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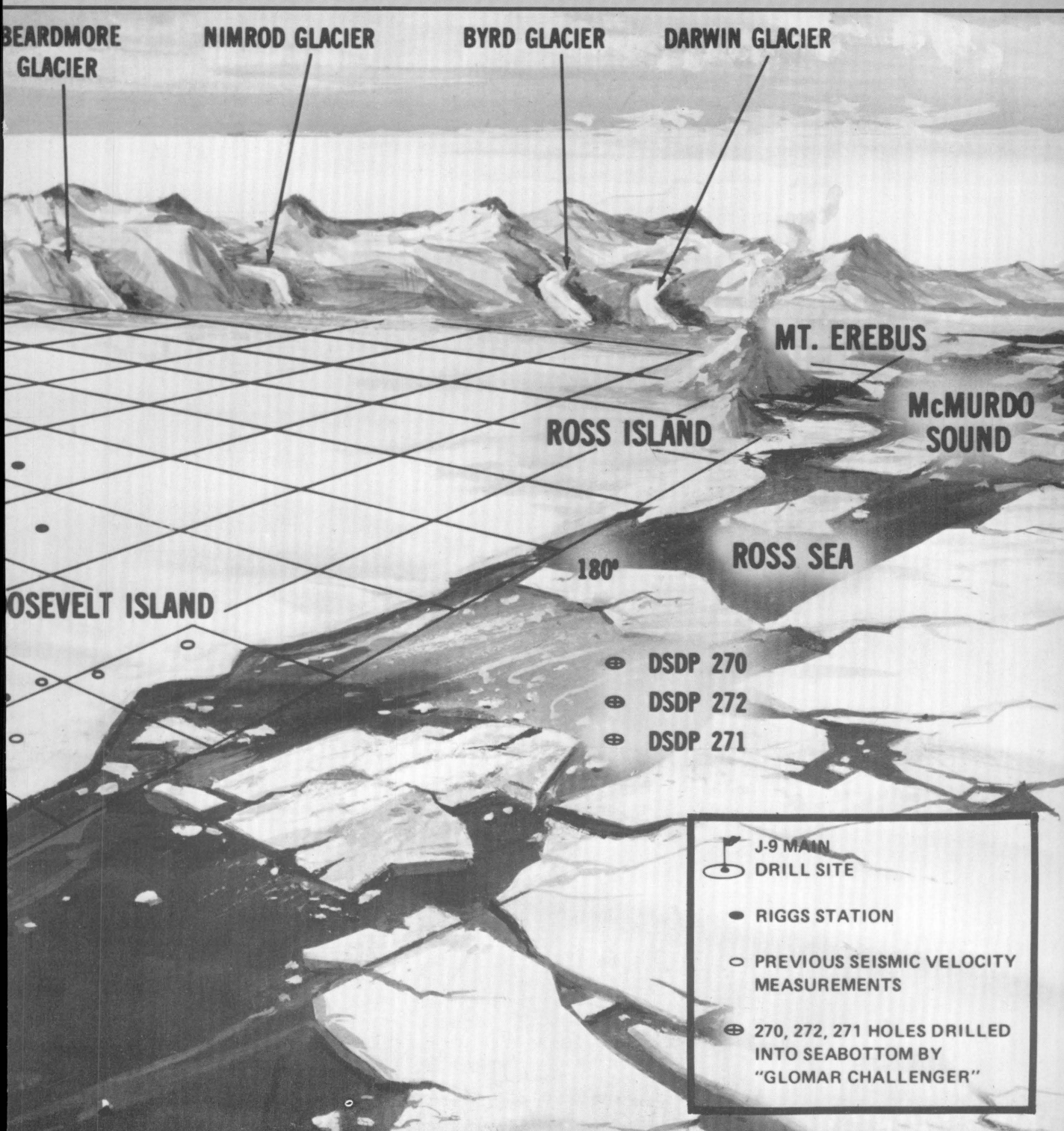

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Although the National Science Foundation attempts internally to make papers published in *Antarctic Journal* error-free, papers generally are not refereed for scientific content or merit.

COVER: Artist's concept of the Ross Ice Shelf Project (RISP) and the closely related Ross Ice Shelf Glaciological and Geophysical Survey (RIGGS). RISP fieldwork this season will include drilling through the floating Ross Ice Shelf, which is about the size of Texas, for the first time. RISP/RIGGS 1976-1977 austral summer activities are described on pages 198-200.

Oceans

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Biota

News and notes

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U.S. Antarctic Research Program, 1975-1976

Review of year-round activities

This section of *Antarctic Journal of the United States* comprises the second part of a review of U.S. antarctic projects that were active in 1975 and 1976. It succeeds the September/October issues of former years, when the *Journal* was published bimonthly. Included are descriptions of data analysis at home institutions and reports on year-round observations in the Antarctic. The third part of this review, to appear in the December 1976 issue, will include reports on earth and ice studies and on work at Stateside support centers. The first part of this review, in the June 1976 issue, describes field activities that took place in the 1975-1976 austral summer.

New very low frequency radio direction finder for the Antarctic

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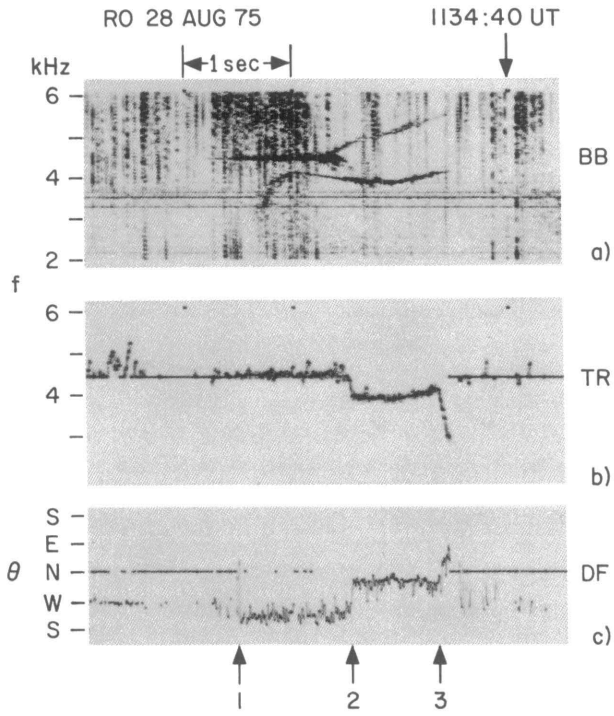
A major objective of very low frequency (VLF) research is the realization of direction finding (DF) on whistler-mode signals. Signals from VLF sources such as lightning or the Siple Station VLF transmitter propagate on magnetospheric field-alined paths, emerging from the ionosphere in the opposite hemisphere at about a 100-kilometer altitude. Direction-finding receivers determine the arrival bearings at one or more ground points; triangulation is used to locate the path exit points. Identification of exit points should permit: (1) determination of the extent of the magnetospheric regions illuminated by ground sources such as the Siple transmitter, (2) study of dynamic effects such as drifts of the magnetospheric plasma, and (3) conduct of *ad hoc* experiments, such as on rockets and balloons, that depend on locating the exit points of VLF wave activity of interest.

In June and July 1975, we and others conducted a direction-finding campaign near Roberval, Quebec, Canada, conjugate to Siple, Antarctica, to test and compare results from three different DF systems. Groups from the University of Tokyo, the University of Southampton/Houston, and Stanford University operated the systems. This paper reports some results from a Stanford system designed as part of a Ph.D. research project by M. K. Leavitt, a graduate student. Dr. Leavitt's system uses a tracking filter for isolating and following the frequency-time behavior of a signal of interest. The system's DF analysis section electronically combines information from two crossed loops and a vertical antenna and indicates in real time the signal bearing. Called the "TR/DF," the system was operated at Roberval with success; consistent arrival bearings were obtained on both Siple transmitter and natural signals over periods ranging from minutes to tens of minutes.

The figure gives an example of operation and capabilities of the system. The upper panel is a spectrogram displaying frequency from 2 to 6 kilohertz versus time. There are two prominent signals on the record: a Siple transmitter pulse at 4.5 kilohertz followed by a rising triggered noise, and a noise event that begins near 4.0 kilohertz. The upper part of a natural whistler triggered the noise event. The middle panel shows the frequency of the tracking filter, which was reset to about 4.5 kilohertz when not in the tracking mode. The bottom panel shows the apparent arrival bearing, with respect to magnetic north, of the signal within the tracker pass band. Before time t_1 several impulsive signals, or spherics, from nearby lightning, captured the tracker; the bottom panel shows the bearings of these spherics to be $-90°$, or to the west. (The conventional goniometer direction finder cannot track spherics; signals of more than several tenths of a second in duration usually are required for a bearing determination.) Between times t_1 and t_2 the tracker followed the Siple transmitter signal; the bearing is relatively well defined and southwest. Between t_2 and t_3 the tracker followed the emission triggered by the whistler. The whistler and its emission are entirely below the Siple signal in frequency. Theory predicts that waves at the lower whistler-



Example of the operation of a new very low frequency frequency-tracking direction finder.

mode frequencies should emerge from the ionosphere at higher latitudes. The data support this prediction; the well-defined bearing is now slightly west of north.

Measurements with the TR/DF during 15 hours of Siple transmissions generally confirm earlier analysis (Carpenter and Miller, 1976), based on broadband information alone, that the endpoints of Siple transmitter signal paths are relatively close to Roberval Station, displaced in latitude only by about ±200 kilometers. The TR/DF bearings also show an apparent concentration at southwest, an effect not understood. This concentration may occur because the geomagnetic conjugate point of the ionospheric region of maximum illumination of the Siple transmitter is slightly southwest of Roberval. Also, distortions of the earth's magnetic field by the impinging solar "wind" might produce such an effect.

Interpretation of the TR/DF data is complicated by multipath propagation effects and by "polarization" error. This latter is associated with signals whose exit points are close to the receiver. These effects require study as part of attempts to refine DF methods. Overall, the outlook appears promising for application of the TR/DF and goniometer techniques in the Antarctic. We are planning such applications for Siple and Palmer as part of cooperative work with experimenters at Halley Bay, Belgrano, and Sanae.

This research was supported by National Science Foundation grants DPP 74-04093 and DES 74-20084.

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Location and time evolution of electron burst precipitation regions in the lower ionosphere

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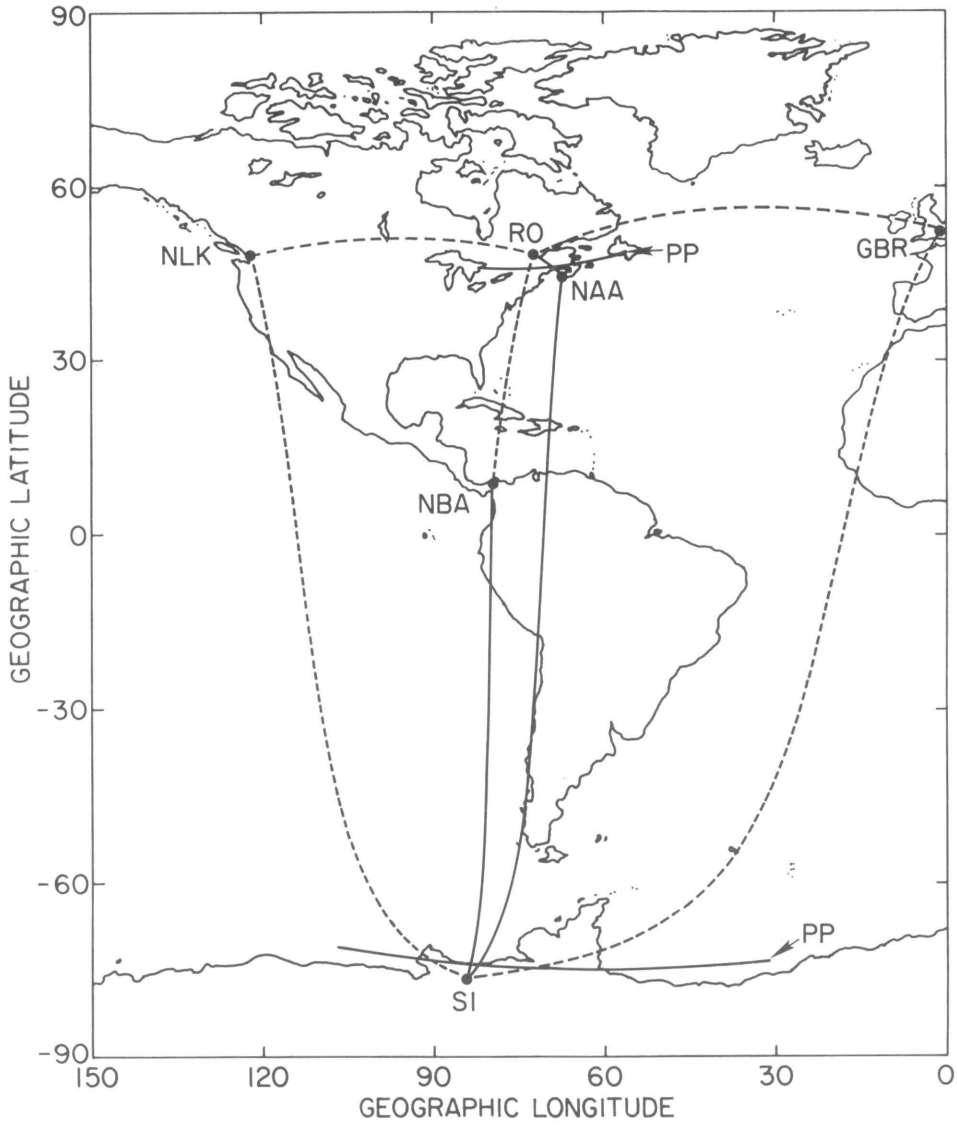
Observations of burst precipitation of energetic electrons from the magnetosphere at subauroral latitudes are rare. Although such bursts are believed to occur frequently, they are difficult to detect. The precipitation is most noticeable when it causes amplitude perturbations of very low frequency (VLF) radio signals propagating beneath the ionosphere (Helliwell *et al.,* 1973; Dingle, 1975). Events of this kind previously have yielded only limited quantitative information on the location and details of the processes at work. A comprehensive new data set acquired at Siple Station and at its Northern Hemisphere magnetic conjugate point in Roberval, Quebec, Canada, contains important new information.

On 11 September 1973 a long series of narrowband VLF noise bursts was recorded at both Siple and Roberval. The bursts lasted for about 10 seconds typically and occurred at approximately 5-minute intervals over several hours from well before dawn to after sunrise. Each of the bursts was associated with an amplitude perturbation of at least one of the subionospheric signals from U.S. Navy VLF stations. These amplitude perturbations have onset rise times corresponding to the burst durations and recovery times thought to be associated with the relaxation time of the lower ionosphere.

