September-October 1967

ANTARCTIC JOURNAL
of the United States

ANTARCTIC JOURNAL of the United States

Vol. II **September-October 1967** **No. 5**

Prepared jointly by
Office of Antarctic Programs, National Science Foundation
and
U.S. Naval Support Force, Antarctica, Department of Defense

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Published bimonthly by the National Science Foundation with the assistance of the Department of Defense. Use of funds for printing this publication approved by the Director of the Bureau of the Budget, October 13, 1965.

Communications should be addressed to the Information Officer, Office of Antarctic Programs, National Science Foundation, Washington, D. C. 20550.

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Greenwich Mean Time is used throughout the issue except where otherwise indicated

A REVIEW OF YEAR-ROUND AND STATESIDE ACTIVITIES IN THE U. S. ANTARCTIC RESEARCH PROGRAM, 1966-1967

Introduction

The second part of a collection of articles on the activities of the U.S. Antarctic Research Program, 1966-1967, is presented in this issue of the Antarctic Journal. *While the last issue dealt with the field programs carried out during the 1966-1967 summer in Antarctica, this issue is devoted to the year-round programs conducted on the Continent and aboard the USARP research vessel* Eltanin, *studies made in the United States on the basis of data and specimens collected in the field during prior years, and the service programs that support USARP scientists in all disciplines. (A third category of research—involving international activities and cooperation—will be the subject of the November-December issue.)*

The projects described were proposed and carried out by scientists of universities, private or commercial institutions, and government agencies. The funding and overall administration of the U.S. Antarctic Research Program are the responsibility of the National Science Foundation. Field support of the program is provided by the U.S. Navy.

METEOROLOGY

Dynamics of the Surface-Wind Regime Over the Interior of Antarctica

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Katabatic winds of impressive strength are frequently observed in the coastal regions of Antarctica. However, in the interior of the Continent, with its uniform, gently sloping surface and a shallow layer of extremely cold air in the lower atmosphere, the occurrence of a systematic downslope air drainage, or even true katabatic winds, is an exception rather than the rule. Generally, the surface wind tends to blow at angles of about 45° to the fall line of the terrain, so that lower elevations remain to the left of a man facing the wind. This is documented by many traverse-party reports and the inland-station climatic records, which have been markedly improved in quantity and quality during the last 10 years. Furthermore, it is remarkable that the surface wind frequently is stronger and significantly more persistent (measured by the vector-standard-deviation, the directional constancy, or any other suitable statistical parameter) than winds at and above the top of the inversion layer. Obviously, this noteworthy decrease of constancy with height is contrary to the behavior of the winds over most other parts of the Earth's surface—wide land areas as well as oceans. This fact indicates that due to the specific temperature stratification in the surface air over Antarctica, a mass distribution exists which favors a systematic alignment of the winds from the free atmosphere down to the surface level. In meteorological terms, this implies the effect of a negative thermal wind.

In 1963, H. Lettau suggested that such a thermal wind is caused by the pronounced horizontal temperature gradient which must exist when cold air of approximately constant inversion depth lies over sloping terrain (see the sketch at the bottom of the figure). Dalrymple, Lettau, and Wollaston (1963, 1966) used the observations made at South Pole from March to September 1958 to show that the surface-wind regime at the Pole indeed can be explained by the "inclined surface-inversion" effect. In view of wider implications of the concept for the understanding of the surface-wind regime of a large part of the Continent, it appeared desirable to test

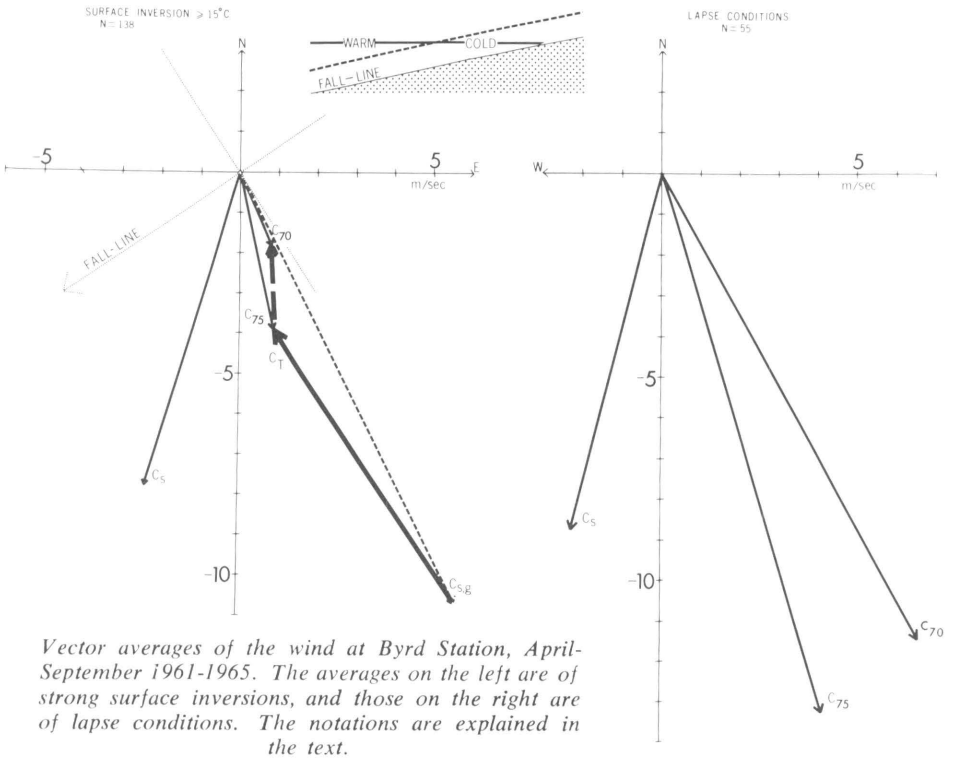
the theory with data obtained at other stations. One such test has now been completed for Byrd Station, employing the observations of five winter periods, namely, April-September, 1961-1965. The station is located at about 80°S. 120°W. and is 1,530 m above sea level, about 700 km from the coast of the Amundsen Sea, and 500 km from the nearest point on the Ross Ice Shelf. Within a radius of about 100 km from this station, the terrain has an ascendent vector of about 2.5 m/km towards the geographical azimuth of about 57° when the South Pole is at 180°. The rawinsonde observations made at Byrd Station were analyzed by means of a new, graphical method which will be explained in more detail in another report. Here it may suffice to state that the speed and direction of the thermal wind caused by the sloping inversion layer can be determined if the following assumptions are valid: (1) the orientation of the fall line of the inversion layer does not depend upon the surface-wind direction, and (2) the ratio of the speeds of the wind at the 10-m (anemometer) level to the geostrophic wind at this level depends only on the intensity of the inversion (the stability of the thermal stratification) and not on surface-wind direction and speed. The second assumption may appear to be restrictive; it can be eliminated by a separate analysis for groups of low, near average, and high surface-wind speeds; such an analysis proved to be unnecessary in cases in which strong inversions occurred over Byrd Station. "Strong," for Byrd Station, means an increase of temperature of 15°C. or more from the surface to the 750-mb level (that is, over a height interval of 500 m on the average); during the six winter months, such conditions exist about 19 percent of the time.

The thermal wind caused by the sloping inversion layer is defined here as the vector difference of the wind at 750 mb minus the geostrophic wind at the surface. For the above-mentioned cases of strong inversion, the thermal wind averages about 8 m/sec from 145°, which compares well with the approximate direction from 147° of the contour lines at 1,500 and 1,550 m in the Byrd Station area, as determined from a new topographic map kindly supplied by M. Giovinetto. It is also interesting to note that surface winds are rarely weak when a moderate or strong surface inversion exists. Only seven occurrences of an inversion of at least 10°C. *and* a wind speed of 3 m/sec or less at the 10-m level were noted, which is only two percent of all such inversions studied. In contrast, nine percent of all cases with lapse conditions were associated with weak winds. For the seven cases of weak winds associated with moderate or strong inversions, the speeds and directions at anemometer and 750-mb levels, respectively, were as follows: 1.1 m/sec from 032° and 4.6 m/sec from 141°. On the basis of these determinations, the thermal wind in the seven cases was approximately 6 m/sec from 150°, which can be due entirely to the sloping inversion.

Thermal-wind effects in the Byrd Station area are illustrated in the figure. On the left side, the resultant wind vector for all 138 days during which inversions of 15°C. or more occurred is indicated for the 10-m level by c_s, for the 750-mb level (approximately 500 m above ground) by c_{75}, and for the 700-mb level (approximately 1,000 m above ground) by c_{70}. The thermal wind between the surface and the 750-mb level is the vector c_T, which has a common terminal point with the 750-mb wind vector. Thus, the thermal-wind vector begins, by definition, at the end point of the geostrophic surface-wind vector, $c_{s,g}$. The angle (α_o) between the observed 10-m wind and geostrophic surface wind amounts to about 45°, a rather large value, and the ratio (r_o) of the speeds is 0.68. According to results listed in Table 13 of Dalrymple, Lettau, and Wollaston (1966), the corresponding values for the South Pole (when averaged for azimuths between 292° and 90°) are $\alpha_o = 50°$ and $r_o = 0.59$; thus the values for the two stations are in reasonable agreement. At the present time, there is no generally accepted "spiral" solution available for the frictional-wind profile in a planetary boundary layer in the presence of both extremely strong inversional stratification of temperature and strong geostrophic shear (or thermal wind). However, there are definite theoretical indications which suggest that, for strong inversions, the angular spread, α_o, must greatly exceed its value for a neutral (barotropic) boundary layer; in view of the exceptionally smooth snow cover over Antarctica, the latter value should be only slightly in excess of about 15°-20°.

If one wants to consider the possibility that the wind at the 750-mb level may not fully represent the free flow (the flow unaffected by surface friction) and that the resultant wind at 700 mb, rather than at 750 mb, is representative of the geostrophic flow above the inversion at Byrd Station, one would find that both values, α_o and r_o, would increase slightly but that the overall picture would not be changed essentially.

The importance of the thermal-wind effect on the surface-wind regime in the Byrd Station area (and presumably over any gently sloped terrain where an inversion normally is found) becomes evident by a comparison of average wind conditions for days with and without a strong surface inversion. Such a comparison is presented in the figure. On the right side are shown the vector averages of the wind



Vector averages of the wind at Byrd Station, April-September 1961-1965. The averages on the left are of strong surface inversions, and those on the right are of lapse conditions. The notations are explained in the text.

at surface, 750-mb, and 700-mb levels for all 55 cases (seven percent of the total number of analyzed soundings) in which there was a decrease of temperature with height of at least 0.1°C./100 m between the surface and the 750-mb level; they are referred to as lapse cases. Here we see conditions such as are normally found in middle latitudes, with the winds aloft being considerably stronger than those near the surface. In essence, if there is no inversion, the behavior of the wind profile is normal. This also is the gist of the following, more detailed statement by Dalrymple *et al* (1963, 1966) that is based on their wind analysis at South Pole: "The results do indicate that the air motion in the lower atmosphere is controlled by surface friction and by geostrophic motion in the free atmosphere above the inversion layer, modified by the thermal wind due to horizontal temperature gradients which result from the general slope of the terrain."

One can further conclude that the surface winds should be strongest where and when a strong temperature inversion is present *and* the direction of the geostrophic flow above the inversion is approximately opposite to the direction of the thermal wind due to the slope effect. This general rule can be verified by the wind records of other antarctic plateau stations, as, for example, with the aid of results summarized by Dalrymple (1966). Obviously, such a rule has practical significance for the prediction of surface-wind conditions at any place on the antarctic plateau, provided the general slope of the surrounding terrain is known and the flow in the free atmosphere above the inversion can be estimated.

It may be worthwhile to discuss briefly the implication of this notion. It is generally well known that where the slope of the terrain is sufficiently steep and the inclined surface and the higher ground act as a cold source, katabatic winds, or at least so-called "air drainage," will occur. (The basic theory of such direct gravitational circulations is reasonably well understood; for a list of references, see Lettau (1966).) However, at least two important limitations are imposed on the possible extent and occurrence of this type of flow. Observations indicate that the flow is restricted to occasional bursts of high intensity or to localized horizontal extent when it lasts for longer periods. These limitations are due mainly to the Coriolis force, which invariably accompanies any fluid motion on Earth, causing significant deflections of flow when the trajectory length approaches an order of about 10-100 km or when the time required to traverse a region exceeds several hours. A second limitation arises from the fact that even moderate katabatic flow rapidly exhausts an existing pool of cold air, as, similarly, the bursting of a dam drains a water reservoir. Any persistent katabatic flow would require either convergence of air currents fed by a drainage area of sufficiently steep inclination or a

highly intense cold source. A third limitation may be the inherent instability of this type of flow, as originally suggested by A. Defant in 1933.

It now has become evident that where the slope of the terrain is gentle and a strong surface temperature inversion persists, as is the case in major parts of Antarctica, the thermal "inversion winds" prevail instead of katabatic flow. These winds blow at a considerable angle off the fall line because they do not represent a direct, or exclusively gravitationally driven, circulation of surface air, but a motion of thicker layers that is modified by the Coriolis force and, of course, by surface friction. Obviously, the inversion wind is less efficient for the downslope transport of both snow and cold air than the katabatic flow. One may speculate that if the surface-wind regime over the interior of Antarctica were predominantly katabatic, the snow-and-ice dome covering the Continent might not persist and might not have been built up in the first place. The frequent presence of the surface inversion may be understood as a necessary condition for the maintenance of a continental ice cap. Conversely, the presence of the snow-and-ice surface favors the formation and maintenance of the surface inversion. Thus, a mechanism of self-preservation of a polar ice cap becomes evident.

It may be added that emphasis on the importance of a direct and purely gravity-driven circulation led, several decades ago, to the concept of the "glacial anticyclone." As presented by W. H. Hobbs, first more than 50 years ago and most strongly in 1926 (Hare, 1951), a semipermanent glacial high-pressure center was expected to overlie the ice caps of Greenland and Antarctica. Hobbs originally thought that such anticyclones played an important part in the world atmospheric circulation. However, modern theory, backed by observations made in Greenland and Antarctica, leads to doubts about the validity of the concept of a "glacial high." In fact, with regard to attempts to explain temporary features, such as Pleistocene glaciation, it can be argued that Hobbs' concept, quite paradoxically, links together a series of processes which would serve to *reduce* snow accumulation. If the concept were valid, the following conditions would prevail: Hardly any fresh snow would fall in anticyclonic weather zones, katabatic flow strong enough to cause central subsidence would move a certain amount of snow across the horizontal boundary, or coastline, and lack of cloud cover in the summer would permit plenty of insolation, with resulting evaporation of snow.

In significant contrast, the concept of thermal wind being due to the cold air of a substantial inversion layer enveloping a snow dome would inevitably lead to the more realistic picture of a cold-core *low-pressure* system centered above the dome. Thus, winds aloft would tend to circulate cyclonically about the snow dome. It could well be that subsequent surface-friction effects would lead to cyclonic inflow of air, giving rise to clouds and precipitation. In short, it is a relatively straight-forward argument that a reversal of the concepts, from Hobbs' glacial high to a cold-core low, is in order and that the latter concept represents the normal conditions. Under special circumstances, the buildup of a glacial ice dome could possibly occur under the processes related to a cold-core low until the accumulated weight of the snow forced the continental crust to yield downward, thus reducing the slope of the flanks of the snow dome. Together with the divergent mass-discharge by glacier movements, these secondary processes might reduce the causes which originally led to the formation of the cold-core low. One could expect that snow accumulation would then stop and that the ice dome, after leveling out, would shrink and possibly disappear in about 10^4-10^5 years, as is suggested by Pleistocene glaciation of various regions.

The preceding discussion concerns part of a continuing investigation of details of atmospheric circulation over Antarctica. Obviously, more research and analyses will be necessary to provide a more solid basis for discussion. With regard to the more specific problem of atmospheric or planetary boundary-layer structure under prevailing conditions of extreme surface inversion, unmarred by the diurnal changes at the Earth-air interface that occur in other latitudes, Antarctica must be considered an important test ground for concepts and theories. Obtaining observations that are more representative and of higher resolution throughout the entire atmospheric boundary layer or surface inversion will greatly facilitate further investigation. It may be mentioned that the first results of analyses of wind-speed and -direction profiles obtained from the 30-m tower at Plateau Station are extremely challenging.

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Radiation Climatology at Plateau Station

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The U.S. Army Natick Laboratories (NLABS) conducted a radiation climatology program at Plateau Station throughout the 1966 winter. Mr. Martin Sponholz, of the U.S. Weather Bureau, ESSA, was responsible for the maintenance of the instrumentation, which Mr. Leander Stroschein of NLABS installed during the 1965-1966 austral summer. Continuous measurements were made throughout the year of net and total global radiation and, throughout days with sunshine, of shortwave and reflected shortwave radiation. The net and total global radiation were measured with the so-called Funk radiometer, made in Australia, and the shortwave and reflected-shortwave radiation were recorded by Kipp solarimeters, made in Holland. Continuous strip-chart recordings were made throughout the year, with the exception of a short period in July and August 1966 when the main generator at the station was inoperative.

NLABS has initiated a program to reduce all strip-chart data, and this should be completed by the time this article is published. A computer program is being prepared to handle the radiation climatology data, monthly summaries of which will be available by the end of 1967. The analysis program, a joint effort of ESSA and NLABS, involves the application of some data on inversions obtained by radiometersondes. The collection of data at Plateau, which will continue through 1968, is now being carried on by Mike Kuhn of the University of Innsbruck.

In addition to the Funk and Kipp instruments installed at Plateau, the first Davos-made four-component radiation balance meter was put in operation there by Kuhn during the 1966-1967 austral summer. This is the first instrument placed in Antarctica that has comparable thermopiles which enable it to measure both incoming and outgoing shortwave and longwave radiation. A comparison will be made between the Funk, Kipp, and Davos radiometers to determine their relative merits. In addition, the University of Melbourne installed a series of radiometers in the snow during the same austral summer. As a result, Plateau probably has the most complete set of devices for measuring radiation ever available at a high-latitude station. At least one new instrument, an ultraviolet radiometer, will be added to this battery of instruments in the coming year.

It is expected that the total global and shortwave radiation for the midsummer months of December 1966 and January 1967 will reach new highs. On January 10, 1967, Kuhn, using the Kipp normal incident pyrheliometer with filters, obtained a series of readings which resulted in a computed value of 1.76 cal/cm^2/min. If this is substantiated after recalibration of the instrument, it will be the highest known value ever obtained on Earth for normal incident radiation.

Meteorological Observations at Palmer Station, 1965-1966

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A program of surface meteorological observations has been conducted in conjunction with a glaciological program at Palmer Station, Anvers Island, since February 1, 1965. These observations are currently being analyzed, and a two-volume report is being prepared for publication.

Palmer Station is located at 64°46′01″S. 64°04′39″W. and at an elevation of 15 m on Norsel Point, a small rocky peninsula on the northern side of Arthur Harbor. Waters of the Gerlache and Bismarck Straits and the open ocean lie adjacent to Norsel Point from the south through west to northwest. From the northwest through east to south, the station is backed by the Anvers Island ice cap, which rises to an altitude of 850 m. To the east, at a distance of 23 km, the mountains of Anvers Island rise to 3,000 m.

Table 1. Meteorological instruments operated at Palmer Station

Instrument	Height Operated (feet)
Maximum thermometer, liquid-in-glass (Wexler)*	6
Minimum thermometer, liquid-in-glass (Wexler)*	6
Exposed Spirit thermometer, liquid-in-glass (Wexler)*	6
Psychrometer, liquid-in-glass (Wexler)*	4
Thermograph, 7-day (Bendix Friez)*	5
Hygrothermograph, 7-day (Bendix Friez)	5
Anemometer, portable (U.S. Navy)	7
Wind recorder, mechanical, 31-day (Lambrecht model 1482)	30
Barograph, 4-day (Bendix Friez)*	5
Barometer, precision aneroid (Wallace and Tiernan)	5
Precipitation gauge, 8 inch, unshielded*	3
Precipitation gauge, 12 inch, automatic weighing, shielded, 7-day (Belfort Instrument Co.)	12
Pyrheliograph, 7-day (Belfort Instrument Co.)	3

*Standard U.S. Weather Bureau Equipment.

Table 2. Meteorological conditions at Palmer Station, 1965.

Conditions	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Average air temperature (°F.)	35.3	35.7	28.0	27.5	23.5	16.7	13.1	24.8	18.1	30.0	31.8
Days with rain and drizzle or freezing rain and drizzle	6	16	1	5	3	1	0	5	0	6	5
Days with snow and sleet	5	10	17	15	20	18	8	22	18	19	16
Average cloud cover (tenths)	8.61	7.98	8.28	7.79	8.14	7.17	4.36	8.26	8.48	9.29	8.41
Average wind speed (knots)	4.9	8.0	7.2	5.9	9.3	4.6	2.1	10.5	6.6	6.4	5.6
Peak gusts (knots)	42 N	46 N	42 N	45 NNW	46 E	45 NNW	46 NNE	55 NNE	47 E	45 NNE	45 NNE

Table 3. Meteorological conditions at Palmer Station, 1966.

Conditions	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Average air temperature (°F.)	35.5	32.9	32.0	27.9	24.3	21.9	07.2	14.7	18.5	23.9	29.6	32.0
Days with rain and drizzle or freezing rain and drizzle	3	3	9	13	1	2	1	1	1	1	4	4
Days with snow and sleet	1	2	20	15	14	17	18	20	17	24	16	15
Average cloud cover (tenths)	8.10	7.03	9.07	8.44	7.83	8.17	7.65	7.97	8.36	9.10	8.39	8.13
Average wind speed (knots)	5.4	3.6	5.5	7.0	7.3	9.8	6.3	8.8	7.7	6.5	4.6	3.6
Peak gusts (knots)	25 ENE	— —	40 NE	50 NNE	40 NNE	60+ NNE	50 N	60 NNW	60+ NNE	40 NW	28 NNE	40 NNE

Palmer Station meteorology facility. The 8- and 12-inch precipitation gauges are at left, the instrument shelter and anemometer tower at left of center, and the pyrheliograph at right of center.

(Photo by author)

The climate in the area of Palmer Station, which is situated in the subpolar low-pressure belt, exhibits predominantly cyclonic characteristics, with frequent, short-lived, though often violent, storms. Precipitation is high, and low-level stratus clouds dominate the sky. The occurrence of sunshine is low, and during some months not one clear day has been recorded.

With the exception of the installation of an automatic-weighing, shielded, 12-inch precipitation gauge in January 1966, the instrumentation of the meteorology facility has not changed since the station's commissioning in February 1965 (Table 1). A summary of meteorological conditions is given in Tables 2 and 3.

This program was supported by the National Science Foundation under grants GA-165 and -747 to the Ohio State University Research Foundation.

Meteorological Research in Antarctica

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The ESSA meteorological research programs conducted in and around Antarctica are part of the United States meteorological contribution to the international scientific program carried out since the IGY. The U.S. meteorological effort in the Antarctic is comprised of several ESSA, Navy, and university research and operational programs. The ESSA programs, which are carried out at Byrd, South Pole, and Plateau Stations and aboard *Eltanin,* are devoted primarily to research in synoptic meteorology, radiation, atmospheric constituents, and associated subjects. These programs have been maintained by three-man teams at Byrd and South Pole (only two men were at South Pole until October 1966), a two-man team aboard *Eltanin* (withdrawn for Cruises 26 and 27), and one research meteorologist at Plateau.

During fiscal year 1967, the research program in synoptic meteorology consisted of simultaneous daily rawinsonde observations at hour 0000 at Byrd, South Pole, aboard *Eltanin* (when at sea), and by the Navy at McMurdo. Surface and climatological observations were made at six-hour intervals beginning at 0000 daily at these stations and at Plateau and Palmer. During the austral summer, additional rawinsonde and surface observations were made at Byrd, South Pole, and McMurdo, and a full surface and upper-air program was carried out by the Navy at Hallett and on a Navy ship stationed at 60°S., midway between New Zealand and McMurdo. Surface observations were also made by the Navy at Brockton Station and Williams Field and by two automatic weather stations on the Ross Ice Shelf.

Radiation research was conducted at Byrd and South Pole Stations and aboard *Eltanin.* During dark periods, daily radiation soundings were made simultaneously by rawinsonde instruments sent aloft from the continental stations and, periodically, from *Eltanin.* At Byrd and South Pole, energy-balance measurements were made of direct solar radiation, total and sky radiation, reflected solar radiation, diffused solar radiation, and net radiation. Continuous snow-temperature measurements were recorded, which, together with the radiation measurements, are being used to compute the direct incoming and outgoing long-wave radiation. Special radiation observations and balloon-borne (slow-rising) radiometer soundings were made at Plateau to study in detail the great antarctic inversion. Temperatures were also measured at various levels between the surface and an altitude of 3 km to provide data for the inversion studies.

Samplings and measurements of various atmospheric constituents were obtained at Byrd, South Pole, and aboard *Eltanin.* On the Continent, observations of total ozone were made three times daily if sky conditions or the phase of the moon permitted. At Byrd and South Pole, two separate, complementary surface-ozone meters were monitored continuously, and once-monthly ozonesonde soundings were taken simultaneously with the rawinsonde observations. At South Pole and aboard *Eltanin,* evacuated flasks were used to obtain air samples for later analysis of carbon dioxide content. A separate carbon dioxide program involving the compression of the gas in special high-compression tanks was carried out at South Pole.

Associated research at South Pole included measuring and/or monitoring the surface radioactivity, wind-chill factor, electric field, and snow density. Observations of snow accumulation and noctilucent clouds were made at Byrd, South Pole, and Plateau. Aboard *Eltanin,* a special comparative rain-gauge measurement program was continued.

The goal of meteorological research in Antarctica is to gain a better understanding of the total effect of the Continent on the weather regimes of the Southern Hemisphere and the world. This research has the following specific objectives: (1) to monitor changes of various meteorological parameters; (2) to develop the climatology of Antarctica; and (3) to provide meteorological information for the World Meteorological and International Antarctic Meteorological Research Centers in Melbourne, Australia, for the several national meteorological centers located in the Southern Hemisphere, including Antarctica, and for the World Meteorological Centers in Washington and Moscow.

The comprehensive ESSA meteorological research programs are planned to phase into the World Meteorological Program, which consists of the World Weather Watch (WWW) and the Global Atmospheric Research Programs (GARP). When WWW networks are completed, they will provide data for research that is necessary to improve meteorological services to mankind. These networks will also provide data for the meteorological experiments and programs to be carried out under GARP. The research conducted in Antarctica since the IGY plus our current studies will phase into the polar programs to be conducted as part of the World Meteorological Program.

Surface and Subsurface Micrometeorology at Plateau Station

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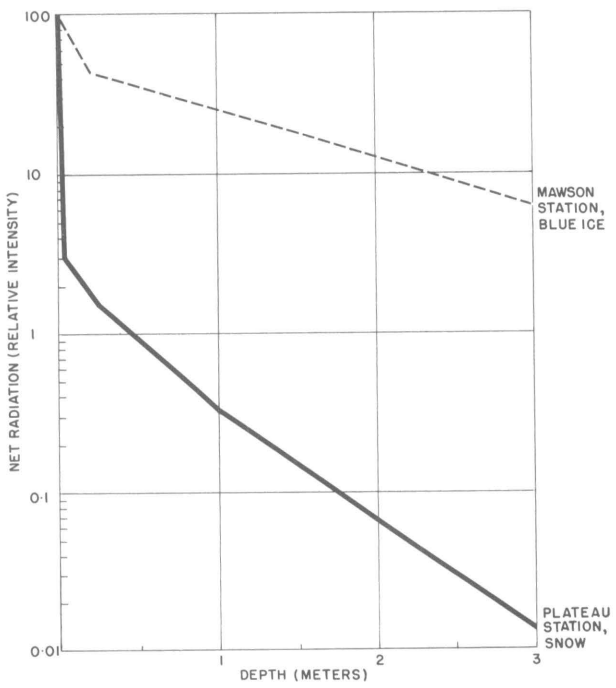
As part of Plateau Station's meteorological and glaciological programs, micrometeorological techniques are being applied in the top 10 m of the firn. The instrumentation includes special subsurface radiometers and heat-flux plates, which provide detailed information on radiative, conductive, and convective heat transfer in the firn. They are monitored by recorders which are housed, together with control equipment, in a seven-foot fiber-glass polyurethane cube kept at comfortable working temperatures by thermostatically controlled electric floor heating. The methods of observation and analysis were tested and perfected by Weller at Mawson Station in 1965. This early work made it clear that an ice or firn cover must be regarded as an energy-exchange layer rather than as a simple heat-exchange surface.

The first results from Plateau confirm that radiant energy undergoes a much more rapid extinction in firn than in the clear ice at Mawson (see figure). At the same time, convective heat transfer appears to be an important process. In summer, the firn temperature at Plateau increases from a minimum of –60°C. at the 4-m level, both towards the surface (–35°C.) and downwards to the level of annual mean temperature (–59°C.). During this period, the flow of air in the firn (caused, it is believed, mainly by changes in air pressure at the surface) appears to be so large as to increase the total heat flow by about one-third. Even stronger convection can be expected when the temperature gradient in the firn reverses its sign later in the year.



Radiation extinction in antarctic blue ice and snow.

The formation and accumulation of snow near Plateau appear to be strongly affected by the station itself. Therefore, values representative of these processes are being obtained from two separate accumulation-stake systems. The topography of the snow surface, which has been found to be extremely variable, is being systematically recorded. The study of drift and sublimation as functions of height has been restricted by the lack of electronic drift gauges. (The gauges were not built in time for use in the 1966-1967 season, but they will be put in operation next year.) However, preliminary measurements are being carried out with self-regulating cyclone gauges. Although snow drift, in the accepted antarctic sense, is not common at Plateau, it has been observed there on a number of occasions, including one "mini-blizzard" during which gusts of up to 30 knots were recorded.

Seasonal Changes of Atmospheric Mass Over the Antarctic Continent

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Ten years after the beginning of the IGY, sufficient observations of atmospheric pressure at station level have been accumulated for both the border and interior of Antarctica to make possible an analysis of the average annual march of pressure for every sector and altitude of the Continent. By proper weighting of the data for the coastal regions, the intermediate heights (Byrd, 1,500 m), and the high plateau (South Pole, 2,800 m; Vostok, 3,600 m), one can determine the average month-to-month variations of surface pressure, and hence the corresponding changes of atmospheric mass, over the entire Continent.

The most remarkable feature of the areally integrated pressure curve is that there are two dom-

inating oscillations—an annual and a semiannual harmonic variation. Indeed, these two components account for approximately 90 percent of the total variance of the series of 12 monthly values. The amplitudes of both the annual and semiannual oscillations are 3.5 mb. The maximum of the annual oscillation occurs on February 12 (climatically, although not astronomically, about the end of the short antarctic summer), while the maxima of the semiannual occur on January 2 and July 2, only 10 days from the solstices. For the combined curve, the principal maximum (+6.6 mb) occurs on January 11, a secondary minimum (−1.7 mb) in April, a secondary maximum (+1.1 mb) in June, and the principal minimum (−6.2 mb) on September 24. Because 1 mb of change over the entire surface of Antarctica corresponds to a change of mass of 12×10^{16} g, the total range of 12.8 mb from September to January represents 1.6×10^{18} g, or about 2 percent of the total mass above the Continent.

An examination of the data obtained at the 15 antarctic stations having records taken over a period of at least 7 years (10 years on the average), which were used for the analysis, reveals that the variability of the time of occurrence of the maxima and minima of the semiannual oscillation is very small; the standard deviation of the mean date is only 3 days, and the extreme range—Mawson versus Halley Bay—is 18 days. On the other hand, the variability of the time of occurrence of the maximum of the annual oscillation is much larger. There is a systematic delay from an early date (one of the first days of February) at the high-elevation stations in the interior of the Continent to a later date (in April) for the stations at lower latitude, near sea level.

The seasonal change of pressure over the entire Continent has several interesting implications. From the climatological point of view, it is noteworthy that in the latitudinal belt between 40° and 50°S. there is a semiannual variation of pressure, with the maxima at the equinoxes, which is just opposite in phase to the variation over Antarctica. This means that in the southern subpolar belt, the poleward pressure gradient, which is directly related to the strength of the westerly winds, is much stronger during the equinoctial months than in the months around the solstices. The effects of these conditions have been observed for many years; in fact, the old Cape Horn sailors often reported on the frequency and intensity of the "equinoctial storms."

Variations of atmospheric mass over the entire Continent must be interpreted as the result of a net meridional transport across, say, the Antarctic Circle. The poleward transport from September to January is the outstanding feature, but there also is a pronounced half-yearly rhythm in the exchange of antarctic and subpolar air masses, with a transport of sensible and latent heat toward Antarctica from April to June. The phenomenon of the coreless antarctic winter, first described by Meinardus in 1930, and in particular the fact that the interior of the Continent (in the area of the South Pole) is, on the average, not colder in June than in April, may be due, at least partly, to this poleward transport. It acts, of course, in addition to the macroturbulent exchange brought about by the intense cyclonic activity in the subpolar belt, which operates on a much shorter time scale. This belt is also characterized by an intensity maximum in the equinoctial months.

