.125, 0.25, 0.5, 1.0, 2.0, and 10.0 m depths to obtain temperature profiles in the snow. The temperature at 10 m depth remained nearly constant at about −56°C. Typical temperature inversions of about 5°C. were observed in the lowest 32-m layer in the summer months, while values of 15–20° were not uncommon in winter.

Unfortunately, a major power failure on February 29 rendered the tower program inoperative during most of the 1968 winter, and winter profiles from the 1967 data will have to be used in the final analysis. Wind shear in the 32-m layer varied from 10 to 90°, with several occasions of shear greater than 90°, and at least one observed period with positive upward shear.

In addition to the continued emphasis on radiation measurements in the visible and infrared regions (solar and terrestrial), observations in 1968 included measurements of the UV component and separation of the visible spectrum for more detailed wavelength analysis (using Eppley pyranometers with OG1, RG2, RG8, and WG7 domes). The Eppley automatic equatorial mount for normal-incidence pyrheliometers was used with limited success, but it was of particular value during the extensive calibration period this past austral summer. The four-component Davos radiometer was used exclusively during the 1968 power crisis. All of the 1966–1967 radiation data have now been reduced from the strip charts and stored on magnetic tape.

Besides several on-site calibrations of the tower instrumentation, a final calibration of these same instruments is planned in the arctic-climate chamber of the Natick Laboratories. All of the paper-tape to magnetic-tape conversion of the 1967–1968 tower data is complete; half-hourly averaged profiles of temperature and wind are being tabulated and plotted, and a careful check is being made of the log books for unreliable or doubtful collection periods and instrument failures. Special computer programs are being written (*e.g.*, to compute Richardson Numbers for the half-hourly integrated profiles) for use in the final analysis of the data.

ESSA's Antarctic Meteorological Program

CHARLES L. ROBERTS, JR.

Weather Bureau
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The ESSA meteorological program conducted at Amundsen-Scott and Byrd Stations and aboard *Eltanin* during the austral winter of 1968 included several research investigations and projects as well as synoptic measurements. Surface and upper-air observations were taken at prescribed times to provide data on temperature, pressure, wind, and the state of the atmosphere for user groups to meet operational needs and research requirements. Field investigations included:

a) Surface and upper-air measurements of ozone and radiation at Amundsen-Scott and Byrd Stations;

b) Air and carbon-dioxide sampling and secular measurements at Amundsen-Scott Station;

c) Carbon-dioxide sampling and radiation soundings aboard *Eltanin*.

The winter marked the beginning of the transition of NSF-sponsored meteorological programs from the research conducted in the post-IQSY era to the initial investigations designed to provide data supporting research planned for the next decade. This change of emphasis continues today; next year's program to a large extent will be concentrated at Amundsen-Scott Station. Synoptic measurements and research aboard *Eltanin* have been transferred to the Australian Bureau of Meteorology, and the program at Byrd has been reduced to surface synoptic and total-ozone observations. At Amundsen-Scott Station, selected "benchmark" projects were established including Atkin nuclei, snow conductivity and pH, atmospheric electricity, and air-earth conductivity current investigations.

The ESSA antarctic meteorology program is designed to provide accurate, reliable information for several national and international programs. Currently, the synoptic data are utilized in the World

Weather Watch (WWW), whose goal is to provide sufficient data on a global scale to eventually monitor weather continuously throughout the world. The program is also designed to provide base data for the investigation of problems associated with atmospheric pollution, weather modification, and climatic control. Data from areas relatively unaffected by industrial contamination, *e.g.*, the geographic south pole, are especially valuable for these studies.

Micropulsation Studies in the Polar Caps

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Geophysical Institute
University of Alaska

H and *D* component induction magnetometers have been in continuous operation since December 1964 at Vostok, near the south geomagnetic pole, and at Kanak, Greenland, near the north geomagnetic pole. A *Z* component was added to the program at Vostok in 1967, and another is planned for the Kanak operation. Recording is by strip chart and magnetic tape at speeds and sensitivities which provide data for incidence, amplitude, and polarization of micropulsations in the frequency range 0.001-1 Hz. All recording is in duplicate to provide original copies for the cooperating Soviet and Danish scientists. The investigators also operate compatible recording systems at several sites in Finland and Alaska, ranging in geomagnetic latitude from several degrees south to several degrees north of the auroral zone.

The objectives at the beginning of this research program were to study the characteristics of magnetic micropulsations at very high latitude and to determine to what extent the significant magnetoconjugate relations regularly observed at lower latitudes are also observed at the geomagnetic poles. However, the availability of the extensive auroral zone and polar cap data from the investigators' related programs has made it possible to include a study of the propagation of micropulsations in the polar cap ionosphere.

As structured *Pc* 1 is known to originate on closed field lines, its incidence at the poles is dependent on horizontal propagation in the *F* region of the ionosphere, acting as a waveguide. The analysis of the poleward propagation of *Pc* 1 activity requires that given elements of an event must be identifiable between at least two, and preferably among several, stations. The preliminary selection of such events should be made from Rayspan records and the final analysis from the more detailed sonagrams. Since only a very few of the total events occurring possess the qualities required for analysis, a large amount of data must be scanned. Practically, the selection can only be made from good resolution Rayspan records such as the one shown in Fig. 1, a 35-mm record of a *Z*-axis-modulated oscilloscope display of the Rayspan filter-system output. Since knowledge of the micropulsation polarization is also needed for the analysis, and the 6 in/hr tape does not provide sufficient resolution for *Pc* 1 polarization, a 180 in/hr magnetic tape transport was installed at Vostok in January 1969 and a similar unit is scheduled for installation at Kanak.

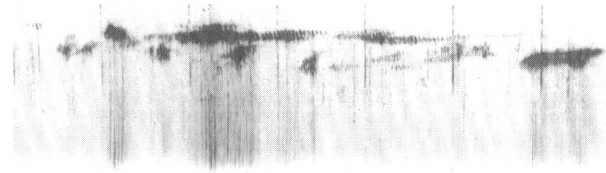

Figure 1. Rayspan record of structured *Pc* 1 activity.

A preliminary analysis of micropulsation data extending to the geomagnetic poles (Troitskaya *et al.*, 1968) shows that the positive magnetoconjugate correlation so characteristic of the subauroral zone decreases progressively toward the higher latitudes. At the poles, coincidence of *Pc* regimes or separate bursts are observed only rarely. The *Pc* pulsations at the poles have a clear diurnal variation with a maximum approximately 2 hours before geomagnetic midday, and a marked decrease in amplitude and incidence during the local winter (polar night effect). The maximum amplitudes of *Pc* 3 and *Pi* 2 occur near the auroral zone. The reduction in amplitude at the poles corresponds to the value at low and middle latitudes.

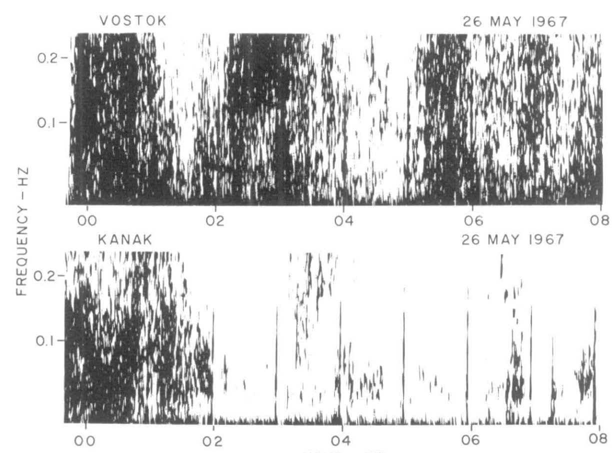

Figure 2. Anticorrelation of *Pi* activity at the geomagnetic poles.

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The lack of correlation of micropulsation activity at the poles is illustrated in Fig. 2. Similar activity occurred at both poles throughout the previous day with a corresponding lack of correlation. Narrow-band *Pc* 3, 4 activity at one pole was not observed at the other, and strong bursts of *Pi* activity did not appear simultaneously at both sites.

A study of 0.1-2 Hz polar cap micropulsation activity (Heacock *et al.*, 1969) shows a pronounced seasonal variation in incidence of structured *Pc* 1 at the pole, it being ten times as frequent in winter as in summer. This fact, together with the low amplitudes of the activity at the pole—less than one-tenth that of the activity at the auroral zone—and the accepted theory of their source on closed field lines, indicate a pronounced seasonal variation in *Pc* 1–2 propagation conditions to the pole. No structured *Pc* 2 (T=5–10 sec) were found on the Kanak records although they are fairly common at College, Alaska. *Pc* 1 frequencies above 2 Hz have not been observed in this study at Kanak. The unstructured *Pc* 1–2 activity at Kanak differs greatly from structured *Pc* activity in seasonal variation of incidence and amplitude, suggesting a source on the open polar cap field lines.

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Investigations of Cosmic Ray Intensity Variations in Antarctica

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Bartol Research Foundation of The Franklin Institute

The emission by the sun of nuclear particles having energies as high as several hundred MeV is a rare occurrence which, on the average, happens only once every two years. Thus, although the data recorded at the antarctic cosmic ray stations continue to provide the basis for a number of unique analytical studies in which galactic particles serve as probes for investigating the solar-controlled electromagnetic conditions in interplanetary space, the arrival from the sun of "newborn" cosmic rays having sufficient energy to propagate their effects through the earth's atmosphere is by far the most spectacular phenomenon that we can hope to observe with ground-based detectors. Two such events occurred during 1968: on September 29 and on November 18. The magnitude of the first was too small to permit extensive analysis (solar-particle intensity less than one percent above the galactic cosmic ray background). However, the second was sufficiently unusual to warrant detailed description here.

It is interesting to recollect that earlier theories of propagation precluded the arrival of solar particles at polar stations. However, cosmic ray flux increases have been observed during every so-called "ground level event," and, in fact, their magnitude has generally been greater than that at lower-latitude stations having directions of viewing in the equatorial plane. Studies of these events have revealed that diffusion mechanisms play an important role in the transport of particles from the sun to the earth (Pomerantz *and* Duggal, 1961; Pomerantz *et al.,* 1961a, b, c; Pomerantz *and* Duggal, 1962; Baird *et al.,* 1967).

The November 18, 1968 event is the first in which direct impact of solar particles in the polar regions has been observed with the new, high counting-rate neutron monitors. The earlier instruments would not have provided the high resolution required for the quantitative analysis that has led to the conclusion that the dominant mode of propagation in this case was guidance directly from the sun along magnetic lines of force. Fig. 1 shows the intensity of solar cosmic rays as recorded by the Bartol neutron monitors at McMurdo and South Pole Stations, as well as at the arctic station at Thule, Greenland, and at Swarthmore, where the particles arrive from the equatorial plane. Because of its altitude, the South Pole detector responds to lower-energy particles than the other stations, hence the magnitude of the increase is enhanced.

The most striking feature is the sharp rise time, in marked contrast to the slower-developing previous events, particularly the last one (January 28, 1967), described in this journal (Pomerantz, 1968). Maximum intensity was attained 15 min after onset, and the major activity subsided in about 2 hours. This event occurred while a cosmic ray storm was in progress, and was associated with a relatively minor (1B) limb flare at N21° W87° on the solar disk. The spectrum, deduced from an analysis of data from 18 stations, was of the form k exp(–P/550), where P is the magnetic rigidity in units of MV.

After normalizing the data to remove the effects of differences in altitude and geomagnetic threshold rigidity, a large variance remains in the magnitude of the increase as recorded at different stations near the peak of this event. For example, the percentage increase observed at Thule (76.6°N. 291.6°E.) was twice that at Alert (82.5°N. 297.7°E.), while no enhancement was recorded at the Soviet station at Tiksi Bay (71.6°N. 128.9°E.).

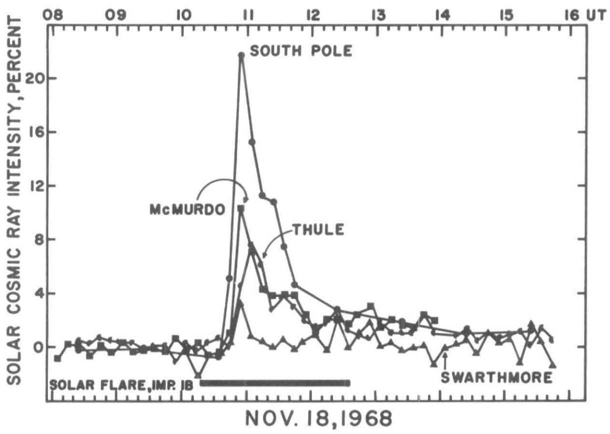
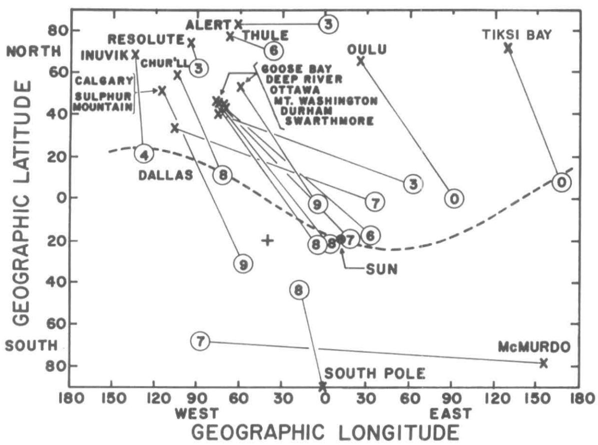


Figure 1. (above). Solar cosmic ray event of November 18, 1968, as observed by Bartol neutron monitor stations. The ordinates are percentage increase in intensity above the galactic cosmic ray background. South Pole Station recorded the largest flux detected anywhere on the earth's surface.

Figure 2 (below). For each station from which data were available, X represents its geographic location, O is the asymptotic direction of viewing of its detector, and the number indicates the percentage enhancement (appropriately normalized to remove the effects of altitude and geomagnetic cutoff differences) above the galactic cosmic ray background. The axis of symmetry, +, represents the position of the apparent source, which is 50° west of the sun-earth line, corresponding to the garden-hose angle characterizing the Archimedean spiral structure of the interplanetary magnetic field.