The noise bursts are thought to originate in the magnetosphere, where they interact with energetic



Subionospheric propagation paths from four very low frequency transmitters (NAA, NBA, NLK, GBR) to Siple (SI) and Roberval (RO). Solid lines denote paths that show amplitude perturbations in association with noise bursts at various times on 11 September 1973. Dashed lines show unaffected paths. The position of the plasmapause (PP) is indicated. The precipitation regions should be located near the points where the disturbed paths cross the plasmapause. The geographic outline is only an approximation.

electrons trapped in the radiation belts and cause some of the electrons to precipitate into the lower ionosphere. The precipitation results in increased ionization, which in turn affects VLF signals propagating in the earth-ionosphere waveguide. The regions of enhanced ionization are thought to be limited in extent and may be as small as perhaps 30 kilometers in diameter. They can be located by finding the intersection of the disturbed subionospheric VLF paths with the locus of possible exit points of the precipitating electrons from the magnetosphere. Since the causative noise bursts appear to be triggered by whistlers traveling along or near the plasmapause, the precipitating electrons probably are leaving the magnetosphere where the plasmapause intersects the ionosphere. This intersection is plotted in the figure. Also shown are the subionospheric paths from several VLF stations to the receivers at Siple and Roberval. The precipitation regions should be near the points where the plasmapause crosses the disturbed paths.

Details of the time development of the amplitude perturbations give diagnostic information for processes in both the ionosphere and the magnetosphere. During the night, some of the amplitude perturbations showed an undershoot when they recovered, indicating that the noise bursts may turn off a background drizzle precipitation. Near dawn, some perturbations showed double onsets, suggesting that more than one precipitation burst may have been associated with a single noise burst. Also near dawn, the amplitude recovery time increased markedly, suggesting a transition from one type of recovery mechanism to another as the sun rose.

After sunrise, the perturbations disappeared altogether, showing that solar-produced ionization probably masked that caused by the electron precipitation.

This research was supported by National Science Foundation grant DPP 74-04093.

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VLF wave-wave interactions in the magnetosphere

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The magnetosphere is a source of powerful very low frequency (VLF) waves thought to be generated by radiation belt particles. Manmade signals injected from ground sources, such as the very low frequency transmitter at Siple Station, Antarctica, can trigger such waves and thus control the magnetosphere. Coherent VLF signals from Siple Station typically are amplified up to 35 decibels and interact with other signals in the magnetosphere (Helliwell and Katsufrakis, 1974). Harmonic radiation from the Canadian power system has a role in controlling magnetospheric wave-particle interactions (Helliwell *et al.*, 1975).

A new result is the entrainment of artificially stimulated emissions (ASEs) by 50-millisecond pulses from the Siple transmitter. Figure 1 shows 0.5-second pulses on 4.5 kilohertz that grow in time to about 20 decibels above their initial value. At the end of each pulse a strong falling tone is stimulated. In the 0.5 second between adjacent 0.5-second pulses is a sequence of 50-millisecond pulses that alternates between 4.0 and 4.1 kilohertz. They are too short to show significant growth. However, when the strong falling tone encounters one of the weak 50-millisecond pulses, the falling tone is immediately "captured," with its frequency becoming locked to that of the 50-millisecond pulse. On termination of the pulse, this enhanced signal either stops or continues to move downward in frequency. Entrainment, as illustrated in figure 1, helps to explain the remarkable ability of relatively weak power line radiation to control much larger signals. The rapidity of the capture suggests that the free-running oscillation (that is, the falling tone) is captured at the location in space where it is generated. This result will aid in extending one of the current theories of cyclotron resonance interaction in which the change in frequency with time (DF/DF) of an emission is proportional to the distance of the interaction region from the Equator (Helliwell, 1967).

During further examination of the data we

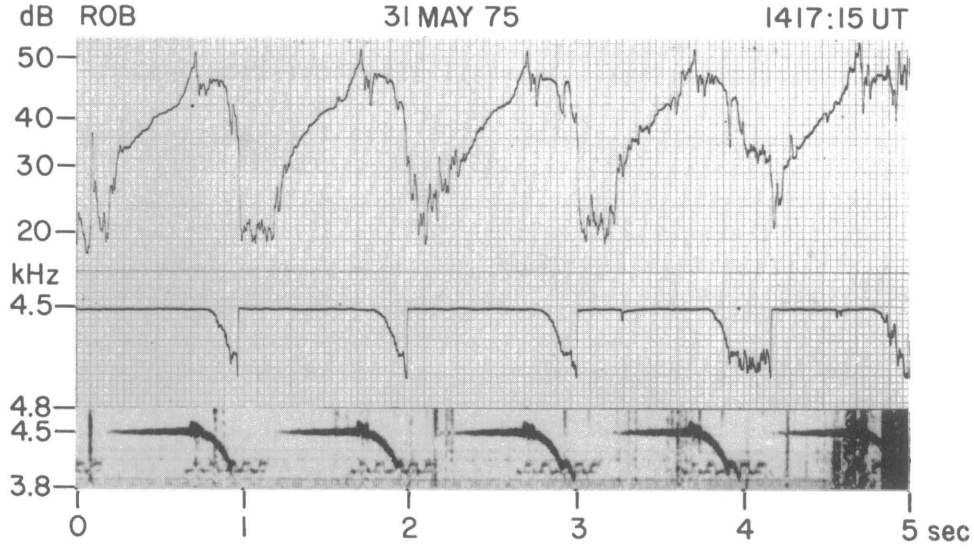

Figure 1. Series of Siple transmissions showing growth of 0.5-second pulses on 4.5 kilohertz, artificially stimulated emissions (ASEs), and entrainment of ASEs by 50-millisecond pulses on 4.0 and 4.1 kilohertz. Lower panel: dynamic signal spectrum. Middle panel: frequency of automatic tracking filter (bandwidth, 340 hertz). Upper panel: amplitude (log scale) of tracking filter output.

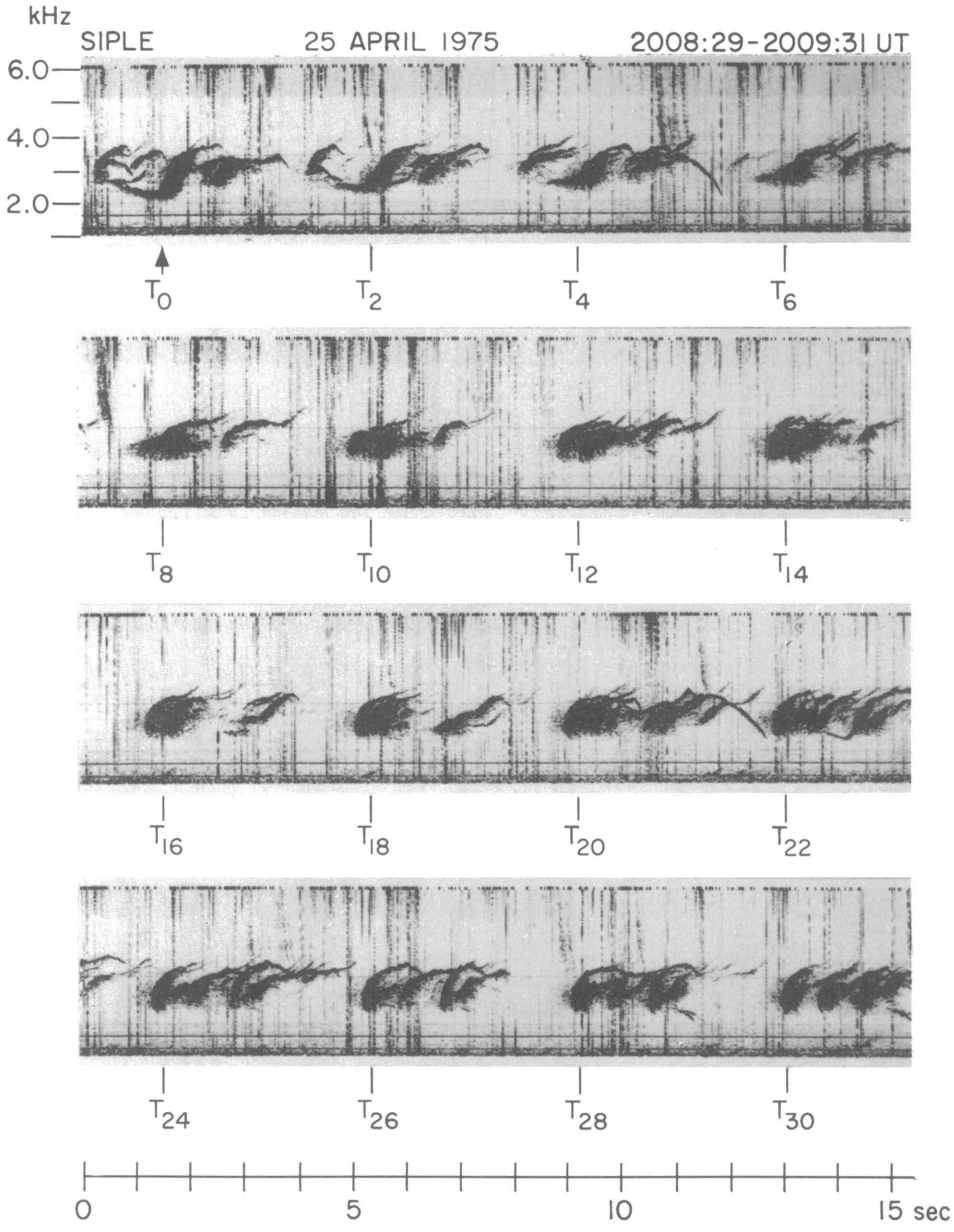

Figure 1. A natural very low frequency (VLF) periodic emission (T_0, T_2, T_4, . . . T_{30}) recorded at Siple Station on 25 April 1975. The two-hop whistler-mode travel time (interval T_0 to T_2) in this event is about 3.8 seconds.

during extended operation. During this time the VLF receivers are muted to prevent overloading, and no local VLF reception is possible.

(3) The transmitter is off from the 20th to the 24th minutes. During this period, magnetospheric wave activity (whistlers, VLF emissions, etc.) is detected and observed on a high-resolution video display. The VLF spectrum (1 to 6 kilohertz versus time) shown in figure 1 is an example of this activity observed at Siple on 25 April 1975. The noise bursts labeled T_0, T_2, T_4, . . . T_{30} are natural periodic emissions in which the period is equal to the two-hop whistler-mode travel time along a magnetospheric field-alined path (from the vicinity of Siple to the opposite hemisphere and back again). The two-hop delay in this event is about 3.8 seconds.

(4) A special pulse and listen program with frequencies bracketing the starting frequency (about 2.7 kilohertz) of the periodic emissions is now transmitted, as shown at the left in figure 2a. A 3-second

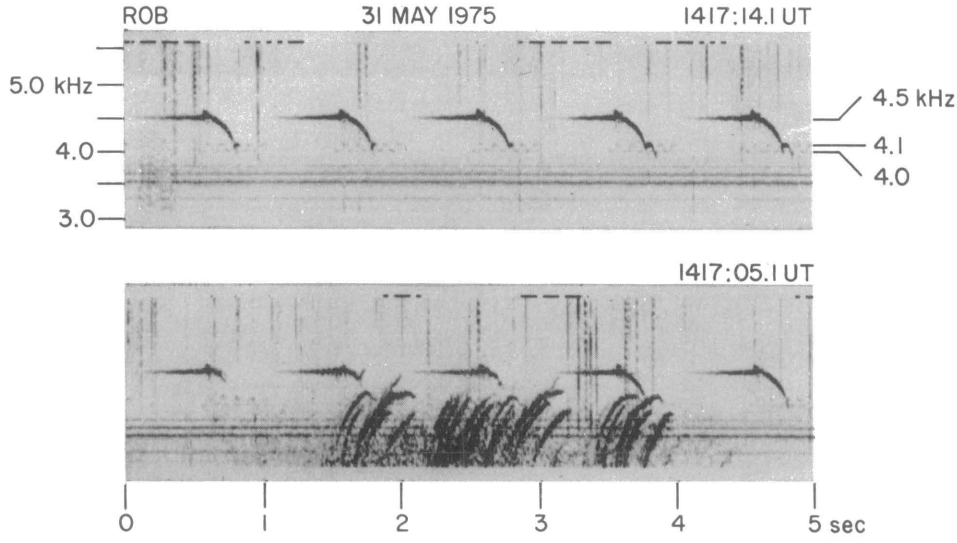

Figure 2. Same Siple program as in figure 1. Top panel shows entrainment of ASEs by 50-millisecond pulses at 4.0 and 4.1 kilohertz. Bottom panel shows breakup by whistler of smooth wave growth. In addition, there is an increase in value of lowest frequency reached by falling tone, a disruption of entrainment of ASEs, and the appearance of frequency modulation on the 0.5-second pulses and the whistler components.

noticed that frequency modulation (FM) of the main pulse, often seen on both manmade and natural emissions, occurred near the time of reception of a two-hop multipath whistler. Figure 2 shows an example. The FM appears *before* the whistler components that are believed to follow the same magnetospheric field-alined paths as the signal. We have identified two prominent paths. This association has not been explained, but could mean that the southward traveling one-hop whistler is in some way modifying the factors (for example, electron streams) that control the amplification of the northward traveling Siple signal. Another effect coincident with the FM is a temporary increase in the value of the lowest frequency reached by the falling tone. These signal interaction effects provide important clues to understanding wave-particle interactions in the magnetosphere. They also show that the magnetosphere is extremely sensitive to the injection of weak coherent waves in the VLF range.

This research was supported by National Science Foundation grants DPP 74-04093 and DES 75-07707.

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Man, computer, and VLF transmitter at Siple: interactive wave injection experiments to perturb the energetic particles of the magnetosphere

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Stanford University magnetospheric probing experiments at Siple Station are being developed to increase the interactive role of the on-site scientists. The instrumentation, consisting of a very low frequency (VLF) transmitter, a computer, VLF receivers, and a spectrum analyzer, permits adjustment of the parameters of the transmitted waves according to the observed response of the magnetosphere. Following is an illustration of interactive transmission procedures during a 30-minute period.

(1) The specific frequency-time format to be transmitted is selected from a library of computer-generated programs.