Finally, it is interesting to question whether the change of pressure over Antarctica has any effect on an entirely different geophysical phenomenon—namely, the periodic variations of the rate of rotation of the Earth. A change of mass over the entire Continent must affect the moment of inertia of the Earth and thus its rate of rotation. The same is not true for ocean areas (including the Arctic Basin), because over large water bodies the so-called "inverted barometer" principle (approximately 1 cm depression of sea level for 1 mb increase of pressure) applies. Seasonal pressure variations over nonpolar continents, such as Asia, indeed do affect the oscillation of the axis of rotation (and can produce a "wobble"), but because of the proportionally much smaller dislocation of mass from the axis of rotation, these variations cannot essentially affect the rate of rotation.

Quantitatively, the effect of the seasonal variations of atmospheric mass over Antarctica on the periodic variation of the length of day is very small indeed. It amounts to only about one percent of the magnitude of the most important effects, the annual and semiannual variations of the relative angular momentum of the entire atmosphere. This latter phenomenon, of which a new analysis was made employing all available aerological data of recent years, tends to maximize the length of day in the second half of March and to minimize it in the second half of July, the March-July range being about 0.7 milliseconds. Nevertheless, a considerable part of the astronomically observed periodic variations of length of day still remains unexplained, which was the specific reason for examining the possible magnitude of the antarctic effect.

Two forthcoming papers in the *Journal of Geophysical Research* will give a more detailed report on the results of the studies that have been only briefly described here.

Interdisciplinary Program in Antarctic Meteorology

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During the past year, accomplishments of the Polar Meteorology Group included research in the following fields:

Radiation. Results of an investigation of the recent decrease in solar radiation observed at the South Pole were presented at the Symposium on Polar Meteorology in Geneva, September 1966. A more detailed report on this phenomenon has been submitted for publication in *Tellus*.

Stratospheric circulation. A series of mean monthly 20-mb charts for the high-latitude Southern Hemisphere was issued as an ESSA Technical Memorandum in February 1967. A similar series for the 50- and 100-mb levels has been completed.

Studies are in progress on the dynamics of the polar vortex in late autumn and winter and on the relations of observed stratospheric warming to the dynamics of the jet stream. An investigation of stratospheric-aerosol density and sources is also being conducted.

Ozone. Results of the analysis of the ozonesonde observations in Antarctica during 1964 were presented at the Symposium on Polar Meteorology in Geneva, September 1966. Antarctic ozone observations for other years are now being analyzed to relate observed variations in atmospheric ozone concentrations to atmospheric motions.

Map Folio Series. Folio 4 of the Antarctic Map Folio Series (American Geographical Society), which contains climatological charts and discussions of the free atmosphere over Antarctica, was published in December 1966. The preparation of material for a folio on the climatology of the surface environment has been completed.

Satellite data. Photographs of Antarctica and the surrounding seas, taken by the satellites ESSA III and ESSA V, are being analyzed to determine mean cloud cover and pack-ice boundaries by 10-day periods for the calendar year ending October 1967.

Subsurface heat flux. The results of a study of the mechanism of heat flow and storage in the upper layers of snow on the central plateau of Antarctica were presented at the Symposium on Polar Meteorology in Geneva, September 1966. This investigation resulted in the evaluation of conductivity coefficients and other thermal parameters in the upper layers of snow, and it related the heat flux in the snow to the heat budget at the snow surface.

Wind-shear components. Pilot balloon data from Little America were used in a study of the frictional and thermal components of the wind shear in the boundary layer. It was found that the components of the total wind shear could be evaluated with quite consistent results, and that the thermal component could be used to establish the mean temperature pattern in the vicinity of the observational site. A report of this work will be published in the *Monthly Weather Review* for September 1967.

Moisture transport. The analysis of summer meridional moisture-transport values at Byrd Station permitted the construction of an empirical expression for moisture transport as a function of height over Antarctica. By making certain assumptions about moisture deposition at the surface as related to transport, an expression was obtained for surface moisture accumulation as a function of the distance inland. Observational data fit the model remarkably well. Implications of snow accumulation under the present climatic regime with respect to variations in ice thickness over Antarctica are discussed in a paper that was presented to the meteorology section of the International Union of Geodesy and Geophysics, which met in Lucerne, Switzerland, in September 1967.

Other contributions. Personnel of the group prepared a discussion of antarctic climatology, in which emphasis was placed on the local climatology of ice-free areas; it was published as a chapter in volume 8 (1966) of the *Antarctic Research Series*. Contributions were also made to a review of the status of observations of surface winds and surface currents of the ocean surrounding Antarctica, presented at the Antarctic Oceanography Symposium in Santiago, Chile, September 1966.

Meteorological Studies on the Antarctic Plateau

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In the first winter of operations at Plateau Station, 13 series of balloon observations comprised of 65 individual balloon ascents were made through the inversion layer. On each flight, measurements of temperature, pressure, and both upward and downward radiative fluxes were transmitted by radio to ground

recorders in the meteorological office. In addition, each balloon was tracked by two theodolites so that the wind structure of the lower atmosphere could be determined reliably. It was found that the top of the temperature inversion was generally 1 km or less above the snow surface throughout the winter. The data obtained are now being reduced in preparation for an investigation of the structure of the great antarctic inversion and relations of changes in thermal structure of the inversion layer to changes in the wind field and in the radiative transfer of heat through the layer.

Temperatures at several levels within the upper few meters of the snow were measured at least once daily. These data are also undergoing reduction, after which they will be analyzed to evaluate the seasonal heat storage in the snow and other thermal parameters.

Regular synoptic measurements of surface pressure, temperature, and winds were made every six hours, and visual observations were made of other meteorological conditions, such as cloud types and cover. On the basis of the first year's observations, the climate of the Plateau area may be characterized as cold, dry, and generally clear, with light to moderate winds. The mean annual temperature was —56.6°C. (—69.9°F.), and the lowest temperature measured was —85.2°C. (—121.4°F.). The average cloud cover was less than three-tenths, and two-thirds of the days were clear. The mean wind speed was about nine knots, and blowing snow that restricted visibility to one-fourth mile or less occurred on 17 days during the year.

UPPER ATMOSPHERE PHYSICS

Kotzebue, Alaska—Macquarie Island Conjugate Point Micropulsation Experiment

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During the 1966-1967 austral summer, the Geophysical Institute of the University of Alaska installed a three-component induction-loop magnetometer on Macquarie Island. This island is the site of a permanent scientific station of the Australian National Antarctic Research Expedition (ANARE). Logistic support for the project was provided by the Australian government, while the Geophysical Institute, under NSF Grant GA-726, provided the instrumentation and a geophysicist to install it.

The Macquarie Island magnetometer is identical to one installed by the Geophysical Institute at Kotzebue, Alaska, in November 1966. The Macquarie Island and Kotzebue stations are a conjugate pair.

The induction-loop magnetometer, which measures the rate of change of the Earth's magnetic field, is suitable for remote field operations because of its simplicity of design and lack of moving parts. The information received by these magnetometers at Kotzebue and Macquarie Island is being recorded on pen-and-ink analog charts and magnetic tape. This method provides both a visual record of the amplitude of micropulsation events and a tape recording, which is used for the frequency/time analysis of various magnetic-field fluctuations.

The purpose of this project is to study, at conjugate points, the three-dimensional polarization and frequency/time characteristics of geomagnetic-field micropulsations in the frequency range from 1 to .001 cps. It is well known that certain types of micropulsations exhibit identical characteristics at conjugate points. The most notable are Pg and Pc-5 events, which have been shown to be due to field-line-guided hydromagnetic waves. Until the recent installation of the Kotzebue and Macquarie Island induction magnetometers, it was necessary to use the Macquarie Island—College, Alaska, rapid-run magnetograms for conjugate-point research. Significant results have been obtained by means of the Macquarie Island—College data, but the lack of conjugacy between these stations and the low sensitivity of the equipment restricted the analysis to long-period micropulsations. The Macquarie Island and Kotzebue induction magnetometers extend the useable frequency range for analysis to shorter period pulsations, and their location is within a few kilometers of conjugacy. Records obtained over a period of two months in early 1967 at Macquarie Island were sent to Alaska at the end of summer operations. These data are now being analyzed at the Geophysical Institute in conjunction with the data recorded simultaneously at Kotzebue.

The two stations have been operating satisfactorily since January 1967, and it is expected that they will continue to do so. Scientists spending the 1967 winter at Macquarie Island are maintaining the equipment and changing records daily as part of the cooperative program between the Geophysical Institute and ANARE.

Radiation from Atomic Hydrogen In Aurorae

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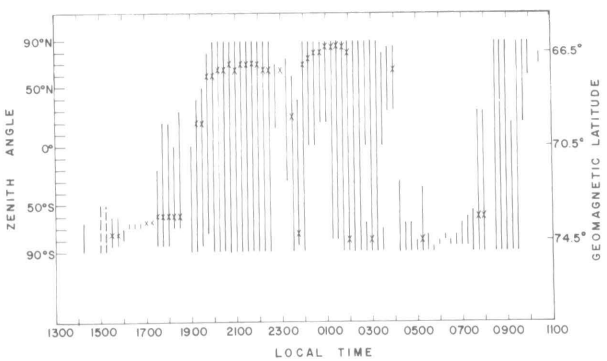
Observations of auroral hydrogen commenced at Byrd Station in mid-April, as soon as darkness permitted. A meridian spectrograph is used to record on film a narrow segment of the sky from horizon to horizon. Spectral features in the wavelength region between about 3900 A and 6700 A were recorded. The instrument was oriented so that the entrance slot was about normal to the average alignment of the auroral arcs; such orientation is optimal for recording the motion in longitude of the faint arcs which contain the hydrogen radiation. The speed at which the arcs move determines the length of exposure which can be used. Experience has indicated that a 15-minute exposure gives a good film density for the Balmer-alpha line of hydrogen, while successive exposures show the migration of the arcs.



Record of the Balmer-alpha line of hydrogen made at Byrd Station on the night of May 25-26, 1966. See text.

In the accompanying diagram, the results of one night's observations are shown. Each line represents a 15-minute exposure, the length of the line being an indication of the exposure's extent in zenith angle on the original film. Sometimes Balmer-alpha was recorded from horizon to horizon, while at other times it was localized. A distinct maximum on the film is shown by a cross on the diagram. On this particular night, 20 hours of records were obtained before twilight ended the observations. A characteristic motion of the hydrogen arc was noted, first equatorward, then poleward. Observations were made on only portions of other nights and some of these still require analysis. It is premature, therefore, to draw any conclusions at this time.

Twilight and Nightglow Spectrometry At South Pole Station During the 1966 Winter

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Many studies have been made at middle latitudes of the occurrence of metallic atoms and ions, particularly atomic sodium, in the upper atmosphere. The data show that the concentration of atomic sodium reaches a peak at an altitude of about 90-95 km. It has been suggested that the source of the sodium is either seawater vapor that has been carried high into the atmosphere or the remnants of meteors that have evaporated in the atmosphere. It becomes obvious, after examination of the mid-latitude data, that the solution of this problem involves study of the ionization equilibrium of sodium, the chemical properties of the upper atmosphere, and the modification of the chemical properties of the atmosphere by meteorological-transport processes, both horizontal and vertical.

The sodium is most easily observed at twilight, when the sun no longer illuminates the lower atmosphere but is still resonantly exciting emission from sodium in the upper atmosphere. At middle and low latitudes, conditions are suitable for observation for only a few tens of minutes at dawn and dusk. At the South Pole, the year's twilight is concentrated into two periods of several days each, during which continuous observation is possible.

A scanning photoelectric spectrometer was set up in the auroral tower of South Pole Station in January 1966 and made fully operational before the beginning of twilight in late March. The spectrometer operated well, thanks to project-assistant Richard Przywitowski, throughout both this twilight period and the second one, which started at the beginning of September. The data obtained during the first twilight, which were recorded on many thousand feet of paper tape, have been reduced and found to reveal a number of interesting and unexpected features. First, the sodium layer appears to be 10-15 km higher over the South Pole than it is at middle latitudes. Second, quite large changes in the amount of sodium apparently occur from hour to hour, possibly indicating a genuine daily variation in abundance. This finding is a little surprising in view of the fact that at the equinoxes the South Pole is symmetrically located with respect to most geographical and astronomical coordinates.

A search was also carried out for other metallic emission lines in the spectrum of the twilight sky. The first reduction of the data has shown that these lines were not present, and upper limits to the amount of the metals that could be present are being worked out.

During the polar night, the scanning spectrometer was used to measure the intensities of various auroral- and airglow-emission lines. The data obtained will be used to give reference points for investigations of the emission processes in the night sky well inside the auroral zone.

The ITSA Antarctic Riometer Program

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Environmental Science Services Administration

In ITSA's antarctic riometer program, ionospheric-absorption measurements were made at Byrd, South Pole, and Vostok Stations (at Vostok the project is conducted in cooperation with the Soviet Antarctic Expedition). During 1966, absorption measurements were also made at Plateau Station. The investigation was initially part of a larger conjugate-point program, and conjugate aspects of the observations are still under study, with emphasis on the conjugate pair of Byrd and Great Whale River, Quebec, Canada. At both locations, multiple-antenna riometer systems employing digital outputs were installed early in 1966 and have operated fairly continuously since then. The objective of this investigation is to study the small-scale spatial variation of magnetic conjugacy and to look for temporal variations in conjugacy. Some preliminary analyses were made during 1966, and more thorough analyses are now in progress.

Excellent data were obtained from all of the antarctic riometers during the intense polar cap absorption (PCA) events of August-September 1966 and January-February 1967. These events, which are caused by influxes of energetic protons from the sun, are a phenomenon unique to very high magnetic latitudes, and detailed study of them has proved to be one of the richest sources of information on the properties of proton fluxes and the lower ionosphere, where radio-wave absorption takes place.

The events of 1966-1967 have shown that there may be important differences in composition between the arctic and antarctic ionospheres, and this possibility is currently being studied in some detail. During 1966, analyses of earlier PCA events were also carried out. A detailed investigation of the event of February 1965 revealed hitherto unexpected evidence of nonuniformity in proton precipitation over the polar caps. Fig. 1 shows the growth and the early part of the decay of the absorption recorded during this event at Vostok, South Pole, and Byrd Stations. A theoretical investigation of geomagnetic cutoffs for incoming solar protons at high magnetic latitudes was also completed.

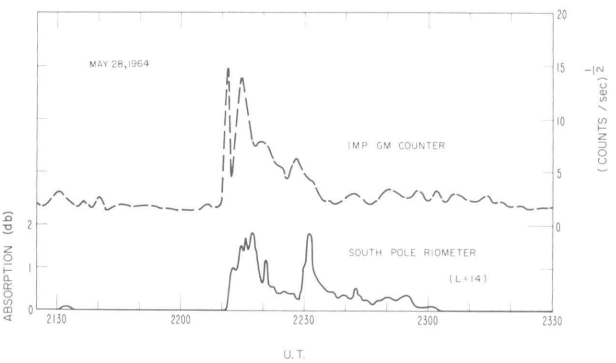

Figure 2. Example of correspondence between bursts of electrons recorded by the satellite IMP-1 at 28 Earth radii and absorption measured at South Pole Station.

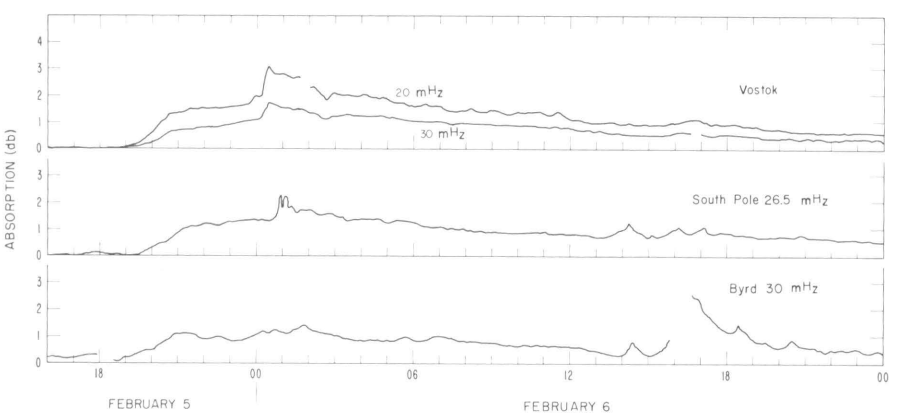

Figure 1. Growth and early part of decay of absorption during event of February 1966. See text.

In the field of auroral absorption, which is related to the precipitation of energetic electrons into the upper atmosphere, research has been concentrated on the broad statistical properties of absorption and the variations in absorption with geomagnetic activity and other parameters. The correspondence between bursts of energetic electrons observed by satellites at great distances from the Earth and auroral absorption measured by riometers has been examined, and further work is in progress. An example of the correspondence seen occasionally is given in Fig. 2, in which the response of a particle counter on board the satellite IMP-1 (at a distance of 28 Earth radii in the antisolar direction) is shown with the simultaneous response of the riometer at South Pole Station. The general similarity of the two sets of data suggests a direct link of some kind between the two locations. It is also consistent with recent models of the distant geomagnetic field that predict a great extension of the field in the antisolar direction and a connection between this geomagnetic "tail" and auroral phenomena.

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Auroral Studies at Plateau and Byrd Stations

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The Arctic Institute of North America's program of auroral studies in Antarctica during 1966-1967 was in part an extension of aurora and airglow observations conducted at several antarctic stations since the IGY and in part a new approach to antarctic ionospheric studies. In conformation with the earlier programs, an observer was sent to the newly established Plateau Station to determine the frequency of occurrence of aurorae at a new location within the zone of maximum frequency. Events were recorded on black-and-white film with a 16-mm all-sky camera and in color with a wide-angle 35-mm camera. A single-line photometer recorded emissions at 5577 A, and a sequential photometer recorded them at 3914, 5300, 5577, and 6300 A. Copies of the data have been filed with auroral data centers. A preliminary study of the data shows an apparent, intriguing correlation with VLF occurrences, and a detailed analysis is now under way.

The program at Byrd Station was conducted in conjunction with its geomagnetically conjugate station—Great Whale River, Quebec, Canada—where for several years the National Research Council of Canada has conducted ionospheric research. Data were sought on the simultaneity of auroral onset, cessation, and variations of brightness, form, and motion. To insure that the methods of measurement at the two stations were as nearly identical as possible, personnel of the National Research Council fabricated a second set of all-sky cameras and a photometer for use at Byrd Station. With this equipment and identical films and procedures, it is believed that the data obtained on emissions at 3914, 4861, 5400, 6300, and 6563 A will provide worthwhile insight into the behavior of the Earth's magnetosphere. The information from both stations is now being analyzed in Ottawa.

Geomagnetic Studies at Byrd, South Pole, and Plateau Stations

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U.S. Coast and Geodetic Survey
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Continuously recording magnetographs producing permanent records of variations in magnetic declination and horizontal and vertical intensity re-

mained in operation at Byrd, South Pole, and Plateau Stations throughout the past year. Absolute observations of the magnetic elements were made at frequent intervals for the following reasons: so that absolute values could be assigned to these elements at any point in time; so that secular-change rates could be established for accurate map-making; and as an aid in investigations in solid-Earth physics through studies of the spatially varying secular-change rates. Obtaining data from these three stations is of special importance because few reliable magnetic measurements have been made in that part of the world in the past, partly because of the relatively short history of all magnetic recording stations there.

A major responsibility associated with the geomagnetism program of the U.S. Coast and Geodetic Survey is the compilation of the World Magnetic Charts at 5- and 10-year intervals. The determination of secular-change rates in Antarctica for compilation of the next (1970) updating of the World Magnetic Charts will depend almost entirely on geomagnetic data obtained at Byrd, South Pole, and Plateau Stations and at similar stations operated by other nations on the Continent. In Antarctica, there are no "repeat" observations—precise measurements of the strength and direction of the magnetic field made at exactly the same points, similar to those made on other continents—that would assist in determining the secular-change patterns.

After their receipt (about March 1968) at the headquarters office of the Coast and Geodetic Survey, the magnetic data recorded during the past year at Byrd, South Pole, and Plateau Stations will be available to all researchers desiring them through World Data Center A.

Electron Content of the Antarctic Ionosphere, 1966

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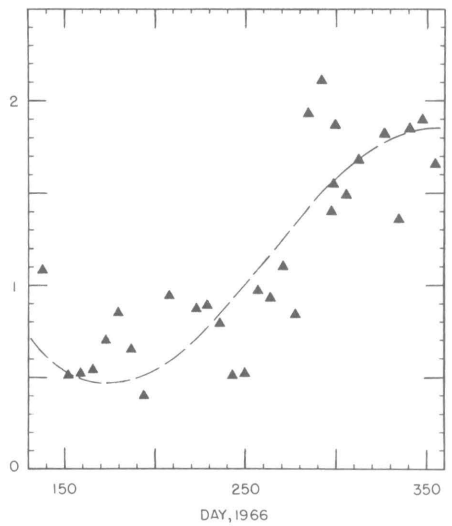
Measurements of the total electron content of the antarctic ionosphere have been made by reference to data obtained by measuring the Doppler shift of radio-frequency signals from Earth satellites. The data were recorded at the Doppler satellite tracking station at McMurdo, which was operated by the Physical Science Laboratory of New Mexico State University (Mott, 1966).

The results of the measurements are shown in the figure. Each point represents information collected during one satellite pass over the station. During each pass, a series of columnar electron-density measurements was taken. A least-squares smoothing process was applied to this series of values to obtain the value reported for that pass (Stephens, 1967). All data were recorded in the morning hours, local time.



Columnar electron density in units of 10^{17} electrons per m^2. The superimposed sinusoidal curve indicates an apparent seasonal trend in the data.

The continued presence of a substantial ionosphere during the extended period of total darkness supports the hypothesis that the protonosphere acts as a source of charged particles for the ionosphere (da Rosa *and* Smith, 1967).

A correlation of the variations in electron content with geomagnetic activity is apparent. Days of high geomagnetic activity, as indicated by the values of the daily index A_p, are listed in the table. Our results indicate that the electron content of the antarctic ionosphere decreases during periods of high geomagnetic activity.

The observed ionospheric variations can be understood on the basis of a theory ascribing magnetic-storm behavior to distortion of the magnetosphere by the solar wind (Stephens, 1967). The enhanced solar wind, resulting from an eruption at the surface of the sun, induces fluctuations at the boundary of the magnetosphere. Redistribution of the magnetic-field lines causes collisions of charged particles with stationary neutral particles in regions where the density of both types of particles is substantial. The net result is an increase in heat in the

Days of high planetary geomagnetic index (A_P) for the period May through December 1966. From Solar-Geophysical Data *(1967).*

Day of Year	Date	A_P
146	May 26	78
151	May 31	48
190	July 9	36
242	Aug 30	82
246	Sept 3	92
247	Sept 4	112
251	Sept 8	42
278	Oct 5	36
304	Oct 31	34
348	Dec 14	48

ionosphere. In the antarctic region, the consequent temperature increase is sufficient to shift the scale height of the ionosphere upward to such an extent that the total electron content below the 1,000-km altitude of the satellites involved in this study is reduced.

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Investigations of Cosmic Ray Intensity Variations in Antarctica

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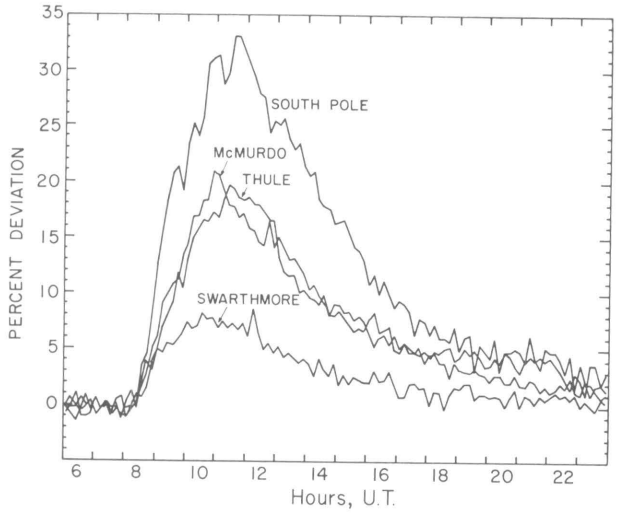
Bartol Research Foundation of The Franklin Institute

As a consequence of the role played by the geomagnetic field in determining the "optics" of cosmic ray detectors, it is possible to view directions of arrival of particles significantly inclined to the ecliptic plane only in the polar regions. Thus, observations made with continuously recording ground-based neutron monitors at fixed locations in the Arctic and Antarctic afford a unique means for investigating anisotropies that may arise in a direction perpendicular to the equatorial plane.

A systematic cosmic ray intensity gradient along the Earth's rotational axis has been observed for the first time. An analysis of data recorded by the network of high-counting-rate neutron monitors during the recovery phase of a Forbush decrease in March 1966 revealed the occurrence of a significant north-south asymmetry. Data from South Pole and McMurdo Stations were crucial in the discovery of this phenomenon. A theoretical model that accounts for all of the observed effects, including latitude dependence, has been developed. The anisotropy is envisaged as arising from the diffusion of cosmic rays through disordered magnetic fields in the vicinity of the Earth, the diffusion being associated with many conspicuous solar disturbances during this period of resurgent solar activity. The two components of the vector in three-dimensional space that defines the direction of anisotropy were determined by combining the information deduced from the study of the north-south asymmetry with data on the associated diurnal variation. During one of the two epochs that has been studied in detail, the greatest flux of cosmic ray particles was incident from the direction in space of $-83.5^\circ \pm 3.5^\circ$ declination and 13.3 ± 0.7 h right ascension. Thus, the configuration of the magnetic fields of solar origin that enveloped the Earth at this time was not symmetrical about the equatorial plane. Alternative interpretations of this result are (1) that the lines of force were temporarily directed almost perpendicularly to the solar equatorial plane, permitting the preferential flow of particles along these lines, or (2) that the lines of force were parallel to the equatorial plane, as usual, and the density gradient in the north-south direction was a consequence of the asymmetrical spatial distribution of the cosmic ray "shield."

During 10 years of operation of neutron monitors in the polar regions, solar particles having sufficient energy to propagate to sea level (rigidity $\geqslant 1$ GV) have been detected on only eight occasions. After a lapse of five years, the first flare-associated solar-particle emission that produced detectable effects in ground-based cosmic ray detectors occurred on July 7, 1966, following the 2B flare that commenced at 0020 UT. This event is especially noteworthy because it was the first observed by the network of high-counting-rate neutron monitors currently operating in both polar regions. The maximum increase was about two percent. The first significant effect occurred at 0115 UT, 55 minutes after the onset of the flare.

A second and quite unusual event occurred on January 28, 1967. An analysis based upon a comparison of the recordings from South Pole (atmospheric depth, 694 g/cm^2) and McMurdo (atmospheric depth, 993 g/cm^2) made it possible to determine the absorption coefficient of the solar cos-



Percent deviation of absorption from normal level as recorded at four stations during the event of January 28, 1967.

mic rays. This event is anomalous in that either it represents the first observation of solar particles reaching the Earth from the back side of the sun or it is associated with a relatively feeble flare ($<$1B) that occurred in the eastern hemisphere of the visible disk. Neither region connects direcly with the Earth via a magnetic tube that provides easy access for energetic particles. The propagation of solar particles in this event was evidently controlled by a diffusion mechanism, in view of the fact that the observations are consistent with predictions based on alternative theoretical models of this process.

VLF Studies at Plateau Station

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Plateau Station is located in an exceptionally favorable position (79°15′S. 40°30′E.) for very low frequency (VLF) observations. In addition to the usual phase and amplitude variations observed on VLF signals that have traveled over long paths to high magnetic latitudes, other variations occur which are believed to be related to magnetic disturbances and the precipitation, or dumping, of electrons from the Van Allen belt. When these electrons impinge upon the *D* region, they are believed to create abnormal ionization. The region of the South Atlantic magnetic anomaly should be the region most sensitive to the conditions which cause this dumping. Plateau Station is so situated that signals from VLF transmitters that are recorded there pass either through, near, or far away from the magnetic anomaly, providing both observational and control data for this study.

The data obtained at Plateau, together with that taken at Byrd Station, should also provide valuable supplements to data on polar cap events (PCE) obtained in the north polar region. The data from the two regions indicate that there are interesting temporal and spatial variations of PCE over the polar caps. The antarctic data should provide additional information on these variations and on the conjugacy of PCE. The observation of PCE by VLF techniques also has some advantages over the observation of absorption caused by PCE riometer or forward-scatter techniques since the VLF techniques seem to be almost equally sensitive whether the paths are sunlit or not. This is in contrast to the measurement of absorption because of the relative insensitivity of the observing instruments at night.

The past antarctic winter's records were received early this year, and a cursory examination reveals that the data are generally of good quality. The greatest general problem with them is the very large diurnal amplitude variation, which is characteristic of long-path, high-latitude VLF observations. An automatic gain control (AGC) system that was sent to the station during the past summer, and which is now being installed, will greatly increase the range of amplitudes over which the equipment will operate and record properly. A digital data-acquisition system, which is also being added, will produce digitized data at a rate high enough to properly define the rapid variations characteristic of high-latitude, long-path VLF signals.

A fourth recording channel was installed and placed in operation in late April. It is now being used to record signals from the Navy VLF transmitter NAA (17.8 kHz) at Cutler, Maine, which recently changed its operating procedures so that it is again useful for VLF phase and amplitude measurements. The path from this station passes very close to the center of the South Atlantic magnetic anomaly.

Future plans for the project include the addition of a fifth recording channel, which will be used for the new U.S. Navy VLF station NWC, at North West Cape, Australia, which should go into operation sometime this year. The paths from this transmitter to Plateau and Byrd include a considerable distance over the polar ice cap and should provide valuable supplements to the data on PCE.

Plans for improved equipment at Byrd Station include a complete electronic phase-tracking system to replace the present electromechanical servos, which are showing considerable wear after many years of use. Electronic phase-tracking systems are inherently faster and can provide better results at low signal-to-noise ratios than the old mechanical servo systems. A complete set of AGC systems, to work with the electronic phase-tracking systems, and a digital acquisition system similar to the one at Plateau, are also planned for installation at Byrd during the next antarctic summer.

University of Washington's Antarctic Research Program, 1966-1967

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During 1966-1967, progress was made by the University of Washington in the following four

D-region studies. The very low frequency (VLF) ionospheric step-frequency sounder installed at Byrd substation, 11 miles from Byrd Station, has been in almost daily operation since March 1966. The schedule during the 1967 austral winter has called for a series of pulsed transmissions of about 1 minute duration every 15 minutes, during which the transmitted frequency is stepped between 3.0 and 30.0 kHz in 100-Hz increments. The peak power delivered to the 21-mile dipole antenna is now 25 kw.

Data obtained during the first year of operation were returned to the University of Washington in February 1967 for processing. Although all of the records have not yet been processed, the results are very encouraging. Several typical oscilloscope waveforms are shown in Fig. 1. The upper portion of the figure shows the waveform of the transmitted current in the antenna at a frequency of 5 kHz (I_a). The "pulse" contains little more than one cycle of the 5 kHz signal. The lower portion of the figure shows the intermediate frequency (IF) output of the receiver, as telemetered from Byrd Station back to the long-wire antenna site. The first hump on the left is the ground signal, which was transmitted 20 km over the ice, and it is followed by a strong *D*-region echo.

The lower oscilloscope waveform shows the transmitted current at a frequency of 30 kHz (I_a). The

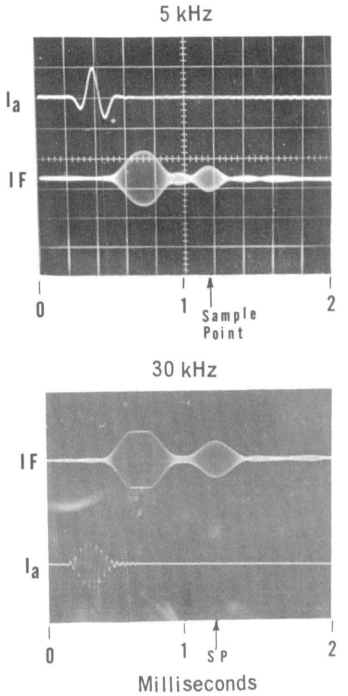

Figure 1. Oscilloscope waveforms of transmitted and ionospherically reflected pulses.

receiver IF displays both the direct wave and a very strong *D*-region echo. The points marked "SP" show the instant at which the waveform was sampled to determine the phase shift between transmitted and reflected waves.