In Fig. 2, the normalized maximum percentage increases during a 20-min interval are indicated in circles representing the approximate asymptotic directions of arrival of the solar particles to which the detectors at the specified locations (X) respond. Our analysis reveals that the intensity increase was symmetric with respect to a point on the celestial sphere with geographic coordinates 20°S. 40°W. This location was 50° west of the position of the sun at that time, which conforms with the Archimedean spiral structure of the interplanetary magnetic field and confirms that the solar particles were magnetically guided from the source. Because of the rapid decrease in the flux to a low level shortly after the maximum, it is not possible to determine when diffusion ultimately became the principal propagation mechanism.

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Doppler Radio Soundings of the Antarctic Ionosphere During 1968

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The original objectives of this program and the experimental techniques employed have been described previously by Davies and Jones (1968). Essentially, the frequency perturbations of 6-MHz radio echoes were recorded continuously during the period November 1967 through November 1968 over several paths originating at South Pole.

One of the original objectives was to determine the velocities of large-scale traveling ionospheric disturbances by means of space and time correlations. However, because of the diffuse character of the antarctic Doppler-frequency records, such correlations have not yet been possible. The typical characteristics of the records are illustrated in Fig. 1a and 1b for summer and winter, respectively. During the day in late summer, the signal is reflected from a rather stable *E* layer at a height of about 100 km, whereas during the night, reflection is from the *F* layer (~250 km). The *F* layer echo is usually spread and essentially structureless, especially during winter. Sometimes it contains a central core (Fig. 1b).

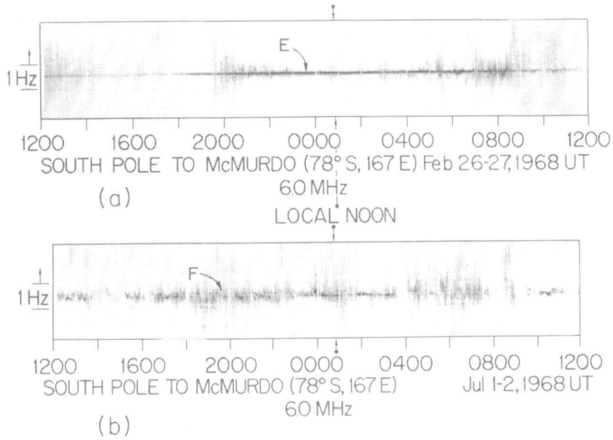

Figure 1. Frequency records for (a) a summer day, (b) a winter day.

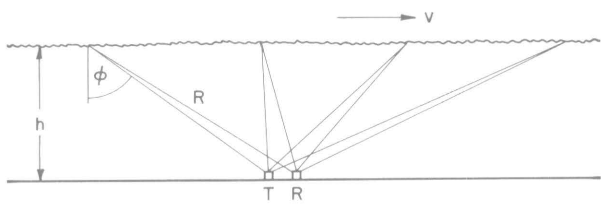

Figure 2. Ionospheric model explaining the symmetrical broadening of carrier frequency.

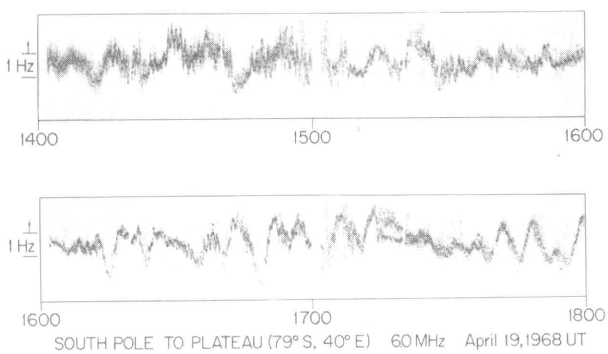

Figure 3. Example of short-period fluctuations in echo frequency.

The frequency spreading of *F*-region echoes is associated with rapid amplitude fluctuations or fading of the radio signals and is, therefore, of considerable importance in antarctic radio communications. The symmetrical frequency spreading seen in Fig. 1a can be explained, for example, by a "perfectly rough" ionospheric model moving horizontally as illustrated in Fig. 2. With this model, weak reflections are obtained from a relatively large area of the ionosphere. The reflecting centers moving towards the path's midpoint will give rise to positive frequency shifts, and those receding will give rise to negative shifts. When the ionosphere is not perfectly rough, the echo will consist of a spread spectrum superimposed on a specular component (Fig. 1b). The frequency of the

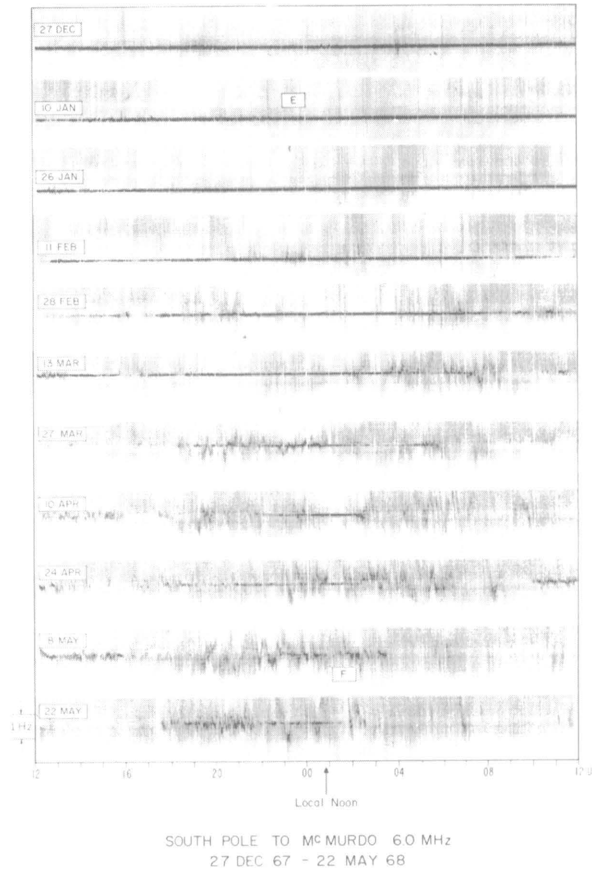

Figure 4. Seasonal variation of frequency records.

specular component (the core) may itself vary because of height variations of the entire reflecting/scattering region.

These latter height variations (see Fig. 3) often result from the passage of atmospheric (acoustic-gravity) waves through the neutral atmosphere (Hines, 1960). The ionospheric electrons are moved by collisional interaction with neutral molecules. Close inspection of Fig. 3 shows small amplitude fluctuations with periods of around 1 min superimposed on periods in the range 5 to 10 min. Ionospheric disturbances with these periods have been observed in middle latitudes (Baker *and* Davis, 1968, 1969).

The seasonal variation in the frequency structure is shown in Fig. 4. In mid-summer (December), continuous reflection is from the stable *E* layer, and there is relatively little frequency broadening. With the approach of winter, the presence of *E* echoes is confined more and more around local noon, essentially disappearing in April. During winter days, the *F* echoes exhibit little or no frequency structure. It may be noted here that the above interpretation is in close agreement with ionogram data from Antarctica in that diffuse frequency structure is almost invariably associated with spread *F*.

The program is continuing through 1969, but because of the closing of Plateau Station, some rearrangement of transmitting and receiving stations was necessary. In the present arrangement, a 7-MHz signal from McMurdo is received at South Pole and Byrd, and a 6-MHz signal from South Pole is received at Byrd. In addition, both the 6-MHz and 7-MHz signals are being received at Vostok. The reflection points of these signals are more closely spaced than those in the previous arrangement.

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Geomagnetism Program at Byrd, South Pole, and Plateau Stations

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The antarctic geomagnetism program of the Coast and Geodetic Survey (C&GS) continued during 1968 with the recording of variations of three orthogonal magnetic components—including vertical intensity—in the earth's magnetic field at Byrd, South Pole, and Plateau Stations. After nearly three years of continuous operations, the program at Plateau Station was terminated in December, 1968, as that station was being prepared for closing.

Having acquired an operational longevity of some 11 years, Byrd and South Pole Stations are solidly established among C&GS's 14 magnetic observatories as sources of data having the degree of accuracy and reliability necessary for the determination of secular change rates and patterns used in magnetic charts. Although the Plateau observatory was in operation only for a relatively short period, the data from that part of Antarctica will contribute significantly toward improved accuracy in the 1970 issue of the World Magnetic Charts.

In addition to the continuously recording magnetographs at each of the three antarctic magnetic observatories, absolute instrumentation of a high degree of resolution (tenths of gammas) and accuracy, traceable to international magnetic standards, were employed frequently for calibration purposes.

Aside from the more obvious geophysical considerations and remoteness factors, antarctic magnetic observatories benefit from a seldom-recognized natural advantage unduplicated any other place in the world. This advantage is provided by the thickness of the ice, which removes the sensors (up to almost two miles at South Pole Station) from the effects of crustal sources of magnetic anomalies and of structural geologic materials having varying induction characteristics.

Data from C&GS antarctic observatories collected in 1968, as well as all data from previous years, are being analyzed for the time-space dependent variations of secular change. The results of the analysis will be reflected in the 1970 issue of the World Magnetic Charts. This series of charts is compiled at 5-year intervals by C&GS. In general, there is a relatively rapid decrease in the antarctic total field intensity (on the order of 100 gammas annually); however, a complete analysis of all the magnetic elements is necessary to portray the dynamics accurately in graphic form.

All geomagnetic data collected by C&GS are available through World Data Center A, at cost of reproduction.

Auroral Observations at the South Pole

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In the past, a considerable amount of upper atmosphere research was conducted along the auroral zone under the assumption that this zone was the belt of maximum occurrence of auroras and that significant phenomena occured only in this belt. We know now that auroras occur in the auroral oval, more than half of which lies a little inside the auroral zone. For this reason, studies of upper atmosphere phenomena which occur a little inside the auroral zone have become important. Fig. 1 shows the approximate location of the southern auroral oval at 16 UT, together with the location of the auroral zone.

The uniqueness of the South Pole for auroral observations is that it is located near or under the auroral oval for most of the day (except for the few hours around midnight), whereas a typical auroral-zone station comes under the oval for only a few hours around midnight. Furthermore, the magnetic midday auroras (that is, auroras which occupy the midday part of the oval) can best be observed from the Pole because the shadow is highest there, thus affording the best seeing conditions.

We know now that the auroral oval, which appears along the intersection between the outer boundary of the trapping region and the ionosphere (Fig. 2), is closely related to the internal structure of the magnetosphere. At 16 UT, the South Pole is located near the "foot" of the field line that lies close to the midday boundary of the magnetosphere around that particular hour. The nature of the boundary of the magnetosphere is a matter of controversy, but it is generally believed that it is of the tangential discontinuity type during quiet conditions and that it becomes a contact or rotational type during disturbed conditions. Thus, we are interested in the behavior of midday auroras for different magnetic conditions.

Fig. 3 shows two all-sky photographs of auroras in the midday sector, taken on June 20, 1968 only several minutes apart. Note that a single band appears to have split into two bands, both of which show well-developed folds. There are many other types of activity associated with midday auroras. We plan to examine worldwide magnetic records to determine relationships between different types of auroral activity in the midday sector and the corresponding magnetic activities.

The South Pole moves under the auroral oval for several hours in the "dark" afternoon. Such a condition does not exist in any part of the U.S.A. or Canada (it does occur occasionally at the T-3 drifting station in the Arctic Ocean). A preliminary scanning of the South Pole films shows a large number of surges traveling westward along the oval after being generated in the midnight sector during auroral substorms. Thus, the South Pole data are useful in elucidating auroral morphology along the oval in the afternoon sector, which is still poorly known. It is hoped that the all-sky records will prove useful also in other upper atmosphere studies being conducted at the South Pole Station.

This project is supported by National Science Foundation grants GA-1172 and GA-13556.

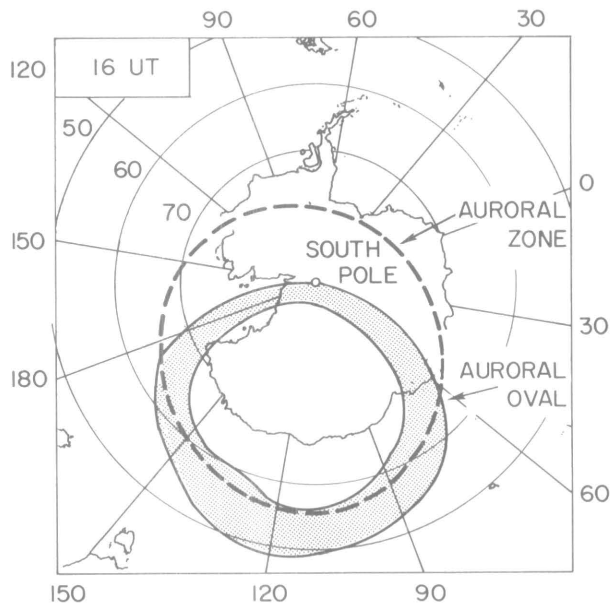

Figure 1. Location of the auroral oval at 16 UT over the Antarctic. The location of the auroral zone is also shown.