(2) The computer controls all functions of the transmitter for the first 20 minutes. The modulation during this time is at 100-percent duty cycle to maintain a constant load on the diesel power generating units and thus prevent overstressing the units

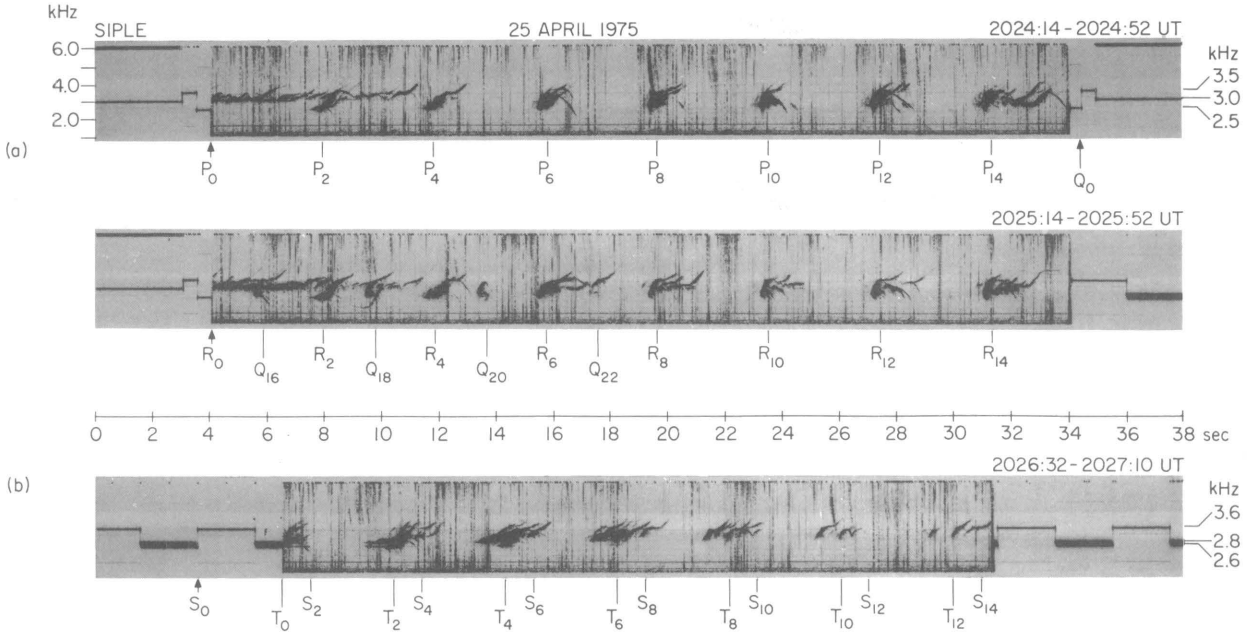

Figure 2. Artificially stimulated VLF periodic emissions. The spectral shapes of these emissions are similar to the natural emissions shown in figure 1.

pulse at 3.0 kilohertz is followed by 0.5-second pulses at 3.5 and 2.5 kilohertz. The immediately following observations of the broadband spectrum show: (a) multiple rising tones initiated by the pulse at 3.0 kilohertz (from about 4 to 11 seconds on the time scale below the second panel), (b) no response to the pulse at 3.5 kilohertz, and (c) periodic emissions (P_0, P_2, P_4, . . . P_{14}) initiated by the 2.5-kilohertz pulse. The spectra of the higher order periodic emissions appear much like the spectra of the natural higher order emissions shown in figure 1. Also, the two-hop period of the natural and artificially stimulated emissions is the same.

Thirty seconds after the 2.5-kilohertz pulse (P_0) a new series of pulses is transmitted (at right of upper panel). One-half-second pulses at 2.5 kilohertz (Q_0) and 3.5 kilohertz are followed by a 28-second pulse at 3.0 kilohertz (continued in middle panel) and 0.5-second pulses at 3.5 and 2.5 kilohertz (R_0). The observations then show: (a) periodic emissions Q_{16} through Q_{22}, apparently initiated by the first 0.5-second pulse (Q_0) (the receiver was muted during the transmissions, hence the emissions Q_2 through Q_{14} were not detected), (b) multiple rising tones initiated by the pulse at 3.0 kilohertz, (c) no response to the pulse at 3.5 kilohertz, and (d) periodic emissions (R_0, R_2, R_4, . . . R_{14}) initiated by 2.5-kilohertz pulse. Again, the spectra of the artificially induced emissions resemble the earlier natural activity, and the two-hop travel time is the same.

(5) At the time of figure 2b the modulation is changed to a combination of 2-second pulses at 3.6 kilohertz and 50-millisecond pulses frequency-shift-keyed between 2.6 and 2.8 kilohertz (see frequency scale at lower right). The observations show: (a) no response at 3.6 kilohertz, (b) echoes of the 50-millisecond pulses, and (c) emissions triggered by these echoes. The spectra of the emissions in this case differ from those in figure 2a, and echoing proceeds for a shorter time.

This type of realtime interaction of the experiment with the experimental results has increased the scientific productivity of Siple programs. We hope to strengthen further this interaction capability by providing realtime communications between Siple Station, its conjugate at Roberval, Canada, and our home laboratory at Stanford. The communications link would employ the geostationary satellite ATS-3. We also plan to have spectrum readout of the Stanford VLF experiments on the forthcoming international Sun-Earth Explorer (A) and Electrodynamics Explorer satellites. This will enable us to vary the Siple VLF transmitter parameters so as to affect the growth of transmitter signals and associated emissions detected by the satellite. In addition we hope to monitor in real-time the changes in the particles measured on the satellites and correlate these changes with our transmissions.

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Plasmapause studies using whistlers received at Siple Station

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The plasmapause, a magnetic field-alined boundary where the dense (a few hundred electrons per cubic centimeter) plasmasphere terminates, is a region of special geophysical interest because the large density gradients there give rise to a variety of plasma phenomena. Examples include the generation of intense very low frequency (VLF) radio noise (Carpenter *et al.,* 1968), strong pitch angle diffusion of energetic particles (Williams and Lyons, 1974), excitation of stable auroral red arcs (Hoch, 1973), and changes in the polarization and amplitude of hydromagnetic waves (Lanzerotti *et al.,* 1974). The plasmapause also has been associated with a number of ionospheric features such as the light-ion trough (Taylor and Walsh, 1972).

Whistlers provide a powerful tool for monitoring the plasmapause, and most of what we know today about the dynamics of this region was first learned through the whistler technique (see, for example, a recent review paper by Carpenter and Park, 1973). Figure 1 shows an equatorial electron density profile with a well-defined plasmapause at an equatorial distance of 3.6 earth radii. The data points come from whistlers recorded at Siple Station. Using this technique, it was possible to monitor the plasmapause position continuously during the period 17-22 June 1973. The results are shown in figure 2 along with the 3-hour Kp index, which is a rough indicator of geomagnetic disturbance level. These results confirm many earlier findings including an inward shift of the plasmapause during more disturbed times (larger Kp values) and the more rapid variations that depend on the local time of the observing station (see, for example, Carpenter, 1966 and 1970). Park and Seely (in press) discuss these results in more detail.

The plasmapause information in figure 2 is the basis for detailed correlative studies involving both ground-based and satellite experimenters. Underway studies include comparisons with (1) electron

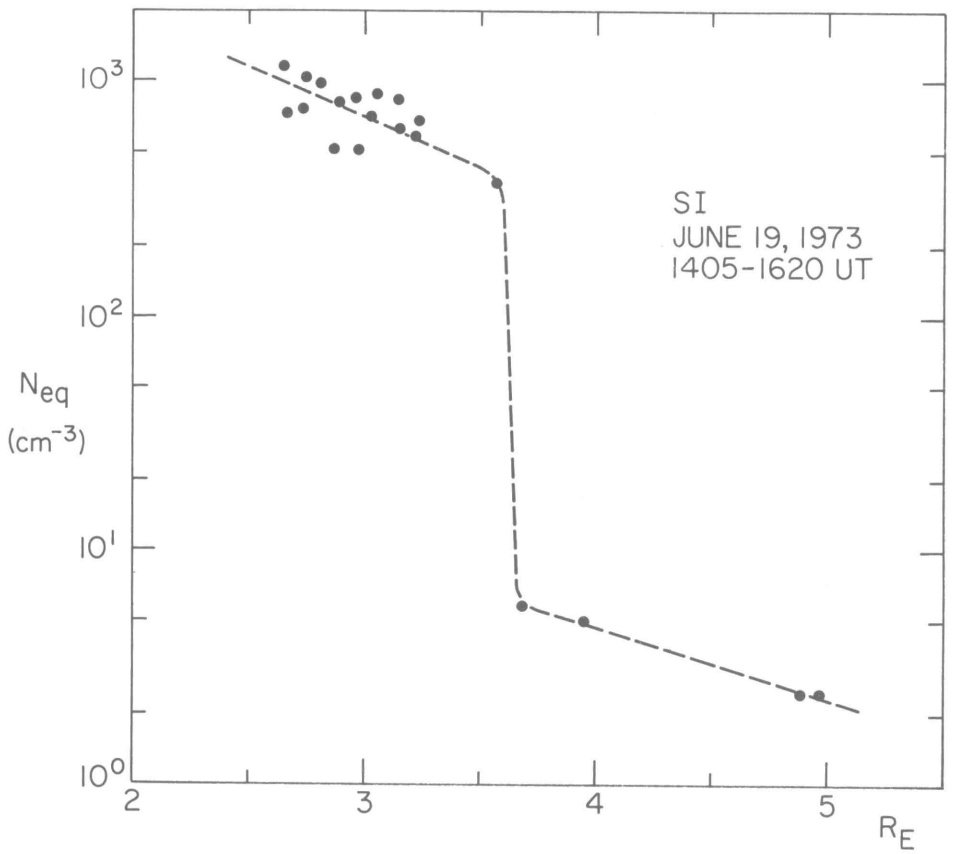

Figure 1. Equatorial electron density versus geocentric distance in units of earth radius.

densities derived from geomagnetic pulsations detected at Siple Station and a latitudinal chain of stations in the conjugate region (L. J. Lanzerotti, Bell Telephone Systems), (2) the generation region of hydromagnetic waves near 1 hertz detected at Siple Station (L. J. Cahill, Jr., University of Minnesota, and R. L. Arnoldy, University of New Hampshire), (3) trapped and precipitating energetic electron fluxes measured by ISIS-II satellite (R. Burrows, National Research Council, Canada), (4) electron density and temperature measurements by a Langmuir probe aboard ISIS-II (L. Brace, NASA Goddard Space Flight Center), (5) ion density measurements by a retarding potential analyzer on ISIS-II (E. Maier, NASA Goddard Space Flight Center), (6) ion mass spectrometer results from ISIS-II (J. Hoffman, University of Texas), (7) scanning photometer results from ISIS-II (C. Anger, University of Calgary, Canada), (8) electron density and temperature measurements by ESRO-4 satellite (J. Raitt, University College, London, United Kingdom), (9) energetic proton precipitation events detected by Air Force satellites (J. Reagan, Lockheed Research Laboratories), and (10 bottom-side ionosonde data available from the World Data Center.

This research was supported by National Science Foundation grants DPP 74-04093 and DES 74-20084.

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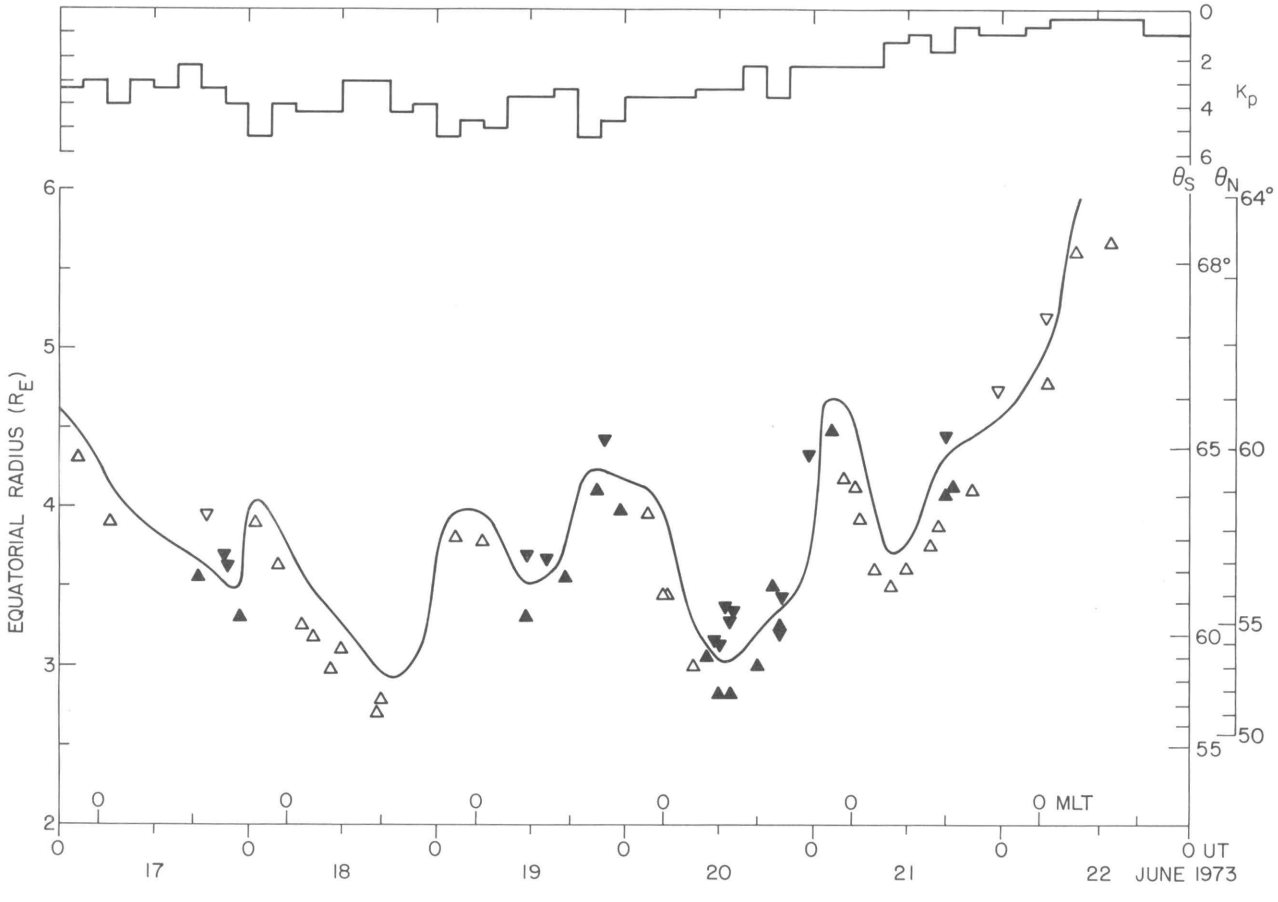

Figure 2. Plasmapause position deduced from whistlers received at Siple Station. The two horizontal scales at the bottom are Universal Time and Magnetic Local Time at Siple. The vertical scale at left is geocentric distance at the equator, and the two vertical scales at right are the corresponding geomagnetic latitudes where the field lines intersect the earth. The triangles with the apex pointing up represent the inner limit of the plasmapause, while those with the apex pointing down represent the outer limit. Filled triangles indicate greater accuracy.