A number of significant ionospheric events have been revealed in the processed *D*-region data. Fig. 2 shows a striking correlation between VLF hiss, as recorded by Stanford University at Byrd Station, and ionospheric virtual height. A strong burst of 12 kHz hiss on August 7, 1966, was immediately

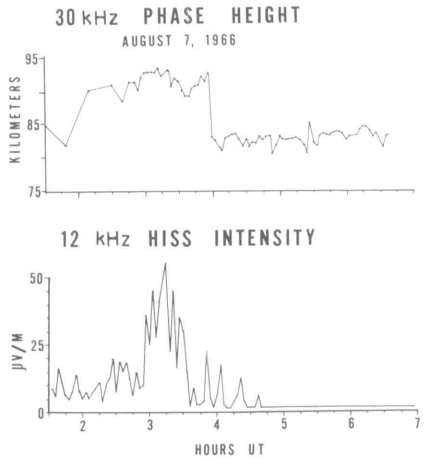

Figure 2. Correlation between D-layer virtual height and VLF hiss intensity.

followed by a sudden, sharp drop in *D*-layer height. About five more significant events have been observed in the height data at times when VLF hiss data were available. The lowest *D*-layer height yet observed was 60 km, recorded on September 2, 1966, during a polar cap absorption (PCA) event.

Exospheric electron density. The objective of this project is to determine exospheric electron densities by means of time-delay versus frequency measurements of VLF signals transmitted between the long-wire antenna site and Friday Harbor, Washington.

During the austral summer of 1966-1967, the long-wire antenna's transmittable power was increased to 25-kw input to the antenna terminals. This is twice the previous capability. The receiving station was subsequently established at Friday Harbor to record possible whistler-mode echoes from the semiorthogonal 64-bit code which is transmitted from Antarctica. The transmitted frequencies, which are accurate to about 2 parts in 10^5, are 5.45, 10.90, 15.70, and 21.80 kHz. The normal schedule consists of transmissions 10-15 minutes past each hour. Details of the transmissions and the coded sequences will be furnished to interested persons by the University of Washington on request.

Earth-ionosphere cavity resonances. On February 14, 1967, the first known effort was made to excite artificially the Earth-ionosphere cavity at its lowest resonance. A 7.5-μf capacitor was continuously charged to 30,000 V and mechanically switched into the terminals of the 21-mile dipole at frequencies of 4.03, 5.3, 6.5, and 7.7 Hz. Several ELF recording stations in different parts of the world were advised of the test. To date, no distant reception of the signals has been reported, but all data have not yet been analyzed. Strong signals from Byrd substation were recorded at Byrd Station by the Pacific Naval Laboratories' equipment, providing accurate timing data for the experiment.

In addition to this experiment, natural background noise at the long-wire antenna site is being recorded periodically from a magnetic pickup in the 5-100 Hz range.

Antenna measurements. The input impedance of the 21-mile and 8.4-mile dipoles has been measured as a function of frequency on a monthly basis. This information is being used to compare the measured and theoretically predicted performances of the antennas as their depth of burial gradually increases. The measurements also serve the practical purpose of indicating the possible presence of breaks in the wire. During the 1966-1967 austral summer, the locations of several breaks were detected to within a foot by means of a pickup loop mounted on a snow vehicle that was driven beside and parallel to the entire length of the wire.

Very-Low-Frequency Studies

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For a number of years, Stanford University has conducted studies in upper atmosphere physics at antarctic stations and its Palo Alto Laboratories as part of the U.S. Antarctic Research Program. During the past few years, this work has involved an increasing number of graduate students, including Chung Park (field engineer at Byrd Station in 1966), Keppler Stone, Fernando Walter, and Steve Lasch.

An important study pursued during the past year concerns data obtained at Eights and Byrd Stations on the magnetospheric electric field and associated hydromagnetic drift motions during the polar substorm which began at about 0600 UT on July 15, 1965 (Carpenter *and* Stone, 1967). Through the analysis of whistler measurements of drifts near L=4, it was possible to identify the previously undetected magnetospheric electric field that may be associated with the substorm electrojet. A major feature of the event was the onset of inward drift motions at L=4 roughly 20 minutes prior to the beginning of the substorm bay at the Byrd/Great Whale conjugate pair. Further studies of this time relationship are being conducted.

A number of studies were made of the plasmapause phenomenon. Statistics on the equatorial radius of the plasmapause at dawn were obtained from data taken at Eights Station during 1963 and plotted with respect to various indices of magnetic activity (Carpenter, 1967). It was found that the equatorial radius at dawn is particularly sensitive to substorm activity on the preceding night, a result consistent with the known role of the substorm electric field in the inward displacement of the plasmapause.

As part of a worldwide effort to study the proton flare and associated magnetic storm of early July 1966, Chung Park has investigated in detail the position of the plasmapause for a period of roughly 10 days from July 5 to 15, 1966. Using data obtained both from the long-wire recording site and the loop system at Byrd Station, Park was able to obtain much high time-resolution information on the position of the boundary. The long-wire recordings provided uniquely detailed information during periods when the loop system was inadequate for this purpose.

The study of the July 9 storm is being carried out in cooperation with a French group investigat-

ing whistlers, and the data obtained are being correlated with several experiments being conducted by means of the OGO-III satellite. In its effort to identify the plasmapause, the Stanford workers are cooperating with a number of other research groups whose approaches range from ground-based ULF whistler techniques to various forms of wave and particle detection from satellites. In this correlative role, the data recorded at Eights and Byrd Stations take on new importance in that the range of experiments available for comparison is extremely broad, extending over long periods in recent years; in the future, of course, the number and variety of such experiments is expected to increase considerably.

An important study begun recently by Fernando Walter is the detailed comparison of Eights and Byrd measurements with simultaneous whistler cutoff and associated noise effects observed approximately overhead by Alouette I (Carpenter *et al.*, 1967). The records show close agreement between the ground and satellite effects. A small but systematic disparity in the two results suggests the possibility that the whistler data may be used to study magnetospheric dilation by plasma currents.

As noted above, the long-wire antenna offers special advantages as a receiving device. Its great sensitivity at the low whistler frequencies associated with L values from 5 to 9 is particularly appropriate for studying the low-density region outside the plasmapause. The first recordings, made in December 1965, provided information on a region in the outer sector that had not been observed previously by the regular loop system. The unique characteristics of the long-wire antenna were exploited during the storm of July 9, 1966, providing data for the first extensive case study of a storm.

Steve Lasch is currently investigating the noise, stimulated by fixed-frequency transmitters, that was observed at Eights in 1963 and 1965. Attention now focuses on a special problem—the fact that when the transmitter frequency of NAA (10^6 watts), Cutler, Maine, was raised from 14.7 to 17.8 kHz, the number of cases of triggered noise dropped abruptly.

The data obtained at Plateau in 1966 are unique from the standpoint of the high time-resolution information they have provided on the association between auroral activity and VLF and LF noise. The uniqueness is accounted for in part by the clear weather and long periods of darkness that occur in the winter. A preliminary description of the data is being prepared by Robert Flint, field engineer at Plateau in 1966, and Hugh Muir, of the Arctic Institute of North America, with help from T. Jφrgensen, a visiting research associate from Denmark.

Transmissions from Stanford University's 150-kw VLF transmitter are providing data on propagation

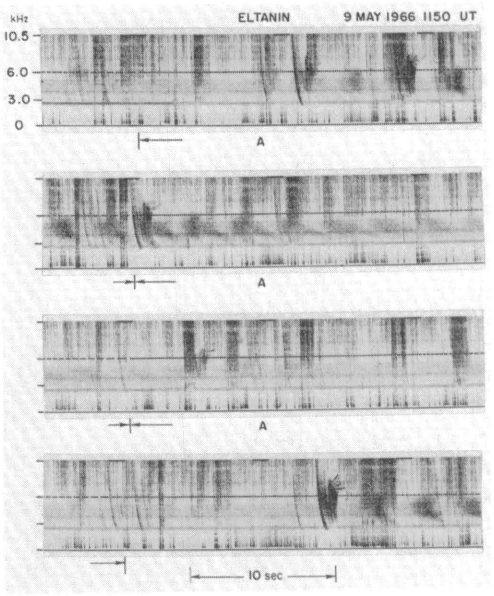

Figure 1. Record made aboard Eltanin *of VLF FSK transmission from Byrd substation. See text.*

through the southern polar ionosphere and over the polar cap. The use of satellites and widely spaced ground stations in the observing program provides the possibility of studying large-scale features of the ionosphere.

During May 1966, frequency-shift-keyed (FSK) pulses of varying length were transmitted. The frequency was shifted between 3 and 6 kHz. An interesting result of this program is that only the 6 kHz pulses were received aboard *Eltanin* while she was operating a few hundred miles southeast of New Zealand. Spectrographic records of the *Eltanin* data are illustrated in Fig. 1 in coordinates of frequency (0-10.5 kHz) versus time. The intervals marked

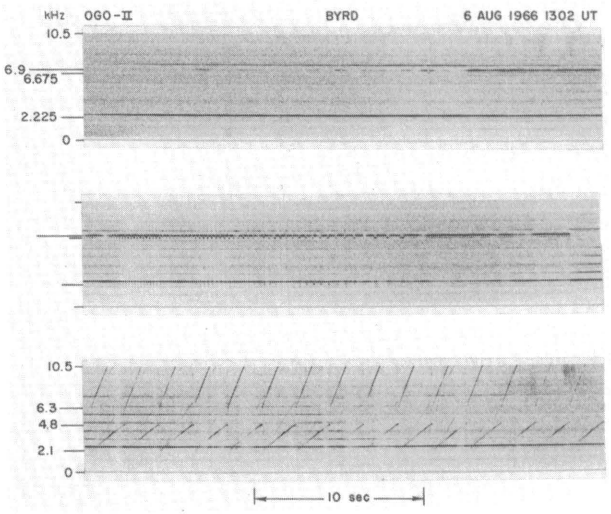

Figure 2. Record of VLF FSK transmission received by OGO-II from Byrd substation. See text.

"A" consist of pulses that varied continuously from 75 to 200 msec every 30 sec.

Transmissions received in the ionosphere by OGO-II were FSK variable-length pulses and swept-frequency ramps. OGO-II spectra are illustrated in Fig. 2, in which the upper two panels show observations of the FSK frequencies 2.225 and 6.9 kHz and the third panel shows transmissions in the sweeping mode between 2.1 and 4.8 kHz. The presence of harmonics of the fundamental frequencies is evidenced in the upper panels by the occurrence of the third harmonic of 2.225 and in the lower panel by the ramp extending upward from 6.3 kHz. The output wave form of the transmitter is rich in harmonics, a feature providing additional information on propagation at the higher frequencies.

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Ionospheric Forward-Scatter Program In the Antarctic

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Bartol Research Foundation of The Franklin Institute

The increasing level of activity on the sun during the new solar cycle has manifested itself in the number of polar cap absorption (PCA) events observed during the past year. While only one such event occurred in 1965, four were detected by the forward-scatter links in 1966, and several more have already been noted in 1967. Two were marked by significant increases in the counting rates of the associated ground-based neutron monitors.

Detailed studies of the events of July 7, 1966, and January 28, 1967, have been carried out. The neutron-monitor data recorded during all of the PCA events have been analyzed, but no significant increases were indicated. This suggests that the proton spectrum during a PCA is usually too steep for the effects of the solar particles to be observed on the ground. The event of January 28, 1967, is particularly interesting because no obvious source was visible on the sun.

Thus far, no relativistic electron precipitation (REP) events have been detected on any of the antarctic forward-scatter paths. Except during PCA and sporadic-*E* events, no large fluctuations in scatter signal intensity have been recorded.

The sporadic-*E* occurrence on the McMurdo-Vostok link has recently been analyzed in detail. In particular, the daily and seasonal variations at this very high latitude station have been investigated. One interesting discovery is that the diurnal variation depends on the season. The occurrence rate is single-peaked in winter and double-peaked in summer. The total daily occurrence, however, is approximately the same in winter and summer, but it declines markedly at the equinoxes. This is in contrast to the results from the Byrd-McMurdo link, which do not show a significant seasonal change in the total daily occurrence or the diurnal variation.

Solar Cosmic Ray Activity

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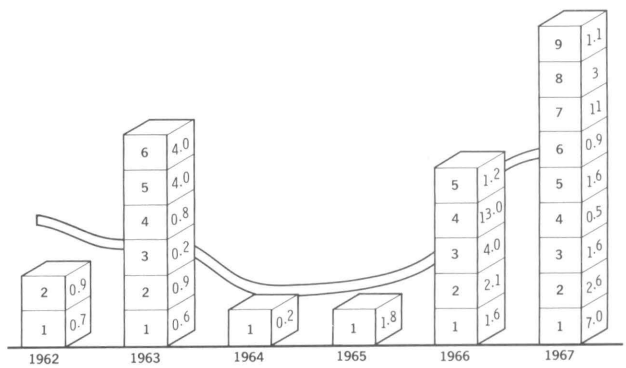
Space Sciences Department Douglas Aircraft Company

A significant increase in solar cosmic ray activity began in early 1966. From March 1966 to June 1967, 14 events were observed. By comparison, only one event was observed in each of the years 1964 and 1965. The distribution of events from 1962 to early 1967, with the variation in the smoothed sunspot number, is shown in the figure. The maximum absorption in decibels for 30 mHz is



The distribution of solar cosmic ray events observed by 30-mHz riometers at the Douglas Geophysical Observatories, with the variation in the smoothed sunspot number given near solar minimum. The front face of each block illustrates the events sequentially, while the side face gives the maximum 30-mHz absorption. Information for 1962 is based on 10 months of operation at McMurdo Station, and for 1963, on 6 months of operation at Shepherd Bay and 12 months at McMurdo. Data for the last four years, through June 1967, are based on continuous observations at both stations.

Solar cosmic ray events.

Date	Time of Flare	Imp	Position	Type IV	Max db (30 mHz)	Delay Time (min)
			1966			
Mar 24	0225 Mar 24	3B	N18 W37		1.6	~30
Jul 7	0020 Jul 7	3B	N34 W48	0053-0203	2.1	~50
Aug 28	1522 Aug 28	4B	N22 E04	1547-1749	4.0	~90
Sep 2	0538 Sep 2	3B	N21 W55		13.0	22
Sep 14					1.2	
			1967			
Jan 28					7.0	
Feb 2	0152 Feb 2	2N	N27 E61		2.6	
Feb 7	1825 Feb 6	2N	N25 E83		1.6	
	1025 Feb 7	2B	N18 E29			
	1136 Feb 7	2N	N18 E74			
	1255 Feb 7	2F	N17 E73			
Feb 13	1746 Feb 7	4B	N22 W10	1829-a2438	0.5	
Mar 11				1115-a1700	1.6	
Mar 23	0025 Mar 22	3B	N25 E70		0.9	
	0416 Mar 23	2N	N27 E53			
	1920 Mar 23	2B	N22 E46			
May 23	1803 May 23	3B	N31 E25	1537-0200	11.0	
	1834 May 23	3B	N28 E24			
	1932 May 23	2B	N28 E28			
May 28	0525 May 28	3B	N28 W30	1105-1155	3.0	
	0718 May 28	2B	N23 W42	1955-2150		
	0725 May 28	2B	N27 W45			
Jun 6	1858 Jun 5	2B	S20 W58		1.1	

shown also. The abrupt increase in solar cosmic ray activity from the time of the last solar minimum to the present is illustrated. Since only the first six months of 1967 are included, the increase may become even more pronounced than shown.

Data on the 14 events observed by Douglas Aircraft Co.'s riometers at McMurdo Station, Antarctica, and Shepherd Bay, Canada, in 1966 and early 1967 are given in the table. The maximum absorption in decibels at 30 mHz for each event, solar information, and the delay time from the beginning of the flare to the observation of absorption are also indicated. In general, the events shown have intensities higher than 10 protons/cm^2 sec sterad for energies greater than 0.5 Mev. The three largest events observed since February 1962 occurred between September 1966 and May 1967. The September 2, 1966, event, which reached a maximum of 13 db, was the largest since July 1961. The May 23, 1967, event was the next largest, reaching 11 db, and the January 28, 1967, event reached 7 db.

Antarctic Geophysical Research and Data Analysis

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and
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Avco Corporation

In 1962, Avco's Space Systems Division began conducting a general program of geophysical research dealing with the Antarctic. The myriad of data obtained since the beginning of the International Geophysical Year constitute an important element of these studies. The major sources of information are the World Data Centers in Boulder, Colorado (ionospheric data), and Rockville, Maryland (geomagnetic data).

We have found that the study of observations made during special geophysical events is a very fruitful approach. To determine the usefulness of satellite observations for an investigation of the upper ionosphere during a magnetic storm, we selected for analysis the observations of the *M*-region storm of December 17, 1962. Topside ionosonde data from the Alouette satellite, electron-counter data (40 Kev-1.6 Mev) from Explorer XIV, and ground-based magnetic and ionosonde recordings were used (Katz *and* Rourke, 1967). During the day for the mid-latitude regime, an increase in integrated electron density (between the *F*2 peak and 1,000 km), as well as in electron density at 1,000 km, was observed shortly (11

minutes) after the storm sudden commencement (SSC). This immediate effect is explained as heating around the *F*2 peak caused by hydromagnetic waves and subsequent electron drift upwards. This explanation is borne out by ground observations. At high latitudes, a peak of integrated electron density and of electron density at 1,000 km was also observed, but it is about 5° wide (in latitude) and occurs around L=5. This peak persists for several days after the SSC. Since a very selective source mechanism is required to produce such a geographically limited electron increase, an influx of charged particles is assumed. The increase in scale height is regarded as confirmation of the assumed heating mechanisms provided that no change in ion composition occurs.

Traveling disturbances over the Weddell Sea area are being investigated by Bowman (1967). Direction-of-arrival information is available on ionograms from Ellsworth Station because of interference effects caused by the Filchner Ice Shelf. This information allows the detection of giant traveling ionospheric disturbances that appear to move toward the Equator in the vicinity of the auroral zone during a period of several hours before local midnight. These disturbances produce troughs as wide as 1,000 km in the bottomside ionosphere. In the troughs, the *foF*2 values, *i.e.*, the electron densities at the *F*2 peak, fall by factors that vary between 3 and 7 for the cases investigated. The height of the *foF*2 peak can increase by 300-400 km from the boundary to the center of the trough. Disturbance effects are also recorded in the *D* and *E* regions. Associations with radio and optical aurorae and magnetic activity have been found, suggesting that these disturbances are intimately related to auroral-zone activity. Speeds of the order of 100 m/sec have been noted. It is suggested that the disturbances result from the propagation of internal gravity waves generated at magnetic noon at a magnetic latitude of about 80°.

Several research problems are currently being investigated. The use of topside ionosonde information from Alouettes I and II is being investigated further, and it is hoped that read-out data obtained at Byrd Station will extend the present coverage to areas over the polar cap. The aim is to understand the electrodynamic forces that create such large changes in the ionosphere over Antarctica. Another study is under way to summarize the present knowledge of the antarctic ionosphere. It is based on the Avco investigations as well as on the large body of published papers on the antarctic ionosphere.

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TERRESTRIAL GEOLOGY AND GEOPHYSICS

The Hallett Volcanic Province*

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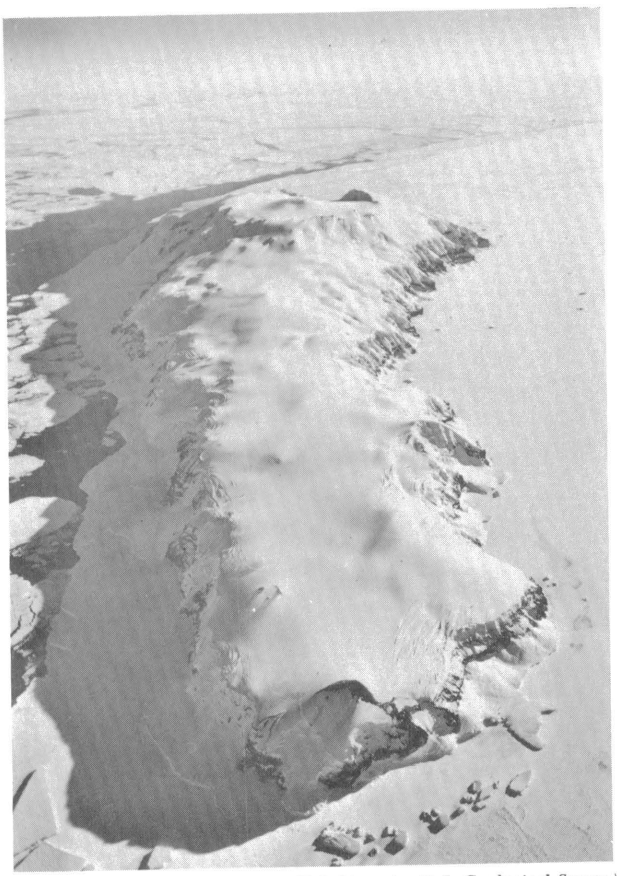
Four long, narrow piles of late Cenozoic basalt and trachyte rise from the continental shelf in a broken line trending northward along the mountainous Ross Sea coast of northeastern Victoria Land. From south to north, the piles are Coulman Island (the shortest, 33 km), Daniell Peninsula, Hallett Peninsula, and Adare Peninsula (the longest, 77 km). Each pile consists of a thick foundation of palagonitic breccias, pillow breccias, dikes, and sills and is topped by a veneer of subaerial flows and tuffs. Each long pile is a composite of overlapping products from central vents, most of which occur within a narrow zone; altitudes of the major young volcanoes are typically about 2,000 m.

Daniell Peninsula would be an island if the grounded ice filling the trough separating it from the mainland melted. Hallett and Adare Peninsulas are joined to the mainland only by short saddles that occur where volcanic rocks overlap mainland hills. The islands and peninsulas are entirely volcanic except for one small island of Paleozoic granodiorite overlapped by the Daniell pile.

Coulman Island (see figure) and Daniell Peninsula are each symmetrical, their medial topographic crests coinciding with the lines of major volcanoes which formed them. The Daniell crestal zone of volcanic centers projects northward across the fjord formed by Tucker Glacier to "Harcourt Volcano" on southwestern Hallett Peninsula. The high, young volcano at the opposed end of each pile has been truncated deeply by Tucker Glacier, across which the vent zone apparently is continuous.

The main mass of Hallett Peninsula lies to the east of the Daniell-Harcourt zone and is formed of

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



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

Aerial view southward along Coulman Island, November 25, 1962. The caldera rim of subaerial trachyte at the far end of the island is 1,900-2,200 m above sea level and 6 km in diameter. The island was formed by eruptions of ice-contact breccias and subaerial lavas from axial vents.

the western part of a line of overlapping volcanoes whose vents lay offshore from the present east edge of the peninsula and whose innards are now exposed in 2,000-m cliffs.

Adare Peninsula is similarly asymmetric. Although several major volcanic centers are preserved within it, many of the main vents lay east of the bounding eastern clifftop. The small islands—"McCormick" and the Possessions—east of the southern part of the peninsula are erosional remnants of the pile. Submarine topography suggests that the Adare volcanic pile extends far to the east and north beneath the sea, over the upper part of the continental slope.

The volcanic rock types range from ultramafic basanites to extremely sodic trachytes. The most common rocks are varied alkaline augite, olivine, and plagioclase basalts. Anorthoclase is shown by X-ray study to be abundant in the groundmass of many basalts, although it is obvious petrographically only in a few; sodic minerals in the trachytes include anorthoclase, sanidine, oligoclase, analcite, and nepheline. Comparison of 33 chemical analyses of rocks from the Hallett province with 22 new analyses of rocks from the McMurdo volcanic province of the southern Ross Sea shows the two terranes to be similar chemically.

The volcanic piles are constructional edifices, not tilted fault blocks. In the palagonitic breccias and pillow breccias, which form the bulk of each pile, evidence is found of extreme chilling, like that known to have been due to eruption beneath or against ice elsewhere. These breccias form continuous cliff sections reaching altitudes of 1,500 m on Coulman Island, 1,700 m on Hallett Peninsula, 1,800 m on southeastern Adare Peninsula, and 600 m on poorly exposed Daniell Peninsula; above these altitudes, all rocks exposed are subaerial flows and pyroclastics, which partly overlie, and partly give way down-dip to, the breccias.

Most of the volcanism occurred when the Ross Sea was filled by ice to present altitudes of 1,800 m, even at southern Adare Peninsula. (The depth of the sea floor is generally about 500 m, and there is no grounded ice on it now.) The bevelled spurs, hanging valleys, overridden shoulders, etc. of the mainland mountains to the west also show signs that previous ice levels were high above the present ones. No age determinations are yet available from the volcanic piles, the dating of which would provide minimum ages for the onset of Late Cenozoic glaciation, which extended far beyond present ice limits. Volcanic activity has continued to the present time, and each mass has many very young cinder cones on it.

Glaciation well beyond present limits, but perhaps less than that indicated by the highest breccias, is shown also by the erratics of mainland metamorphic and granitic rocks now strewn on the northern tip of Adare Peninsula up to an altitude of 500 m. Cape Adare is 30 km beyond the present mainland ice. The projection of a typical antarctic ice profile upward and southward from the 500-m level at the Cape requires that the ice was at one time at least 800 m thicker at the present mainland coast than it is now, even without making allowance for the probable many hundreds of meters of erratic-free ice in the upper part of the ice sheet. Grounded ice probably covered the entire antarctic continental shelf.

Isostatic depression under the additional glacial load would, however, have decreased the difference between past and present absolute altitudes of glaciation.

Pensacola Mountains Geologic Project*

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The U.S. Geological Survey has been conducting laboratory studies and compiling field data on the geology of the Pensacola Mountains since the last field investigation in the area during the 1965-1966 austral summer (Huffman *and* Schmidt, 1966).

The discovery by Schmidt and Willis H. Nelson (Schmidt *and* Ford, 1966) of folded sedimentary rocks containing a glossopterid flora in the northern Pensacola Mountains indicates an orogeny of latest Paleozoic or younger age that is not recognized elsewhere in the Transantarctic Mountains (a part of northern Victoria Land may be an additional exception). This folding suggests a structural tie with the Ellsworth Mountains, where glossopterid-bearing rocks are also folded.

James M. Schopf's correlation of the Gale Mudstone in the Pensacola Mountains and the Whiteout Conglomerate in the Ellsworth Mountains with the Buckeye Tillite in the Ohio Range seems valid (Nelson *et al*, in press). Plant microfossils suggest an Early Permian age for fluvial beds near the middle of the Buckeye. The glossopterid-bearing coal measures of the Pensacola Mountains correlate with the Polarstar Formation of the Ellsworth Mountains and the Mount Glossopteris Formation of the Ohio Range.

A. B. Ford and W. W. Boyd, Jr., believe that the Dufek stratiform intrusion of post-Permian age in the northern Pensacola Mountains was probably involved in at least the later part of the folding of the adjacent Upper Paleozoic sedimentary rocks (Schmidt *and* Ford, 1966). The interpretation of aeromagnetic anomalies by J. R. Henderson and J. C. Behrendt indicates that the Dufek gabbro underlies an area of at least 9,500 km^2, making it one of the world's largest stratiform bodies (Behrendt *et al,* 1966). The stratiform body is considerably more than 4 km and perhaps as much as 7 km thick. The intrusion consists predominantly of pyroxene gabbro interlayered with lesser amounts of anorthosite and pyroxenite, and it is capped by at least 300 m of granophyre. Neither the base nor top of the body is exposed; lateral contacts are discordant against folded Paleozoic sedimentary country rocks.

Systematic magmatic differentiation during crystallization of the intrusive gabbro is indicated by mineralogic and petrographic studies by Ford and Boyd; the anorthite content of the plagioclase decreases upward, whereas the quartz and alkali-feldspar content increases upward, as do the iron-oxide minerals, chiefly magnetite. Studies of the pyroxenes and isotopic age determinations are in progress.

The direction and intensity of remanent magnetization and magnetic susceptibility are being studied by Myrl E. Beck, Jr., assisted by Nancy C. Lindsley (Beck *et al,* in press). Such measurements aid in stratigraphic correlations within the stratiform body. At least two zones of opposite magnetic polarity occur within the body. The gabbros of the Dufek Massif consistently indicate a paleomagnetic pole position that is significantly different from other published paleomagnetic-pole positions for Antarctica.

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

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Magnetic Signature of Rocks from Ellsworth Land

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One of the most important objectives of antarctic geoscience research should be the clear definition of geologic provinces and their boundaries. This need becomes clear when one considers the proposed reconstructions of the southern continents wherein West Antarctica cannot be accommodated. Only when South America and the Antarctic Peninsula are considered separately do the reconstructions make any sense. Thus the definition of geologic provinces, particularly those of West Antarctica, is essential to understanding both the intra- and inter-

continental relationships that exist. The author believes that the Antarctic Peninsula, with its kindred intrusives, extends into Ellsworth Land and can be defined as a geologic province. Its boundaries can be established by reference to the magnetic signatures of the Ellsworth Land intrusives and associated sedimentary and volcanic rocks. The Ellsworth Land intrusives, which invade Jurassic sedimentary strata and are associated with probable Jurassic or older dacitic volcanics, describe the southern terminus of peninsular intrusives and may reveal that the western boundary lies along a NNW-SSE line east of the now inactive Eights Station.

The above assessments were made on the basis of rock samples and magnetometer data obtained during the 1965-1966 traverse into the Ellsworth nunatak area (about 160 km east of Eights Station). The rock samples were collected at 35 locations, and the magnetometer data were taken over a distance of about 600 km.

Fixing the magnetic signature of the region has included making determinations of scalar and vector magnetic properties. The available chemical data from representative igneous rocks suggest a simple trend in chemical differentiation for the Ellsworth intrusives. A plot of total iron content against silica content shows a linear trend related to silica content, but no clearly defined trend is observed in a plot of titania content against silica content. The iron and titania are of particular importance because the opaque oxides of the TiO_2-FeO-Fe_2O_3 ternary system are responsible for magnetization in rocks. The measured magnetic properties do not correlate with the chemical trends, and it is suggested that the magnetic properties reflect the particular physicochemical environment of the plutonic rock body during emplacement.

The magnetic crust in Ellsworth Land consists of the following components: (1) magnetic and nonmagnetic plutons of acid-to-basic composition (acid, $>$ 65 percent SiO_2; intermediate, $<$ 65 percent but $>$ 52 percent SiO_2; basic, $<$ 52 percent SiO_2); (2) nonmagnetic volcanics of acid-to-intermediate composition; and (3) local extremes in magnetic and nonmagnetic signature due to iron enrichment and residual silica-rich intrusives, respectively. Intensities ranging from 10^{-1} to 10^{-6} emu/cm^3 and susceptibilities ranging from 10^{-2} to 10^{-6} emu/cm^3 have been measured.

Measurements of many cores drilled from the oriented samples show, within the same sample, normal and nearly reversed directions of magnetization as well as directional variability related to core depth. Significant intensity and directional response to small shocks have been recorded, suggesting that hammering on samples and drilling cores can seriously affect the magnetization. Because a fundamental precept of paleomagnetic research (*i.e.*, the dipole approximation) is violated in some cores, the usefulness of such cores for paleomagnetic analyses is being investigated.

Owing to these conditions and the extreme variability of magnetic stability in cored specimens, an alternative approach to studying the magnetic properties of rocks is being developed. In this approach, which at present we refer to as "magnetic petrology," primary significance is placed on the mineralogy associated with magnetic properties. This enables us to plan experiments according to what we "see." In this connection, a magnetite colloid was developed to reveal a clear distinction between magnetic and nonmagnetic opaque grains and phases (Wasilewski *and* Carleton, 1967).

A short-term secular variation of the geomagnetic total force is suggested from data collected during the 1961-1962 and 1965-1966 field seasons (Wasilewski, 1966). An approximate 100γ decrease in total force is apparent, in accordance with trends suggested by Nagata (1964) and Orlov (1965).

Certain tentative conclusions can be drawn from investigations conducted to date:

Ellsworth Land, specifically the area from Eights Station eastward, is a separate tectonic element of West Antarctica.

A series of intrusive bodies is responsible for the broad, high-amplitude magnetic anomalies, and the Ellsworth intrusives mark the southern termination of such bodies (if one assumes that the Ellsworth intrusives are kin to the peninsular intrusives).

There is a wide range in the magnetism of the crust with magnetic and essentially nonmagnetic plutonics of intermediate-to-basic character.

The types of magnetic crustal segments seem to be related to pre-intrusive volcanism.

The ice sheet was at least 400 m thicker at some time in the past than it is at present, and the sculpting of exposed rocks is due to glacial action.

The secular-variation tendency for most of West Antarctica, as determined on the basis of short-term observational data, is $\backsim -100$ γ/year, which is in agreement with Nagata (1963), Orlov (1965), and Slaucitajs (1966).

Chemically, the Ellsworth intrusions resemble a differentiated suite, but magnetically they bear no relation to basicity, the reason for which is not yet apparent.

A geologic province which is bounded on the west at about 80°W., on the south at 76°S., and on the east at the boundary of the Filchner Ice Shelf breaks West Antarctica into distinct provinces. Unfortu-

nately, most of the detail necessary for more complete delineation of these provinces is not available.