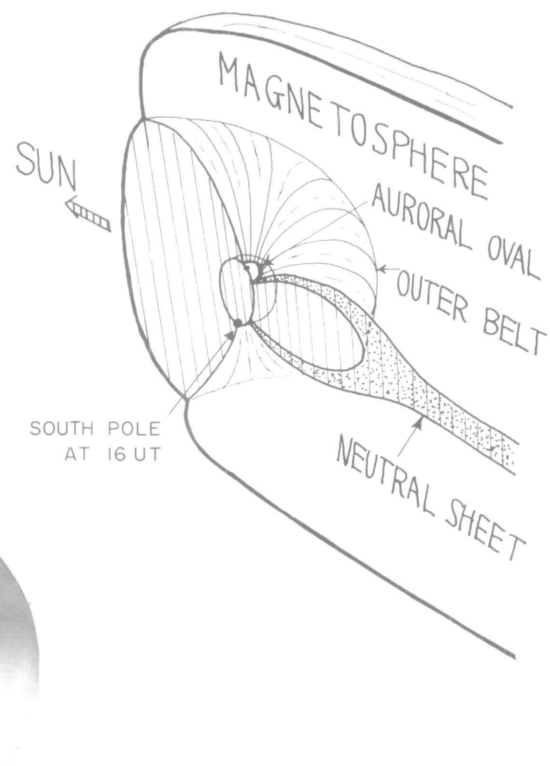

Figure 2 (above). Noon-midnight meridian cross-section of the magnetosphere. Note the location of South Pole Station at 16 UT.

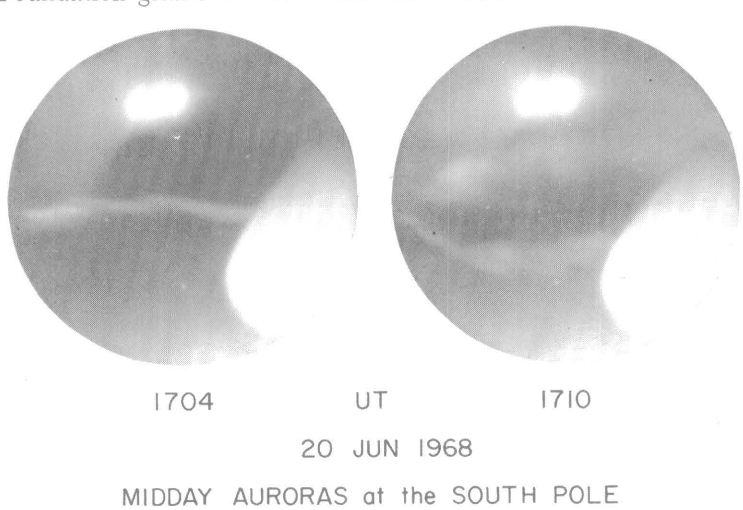

Figure 3 (left). Photographs of the auroras in the midday (magnetic) sector, taken from South Pole Station on June 20, 1968.

Riometer Observations of the Antarctic Ionosphere

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W. L. ECKLUND, *and* F. C. COWLEY

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Continuous observations of ionospheric absorption events were carried out during the past year at Byrd, South Pole, and Vostok Stations (in cooperation with the Soviet Antarctic Expedition), using riometers at frequencies of 30 and 50 MHz. Solar activity increased markedly over its relatively low level during the preceding year, and a considerable amount of data on polar-cap absorption (PCA) events was obtained. Detailed analysis of the PCA data is now under way.

Much of the effort has gone into analysis of data obtained in earlier years, and the detailed results of this analysis are now appearing in the literature. In connection with PCA, a study of the riometer data obtained from high-latitude locations in both hemispheres during the major event in September 1966 has been completed (Reid, 1969). Fig. 1 shows the 30-MHz absorption at five stations during both daytime and nighttime conditions in the ionosphere. The difference between these two sets of observations is quite noticeable, and comparison with simultaneous

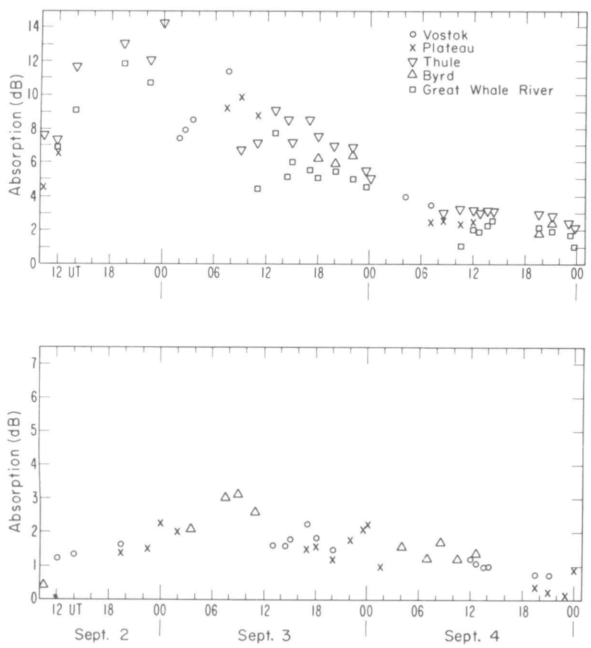

Figure 1. Vertical radio-wave absorption recorded by 30-MHz riometers at five high-latitude locations during the PCA event of September 2-5, 1966. The upper diagram shows data obtained during daylight in the lower ionosphere, and the lower diagram shows night-time data.

satellite measurements of proton flux and spectrum has yielded evidence supporting earlier suggestions that atomic oxygen is of major importance in determining electron concentrations in the lower ionosphere.

A detailed study of data obtained from the five-way riometer system operated for two years at Byrd and its magnetically conjugate station, Great Whale River, has also been completed (Hargreaves, 1969). Analysis of about 600 auroral absorption events has shown that the relative positions of event centers in the two hemispheres (which may be identified with conjugate points) vary seasonally over distances of the order of 100 km. This seasonal variation is insufficient, however, to explain the winter asymmetry in absorption between hemispheres that was discovered some years ago (Hargreaves *and* Chivers, 1965), and it has been examined in considerably more detail in the present study. It appears likely that this asymmetry, which has a marked diurnal variation, is caused by a real difference in electron-precipitation intensity between the summer and winter hemispheres, although a seasonal variation in chemical composition of the lower ionosphere cannot be ruled out entirely.

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Reid, G. C. 1969. Associative detachment in the mesosphere and the diurnal variation of polar-cap absorption. *Planetary and Space Science,* 17: 731-736.

Conjugate-Point Auroral Studies at Byrd and Great Whale Stations

PETER M. MILLMAN

National Research Council of Canada

The magnetic field line that passes through Byrd Station in the Antarctic touches the earth at its northern end near Great Whale Geophysical Station, on the eastern shore of Hudson Bay, Canada. The latter station is operated by the National Research Council of Canada (NRC), and for several years conjugate-point auroral research has been carried out at Byrd and Great Whale in cooperation with the ESSA Research Laboratories in Boulder, Colorado, and the Arctic Institute of North America (AINA) in Washington, D.C.

High-latitude conjugate-point studies are handicapped by the fact that, during most of the year, there is darkness at one conjugate point when there is daylight at the other. If, however, we include periods of twilight (when the sun is more than six degrees below the horizon), we have some 1200 hours a year when the sky is dark simultaneously at Byrd and Great Whale. The periods of clear, dark sky at any one station will total less than half the above figure, however, and the periods of clear, dark sky simultaneously at both stations will be very much less.

The identical auroral instrumentation which has been operated at both stations consists of an auroral photometer utilizing a photomultiplier tube, and two all-sky cameras, one using black and white 35-mm film, and the other, color 16-mm film. The photometer covers a field of 13° width centered on the zenith, and produces an analog signal on a strip-chart recorder with a time resolution of a few seconds. The recorded wavelength is a band about 50 A wide at 5577 A, the forbidden green line of OI.

During 1968, the two photometers recorded simultaneously for some 1300 hours and produced good records during this time. The four all-sky cameras operated simultaneously for approximately 1200 hours. During these periods, there were 100 hours when the sky was clear at both ends of the field line, and the prime records obtained during these periods are now being analyzed to determine variations in the degree of conjugacy between the two stations. Future plans call for a network of auroral photometer stations around Great Whale to enable more detailed studies of how the field line passing through Byrd fluctuates at the northern end with the changing parameters of the earth's magnetic field.

The operators of the equipment at Byrd Station in 1968 were Messrs. M. Frederick Cady of ESSA Research Laboratories and Gregory S. Richter and Michael Kramer of the ESSA Weather Bureau. It is to their credit that the 1968 records are of such good quality and that the down-time of the instruments was less than 5 percent. The scientists involved in setting up the equipment and in studying the results in Ottawa include Dr. Michael D. Watson of NRC and Mr. A. Lawrence Spitz of AINA.

Translation in Preparation

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

Arctic and Antarctic Scientific-Research Institute. *Scientific results of Soviet antarctic expeditions.* Leningrad, 1968. 264 p. (*Its* Transactions of the Soviet Antarctic Expedition, vol. 38).

Support Services

Cartographic Activities of the U.S. Geological Survey, 1968-1969

R. B. Southard

Topographic Division
U.S. Geological Survey

Geological Survey topographic field operations in Antarctica were described in the July–August 1969 issue of the *Antarctic Journal.* Other activities in connection with the antarctic mapping project were performed in the Washington, D.C. area.

The results of earlier field work were computed and used with aerial photographs obtained by U.S. Navy Antarctic Development Squadron Six to Survey specifications for the compilation of maps in support of U.S. Antarctic Research Program activities. Nine maps completely covering the Pensacola Mountains, and four maps of the area between 74° and 76°S. in southern Victoria Land, were published at 1:250,000 scale covering about 46,000 sq. miles. Mapping at the same scale is in progress for 14 maps in northern Victoria Land and 22 maps in the coastal area of Marie Byrd Land between Cape Colbeck and Bear Island. Three 1:500,000-scale sketch maps were published in shaded-relief editions, covering the coastal areas of Ellsworth Land between Thurston Island and the Lassiter Coast (about 120,000 sq. miles of previously unmapped area).

Fifty-eight completed quadrangles in shaded-relief editions at 1:250,000 scale, covering 238,785 sq. miles, and 7 sketch maps at 1:500,000 scale, covering 331,700 sq. miles, are now available. An *Index to Topographic Maps Antarctica, Scale 1:10,000,000* was issued showing all antarctic maps published by the U.S. Geological Survey.

The AGS 1:3,000,000-Scale Map of Antarctica

Douglas Waugh

American Geographical Society

Since reporting in the September-October 1968 issue of the *Antarctic Journal* (vol. III, no. 5, p. 214), the American Geographical Society has continued to keep up to date its four-sheet map of Antarctica at a scale of 1:3,000,000.

After some of the more extensive changes of last year, the alterations this year are somewhat smaller by comparison, but nonetheless important for a more complete and accurate picture of the Continent. The most recent adjustments (see accompanying map) are as follows:

1. Addition of bathymetric details and changes in Coats Land (Chart H.O. 6640, 1:5,000,000, U.S. Naval Oceanographic Office, October 28, 1968);

2. Changes in positions of features and additional cartographic detail and new names in southern Palmer Land (U.S. Geological Survey 1:500,000 shaded relief map of Ellsworth Land east–Palmer Land south);

3. A new configuration of the Larsen Ice Shelf (British D.O.S. sketch map of the Antarctic Peninsula, 1:3,100,000, 1968);

4. A small adjustment in the edge of the Filchner Ice Shelf (series on the Argentine expedition to the South Pole, 1:200,000, 1965);

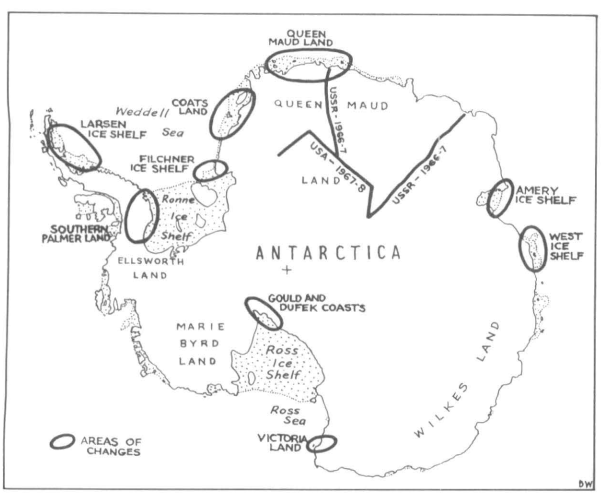
5. A change in the Fimbul Ice Shelf due to the breaking off of the "Trolltunga" ice tongue (satellite photography);

6. Additional data along the final leg of the South Pole–Queen Maud Land Traverse of 1967 (published records);

7. A new ice front to the Amery Ice Shelf (ANARE charts of the expedition of *Nella Dan,* 1:1,000,000, 1968);

8. Some improvements in the coastline of central Victoria Land and in the Gould and Dufek Coast regions (U.S.G.S. compilations and published maps, 1:250,000, 1968).

A new 9-sheet U.S.S.R. map at a scale of 1:3,000,000 shows more detail on the locations, elevations, and ice thicknesses along the 1967 Molodezhnaya–Novolazarevskaya traverse, and some noticeable changes along the coast of Queen Maud Land near Novolazarevskaya and in the West Ice Shelf.



Antarctic Map Folio Series

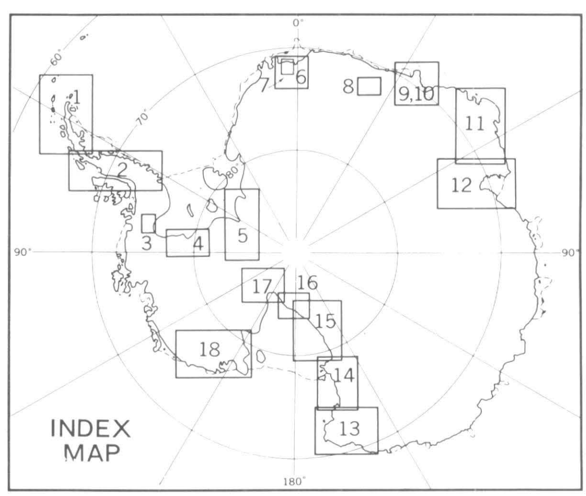
Vivian C. Bushnell

American Geographical Society

Cartographic and editorial work are in progress on five folios. The three described here are nearest to completion.