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Atmospheric electric field measurements at Vostok, Antarctica

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A U.S. scientist has wintered at Vostok Station (78°28'S. 106°48'W.) in alternate years as part of a U.S.-U.S.S.R. exchange scientist program that started during the International Geophysical Year (IGY). Robert B. Flint, Jr., who wintered there in 1974, measured the vertical atmospheric electric field in addition to his regular duties that included the operation of geomagnetic pulsation detectors and very low frequency (100 hertz to 100 kilohertz)

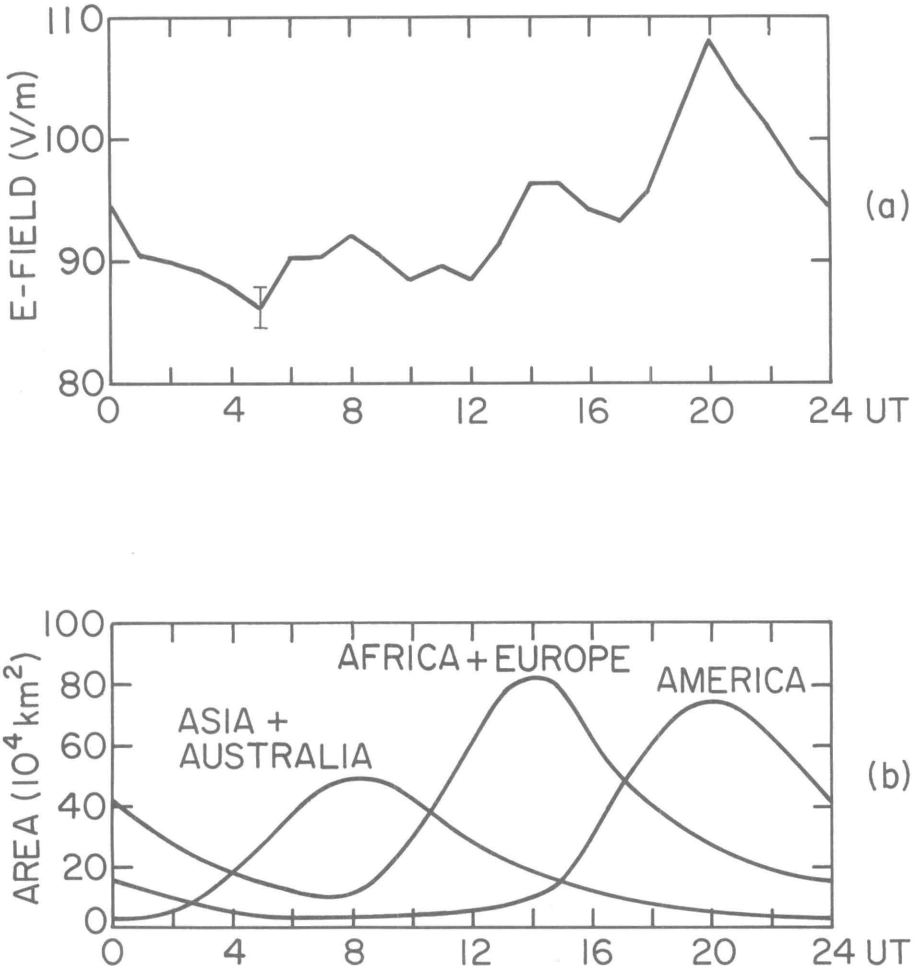

Figure 1. (a) Vertical electric field measured at Vostok versus universal time (UT). Positive electric field is directed downward. The vertical bar at 0500 UT shows the standard error of the mean. (b) Estimated thunderstorm area in major continents of the world plotted against UT (reproduced from Whipple and Scrase, 1936).

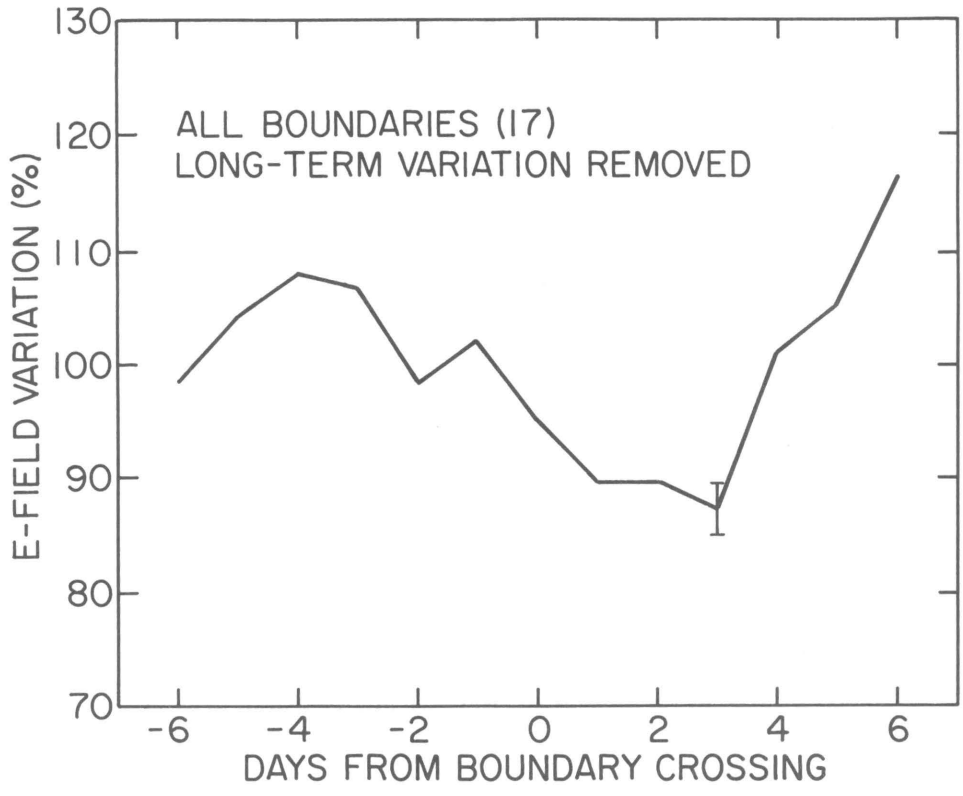

Figure 2. Average response of the Vostok electric field about the time of solar magnetic sector boundary crossing.

radio receivers. The equipment used for atmospheric electric field measurements was developed at Stanford University and has a response time of about 1 second. The sensor consists of a dipole antenna (60 centimeters tip to tip), which is rotated by an induction motor at 1,800 revolutions per minute. The alternating current signal induced in the antenna is first amplified and then processed through a synchronous detector and a low-pass filter. The rotating antenna makes it possible to follow electric field fluctuations up to 1 hertz, the upper cutoff frequency of the output filter. By contrast, a stationary antenna would have a response time of the order of ½ hour, which is the time required for the antenna to charge and discharge through the poorly conducting atmosphere. The sensor was installed upwind of the station at a height of 1.5 meters and operated continuously for approximately 8 months.

Figure 1a shows the diurnal behavior of the electric field plotted against universal time (UT). Figure 1b shows the expected thunderstorm area over major continents of the world as a function of UT (Whipple and Scrase, 1936). The peaks occur when these continents go through the afternoon. The good agreement between these peaks and the three peaks in figure 1a indicates that the electric field data from Vostok do in fact reflect the changes in global ionospheric potential and that the data are not significantly contaminated by local disturbances. Figure 1a also agrees with earlier measurements made at polar latitudes and over oceans (Kasemir, 1972; Israel, 1973).

An interesting result is found when the electric field data are correlated with the solar magnetic sector structure. This is illustrated in figure 2, which shows the result of a superposed epoch analysis in terms of percentage change in the electric field as a function of days from the passage of sector boundaries. The electric field is depressed by 15 percent 1 to 3 days following sector boundary encounters. This depression appears to be statistically significant when compared to the standard error of the mean. If this correlation is real, it has many important implications for coupling between solar terrestrial phenomena and atmospheric dynamics in the lower troposphere. A more detailed statistical analysis of the electric field data and the physical implications of the results are in Park (in press).

The high plateau in the antarctic interior offers an ideal location for studying the fair-weather atmospheric electric field. The favorable factors include high altitude, absence of local thunderstorms, exceptionally clear sky throughout the year, low wind speeds, and low atmospheric pollution levels.

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Atmospheric electric measurements

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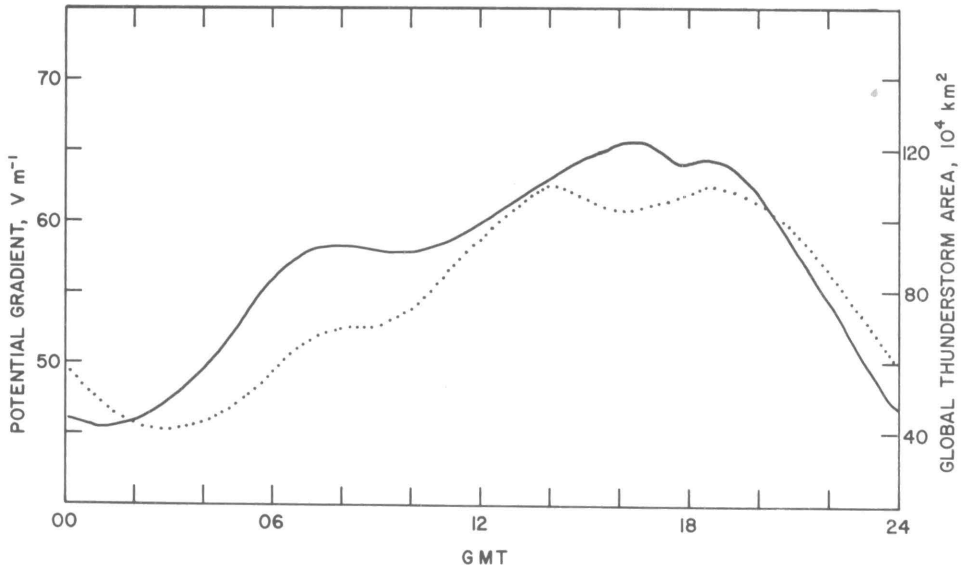
The National Oceanic and Atmospheric Administration's 5-year program of atmospheric electric measurements at Amundsen-Scott South Pole Station is in its third year. Electrical parameters are monitored continuously at the surface, and balloon-borne sensors are released frequently to measure the air-earth conduction current aloft. The objective is to establish an environmental benchmark of the atmospheric electric climate on the polar plateau and also to investigate the origin and maintenance of the earth's atmospheric electric field.

The classical theory of atmospheric electricity is that the earth and the ionosphere form the conducting plates of a spherical condenser. An imperfectly insulating atmosphere separates the plates. The electrical current known to flow between the plates of this "leaky" capacitor is produced, maintained, and controlled by the ever present global thunderstorm activity: positive current flows to the earth in fine weather and is returned to the ionosphere in thunderstorm areas.

The classical hypothesis is based largely on measurements made aboard the sailing ship *Carnegie* in the 1920s. Perhaps the most convincing evidence since that time is being obtained from the potential gradient measurements at the South Pole (figure).



Mean diurnal variation of the potential gradient (solid line) at the South Pole and of the global thunderstorm activity according to the Whipple and Scrase curve (Geophysical memoirs of the British Meteorological Office, 1936). Both the global thunderstorm activity and the potential gradient peak from 1300 to 2000 Greenwich Mean Time (GMT) correspond in time with the sun's passage over Africa and Europe soon followed by North and South America. Solar heating of these large land areas results in the greatest thunderstorm activity. A secondary peak occurs at about 0800 GMT associated with the afternoon thunderstorm activity in Asia and Australia, and the minimum global thunderstorm activity occurs at about 0300 GMT when the sun is over the Pacific Ocean.

Hydromagnetic whistlers propagating near the plasmapause

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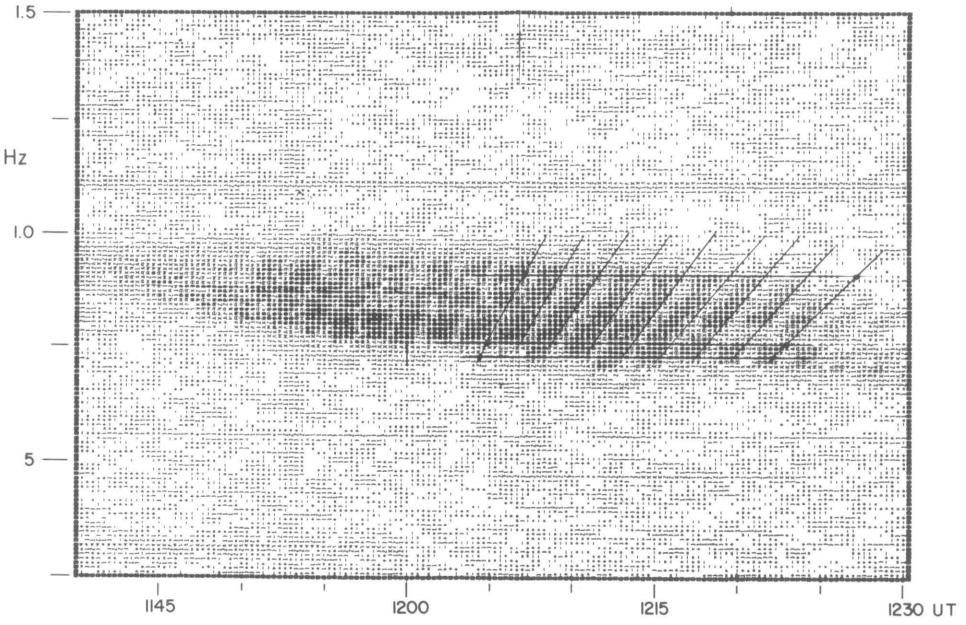
The University of Minnesota and the University of New Hampshire have operated large searchcoil sensors since January 1973 at Siple Station. Naturally occurring magnetic fluctuations in the range .01 to 10 hertz (100-second to .1-second period) have been recorded continuously with a digital magnetic tape recorder. Magnetic fluctuations in this frequency range are classified as micropulsations in the Pc-1 (0.2 to 5 seconds), Pc-2 (5 to 10 seconds), Pc-3 (10 to 45 seconds), and Pc-4 (45 to 150 seconds) bands, as well as the Pi-1 (1 to 40 seconds) and Pi-2 (40 to 150 seconds) bands (Jacobs, 1970). Pc micropulsations are relatively narrow frequency band signals that appear nearly sinusuidal, while Pi micropulsations are broadband, irregular signals that appear to be noise. The amplitudes of these signals vary from several gammas ($1\gamma = 1$ nanotesla) to fractions of a milligamma. The sensitivity of our sensors is in the order of 1 milligamma at 1 hertz.

During 1975-1976 we examined Siple records from 1973 and 1974, and a few 1975 records from Siple and from an identical observation system installed at Roberval, Quebec, Canada (magnetically conjugate to Siple) in July 1975. Work on Siple records had advanced in 1975 to the state that comparisons of data between several Siple instruments became possible.

One particularly interesting comparison was between the whistler observations conducted by Stanford University and the Pc-1 micropulsations. Whistlers generated by lightning show frequency dispersion and are used to determine the equatorial propagation distance of the whistler and the plasma density. By determining the plasma density through observing several whistlers at different distances from the earth, the location of the plasmapause (a sharp decrease in plasma density, by one or two orders of magnitude, that is observed near 4 earth radii in the equatorial plane) can be determined. Certain structured Pc-1 signals have similar frequency dispersion, as shown in the figure. These signals have been termed hydromagnetic whistlers since the waves, well below the proton gyro frequency, propagate in the hydromagnetic mode. Dispersion analysis in these signals also yields the equatorial propagation distance and plasma density (Watanabe, 1965).