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Seismology at Byrd and South Pole Stations

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Since 1957, seismographs have been operated by the Coast and Geodetic Survey at Byrd and South Pole Stations. These sensitive instruments have shown Antarctica to be the least active seismically of all of the continental land masses. No earthquakes have been located instrumentally in Antarctica, although minor tremors have occasionally been recorded in the vicinity of Mount Erebus. The seismic observatories have significantly added to the number of epicenters which can be located in the Southern Hemisphere. Of even more importance is the fact that they have added southern control, thus greatly enhancing the accuracy of the locations.

In February 1963, South Pole Station was equipped with the sophisticated instruments of the World-Wide Standardized Seismograph Network, which consists of 114 stations with matched instrumentation. This network has been a cornerstone for research in seismology because it provides, from one source and at a nominal cost, copies of seismograms from stations around the world. The seismograph at South Pole Station, being at a seismically quiet site, has been able to sustain a magnification setting of 100,000, the most sensitive at which seismographs have ever operated on the Continent and among the highest obtainable anywhere.

The data from Byrd and South Pole Stations have been used to study storm-generated microseisms, continental structures of Antarctica as deduced from surface-wave dispersion, and the circum-Antarctica belt of seismicity related to the oceanic rises. The two stations support larger investigations of the velocity distribution of seismic waves in the Earth's mantle and core, world seismicity, travel-time anomalies, and the magnitude of seismic events. The data obtained, which are reported by telegram to permit the rapid location of epicenters, are published later in the *Antarctic Seismological Bulletin.*

Geophysical Investigations*

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Gravity increase at the South Pole. Measurements made between December 1957 and January 1966 of the gravity difference between the McMurdo Sound pendulum station, which is on bedrock, and the South Pole station, which is on the antarctic ice sheet, show that the gravity at the South Pole has increased by 0.11 milligals per year. The most likely hypothesis is that the increase is being caused by ice flowing downslope across a gravity gradient and by the sinking of South Pole Station because of the ice accumulation. An alternate hypothesis, that the gravity increase is being caused by a decrease in ice thickness of about 40 cm per year, is theoretically possible but is not supported by direct evidence.

Magnetic maps of Antarctica. Data on absolute total magnetic intensity collected in the area south of 55°S. by expeditions of Australia, Great Britain, Japan, New Zealand, the United States, and the U.S.S.R. have been used to compile a map of residual total magnetic intensity. Weighted means of residuals of observed data compared with the 1965 epoch map (U.S. Naval Oceanographic Office), corrected for secular variation, were computed for two-degree squares. Residual anomalies exceeding + 400 and − 600 gammas extend over large areas. Generally, West Antarctica appears to have a more positive residual anomaly than East Antarctica. There is a transition zone from positive to negative which is roughly coincident with the Transantarctic Mountains; other geophysical evidence indicates that these mountains may be related to a structural discontinuity in the crust.

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

All available data obtained on magnetic traverses south of 55°S. were used to construct a map showing the areal distribution of narrow-width (<50 km) magnetic anomalies. Numerous anomalies are associated with outcrops of rocks known to have high magnetic properties, such as the McMurdo volcanics, and they extend beneath the ice sheet. Other areas in which there are many anomalies occur beneath the ice or sea; in such areas for which no other geologic information is available, the magnetic data provide a means of inferring the subglacial or submarine geology.

MARINE GEOLOGY AND GEOPHYSICS

Paleomagnetic Studies of Deep-Sea Sediments from Antarctic Seas

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The natural remanent magnetism (NRM) of the *Eltanin* submarine cores collected from the Scotia Sea to New Zealand has been examined at two levels:

An astatic magnetometer has been used to determine the polarity of the original NRM in over 18,000 specimens taken at 10-cm intervals from more than 150 cores having an average length of 11 m. The Brunhes/Matuyama boundary contours define a prominent east-west zone having a low rate of deposition from 110° to 50°W. (from the Bellingshausen Basin to the Scotia Sea) and minor south-north channels in which the deposition rate is also low at 128° and 39°W. and south of 67° and 60°S., respectively (Goodell *and* Watkins, 1967). The polarity boundary correlates strongly with an independently defined radiolarian-assemblage extinction horizon in nine cores (Watkins *and* Goodell, 1967a). The distribution of manganese nodules is closely associated with the major low deposition rate zones. The distribution of ice-rafted material, as revealed in the cores, suggests that an antarctic ice-initiation began prior to five million years ago (Goodell *et al,* 1967).

A slow-spinner magnetometer and an alternating magnetic field demagnetizing apparatus have been used in determining the NRM in over 3,000 specimens taken at 2-cm intervals from cores in which apparent geomagnetic polarity events (the Jaramillo, Gilsa, Olduvai, Kaena, Mammoth, and events within the Gilbert geomagnetic polarity epoch) have been detected (Watkins *and* Goodell, 1967b). Although an arbitrary sedimentation-rate test, combined with the terrestrial geomagnetic polarity time scale, yields compelling indications of the reality of each event during the Matuyama epoch in several of these cores (Watkins *and* Goodell, 1967c), inconsistencies make it impossible to reach positive conclusions about the actual magnetic morphology of the polarity events or the number of real events until criteria are established to reliably distinguish between true geomagnetic field behavior and possible spurious NRM in the cores. There is some indication, however, that the geomagnetic field behavior was more complex during the events within the Matuyama epoch than at other times in the past three million years.

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Marine Geological Investigations

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Cruises 24 through 27 of USNS *Eltanin* were completed during the period July 1966—February 1967. All of these took place in the South Pacific sector of the antarctic seas. In addition, on Cruise 27, the ship entered the Ross Sea and called at McMurdo Station. All of the cores and the materials dredged have been returned to Florida State University, opened, and described. The marine geological activities during Cruises 1-27 are summarized in the table.*

* The routine investigations of the materials listed are summarized in the *Antarctic Journal,* vol. I, no. 5, p. 203.

Numbers and lengths of piston cores obtained during Cruises 1-27. (Only the lengths of undisturbed cores are tabulated.)

Cruise	No. of Cores	Core Lengths (cm)			
		Longest	Average	Total	Cumulative
1-21	433	2,642	665.5	288,146	288,146
22	34	1,252	535.8	18,218	306,364
23	20	1,981	1,189.0	23,780	330,144
24	14	1,304	869.3	12,170	342,314
25	21	1,219	397.5	8,347	350,661
26	3	1,634	860.0	2,580	353,241
27	27	2,173	607.0	16,407	369,648
Totals:	552	2,642	669.7	369,648	369,648

Numbers of Phleger cores and dredge hauls obtained:

	Cores	Hauls
Cruises 1-21:	116	311
22-27:	64	69
Totals:	180	380

Black-and-white bottom photography, Cruises 1-27:

Stations occupied:	526
Frames obtained:	6,691

Special studies are under way on (1) the geochemistry, mineralogy, and texture of the surface sediments, (2) the petrology and geochemistry of volcanics obtained by dredging, (3) the paleosedimentology at the Brunhes/Matuyama geomagnetic-polarity boundary (formed 700,000 years ago), (4) the distribution, mineralogy, and geochemistry of manganese nodules, (5) the coccolith stratigraphy, (6) the identification and time of appearance of ice-rafted debris, (7) the absolute-age determination of bottom sediments by radioisotope techniques and thermoluminescence, and (8) the determination of the paleomagnetic stratigraphy beneath antarctic seas by reference to the geomagnetic polarity (detrital remanent magnetism) of core samples.

Surface Sediments of Drake Passage

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Ice-rafting is the dominant transportation medium for Drake Passage detrital sediments, which range in size from colloids ($< 1\ \mu$) to large boulders. Secondary transporting agents are not important south of the Antarctic Convergence; however, north of the Convergence, especially in the north-central area where bottom currents are exceptionally strong, the surface sediments are better sorted than in areas of weak or nonexistent bottom currents. Mechanical analyses of carbonate and insoluble fractions show that most of the fine-grained material from both fractions has been removed from the north-central area of the Passage where photographs show a rippled bottom. A linear distribution of manganese nodules in the central portion of Drake Passage occurs where moderate bottom currents exist. The distribution of nodules also coincides with the position of the Convergence, but the relationship may be fortuitous.

Calcium carbonate values of 5 percent or less were obtained for locations south of the Convergence, whereas the values increase progressively northward to a maximum of 70 percent in the northwestern part of the Passage. High carbonate values in the northwestern area are related to the influx of Pacific water, with its more abundant planktonic Foraminifera, and also to the presence of a topographic high. Anomalously low carbonate values in the north-central area probably represent older surface sediments which have been exposed as the result of winnowing and erosion by bottom currents that have a velocity of at least 30-50 cm/sec. High nitrogen and organic carbon values are associated with fine-grained sediments between the Convergence and the continental slope off Antarctica. Nitrogen and, to a lesser extent, organic carbon in the surface sediments appear to be related to the dissolved-oxygen content of the bottom water.

Sediment sorting was determined by reference to the following index of diversity:

$$I = K \log_{10} \frac{N.'}{n_1.'\ n_2.'\ \ldots\ n_j.'}$$

This index utilizes all size increments of the non-Gaussian distribution typical of Drake Passage sediments. Sorting calculations based on total simple size distributions were strongly biased north of the Convergence owing to the masking effect of biogenic carbonate. However, sorting of the insoluble fraction closely parallels the bottom-water circulation as determined by potential temperature.

GLACIOLOGY

Studies of the Anvers Island Ice Cap, 1965-1966

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By January 1967, the major part of the glaciological research program that has been conducted on Anvers Island since February 1965 had been completed. Only a few details needed attention at

that time, and they required air support from USCGC *Westwind*.

The overall aim of the program was to make a comprehensive assessment of the mass balance of the Anvers Island ice cap, but, because working conditions on the cap are so greatly hindered by bad weather, the entire cap could not be studied. Therefore, the southern section (approximately 380 km^2) was taken as representative of the whole.

As data representative of all of the ice cap from the coastal areas to the inland regions were sought, a "profile" system was employed in the study. Over 1,000 accumulation poles and 68 ice-movement stations were established during the first year in the field. The rate of accumulation was measured at these poles at frequent intervals, and during the latter part of 1966 the ice-movement network was resurveyed.

As very few rock outcrops occur on the ice cap, the number of fixed reference points available is limited. To accomplish the survey, therefore, a system of open traverse lines was employed. Preliminary azimuth was established by celestial observations at a point near Palmer Station, from which control was extended to a fixed point on Litchfield Island, where the ice-movement survey was begun. From that position, all traverse distances were measured with Tellurometers (model MRA 1), and the intervening angle was measured with a Wild T2 theodolite.

The field data are still in the early stages of analysis, but preliminary calculations indicate that the ice is moving at a rate of about 6.5 cm per day at the ice cliffs behind Arthur Harbor. Snow accumulation, which increases significantly with altitude, is very high and may prove to be the highest on record in Antarctica. The maximum annual snowfall, 6.8 m, was recorded at an altitude of 850 m; this snow was of relatively high density. Preliminary calculations have yielded the following accumulation values for various altitudes:

Altitude (m)	*Accumulation (m water)*
850	2.7
700	2.4
500	1.6
300	1.1
200	0.6

The ice cap appears to be relatively warm, which may reflect the extremely high incidence of cloud cover there (the annual average cover for 1965 was 7.88 tenths and for 1966, 8.18 tenths). Ice temperatures measured at depths of 10-12 m ranged from −0.8°C. at 200 m elevation to −4.9°C. at 840 m elevation. Thus the ice cap might be described either as subpolar or between subpolar and temperate.

Melting occurs over the entire surface of the ice cap during summer, and much of the area of the ice cap lies within the soaked and saturated zones (Benson, 1959). There is an extensive percolation facies but no dry-snow zone. The classical ablation zone, where mass is lost by melting and runoff, is virtually absent; where it exists, it is restricted to very small areas on the coastal ramps. The equilibrium line appears to lie at approximately 100 m elevation. The major loss of mass is by calving at the ice cliffs, which characterize the coastal boundary of the entire ice cap.

This program was supported by the National Science Foundation under grants GA-165 and GA-747 to the Ohio State University Research Foundation.

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OCEANOGRAPHY

Physiography and Bottom Currents in the Bellingshausen Sea

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A study has been completed of the bottom photographs obtained at over 400 *Eltanin* stations in the Bellingshausen Sea. Nearly all of the major types of bottom are found north of the Antarctic Convergence (Polar Front), including rocky outcrops, littered rocks and nodules (with and without evidence of having been moved by currents), and soft, undisturbed mud. In the deeper waters of the Bellingshausen Sea, scattered rocks and nodules, together with rock outcrops, are seen in the vast majority of photographs. Of the photographs taken at almost 100 camera stations on the crest and upper flanks of the Mid-Oceanic Ridge, nearly half reveal rock outcrops, many of which are craggy; several of the outcrops are clearly pillow lava. Immediately to the north of the Convergence, rocks and rock outcrops are found on

the ocean-basin floor as well as on the Mid-Oceanic Ridge.

Many of the photographs from the ocean-basin floor reveal evidence of current winnowing or scour (Figs. 1 and 2). However, between the Convergence and the limit of pack ice, rock outcrops and even scattered rocks are rare, and most of the photographs reveal a muddy bottom which is anomalously smooth. South of the limit of pack ice there are increasing numbers of scattered, probably ice-rafted boulders on the muddy sea floor. Immediately off the southern tip of South America, ripple marks and strong scour marks have been observed at depths of over 4,000 m. South of these ripple marks is a prominent distributional pattern of manganese nodules, and still farther to the south the bottom is characteristically muddy with occasional ice-rafted boulders. Ice-rafted boulders appear more frequently in the sector immediately to the west of the Antarctic Peninsula.

(NSF Photo)

Figure 1. Photograph of ocean bottom showing evidence of scour and fill.

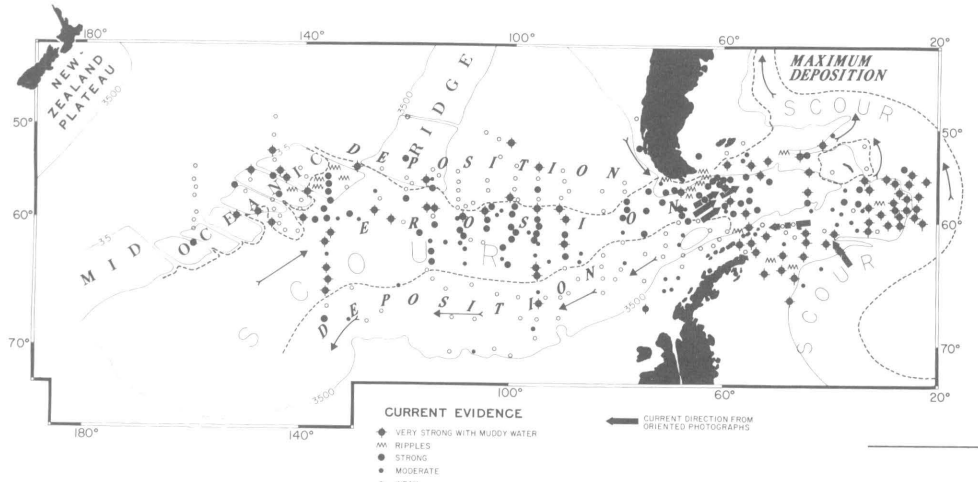

Figure 2. Strengths and directions of ocean-bottom currents as indicated by oriented bottom photographs.

The strengths and directions of currents are shown in Fig. 2. The photographic evidence indicates that the strongest current in the areas examined is located beneath the axis of that part of the antarctic current which flows from west to east at the base of the Mid-Oceanic Ridge.

Physical Oceanography Aboard *Eltanin*, 1966

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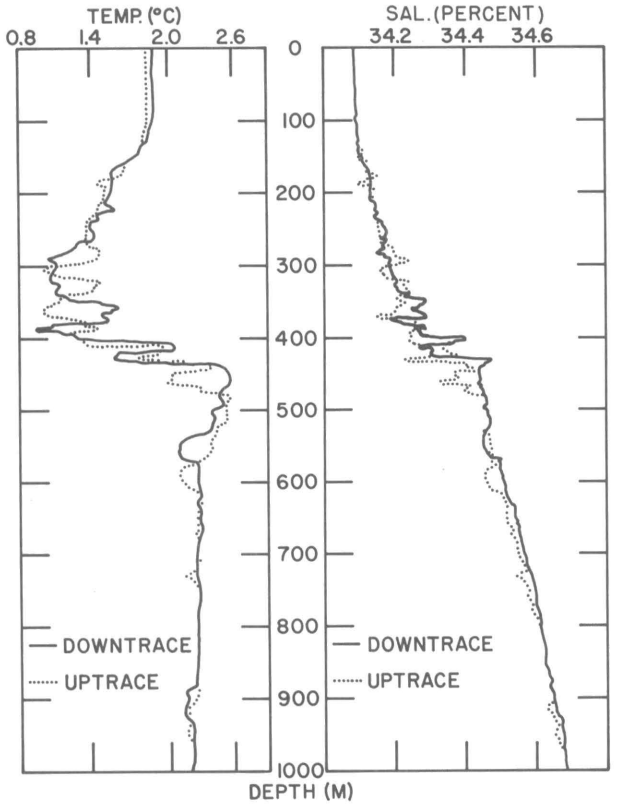
By the end of 1966, *Eltanin* had completed her 619th hydrographic station since entering antarctic waters in 1962. The year began with a return cruise (the 22nd) to the Scotia Sea and the area east of the South Sandwich Islands. The data obtained clarified some of the problems concerning bottom circulation that arose during the study of data gathered on previous cruises. It appears that the main northward penetration of antarctic bottom water is east of the South Sandwich Trench. In addition, cold bottom water derived from the Trench, or a location east of it, is carried northwest of South Georgia at least to 40°W. The very rapid change of bottom temperature observed previously in the northern Drake Passage was found to extend farther eastward into the Scotia Sea and must represent an extremely swift bottom current.

Beginning with Cruise 25, *Eltanin* was equipped with a continuously operating, *in situ,* salinity-temperature-depth (STD) recorder. This instrument facilitates the study of the microstructure (including the numerous secondary inversions) of the water column from the sea surface to the bottom. Such detailed observations could not be obtained with the Nansen bottle casts made previously. The STD data are recorded in analog form for immediate study and in digital form for more detailed study conducted on computers at Lamont. For calibration, six Niskin bottles with reversing thermometers, each of which could be tripped at will



STD analog record at Eltanin *station 607.*

from the ship, were placed around the STD sensors. Such calibration indicates that the observed microstructure is real. The figure shows the salinity and temperature analog trace of the upper 1,000 m for station 607 (59°S. 127°W.). Note the differences between the up and down traces. This may be due to shifting of the secondary inversions, which are probably of small horizontal extent. The inversions are of greatest magnitude within the T_{min} layer. An STD profile along 127°30′W. clearly shows the sinking and gradual deterioration of the T_{min} layer (along with the secondary inversions) in the vicinity of the Antarctic Convergence. A similar structure is observed in the salinity values. The STD data promise to open a new dimension to the physical oceanographer.

The bathythermograph (BT) program was continued throughout 1966. Analyses of the BT data for Cruises 25 and 27 (the latter one taking place during the first two months of 1967) indicate that a double Antarctic Convergence zone (primary and secondary components) occurs west of the Albatross Cordillera; such a zone had been found previously in the western part of the Southeast Pacific Basin. The eventual digitization of all of the BT data will enable them to be used more efficiently.

On Cruises 23 and 24, the Antarctic and Subtropical Convergences, respectively, were investigated. While the determination of temperature changes was the most important factor in defining the Antarctic Convergence, the observation of salinity variations was more significant to the definition of the Subtropical Convergence. On Cruise 26, activity was confined to the Tasman Sea, where hydrographic stations were occupied mainly in support of the biological program.

Alkalinity and Strontium Profiles in Antarctic Waters

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In continuation of our work on the distribution of the alkaline-earth metals in antarctic and adjacent waters as possible indicators of oceanic mixing processes, we have analyzed samples of seawater from the antarctic seas for strontium and alkalinity. Two profiles in the eastern Pacific sector of Antarctica (*Eltanin* Cruise 11) have been analyzed for strontium (Turekian *and* Schutz, 1965), and these two profiles as well as two profiles from the western Atlantic sector of Antarctica (*Eltanin* Cruise 22) have been analyzed for specific alkalinity.

Analyses by X-ray fluorescence of the amounts of strontium in seawater are subject to an error of 2.2 percent coefficient of variation. The range of values obtained for water samples from antarctic seas exceeds this analytical error, whereas the range for samples from the rest of the world's oceans can be explained in terms of the error. The contour intervals of Fig. 1 are drawn with the analytical error in mind, and the resulting pattern shows the general features of distribution of strontium concentration with longitude. Clearly, the profile at 115°W. reveals a higher average strontium level (normalized to a constant chlorinity) than the profile at about 90°W.

Alkalinity, as determined by the method of Anderson and Robinson (1946), was converted to specific alkalinity on the basis of salinity data obtained by the Lamont Geological Observatory at the time of collection. The results are presented in Fig. 2.

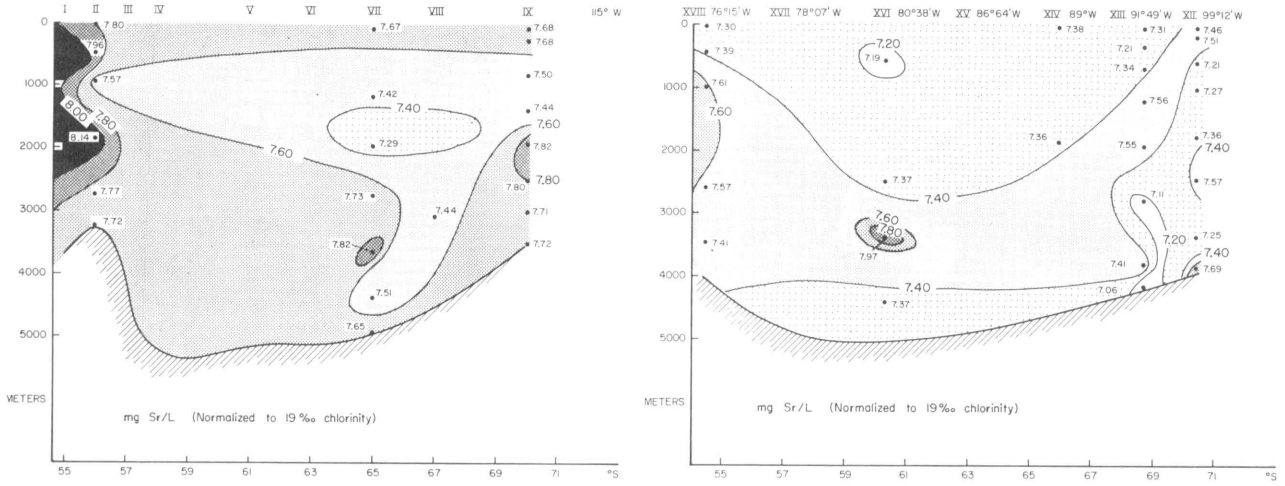

Figure 1. The distribution of strontium in the waters of the east Pacific sector of the antarctic seas (115° W. and about 90° W.).

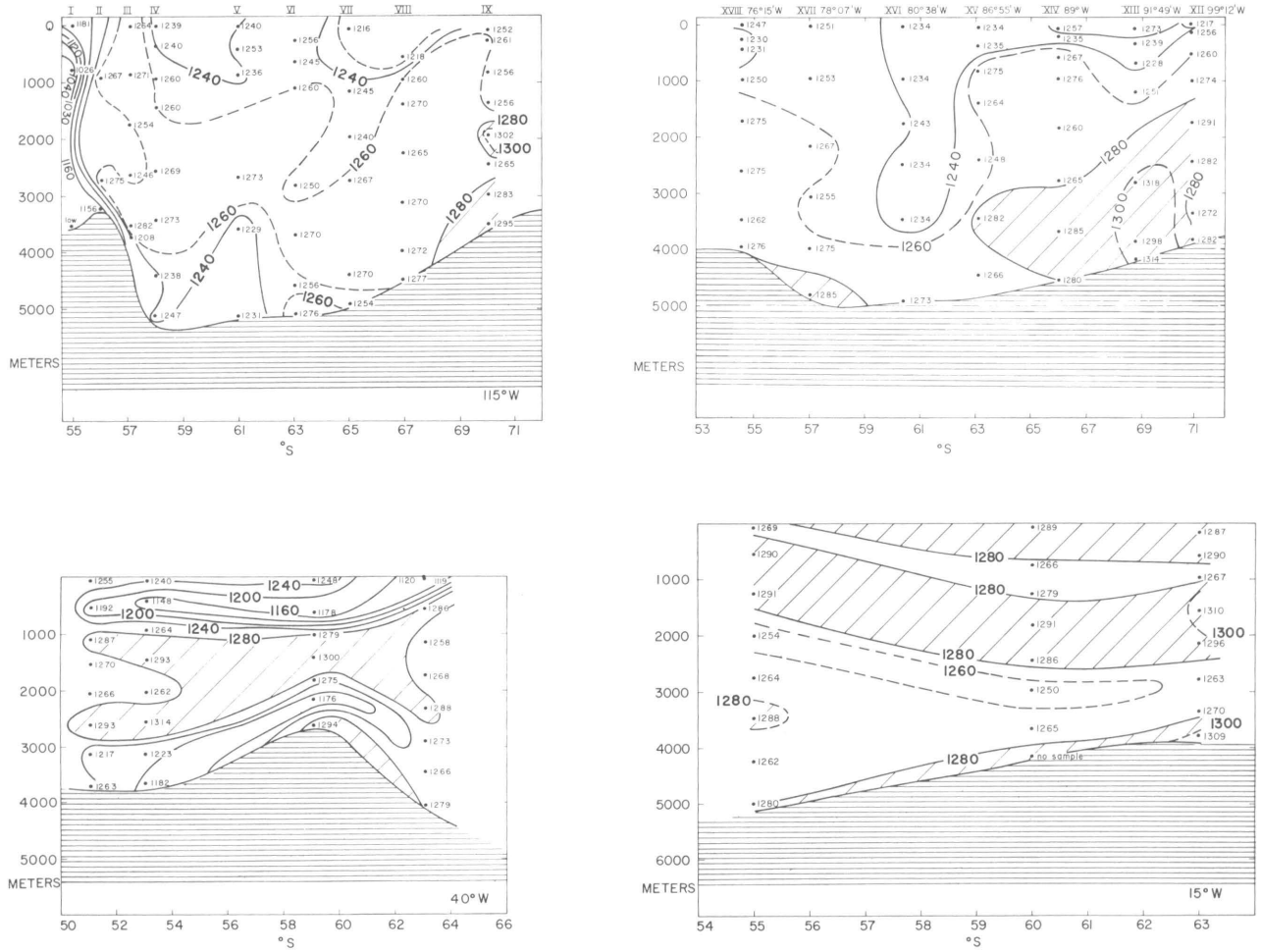

Figure 2. The distribution of specific alkalinity (× 1,000) in the waters of the east Pacific (115° W. and about 90° W.) and the west Atlantic (40° W. and 15° W.) sectors of the antarctic seas.

It is evident that the two profiles in the Pacific sector (115° and 90°W.) and the one in the westernmost Atlantic sector show highly convoluted patterns with values ranging from 0.1026 to 0.1318—a difference of 30 percent. On the other hand, the profile at 15°W. is almost homogeneous in specific alkalinity.

Along the 115°W. profile, a marked change in specific alkalinity appears to occur at the southern extension of the Albatross Cordillera between antarctic and Pacific waters. This discontinuity is seen not only in the level of strontium but also in that of the trace elements silver, cobalt, and nickel (Schutz *and* Turekian, 1965).

Any interpretations we make at the present time are tenuous, but they do show the desirable paths for future studies:

(1) On the basis that the water mass surrounding Antarctica has a net westward movement, it appears that it becomes highly textured with respect to specific alkalinity as the result of biological removal of calcium carbonate from the surface waters and its resolution at depth.

(2) Where prominent physical barriers exist, such as the southern portion of the Albatross Cordillera, the chemical properties of the antarctic waters are distinct from those north of the barriers. This is true with respect to specific alkalinity and concentrations of strontium, silver, cobalt, and nickel.

(3) The concentration of strontium in the eastern Pacific sector of Antarctica varies—notably, the average concentration is lower along the 90°W. profile than along the 115°W. profile.

(4) There is no clear correlation between the amounts of barium (Turekian *and* Johnson, 1966) and strontium and specific alkalinity.

(5) Data on specific alkalinity and strontium levels might be useful as indicators of the history of the antarctic water masses.

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BIOLOGY

Zoogeography of Antarctic and Subantarctic Planktonic Foraminifera in the Atlantic and Pacific Ocean Sectors

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One antarctic, two antarctic-subantarctic, and six subantarctic species of planktonic Foraminifera have been observed in the two major faunistic regions that are separated by the Antarctic Convergence (Antarctic Polar Front). The only prolific antarctic species south of the Convergence is *Globigerina pachyderma.* Six species occur generally north of the Antarctic Convergence in subantarctic waters, namely *Globigerina bulloides, Globorotalia inflata, Globorotalia truncatulinoides, Globorotalia scitula, Globigerinita glutinata,* and a yet-unnamed new species of *Globorotalia. Globigerina quinqueloba* and *Globigerinita uvula* are found more frequently in the antarctic region than the other species referred to, but they are also commonly encountered in subantarctic waters.

All species show widely overlapping distributions, but the centers of maximum concentration of each species are clearly delineated and are generally located either in antarctic or subantarctic waters. The subantarctic species can cross the Antarctic Convergence and exist over an average distance of 300 miles southward before they completely disappear.

The preferred seasonal occurrence of *G. truncatulinoides* is between early May and late October, while *G. inflata* proliferates between early August and late December.

In the austral winter (June-September), the upper 100 m of water around Antarctica is comparatively barren of plankton (including Foraminifera), as the bulk of the planktonic populations inhabit waters between 250 and 1,000 m during this period.

In comparing the fossil assemblages in bottom sediments studied by Blair (1965) with living populations from the same regions, we have noted the following facts: The largest populations of fossil representatives of *G. pachyderma* (20 percent isopleth), *G. bulloides* (20 percent isopleth), *G. truncatulinoides* (5 percent isopleth), and *G. inflata* (10 percent isopleth) are all north of the

mean position of the Antarctic Convergence, whereas equivalent populations of living members of these species are located south of the Convergence. The southward retreat of the antarctic *G. pachyderma* and the southward advance of the three subantarctic species are clear indications of the extent of a warming trend since the most recent deposition of sediments and skeletal remains of the species mentioned.

These findings agree with Hays' (1965) observations that the boundary between antarctic and subantarctic Radiolaria in bottom sediments is located 3°–10° north of the mean position of the Antarctic Convergence. He noted also that, north of the Convergence, the radiolarian species in the thin top layer of cores are indicative of a warming period during the past few thousand years.

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Physiological and Biochemical Mechanisms of Cold Adaptation in Fishes of McMurdo Sound

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Fishes of McMurdo Sound constantly experience near-freezing temperatures. The stability of the temperature of the *Trematomus* fishes' habitat is reflected in the lethal temperature limits of these species: the upper incipient lethal temperature is a markedly low 6°C. (Somero *and* DeVries, 1967).

The whole-organism metabolism of the *Trematomus* fishes is highly cold-adapted (Wohlschlag, 1964). Tissues of these fishes were studied *in vitro* to determine whether this high metabolic rate was due to a similarly high level of metabolism fixed in the tissues or whether metabolic adaptation was controlled by serum-transported factors, as is the case in certain temperate-zone eurythermal fishes (Precht, 1964, 1965). The *in vitro* metabolism of tissues of the antarctic fishes was extremely high, indicating that a high rate of metabolic (enzymic) activity has been fixed in the tissues through the course of evolution.

The factors responsible for metabolic adaptation to low temperature are only now becoming well understood. Increased levels of rate-limiting enzymes may be induced during exposure to low temperature (Ekberg, 1962). Modulation of enzymic activity through alteration of the cellular environment in which the enzymes operate may also be important, as Precht's studies suggest. A further type of enzymic change which would promote high levels of enzymic activity at low temperature is the development of enzymes of higher catalytic efficiency. Some investigators have reported a positive correlation between the body temperature of organisms and the activation energies of their enzymic reactions (Vroman *and* Brown, 1963). Thus, organisms with lower body temperatures have enzymes with higher catalytic efficiencies. Data on the succinic dehydrogenase of *T. bernacchii* support this hypothesis.

Metabolic compensation to temperature change has been shown to involve alterations in the relative activities of the metabolic pathways as well as in the total rate of metabolism. A commonly reported change is an increased participation of the pentose shunt in glucose catabolism (Ekberg, 1958; Hochachka *and* Hayes, 1962; Kanungo *and* Prosser, 1960). A high level of pentose shunt activity appears to have been fixed in *T. bernacchii.* In addition, the acclimation of *T. bernacchii* to a "warm" temperature of 4°C. led to decreased pentose shunt participation. This change was observed in the absence of a change in the total rate of tissue oxygen consumption, indicating that metabolic reorganization can occur without a concomitant alteration in the total metabolic rate.