A folio on the bedrock geology of Antarctica, an important achievement in compilation and cartography, will be published before the end of the year. It includes 18 regional maps (see figure) at scale 1:1,000,000, with accompanying text, compiled by 24 geologists from 8 nations. Each contributor is a specialist in the locality covered by his map. The areas of the Continent included in the maps are shown in the figure. In addition, Campbell Craddock of the University of Wisconsin, coeditor of the folio, has compiled a geologic map of the entire Continent and written an explanatory text. Also, some of the most widespread geomorphic features of the Antarctic Continent have been mapped and described by Robert Nichols of Tufts University.

Another folio nearing completion is titled *Circumpolar Characteristics of Antarctic Waters.* In contrast to Folio 6, which dealt only with the waters between 20°W. and 170°W., the forthcoming folio covers all ocean areas surrounding Antarctica as far north as 40°S. The authors are Arnold L. Gordon, Robert D. Goldberg, and Kenneth Hunkins. Plate 1 is a station map with symbols to designate stations of oceanographic cruises occurring (1) before 1930, (2) from 1930 through 1949, and (3) from 1950 till the present. Plates 2 through 8 show isolines for temperature, salinity, and oxygen; Plates 2 and 3 give summer and winter means at 20 m depth, the others annual means at selected depths from 200 m to 3,000 m. On Plates 9 through 16, the above data are presented in a more specific manner. Again, each plate is devoted to a



particular depth, at which average values of temperature, salinity, and oxygen are given for areas bounded by 5° of latitude and 10° of longitude. For any 5° × 10° area, all three values are plotted on the same map around a point which is the average location of the stations within the area. Plates 17 and 18 are devoted to vertical meridional sections showing temperature, salinity, and oxygen variations. Plate 19 contains two maps of sound velocity in the axis of the SOFAR channel; one map is for summer, one for winter.

A third folio is devoted to birds, including penguins, albatrosses, petrels, fulmars, skuas, terns, and others. Sighting and specimen records of some 50 species have been plotted along with breeding localities, when known. Under the supervision of George Watson, Smithsonian Institution, data for the maps have been assembled from extensive published and unpublished records. Compilers include J. Phillip Angle, Margaret Bridge, Peter C. Harper, John C. Boyd, W. L. N. Tickell, and Roberto Schlatter. William J. L. Sladen helped in planning the folio.

Antarctic Geographic Nomenclature

FRED G. ALBERTS

Geographic Names Division
*U.S. Army Topographic Command**

The Geographic Names Division performs the research and other staff functions for the Advisory Committee on Antarctic Names (ACAN), which makes recommendations on antarctic names and policy to the Board on Geographic Names (BGN) and the Secretary of the Interior. The Division maintains records and files on antarctic nomenclature and provides inquiry service on names for this region.

During the year ending June 30, 1969, the ACAN met six times. It recommended the approval of 369 new names and the amendment of two others. New names were provided for use on fourteen 1:250,000-scale maps of the area west of Cape Adare which were in various stages of preparation at the U.S. Geological Survey. Additional new names were provided to authors of reports on Antarctica as needed.

In addition to research on new names, work was completed at the Geographic Names Division for publication of a third edition of BGN Gazetteer No. 14, *Antarctica*. The updating of this publication is of special interest in that it provides the only comprehensive list of names covering the entire Continent. The new volume, to be issued shortly, lists all 10,000 names approved by the BGN, including approximately 1,500 new names and two dozen amended names approved since 1966. The bulk of the new names apply to landmarks in eastern Marie Byrd Land, Ellsworth Land, southern Palmer Land, the Pensacola Mountains, and northern Victoria Land—all areas mapped in the past few years by the U.S. Geological Survey. Older feature names within these areas have been reviewed, and precise map locations for discoveries reported earlier have been determined. Reflecting this aspect of the research, the new gazetteer provides revised geographic coordinates for over 500 names listed in the previous edition.

Hundreds of inquiries on antarctic names were received and answered by the Geographic Names Division. These inquiries generally pertained to the correct spelling of names, the location of features, the origin or meaning of names, and their application. Galley proofs were reviewed for volumes 13 and 14 of the *Antarctic Research Series*. Name information was provided to the American Geographical Society for use in maintaining an up-to-date map of Antarctica, and various Government maps and charts of the region were edited prior to their publication.

* Formerly U.S. Army Map Service.

Smithsonian Oceanographic Sorting Center Continues its USARP Activities*

In six years of cooperative work with USARP, the Smithsonian Oceanographic Sorting Center (SOSC) has received over 8,000 samples of antarctic animals and plants, the majority of them from marine collections, primarily of benthic and planktonic invertebrates. From 16 USARP sources, 183 separate collections have been sent to the Center for processing and distribution. Most of the collections are from USNS *Eltanin* cruises, although some material has been received from USCGC *Eastwind* and R/V *Hero*, and from shore and continental expeditions. The Center recently received over 1,000 bryophyte specimens collected by the late Dr. R. Hatcher during the Chile–United States Botanical Expedition to Juan Fernández Islands—1965 and arranged into several duplicate sets by Dr. Henry A. Imshaug of Michigan State University. SOSC distributed these sets to 11 cryptogamic herbaria in 5 countries.

In contrast to the high collecting activity of earlier years, the Sorting Center received only 232 samples from 6 USARP expeditions during the past year. The Center did not receive any collections from four of last year's six *Eltanin* cruises.

* Prepared by the staff of the Smithsonian Oceanographic Sorting Center of the Smithsonian Institution.

In spite of the decrease in the number of new USARP biological collections, the processing activities at the Sorting Center have continued at a high level, and the backlog of older collections is being eliminated. By mid-1969, the Center had distributed more than 4,000,000 sorted USARP specimens to 100 specialists in 10 countries. A more substantial portion of the collection backlog would have been processed had it not been for the considerable reduction in available NSF funds, which forced the dismissal of about one-third of the USARP-supported staff at mid-year.

Over 3,000 unprocessed samples are left from older collections. The demand for certain types of specimens remains high, and there is ample work for several years at the present funding level, even if no new material is received. However, to maintain interest in antarctic specimens and to satisfy the increasing number of requests from new specialists, future USARP expeditions should broaden rather than curtail their collecting programs so that additional new material will be available for distribution by SOSC.

Air-conditioning and other recent improvements to the Sorting Center's physical facilities will increase the efficiency of operations and augment the specimen-storage capabilities.

Rock Samples from the Antarctic Seas

Tom Simkin

Smithsonian Oceanographic Sorting Center
Smithsonian Institution

Bottom trawls or dredges have been lowered from the deck of *Eltanin* at least 700 times since 1962. Research efforts have concentrated on the biological samples recovered, but with increasing interest in marine geology and attendant awareness of our ignorance of sea-floor rocks, attention is now being turned also to the rocks brought up by these samplers. The Smithsonian Oceanographic Sorting Center (SOSC) inventories the full sample obtained from each locality and then distributes individual specimens in response to specific requests. Initial SOSC identification of the full sample maintains the coherence of the collection, and distribution of appropriate specimens to specialists assures optimum scientific benefit from it.

As a by-product of its biological sorting activities,* SOSC has received rock samples from 130 stations and, in January 1969, 2,500 pounds of rock samples were transferred to SOSC from Florida State University. SOSC now has samples from 314 station locations on which the first stage of a collection inventory has been completed. A description of each full sample is condensed into a tabular format that can be quickly scanned for a particular lithology, topographic feature (*e.g.*, ridge crest), depth, or geographic location. Weight, number, size, and shape of the specimens in each sample is also noted and, since ice-rafted rocks form a significant proportion of sea-floor samples near Antarctica, additional data have been included on sampling history, local bathymetry, and associated sea-floor photography that will help in assessing the relationship of locally derived rocks to ice-rafted erratics in a specific sample.

As optical petrographic identification of individual specimens (the second stage of the inventory) proceeds, the preliminary inventory will be revised and expanded where necessary. Specimens will be supplied to qualified investigators making specific requests, and copies of the preliminary inventory will be mailed to interested specialists.

* See *Smithsonian Oceanographic Sorting Center Continues its USARP Activities,* in this issue.

Status of the National Data Bank for Antarctic Natural History Collections

B. J. Landrum

Smithsonian Oceanographic Sorting Center
Smithsonian Institution

The Smithsonian Oceanographic Sorting Center (SOSC) has completed its first year of application of automatic data processing techniques to some of the problems of maintaining records on the national collections of antarctic natural history specimens. Most of the programming needs have been met, and minor modifications to improve the system should be complete by fall. Capabilities of the system include rapid storage and retrieval of records on taxonomic groups of plants and animals ranging from phylum to species levels, and the ability to reconstitute and selectively retrieve all data on the original sample contents regardless of the level of identification or location of the specimens.

By July 1969, the data bank comprised over 50,000 records. Particular emphasis during the year was placed on processing a backlog of information on antarctic samples sorted at SOSC since the organization first became involved in the USARP activities in 1963. These records pertain to the majority of marine invertebrate specimens collected on USNS *Eltanin* cruises. The records now on magnetic tape cover approximately 1,425 samples taken on Cruises 8–21 by the Lamont-Doherty Geological Observatory staff, 713 samples taken by Texas A&M participants on Cruises 22–30, about 413 samples in the Smithsonian Institution collections from Cruises 17, 20, 21, 25, and

31, and records on the invertebrates sorted at SOSC from samples taken by representatives of the University of Southern California on Cruises 1–32. The sorting of both benthic and pelagic samples from these collections are represented in the inventory. In addition, approximately 1,692 records are listed on specimens found in 92 benthic samples which were sorted at the American Museum of Natural History. These latter samples were collected by representatives of the Lamont-Doherty Geological Observatory aboard R/V *Vema.*

With incorporation of the backlog of SOSC records nearing completion, emphasis in the forthcoming months will shift to the compilation and processing of records from the many other institutions with holdings of antarctic specimens. An initial index to such collections is being prepared, noting the general types and quantities of materials by institution or responsible scientist or both. Successful attempts to acquire the necessary records, including basic sampling data, from throughout the country will result in a centralized data source on the locations, types and quantities of specimens, stage of identification, and availability of specimens for study.

As part of the National Science Foundation's continuing effort to realize as much scientific gain as possible from the USARP marine collections, SOSC this year was requested to devise and supply the research vessels with data recording forms. These forms, to be used by all participating biologists, have been provided for USNS *Eltanin,* R/V *Hero* and USCGC *Glacier.* A preassigned sample number, from a consecutive series for each vessel, is printed on the forms, and spaces are designed for the recording of basic sampling data and other desirable information such as environmental factors in the area at the time of sampling, and station numbers for later correlation with hydrographic and other activities. The data sheet for each sample is prepared in triplicate, with one copy designated for the vessel library, one for the collector, and one for return to SOSC. The latter copy will enable systematic documentation of the USARP marine sampling efforts as a valuable data source for present and future studies of the biota of antarctic waters.

Antarctic Research Series

JUDITH S. McCOMBS

American Geophysical Union

The *Antarctic Research Series,* initiated in 1963 by the American Geophysical Union with the aid of a grant from the National Science Foundation, provides a focal point for research papers in all fields of antarctic science. The series presents collections of original contributions that are of value not only to scientists and students involved in antarctic studies, but also to those whose major scientific interests lie outside that region. Since September 1968, volumes 12 and 13 have been released.

Volume 12, *Antarctic Bird Studies,* edited by Oliver L. Austin, is representative of recent years' upsurge of interest in the opportunities for biological research afforded by the great rookeries of antarctic birds. The 262-page volume contains 8 papers with illustrations, and is priced at $16.50.

Volume 13, *Antarctic Ascidiacea,* is a monograph by Dr. Patricia Kott of the University of Queensland. This book presents a comprehensive summary of available information on the 126 known species of these marine organisms, based on examination of specimens collected under U.S. Government auspices, 1947–1965. It contains a thorough discussion of the ecology and zoogeographic distribution of the ascidians as well as a systematic account. The 239-page, illustrated volume is priced at $14.00.

Volumes on oceanography, geology, glaciology, biology, human adaptability, micropulsations, and meteorology, as well as a biological monograph are being compiled. Several other volumes are in the early planning stages and will be devoted to petrology, terrestrial biology, the International Weddell Sea Expedition, and botanical studies at the Juan Fernández Islands; in addition, four biological monographs are planned.

The first 11 volumes of the series (see *Antarctic Journal,* vol. III, no. 5, p. 211) are still available through the American Geophysical Union, Suite 435, 2100 Pennsylvania Avenue, N.W., Washington, D.C. 20037.

Translation of the *Soviet Antarctic Expedition Information Bulletin*

WALDO E. SMITH

American Geophysical Union

The production of the English edition of the *Soviet Antarctic Expedition Information Bulletin* is continuing, and the English editions are issued as promptly as possible after the receipt of the Russian editions from the U.S.S.R. Since the time of the last report (see *Antarctic Journal,* vol. III, no. 5, p. 211), we have completed numbers 63–66, comprising the last four numbers of the 12 issues that have been designated volume 6, and we have initiated the production of the first 5 numbers of volume 7 (numbers 67–78 inclusive). The translations of numbers 67 and 68 are complete and should be issued in English edition soon. Numbers 69–71 have been received and are in various stages of translation, composition, or printing. Arrival of the numbers is still very slow.

In number 65 of volume 6, the Russian edition included two color photographs which were reproduced in color through the loan of slides of the original figures by the *Bulletin*'s chief editor, E. S. Korotkevich.

Early indications are that, in the number of pages, the 12 numbers of volume 7 will average out closely to those comprising volume 6. The tendency to maintain a higher level of scientific approach is continuing to be in evidence in the numbers of volume 7 received thus far. In general, each number consists of articles comprising some 90 percent of the total page numbers; the balance is devoted to information concerning radio exchanges with the homeland, brief notes of specific and unusual occurrences, items from the foreign press relating to activities in the Antarctic, and a substantial bibliography. Frequently, the bibliography totals 40 items or more, almost exclusively from the Russian scientific literature. The *Bulletin* is thus a valuable source for further pursuit of information on the antarctic work being done by the U.S.S.R.