The propagation distances of the hydromagnetic whistlers are usually determined to be 1 or 2 earth radii above the usual plasmapause location. Yet the



Structured Pc-1 pulsations observed at Siple Station on 7 September 1973. The frequency band extends from .75 to 1.0 hertz and lasts from 1145 to 1230 Universal Time. Note the rising frequency structure with higher frequencies arriving later in each recurrence.

amplitudes of these waves, as observed on the ground, are often highest at stations somewhat lower in latitude than would be indicated by the equatorial propagation distances determined by the dispersion analysis (Heacock, 1971). There thus is evidence that the hydromagnetic whistlers propagate in or near the plasmapause.

Park and Seely (1976) provided a detailed history of plasmapause location at Siple longitude during a magnetically disturbed interval on 17-22 June 1973. The plasmapause location varied each day, rising highest in the evening sector. It also moved lower in altitude as magnetic activity increased, and it was observed to be located near field lines that come to earth closer to the equator than Siple during much of 18, 19, and 20 June. Only in the evening hours on these days did the plasmapause rise to field lines connected to Siple.

Several hydromagnetic whistlers were analyzed in this interval, and as expected these indicated propagation distances 1 to 4 earth radii above the plasmapause. There were very few events observed, however, on 17, 18, 19, and 20 June, when the plasmapause was below Siple field lines. Those that were observed occurred in the evening at times when the plasmapause moved briefly above Siple field lines (Cahill and Johnson, in press).

Whistler and hydromagnetic whistler comparisons thus indicate that the hm whistlers may propagate near the plasmapause since they are seen (in this limited sample) only when the plasmapause rises above Siple. The discrepancy between this observation and the higher propagation distances determined by dispersion analysis remains unexplained. Corrections to account for the evening sector ring current inflation of the magnetosphere will somewhat lower the calculated propagation distances. Also, it is possible that the presence of heavier ions than protons may modify the dispersion relations.

Some Pc-1 micropulsations persist continuously for several hours in the Siple records. These have been named "long duration micropulsations," and the highest frequency in the rather complex frequency-time structure exhibits a rise in the morning hours and a fall in the forenoon and afternoon hours. It appears that this behavior may also be related to the plasmapause. The plasmapause moves in during the early morning hours and out again in the forenoon toward the evening maximum. If the upper edge of the long duration event frequency band represents pulsations generated and propagating in the plasmapause, then we would expect just this frequency signature—as the plasmapause moves in hydromagnetic signals propagating there —would be raised in frequency as the gyro frequency increases (Lewis and Arnoldy, in press).

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Hydromagnetic waves near L=4 in Antarctica

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A fundamental observational problem in magnetospheric physics concerns the extent in space of the observed phenomena. With one or two space probes it is unlikely that the geomagnetic extent of some magnetospheric phenomena, such as ultra low frequency (ULF) waves, will be understood. Only with coordinated ground-based and satellite measurements will it be possible to resolve questions concerning the magnetospheric scale sizes of phenomena with dimensions of the order of several earth radii.

We compared magnetospheric ULF signals measured at Sanae (SA) and Siple (SI), two antarctic stations near L=4, to examine the longitudinal scale size of magnetospheric signals in the 10- to 50-millihertz frequency range (Barker *et al.,* in press). The South African station SA is 5 hours geographically and 3 hours geomagnetically from SI (figure 1). The Siple instrument is outlined in Lanzerotti *et al.* (1972).

We compared data collected on 2 days during

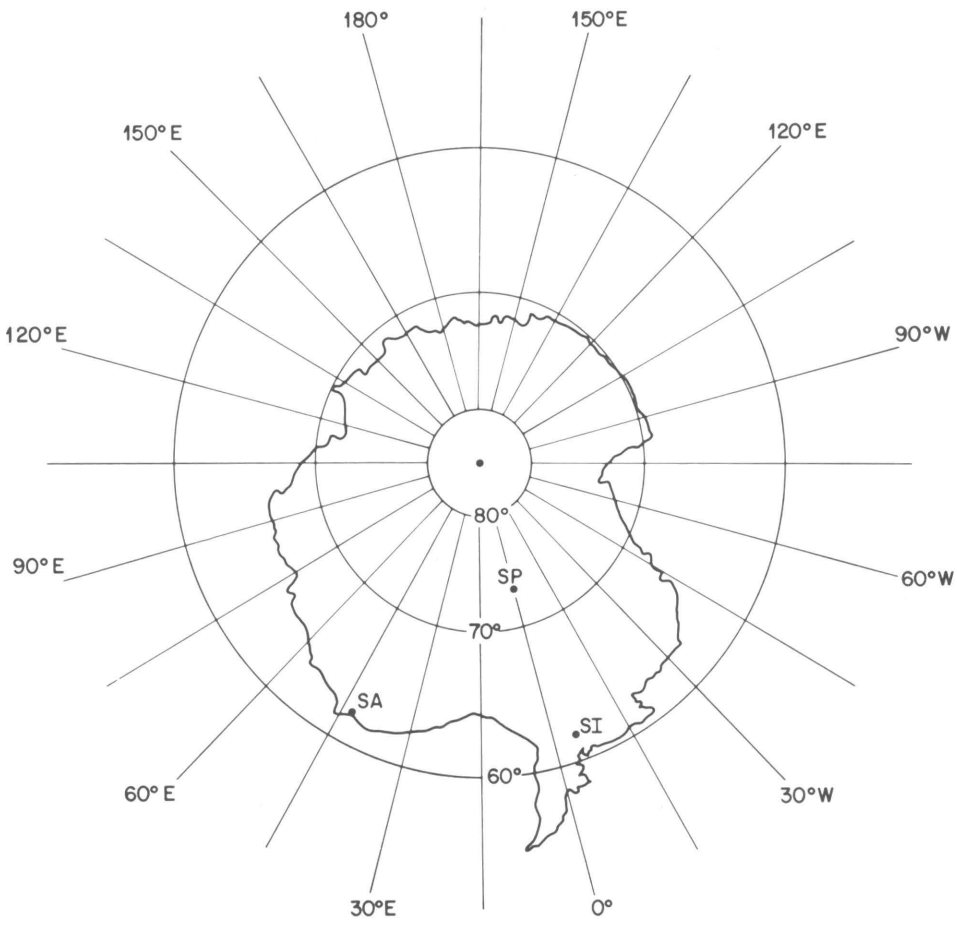

Figure 1. Antarctica (geomagnetic coordinates) with stations South Pole (SP), Siple (SI), and Sanae (SA) indicated.

which substantial ULF wave activity existed in the 10- to 50-millihertz frequency band. The wave signals often were not correlated at the two stations, indicating an azimuthal scale length of less than 5 hours for these frequencies. One-to-one relationships between the observations at the two stations could be identified at times for irregular nighttime waves of frequency 10 to 17 millihertz. A reversal in wave polarizations from lefthand to righthand was observed around local noon at SI; no such reversal was seen at SA.

The overall relationship between the data observations at SA and SI can be observed in the compressed time scale wave amplitude plots shown in figure 2. In this figure a 200-second sliding average was applied to the SI data before plotting. The mu metal core search coil sensor used at SA makes this instrument rather insensitive to waves with periods over about 200 seconds. The impression from this data display (figure 2) is that, even though the stations are separated by nearly 5 hours geographically, the ULF wave enhancements appear to occur at about the same times at the two stations.

Comparisons of actual wave trains showed qualitative associations ranging from very good to none at all. Six events showing typical associations of waves of 33-millihertz in frequency are shown in figure 3. Similar frequencies are seen at both stations within these time intervals, but it is not easy to identify individual cycles at both stations in order to derive azimuthal wave numbers or phase velocities. This conclusion was found to be valid for all time intervals when waves of this frequency (~22-100 millihertz) were observed at the two stations. In general, we found that waves with periods between about 60 and 100 seconds were most easily identified at the two separate stations. Rostoker (1967) was able to identify individual Pi2 waves at several stations spread across the North American continent.

We calculated the polarization ellipses in the horizontal plane for a large number of events at each station on both days. Plotted in figure 4 are the ellipticities for a number of wave events measured around local noon at SI and SA. The time scale at SI is shifted by 5 hours so that the ellipticities are compared at equal geographical local time. Clearly, the wave polarizations observed at SI switch from lefthanded to righthanded across local noon. No such switch is seen at SA. In terms of current

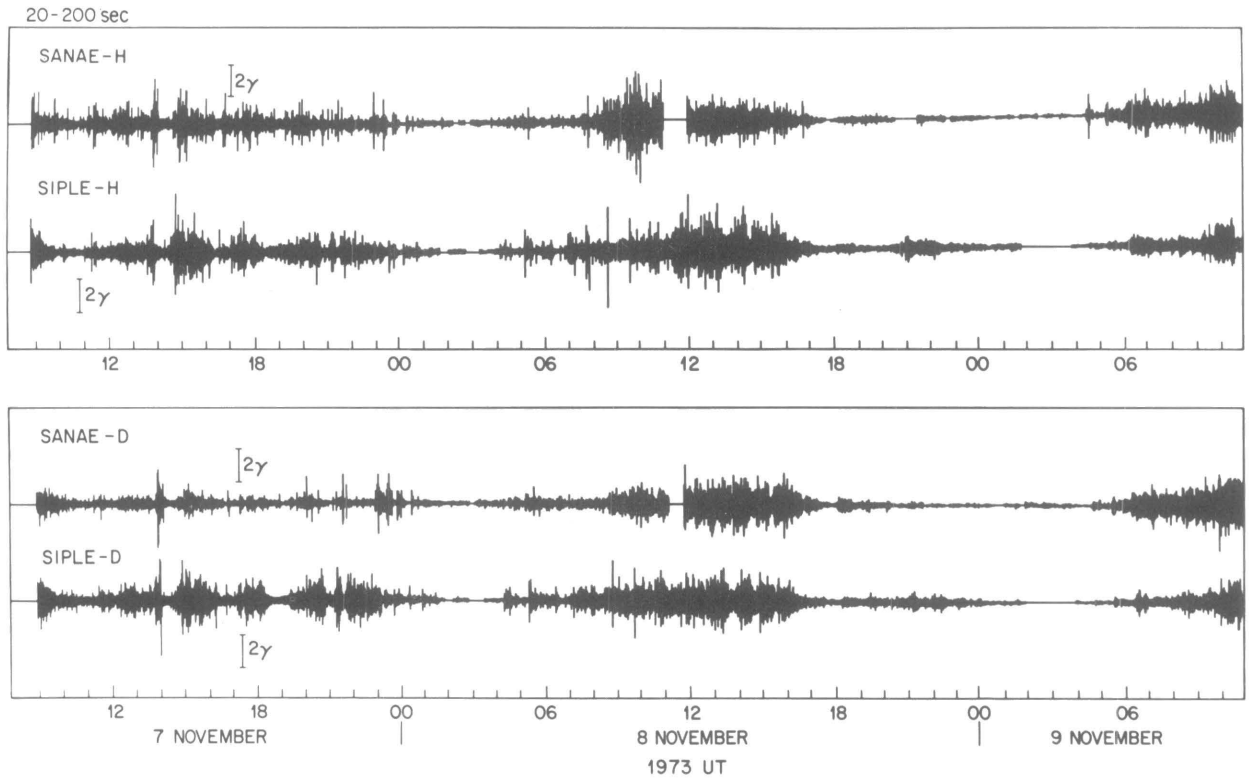

Figure 2. Field variations (20 to 200 seconds) for 7, 8, and 9 November 1973 at SI and SA.

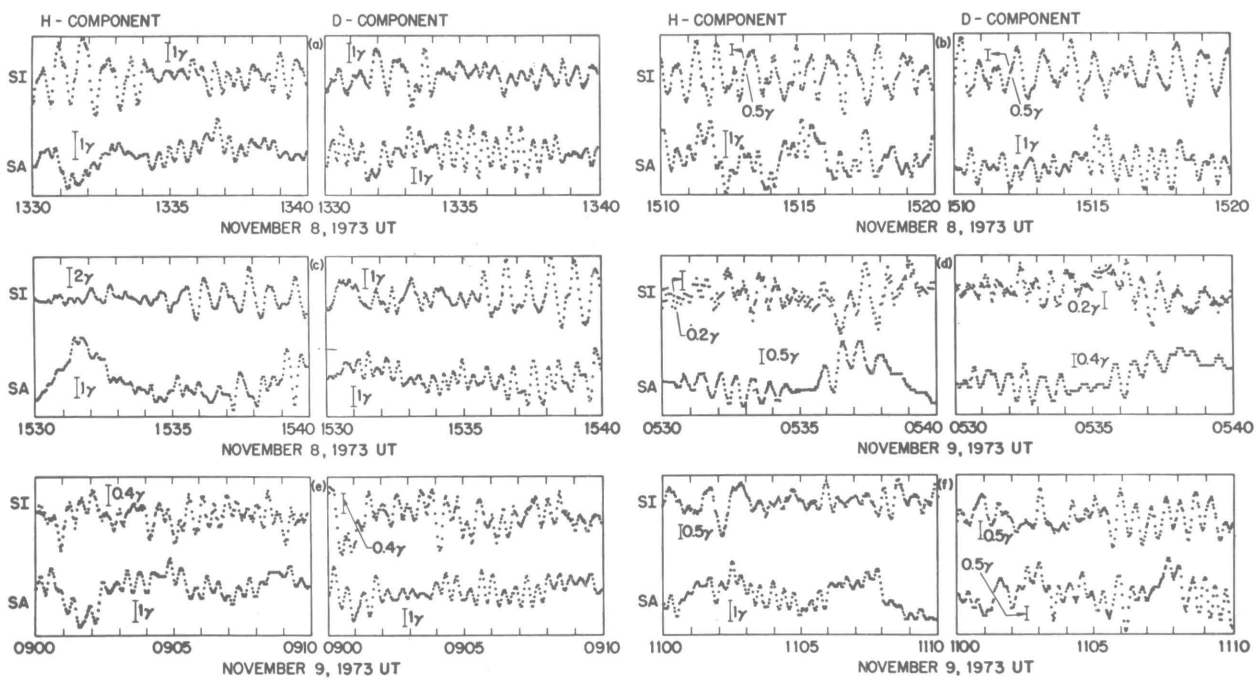

Figure 3. Pulsations (about 30-second period) at SI and SA.