Acclimation to "warm" temperature led also to significant changes in tissue water content and metabolic sensitivity to cyanide poisoning.

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Antarctic Phytoplankton Distribution

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The vertical and horizontal distribution of phytoplankton in antarctic and adjacent waters has been studied by Mr. John Walsh and is to form the subject of his M.S. and Ph.D. theses.[1] In the Antarctic Peninsula region and in the areas sampled by scientists aboard *Eastwind,* there was considerable variation in the depth of the maximum occurrence of phytoplankton.[2] In Bransfield Strait, the maximum was at 100 m, but along a transect made by *Eltanin* from South America to New Zealand, it was usually between the surface and 30 m. There was no direct correlation between the phytoplankton numbers and salinity, temperature, or nutrients, but, as would be expected, the numbers did correlate with oxygen content. From the limited information available, it appears that the maximum occurrence of phytoplankton is related to incident light, although the meter used gave only light intensity relative to surface illumination and not to actual light values.

When we compare the figures derived from *Eastwind* and *Eltanin* cruises on the production of phytoplankton in antarctic waters with those obtained in the same manner from the Straits of Florida and the Caribbean Sea, it would seem that the annual production in the tropical Atlantic Ocean is of the same order or higher than that in the antarctic waters. One would expect to find a still higher annual productivity in the Cartagena area, off the north coast of Brazil, and in the Gulf of Guinea.

In studying the qualitative species distribution at the antarctic stations, we find that maximum diversity of species usually does not parallel maximum population. Below 200 m there is a sharp diminution in the number of species, but at certain stations a secondary increase in the number of species occurs between 1,500 and 2,000 m, presumably associated with the antarctic intermediate water. It would seem that a number of species can exist for a considerable time in the deeper waters after being carried there by downwelling.

[1] It is expected that Mr. Walsh's M.S. thesis will have been submitted by September.

[2] The results obtained aboard *Eastwind* should be available by October or November.

Surviving Macromolecules in Antarctic Seal Mummies

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The finding of a number of mummified seal carcasses in Taylor Valley during the International Geophysical Year (Péwé *et al,* 1959) presented an unprecedented opportunity to study the survival of biological materials under nearly ideal conditions. Two specimens previously obtained indicated, by the carbon dating technique, that the seals had died some 2,000 years ago. If biological polymers could be obtained from similar ancient specimens, then a comparison of their molecular structures with those of their modern counterparts would be of invaluable assistance in interpreting the nature and trend of evolution.

Collection of specimens. In December 1966, T. Blair collected two complete mummified seals, one a crabeater and the other a Weddell, and pieces of several others found in Taylor Valley near Lake Bonney. Sections from a seal which had been dead for about one year were collected by Dr. W. Dort (*Antarctic Journal,* vol. II, no. 1, p. 23-24). A freshly killed crabeater and a Weddell that had died recently were also collected for comparison. The pieces, which were brought to Northwestern University in January, were sent to Dr. James B. Griffin at the University of Michigan Anthropology Museum for radiocarbon dating, and the two mummies with their modern counterparts were shipped here in April for histological and chemical studies.

Ages of seals. The seal known to have been dead approximately a year was dated as 615 $\pm$ 100 years BP, indicating that antarctic seals subsist on carbon with a lower C^{14} content than that of the temperate trees used as radiocarbon standards. The dates for

the skin and flipper fragments of seal mummies ranged from 845 ± 100 to 2,150 ± 200 years BP, or from 200-1,500 years older than the modern seal, suggesting that the seals wandered in to starve and freeze randomly in time and not in one mass migration. The radiocarbon dates were not correlated with the degree of weathering, since the oldest seal was a relatively well preserved one found in a depression partially protected from the wind.

Histological studies. Specimens of skin taken from the Weddell mummy, which was found to be at least 1,000 years older than the modern seal, were fixed and processed for histological sections. The sections were stained with hematoxylin and eosin, Mallory's connective tissue stain, periodic-acid Schiff's reagent, and alcian blue.

The histological structure of the skin is well preserved. The surface is made up of ridges of connective tissue covered with epidermis, and although much of the epidermis had been torn away, intact fragments indicated that most of the cells are keratinized. Well-preserved hairs protrude through the indentations between the ridges of connective tissue and penetrate into the subepithelial connective tissue. Cross sections show that there is an organized group composed of one large hair and several smaller ones embedded in connective tissue. The connective tissue itself is composed of large, dense bundles of collagenous tissue, amongst which looser, more fibrous tissue is interspersed. Individual cells are rarely observed in the connective tissue, the identifiable cells being mainly in the epidermis and in the hair follicles.

The most striking feature of the ancient skin is the presence of a network of tubules of solid yellow material (cellular ?) that appears the same in stained and unstained preparations. The branches of the network migrate throughout the connective tissues, around hairs, and into the ridges. The origin of this network, which is not apparent in modern sealskin, is under investigation.

Biochemical studies. Aqueous extracts of skin from both the ancient and modern Weddell seals were fractionated by chromatography on DEAE-cellulose. Although soluble protein could be clearly demonstrated in the ancient seal, the fractions did not correspond exactly to those of the modern seal. Protein components which were clearly separable on chromatography of modern seal extracts tended to run together in ancient seal extracts and often contained an orange-brown component which interfered with analytical procedures. Although the patterns are not identical, they are similar, leading to the possibility that a common protein from both specimens might be isolated, purified, and compared on a molecular basis.

The skin extracts were also found to contain ribonucleic acids. Mr. Lung-Hsuing Hsu, a graduate student, has successfully isolated a fraction corresponding to soluble RNA from both the modern and ancient seals. The fraction exhibits the usual properties of RNA, but has not yet been isolated in sufficiently large quantities to allow definitive characterization. Efforts are currently being directed toward the purification and elucidation of the components of this fraction.

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Ecology of Articulate Brachiopods in Antarctic Regions

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Ecologic and behavioral studies are continuing on brachiopods collected in subantarctic regions during the past two years. Seven brachiopod species are currently under investigation. Filtering currents measured directly and continuously with a thermistor flowmeter reveal that each species has a characteristic flow pattern. The flow patterns of brachiopods from near-shore environments and deeper, offshore environments are being compared in an attempt to determine characteristics of filtering currents in the two environments. Also, the reaction of filtering currents and muscular activity to physical and chemical changes in the environment is being studied to learn about adaptability in brachiopods. By knowing these organisms' limits of tolerance to physical parameters, it is hoped that a better understanding of its geographic distribution will be obtained.

Rhythmic behavior has been discovered in brachiopods. One of the rhythms appears to be correlated with tides, but another is present which cannot be related to tides, barometric pressure, temperature, light, or food availability. Magnetic effects on this periodicity will be studied.

Subantarctic populations of brachiopod species of the Recent are being analyzed and compared with populations of the same species from the Pleistocene Epoch to determine changes which have taken place in the populations in respect to size and shape, shell composition, and associated fauna.

A Summary of Harvard University's Brachiopod Studies on *Eltanin* Cruise 27

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More brachiopod specimens were collected on Cruise 27 of *Eltanin* than on any other previous oceanographic expedition. Approximately 10,000 individuals are represented in the collections made and preserved during this cruise. About 600 of these are from the vicinity of Antarctica; the others were obtained off Antipodes and Macquarie Islands.

Brachiopods were found to be widely distributed in the shallow waters in and adjacent to the Ross Sea; 75 percent of the bottom trawls made south of 70°S. contained brachiopods.

Preliminary studies suggest that 11 genera and 23 species of brachiopods were collected, constituting the greatest variety of these organisms ever dredged on an oceanographic cruise of such short duration (59 days). Approximately 3,000 specimens of *Gyrothyris mawsoni* and 5,000 specimens of *Aerothyris macquariensis* were obtained. These two genera and species were previously described on the basis of only a few poorly preserved shells collected on the beach at Macquarie Island. This material will permit a much better understanding of these poorly known taxa.

Near the Balleny Islands, four deep-water brachiopods were collected at depths of over 1,000 fm—*Pelagodiscus atlanticus* and three specimens which have been tentatively assigned to *Eucalathis, Neorhynchia,* and *Aerothyris.*

The data obtained on this *Eltanin* cruise expand the known areas of distribution of most of the species collected and greatly extend the known ranges of several taxa. The cruise marks the first time that the genus *Macandrevia* has been reported to occur in the Ross Sea. The findings extend the known ranges of *Aerothyris macquariensis* and *Gyrothyris mawsoni*—hitherto considered endemic to Macquarie Island—750 miles northeastward to Antipodes Island. The known range of *Neothyris lenticularis* was extended also, from New Zealand 380 miles southward to Antipodes Island; it was the first time that this genus had been reported to occur beyond the immediate vicinity of New Zealand. Good samples for further quantitative and developmental studies were collected of *Neothyris lenticularis, Aerothyris macquariensis,* and *Gyrothyris mawsoni.*

By studying trawls containing brachiopods, useful ecological information was obtained, particularly on substrate relations and biological associates.

(Photo by author)

Aerothyris macquariensis.

Field observations suggest that terebratulidines and terebratellidines can be readily distinguished externally by the regularly branched distal tip of the pedicle in the former.

Limited observations of the behavior and morphology of living specimens were made. A number of black-and-white and color photographs were taken when time permitted. Both *Aerothyris macquariensis* and *Gyrothyris mawsoni* exhibited considerable, apparently random movement on their pedicles when kept in a tank on the ship. In a number of cases, the movement followed rapid closure of the valves. Currents induced in the tank did not appear to stimulate directive movements. The relative hardiness of these brachiopods is suggested by the fact that all of the *Chlamys delicatulus,* to which the brachiopods were attached, died several days before the brachiopods as the aquarium water warmed up during the passage from Macquarie Island to Melbourne, Australia.

Bacteriology of Antarctic Region Waters and Sediments

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During 1966, studies were initiated to determine the distribution of bacteria in marine sediments and the overlying water column in antarctic regions. The facilities of USNS *Eltanin* were used to collect marine sediments along the Antarctic Convergence (Cruise 23) and both sediments and water samples from antarctic and South Pacific waters (Cruise 25). A total of 122 different water levels

were sampled at 13 geographical locations between the surface and a depth of 3,542 m. These samples were collected aseptically by the use of Niskin biosamplers fitted with sterile plastic bags and opened by messengers at the desired sampling depth. Metal Phleger coring tubes, 24 inches in length, were used to collect sediment samples at 35 geographic locations. An attempt was made to keep the collecting devices as free from contamination as possible by steam-sterilizing the coring tubes and grabs in an autoclave for 30 minutes at 18 psi and inserting plastic liners that had been sterilized by ethylene oxide gas; these units were sealed in sterile plastic bags. Sediments were exposed to possible contamination by organisms in the waters overlying the deposits, inasmuch as no satisfactory way had been devised to shield the tubes from these waters. The number of bacteria present in the seawater becomes quite low at the greater depths, however, and this water acted as a mechanical flushing agent for the open core pipes just before impact.

The various kinds of sediments were cultured in one-gram quantities in six different enrichment media, which were designed to favor the growth of bacteria that have different nutritional requirements. By this means, the existence and numbers of these organisms, in relation to the sediment types, could be established. Since essentially complete anaerobiasis prevails in deep-ocean sediments, the media were formulated to favor the growth of bacteria capable of anaerobic metabolism. No attempt was made to simulate the barometric pressures of the habitats. Aerobic heterotrophs were isolated from the overlying water columns by filtering measured volumes of seawater through sterile millipore filters and transferring the filters to appropriate solidified media for incubation and counting.

The cultures collected are being analyzed in the bacteriology laboratories at the Georgia Institute of Technology. A detailed study of 30 species that have been isolated in pure culture from sediments indicates that the bacteria taken from deep-sea sediments in antarctic regions conform to the general pattern of marine microorganisms studied in other ocean regions, *i.e.*, gram-negative motile rods predominate, and the majority of the organisms are facultatively, rather than strictly, anaerobic. Their biochemical capacities are quite varied, however. Sulfate reduction has not been demonstrated by microorganisms in the sediments examined thus far, but organisms capable of utilizing all other energy sources provided have been isolated from one or more of the sediments. Water-column data examined thus far indicate that the aerobic, heterotrophic bacterial population density is a function of both depth and geographic location. The results indicate a concentration of organisms at or near the water surface, but, in many cases, with a second peak concentration anywhere between depths of 500 and 1,250 m. Before final analysis, correlative physical and biological data collected by other groups on *Eltanin* will be studied in an attempt to explain any unusual findings on bacterial species or their distribution. Experiments and the evaluation of results are still in progress.

Distribution of Antarctic Marine Fungi

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For the second year, the laboratory facilities at Palmer Station were used for studies of the distribution of inshore marine fungi. As other investigations made elsewhere in Antarctica have shown, significant populations of soil microorganisms exist in association with the cryptogamic flora and bird colonies, especially of penguins, petrels, and skuas. A primary objective of the Palmer study was to find out to what extent propagative cells of terrestrial fungi occur in inshore waters. It was also important to determine the ultimate fate of such cells and to learn whether or not they are capable of survival and reproduction under marine conditions. Moreover, we were anxious to know if a distinct marine fungal flora is present in these waters and, if so, how far seaward it could be traced, and finally, what relationship it has to the fungal flora of the open ocean.

During the past austral summer, soils, muds, and waters were sampled. Extensive use was made of a 40-foot Greenland cruiser and two helicopters from the icebreaker USCGC *Westwind*. Numerous inshore stations were reached with the cruiser, whose maneuverability and ice-shielding proved ideally suited for work in relatively narrow passages where icebergs and light pack ice are frequently encountered. Nineteen hydrographic stations were occupied by the boat, permitting water collecting with Niskin samplers. Temperatures and salinity samples were taken along with microbiological samples. As this work was coordinated with the geomicrobiological studies of a group from Florida State University (cf. *Antarctic Journal,* vol. II, no. 4, p. 103), supporting chemical and bacteriological data will be available.

Stations were selected to provide a transect outward from the ice cliffs that characterize much of the coastline of Anvers Island and to permit sampling of waters and bottom sediments in the channels separating the numerous, small nearby islands, such as Humble, Litchfield, and Torgersen, which are rich biologically. The cruiser provided access to other important areas, including Cape Monaco, Biscoe Bay, Port Lockroy, Paradise Bay, Peltier Channel, and the Danco Coast. Helicopters carried field parties to 12 relatively inaccessible sites within a 40-mile radius of Palmer Station. One highly significant feature of this mode of transport was the opportunity to make "in-flight" selections of sampling localities in poorly mapped areas.

Although most of the emphasis in this study was on the Anvers Island area, two other localities provided interesting comparative data—Adelaide and Deception Islands, which, respectively, lie to the south and north of Anvers Island. Work at Deception Island was made possible through the hospitality of the British Antarctic Survey.

While some of the collections were processed at Palmer Station, others were returned chilled or frozen to the Institute of Marine Sciences (IMS) at Miami. The delivery of this temperature-sensitive material directly to the Institute was efficiently accomplished by helicopter as *Westwind* proceeded northward through the Florida Straits en route to her home port of Baltimore.

The examination of this collection is presently under way at IMS. By analyzing the patterns of response of certain filamentous isolates to various combinations of environmental factors under controlled laboratory conditions, some general trends may become apparent which will assist in the recognition of well-adapted antarctic marine fungi.

Also in conjunction with the land-based studies at Palmer Station, we are examining the occurrence and distribution of oceanic fungi. Our purpose is to determine the relationship of fungal populations to hydrographic conditions and to such biological factors as the occurrence of phytoplankton, bacterial population, and micronutrients in the various water masses between Antarctica and the Subtropical Convergence. To date, five cruises have been made: *Eastwind*-1966, in the offshore region of the Antarctic Peninsula; *Eltanin*-23, which crisscrossed the Antarctic Convergence; *Eltanin*-24, across the Subtropical Convergence; *Eltanin*-26, in the Tasman Sea; and *Eltanin*-27, on which a transect was made from the Antarctic Continent to the Subtropical Convergence.

The fungi are collected aseptically with Niskin biosamplers at standard hydrographic depths from the surface to the bottom. To obtain synoptic data, the microbiological collections aboard *Eltanin* are made in cooperation with Lamont Geological Observatory's hydrographic program. The Niskin biosamplers are placed on the hydrographic wire in tandem with Lamont's Nansen bottles. After retrieval, 1-2 liters of water are filtered through a cellulose acetate membrane (0.45 μ porosity) and the membrane placed on a medium that is appropriate for fungal growth. Following from one to two weeks of incubation at 10°-12°C., the organisms are counted and representative colonies subcultured for systematic and physiologic study at IMS. The results indicate a diversity of fungi, many of which are new genera and species endemic to the antarctic seas and/or specific water masses. Psychrophilic organisms (maximum temperature near 15°C.) are prevalent; a comprehensive report of their systematics and ecology is in preparation.

The Lipids of Antarctic Fish

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Previous studies in Texas A&M University laboratories on the lipids of members of the antarctic food chain were continued by examining the lipids of antarctic fish. Analyses were performed on individual samples collected in the Pacific sector of the antarctic seas during various expeditions of *Eltanin*.

Six genera of fish were examined for their lipid content. The average content was 20 g per 100 g of dry weight, but the variations were wide, ranging from 3.4 to 36.6g/100g. The proportions of the different lipid classes, as determined by silicic acid column chromatography, also varied widely. However, in most cases, the complex lipid fraction was the preponderant lipid class, followed by triglycerides and, at much lower levels, by free fatty acids, sterol esters, partial glycerides, sterols, and hydrocarbons and waxes. Similar preponderance of the complex lipid class has been observed in antarctic *Euphausia* (Jeffrey *et al,* 1966). Phosphatidyl choline and phosphatidyl ethanolamine were the major components of the complex lipids of both fish and euphausids.

Examination of the fatty-acid compositions of the triglycerides and complex lipids of fish showed that the concentrations of palmitic, stearic, and eicosapentaenoic acids were essentially the same

in both, whereas myristic, palmitoleic, and oleic acids predominated in the triglycerides and docosahexaenoic acid in the complex lipids. Thus, the complex lipids were much more unsaturated than the triglycerides. In view of this observation and the fact that the complex lipids of antarctic fish do not show a higher degree of unsaturation than the complex lipids of fish living at higher environmental temperatures, the following conclusions were reached: The relatively high degree of unsaturation of the total lipids of fish living at low environmental temperatures (observed previously by many other investigators) is due to a relatively high proportion of complex lipids with respect to triglycerides.

The determination by pancreatic lipase hydrolysis of the fatty-acid distribution in the triglycerides of two fish, *Electrona antarctica* and *Argyropelecus hemigymnus,* showed that stearic acid occupies mainly the 1,3-positions in both triglycerides, and docosahexaenoic acid predominates the 2-position. The distribution of all of the other acids differed from one fish to another. The fatty-acid arrangement in the triglycerides of *Electrona antarctica* resembled that in the *Euphausia* triglycerides.

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Research on Antarctic Isopods, 1966-1967

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Besides discovering several new and known species of antarctic deep-sea isopods in the *Eltanin* collections during the past year, Duke University biologists have made special efforts to achieve an important objective of this continuing project, *i.e.,* determine the origin and the zoogeographic characteristics of abyssal antarctic isopods. A typical deep-sea genus, *Storthyngura,* comprising 38 species (including 12 antarctic species), was chosen for a thorough analysis of species characteristics and affinities to species elsewhere. Close attention to species differentiation was necessitated by the little-known fact that zoogeographic separation at abyssal depth occurs mainly at the species level (George *and* Menzies, 1967a and 1967b). For considerations of phylogenetic relationships, it is essential that "true" affinity between species be established by more sophisticated and less subjective methods. This necessitated a detailed qualitative analysis and a quantitative computer analysis of 158 characteristics by employing the programming of Rogers and Fleming (IBM 7044 and CEC 1604) of the taxometric computer program at Colorado State University, Ft. Collins, Colorado. The results indicate a high-percentage relationship between the computer and qualitative analyses. On the basis of this detailed study, a phylogenetic tree showing the different evolutionary routes has been constructed. Further, the geographical distribution of morphologically allied species indicates that 100 percent of the groups represented in the Antarctic have certain striking patterns. This group analysis suggests that the genus probably evolved in the antarctic and radiated into other world oceans.

Data on *Storthyngura* species collected by *Eltanin* in different months of the year in the Scotia Sea indicate a seasonal or cyclic reproductive activity in abyssal organisms (George *and* Menzies, 1967c). Since there are no known seasonal environmental changes in the deep sea comparable in magnitude to those at the sea surface, the persistent breeding cycle of deep-sea isopods may reflect their derivation from shallow-water organisms.

Based on the isopod material collected on *Anton Bruun*'s Cruise 11 and *Eltanin*'s Cruise 3, a monograph entitled *The systematics, distribution, and origin of marine isopod Crustacea of the Milne-Edwards Trench* has been compiled. The ecological and distributional data gathered over 500-m increments to a depth of 6,200 m have been subjected to a factor analysis in order to determine the salient features correlated with abyssal life. The results led us to question the concept that a hadal or ultra-abyssal fauna is an ecologic or faunistic unit with distinctive characteristics (Menzies *and* George, 1967).

A study was made of the distribution of eye-bearing and blind benthic isopods in relation to depth and latitude. The ocular index, *i.e.,* 50 percent of species blind, is located at a shallow depth (100-500 m) at arctic and antarctic latitudes and in deeper water (1,300 m) at lower latitudes. This equatorial submergence of ocular index 50 can probably be explained by the emergence of typically abyssal genera to shallow water in polar regions.

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Nonetheless, on the basis of the presence or absence of eyes alone, it is a reasonable conclusion that the shallow waters of the polar regions are equivalent to much greater depths in the tropics (Menzies *et al,* submitted).

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Studies of the Mite *Alaskozetes antarcticus* (Michael)

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Alaskozetes antarcticus (Michael) is a large (1,059.0 micron) orbatid mite which is suitable for some physiological and behavioral testing. During 1966, it was studied at Norsel Point on the Antarctic Peninsula by representatives of the Bernice P. Bishop Museum.

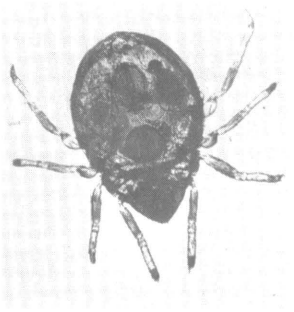
This mite occurs in dense aggregations on the sides and undersurfaces of rock rubble and in small cracks on vertical cliffs. It is associated with soil materials that are rich in phosphorus and potassium, which probably come from animals directly or indirectly associated with the marine environment. For example, conspicuous concentrations of *Alaskozetes* were observed near the wallows of the southern elephant seal, *Mirounga leonia,* where the ammonia and organic nitrogen content of the soil was sufficiently high to limit the growth of chlorophytic algae.

Alaskozetes is found at the periphery of avian roosting and nesting sites, and it occurs within the feather debris left by the giant petrel, *Macronectes giganteus,* which nests at Norsel Point. Often *Alaskozetes* is associated with microalgae, such as *Chlorococcum* sp., and it may be seen on the thallus of the chlorophyte *Prasiola* sp.

Alaskozetes is occasionally found in aggregations that have an internal three-layered stratification. Eggs and larvae form a layer adjacent to the substratum. They are covered by the empty skins and the inactive bodies of larger deutonymph and tritonymph juveniles. The uppermost layer is composed of the resting bodies of newly emerged adults, individuals that have lived through the winter, and gravid females.

In the larger aggregations, accumulations of moulted skins that approach 0.5 cm in thickness form a diversified and protective habitat for small larvae.

Fecal pellets from the adult *Alaskozetes* transmit viable chlorococcoid algae into areas where egg incubation occurs. This fact was demonstrated by the preparation, in the laboratory, of algal cultures from isolated fecal pellets. Also, newly emerged larvae were observed feeding on the algae *Eremo-*



(Photo by author)

Alaskozetes antarcticus *(Michael). The adult mite is about 1 mm in length.*

(Photo by author)

A small portion of an aggregation of Alaskozetes antarcticus *(Michael).*

sphaera sp. and *Chlorococcus* sp., which had adhered to the eggs; these algae were also found in ruptured fecal pellets deposited by the adult mites.

Not only may these processes have the effect of transmitting algae into areas that might not otherwise be suitable for their growth, but they also appear to bring "fodder" to the type of habitat that is necessary for larval growth and development.

Cultures were run to gather data on egg-laying rates of females subjected to different population densities. In cultures containing 50 or more females, the average fecundity rates were higher than those of comparable cultures containing isolated females. These studies tend to support the impression gained in the field that the juxtaposition of *Alaskozetes* individuals initiates life-cycle activities.

The mite's temperature and humidity preferences were also determined. On the average, *Alaskozetes* sought a relative-humidity level of between 70 and 90 percent, and it carried on its life-cycle activities most efficiently at a temperature of about 10°C. *Alaskozete*s withstood a temperature of 44°C. for short periods of time without a noticeable effect on its general life-cycle activities.

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Study of Sleeping, Dreaming, and Waking Patterns of Antarctic Wintering-Over Personnel

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A biomedical study of the psychophysiology of sleeping, dreaming, and waking behavior of wintering-over personnel in the Antarctic was initiated in the 1966-1967 austral summer at South Pole Station by a four-man team (Jay T. Shurley, Chester M. Pierce, Robert E. Brooks, and Kirmach Natani) from the Oklahoma Medical Research Foundation, the Department of Psychiatry of the University of Oklahoma School of Medicine, and the Behavioral Sciences Laboratories of the Veterans Administration Hospital, all of Oklahoma City. The two primary objectives of the undertaking are to survey generally the waking and sleeping activity patterns of personnel at U.S. stations and New Zealand's Scott Base and to study repeatedly and in depth the psychophysiology of the sleeping and dreaming behavior of 10 volunteers among the group wintering over at South Pole Station this year. The survey is being carried out by means of daily self-report cards indicating half-hourly periods of sleep, sleeplessness, work, talk, and recreation during four separate eight-day periods for each man at Plateau and South Pole Stations and Scott Base and for a representative sample of men at Byrd and McMurdo.

The psychophysiological study of sleep is being conducted by means of an eight-channel Beckman Biomedical Data Acquisition System (polygraph), whose signals are transferred to magnetic tape by an Ampex model SP 300 recorder. At South Pole, skin-surface electrodes are used to record brain waves, eye movements, muscle tone, heart activity, and electrodermal responses continuously throughout three consecutive nights' sleep of each volunteer once during the austral summer and three times during the winter. From these records, the duration of the various stages of sleep and periods of rapid eye movement are being calculated. Base line data were recorded at Davisville, Rhode Island, from each of the 10 men selected, prior to their departure for Antarctica, and follow-up studies of the same parameters will be made at Oklahoma City after the men return from Antarctica. It is expected that such information may provide an objective, qualitative measure of the general pattern of psychophysiological changes involved in the adaptation of healthy young men to the unique environmental conditions at the South Pole.

The summer-period sleep-activity cards and the tape-recorded sleep data have been under study in Oklahoma City, while Mr. Natani has collected additional data throughout the winter night. It is expected that some indication of the prevalence and nature of polar insomnia, popularly known as "the big eye," will be obtained.

The sleep-card study has been made possible by the active participation and cooperation of the following men: Lt. Denis Casey, CHC, USNR, at McMurdo; Lt. Elmer Cranton, MC, USN, officer-in-charge at Byrd Station; Mr. Peter Whiteford, scientific officer at Scott Base; and Lt. Archie Blackburn, MC, USN, officer-in-charge at Plateau Station. An effort to obtain preliminary data of a similar nature from the U.S.S.R.'s Vostok Station is being made through the cooperation of Dr. Davidov, high-altitude physiologist at that station.

Vertical and Horizontal Distribution of Pelagic and Benthic Fauna in Antarctic Seas

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With the support of the U.S. Antarctic Research Program (grants G-19497, GA-238, and GA-448), the University of Southern California has continued in 1966-1967 to analyze the extensive biological collections obtained during *Eltanin* cruises. As stated in our last report in the *Antarctic Journal* (vol. I, no. 5, p. 221), the initial program was mainly exploratory, whereas the 1965-1966 program emphasized the elucidation of ecological patterns in specific areas. These approaches are being continued, but the program is evolving into one in which the greater attention is given to the following subjects: (1) the relationships of antarctic species to world faunal distributions and (2) details of the bone structure, reproduction, development, and biochemistry of individual species. Much of the research has been devoted to fishes. For example, an extensive series of distributional maps has been prepared by Dr. H. H. DeWitt for the *Antarctic Map Folio Series,* a number of studies have been made by graduate students on various groups of fishes and their relationships to the physical features of antarctic waters, and a study of the ultrastructure and biochemistry of photophores has been initiated. The recent shift in emphasis has been due in part to the interests of Dr. B. Nafpaktitis, who recently joined the department.

Pelagic invertebrates and their contribution to the standing crop of antarctic and subantarctic waters have been studied by specialists. The part of this work that relates to the standing crop has been directed by Dr. T. Hopkins, whose publications this year demonstrate his desire to determine the catch of zooplankton and micronekton by the various nets in use by *Eltanin* and to combine these data in such a way as to estimate the plankton biomass.

The study of both fossil and living benthic invertebrates continues. Foraminifera and Radiolaria in the sediments have been examined by Dr. O. L. Bandy to determine the extent of past glaciation. Data obtained in the New Zealand sector have been studied by Dr. J. P. Kennett to demonstrate that changes in the morphology of Foraminifera reflect shifts in the Antarctic Convergence. Information on the relative abundance of Foraminifera, Radiolaria, and diatoms formed the basis for the conclusions reached by Dr. R. J. Echols on productivity in the Scotia and Weddell Seas. Dr. O. Hartman has completed the third part of her studies of antarctic polychaetes; she finds great diversity and abundance of these organisms, discusses changes in the composition of the fauna with depth and types of sediments, and includes sections on reproduction, development, and sources of food of some of the 367 species named.

Since the time of last year's report, six papers on these subjects have been presented at meetings and symposia, and nine papers are presently in press. Papers that have been published during 1966-1967 but not noted previously in the *Antarctic Journal* (cf. vol. I, no. 4, p. 173-174) are cited below.

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Endoparasites of Antarctic Vertebrates

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The study of helminths from antarctic vertebrates, now in its third year, will increase understanding of the systematics, ecology, and zoogeography of these endoparasites as well as of the host vertebrates.

The occurrence of juvenile *Corynosoma hamanni* (Linstow, 1892) in eight piscine species of three families indicates a lack of qualitative specificity. Adult *C. hamanni* appear to be specific to marine mammals. One of twelve guinea pigs fed juvenile *C. hamanni* yielded immature intestinal worms. The recovery of only one immature female *C. hamanni,* which had infected *Pygoscelis adelie,* from 86 antarctic breeding birds examined indicates that birds are heterologous hosts.

Statistical taxonomic analyses reveal a homogenous population of juvenile *C. hamanni* in fishes of McMurdo Sound. Different modal values for the number of rows of hooks in juveniles are insignificant. Eight *Corynosoma* species that occur in geographical ranges of seal hosts of *C. hamanni* may be differentiated on the basis of juvenile characters. Incidences of infection in four nototheniid species and one zoarcid species examined indicate the probable importance of these fishes in transmitting worms to pinnipeds. Three hosts occurring at depths of 115-582 m have higher incidences of infection than two surface and shallow-water species (2-86 m). Higher incidences of infection may be related to the reported vertical amphipod stratification in McMurdo Sound. Comparisons of data on Weddell seal diving with incidences of *C. hamanni* infections and the vertical distribution of five piscine hosts reveal that the frequency of deep dives by the seals is unrelated to the incidence of infection in *Rhigophila dearborni.*

Of 2,300 amphipods of the *Orchomenella plebs-rossi* complex that were exposed to eggs from 116 *C. hamanni,* 812 were examined microscopically. Two eggs of dubious significance were found in the intestine of one amphipod five days after exposure.

Four species of *Ascarophis* Beneden, 1871 are known to occur in antarctic piscine hosts. Two species may have been combined in *Ascarophis nototeniae* Johnston and Mawson, 1945, or errors were made in the metric analyses of ova and spicule no. 1. The eggs have two bifilamented polar plugs, a feature not previously observed. The redescription of *Ascarophis* renders the generic assignment of *A. chalinurae* Johnston and Mawson, 1945 untenable. The description of *A. campbelli* (Chatin, 1885) Johnston and Mawson, 1943 is incomplete. *A. lycodichthys* Johnston and Mawson, 1945 is synonymized with *A. nototeniae.*

We have reported on a technique for removing mercurial precipitates from digenetic trematodes and on the preparation of soft-tipped forceps. Manuscripts are in preparation on antarctic Acanthocephala and two new helminth species obtained from fishes.