The sales of the *Bulletin* have remained almost constant during the past year, and it would not be possible to continue the production without grant support from the National Science Foundation. The subscription rate for the volume comprising the 12 numbers placed under six covers is $40. Prospective subscribers should write to the American Geophysical Union, 2100 Pennsylvania Avenue, N.W., Washington, D.C. 20037 for details.

Antarctic Bibliography

GEZA T. THURONYI

Science and Technology Division
Library of Congress

The Antarctic Bibliography Project in the Science Division of the Library of Congress was conceived essentially as a support activity to the polar information section of the Office of Antarctic Programs, National Science Foundation. The purpose of the project is to provide bibliographic control of antarctic literature on a worldwide basis.

Because of the multidisciplinary character of antarctic research, literature dealing with it is scattered throughout a large number of scientific journals and other publications. Articles dealing with the Antarctic may be found in biological, medical, meteorological, geophysical, geological, engineering, and military journals, and many more. Consequently, the Antarctic Bibliography Project staff faces a much heavier search load (per item) than that of a discipline-oriented abstracting service. In addition to journal articles, the project covers books and monographs, government-sponsored research reports, and publications emanating from various expeditions. Many of these publications are available at the Library of Congress; others are obtained directly from the publisher or author, from the Office of Antarctic Programs, or through interlibrary loan.

Services are provided in the form of three main products: microcopy, index cards, and a book-form bibliography, viz:

Microcopy. Each book, report, or article selected for inclusion in the *Antarctic Bibliography* is reproduced *in toto* on microfiches, using a camera located in the Division's quarters. The film is then processed by the Library's Photoduplication Service and made available to the Office of Antarctic Programs.

Index Cards. A 3×5-inch card is prepared for each entry. The card contains the bibliographic citation, an abstract, and the following classification and indexing elements: Universal Decimal Classification number, author, subject, geographic location, and NSF grantee institution. Several copies of each card are supplied to the Office of Antarctic Programs, which maintains complete files and stocks for reference services. Copies of the cards are distributed on request to some 155 recipients, mostly research institutions and scientists. Close to 7,000 items have been distributed so far.

Book-form bibliography. The bibliographic citations and abstracts are assembled into bound books in lots of 2,000 under the title *Antarctic Bibliography*. Each book also contains author, subject, geographic, and grantee indexes. Volume 3 of the bibliography (items 4,001–6,000) was published earlier this year and is available, like the earlier volumes, from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Volumes 1 and 2 are priced at $4.25 each, and volume 3 at $6.00.

Antarctic Bibliography 1951-1961

In addition to providing current literature coverage since 1962, the Antarctic Bibliography Project, under a separate funding agreement with the National Science Foundation, undertook to prepare a retrospective bibliography for the period 1951–1961. This bibliography will be issued in book form with indexes. Neither microform reproductions of documents nor index cards will be issued. Work is now in the stage of final typing and index preparation, and the bibliography is expected to be completed later this year.

Recent Activities of the Committee on Polar Research

LOUIS DE GOES

Committee on Polar Research
National Academy of Sciences

The Committee on Polar Research (CPR) of the National Academy of Sciences advises on U.S. research programs in polar regions and represents the Academy in the Scientific Committee on Antarctic Research (SCAR) of the International Council of Scientific Unions. Dr. Laurence M. Gould is chairman of the CPR and is now serving a second term as president of SCAR. The Committee is composed of 14 members, 7 of whom serve as chairmen of the following panels: Biological and Medical Sciences (W. S. Benninghoff); Geodesy and Cartography (R. B. Southard); Geology and Geophysics (C. Craddock); Glaciology (A. L. Washburn); Meteorology and Climatology (R. M. Goody); Oceanography (K. L. Hunkins); and Upper Atmosphere Physics (S. A. Bowhill). Other members of the CPR are: D. K. Bailey, B. Haurwitz, W. Lyon, J. E. Oliver, M. A. Pomerantz, and A. H. Shapley. Altogether, the CPR and its panels involve more than 80 scientists from universities, research institutes, industry, and government.

Mr. Morton J. Rubin, chairman of the SCAR Working Group on Meteorology, represented SCAR at a meeting of the World Meteorological Organization's Working Group on Antarctic Meteorology held in Buenos Aires during April 17–25, 1969. Consideration is being given to holding the Second SCAR/ICPM/WMO Symposium on Polar Meteorology in Moscow in 1971, at the time of the IUGG General Assembly. Dr. Richard C. Kirby was nominated convenor of a proposed SCAR working group to consider technical and scientific problems affecting communications in Antarctica. This group will be concerned with radiowave propagation, and with interference, drift static, and other phenomena affecting radio communications. Dr. Louis O. Quam and Mr. Mort D. Turner of NSF's Office of Antarctic Programs and Dr. Campbell Craddock, U.S. member of the SCAR Working Group on Geology, are developing plans for participation by U.S. scientists in the Second SCAR/IUGS Symposium on Antarctic Geology and Solid Earth Geophysics to be held in Oslo, Norway, in August 1970 along with the Eleventh Meeting of SCAR.

The updated CPR report on the status of research in polar regions discussed earlier in the *Antarctic Journal* (vol. III, no. 5, p. 215), will be issued in late 1969 as an Academy publication.

The Committee met at the Academy on October 19, 1968, at which time Dr. Gould and Dr. Craddock reviewed results of the Tenth SCAR Meeting in Tokyo; Prof. Benninghoff and Dr. Sladen reported on the SCAR/IUBS Symposium on Antarctic Biology held in Cambridge; Dr. William Field gave an account of the SCAR/IASH Symposium on Antarctic Glaciological Exploration in Hanover; and Dr. T. O. Jones and Dr. Quam reviewed the National Science Foundation's antarctic program. Other items of business included reports by Dr. Maxwell E. Britton on the U.S. Navy's arctic program; by Dr. Leonard S. Wilson on the U.S. Army's polar program; and by Rear Admiral Orvan R. Smeder, Capt. Robertson P. Dinsmore, and Dr. Charles C. Bates on the U.S. Coast Guard's polar activities. Panel chairmen reported on the activities of their respective panels, which were largely concerned with preparation of their contributions to the CPR study.

Professor William S. Benninghoff has replaced Dr. W. J. L. Sladen as U.S. member of the SCAR Working Group on Biology, and Dr. A. Lincoln Washburn has succeeded Dr. Field as chairman of the Glaciology Panel. The Glaciology Panel met on September 7, 1968, during the SCAR/IASH Symposium on Antarctic Glaciological Exploration, and again on April 24, 1969; items on the agenda included preparation of the Panel's contribution to the CPR report, the emerging panel report on glaciological data, a review of the status of the WDC–A subcenter on glaciology, and future plans.

Radiation Records Available

The records of a CSIRO net radiometer operated at South Pole Station from March 1965 through September 1966 have been evaluated, those for the winter of 1965 by the Polar Meteorology Group of ESSA, and the remainder at the Department of Meteorology of the University of Wisconsin. The hourly values for the summer months show a pronounced diurnal variation and must therefore be considered questionable. For March through September, when the direct solar radiation is zero, or so small that its effect on the measurements is negligible, the monthly averages of the net outgoing radiation are as follows (in ly/hour):

Year	March	April	May	June	July	August	Sept.
1965	0.81	1.19	1.25	1.16	1.26	1.22	1.36
1966	1.25	1.11	1.14	1.07	1.31	1.38	1.25

Copies of 14 sheets listing the hourly values for each day of these months can be obtained from the National Weather Records Center, ESSA, Asheville, N. C. 28801. —W. SCHWERDTFEGER

USARP Personnel, 1968-1969

Summer 1968-1969

Byrd Station

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International Weddell Sea Oceanographic Expedition, 1969

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Abbreviations:

ANARE=Australian National Antarctic Research Expeditions
RL=Research Laboratories
ESSA=Environmental Science Services Administration

Note: U.S. Army Terrestrial Sciences Center is now U.S. Army Cold Regions Research and Engineering Laboratory

Winter 1969

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Abbreviations:

RL=Research Laboratories
ESSA=Environmental Science Services Administration

New Publications

Volume 3 of the *Antarctic Bibliography* is available at $6.00 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. The 491-page publication, edited by Geza Thuronyi, contains 2,000 abstracts grouped into 13 major categories, with author, subject, geographic, and grantee indexes appended.

Volume 13 of the *Antarctic Research Series*, a monograph by Patricia Kott entitled *Antarctic Ascidiacea,* was published in May. This 239-page publication is available at $16.50 from the American Geophysical Union, Suite 435, 2100 Pennsylvania Avenue, N.W., Washington, D.C. 20037.

Folio 11 of the *Antarctic Map Folio Series* is entitled *Distribution of Selected Groups of Marine Invertebrates in Waters South of 35°S Latitude,* and was prepared by A. W. H. Bé; H. Boschma and T. P. Lowe; J. S. Bullivant; E. W. Dawson; J. H. Dearborn and J. A. Rommel; R. K. Dell; S. J. Edmonds; H. B. Fell and S. Dawsey; H. B. Fell, T. Holzinger, and M. Sherraden; M. W. Foster; S. R. Geiger and C. Brahm; J. W. Hedgpeth; N. S. Hillman; D. E. Hurley; V. M. Koltun; P. Kott; D. L. Pawson; A. Ross and W. A. Newman; and D. F. Squires. The 40-page, 29-plate folio is for sale at $10.00 a copy from the American Geographical Society, Broadway at 156th Street, New York, New York 10032.

Testing the Feasibility of Using Concrete in Antarctica

Don W. Barber[1]

Office of Personnel Operations
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The post-IGY antarctic program of the United States has involved the construction of larger, more complex, and more permanent facilities, requiring a continuing search for improved construction methods. Such a search must take into account the economics of construction in terms of both manpower and materials, and should include an examination of the usefulness of locally available materials.

While the use of indigenous materials is generally a sound principle of construction economics, it is made more imperative in the Antarctic by the brevity of the shipping and construction season, by the difficulties —and occasionally the uncertainty—of sea transport, and by the great distances involved in importing materials to most points. Unfortunately, there is little that nature has provided locally for construction on the Antarctic Continent. Ice and snow have been used as construction materials at Byrd Station, forming the station's walls and roof, and for snow roads between McMurdo Station and Williams Field, but at the stations built on relatively ice-free sites—McMurdo, Palmer, and Hallett—such conventional, imported materials as wood and steel have had to be used. At those locations, and most notably at McMurdo, a major problem has been the preparation of foundations capable of supporting large structures.

Problems of Earth-Fill Foundations

To date, earth fill has been used for foundation pads at McMurdo Station,[2] which is the site of the largest *Deep Freeze* construction effort, but obtaining the fill is a very slow and tedious process. One visiting engineer likened it to a strip-mining operation in which "bulldozers labor up the steep (up to 50°) surrounding hills, turn around and come grinding, sliding and bumping down with blades lowered. In a good day's work, they manage to worry loose about 2 or 3 in. of cindery soil." [3] The inadequacies of this

[1] Formerly on the civil engineering staff of the U.S. Naval Support Force, Antarctica.

[2] Hallett is situated on a sandy point, and its modest-size buildings rest on timber foundations. At Palmer, considerable blasting of the native rock was required to level the construction areas, on which foundation pads of crushed rock were prepared to support timber foundations. (See *Antarctic Journal,* vol. II, no. 4, p. 142-143.)

[3] Joseph Wilkinson in *Engineering News-Record,* December 1968.

procedure may be better appreciated with knowledge of the fact that the foundation pad for the recently built personnel building required an estimated 4,850 cubic yards of fill.

Although earth-fill foundation pads are perfectly adequate structurally, there is a second major shortcoming in their construction: considering the short (4-month) construction season, the time required for the pads to consolidate sufficiently to support a structure is unacceptably long. The standard derived from experience is one year.

Concrete Data Sought

Consequently, a different method of providing the building base was sought, and the possibility of using concrete naturally entered into consideration. Although there has been some use of concrete in the Antarctic by expeditions of several nations (Fig. 1), a preliminary review revealed little published information on the subject. Thus, in *Deep Freeze 68,* the U.S. Naval Support Force, Antarctica requested the Naval Civil Engineering Laboratory (NCEL), located at Port Hueneme, California, to investigate the feasibility of using concrete at McMurdo Station.

Among the more important questions that NCEL was asked to consider were the following: (1) Were the local aggregates suitable for use with Portland cement? (2) What would be the optimum mix (admixture, types of cement, etc.) incorporating local aggregates? (3) What, if any, unconventional equipment would be needed for mixing and curing the concrete? (4) What were the parameters for mixing the concrete at McMurdo—minimum ambient temperature, temperatures of mixing water and aggregate, etc.? (5) How could the concrete be cured in the shortest possible time consistent with good qualities of structural strength and durability? (6) What are the effects of direct contact between concrete and permanently frozen ground (permafrost[4])?

Slight discussion of just the last of these questions may give the non-engineer some insight into the number of factors to be considered in the study as a whole. Since water decreases in volume upon changing from the solid to the liquid state (it is one of the few substances that does), the thawing of permafrost can cause surface subsidence, with dramatically serious structural effects (Fig. 2). Therefore, great care must be taken in the construction so as to avoid disturbing the thermal regime of the ground. Such disturbance may originate from several sources. Heat radiated or conducted—perhaps through the foundation—from the building's interior is one potential

Photo by Archer E. Church, Jr.

Figure 1. At Britain's Argentine Islands Station in the Antarctic Peninsula, concrete has been used for foundation posts and paving of paths.

Photo courtesy R. J. E. Brown, National Research Council of Canada

Figure 2. Damage done to a house in Canada by permafrost subsidence.