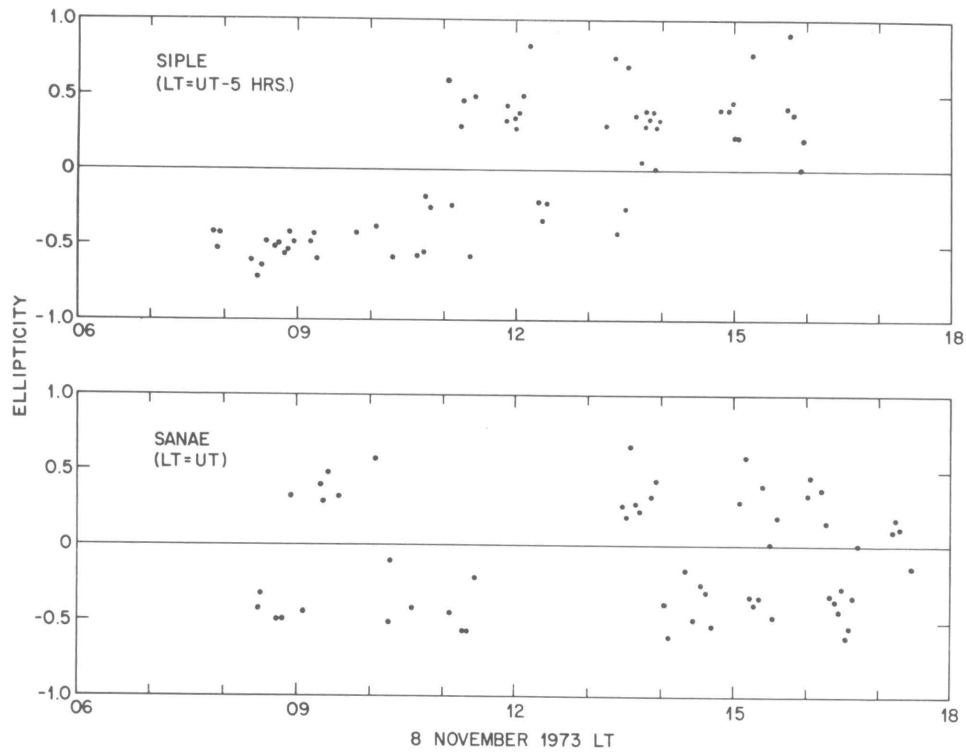

Figure 4. Wave ellipticities at SI and SA on 8 November 1973 plotted at the same local times.

models of hydromagnetic wave renonances at localized latitudes (radial distances) within the magnetosphere, this observation implies that SI was on the equatorward side of the resonance region (Lanzerotti *et al.*, 1974). The fact that a mixed wave polarization is observed throughout the interval at SA suggests that SA was near a resonance region throughout the time interval, lying alternately equatorward and poleward of the resonance.

The difference in the wave polarization characteristics at SA and SI could then be interpreted as a difference, or a change, in the plasma conditions near L=4 during the 5-hour time interval between the two sets of local noon observations. No significant change in geomagnetic conditions (as recorded in the geomagnetic Kp indices) occurred during this time period.

The ellipticity data of figure 4 present the exciting possibility that instantaneous longitudinal plasma conditions in the magnetosphere might be deduced from ULF wave polarization determinations provided sufficient closely spaced stations were available. Further studies such as these near L=4 could be made using antarctic data from stations intermediate between SA and SI; for example, Halley Bay.

The apparent change on a global scale of the amplitude of the envelope of the pulsation trains (figure 2) is strong evidence for the influence of a wave source external to the magnetosphere, such as the solar wind. Several authors have presented evidence for a connection between pulsation periods as observed at the earth and solar wind parameters such as velocity (Troitskaya, 1967; Barker, 1975) and magnetic field amplitude (Gul'elmi, 1974).

Recently, results have been presented that demonstrate an association between the direction of the interplanetary magnetic field and the modulation of pulsation amplitudes as observed at the earth (Troitskaya *et al.*, 1974; Webb and Orr, 1976); wave amplitudes are found to be a maximum for a radially directed interplanetary field (as proposed by Greenstadt, 1973).

Thus it appears that, although in most cases it is very difficult to relate individual wave cycles observed at stations with large longitudinal separations, the overall characteristics of continuous pulsations (including frequency) may be determined on a much larger global scale. Further investigation of these topics is in progress at Bell Laboratories.

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High-latitude ionospheric absorption

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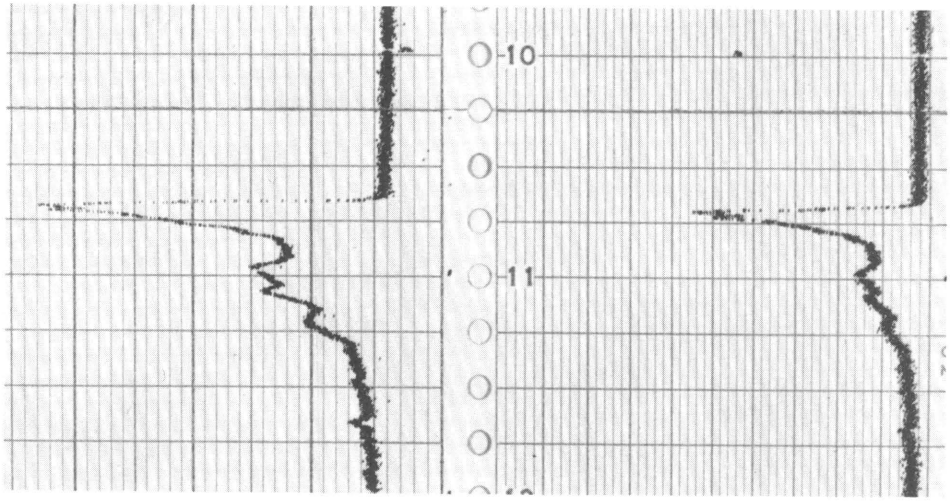
Various riometer (relative ionospheric opacity meter) systems with new fast-response units were operated in Antarctica in 1975. All had wide-beam antennas directed vertically to record overhead ionospheric absorption caused by entry of energetic particles into the earth's atmosphere under disturbed conditions.

At Siple Station, a 30-megahertz riometer was operated as part of the coordinated observations being made there and at the conjugate station near Roberval, Quebec, Canada, to investigate the magnetosphere. Previous investigation of analog recordings made at the site already has illustrated complex relationships among absorption, magnetic field changes, and very-low-frequency phenomena. Emphasis now is on detailed analysis of the simple isolated events that occur at Siple. Digital magnetic tape records made in parallel with the analog records are being used for this analysis. Riometer observations made with both wide-beam and narrow-beam systems at Roberval now are available and will be compared with simultaneous recordings made during 1975 at Siple.

With the cooperation of personnel of the National Oceanic and Atmospheric Administration (NOAA), wide-beam riometer observations at 30 and 51.4 megahertz were made continuously at Amundsen-Scott South Pole Station throughout 1975. The station intersects the auroral oval daily, so absorption occurs frequently. At the South Pole, there is no confusion of the riometer records by either daily solar elevation changes or variations in sky background; thus analysis of the records is straightforward. Although a digital magnetic tape recording was not made, high quality analog records were obtained. We find that the onset of absorption for events occurring when the station is in the night sector is faster than expected from previous observations. The figure shows an example. Although the chart speed is only 2.5 centimeters per hour, since the recorder operated by making impulses every 2 seconds, it is possible to measure the onset duration accurately. In the figure, absorption reaches a maximum of 7.1 decibels at 30 megahertz and 3.2 decibels at 51.4 megahertz in about 150 seconds. Detailed analysis of events like this shows that they are caused by absorbing ionization that initially occupies a narrow strip above the station. This strip of ionization is quickly replaced by broad ionization filling the beam. The mechanism for this rapid change is either expansion of the original strip or movement across the beam of an absorbing region that has a narrow band of intense ionization at its leading edge. Although the latter explanation is attractive because of the similarity to westward surges observed optically in satellite auroral pictures, a firm explanation cannot be made until spaced-station, narrow-beam riometer observations are possible. Only in this way can dynamic analysis of the auroral ionization be made for comparison with magnetospheric phenomena.

Operation of a 30-megahertz wide-beam riometer near McMurdo was made possible through the cooperation of the N.Z. personnel at Scott Base and at Lauder, New Zealand. The instrument operated successfully until September 1975, when an external cable broke. Operations were restored in January 1976. Initial analysis of the records shows no significant polar cap absorption during the operating period, although observing conditions were good. Several small events of short duration were observed. The facilities at Arrival Heights were expanded during the 1975-1976 austral sum-



Absorption event recorded on 30 and 51.4 megahertz at South Pole, 2240 Greenwich Mean Time, 14 March 1975.

mer so that 30- and 51.4-megahertz riometers are now operated there. Ratio analysis of these records will make possible a determination of whether the polar cap absorption events change in size as do those observed in the auroral oval.

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Electron precipitation and associated phenomena near the plasmapause

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During July 1975 the University of Maryland, in collaboration with the University of Houston and the Norwegian Institute of Cosmic Physics, conducted high-altitude measurements from balloons of X-rays, direct-current electric fields, and very low frequency (VLF) radiowave emissions. These measurements were made in the vicinity of Roberval, Quebec, Canada (48°N. 72°W.) and formed part of a cooperative program that included groundbased VLF direction-finding measurements in the Roberval area by groups from Stanford University, the University of Southampton, England, and the University of Tokyo, Japan.

The scientific purposes were (a) to investigate particle precipitation phenomena induced by natural VLF radio waves in the magnetosphere and by signals from the VLF transmitter at Siple Station (76°S. 84°W.), (b) to make direction-finding measurements on the magnetospherically propagated signals from the Siple transmitter in order to evaluate various types of direction-finding systems, and (c) to study the positions, movements, and relation to the plasmapause of particle precipitation regions and transmitter signal paths.

This report deals primarily with the balloon program. Six successful launches were made from 5 through 22 July. The table summarizes these flights. All flights carried an uncollimated sodium iodide scintillation counter provided by the University of Maryland. X-rays from precipitating electrons were detected and sorted into two integral energy channels (greater than 25,000 and greater than 500,000 electron volts) and seven differential energy channels between 25,000 and 500,000 electron volts. Four of the flights carried three-axis direct-current electric field probes provided by the University of Houston. The other two flights carried broadband (0 to 5,000 cycles per second) VLF radio receivers provided by the University of Oslo.

Measurements were made during both quiet conditions and geomagnetically disturbed periods. Rapid time variations of the enhanced X-ray flux and VLF emission intensity were evident during the disturbed periods. The E-field measurements also indicated the possibility of interesting correlative features with the X-ray flux. Two flights (on 15 and 22 July) were aloft when signals from the Siple transmitter were received at Roberval. Data from these flights are being examined for evidence of artificially stimulated effects in the particle precipitation. For the most part, however, the enhanced X-ray fluxes apparently resulted from

Balloon flight summary—Roberval, Quebec, Canada, July 1975.

Date	Launch (UT)	Terminate (UT)	Instrumentation	Remarks*
5	0426	1340	X-ray/E-field	Q
9	0828	2023	X-ray/E-field	DX
11	0844	1340	X-ray/VLF	DXV
15	0932	1725	X-ray/VLF	DXV
18	0920	1643	X-ray/E-field	DX
22	0802	1400	X-ray/E-field	Q

*Q = quiet conditions. DX = geomagnetically disturbed enhanced X-rays. DXV = geomagnetically disturbed enhanced X-ray and VLF emissions.

electron precipitation associated with natural wave-particle interactions and the occurrence of magnetospheric substorms.

A sequence of correlated X-ray and VLF bursts that occurred on 15 July is being analyzed in detail. A model that appears to account satisfactorily for the temporal relationships in these bursts has many features similar to the cyclotron resonance model used previously (Rosenberg *et al.*, 1971; Foster and Rosenberg, 1976) to explain correlated bursts observed at Siple Station. The new data, in addition, indicate the possible occurrence of natural electron echoes associated with magnetospheric wave-particle interactions. Other correlative studies are in progress. In a joint study with ISIS satellite particle experimenters, we are examining profiles of precipitated electron flux versus magnetic latitude obtained during balloon flights from Roberval in 1975 and 1973 and from Siple Station in 1971. These profiles could provide evidence that enhanced electron precipitation (energies over 40,000 electron volts) just outside the plasmapause is characteristic of the subauroral response to magnetospheric substorms.

The research at the University of Maryland was partially supported by National Science Foundation grant DPP 74-01704. Additional support for operations in Canada was provided by the Office of Naval Research under contract N00014-67-A-0239-0033.

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Sudden impulses in the magnetic field at high latitudes

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Operation of the three-component induction magnetometer and associated data recording systems at the Soviet Union's Vostok Station (78°28'S. 106°48'E.) continued in cooperation with Soviet scientists of the Arctic and Antarctic Scientific Research Institute, Leningrad. An identical induction magnetometer system was also operated at Thule, Greenland.

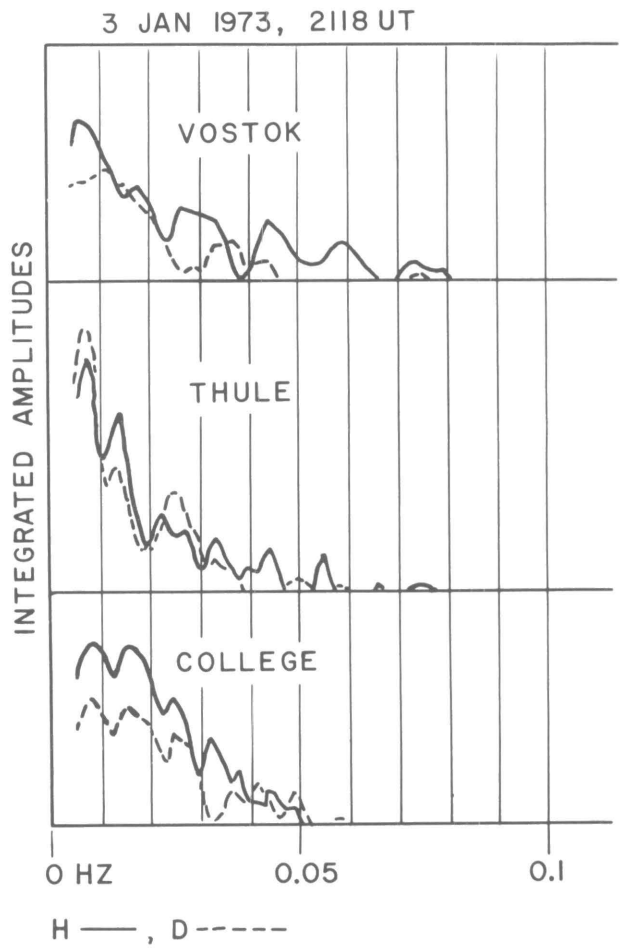

Figure 1. Amplitude spectra for an SSC that occurred at 2118 Universal Time (UT), 3 January 1973. Amplitudes were integrated over a 6-minute interval.

We studied micropulsations associated with magnetic storm sudden commencements (SSCs) and sudden impulses (SIs), and impulses not included in the published ssc and si lists. Those micropulsation effects are divided into two categories: the impulse, itself, and the events of few minutes to an hour in duration that commence with the impulse. It is well known that many SSCs trigger pulsation events of types Pc-1, Pc-2, Pc-3, Pc-4, and Pc-5 (see review in Saito, 1969). Further, our work has shown that SSCs that trigger magnetospheric substorms (Kawasaki *et al.,* 1971) have type Pi pulsation events commencing with the ssc.