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Ecology of Antarctic Pelagic Ostracoda

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Examinations of pelagic ostracods collected on *Eltanin* Cruises 9-19 have been completed. The sampling range covers about 166° of longitude, from 35°W. to 159°E., from the Scotia Sea across the Pacific. The ostracods are being sorted from the *Eltanin* plankton collections with the aid of the Smithsonian Oceanographic Sorting Center. So far, more than 850 select samples have been examined and more than 100,000 ostracod specimens have been counted and identified at Lamont. Approximately 23 species of the genus *Conchoecia* were found between 50°S. and 70°S., but only 16 of them were encountered with any regularity, and only 11 species are common enough to indicate reliable patterns of distribution within a particular sampling area.

There is strong evidence that the Antarctic Convergence inhibits the dispersal of a few pelagic ostracod species and contributes to the decline in occurrence of members of other species. The spe-

cies affected mostly are *Conchoecia chuni* and *C. serrulata,* which have large populations north of the Convergence but very small ones south of it. *C. hettacra, C. isocheira, C. lophura, C. obtusata,* and *C. rotundata,* on the other hand, decline gradually in population in the area of the Convergence. *C. elegans,* apparently a cosmopolitan species, is found from 79°N. in the Atlantic to 68°S. in the southeast Pacific.

Data obtained during *Eltanin* cruises indicate that all of the major ostracod species in the antarctic area, except *C. isocheira,* which is a cold-water species, *C. endentata,* a bathypelagic species, and possibly *C. obtusata,* exhibit some degree of winter subsidence, as is typical of most other plankton groups. Probably the ostracod species mostly affected is *Conchoecia chuni,* whose habitat is about 500 m deeper in the winter than in the summer. In the area just north of the Antarctic Convergence, this species becomes quite rare in the upper 1,000 m during the winter. The winter subsidence of other ostracod species affected is usually less than 250 m.

There appears to be little or no latitudinal shift in ostracod populations with changes in seasons. The major seasonal shift is vertical, and any slight geographic change that occurs is a consequence of this shift.

Holoplanktonic Gastropoda in the Southern Oceans

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Thecosomata, Gymnosomata, Heteropoda, and *Ianthina* are the four major groups of holoplanktonic Gastropoda in the antarctic seas. Three zonations—antarctic, subantarctic, and subtropical—are recognized on the basis of group diversity and respective characteristic species. Thecosomata and Gymnosomata appear in the antarctic zone, Heteropoda is added to them in the subantarctic zone, and all four groups are present in the subtropical zone. The numbers of species increase from antarctic to subtropical waters.

The vertical distribution of holoplanktonic gastropod species can be correlated with different water masses at various depths. In antarctic waters, two thecosomatous species are predominant in the upper 300 m, whereas *Clione antarctica,* of the Gymnosomata, is usually more abundant than Thecosomata below 300 m. *Limacina helicina* is characteristic in the upper 200 m of antarctic surface water, while *Clio sulcata* shows a patchy distribution at a depth of about 300 m in the South Sandwich Trench.

In the subantarctic water, *Limacina retroversa* of the Thecosomata and *Spongiobranchaea australis* of the Gymnosomata are the dominant species in the upper 200 m, while *Clio antarctica* of the Thecosomata ranks first in the relative abundance of gastropods in the intermediate waters. Few specimens of *Pterotrachea* sp. of Heteropoda appear in the surface water.

In the subtropical water, *Ianthina ianthina* occurs mostly in the upper 10 m, and two heteropod species, *Atlanta peroni* and *Pterotrachea scutata,* are usually found in the upper 100 m. Two thecosomatous species, *Limacina inflata* and *L. bulimoides,* are predominant in the upper 300 m.

The species composition of Thecosomata in Recent pelagic sediments of the South Atlantic can be correlated with that in the overlying water column. The tropical species *Creseis virgula conica* is dominant in the sediments of the Mid-Atlantic Ridge north of about 10°S. and in the overlying South Equatorial Current. *Limacina inflata* is the major species collected from sediments of the Mid-Atlantic Ridge in the middle latitudes and the overlying South Atlantic central water. *Limacina bulimoides* is the most important species in the Benguela Current and ranks first in the relative abundance of gastropods in the sediments of Walvis Ridge. *Styliola subula* is a characteristic species in the sediments of Rio Grande Rise and the overlying Brazil Current.

Biological-Productivity Investigations of the Pacific Sector of Antarctica

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Texas A&M's biological-productivity program aboard *Eltanin* in the Pacific sector of Antarctica has the following objectives:

(1) Estimate the standing crop of phytoplankton in antarctic and subantarctic waters at various depths; (2) measure primary organic production in the euphotic zone by the C^{14} uptake method; (3) study the photosynthesis/pigment relationship according to environmental conditions, geographic distribution, and season of the year; (4) study the effect of hydrographic conditions on the distribution and abundance of the phytoplankton, with special emphasis on the effect of the Antarctic

and Subtropical Convergences; (5) study the horizontal and vertical distribution and concentration of soluble and particulate organic carbon in the various water masses at different seasons; (6) study the concentration of the nutrient elements, *e.g.*, phosphates, silicates, nitrites, nitrates, and trace elements in the bodies of water sampled; (7) study the species composition and relative abundance of the phytoplankton and correlate their distribution with the hydrographic features in the areas investigated; (8) measure the amount of solar radiation by solarimeters and measure light attenuation at subsurface levels by a submarine photometer.

To date, biological-productivity and chemical data have been collected during 10 cruises of *Eltanin* in the Pacific sector of Antarctica. Analyses made so far of data on productivity and nutrients obtained from this sector are summarized in the table.

Observations made of the standing crop of phytoplankton, primary production, nutrient salts, and particulate and dissolved organic carbon collected during Cruises 18-25 of Eltanin *in the Pacific sector of Antarctica.*

Subject of Observation	Minimum	Maximum	Mean	Standard Deviation	No. of Observations
Chlorophyll *a* (mg/m^3)	0.01	2.83	0.23	0.25	684
*Chlorophyll *a* (mg/m^2)	0.23	40.19	11.38	5.22	169
C^{14} uptake (mgC/m^3/hr)	0.03	13.05	1.07	1.55	566
*C^{14} uptake (mgC/m^2/hr)	3.54	177.46	33.79	22.42	148
Phosphates (PO_4) (μg at./1.)	0.11	3.14	1.20	0.41	246
Nitrates (NO_3) (μg at./1.)	0.01	30.2	13.36	5.48	185
Nitrates (NO_2) (μg at./1.)	0.01	0.39	0.19	0.07	170
Silicates (SiO_4) (μg at./1.)	0.01	79.0	6.38	12.33	251
Particulate org C (mg/1.)	0.003	0.232	0.068	0.034	142
Dissolved org C (mg/1.)	0.08	1.78	0.85	0.24	150

*Integrated values in the euphotic zone.

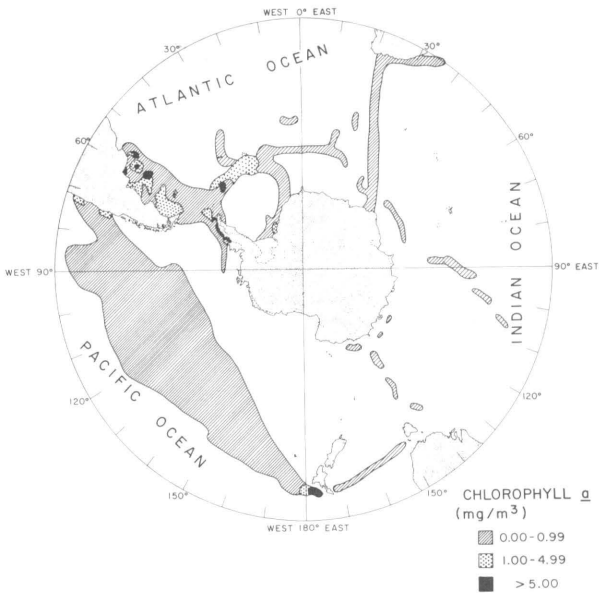

Figure 1. Distribution of chlorophyll a *in surface-water samples collected in antarctic and subantarctic regions. See text for sources of data.*

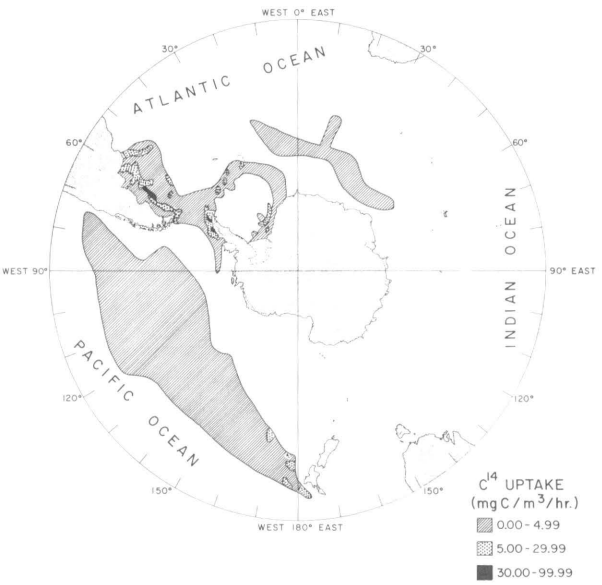

Figure 2. Distribution of C^{14} uptake in surface-water samples collected in antarctic and subantarctic regions. See text for sources of data.

Since a similar investigation was carried out in recent years in the Atlantic sector of Antarctica by Texas A&M University and the Argentine Hydrographic Service, it is instructive to compare the productivity data collected in both bodies of water. Figures 1 and 2 show the surface distribution and concentration of chlorophyll *a* (mg/m^3) and C^{14} uptake (mgC/m^3/hr) in the two sectors. For the sake of comparison, we have included in these two figures productivity data collected in the Indian sector by Japanese and Soviet scientists.

The distribution and concentration of the standing crop of phytoplankton, primary production, nutrient salts, dissolved and particulate organic carbon, etc., will be discussed in Folio 6 of the *Antarctic Map Folio Series.*

Botanical Studies in West Antarctica

I. MACKENZIE LAMB

Farlow Reference Library and
Herbarium of Cryptogamic Botany
Harvard University

This long-term project is presently concerned with the laboratory study, preservation, and taxonomic treatment of terrestrial and marine plants collected earlier in the Antarctic Peninsula area. A 300-page manuscript, "Antarctic Lichens, II: the Genera *Buellia* and *Rinodina,*" was completed early in 1967 for publication in the British Antarctic Survey's Scientific Reports series. Preliminary work has been done towards a third report in this series.

Dr. R. Delépine, at the Laboratoire de Biologie Végétale Marine in Paris, is continuing the taxonomic study of the marine algae collected off the Antarctic Peninsula in 1964-1965. He is expected to come to Harvard in 1968 to prepare the final draft and supervise the preparation of illustrations for a manuscript on the iconography of antarctic marine algae. This work is expected to take about one year, and publication of the manuscript is scheduled for 1970.

Smithsonian Institution Participation in *Eltanin* Cruises

I. E. WALLEN

Office of Oceanography and Limnology
Smithsonian Institution

The Smithsonian Institution maintains an intermittent biological-collecting program for the U.S. Antarctic Research Program, provides field training for sorters in its Oceanographic Sorting Center, and advises on the field preparation of specimens and the kinds of collection data required by specialists. Recognizing that it is in the best interests of the National Science Foundation and the U.S. Government to provide a diverse collecting program, the Smithsonian sends personnel on *Eltanin* cruises when there is a shortage of biologists aboard to properly process the specimens to be collected.

During fiscal year 1967, two scientists and four technicians participated in *Eltanin* cruises to collect specimens for the Smithsonian. The Institution's objective on the cruises was to collect as many organisms as possible from the new areas visited by the ship. Bathypelagic fishes were collected for Dr. R. H. Gibbs, Jr., of the U.S. National Museum. A total of 46 midwater-trawling operations yielded 10,200 fishes representing 28 families. The most abundant groups were the Gonostomatidae, of which 98.1 percent belonged to the genus *Cyclothone*. The Myctophidae were second in abundance but first in frequency of occurrence.

Benthic sampling was carried out primarily to obtain echinoderms and brachiopods. Observations of living and dead organisms were made in various ways, including color photography, in order to record features which are not retained by the organisms when they are placed in preservatives. Seven samples were collected for lipid analysis by Texas A&M. Samples of rocks and manganese nodules were given to Florida State University.

Large numbers of the specimens collected are being made available to USARP scientists through the Smithsonian Oceanographic Sorting Center.

Systematics and Distribution of Antarctic Cephalopods

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University of Miami

During the past year, studies of the systematics, distribution, and various other aspects of the biology of the antarctic cephalopod fauna have been continued by the principal investigator and his associates. Some indications of the areal, temporal, and vertical distribution of the midwater cephalopod fauna are beginning to emerge as a result of the completion of extensive studies by Clyde F. E. Roper of *Bathyteuthis abyssicola,* the most abundant squid in the collections. This species occurs throughout the Atlantic and Indian Oceans and the southern part of the Pacific Ocean. The distribution of the second most abundant species, *Crystalloteuthis glacialis,* contrasts strongly with that of *Bathyteuthis* in that it is restricted to waters south of the Antarctic Convergence. It is hoped that through the study of *Bathyteuthis* and *Crystalloteuthis* guidelines will be formed for the study of the less abundant members of the fauna.

New collections continue to add to our knowledge of the antarctic fauna. One of the most exciting discoveries of the program thus far has been the recent capture of the long-sought juveniles of the

giant antarctic squid, *Mesonychoteuthis hamiltoni.* This squid, which attains a body length of at least seven feet, has occasionally been taken from the stomachs of whales captured in antarctic waters. The juveniles, which were unknown previously and which were needed to determine generic relationships, had consistently eluded midwater trawls. One of the closest relatives of the giant squid is the very abundant *Crystalloteuthis glacialis,* of which the largest specimens captured were juveniles having a total length of 2½ feet.

Also of interest was the rediscovery of the antarctic squid family Psychroteuthidae. This family was first described in 1921 on the basis of fragmentary specimens obtained from seal and penguin stomachs. Until its rediscovery, the description had been considered invalid because the evidence for it was believed to have been compiled from the fragments of several unrelated species.

The principal investigator is nearing completion of his studies of the systematics and distribution of benthic octopods after spending several weeks in Europe examining type specimens.

Cooperative Systematic Studies in Antarctic Biology

I. E. WALLEN

Office of Oceanography and Limnology
Smithsonian Institution

In August 1965, the National Science Foundation awarded funds to the Smithsonian Institution to cover the first year's work on a long-term project involving the study of biological specimens collected during antarctic investigations (but not under active study by specialists) and the publication of scientific reports on them. The Smithsonian Institution agreed to seek personal service contracts with specialists not already working on antarctic specimens to provide publishable reports within specified times.

As of August 1967, nine contracts had been negotiated to cover research on subgroups of asteroids, diatoms, copepods, barnacles, holothurians, octocorals (two), and ascidians (two). Negotiations were well along on two other contracts.

One completed manuscript has been submitted by Dr. Patricia Knott (Mather) for publication in the *Antarctic Research Series.* The contents include (1) a reorganization of ascidians based on phylogeny, (2) observations on the general nature of antarctic abyssal Ascidiacea, (3) data on depth and geographic distribution of these organisms, including inferences on colonization, (4) discussions of 116 species, including 8 new species (5 abyssal), 1 new genus, and 1 new larval form, and (5) keys for identification.

According to Dr. Frederick M. Bayer, about 67 species have been identified of all octocoral orders except Coenothecalia (which is exclusively tropical). The gorgonacean family Primnoidae is a conspicuous component. Several new species and at least one new genus have been tentatively separated from the material.

Dr. William A. Newman has found a new genus and has tentatively established the first new family in the Balanomorpha since Darwin described one in 1854. Several long-standing problems in barnacle taxonomy have been clarified by the antarctic material.

The copepods are being investigated by Miss Gayle Heron, who is working with Dr. T. E. Bowman. Work by Miss Helen E. S. Clark has been essentially completed on one order of asteroids. Dr. Ryuzo Marumo is starting a description of diatoms, and Dr. David L. Pawson will prepare a paper in New Zealand on holothurians.

Anatomical Investigations of Weddell Seals

BARBARA LAWRENCE

Museum of Comparative Zoology
Harvard University

With the support of the National Science Foundation, osteological and myological investigations of the Weddell seal, *Leptonychotes weddelli,* have been finished by Dr. Jean Piérard. While the dissections have been complete and detailed in the classic anatomical style, interpretations of the results have focused on comparative and functional aspects. The seals in question are members of an antarctic subfamily, the *Lobodontinae,* the anatomy of which had never before been studied in such detail. At this time, it may be said that certain aspects of their anatomy are significantly different from those of the related subfamily, the *Phocinae.* Further studies of the other three genera of the subfamily *Lobodontinae* are planned to determine whether these differences are indicative of genetic relationships within the subfamily or are merely functional adaptations of a particular genus.

CARTOGRAPHY

Cartographic Activities of the U.S. Geological Survey in Antarctica

GEO. D. WHITMORE

U.S. Geological Survey

Geological Survey field activities carried out during the past austral summer were described in the July-August 1967 issue of the *Antarctic Journal*. Other activities related to the mapping project were performed throughout the year in the Washington, D.C., area.

The results of earlier field work were computed and used with aerial photographs obtained by Air Development Squadron Six (in accordance with Survey specifications) to compile maps in support of U.S. Antarctic Research Program activities. The last three sheets of the Queen Alexandra Range project were published at a scale of 1:250,000. Thirty-four quadrangles in shaded-relief editions are now available at this scale, covering 135,000 square miles. Two quadrangles in the Heritage Range and four in the Queen Maud Mountains, covering 29,400 square miles, have been completed and are awaiting publication. Thirty maps in this series, representing 151,125 square miles, are in various stages of compilation. Two 1:500,000-scale sketch maps, covering 65,750 square miles of Marie Byrd Land, were published in shaded-relief editions, and three, representing 201,500 square miles, are in production.

The American Geographical Society's Antarctic Cartographic Activities

O. M. MILLER

American Geographical Society

Since reporting in the September-October 1966 issue of the *Antarctic Journal,* the American Geographical Society has received, largely from the U.S. Geological Survey and the New Zealand government, new cartographic information for incorporation in the Society's 1:3,000,000, four-sheet base map, which is constantly being revised under a National Science Foundation (NSF) contract. Extensive revisions have been made on those portions of the map representing the Dufek and Gould Coasts, Ellsworth Land, and the entire coastline of Marie Byrd Land. New names recommended by the U.S. Board on Geographic Names for features in these areas have been incorporated. Prints of this four-sheet map can be supplied at any time on request.

Last year, the Society prepared charts of the South Pacific for plotting data obtained on cruises of the research vessel *Eltanin*. Since then, the Office of Antarctic Programs, NSF, has suggested that this series of charts be extended to cover all of the oceans surrounding Antarctica as far north as 20°S. On the scale of 1:7,500,000, three additional charts will be required.

Antarctic Geographic Names

MEREDITH F. BURRILL

Office of Geography
Department of the Interior

New names for antarctic geographic features were established during the past year, as they have been in previous years, in connection with the exploration and scientific study of the Continent. The official standardizing actions were taken by the Board on Geographic Names (BGN) and the Secretary of the Interior on the basis of recommendations of the Advisory Committee on Antarctic Names. Research and staff work was provided by the Office of Geography. The U.S. Antarctic Research Program and the U.S. Naval Support Force, Antarctica suggested names of U.S. personnel for heretofore unnamed features. Action was taken on 723 new names, 23 amendments of names, 2 redefinitions of features, and the rescinding of 1 former decision. Names were provided for new Geological Survey maps, for maps and folios prepared by the American Geographical Society, and for reports published by the Universities of California, Kansas, Minnesota, and Wisconsin, Ohio State University, and the American Geophysical Union.

Close cooperation with other countries has continued. Names of features given by Australia, New Zealand, the U.S.S.R., Japan, and Norway were accepted by the Board, and other countries agreed with United States name proposals.

A cumulative gazetteer of names standardized by the BGN was issued in January 1967. It contains some 8,500 name decisions and 3,000 cross-references, in the format of the regular BGN series, with designation and location by latitude and longitude, but without descriptive text. A volume with full text, in the format of the 1956 gazetteer, is being prepared for publication.

Antarctic Map Folio Series

VIVIAN C. BUSHNELL

American Geographical Society

The preparation of this series of map folios, begun in 1962, continues. Of the 18 folios planned, 8 have now been published or will be before the end of 1967. The following five appeared in 1966 and 1967 or will be published later this year:

Folio 4: *The Antarctic Atmosphere: Climatology of the Troposphere and Lower Stratosphere;* plates compiled by the National Weather Records Center; text by W. S. Weyant.

This folio includes maps devoted to the seasonal thermal regime, atmospheric circulation patterns, and tropopause heights. In addition, graphs are presented of seasonal relative-humidity values and monthly tropopause temperatures and heights.

Folio 5: *Terrestrial Life of Antarctica;* maps and text by S. W. Greene, J. L. Gressitt, D. Koob, G. A. Llano, E. D. Rudolph, R. Singer, W. C. Steere, and F. C. Ugolini.

Maps show where plants and land arthropods have been found in Antarctica, and a sheet of color photographs presents representative biota in their natural settings. The text describes characteristics of the environment and discusses the geographical distribution of the biota.

Folio 6: *Structure of Antarctic Waters Between 20°W. and 170°W.,* by Arnold L. Gordon.

This folio presents maps of "core layers," dynamic topography, and the "Polar Front Zone." The core layers depicted are temperature minimum, temperature maximum, oxygen minimum, salinity maximum, potential temperature minimum, and deep oxygen maximum. Fourteen plates are included.

Folio 7: *Glaciers of the Antarctic,* by John Mercer. In press.

Maps, text, and tables summarize obtainable information on the glaciers of the oceanic islands and mountains of the Antarctic.

Folio 8: *The Antarctic Atmosphere: Climatology of the Surface Environment;* plates compiled by the National Weather Records Center; text by W. S. Weyant. In press.

This folio includes a map of mean annual temperatures and maps of mean seasonal cloud amounts, monthly cyclone tracks, and wind roses. A series of plates is devoted to graphs of wind and temperature conditions, days with blowing snow, and total cloud amounts.

The folios are for sale by the American Geographical Society, Broadway at 156th Street, New York, N. Y. 10032.

SUPPORT SERVICES

Role of the Smithsonian Oceanographic Sorting Center in Antarctic Research

H. A. FEHLMANN

Smithsonian Oceanographic Sorting Center
Smithsonian Institution

The Smithsonian Oceanographic Sorting Center (SOSC) has participated in the U.S. Antarctic Research Program (USARP) since 1963. Its principal contribution is one of service to the scientists engaged in studies of the natural history of Antarctica and the surrounding oceans. Under a contract with the National Science Foundation, SOSC functions as the prime recipient, sorter, and distributor of the wealth of biological material being collected under the auspices of USARP.

To date, SOSC has received more than 5,500 samples of antarctic and subantarctic fauna and flora. These samples include specimens of vertebrates, planktonic, nektonic, and benthic invertebrates, and algae. Each sample is sorted into taxonomic groups; the level of sorting is dependent upon the requirements of the systematists or ecologists receiving the collections.

Although the majority of the SOSC samples have been taken aboard *Eltanin,* SOSC has also received collections from two of the *Deep Freeze* expeditions and from the 1963 Antarctic Peninsula survey of sites for the permanent Palmer Station. Many of these latter collections have already been processed and distributed. Of the tremendous volume of specimens received from the first 27 *Eltanin* cruises, SOSC has sorted a total of 2,172 samples containing 10,968,-047 specimens. Most of the specimens are currently being studied by systematists, both in the United States and foreign countries. Preliminary reports of investigations in progress indicate that the antarctic region is yielding many species new to science in addition to providing considerable ecological and distributional data on familiar organisms. However, taxa are still available for study by systematists interested in the antarctic fauna.

SOSC is now planning to expand its sorting of the antarctic biota to include the meiofauna. Microscopic organisms of the upper sediments in most areas are not well known, but knowledge of the antarctic meiofaunal communities is nonexistent.

SOSC contributes another service to USARP by providing trained technicians for shipboard collecting

on some of the cruises of *Eltanin*. During 1966-1967, SOSC personnel served as biological collectors on Cruises 20, 21, and 25.

The Antarctic Records Program, 1966-1967

BETTY J. LANDRUM

Smithsonian Oceanographic Sorting Center
Smithsonian Institution

Beginning with the International Geophysical Year and continuing with the present-day operations of the U.S. Antarctic Research Program (USARP), scientists from the United States have intensively collected biological and geological specimens in Antarctica in order to study the natural history of the region. The rapid accumulation of specimens has resulted in an equally rapid accumulation of data, leading to a decision to establish centralized records on the availability, location, and stage of processing and identification of specimens.

The Antarctic Records Program was begun at the Smithsonian Oceanographic Sorting Center (SOSC) in September 1963 under a grant from the National Science Foundation and is presently operated under contract with NSF.

During the past year, effort has been concentrated on devising systems for automatically obtaining and recording data simultaneously with the processing of bulk collections of antarctic specimens at SOSC *(supra)*. With the assistance of systems analysts, the necessary formats and techniques have been designed for computer storage and retrieval of large volumes of sampling, environmental, and taxonomic data. Since most of the specimens taken on *Eltanin* are sorted at SOSC, much of the data can be readily acquired during the routine processing of specimens. Typetronic equipment has been installed which will automatically punch data into paper tape during the typing of labels and invoices resulting from the sorting operations. From the punched paper tape, the data can be transferred to magnetic tape for entry into computer files. The punched-paper-tape method is also very useful in entering all information on the collections, including the following: times, positions, and depths at which organisms were obtained; environmental data, such as sea-surface temperature and swell heights and directions; and gear used. Such information on the *Eltanin* collections is so voluminous that a limited information-processing method, such as that involving standard 80-column punch cards, is impractical.

The computer system has been designed to permit retrieval of data in a variety of ways, *e.g.*, according to the hierarchy of taxonomic classification. Once the system is completely programmed and data are entered, the computer listings will show the kinds of organisms collected, where they were collected, where particular taxa were found, and the present locations of specimens. This information will be continuously updated and related to various parameters of interest to scientists studying the specimens.

Although much of the effort during the past year has been devoted to the automation of record-keeping procedures, the manual preparation, storage, and distribution of data have continued. Reduced data sheets for over 1,100 samples taken on *Eltanin* Cruises 19-27 were completed. Also, the descriptive file on the *Eltanin* bottom photographs has been maintained, and as of now over 10,000 prints have been shipped to scientists at 22 institutions. Data and descriptions of biological and geological features recorded on the photographs are being transferred to end-punch cards, which provide for rapid selection of specific photographs on request. The backlog of cards to be punched has been reduced considerably during the year, and as of now cards for more than 3,600 photographs taken on Cruises 2-13 have been punched. It is expected that the remaining backlog will be eliminated during the coming year.

Recent Activities of the Committee on Polar Research

LOUIS DeGOES

National Academy of Sciences

During the past year, the Committee on Polar Research (CPR) of the National Academy of Sciences (NAS) was largely concerned with preparing for and participating in the Ninth Meeting of the Scientific Committee on Antarctic Research (SCAR) and associated activities conducted in Santiago, Chile, September 20-24, 1966. Laurence M. Gould, Chairman of the CPR, presided over the meeting and was reelected to a second term as President of SCAR. W. J. L. Sladen, of the Panel on Biological and Medical Sciences, served as U.S. member of the SCAR Working Group on Biology. Earlier, CPR panel members worked closely with the National Science Foundation (NSF) in preparing recommendations to present to the Working Group on Biology on species and areas deserving

special protection. These recommendations were used in formulating the U.S. position on the Agreed Measures for the Conservation of Antarctic Fauna and Flora, discussed at the Fourth Antarctic Treaty Consultative Meeting, held in Santiago in November 1966.

Dale F. Leipper, U.S. member of the SCAR Working Group on Oceanography, and others participated in the Symposium on Antarctic Oceanography, which was held in Santiago during the week preceding the SCAR meeting. Morton J. Rubin was the U.S. representative at the Symposium on Polar Meteorology, conducted in Geneva in September 1966 by SCAR, the World Meteorological Organization, the International Union of Geodesy and Geophysics, and the International Association of Meteorology and Atmospheric Physics.

The Glaciology Panel met on April 26, 1967, and discussed the following subjects: (1) reports in preparation by the Panel on major objectives of arctic glaciological research and on spacecraft applications to glaciology; (2) revising the Panel's report of 1965 on long-range planning for antarctic glaciological research; and (3) arctic oceanography, international cooperation in the study of ice cores from deep drilling, relationships with the International Hydrological Decade program, creation of an artificial glacier, mass budgets of glaciers, international cooperation in arctic research, and the impact of designated "wilderness areas" on glacier research. A member of this panel, Charles R. Bentley, was nominated and subsequently appointed as U.S. member of the SCAR Working Group on Glaciology.

The Panel on Biological and Medical Sciences met at the NAS on December 1, 1966, immediately prior to the annual meeting of the CPR. Reports were given by the U.S. member of the SCAR Working Group on Biology and the NSF member of the U.S. delegation to the Fourth Antarctic Treaty Consultative Meeting. A status report was presented on the International Biological Program and, in particular, the U.S. effort in biology; discussions were held on biology programs carried out under the U.S. Antarctic Research Program (USARP); and consideration was given to formulating recommendations on these subjects for submission to the CPR.

The Panel on Geodesy and Cartography met on November 22, 1966. In line with the policy of rotating panel membership, two new members were introduced. Subjects discussed were panel interests and responsibilities, the status of topographic mapping and aerial photography in Antarctica, recommendations of the *ad hoc* Meeting on Antarctic Geology, documents resulting from the Ninth SCAR Meeting, functions of the Technical Advisory Committee on Antarctic Mapping, the PAGEOS Geodetic Satellite System, the *Antarctic Map Folio Series* and the *Atlas of Antarctica.* Also considered were recommendations to be made to the CPR, one of which suggests that a panel or *ad hoc* group be formed to study the application of spacecraft in antarctic research; it was decided to discuss the latter item informally with NSF and the Space Science Board.

In April 1967, a new Panel on Geology was established by Dr. Gould, with J. Campbell Craddock as chairman and membership as follows: Colin Bull, William R. MacDonald, Robert H. Rutford, Dwight L. Schmidt, and F. Alton Wade.

The Committee met on December 2, 1966, and May 22, 1967. At the December meeting, Dr. Gould appointed an *ad hoc* panel composed of M. A. Pomerantz (chairman), W. S. Benninghoff, and A. L. Washburn and charged it with making recommendations on future CPR activities relating to U.S. research in both arctic and antarctic regions and on international cooperation in polar research. The panel first called for information and recommendations from government agencies that sponsor and/or conduct polar research. After reviewing the responses, the panel recommended to the CPR that it undertake a fresh study of polar research with emphasis on the important scientific problems that should be studied during the next few years. At its May meeting, the Committee approved the recommendation, and it is now taking initial steps to implement the study.

Translation of the Soviet Antarctic Expedition Information Bulletin

WALDO E. SMITH

American Geophysical Union

The production of an English edition of this informative publication has continued apace as the issues have arrived from the U.S.S.R. In each English edition, two Bulletins are combined under one cover, six of such issues (12 Bulletins) making up one volume. Since last year's report (*Antarctic Journal,* vol. I, no. 5, p. 228), the remainder of volume 5 (through Bulletin 54) has been published.

Work is progressing on the issuance of volume 6 (Bulletins 55-66), but receipt of issues from the U.S.S.R. has been quite slow; number 56, for example, was not received until the end of December 1966. Numbers through 60 are now in hand, and the first issue of volume 6 will soon be released.

Translations of numbers 57 and 58 have been completed and the composition is in progress. Numbers 59 and 60 are being translated.

There has been a marked change in the character of the more recent Bulletins. Each of the numbers through 56 contains about 60 or 70 pages, but each of numbers 57-59 contains 90-132 pages. Number 60, however, has only 72 pages. The articles have changed markedly in character also, tending to be longer and somewhat more scientific.

The English editions of the first 30 Bulletins were published by the American Elsevier Publishing Company in three bound volumes, each containing 10 Bulletins. AGU began this work with number 31—numbers 31-42 making up volume 4 (unbound). Volume 5, which is also unbound, contains Bulletins 43-54. These two volumes (price, $36 each) and volume 6 (price, $40) are for sale by the American Geophysical Union, Suite 435, 2100 Pennsylvania Avenue, N.W., Washington, D.C. 20037.

Antarctic Research Series

WALDO E. SMITH

American Geophysical Union

The publication of volumes in the Antarctic Research Series, initiated in 1963 by the American Geophysical Union with the aid of a grant from the National Science Foundation, has continued and is moving forward at a rapid pace. This series includes research papers in all fields of antarctic science. Since May 1966, volumes 8 and 9 have been released. Volume 10 should be released by the time this issue of the *Antarctic Journal* is distributed. These books present collections of original contributions that are of value not only to scientists and students involved in the Antarctic, but also to those whose major scientific interests lie outside of that region. All of the published volumes are for sale by the American Geophysical Union, Suite 435, 2100 Pennsylvania Avenue, N.W., Washington, D.C. 20037.