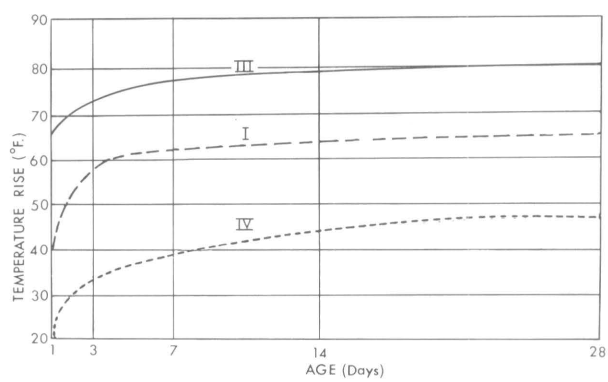


Figure 3. Typical temperature-rise curves in concrete for three types of Portland cement. Type numbers are explained in Figure 4.

source, making the relative conductive properties of the various types of concrete a matter of importance.

Another source of potentially troublesome heat is inherent in the nature of concrete as a temporarily plastic material. As the Portland cement binder in the concrete reacts with the mixing water, heat of hydration is produced. (In concrete, hydration is a combination of gel formation and crystallization.) This heat of hydration can cause an appreciable temperature rise (Fig. 3), the magnitude of which depends on the

[4] The origin of this term and the effects of the phenomenon are reviewed by Troy L. Péwé in *Permafrost and Its Effects on Life in the North* (Oregon State University Press, 1966).

type of Portland cement used (five are recognized), the size and shape (*i.e.*, the volume-to-surface ratio) of the cast in question, and other factors. Moreover, heat of hydration continues to be generated for some time (Fig. 4). This heat can be dissipated through the surfaces of the cast, but as this happens, the outer layers of the concrete unit contract against the warmer core, with a resultant tendency toward cracking if the temperature differential is too great. Thus, the contact of recently cast concrete with permafrost may have deleterious effects on the structural strength of both the concrete and the permafrost.

The natural weathering process that is perhaps most destructive to concrete is repeated freezing and thawing. Fortunately, daily temperature variations passing through the freeze point are less likely to occur in the Antarctic than in many more-temperate climates. Nevertheless, it appeared advisable to increase the freeze-resistance of the concrete by adopting the standard cold-weather concreting practice of air entrainment. (The entrapped air provides space for expansion should the mix water freeze before it is taken up in hydration.)

Work in the United States

The Naval Civil Engineering Laboratory initiated its study in *Deep Freeze 68* by shipping some 10 tons of antarctic aggregates to the United States. The aggregates were tested, using the procedures of the American Society for Testing Materials (ASTM), and found to be more than adequate for use in concrete.[5]

Laboratory work at Port Hueneme produced satisfactory concrete mixes both with and without the admixture of calcium chloride, which accelerates the hardening process and thereby reduces the period during which the concrete must be protected from freezing. (The addition of salt lowers the freezing temperature of the concrete, but at the expense of its strength.) Concrete cylinder strengths in excess of 3,000 psi were obtained after 3 days of curing at 50° to 60°F. Such cylinders were subsequently frozen and thawed with no loss of strength.

In one test, concrete was made in the NCEL cold chamber at 22°F. using dry components at that temperature and water heated to 170°F. The resultant mixture had a temperature of approximately 60°F. and acceptable plasticity. After 3 days of curing at 50° to 60°F., the strength was tested at about 3,000 psi.

Additional cold-chamber tests were conducted to simulate conditions at McMurdo. These included the placement of test sections of concrete in specially prepared frozen ground to determine the effects of con-

[5] NCEL Technical Note N-1000, *Concrete for Antarctica—Aggregate Mix Design for the McMurdo Area,* by J. R. Keeton and N. S. Stehle (December 1968).

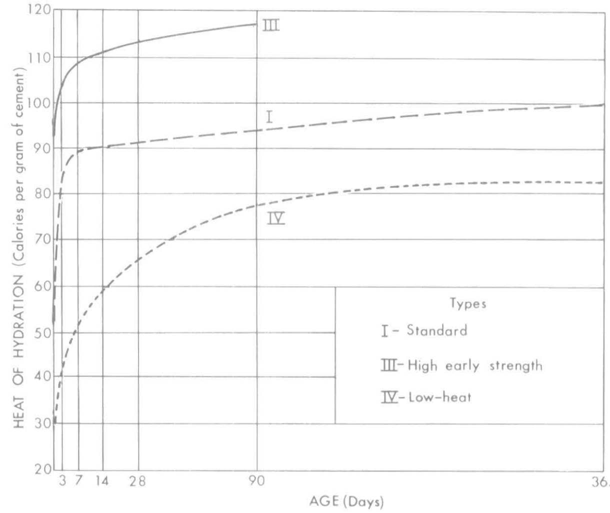


Figure 4. Heat of hydration for three types of Portland cement. Although Type III produces the most heat, it is the best choice for antarctic use because (a) heat is advantageous except when the cast is in direct contact with permafrost, and (b) rapid curing limits the period during which external conditions are critical.

U.S. Navy Photo

Figure 5. General view of test site. Note protective wooden hoods to permit curing at elevated temperatures.

U.S. Navy Photo

Figure 6. Tests also involved taking cores, casting cylinders, and making thermocouple measurements.

crete heat upon the ground and the effects of ambient cold upon the temperature of concrete in the hardening stage. Strength tests of cores taken from the hardened concrete at selected time intervals gave generally satisfactory results.

In the early test, the concrete was prepared with Type III-A Portland cement, which is an air-entraining, high-early-strength cement, but this did not entrain sufficient air. Later laboratory test batches were therefore made with Type III (high-early-strength) cement and an air-entraining agent that was added during mixing.

Field Tests

Concurrently with the conduct of these laboratory experiments, a test series was designed for accomplishment at McMurdo during the 1968–1969 austral summer. The field-test program involved the placement of 10 test sections of two types (8 footings and 2 on-the-surface slabs) in an area adjacent to the fuel storage tanks in the pass at the foot of Observation Hill (Fig. 5).

The aggregate for the test sections was obtained from the "Fortress Rocks" quarry at McMurdo by the Public Works Department of Antarctic Support Activities. The planned program called for on-site testing of the aggregate for sieve grade, specific gravity, absorption, and moisture content. The fresh concrete was to be tested for slump, air content, and unit weights, while the compressive strength of the hardened concrete was to be determined from 3-inch diameter cores taken at 2, 3, 7, 14, and 28 days.

A primary objective of the field tests was to determine the optimum curing time by observation of the interaction between the heat of the concrete and the cold of the permafrost. Accordingly, the test program provided for the collection of air- and ground-temperature data and the determination by thermocouples of the temperature differential between the permafrost and both the fresh and the hardened concrete (Fig. 6). While the field-test data are as yet unpublished, advance information indicates that the test cores exhibited satisfactory compression strengths when sampled after 5–8 days.

It is expected that additional footing and slab-type sections will be cast at McMurdo during *Deep Freeze 70,* and that all sections cast during *Deep Freeze 69* and subsequent years will be reexamined at later dates to determine their durability under exposure to McMurdo's climatic conditions. It is hoped that with the conclusion of the 1969-1970 field studies, adequate technical data will have been obtained to permit a definitive assessment of the usefulness of concrete at selected antarctic locations, and that some general advance will have been made in polar materials technology.

Dr. W. D. McElroy New NSF Director

NSF Photo

On July 11, 1969, the Senate confirmed the nomination of Dr. William D. McElroy, chairman of the Biology Department at Johns Hopkins University since 1956, to become the Director of the National Science Foundation. Dr. McElroy succeeds Dr. Leland J. Haworth, who retired on June 30 after completing his six-year term.

Born in 1917, Dr. McElroy received his B.A. from Stanford University in 1939, M.A. from Reed College in 1941, and Ph.D. from Princeton University in 1943. While at Johns Hopkins University (1946–1969), he participated in many government advisory panels and committees and, from 1962 to 1966, served as a member of the President's Science Advisory Committee. He was elected to the National Academy of Sciences in 1963 and he has served as a member of its Council since April 1968.

Dr. McElroy first became associated with NSF in 1955 as a member of the Metabolic Biology Panel. He has served in other advisory posts for NSF, and is a Trustee of Associated Universities, Inc.

Dr. McElroy is the author of numerous publications in his fields of bioluminescence, bacterial mutations, and biochemical genetics, and has been an active editor. He is a member of several professional societies and has held the presidency of the Society of Biological Physiologists, the American Society of Biological Chemists, and the American Institute of Biological Sciences.

In addition to his professional activities, Dr. McElroy has been a member of the following civic and community organizations: Board of Governors, the Pinchot Institute of Conservation Studies; Board of Directors, Planned Parenthood Association of Maryland, Incorporated; Board of School Commissioners, Baltimore; Board of Trustees of Baltimore Junior

College; and Chairman of the Board of Trustees, Baltimore Community College.

Dr. Haworth has returned to Long Island, where he will serve as Assistant to the President of Associated Universities, Inc., and Special Consultant to the Director of Brookhaven National Laboratory.

SCAR/IUGS Symposium on Antarctic Geology and Solid Earth Geophysics to be Held in Oslo, Norway, August 6-15, 1970

A symposium on antarctic geology and solid earth geophysics, sponsored jointly by the Scientific Committee on Antarctic Research and the International Union of Geological Sciences, will be held in Oslo, Norway, during the period August 6–15, 1970.

The symposium will be held at the new campus of the University of Oslo at Blindern, where there are adequate auditorium facilities. Cafeteria facilities are also available nearby.

Arrangements have already been made for accommodations at the summer hotel at Oslo Studentby (Sogn), which is located within 15–20 min walking distance from the symposium auditorium building. Transportation by bus can be arranged if necessary. There is a branch line of the subway from the center of Oslo to Blindern (10 min) and to Sogn (15 min).

Cost of accommodation at the summer hotel, Sogn, including continental breakfast, is as follows:

Single room with shower	$ 9
Double room with shower	$14
Single room with washbasin (shower shared with 3-4 rooms)	$6-7.50
Double room with washbasin (shower shared with 3-4 rooms)	$12
Single room with washbasin	$5.50
Double room with washbasin	$ 9

More luxurious accommodations are also available in downtown Oslo, but the city is particularly busy during the summer period and it will be necessary to make early bookings for such accommodations. The cost of downtown accommodations vary from about $6 to $20 for single rooms and $12 to $30 for double rooms. If early bookings can be made, it might be possible to reserve accommodations in a central, modern hotel in the price range $6 (single rooms) to $10 (double rooms).

Local field excursions have been proposed for the weekends of August 8–9 and 15–16 and will be arranged to suit the requirements of participants. Two longer, alternative field excursions have been planned during the period August 1–5, but again it will be necessary to have some indication of the requirements of participants. It will not be possible to run field excursions after the conclusion of the symposium, *i.e.*, August 15.

Details of the venue and costs of the local and pre-symposium excursions will be given in a second circular on the symposium. Those who wish to receive this circular, which will contain exact details of the overall program, should write immediately to:

Louis DeGoes, Executive Secretary
Committee on Polar Research
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

stating full name and address, institution or organization, and specific antarctic interests, so that their names can be placed on the list of intending participants.

Change of Command in VXE–6

U.S. Navy Photo

Comdr. J. R. Pilon

On July 10, 1969, the command of Antarctic Development Squadron Six (VXE–6) was transferred from Comdr. E. W. Van Reeth to Comdr. Jerome R. Pilon. The event was marked by ceremonies at Quonset Point Naval Air Station, R. I., the squadron's home station.

Comdr. Pilon is the eighteenth commanding officer of the squadron since its commissioning in 1955 as Air Development Squadron Six, which name it retained until January 1 of this year. Since joining the squadron in July 1966, Comdr. Pilon has completed three deployments to Antarctica, serving successively as administrative officer, maintenance officer, operations officer, and executive officer. He has been a Naval Aviator since 1952.

Expedition to Falkland Islands, 1968*

Henry A. Imshaug

Cryptogamic Herbarium
Department of Botany and Plant Pathology
Michigan State University, East Lansing

Figure 1. Map of collecting localities.

Between the latitudes of 40°S. and 60°S., exposed land, excepting the tip of South America, Tasmania, and New Zealand, is limited to small islands hundreds of miles apart. Their surface area totals only about 10,000 square miles. Within this zone, only the tapering extremity of South America interrupts the strong and persistent westerly winds. The climate of this zone is extremely oceanic and characterized by low temperature with small temperature ranges, low annual sunshine amounts, and moderate rainfall with no dry season. Trees are found only on Gough Island (40°19′S.), Snares Islands (48°S.), and Auckland Islands (50°32′S.). The vascular plant flora per island ranges from 0 or 1 to 170 species. The non-vascular plant flora per island is much larger, and the lichen flora alone is probably larger than the vascular plant flora on any given island.

The Falkland Islands are the largest island group in this zone, with a planar area of 4,618 sq. miles. They are continental islands situated in the South Atlantic Ocean, 300 miles east of the Strait of Magellan and 800 miles north of the Antarctic Peninsula. Two main islands plus more than 100 islets make up the group. Presently administered as a British Crown Colony, they were first colonized by the French (Îles Malouines) and later by the Spanish (Islas Malvinas), with the result that numerous plant and animal species have received the latin epithets *malvina, macloviana,* or *falklandica*.

The 1968 survey was designed to collect the lichens and bryophytes of the islands in order to determine the nature of the terrestrial cryptogam flora and assess its relationships to the various sectors of the antarctic and subantarctic zones. Many expeditions had previously visited the Falklands and collected lichens and bryophytes. These included the voyages of the *Uranie* and *Physicienne* (1817–1820), *Coquille* (1822), *Erebus* and *Terror* (1842), and *Nassau* (1867–1869), as well as the Swedish Antarctic Expedition of 1901–1903 and the Swedish Magellanic Expedition of 1907–1908. None of these expeditions, however, had the collection of lichens and bryophytes as a major objective and, consequently, none returned with more than a small fraction of the total flora.