Prince *et al.* (1965) determined the theoretical impulse response of the magnetosphere, isotropic mode, and Heacock (1969) gave evidence for isotropic mode propagation of the impulse, also noting that the impulse often contains energy to 0.5 hertz. Our discussion is confined to Pc-3 and Pc-4 frequencies (0.007 to 0.1 hertz). The impulse wave packet, propagating across field lines in the isotropic mode, may couple into the anisotropic mode in localized regions, for example at the plasmapause (Chen and Hasegawa, 1974). Spectral peaks thus could be found in data from sites on closed field lines that are not present in the simultaneous Vostok or Thule data. A search for such localized oscillations at College, Alaska, was made with generally negative results. In most cases, the College spectra are very similar to those for Thule and Vostok in the gross features, although fine structure differences always exist. Figure 1 shows amplitude spectra for an impulse that was reported as an ssc by many magnetic observatories.

In some events, marked differences were found between the H and D spectra for the same site (for example, Vostok, figure 1). This characteristic was also reported by Fukunishi (1975) in data recorded at lower latitudes. Our data suggest that the spectrum for waves coming from the morning sector of the magnetosphere is not necessarily similar for a given impulse to that for the afternoon sector. If, for example, the H sensor points into morning and the D into afternoon, the spectrum sensed in H may differ significantly from D.

Figure 2 gives spectra for an impulse not listed as an ssc or an si. As in most cases, the spectra are flatter than for SSCs; that is, there is relatively less energy in the lowest frequencies. Energy must be prominent in the lowest frequencies to recognize the impulse on ordinary magnetograms. The occurrence frequency of unlisted impulses is so high that their total contribution to Pc-3 and Pc-4 activity is significant, consistent with the suggestions of Lanzerotti *et al.* (1975).

Sugiura (1965) found from theoretical considerations that the rise time of a given ssc should be about the same throughout the magnetosphere.

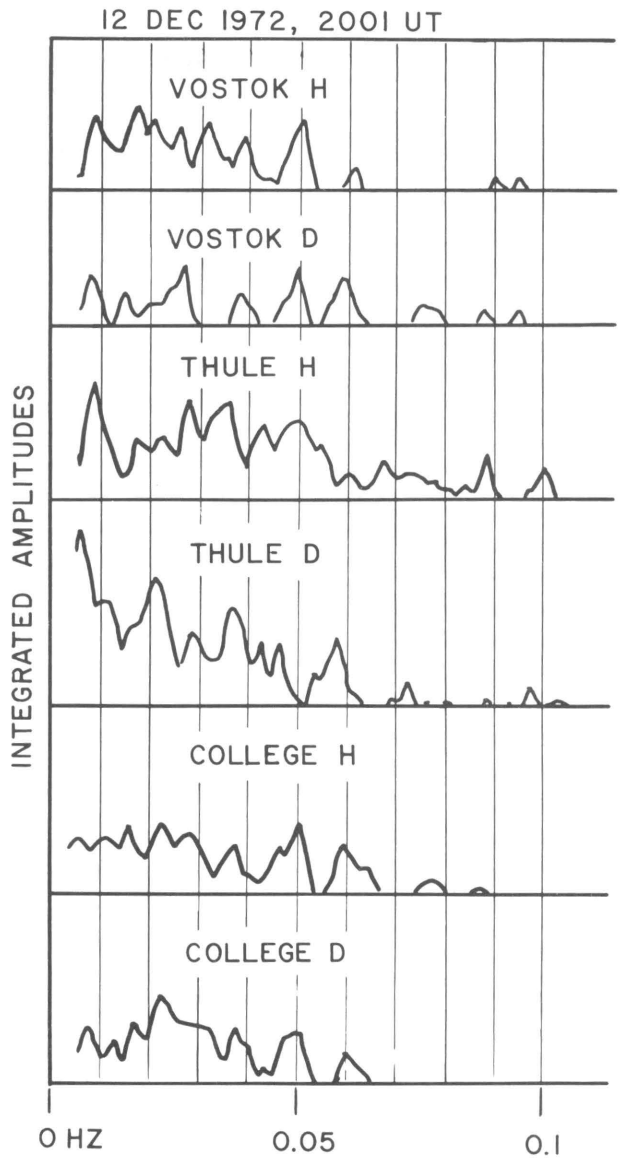

Figure 2. Amplitude spectra for an unlisted impulse that occurred at 2001 UT, 12 December 1972.

This study's observed similarities in steepness of the spectra for Vostok, Thule, and College (figures 1 and 2), i.e. quicker impulses have more abundant high frequencies at all sites, support Sugiura's prediction and show that some characteristics of impulses at the magnetopause can be determined from observations at a single site. Source spectra of the impulses, as measured at satellites near the magnetopause, are needed to extend this work.

This research was supported by National Science

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Cosmic ray intensity variations

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In the last year we have made progress in understanding two diverse phenomena: (1) transient production of relativistic cosmic rays (approximately 1 gigaelectronvolt) in the solar system, an exceedingly rare occurrence, and (2) transient reduction of the galactic cosmic ray intensity, a commonplace occurrence.

Interplanetary acceleration. The extraordinary sequence of solar and interplanetary events that occurred in August 1972 was noted earlier (Pomerantz and Duggal, 1973, 1974a). On the basis of available geophysical and space data, we attributed the abnormal intensity versus time profile observed at South Pole to the arrival of relativistic cosmic rays that had been accelerated in interplanetary space, rather than at the sun (Pomerantz and Duggal, 1974b). In particular, we suggested that the

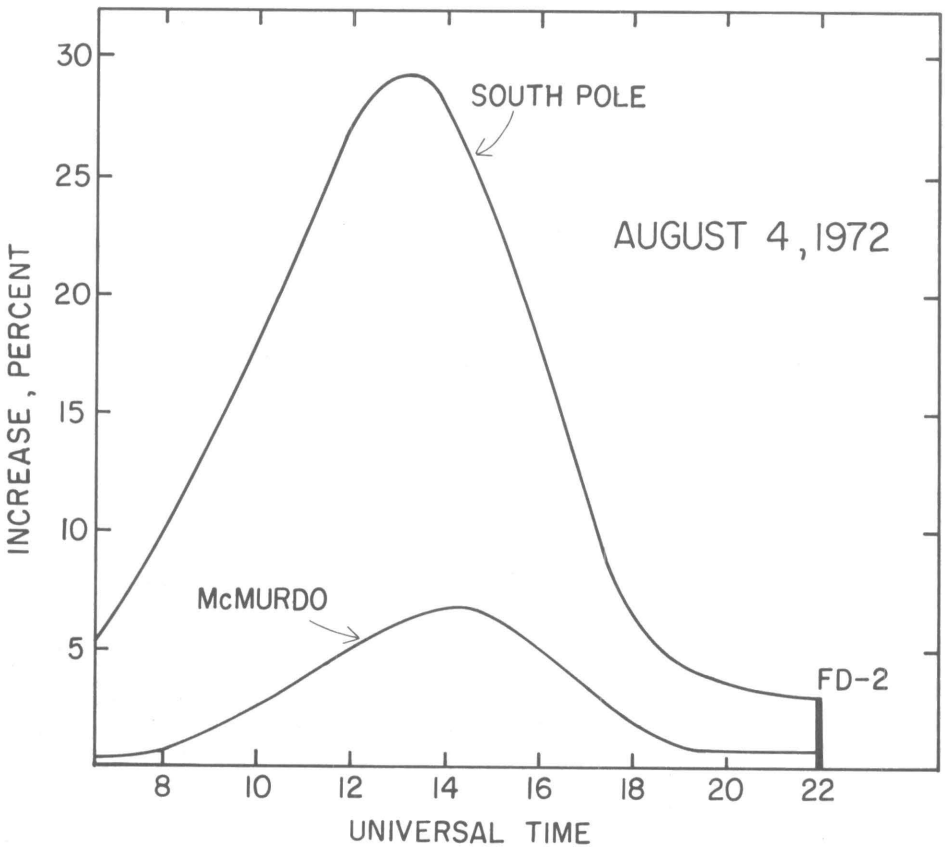

Figure 1. Calculated evolution of the nucleonic intensity enhancements at South Pole and McMurdo produced by relativistic cosmic rays accelerated in interplanetary space. The curves differ because the atmospheric cutoff at the higher altitude (about 0.9 gigavolt) is lower than that at sea level (about 1.1 gigavolts). FD-2 represents the onset of a Forbush decrease produced by the passage of the second shock of the pair between which the particles were multiply reflected.

enigmatic enhancement was produced by particles that had suffered multiple reflections between a pair of converging shock waves which sandwiched the earth. Levy *et al.* (1976) confirmed this model quantitatively by theoretical calculations of adiabatic acceleration through the first order Fermi process.

Figure 1 shows the intensity profiles for McMurdo and South Pole, predicted on the basis of the observed shock parameters. The computed results agree substantially with the nucleonic intensity measurements. Delay in initial growth of the observed flux compared with the calculated curves can be ascribed to late development of the particle reflection coefficient of the interplanetary shock fronts. Further study has revealed that the conditions required for accelerating particles to relativistic energy in this manner occur rarely in the solar system. However, some galactic cosmic rays may be accelerated by this mechanism elsewhere on a far larger scale.

Transient modulation. Forbush decreases and other transient intensity modulations generally have been attributed to the after effects of solar flares. This conventional approach must be modified in the light of a new study that is still in progress. Figure 2 shows the result of a superposed epoch analysis of the nucleonic intensity at McMurdo, with the zero day corresponding to the time of occurrence of all solar flares with Importance of at least 2 during the 11-year period 1964-1974 (one sunspot cycle). This figure reveals an unexpected result: the composite cosmic ray decrease starts several days *before* the time of arrival of solar plasma from the flares, indicated by the vertical dashed line. Consequently, extreme caution must be exercised in assigning specific flares to observed cosmic ray intensity fluctuations. Preliminary investigation of this puzzling finding has indicated that, contrary to folklore, the majority of the transients are, in fact, produced by the central meridian passage of active centers (Duggal and Pomerantz, 1976).

This research was supported by National Science Foundation grant DPP 75-03324.

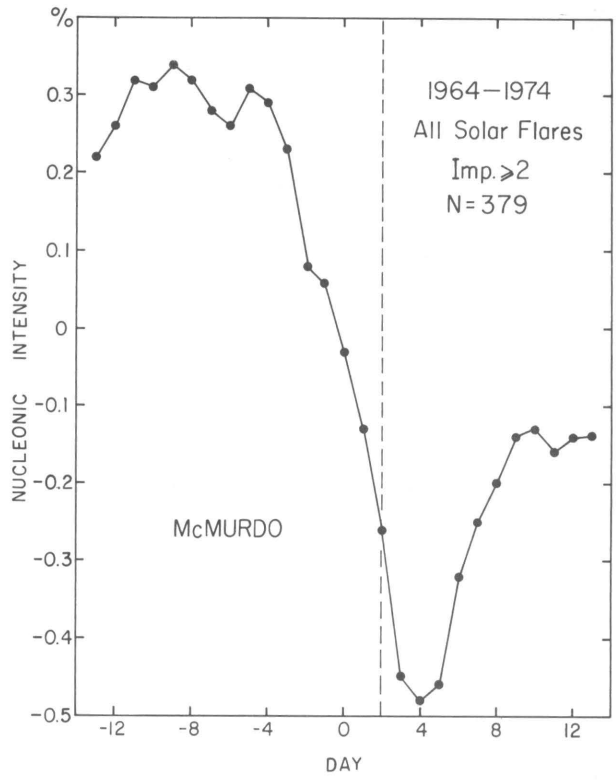

Figure 2. Superposed epoch analysis of the cosmic ray intensity at McMurdo. Day zero is the time of occurrence of each of the 379 solar flares having an Importance of at least 2 during an entire sunspot cycle. The dashed line indicates the arrival near earth of the associated solar plasma that previously was assumed to coincide with the onset of the modulation.

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South Pole auroral photographs taken by DMSP satellites and an all-sky camera

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An exciting event in auroral studies in 1975-1976 was the successful operation of auroral scanners aboard the DMSP (Defense Meteorological Satellite

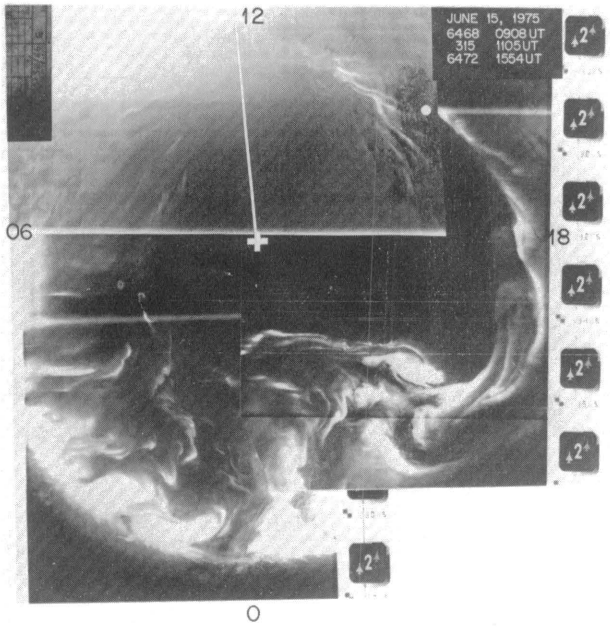

Figure 1. Montage photograph of the auroral oval taken from above the Antarctic on 15 June 1975.

Program) -8531 and -10533 satellites (Snyder and Akasofu, 1976).

The scanners remove sunlight interference and thus provide remarkable photographs of auroras that lie along the late morning, midday, and early afternoon parts of the auroral oval over the Antarctic. Figure 1 shows a composite (montage) photograph taken from DMSP-8351 (orbits 6468 and 6472) and DMSP-10533 (orbit 315) on 15 June 1975 (Akasofu, in press). A cross locates the variant pole, and a line from the invariant pole toward the top of the photograph locates the magnetic noon meridian. The midnight sector of the oval is toward the bottom, the afternoon-morning sector is on the right side, and the forenoon-morning sector is on the left side. Typical substorm features, such as a large-scale poleward expanding bulge, an intense westward traveling surge, and well-developed omega bands, can be identified.

Photographs are taken by DMSP about every 100 minutes. All-sky photographs are taken from the South Pole every minute. The combined availability increases the usefulness of both the DMSP and the all-sky photographs. For example, auroral arcs in the morning sector have not been studied in detail because they occupy a much larger area than an all-sky camera can cover and they vary considerably during the orbital period of DMSP satellites.

Fortunately, we now have both all-sky photographs and DMSP photographs that supplement each other in studying these auroras. Figure 2 shows an example: simultaneous DMSP and all-sky photographs taken at 1023 Universal Time (UT) on 12 June 1975; it also includes several all-sky photographs taken shortly before and after passage of the satellite. Analysis of these photographs is in progress.

This research was supported by National Science Foundation grant DPP 71-04051.