Volume 8, *Antarctic Soils and Soil Forming Processes,* edited by J. C. F. Tedrow, was released in October 1966. It contains six essays by 10 authorities on antarctic scientific problems. The book has 171 pages. Price: $10.

Volume 9, *Studies in Antarctic Meteorology,* edited by Morton J. Rubin, was released in May 1967. This 231-page publication consists of seven essays. Price: $14.

Volume 10, *Entomology of Antarctica,* edited by J. Linsley Gressitt, is now being printed. It contains over 400 pages and 20 essays. Price: $17.

By late 1967, three more volumes, devoted to ornithology, marine biology, and Ascidiacea, should be completed.

Other volumes are in the early planning stages. They will be devoted to glaciology, oceanography, petrology, and the upper atmosphere of the Antarctic. Subjects being considered for the series are investigations of the Weddell Sea, gravity and magnetism, and fishes.

The first seven volumes of the series, listed below, are still available.

Volume 1, *Biology of the Antarctic Seas,* 1964, 187 p., $10

Volume 2, *Antarctic Snow and Ice Studies,* 1964, 277 p., $12

Volume 3, *Polychaeta Errantia of Antarctica,* 1964, 131 p., $9

Volume 4, *Geomagnetism and Aeronomy,* 1965, 236 p., $10

Volume 5, *Biology of the Antarctic Seas II,* 1965, 280 p., $10

Volume 6, *Geology and Paleontology of the Antarctic,* 1965, 281 p. plus plates and maps, $14

Volume 7, *Polychaeta Myzostomidae and Sedentaria of Antarctica,* 1966, 158 p., $10

Bibliography on Snow, Ice, and Permafrost

W. R. FLOYD

U.S. Army Cold Regions Research and Engineering Laboratory

The U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), continuing the program started by its predecessor organization, the U.S. Army Snow, Ice, and Permafrost Research Establishment (SIPRE), sponsors a bibliographic project conducted at the Library of Congress. Since 1950, a highly specialized staff has produced over 25,000 abstracts of scientific and technical articles pertaining to snow, ice, and frozen ground, including a great many items not otherwise available to researchers interested in these subjects.

Standard library reference cards citing these articles are supplied to approximately 50 different libraries on their continuing request. In addition, this same information is published periodically as CRREL Report 12. The primary distribution is made to more than 300 addressees. The latest issue, volume 21, dated June 1967, contains abstracts 24,201 through 25,200.

This bibliographic project serves two specific purposes: First, it provides the necessary and vital literature search for the CRREL research staff, and second, it provides a valuable reference service for the entire scientific and technical community, as evidenced by many routine and special requests for copies.

When the project was initiated, the small staff was able to review substantially all of the then-current applicable literature and even to abstract literature of earlier years. However, the expansion of polar research and the accompanying information explosion has produced so much material that the bibliographic search must be selective in order to include really new and significant information. As research costs have soared, so also have those of documentation and reference services. In consideration of the applicability of CRREL's bibliographic project to antarctic research and the coordinated administration of this project and the *Antarctic Bibliography* project, the National Science Foundation (NSF) supported approximately 25 percent of the cost of CRREL's project in fiscal year 1967. This support permitted continuation of the literature review at the same level of effort as in the prior few years and avoided curtailment of the work and the consequent loss of trained personnel. This generous NSF contribution is greatly appreciated by those responsible for conducting the bibliographic project, and, surely, the many users of the service will benefit by the sustained level of effort.

Abstracting and Indexing Service for Current Antarctic Literature

JOHN F. SPLETTSTOESSER*

Science and Technology Division
Library of Congress

The *Antarctic Bibliography* was initiated in 1963 at the Library of Congress as a continuing project in support of the U.S. Antarctic Research Program. It is issued in two forms—abstract cards and bound volumes. Citations, abstracts, and index terms are given on 3- by 5-inch cards which are eventually reproduced in volumes of 2,000 entries each. Each entry also includes Universal Decimal Classification numbers which identify the abstracted item according to an internationally recognized code. In addition, the entry indicates the document's location, which is usually the Library of Congress. The cards are distributed free to organizations participating in antarctic research by the Information Officer of the Office of Antarctic Programs, National Science Foundation, Washington, D.C. 20550. That office also maintains a master file of the cards arranged in accordance with the hierarchical index code. Volumes 1 and 2 of *Antarctic Bibliography* are for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, for $4.25 each. Volume 3 is in preparation. Each volume contains abstracts that are grouped into 13 major categories. Author, subject, geographic, and grantee indexes are included. The latter index is a record of publications resulting from research which is financially supported by the Office of Antarctic Programs. In order to provide positive identification of serials used in compilation of the bibliography, volume 3 will include a list of serials used in volumes 1 through 3.

* Now at the Institute of Polar Studies, Ohio State University.

Antarctic Bibliography, 1951-1961

JOHN F. SPLETTSTOESSER*

Science and Technology Division
Library of Congress

The preparation of this retrospective bibliography began in 1966 at the Library of Congress. The procedures of compilation are similar to those used in the current bibliography (*supra*). The end products of the two projects differ, however, in that the retrospective project will result in a final, bound volume; no card service will be provided. Also, the compilation will not contain abstracts, although brief annotations will be appended where necessary.

To expedite the procedures of searching for and acquiring materials, the services of the Scott Polar Research Institute, Cambridge, England, were used. The Institute's excellent library resources provided more than 7,000 bibliographic references as part of a preliminary survey of existing literature. Those references, together with the collections of the Library of Congress and specialized libraries in the Washington, D.C., area, will provide the bulk of the material in the bibliography. Other sources are being consulted, as necessary, to provide an exhaustive coverage of the 1951-1961 literature.

* Now at the Institute of Polar Studies, Ohio State University.

Other Research Projects Active During the Past Year

Ultra-Low-Frequency Observations in Antarctica. Environmental Science Services Administration; Wallace H. Campbell, Principal Investigator.

Comprehensive Studies of Geomagnetic Variations in the ULF Range in Antarctica. University of Pittsburgh; Takesi Nagata and Yuji Inoue, Principal Investigators.

Extension of Geophysical Studies from Eltanin *for 1966.* Lamont Geological Observatory, Columbia University; James R. Heirtzler, Principal Investigator.

Study of Deep-Sea Sediments and Submarine Volcanics in the Subantarctic Region. University of Washington; Y. R. Nayudu, Principal Investigator.

Analysis of Deep Ice Cores and Particulates from the Greenland Ice Sheet. U.S. Army Cold Regions Research and Engineering Laboratory; Chester C. Langway, Jr., Principal Investigator.

Atmospheric Carbon Monoxide Concentrations over the South Pacific. Stanford Research Institute; Elmer Robinson and R. C. Robbins, Principal Investigators.

A Biogeochemical Study of the Skeletal Carbonates of the Benthic Organisms in the Antarctic Seas. California Institute of Technology; Heinz A. Lowenstam, Principal Investigator.

Lichen Flora of the Subantarctic Islands. University of Vermont; Carroll W. Dodge, Principal Investigator.

Parasites of Antarctic Vertebrates and Invertebrates. Virginia Institute of Marine Science; William J. Hargis, Jr., Principal Investigator.

Measurement of Common Lead in Antarctic Snow. California Institute of Technology; Clair Patterson, Principal Investigator.

Propagation of Seismic Waves in Heterogeneous Snow Structures in Antarctica. University of Utah; Edwin S. Robinson, Principal Investigator.

Influence of Clouds and Pollution in the Arctic Region. Ohio State University Research Foundation; Eberhard Vowinckel, Principal Investigator.

The Benthic Algal Vegetation of Antarctica, I-II. Old Dominion College; Jacques S. Zaneveld, Principal Investigator.

Wintering-Over Personnel, 1967

At the conclusion of the 1966-1967 summer season, 263 men were left to winter over at U.S. stations in Antarctica. Of this number, 229 are support personnel, 34 are USARP researchers, and one (Mr. Petr Astakhov) is a Soviet exchange scientist. In addition, one U.S. researcher (Dr. E. E. MacNamara) is wintering at a Soviet station, Molodezhnaya. The scientific personnel are conducting studies under the auspices of the U.S. Antarctic Research Program (USARP) of the National Science Foundation. The military personnel are assigned to Antarctic Support Activities (ASA), the Naval Nuclear Power Unit (NNPU), or Air Development Squadron Six (VX-6).

Summary of Wintering-Over Personnel, 1967 [1]

Station	Military Officers	Enlisted Members	USARP Personnel	Totals
Amundsen-Scott South Pole	1	12	8 [2]	21
Byrd	1	16	11	28
McMurdo	14	177	6	197
Palmer	0	4	5	9
Plateau	1	3	4	8
Totals	17	212	34 [2]	263

[1] Does not reflect personnel changes resulting from winter flights.
[2] Includes Soviet exchange scientist.

Amundsen-Scott South Pole Station

Astakhov, Petr, Soviet Exchange Scientist
Bean, Lawrence D., CEW3, ASA
Brazitis, Peter F., Cosmic Radiation, Bartol Res. Found., USARP
Broome, Howard W., Jr., EM2, ASA
Crain, Harold D. K., UT1, ASA
Des Roches, Joseph H., Jr., Meteorology, Weather Bureau, USARP
Gorham, Charles E., BUL3, ASA
High, Harvey W., CS2, ASA
Macnowski, Francis B., CMHCN, ASA
Natani, Kirmach, Biology, Univ. of Oklahoma, USARP
O'Connell, Richard V., Geomagnetism, USC&GS, USARP
Plankington, John C., Jr., Meteorology, Weather Bureau, USARP
Postel, Philip H., Meteorology, Weather Bureau, USARP
Rivera, James P., ET1, ASA
Sullivan, Ronald C., LT (MC), ASA, *Officer-in-Charge*
Terrazas, Rudolph D., BULCN, ASA
Terwileger, Stephen E., HM1, ASA
Virdin, Floyd (NMN), CM1, ASA
Weininger, Richard B., Ionospheric Physics, ITSA, *Station Scientific Leader,* USARP
Wells, James T., SK2, ASA
White, Noah D., RM1, ASA

Byrd Station

Adams, James G., BU1, ASA
Backer, Walter K., CMC, ASA

Benedict, Philip C., Jr., Aurora, Univ. of Colorado, USARP
Boman, William M., Station Engineer, Univ. of Wisconsin, USARP
Breeding, George H., SK2, ASA
Butcher, Robert S., BULCN, ASA
Clark, Elton G., UTW3, ASA
Cranton, Elmer M., LT (MC), ASA, *Officer-in-Charge*
Crummey, Glenn T., CE1, ASA
Dyment, Donald I., CS2, ASA
Favela, Rafael (NMN), Jr., EON2, ASA
Groux, Roger G., SF1, ASA
Maish, F. Michael, Ionospheric Physics, ITSA, USARP
Manthe, Lawrene L., Meteorology, Weather Bureau, USARP
McKinzie, Richard H., HM1, ASA
Moses, Robert L., Geomagnetism, USC&GS, USARP
Rea, Peter C., EM1, ASA
Reddick, Warren W., Jr., CET3, ASA
Shepherd, Donald C., Ionospheric Physics, ITSA, USARP
Siren, Jan C., Radioscience, Stanford Univ., USARP
Slusher, Harold E., Meteorology, Weather Bureau, USARP
Smith, Rossman W., Jr., Radioscience, Stanford Univ., *Station Scientific Leader,* USARP
Sneddon, Donald L., ET1, ASA
Suchland, Everett B., Jr., RM1, ASA
Velie, Edward C., Jr., Meteorology, Weather Bureau, USARP
Webber, George E., Electrical Engineer, Univ. of Washington, USARP
Weikman, Edward R., Jr., CMH2, ASA
Witte, Paul F., CM1, ASA

McMurdo Station

Albrecht, Lawrence J., ET1, ASA
Aldridge, James A., ADJ3, VX-6
Allara, Victor G., SP5, U.S. Army, NNPU
Archambault, John L., LT (MC), ASA
Armagost, Harry M., EOC, ASA
Austin, Hurshel L., ABF1, ASA
Baner, Billy A., RM1, ASA
Barela, Ruben E., AMS3, VX-6
Barker, Robert E., SF1, ASA
Bartley, John D., CECS, NNPU
Basta, George E., SK3, ASA
Berkowitz, Robert J., UT1, NNPU
Bertalan, Robert E., RM1, ASA
Bishop, William T., SF1, ASA
Black, Albert K., CEC, NNPU
Bless, Jurgen W., HM2, NNPU
Bontempo, James E., SP5, U.S. Army, NNPU
Bramble, Edward J., ADR2(AC), VX-6
Brewer, Jerome S., HM3, ASA
Brewer, Thomas J., CS1, ASA
Brunner, James R., SH2, ASA
Bunch, Stephen C., CMHCN, ASA
Burns, John P., RM1, ASA
Bush, Thomas B., AN, ASA
Cadugan, Kenneth R., CMHCN, ASA
Carnes, James J., EMC(SS), ASA
Carroll, John W., SA, ASA
Carson, Gene A., CEC, NNPU
Casey, Denis (NMN), LT, ASA
Chaplin, Alexander R., CEW3, ASA
Chisolm, Johnny A., AN, ASA
Christopherson, Douglas S., AG1, ASA
Clark, Robert J., EM2, ASA
Cobb, Robert O., CE1, NNPU
Cooke, John T., AK2, VX-6
Cooper, Ronald R., BUC, ASA
Cornelius, Larry J., AG1, ASA
Costa, Gilbert (NMN), Jr., CMHCN, ASA
Coulston, Peter W., ATN2, VX-6
Crowson, Francis R., SFC, U.S. Army, NNPU
Curtis, Charles C., PH1, ASA
Daniels, William L., EN2, ASA
Davis, Gary L., RM3, ASA
Davis, Larry J., DTG1, ASA
Deming, Ralph A., AE2, VX-6
Ditges, John J., CMH2, ASA
Doe, Wilfred I., HM2, ASA
Donovan, Lawrence K., LCDR, NNPU, *Officer-in-Charge*
Dooley, John E., HM1, NNPU
Draeger, Ernest J., RMC, ASA
Dunn, Robert (NMN), CSC, ASA
Durham, James T., HM2, ASA
Eash, Ervin D. I., RM2, ASA
Eldridge, David B., Jr., LCDR, VX-6, *Officer-in-Charge*
Emerson, George L., SW1, ASA
Erickson, Dean L., HM1, NNPU
Feezer, David T., ABF2, ASA
Fields, Ralph V., BULCN, ASA
Frock, Marion D., SF1, ASA
Galan, Michael P., Station Engineer, Univ. of Wisconsin, USARP
Gan, Francisco L., Jr., DK1, ASA
Garofalo, Lawrence J., SKSN, ASA
Gendron, Richard A., BULCN, ASA
Germain, Armand J., CE1, ASA
Gibbs, Maurice E., LTJG, ASA
Gibson, David T., RM1, ASA
Gooden, Arlan W., UTP2, ASA
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Gould, Stuart S., LT, ASA
Gray, Robert L., EN2, ASA
Griffith, Harry G., LT, ASA
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Halverson, Jack E., ETC, ASA
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Holmes, William A., CMCS, NNPU
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Poorman, Dean A., ADJ1, VX-6
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Ray, Carl J., SKSN, ASA
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Smith, Joseph A., CEC, ASA
Smith, Keith A., RM2, ASA
Sprague, Ellis B., EASCN, ASA
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Tocci, Joseph J., II, AG2, ASA
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Verhage, Ronald G., LT, ASA
Waring, James T., ACC, ASA
Warren, Harrold E., EO1, ASA
Webb, Alvin C., YN1, ASA
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White, William G., EM3, ASA
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Williams, Thomas J., EON2, ASA
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Wollam, Lyle D., Jr., CMHCN, ASA
Wood, Vernon P., YN2, VX-6
Wright, Tommy D., IC1(SS), ASA
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Stout, Dennis K., RM1, ASA
Suydam, E. Lynn, Biology, Virginia Inst. of Marine Science, USARP
Whillans, Ian M., Glaciology, Ohio State Univ., USARP
Woods, Clifford R., Jr., HM1, ASA

Plateau Station

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Oliver, Thomas H., ETN2, ASA
Pranke, James B., Geomagnetism, USC&GS, *Station Scientific Leader,* USARP
Sowle, Melvin L., CMA2, ASA
Wagner, John K., Radioscience, Stanford Univ., USARP

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* Brought out on June flight.
ITSA = Institute for Telecommunication Sciences and Aeronomy
USC&GS = U.S. Coast and Geodetic Survey

Fresh Water for McMurdo Station

RICHARD D. WHITMER [1]

Lieutenant, CEC, USN

Staff, Commander, Naval Construction Battalions, U.S. Atlantic Fleet

Obtaining water has always been a problem for men in Antarctica. The traditional method—melting snow—consumes fuel that must be imported at great expense and assumes the availability of uncontaminated snow. The growth of McMurdo Station has brought both an increasing demand for water (and hence for fuel) and an increasing contamination problem. Vehicles have had to travel farther and farther from the station to get pure snow for the snow melters, consuming in the process still more fuel. The Navy's answer was to desalinate seawater, preferably by using nuclear power.

During *Operations Deep Freeze* 63 and 64, a water-distillation plant and the beginning of a distribution system were installed by the Seabees. The distillation plant basically consists of a flash-distillation unit with a daily production capacity of 14,400 gallons, two 55,000-gallon bolted-steel storage tanks (one for fresh water and one for salt water), and an oil-fired boiler; these were installed in a heated Robertson building erected in the PM-3A nuclear power plant complex, on the side of Observation Hill. Also installed were pipelines to carry seawater to the distillation plant and to return concentrated brine to McMurdo Sound.

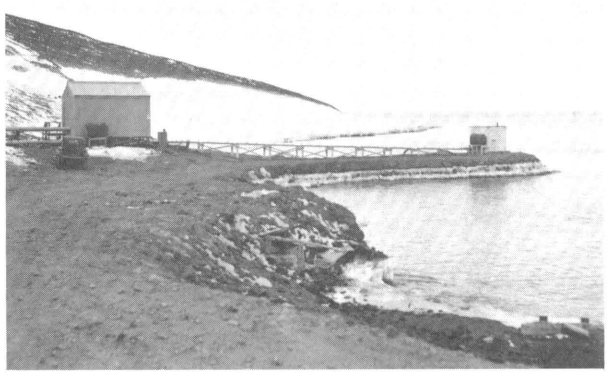
Intake System

A variety of intake systems were installed and tested in an effort to find one that would work year-round with a minimum of maintenance. An offshore raft, tried during *Deep Freeze* 65, worked well for a while, but icebergs destroyed it during a storm (Fig. 1). During *Deep Freeze* 66, a heated hose was installed. It proved successful in two out of three situations: when the annual ice was completely out, the hose was simply placed in the water at the shoreline; when the ice was solidly formed, the hose was run across the ice to a small, heated shack that prevented a hole in the ice from refreezing. The problem was the period in between, when the ice was still present but was too rotten to be trustworthy. Under those conditions, use of the heated hose was a tricky operation involving constant surveillance and frequent changes of location. Since this situation exists for nearly half the austral summer, U.S. Naval Construction Battalion Unit (NCBU) 201 designed another system in an attempt to solve the problem permanently.

(U.S. Navy Photo)

Figure 1. Rafts for saltwater intake were damaged by rough seas.

The permanent intake system was constructed during *Deep Freeze* 67. The main component is a jetty—built of 15,000 cubic yards of native fill—that extends 110 feet into McMurdo Sound (Fig. 2). For ease of maintenance access, the top surface is 20 feet wide. Before the tip of the jetty was built, a T-shaped intake pipe (made of welded sections of 36-inch-diameter culvert pipe) was set in place 100 feet from the pump house.[2] The two inlets to the T are 20 feet below the jetty surface—well under the freeze line—and a small shack was built above the intake pipe. Warm air from an electrical heater (or from a standby oil-burning unit that is used when the PM-3A reactor is shut down) is blown into the culvert opening to keep it ice-free. A length of



(U.S. Navy Photo)

Figure 2. Pump house, heated pipe, and intake house on new jetty.

[1] Formerly Officer-in-Charge, NCBU 201.

[2] *Antarctic Journal,* vol. II, no. 4., p. 138.

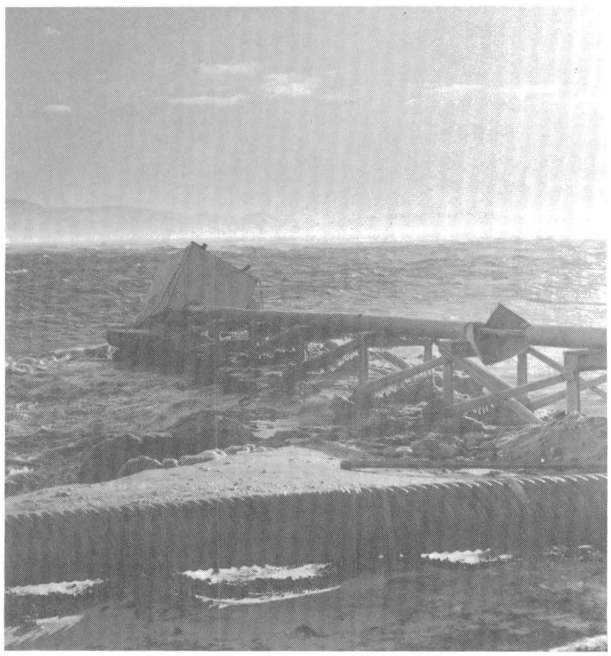
heated hose, suspended in the culvert opening, is connected to the pump house at the foot of the jetty with heated copper pipe set on wooden cribbing. (The pump house is a small, heated Robertson building, erected during *Deep Freeze* 64, that houses two 150-gallon-per-minute pumps.)

Operationally, the new system proved highly successful, but a storm in early March drove heavy swells over the jetty, washing away sections of the pipe and cribbing and damaging the intake house (Fig. 3). The jetty and culvert, however, remained intact and were repaired by the wintering-over party. Although the exposed pipe and intake house will require additional protection from severe wave action, the present intake system is basically of sound design.

Distillation Plant

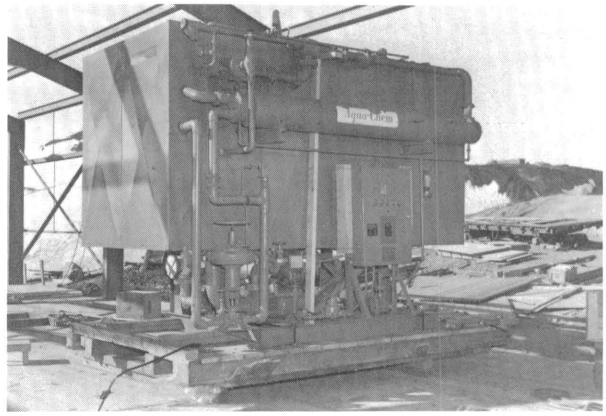
From the pump house, seawater is lifted nearly 300 feet to a 55,000-gallon storage tank at the water-distillation plant. The flow to the tank is continuous while the distillation unit is operating. (A float switch automatically stops the pump when the tank is filled.) Seawater from the storage tank goes through the Aqua-Chem distillation unit (Fig. 4), which produces approximately 1 gallon of fresh water from 10 gallons of salt water.

The Aqua-Chem distillation unit is a multistage flash evaporator. Seawater that has been preheated to 170°F. is successively passed through 16 stages. In each stage, it is subjected to a high vacuum, causing flash vaporization of a portion of the water.



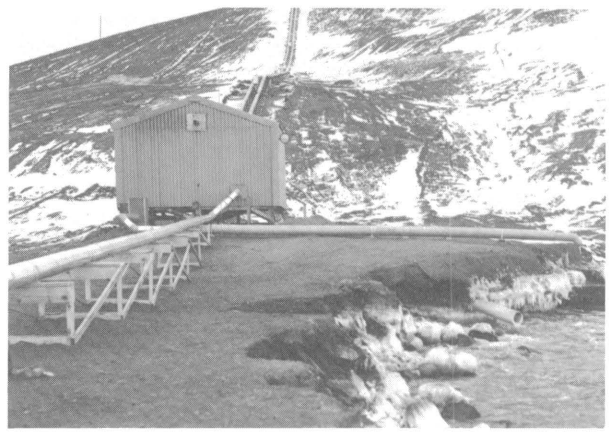
(U.S. Navy Photo)

Figure 3. Storm-whipped waters battering pipe and intake house in March 1967.



(U.S. Navy Photo)

Figure 4. Distillation unit being placed in building.



(U.S. Navy Photo)

Figure 5. Intake line (left), supply and return lines between pump house and plant, and brine discharge pipe (right).

(The vacuum is steadily increased to compensate for the heat lost during evaporation in the preceding stage.) The vapor is condensed on baffles and the condensate, which has a salinity of approximately one part per million, is drawn off as fresh water at approximately 70°F. The concentrated brine is returned down the hill to a point near the pump house (Fig. 5).

A system of piping crossovers allows the distillation unit to be powered with steam from either the PM-3A or a standby oil-fired boiler. The boiler installed during *Deep Freeze* 64 for test purposes was replaced the following season by a Cleaver-Brooks boiler which produces enough steam to accommodate two distillation units as well as that needed to heat the water-distillation building.[3] To completely preclude the possibility of radioactive con-

[3] The boiler's steam output is actually sufficient to heat the entire PM-3A complex, but such use is not presently contemplated.

tamination, a separate reboiler was installed during *Deep Freeze* 66 (and the following winter) to provide "nuclear steam" to the distillation plant: the steam indirectly produced by the superheated water from the reactor is passed through the reboiler to produce the steam that boils the seawater in the water-distillation unit (Fig. 6). Thus there are three closed loops involved in transferring energy from the reactor core to the distillation unit, and all of them would have to leak simultaneously to cause contamination of the fresh water produced.

The distillation plant has worked quite well. In fact, the most significant problem encountered in its operation was caused by failures in the distribution system. When shut down because of such a failure, the distillation unit dries out, making the task of returning it to operational status extremely difficult.

(Photo: S. J. Verlautz)

Figure 7. Electrical heating tape keeps flanged pipes from freezing.

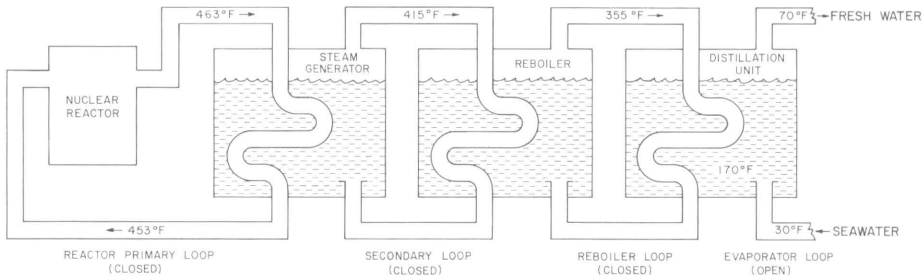


Figure 6. Schematic representation of energy-transfer process. Before entering unit (right), seawater is heated slightly when used to condense vapor and then is brought to 170° F. with steam previously used in air-ejector to create vacuum. (NNPU Drawing)

For that reason, trucking water to the station when the distribution system fails is an advantage to both the plant's operators and the consumers of the water.

Distribution System

As originally installed, the freshwater distribution system consisted of Ric-Wil heated pipe. The system failed early in its operation and was rebuilt during *Deep Freeze* 66, at which time its layout was also altered significantly to correspond to the long-term plan for station development, and construction of a sanitary sewer system was started. (Additional work on both the distribution and the sewage systems during *Deep Freeze* 67 has made flush toilets a reality at McMurdo.)

Fresh water, salt water, effluent brine, and sewage are now transported through flanged copper pipe that is elevated above the ground on timber cribbing. Electro-Wrap tape was placed along the pipe (Fig. 7) before it was covered with insulation and encased in either steel or aluminum (Fig. 8). The heat tape, which operates at 88 volts and is rated at 24 watts per foot, is regulated by thermostats that control 100-foot sections of the systems. The thermostats, associated transformers, and circuit breakers are housed in galvanized steel cabinets.

(U.S. Navy Photo)

Figure 8. Pipe is covered with insulation and jacketed in metal.

The present safeguards against freezing are considered satisfactory, but other problems—principally excessive water pressure—still create operational difficulties. Because the distillation plant is some 300 feet above the main part of the station, considerable pressure is created within the lower portion of the distribution system. During *Deep Freeze* 67, NCBU 201 installed a pressure-reducing station to control the line pressure in the distribution system; the variety of building elevations being served,

however, makes the settings at the station critical. During the same season, an accumulator was installed at the pressure-reducing station in a further effort to eliminate water hammer, which causes minor leaks and, by damaging the heat tape, leads to isolated freezing in the system.[4]

Production per Person

While a great improvement, the new water-production system will not make water abundant at McMurdo Station. At maximum daily capacity, it can provide 72 gallons of water for each of 200 people—which is roughly the population this winter. In summer, when the average population increases to over 700, the daily ration amounts to less than 20 gallons per person.[5] The installation of a second distillation unit, planned for the near future, will help to assure continuous operation and will increase the daily production capability. Combined with increased experience in operating the present facility, this should assure McMurdo Station of a continuous and—for the Antarctic—relatively plentiful supply of good, fresh water.

Second Winter Flight Successful

An LC-130 Hercules made the second scheduled winter flight to Antarctica on September 2 to bring two scientists and a Navy officer, as well as mail and provisions, to McMurdo Station. The two scientists, Dr. Robert E. Benoit and Mr. Ruff Lowman, both of Virginia Polytechnic Institute, will conduct studies of microorganisms in the volcanic soils of Taylor Valley in the Royal Society Range. The Navy officer was Captain H. A. Kelley, the commanding officer of Antarctic Support Activities, Davisville, Rhode Island, who made a brief inspection of the station.

Returning aboard the aircraft were Captain Kelley, a scientific party of three men headed by Dr. Jacques S. Zaneveld of Old Dominion College, Norfolk, Virginia, and two injured members of VX-6: Lt. Brian H. Shoemaker and AZ2 Joseph Musser.

The first scheduled winter flight to Antarctica took place on June 18, 1967 (cf. *Antarctic Journal*, vol. II, no. 3, p. 81, and no. 4, p. 153).

[4] Water hammer (the concussion produced in an airtight water vessel upon a sudden stoppage or start of flow) was a problem in the intake pipes, too, and a series of accumulators was installed in the saltwater pump house.

[5] General engineering practice in the United States is to provide 150 gallons of water per person per day.

The Use of Weather Satellites in Antarctica

RALPH W. SALLEE
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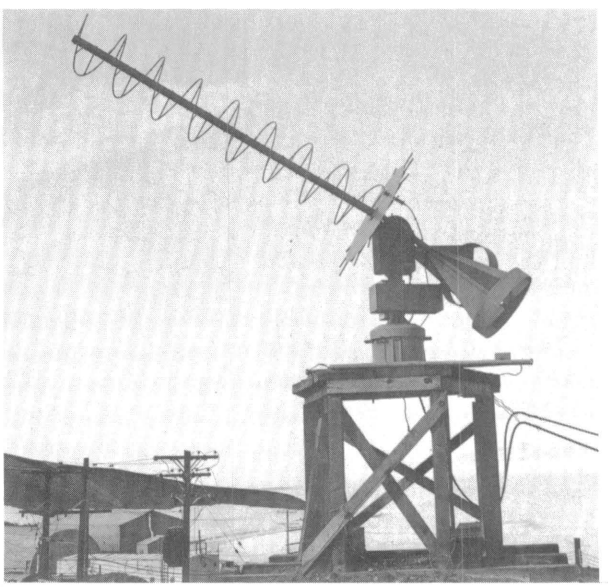
In 1965, *Operation Deep Freeze* was furnished two Fairchild-Stratos Automatic Picture Transmission (APT) receivers. These early-model receivers were installed at opposite ends of the 2,500-mile track followed by *Deep Freeze* aircraft and ships between New Zealand and Antarctica—one at the Naval Support Force's advance headquarters in Christchurch, New Zealand, and the other at McMurdo Station, Antarctica (Fig. 1).

These two ground stations were of little use during the remainder of the *Deep Freeze* 66 season and the subsequent austral winter. Not until *Deep Freeze* 67, when the extremely successful ESSA II and IV and Nimbus II satellites were in orbit, was full and productive utilization of the stations achieved. During the 1966 austral winter, New Zealand meteorologists placed the Christchurch ground station in operation and maintained it until they were relieved in September by Navy personnel. As sunlight returned to Antarctica, the equipment at McMurdo Station also became operational. Since the operation of the APT station at



(U.S. Navy Photo)
Figure 1. APT antenna at McMurdo Station.

Christchurch is similar to that of other mid-latitude ground stations, the remainder of this article will deal mostly with the use of the McMurdo facility, which is rather unique.