The 1968 expedition included specialists on lichens (Henry A. Imshaug, assisted by Richard C. Harris) and a specialist on hepatics (John J. Engel), all from Michigan State University. The party arrived in Punta Arenas (Chile) on the Strait of Magellan on December 16, 1967. Inasmuch as transportation to the Falkland Islands via RRS *Shackleton* was not scheduled until December 30, a period of two weeks was utilized in field work on the Brunswick Peninsula. This work proved very valuable as an introduction to many species which occur also in the Falklands. RRS *Shackleton* arrived in Stanley on January 2, 1968. His Excellency the Governor, Sir Cosmo Haskard, was expecting our arrival and arrangements for housing in Stanley had been made through the Office of the Assistant Colonial Secretary. Through the efforts of Messrs. E. C. Clapp and Ray Clements of the British Antarctic Survey in Stanley, we were able to visit all desired localities without any wasted time, and their assistance, as well as that of the British officials, is most gratefully acknowledged.

The localities visited (Fig. 1) were selected so as to emphasize mountain summits, including the highest peaks, as well as a series of sites from the westernmost islets to the easternmost shores. They included areas around the settlement of Darwin, Fox Bay East, Fox Bay West, Hill Cove, New Island, Port Howard, Weddell Island, and Westpoint Island, as well as Stanley. Transportation from one settlement to another was primarily by DeHavilland Beaver seaplanes in the Government Air Service. The government launch and MV *Forrester* were also utilized to visit Kidney Island, outside Stanley Harbour, and Port William. We are grateful to Mr. Jim Kerr and the Harbour Master for their help in arranging the necessary transportation, not only for ourselves but for our collections as well. A visit to the plains of Lafonia

* The islands are claimed by Argentina as the Islas Malvinas and by the United Kingdom as the Falkland Islands.

(North Arm Settlement), southern part of East Falkland Island, was planned, but bad weather delayed flights so that this area could not be visited.

We left the Falkland Islands on February 16, 1968 on board RMS *Darwin*. The bulky and heavy rock collections were transported to Punta Arenas later on board RRS *Shackleton*.

A total of 2,738 lichen collections and 1,170 bryophyte collections were made in the Falkland Islands. An additional 972 lichen collections and 572 bryophyte collections were made in the Brunswick Peninsula of Chile. The lichens are being studied by Dr. Imshaug and Mr. Harris, the hepatics by Mr. Engel, and the mosses by Dr. H. Roivainen, University of Helsinki, Finland.

A preliminary assessment of the lichen flora indicates a total flora of about 235 species. As expected, most of the previously unreported species came from inland mountain areas. Large collections from sea level resulted in the synonymizing of many previously described species. Of particular interest is the clarification of the identity of a species known in the Antarctic only in a sterile leprose state—*Lepraria pallidostraminea* Vain. In the Falkland Islands, it is frequently fertile and was earlier described as *Haematomma erythromma* (Nyl.) Zahlbr. Another example of the relevance of subantarctic studies to antarctic studies is the assessing of relationship of critical taxa. For example, *Himantormia lugubris* (Hue) Lamb was considered endemic to the Antarctic Peninsula area with no close relatives. On the highest mountain tops of the Falklands, however, we discovered another species of *Himantormia*, a clue then as to the possible origin of the antarctic species.

This expedition provided a unique opportunity for three specialists in terrestrial cryptogams to visit a group of austral islands and make mass collections for biosystematic studies of populations, in order to analyze morphological and chemical characteristics wherever appropriate, as well as characteristics available only in living material. Completion of the determination of material collected will permit an analysis of the entire terrestrial flora (vascular and non-vascular) so that generic and growth-form spectra may be obtained for comparison with similar spectra of antarctic, subantarctic, and south temperate floras. If similar studies are completed in other austral regions, our biogeographic knowledge of the Antarctic will be considerably advanced. We are indebted to U.S.A.R.P. for this opportunity to study in detail the flora of these isolated austral islands. Representative samples of all identified plants will be deposited in herbaria of the U.S. National Museum, Smithsonian Institution, Washington, D.C.

Photo by J. J. Engel

Figure 2. New Island, westernmost settlement of Falkland Islands. Deeply indented coastline and hilly islets characterize much of the islands. *Empetrum*-heath in foreground.

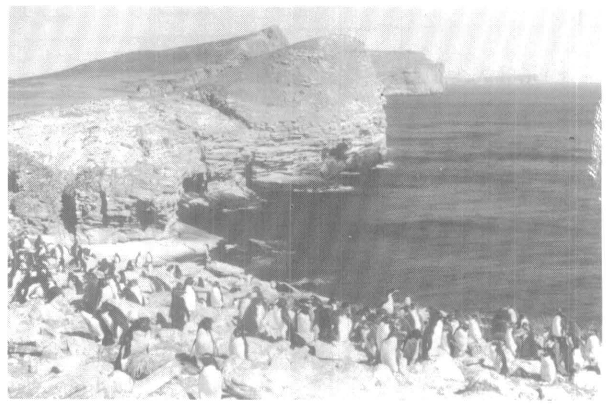


Photo by H. A. Imshaug

Figure 3. Coastal cliffs and colonies of rockhopper penguins (*Eudyptes crestatus*), king shags (*Phalacrocorax albiventer*), and mollymauks (*Diomedea melanophris*) on west side of New Island.

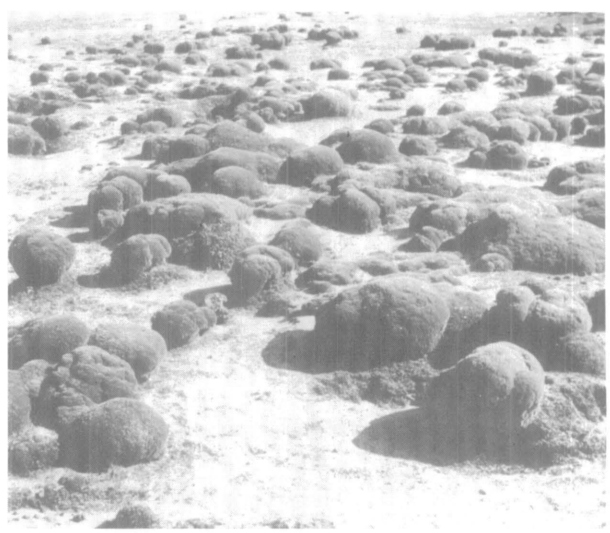


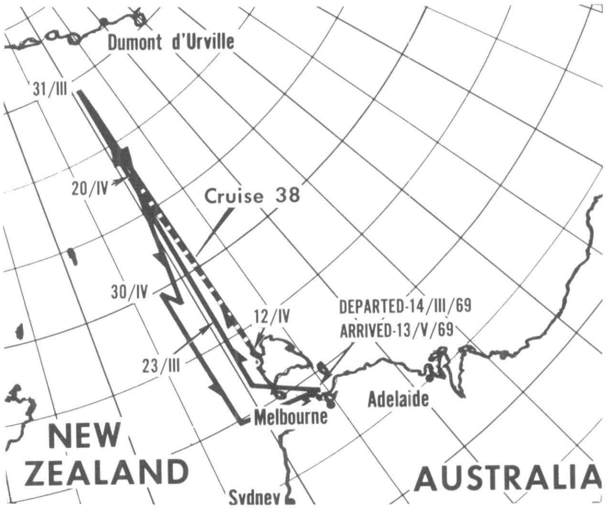
Photo by H. A. Imshaug

Figure 4. Wind desert with hummocks of *Azorella caespitosa* near Landsend, New Island.

Eltanin Cruise 38

L. R. Pomeroy*

Department of Zoology
The University of Georgia



Cruise 38 was a special-purpose cruise, centered around the study of total metabolic processes of living organisms in the southern oceans. Six positions were occupied along 150°E. from 40°S. to 64°S. At each, we spent from four to eight days. This departure from a conventional oceanographic cruise plan proved highly successful. The scientific programs alternated use of the winches so that most had essentially continuous work. The joint objective of the principal programs was a total estimate of metabolism in the water column at each position.

Two programs were concerned with photosynthesis. Sayed Z. El-Sayed, Texas A&M University, compared the simulated *in situ* method of measuring photosynthesis with actual *in situ* measurements. The *in situ* samples were suspended from a buoy. H. R. Jitts, C.S.I.R.O. Division of Fisheries and Oceanography, experimented with the effects of light and temperature on the rate of photosynthesis of phytoplankton, using apparatus of his own design.

A group from the University of Georgia measured respiration of consumer organisms. Since metabolic rates tend to be inversely related to body size, emphasis was on small organisms. W. J. Wiebe and Charles Hendricks examined the distribution and modes of nutrition of bacteria. L. R. Pomeroy measured the respiration of plankton and bacteria, using respirometers equipped with continuously recording oxygen electrodes. Net plankton was concentrated with a Clarke-Bumpus sampler and ultraplankton with Dodson-Thomas concentrators. Extracts of ATP were prepared from aliquots of each sample as a parameter of microbial biomass. A specially mounted microscope was used for both observation and photomicrography of living microorganisms. Dirk Frankenberg took grab samples, both to estimate biomass and to obtain live organisms for respirometry. William L. Layton, Jr. was in charge of a camera program to aid in the estimation of biomass of the larger benthic organisms and the epibenthos. The positions of camera and grab stations were overlapped precisely with the aid of satellite navigation. Frankenberg also took oblique Isaacs-Kidd midwater trawls at each position. Viable organisms from the IKMWT were used for respirometry.

J. W. Fell, University of Miami Institute of Marine Sciences, continued his studies of the distribution of yeasts in the Antarctic. He was also in charge of hydrographic observations. Nansen casts were combined with microbiological sampling, using Niskin sterile samples. El-Sayed's group did phosphate, nitrate, and silicate analyses in conjunction with the hydrographic program.

Other programs were conducted by E. G. Driscoll, Wayne State University, who took a series of grab samples to study processes of formation of fossils from the living assemblage of organisms. Cores were taken for Grant Goodell, Florida State University, and samples of naturally occurring radiocarbon for G. W. Fairhall, University of Washington. Materials for the study of echinoderm physiology were collected for A. C. Giese, Stanford University.

The combined results of Cruise 38 will provide an estimate of total biomass and total metabolism for a section across the southern oceans. Inevitably it will be incomplete and crude, but only by making this attempt can we discover the problems to be overcome before a truly definitive measure becomes possible.

* U.S. Antarctic Research Program Representative on Cruise 38.

Erratum in vol. IV, no. 3, p. 70: The organisms in the photo (top, right) are erroneously identified as *Euphausia superba*. Actually, the following genera are represented in the photo: *Acanthephyra, Sergestes, Gnotophausia,* and *Gennadas* (?). A photo of *Euphausia* sp. is shown at right.

Photo by G. A. Llano

Chronology of U.S. Navy Support Activities

September 1, 1968—March 31, 1969

September

1—Air Development Squadron Six (VX-6) reported to operational control of CTF-43.
3—Two VX-6 LC-130Fs arrived and departed Williams Field on *Winfly*.
—Plateau Station generators failed, causing a 36-hour power outage.
8—First helicopter flight of season by LH-34D of VX-6.
13—PM-3A nuclear power plant shut down due to cooling-system malfunction.
24—PM-3A resumed power output.
—CTF-43, Rear Adm. J. L. Abbot, Jr., departed Washington for Christchurch.

October

3—Rear Adm. Abbot arrived Christchurch.
7—First LC-130F flight of season landed at Williams Field with CTF-43 aboard.
—Detachment Alpha, Antarctic Support Activities, disestablished with the arrival at McMurdo of Commander, Antarctic Support Activities, Capt. H. A. Kelley, USN.
—VX-6 Det. McMurdo disestablished.
—McMurdo Representative, Commander, U.S. Naval Support Force, Antarctica established.
9—First C-121 turnaround flight of season arrived Williams Field.
10—Brockton Station reopened.
11—Hallett Station reopened.
14—Naval Construction Battalion Unit 201 (NCBU-201) reported to operational control of CTF-43.
18—First flight of the season to Byrd Station.
19—PM-3A nuclear power plant shut down for maintenance.
21—Air Vice Marshal C. A. Turner, RNZAF, arrived McMurdo.
22—Lt. D. W. Hagley, USN, relieved Lt. (jg.) J. R. Clark, CEC, USNR, as Officer-in-Charge of Byrd Station.
—First RNZAF C-130H flight of the season arrived Williams Field on *Operation Ice Cube*.
23—Air Vice Marshal Turner departed McMurdo for New Zealand.
24—PM-3A resumed power output.
27—U.S. Army Aviation Detachment (Antarctica Support) arrived Christchurch and reported to operational control of CTF-43.
28—Ellsworth Land camp 1 established after unsuccessful attempt on 24th.
29—First of eight MAC C-141 turnaround flights landed at Williams Field, completing the fastest flight ever made from Christchurch to McMurdo (4 hours, 57 minutes).
31—First of Army Aviation Detachment's UH-1D helicopters delivered to Williams Field by LC-130F.
—*Project Magnet* C-121 arrived McMurdo.