Area Covered

Because of its relative proximity to the South Pole, the McMurdo APT station is capable of tracking a portion of all the orbits of a satellite in a polar or semipolar orbit. The principal restricting factor is sunlight coverage: a maximum area is illuminated in late December and a minimum area in late June. During most of the *Deep Freeze* 67 operating season (early October 1966 to late February 1967), photographic coverage from about six or seven Nimbus II orbits was received each day at McMurdo. The orbits numbered 1 through 7 in Fig. 2 provided fairly good coverage during the six-hour periods on either side of local noon. (Fig. 3 shows the approximate area covered by each Nimbus II picture during a typical orbit over or nearly over the Ross Sea.) Orbits 8 through 13 provide considerably fewer pictures to McMurdo—as few as one in the case of orbits over Enderby Land and Queen Maud Land, on the opposite side of the Continent from McMurdo Station. Despite the fact that definition and signal strength are quite poor due to low antenna angles at the greater distances, it is still significant that the McMurdo APT facility can acquire pictures of the complete coastline of Antarctica. While the combination of sun angles and low antenna angles keeps the large and rather featureless plateau region of East Antarctica out of usable view, it is possible that another Nimbus satellite in an orbit precisely opposite to that of Nimbus II will expose this little-known expanse to daily observation.

An Aid to Photomapping

One of the main reasons for the success of the *Deep Freeze* 67 aerial photography program, in which more photography was obtained than in any previous season,[1] was the use made of weather-satellite information. Meteorological information furnished by the National Environmental Satellite Center through the Navy's *Project Famos* contributed greatly to the photographing of Palmer Land and Alexander Island by a C-121J based at Punta Arenas, Chile. Guided by forecasts based on *Famos* information, this aircraft photographed more of its assigned area than had been expected. At the same time, APT data from McMurdo were used to forecast for the flights of an LC-130F photo aircraft which operated from Byrd and McMurdo Stations to map Marie Byrd Land and Ellsworth Land in West Antarctica.[2]

Using APT information to brief flight crews for photomapping missions involves determining the cloud coverage over ice- and snow-clad areas. Snow and clouds possess approximately the same albedo, so the images formed from their reflected light in the satellite's camera are nearly identical in tone. Therefore, something other than these images must be analyzed to distinguish between clouds and snow masses. Cloud shadows have proved to be an extremely effective answer to this problem, and when one has learned to recognize certain unique mountain shadows, the combination of cloud shadows and known landmarks can be analyzed to produce a fairly accurate concept of the cloud systems over a given snow-covered area. The Sentinel Range, the Transantarctic Mountains, and other elevated features, as well as several known coastal polynyas and ice tongues, are all helpful references.

To obtain maximum cloud- and mountain-shadow effects, however, it is necessary to use APT pictures that have been taken at an extremely low sun angle. Just as the setting sun casts long shadows, so also does a low sun angle produce the maximum shadow for satellite photography. In each orbit of Nimbus II, no matter in what quadrant from McMurdo, the initial picture is taken as the satellite comes over the horizon from the dark hemisphere to the lighted side of the Earth. This provides the lowest sun angle and the maximum cloud definition. Subsequent pictures, taken as the satellite heads toward the sun and encounters increasing sun angles, have decreasing definition. While the last pictures have absolutely no detail over snow masses, they do give excellent resolution of the oceanic areas as the satellite passes northward away from the Continent. From the tables contained in *Daylighter,* a publication of the Navy Weather Research Facility, it has been approximated that sun angles of less than 15° give maximum shadow and resolution, angles of 20°-25° provide fair shadow, and angles greater than 30° result in total, uninformative whiteness over snow-covered areas.

Satellites in Ice Reconnaissance

The main features of the ice pack about the periphery of Antarctica may be determined from APT pictures. Overall concentration, *i.e.,* the percentage of water area covered by ice, is readily apparent. During the *Deep Freeze* 67 operating sea-

[1] *Antarctic Journal,* vol. II, no. 4., p. 135.

[2] The Balleny Islands, where photomapping efforts have been thwarted by weather for seven years, also fell to the APT/LC-130F team.

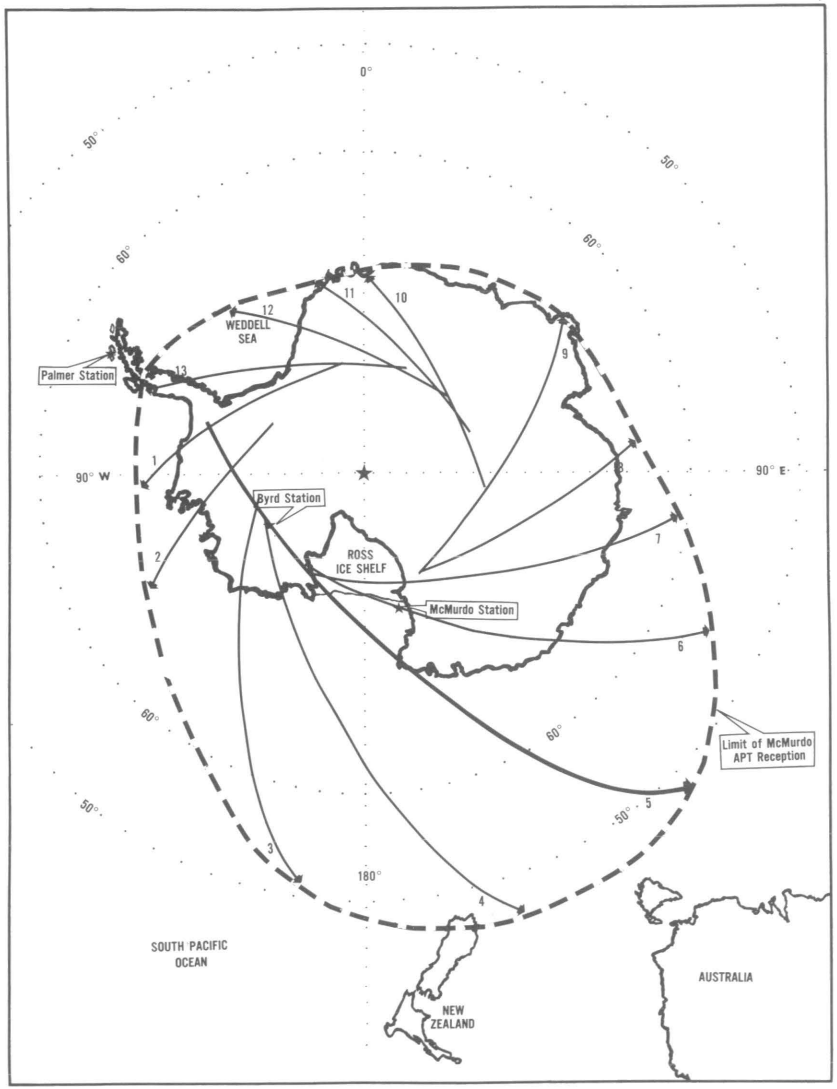


Figure 2. In a 24-hour period, Nimbus II passes over Antarctica 13 times. Photographs from orbits 1 through 7 are normally received by the McMurdo APT station, which can also acquire orbits 8-13 (within the limits shown), but seldom does.

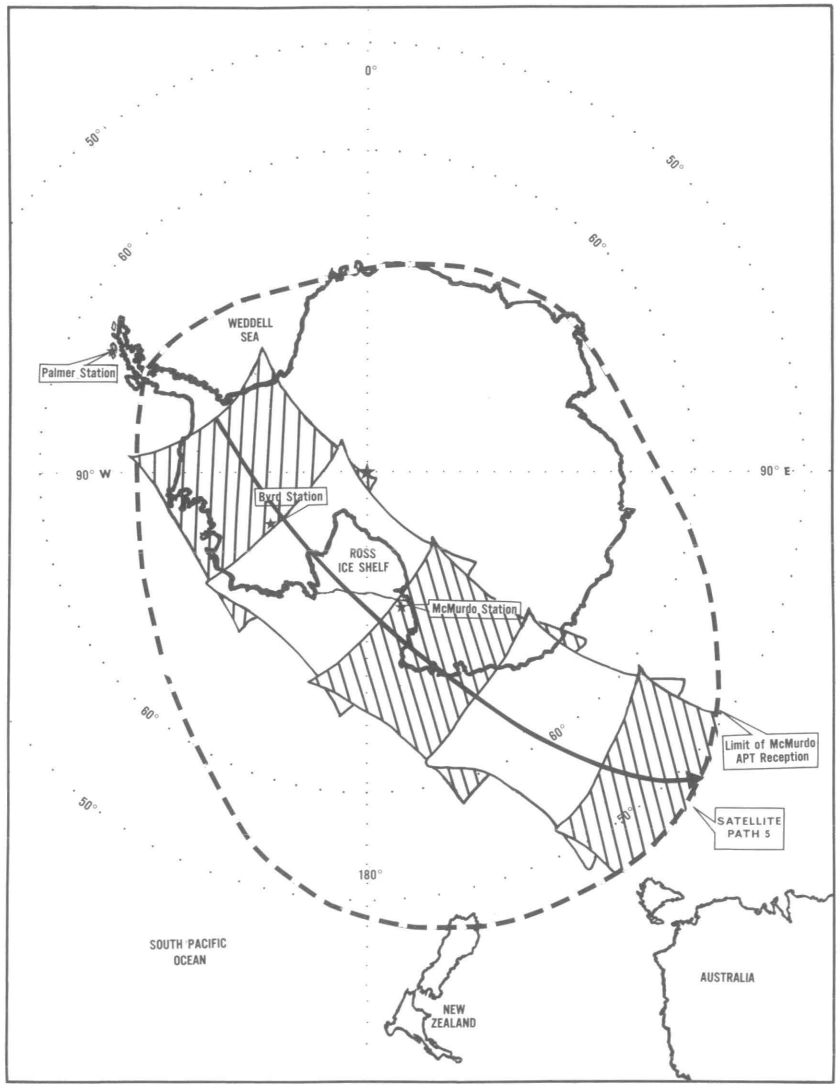


Figure 3. Approximate areal coverage of each picture taken during a typical orbit over the Ross Sea (orbit 5 in Fig. 2). Successive pictures have a 30-40 percent overlap.

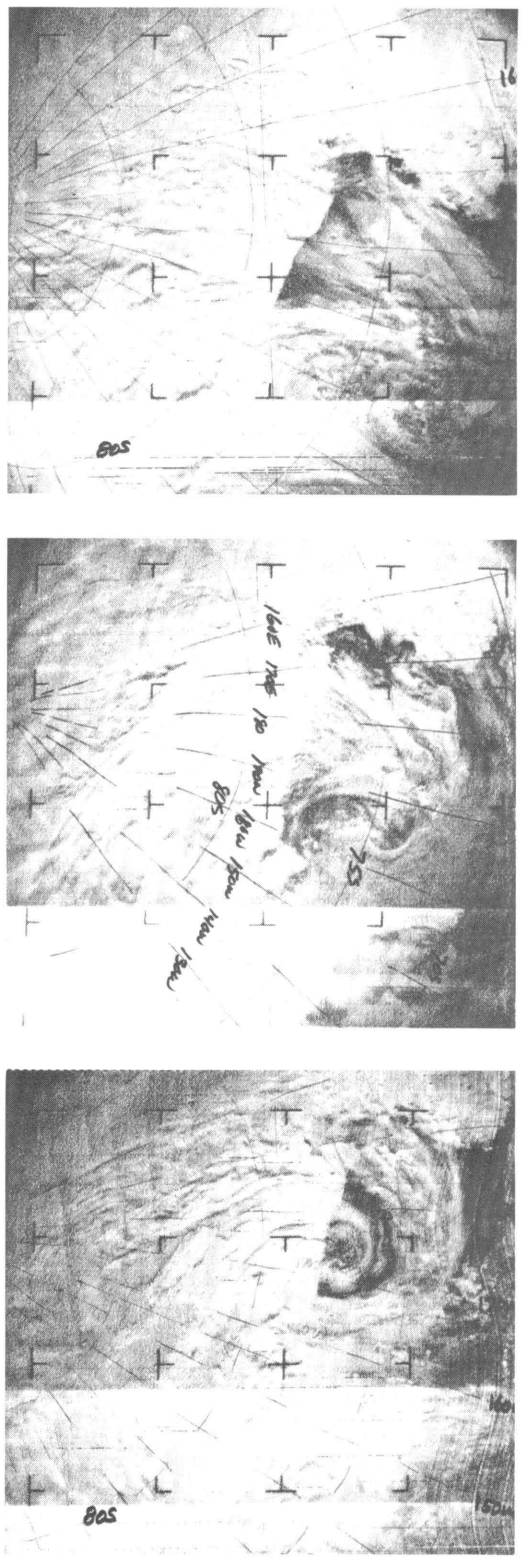
son, the Naval Oceanographic Office's ice forecasters made considerable use of APT information, and the brief prepared for USCGC *Eastwind*'s survey of East Antarctica was based almost exclusively upon APT data. Smaller features, such as size of floes and depth of ice, are not so easily identified. Further study along this line will no doubt produce improved methods.

Due to the excellent contrast between the ice and the surrounding water, a high sun angle is acceptable for ice reconnaissance—possibly even desirable. The problem in analyzing photographs of the ice pack is to distinguish ice from cloud systems, which have almost the same albedo. Careful study of the area of interest over several days or weeks can provide the solution. Cloud systems, understandably enough, are less persistent and tend to change from day to day—sometimes from picture to picture—whereas the pack ice, though changing with the season, is more permanent. Strong storms passing over an ice pack have been noticed to cause shifting or deformation of the ice field. All these changes may be detected only by detailed study over a period of time.

Weather Forecasting

In November 1966, the APT operator at McMurdo Station noticed a small but distinct cloud formation moving across the Ross Ice Shelf toward McMurdo Station. Analysis indicated that the formation might be one of the minute Ross Sea cyclones that sometimes strike the area. A storm condition was announced, and all airplanes and helicopters were ordered back to base. Six hours after the warning was issued, the storm hit with the fury of a small hurricane. It was fortunate that this particular storm had approached McMurdo Station at a time when it was under Nimbus II surveillance. Had the storm arrived 12 hours earlier or later, Nimbus II would have been over East Antarctica and the cyclone would have arrived unannounced. Such an event suggests that placing a second Nimbus in opposite cycle may be beneficial.

Fig. 4 is a sequence of Nimbus II photographs of a storm that hit McMurdo in early February 1967. The pictures show the storm forming over the northeastern Ross Sea and gaining strength as it moves steadily toward and then across the Ross Ice Shelf in the direction of McMurdo Station. Weathermen subsequently tracked the storm into the Ross Sea area, where it dissipated north of McMurdo Station. The tracking of this storm is particularly significant because it occurred at a time when most antarctic communications were blacked out. The



(U.S. Navy Photos)

Figure 4. Nimbus II pictures show the development and movement of a February 1967 storm that passed over McMurdo Station during a communications blackout.

APT system, however, continued to function as designed and for several days was McMurdo Station's only source of weather data, other than local observations. During this period, surface and 700-millibar analyses were continued, using only APT data and local observations. Following the return of normal communications and the resumption of conventional weather reporting, the analyses that had been based on the APT data were verified as essentially correct.

Photographic identification of the jet stream and other systems along and approaching the flight track between Christchurch and McMurdo has assisted forecasting for this route. Further study of the appearance of these systems in APT photographs will no doubt greatly improve the accuracy of flight forecasts and may, in time, even negate the meteorological requirement for stationing a vessel beneath this air route.

Further Development

With only one season's experience in the use of APT data, we must be wary of making strong recommendations, even though initial successes seem so evident. Some recommendations, however, deserve consideration:

First, there is a need for recorders that will render the full resolution of the pictures obtained by satellite cameras and transmitted to the ground station. The Fairchild-Stratos recorders in current use are prototypes which subsequent experience and research must necessarily improve.

There is also a need to develop a portable APT receiver that can easily be deployed to remote areas or placed aboard ship to support operations at some distance from a regular APT ground station.

As mentioned earlier, it would be beneficial to place Nimbus satellites—which are superior because of both their lower orbital altitude and their coding system—in opposing orbits so that a given area will be under identical surveillance every 12 hours rather than every 24 hours.

In order to derive some objective rules for analyzing satellite ice-reconnaissance photography, it will be necessary to compare all of the *Deep Freeze* 67 APT data and other environmental-satellite data with that obtained during the corresponding period by aerial ice reconnaissance, icebreaker observation, and aerial photography of coastal areas (Palmer Land, Alexander Island, the eastern Ross Sea, the Balleny Islands, etc.).

A study should also be made of the jet stream, troughs, ridges, and other systems at the 300-millibar level. This will aid flight forecasting for the relatively hazardous 2,500-mile route between Christchurch and McMurdo Station.

Operational History of the McMurdo Station Water-Distillation Plant

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Naval Nuclear Power Unit
Fort Belvoir, Virginia

The water-distillation plant at McMurdo Station is currently in its first winter of continuous operation. Installation of the plant and the majority of its associated equipment was completed during *Deep Freeze* 64.* In February 1964, initial operational tests were conducted using a temporary oil-fired boiler as the steam source. During these tests, the saltwater-intake system froze, and difficulties were encountered in adjusting and operating the distillation unit. As the equipment necessary to correct those difficulties could not be received prior to the next austral summer, it was decided, in early March 1964, that no further attempt would be made to operate the system during the 1964 austral winter, and the unit was drained and the equipment placed in storage.

Early in *Deep Freeze* 65, a new oil-fired boiler, which had arrived at McMurdo Station at the end of the preceding season, replaced the temporary boiler that had been used for the initial testing. The distillation unit was operated on a test basis throughout the 1964-1965 summer season, and it produced a small quantity of water for use by McMurdo Station's personnel. Problems with the distribution system, however, required that the unit again be deactivated for the austral winter.

Reactivated for *Deep Freeze* 66, the plant started producing potable water early in 1966, again using the oil-fired boiler. On February 19, a test was begun in which "nuclear steam" obtained directly from the PM-3A's secondary system was used as the heat source for the evaporator. The 4,000 gallons of fresh water produced during this test constituted the first water production by a desalination plant using "nuclear steam" from a shore-based reactor. The test was terminated and the plant shut down when freezing of the seawater-intake and freshwater-distribution systems recurred. The plant remained shut down throughout the 1966 austral winter, during which a major modification was made.

* See accompanying article by Lt. Whitmer.

The modification consisted of installing a reboiler in the PM-3A Secondary Building to allow continuous operation of the distillation unit with nuclear power. The PM-3A crew completed this task just prior to the start of *Deep Freeze* 67. During the past austral summer, a major overhaul of the water-distillation plant itself was completed, including cleaning and reconditioning the freshwater- and saltwater-storage tanks. The plant was then ready for operation, and in December 1966, by agreement with the Commander, Antarctic Support Activities, responsibility for the operation and maintenance of the water-distillation plant (exclusive of the seawater and water-distribution systems) was transferred to PM-3A's personnel.

On December 29, 1966, the plant started supplying potable water to McMurdo Station. This operation used the Cleaver-Brooks auxiliary boiler. Two weeks later, on January 16, 1967, regular production was begun with nuclear-generated steam obtained via the reboiler. Coupled with the modifications to the intake and distribution systems accomplished by NCBU 201, use of the reboiler has allowed successful operation of the water-distillation plant since January. On May 14, the plant produced its millionth gallon of fresh water, and on July 3, the millionth gallon from nuclear energy.

On May 9, 1967, a permanent agreement was executed between the Commander, Antarctic Support Activities and the Officer-in-Charge, Naval Nuclear Power Unit, providing for operation, maintenance, logistic support, repair, and modification of the water-distillation plant by NNPU.

This winter's success indicates the feasibility of year-round operation, and the addition of a second distillation unit, scheduled for *Deep Freeze* 68, should increase the reliability of the water-distillation plant and allow PM-3A to better serve McMurdo Station's personnel.

Summary of Research at U.S. Antarctic Stations During June and July 1967

Byrd Station

All operations were routine in Stanford University's ultra-, extremely-, and very-low-frequency (ULF, ELF, and VLF) programs, except from June 16 to July 18, when synoptic VLF recordings were made for only one minute per hour. Chart and magnetic-tape recordings of micropulsations, magnetic-field intensity, ELF signals, and ionospheric opacity were maintained. Continuous chart recordings of the phase and amplitude of VLF stations NSS, NBA, and NPG were obtained during June. In July, a VLF receiver was tuned to station NPM at 23.4 kHz and phase-tracking carried out. In addition, Alouette-satellite passes were tracked and recorded.

The second successful first-orbit acquisition after as many satellite launches was achieved at 1449 hours on July 28, just 29 minutes after POGO-D was fired from Vandenberg Air Force Base in California. Special-purpose telemetry signals were received during the first few passes, and telemetry signals from the satellite's VLF receiver were recorded beginning on the second day after the launch.

The observer from the Institute for Telecommunications Sciences and Aeronomy (ITSA) of the Environmental Science Services Administration (ESSA) continued to make ionospheric and spectrophotometric measurements for ITSA, forward-scatter recordings for the Bartol Research Foundation, and all-sky auroral observations for the National Research Council of Canada.

Only minor activity was recorded in ITSA's conjugate-point program. The maximum absorption recorded by the riometers was 17.7 db on June 7. Auroral displays, though strong, were usually colorless. Micropulsation activity dropped off considerably toward the end of June.

Four good and four partial 24-hour records of hydrogen emission were acquired in June as part of the University of Colorado's auroral program. The hydrogen either appeared suddenly over the entire sky or it moved toward and reached the zenith as soon as three hours after its first appearance. Because of the diffuse nature of the hydrogen and the 30-minute exposure time of the observing instrument, the borders of the hydrogen bodies were difficult to delineate.

The U.S. Weather Bureau, ESSA, reported a maximum temperature of −16.7°C. and a minimum of −57.2°C. during the two-month period. The averages were −32°C. in June and −38.3°C. in July. Only a trace of snowfall was recorded. Clear skies during the middle of June permitted the first good ozone measurements to be made at Byrd this

winter. Reduced sensitivity of the spectrophotometer prevented making reliable ozone observations in July.

Stanford University's work at Byrd substation was resumed from June 15 to 30, with VLF transmissions at 88-kw peak power and frequency-shift keying at 1 cps between 12 and 14 kHz from 1000-1200 UT. Whistler-mode signals from the station were successfully received in Suffield, England. Beginning on June 16, tapes were run continuously at 7.5 ips throughout the remainder of the two-month period. The quality of the recordings was excellent.

On June 26, VLF antenna-impedance measurements made by the University of Washington at Byrd substation verified the probable existence of breaks in both the 10- and 21-mile antennas. In late July, repairs were made on three breaks in the 10-mile antenna and two in the 21-mile antenna. The *D*-region sounding, whistler, and Schumann-resonance experiments progressed satisfactorily.

Operations were normal in the U.S. Coast and Geodetic Survey's seismology and geomagnetism programs.

McMurdo Station

On June 22, the first scheduled winter flight ever made to Antarctica brought to McMurdo scientific parties from Old Dominion College and the University of Miami to conduct studies of algae and protozoans in and under the pack ice.

A major storm and unusually warm temperatures toward the end of June thwarted attempts to move the Old Dominion College group to Cape Royds for a three-week stay. A trial trip was made there on July 23, and plans were formed to move the party a week later.

During an experimental dive near Hut Point, the same invertebrates and diatoms were found as had been collected in previous summers. The first algae specimen (a juvenile form of *Iridaea obovata*) was found on July 14, and other algal fragments were collected on subsequent dives. As was the case in summer, the distribution of algae was found to be very patchy.

The group from the University of Miami made eight dives of 10- to 40-minutes duration at Hut Point to test gear, erect a sub-ice platform, collect water and ice samples, and measure the pH and the salinity, oxygen, phosphate, nitrite-nitrate, and carbon content of the water and ice. Cell counts and pigment analyses were made also. Phytoplankton were cultured, but no growth of these organisms was noticed.

The cosmic ray program of the Bartol Research Foundation was hampered by a severe storm during June 23-July 1 that short-circuited the power cables to the building and toppled the broadside-array antenna. Micropulsation activity was observed on the ITSA equipment on June 29 and 30.

About 18 aurora-type absorption events were recorded during June and July on the 30- and 50-mHz riometers, the magnetometers, and (at the 3914A and 5577A lines) the photometers of the Douglas Aircraft Co. The maximum absorption was recorded on July 29 at 0438.

Palmer Station

During 9 of the last 10 days of June, the temperature rose to above freezing, and on occasions streams of meltwater were observed. Young ice formed in Arthur Harbor in early June, but during the remainder of the month local waters were generally open. Ice began forming again in the harbor on July 3, and by the 14th it was strong enough to support human travel. The ice disappeared again by the 31st, however, when only a small amount of brash was visible.

The Virginia Institute of Marine Science's biology program was carried forward with the collection in June of two specimens of *Notothenia coriiceps* and laboratory studies of the parasites of these and some of the 185 specimens collected previously. During July, inclement weather prevented biological collecting on all but six days, when 50 fish were caught. These included 43 specimens of *N. coriiceps,* 4 *N. nudifrons,* 1 *N. gibberifrons,* and 2 *Trematomus bernacchii.* Epidermal examinations revealed the presence of 164 trematodes and 24 copepods.

Wildlife was abundant at intervals during July. Adélie penguins, a lone gentoo, sheathbills, black-backed gulls, and many giant fulmars were seen, and snow petrels and cormorants were common when the harbor was open. Leopard and Weddell seals and one elephant seal were also observed.

Ohio State University's glaciologists continued their studies of the percolation of meltwater in firn. Extensive percolation was observed late in June, with a net low occurring 1.5 m below the surface at the highest station on June 28th.

On the few days that were suitable for travel in July, the snow-accumulation stakes were inspected and found to be in good condition, accumulation on the ramp was measured, and the percolation experiment resumed. A severe storm on July 20-21 deposited as much as 10 cm of hard ice on one bamboo accumulation stake at an altitude of 250 m and broke other stakes.

South Pole

With the exception of a slight decrease on June 5 and 28, normal low cosmic-radiation activity was recorded during June and July by the instruments of the Bartol Research Foundation. The forward-scatter program, also managed by the Foundation, was conducted for only about eight hours each day in June because of a breakdown in the equipment. Although repairs were completed by July, operations were suspended a part of each day during that month because of a time-sharing arrangement with the operators of transmitters at Byrd Station.

The auroral observations conducted by the ITSA observer proceeded routinely, except for periods during which intermittent problems were experienced with the shutter mechanism of the three all-sky cameras. There were mechanical problems also with equipment used by ITSA in ionospheric and micropulsation studies.

Seismological recordings by ESSA's Coast and Geodetic Survey were made satisfactorily throughout June and the first few days of July, with events being observed on June 12, 14, and 17 and July 1. On July 4, an oil heater was overturned, causing a fire that damaged some of the equipment. The fire was extinguished quickly, but 11 days were required to clean and repair the damaged components and put the equipment back in operation.

Geomagnetic observations were normal until July 14, when the visual monitor failed.

The second phase of the University of Oklahoma's sleep study was begun in June and completed in July. Slow-wave sleep stages (stages 2-3) were observed at brief intervals in two individuals. The sleep stages of all other persons monitored were the same or slightly lighter than during the first phase of the winter study.

A failure on June 23 in the digital system of the earth-tide program of the University of California (Los Angeles) interrupted that program temporarily. A progress report on the program for July was not available at the time this review was written.

Observations in the Weather Bureau's meteorological program were, in general, normal.

Plateau Station

A report on activities at Plateau Station had not been received as this issue of the *Antarctic Journal* went to press.

Notes

Louis O. Quam Appointed Chief Scientist Office of Antarctic Programs

Dr. Louis O. Quam, former Director of the Earth Sciences Division of the Office of Naval Research, has been appointed Chief Scientist of the Office of Antarctic Programs, Division of Environmental Sciences (DES), at the National Science Foundation. He succeeds Dr. A. P. Crary, now Deputy Director of DES.

Dr. Quam, who had been with ONR since 1950, also served as Head, Geography Branch. Prior to joining ONR, he was Associate Professor of Geography at the University of Virginia.

Experienced in arctic research and formerly in charge of the Navy's scientific program for that region, Dr. Quam will be responsible for planning and developing long-range scientific programs for the Antarctic.

He received a B.A. in 1931 and M.S. in 1932, both from the University of Colorado, and his Ph.D. in 1938 from Clark University. He is a member of several scientific organizations, including the Association of American Geographers (of which he is a past president), the Geological Society of America, and the American Geophysical Union. Dr. Quam is currently Vice President of the American Association for the Advancement of Science and Chairman of the AAAS Geology-Geography Section.

New Publications

Two publications of special interest to the antarctic community appeared in August: Folio 6 in the *Antarctic Map Folio Series* and a complete translation of the text and legend matter of the Soviet *Atlas of Antarctica.*

Folio 6, by Arnold L. Gordon of Lamont Geological Observatory of Columbia University, is entitled *Structure of Antarctic Waters Between 20°W. and 170°W.* It is for sale at $6.00 a copy from the American Geographical Society, Broadway at 156th Street, New York, New York 10032.

The translation of *Atlas of Antarctica* was published as the May-June issue of the American Geographical Society's *Soviet Geography: Review and Translation.* The 246-page issue is available at $1.50 a copy from AGS.

The preparation of both of these publications is supported by the National Science Foundation.

Eltanin Enters Drydock

After voyaging 184,000 miles and completing 29 cruises over a period of five years, the antarctic research ship *Eltanin* arrived at San Francisco on September 21 for her first visit to a U.S. port since she left New York in 1962. The ship, which is supported by the National Science Foundation, is scheduled to remain in the shipyard for two months, during which she will be renovated inside and out and provided with improved scientific facilities.

Between her brief appearances in ports such as Valparaiso and Punta Arenas, Chile, and Wellington, New Zealand, *Eltanin* has spent 1,526 days, or 77 percent of her time, at sea since 1962. Her scientific complement, which ranges between about 30 and 40 per cruise, has conducted research in marine biology, physical and chemical oceanography, marine geology, geophysics, upper atmosphere physics, meteorology, ornithology, and other disciplines. Most of this research has been carried out in the high latitudes of the South Pacific Ocean. The scientists have come from nearly 20 United States universities, nonprofit research organizations, and Government agencies. In addition, scientists of 10 other countries have been accommodated aboard the ship, conducting projects of their own or participating in the work of U.S. institutions.

Upon completion of her yard period, *Eltanin* will work principally in the high latitudes of the Indian Ocean for the next few years.

Grant Awarded for Design of Automatic Antarctic Station

The National Science Foundation has awarded a grant to Stanford University for a systems-design analysis for an unmanned, automatic geophysical observatory for use in Antarctica. The objective of the project will be to study the design and determine the feasibility of a small, remote-sensing station that would collect upper atmosphere and other geophysical data continuously throughout the year. Once established, the station would have to be inspected and maintained only once annually, during the austral summer. The station would be powered by a radioisotopic butane or similar thermoelectric source, and the data collected would be transmitted to the United States via satellite links. Such a station, which would not have been feasible 10 years ago, is now a practical consideration in the U.S. Antarctic Research Program because of recent advances in the aerospace and electronic industries and in isotopic-power development.

Coinvestigators in the Stanford project are R. A. Helliwell and Bruce B. Lusignan, electrical engineering professors, Peter Z. Bulkeley, professor in the Mechanical Engineering Design Division. Mr. John Katsufrakis, Research Associate in the Radioscience Laboratory, and two doctoral candidates, Messrs. Jon Jenny and William Lapson, are also involved in the study.

It is expected that unmanned stations would collect information on ionospheric parameters, cosmic radiation, geomagnetism, and very-low-frequency energy transmission on a programmed basis, and, at the same time, record weather information, including micrometeorological and snow-temperature data, in the vicinity of the station. As a protection against severe weather, it is planned to have many of the sensing devices buried in the snow.

Preliminary studies reveal that an unmanned station could be established with from six to eight flights by LC-130 aircraft. A system of such stations could extend data-collection capabilities in Antarctica without materially increasing logistic air support over the present levels.

The design studies will be completed early in 1968.

Translations in Preparation

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

Academy of Sciences of the U.S.S.R. Interdepartmental Commission on Antarctic Research. Antarctica: Commission Reports, 1964. Moscow, izd-vo "Nauka," 1965. 172 p.

Academy of Sciences of the U.S.S.R. Interdepartmental Commission on Antarctic Research. Antarctica: Commission Reports, 1965. Moscow, izd-vo "Nauka," 1966. 167 p.

Dubrovin, L. I. *and* V. N. Petrov. Scientific Stations in Antarctica, 1882-1963. Leningrad, Gidrometeorologicheskoe izd-vo, 1967. 281 p.

Biological Symposium Planned

The Second Antarctic Biological Symposium under the auspices of the Scientific Committee on Antarctic Research is planned for July 1968. The National Science Foundation will shortly circulate to USARP grantees details on the proposed program.

PUBLISHED BY THE NATIONAL SCIENCE FOUNDATION
WITH THE ASSISTANCE OF THE DEPARTMENT OF DEFENSE