November

1—First flight of the season to South Pole Station; CTF-43 aboard.
—Lt. B. J. Bowman, USN, relieved Lt. (jg.) J. R. Hedley, CEC, USNR, as Officer-in-Charge of South Pole Station.
5—Lt. J. P. Kurtz, CEC, USN, relieved Lt. Comdr. A. D. Kohler, Jr., CEC, USN, as Officer-in-Charge of Naval Nuclear Power Unit's McMurdo detachment.
11—Distinguished visitor group arrived McMurdo to tour U.S. stations. Group included representatives of 10 Antarctic Treaty signatories and the Hon. W. H. Crook, U.S. Ambassador to Australia.
12—Japanese Antarctic Research Expedition (JARE) traverse party from coastal Showa Station arrived at Plateau Station.
13—USCGC *Southwind* arrived Wellington and reported to operational control of CTF-43.
—Ambassador Crook and party departed McMurdo for New Zealand.
—USCGC *Glacier* arrived Port Lyttelton and reported to operational control of CTF-43.
—USCGC *Burton Island* arrived Auckland and reported to operational control of CTF-43.
—Last of three Army UH-1D helicopters delivered to Ellsworth Land camp 1 by LC-130F.
15—First flight of season to Plateau Station.
16—Treaty signatory representatives departed McMurdo for New Zealand.
—JARE traverse party departed Plateau Station for South Pole.
20—PM-3A nuclear power plant shut down due to a malfunction.
—Gen. H. M. Estes, Commander, Military Airlift Command (MAC), visited McMurdo.
22—Byrd memorial flight carrying 60 passengers arrived and departed Williams Field.
—Norwegian field party delivered to Kraul Mountains by VX-6 LC-130; the 1,980-mile flight from McMurdo was the most distant field placement ever accomplished. British field party delivered to Shackleton Range on next leg of flight.
—USCGC *Southwind* departed Wellington for Ross Sea.
—Ross Sea Ship Group (TG 43.3) activated with the departure of USCGC *Burton Island* from Auckland for the Ross Sea.
—Congressmen W. L. Dickinson (R-Ala.), C. A. Halleck (R-Ind.), and P. Hardy, Jr. (D-Va.) arrived McMurdo to view U.S. activities.
23—USCGC *Glacier* departed Port Lyttelton for Ross Sea.
24—Congressmen Dickinson, Halleck, and Hardy departed McMurdo for New Zealand.
25—PM-3A resumed power output.
—USCGC *Southwind* called at Campbell Island.
27—Two VX-6 LH-34Ds from McMurdo landed at Hallett Station, completing one of the longest antarctic helicopter flights on record.
29—Last flight of the season to Hallett Station.

December

1—C-141 departed Williams Field on special animal airlift.
—Hallett Station ice runway closed.
3—Ross Sea Ship Group (USCGCs *Burton Island, Southwind,* and *Glacier*) commenced breaking ice in McMurdo Sound.
7—Comdr. E. G. Lightsey, Jr., USN, relieved Comdr. L. M. Johnson, USN, as Officer-in-Charge, Det. One, U.S. Naval Support Force, Antarctica.
9—USCGC *Edisto* arrived Punta Arenas, Chile, and reported to operational control of CTF-43. Antarctic

Peninsula Ship Group (TG 43.4) activated aboard *Edisto.*
—Congressmen G. E. Brown, Jr. (D-Cal.), L. J. Burton (R-Utah), and T. R. Kupferman (R-N.Y.) arrived McMurdo to view U.S. activities.
12—Congressmen Brown, Burton, and Kupferman departed McMurdo for New Zealand.
14—USCGC *Edisto* departed Punta Arenas for Palmer Station.
17—USNS *Alatna* arrived Port Lyttelton and reported to operational control of CTF-43.
—USCGC *Edisto* arrived Palmer Station.
—VX-6's newly assigned fifth Hercules, an LC-130R, arrived Williams Field carrying the largest payload ever airlifted by LC-130 from Christchurch to McMurdo (16,900 pounds).
18—Fire destroyed two Jamesway barracks at Palmer Station.
19—Ellsworth Land camp 2 established.
—JARE traverse party arrived at South Pole Station.
21—Mr. Max Conrad landed his Piper Aztec at Palmer Station.
22—Construction of Ellsworth Land camp 2 completed.
—McMurdo channel opened; Ross Sea Ship Group arrived McMurdo.
—USNS *Alatna* departed Port Lyttelton for McMurdo.
23—USNS *Towle* arrived Port Lyttelton and reported to operational control of CTF-43.
—Max Conrad departed Palmer Station for Adelaide Island.
—USCGC *Southwind* departed McMurdo for Wellington
25—R/V *Hero* arrived Palmer Station for first time.
—JARE traverse party departed South Pole Station for Showa via Plateau.
—USNS *Towle* departed Port Lyttelton for McMurdo.
26—USCGC *Burton Island* departed McMurdo and called at Hallett Station.
27—USCGC *Edisto* departed Palmer Station for Punta Arenas.
28—USCGC *Burton Island* arrived McMurdo.
30—USCGC *Southwind* arrived Wellington.
—USCGC *Edisto* arrived Punta Arenas.

January 1969

1—PM-3A nuclear power plant shut down due to a malfunction.
—Air Development Squadron Six (VX-6) redesignated Antarctic Development Squadron Six (VXE-6).
2—PM-3A resumed power output.
5—Sir Arthur Porritt, Governor-General of New Zealand, and party arrived McMurdo.
6—USNS *Alatna,* first resupply ship of *Deep Freeze 69,* arrived McMurdo escorted by USCGCs *Burton Island* and *Glacier.*
7—USCGC *Edisto* departed Punta Arenas for Palmer Station.
8—USNS *Alatna,* escorted by USCGCs *Burton Island* and *Glacier,* departed McMurdo for New Zealand.
9—USCGC *Southwind* departed Wellington for McMurdo.
10—USCGC *Edisto* arrived Deception Island.
—Sir Arthur Porritt and party departed McMurdo for New Zealand.
—Move from Ellsworth Land camp 1 to camp 2 completed.
11—PR1 R. Spaulding, of VXE-6, established new McMurdo parachute altitude record of 12,500 feet.
—USCGC *Edisto* departed Deception Island and called at Livingston Island.
12—USCGC *Edisto* arrived Palmer Station.
13—USNS *Wyandot* reported to operational control of CTF-43 upon arrival at Punta Arenas; departed the same day for Palmer Station.
14—JARE traverse party arrived Plateau Station from South Pole.
15—VXE-6 LC-130R landed at Vostok on season's only U.S. flight to that Soviet station.
—PM-3A nuclear power plant shut down for annual maintenance.
16—Lt. J. E. Perry, Jr., CEC, USN, relieved Lt. J. R. Finn, CEC, USN, as Officer-in-Charge, NCBU-201.
—USNS *Towle,* escorted by USCGC *Glacier,* arrived McMurdo.
—USNS *Wyandot* arrived Palmer Station.
17—HMNZS *Endeavour,* escorted by USCGCs *Southwind* and *Glacier,* arrived McMurdo.
—USNS *Alatna* arrived Port Chalmers.
18—HMNZS *Endeavour,* escorted by USCGCs *Southwind* and *Glacier,* departed McMurdo. Both icebreakers broke off escort the same day; USCGC *Glacier* departed for Valparaíso.
20—Kraul Mountains field party picked up.
—USNS *Alatna* moved from Port Chalmers to Port Lyttelton.
—JARE traverse party departed Plateau Station for Showa.
21—USNS *Wyandot* departed Palmer Station for McMurdo.
—Lt. (jg.) L. Hellerman, USN, relieved Lt. (jg.) W. V. Kelly, USN, as Officer-in-Charge of Palmer Station.
22—USNS *Alatna* departed Port Lyttelton for McMurdo.
—Tour ship *Aquiles* visited Palmer Station; high winds temporarily stranded groups of tourists at the station and aboard USCGC *Edisto.*
—USCGC *Southwind* arrived and departed Hallett Station.
—PM-3A resumed power output.
23—USNS *Towle,* escorted by USCGC *Burton Island,* departed McMurdo.
—Group of distinguished U.S. and N.Z. visitors arrived McMurdo to view U.S. activities; N.Z. members of the party included Messrs. W. L. Young and T. T. Young of the New Zealand Parliament, and Mr. Peter Snell, Olympic gold medalist.
24—USCGC *Burton Island* completed escort of USNS *Towle* and departed for Wellington.
—USCGC *Southwind* arrived McMurdo; command of Ross Sea Ship Group passed from *Burton Island* to *Southwind.*
26—Shackleton Range field party picked up and returned to Halley Bay.
28—USNS *Towle* arrived Port Lyttelton.
—USCGC *Southwind* departed McMurdo to escort USNS *Alatna* inbound.
—Annual-ice runway at Williams Field closed due to ice deterioration.
—USCGC *Edisto* departed Palmer Station for Adelaide Island.
—Distinguished visitor group departed McMurdo for New Zealand.
29—HMNZS *Endeavour* arrived Port Lyttelton.
—Plateau Station deactivated.
—USCGC *Edisto* arrived Adelaide Island.
30—USCGC *Edisto* departed Adelaide Island for Palmer Station.
—Pickup of Ellsworth Land Survey party completed; camp 2 deactivated.
—USNS *Alatna,* escorted by USCGC *Southwind,* arrived McMurdo.

—USCGC *Burton Island* arrived Wellington.

31—USCGC *Edisto* arrived Palmer Station.

—USNS *Alatna,* escorted by USCGC *Southwind,* departed McMurdo for Port Lyttelton.

—USNS *Towle* departed Port Lyttelton and operational control of CTF-43.

February

1—USNS Wyandot, escorted by USCGC *Southwind,* arrived McMurdo.

2—USCGC *Glacier* arrived Valparaíso.

5—USCGC *Burton Island* departed Wellington for McMurdo.

—Army Aviation Detachment departed Christchurch and operational control of CTF-43; this completed the eighth and final season of Army helicopter support in Antarctica.

6—USCGC *Edisto* departed Palmer Station and arrived Deception Island.

7—USCGC *Edisto* departed Deception Island for Punta Arenas.

—USCGC *Glacier* departed Valparaíso for Punta Arenas.

—USNS *Alatna* arrived Port Lyttelton.

—USNS *Wyandot,* escorted by USCGC *Southwind,* departed McMurdo for Port Lyttelton.

8—VXE-6 C-121J made first landing of the season at Outer Williams Field.

—USCGC *Southwind* called at Hallett Station and departed to aid M/V *Thala Dan,* trapped in the ice off Wilkes Station.

—USNS *Alatna* departed Port Lyttelton for McMurdo.

9—Command of Ross Sea Ship Group passed from USCGC *Southwind* to USCGC *Burton Island.*

—HMNZS *Endeavour* departed Port Lyttelton for McMurdo.

10—USCGC *Edisto* arrived Punta Arenas.

11—USCGC *Burton Island* called at Hallett Station.

12—USCGC *Glacier* arrived Punta Arenas.

13—Photo flights terminated for the season.

—USNS *Wyandot* arrived Port Lyttelton.

—USCGC *Glacier* departed Punta Arenas on International Weddell Sea Oceanographic Expedition—1969 (IWSOE-1969).

—USCGC *Burton Island* arrived McMurdo.

14—USCGC *Edisto* departed Punta Arenas for Palmer Station.

—USCGC *Southwind* made rendezvous with M/V *Thala Dan.*

—Water distribution system at McMurdo placed back in operation after being out of service for two years.

15—USNS *Wyandot* departed Port Lyttelton and operational control of CTF-43.

—Last flight of the season departed South Pole Station; CTF-43 aboard.

16—USCGC *Southwind* arrived Wilkes Station escorting M/V *Thala Dan.*

—USNS *Alatna* arrived McMurdo Station.

17—USNS *Alatna* departed McMurdo for Port Lyttelton.

—Last flight of the season departed Byrd Station.

—USCGC *Edisto* called at Livingston Island en route to Palmer Station.

18—Brockton Station deactivated for the winter.

—USCGC *Edisto* arrived Palmer Station.

—Final C-121J turnaround flight of the season departed Outer Williams Field.

19—USCGC *Southwind* departed newly dedicated Casey Station, escorting M/V *Thala Dan* outbound.

20—HMNZS *Endeavour* arrived McMurdo.

21—VXE-6 helicopter operations terminated for the season.

—USCGC *Southwind* completed escort of M/V *Thala Dan* and departed for Fremantle, Australia.

22—USCGC *Burton Island* departed McMurdo and arrived Hallett.

23—USCGC *Burton Island* completed evacuation of Hallett Station and departed for McMurdo; Hallett deactivated for the winter.

—USNS *Alatna* arrived Port Lyttelton.

24—USCGC *Burton Island* arrived McMurdo and departed to take ice-prediction stations in the Ross Sea.

26—USCGC *Edisto* departed Palmer Station en route to Livingston Island and Punta Arenas.

27—USCGC *Southwind* arrived Fremantle and was released from operational control of CTF-43.

—USCGC *Edisto* called at Livingston Island.

—USNS *Alatna* departed Port Lyttelton for McMurdo.

March

2—USCGC *Edisto* arrived Punta Arenas and departed for Palmer Station.

3—USCGC *Burton Island* returned to McMurdo from ice-prediction project.

5—USCGC *Burton Island* departed McMurdo to escort USNS *Alatna* inbound.

6—USCGC *Edisto* arrived Palmer Station and departed for Punta Arenas.

—PM-3A nuclear power plant shut down due to a malfunction.

7—USNS *Alatna,* escorted by USCGC *Burton Island,* arrived McMurdo.

8—PM-3A resumed power output.

—Representative McMurdo, Commander, U.S. Naval Support Force, Antarctica disestablished, and Detachment Alpha, Antarctic Support Activities (Comdr. W. G. Hunter, USN, commanding) established.

—USNS *Alatna,* escorted by USCGC *Burton Island,* departed McMurdo; this was the latest date for the departure of a ship, other than an icebreaker, from McMurdo Sound since the beginning of *Deep Freeze.*

—*Deep Freeze 69* summer season officially closed with the departure of the last flight from McMurdo.

9—USCGC *Edisto* arrived Punta Arenas and was released from operational control of CTF-43.

10—CTF-43 departed Christchurch for the United States aboard VXE-6 LC-130R; command and administration of U.S. Naval Support Force, Antarctica shifted from Christchurch to Washington.

11—Last flight of the season departed Christchurch for the United States.

13—NCBU-201 released from operational control of CTF-43.

15—USNS *Alatna* arrived Port Lyttelton and was released from operational control of CTF-43.

16—USCGC *Burton Island* arrived Wellington and was released from operational control of CTF-43; Ross Sea Ship Group deactivated.

18—VXE-6, less one LC-130R, released from operational control of CTF-43.

20—Upon completion of IWSOE-1969, USCGC *Glacier* departed Weddell Sea for Palmer Station.

26—USCGC *Glacier* arrived Palmer Station and departed for Punta Arenas.

28—Last VXE-6 aircraft, the LC-130R, released from operational control of CTF-43.

29—USCGC *Glacier* arrived Punta Arenas and was released from operational control of CTF-43; Antarctic Peninsula Ship Group deactivated.

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