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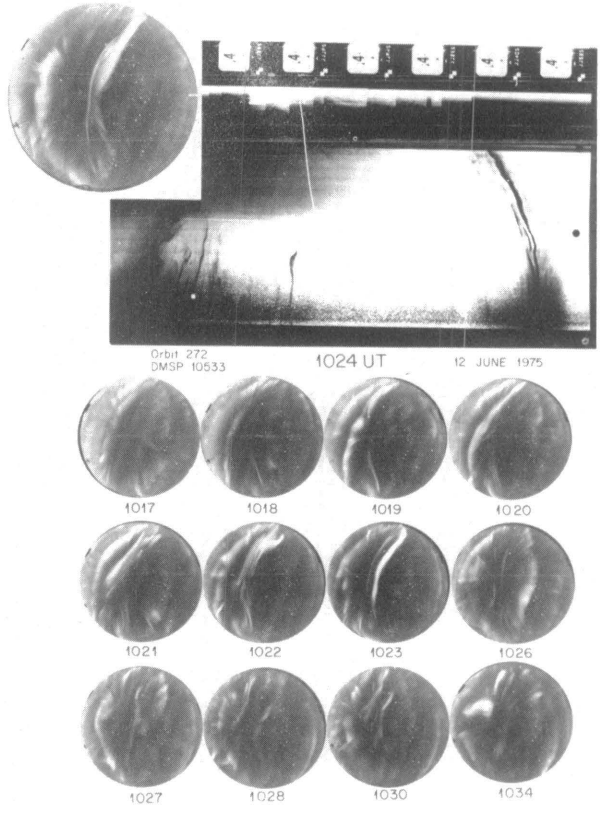

Figure 2. Simultaneous auroral photographs taken from the South Pole and from the DMSP-8531 satellite at 1024 Universal Time, 12 June 1975, together with several all-sky photographs before and after the satellite passage.

Acoustic echo sounding of the atmosphere boundary layer at the South Pole

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An atmospheric acoustic echo sounder, with a vertical range of 600 meters, was operated successfully at Amundsen-Scott South Pole Station throughout 1975. The sounder operates on a backscatter principle similar to that of radar. It utilizes as scatterers small-scale (10-centimeter) temperature inhomogeneities produced by turbulence in regions of larger scale temperature gradients. Such gradients occur typically in temperature inversions and in superadiabatic regions associated with convection from a warm surface. The facsimile recordings obtained from the sounder thus allow one to trace the evolution of inversion layers such as those that generally occur at the South Pole.

The records obtained during 1975 provide a detailed climatology of the atmospheric boundary layer at the Pole. They show the response of the boundary layer to synoptic scale disturbances. Events such as cold fronts are revealed well (figure

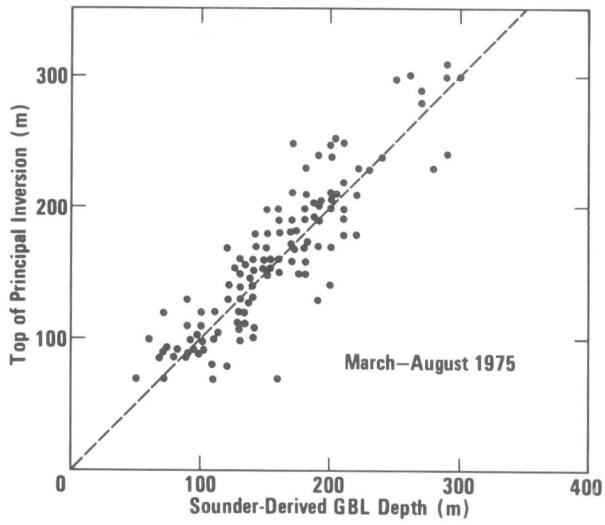

Figure 2. Comparison of the depth of the ground-base layer (GBL) from the sounder facsimile with the depth of the principal ground-based inversion obtained from the daily rawinsonde. The dashed line represents perfect agreement. A least-squares fit gave a slope of 0.94 with an x intercept of 10 meters. The standard deviation from the best-fit line was 20 meters.

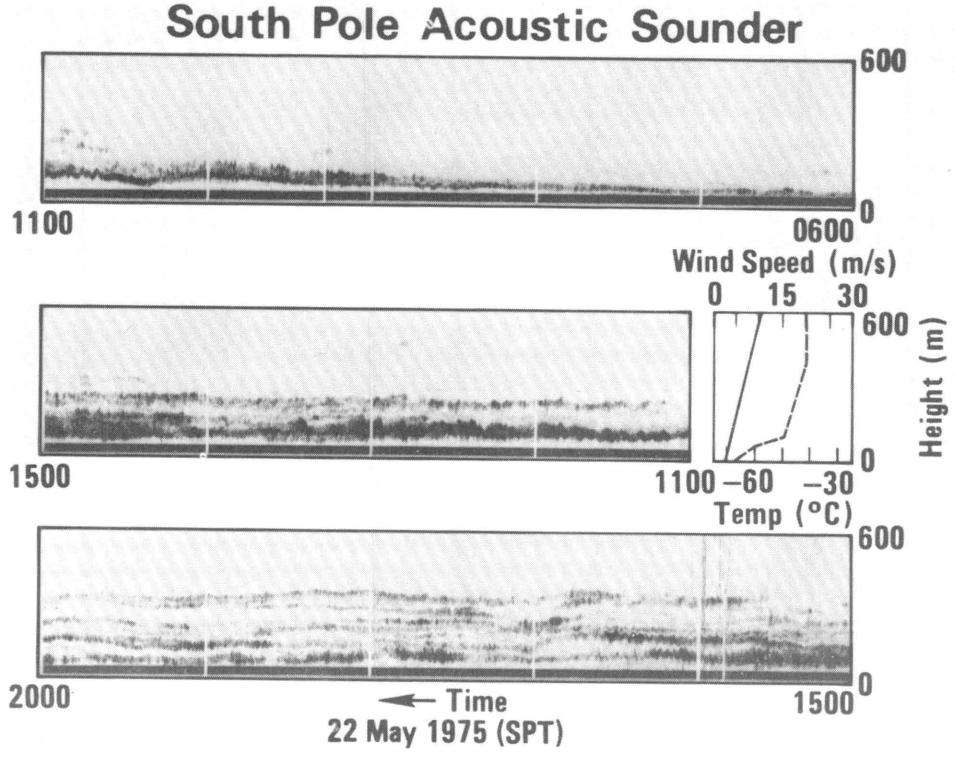

Figure 1. Facsimile recording obtained on 22 May 1975 showing cold "front" arrival at South Pole Station. The surface pressure minimum occurred at 0700 local time (1900 Greenwich Mean Time, 21 May 1975).

1) because of the increased scattering at the boundary of the cold air mass. Such events, because of the filtering effect of the surface inversion and the sparsity of rawinsonde observations, have in the past been ill-defined over the ice dome.

The "undisturbed" inversion layer usually was associated with an almost continuous echo that extended beyond the 40-meter minimum range of the sounder to heights as great as 300 meters. The deepest layers generally occurred during the strong winds that typify warm, moist advection from the quadrant west of the Greenwich meridian. The top of the echo region corresponded to the top of the principal ground-based inversion measured by the daily rawinsonde. Figure 2 is a scatter diagram based on the period March to August 1975. The depth of the echo layer was found to vary inversely with the static stability. This behavior, described in more detail by Neff and Hall (in press), suggests a turbulent Ekman layer. We are testing this hypothesis in cooperation with the University of California at Davis using the University's micrometeorological data from the Pole.

During 58 hours of the more than 6,000 hours the sounder operated, the sounder detected convective plumes originating at the ice surface. Five such events occurred, each during a rapid decrease in surface temperature. We hypothesize that rapid intrusion of colder air over the relatively warmer ice sets off the convection. On 17 December plumes extended to 400 meters for 18 hours. This event showed a gradually rising, capping inversion that eventually exceeded the sounder's 600-meter range.

We plan further studies using a bistatic acoustic sounder during 1977 to obtain quantitative information on the turbulence structure above the layer that can be studied using surface instruments. A microbarograph array is to be installed in January 1977 to aid in the interpretation of the acoustic sounder data.

This research is supported in part by National Science Foundation grant DPP 74-24415.

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Terrain-induced vertical motion and occurrence of ice crystal fall at South Pole in summer

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The phenomenon of ice crystal fall so frequently observed on the high antarctic plateau has aroused much interest since Rusin (1961) published frequency statistics of this minute precipitation for several U.S.S.R. stations and the meteorologists of Plateau Station reported their observations (Kuhn, 1970; Miller and Schwerdtfeger, 1972). Falling ice crystals have been measured directly in the last 2 years at Amundsen-Scott South Pole Station by Smiley and Warburton (1975) and by Ohtake (in press). In a comprehensive analysis of the moisture budget of the boundary layer over the plateau, Miller (1974) showed that only in the warmest layer, above the surface inversion, can the air hold enough moisture to account for growth of ice crystals to the observed size. On the other hand, Hogan (1974) found a relationship between high (cirrus) clouds and ice crystal fall near the ground at the South Pole.

During the 1975-1976 austral summer, Mr. Lax, a meteorologist at the South Pole who gave attention to ice crystal precipitation, discovered that on most days with ice crystal fall, the air in the lower layers was moving upslope toward the Pole. This observation has now been examined using the data of five summer seasons (1971-1972 to 1975-1976). Since it is impossible to construct trajectories of the air with the data of a single station, a simple classification for the direction of the vector mean wind at 650- and 600-millibar levels (approximately 300 to 800 meters above ground, the warmest layer on almost all days) was chosen according to the topography of the antarctic plateau: A = days with winds from the half-circle between 45° and 225°, which includes East Antarctica and the Ross Sea sector (that is, winds from terrain higher than South Pole); B = days with winds from the opposite half-circle, including the Weddell Sea sector (that is, from lower terrain). In the two summer months of December and January, measurable snowfall is a rare phenomenon at the South Pole, and on cloudy days no clear distinction is possible between intense ice crystal fall and light snowfall. Therefore, days with

any kind of precipitation were summarily classified as group I, days without as group II. The result is shown in the table.

We conclude that the terrain-induced rising of the warmest layer (which can carry more water vapor than colder layers) with the corresponding adiabatic cooling is instrumental for the occurrence of ice crystal precipitation. Conversely, the sinking of moist air after it passes terrain a few hundred meters higher diminishes the chance for ice crystal formation or survival. This conclusion is supported by statistics of the maximum relative humidity recorded each day in the warmest layer above the inversion in the 1975-1976 summer for which detailed sounding evaluations were available: there were 29 days with a highest relative humidity value of 80 percent or more, which means supersaturation with respect to ice at South Pole temperatures; in 25 of these days, ice crystal fall was observed.

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Number of days, December and January 1971-1972 through 1975-1976 (total = all days with wind soundings).

Group	Sector A	Sector B	Total
I	29	150	179
II	53	48	101
Totals	82	198	280

$X^2 = 39.2$, to be compared with 10.8 for significance with one degree of freedom at the 0.1-percent level.

Lidar studies for polar regions

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In the austral winter of 1975, vertical lidar (optical radar) soundings of the troposphere were taken simultaneously to provide information on precipitation falling out. Bruce Morley operated the equipment. The purpose of the measurements is to determine where ice crystals are formed in the atmosphere and to study the sizes, types, and relative concentrations of crystals under different conditions. Figure 1 is a block diagram of the lidar and data acquisition system. The detection limit is about 0.1 crystal per liter for a crystal size of 400 microns at an altitude of 1 kilometer.

Data reduction is not yet complete, and further data are required before general conclusions can be stated. However, as during summer (Smiley *et al.,* 1975) precipitation was observed from a clear sky and in the presence of cloud layers.

Interesting examples occurred near sunrise. Figure 2 is an average over 5 hours on 23 September 1975 of range-corrected lidar returns. The curve shows a thick cloud layer extending from about 0.6 kilometer to over 7 kilometers above the surface. Light precipitation of crystals was observed during this period. Most of the crystals were shaped like bullets or columns, having a bimodal size distribution with peaks at 125 and 250 microns. The mean size was 200 microns. The mean crystal flux rate was 370 crystals per square centimeter per hour. In addition, there were many smaller plates and columns. In summer, most of the observed crystals were much larger than this. Figure 3 is an averaged lidar return taken just before sunrise showing a thick upper ice crystal cloud layer with a thinner, more tenuous layer at about 0.6 kilometer from which ice crystals are precipitating. Crystals falling out of higher layers may grow in lower layers having enough moisture.

In addition to the field work, we studied a relatively new lidar technique, referred to as differential absorption backscatter spectroscopy, for obtaining vertical profiles of water vapor in the polar atmosphere (Whitcomb and Smiley, 1975). The technique works on a principle developed by Schotland (1966): a laser transmitter emits two

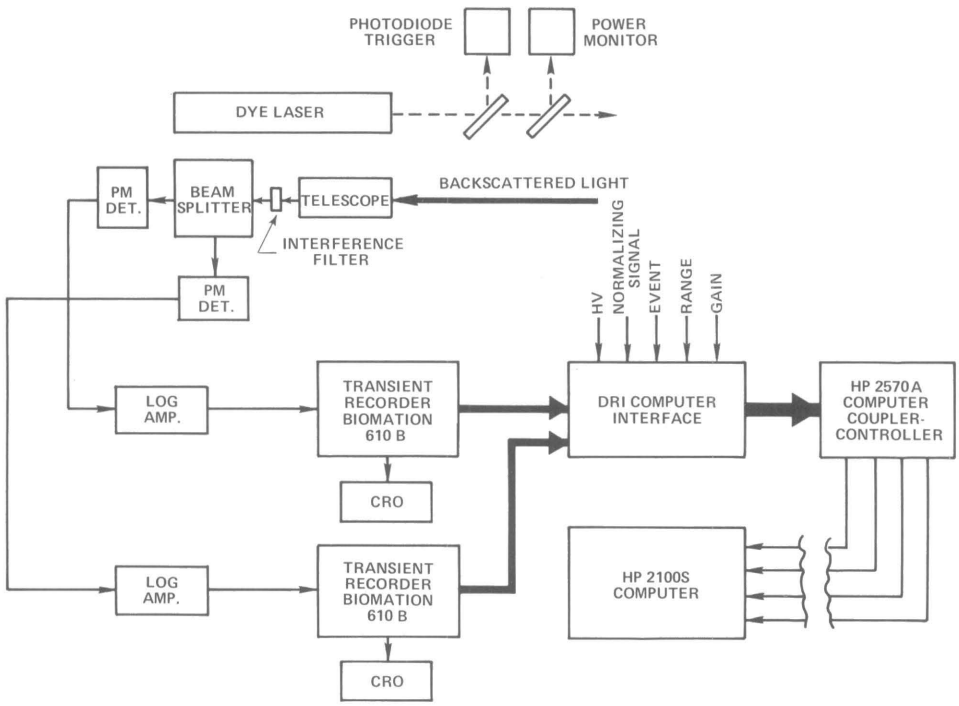

Figure 1. Block diagram of lidar and data acquisition scheme.

pulses at two different wavelengths simultaneously or almost simultaneously. One wavelength coincides exactly with a molecular absorption line for a particular gas under study, and the other with a "window" region free of atmospheric absorption. The gaseous concentration as a function of range can be obtained from the two return signals backscattered by molecules and aerosols. Since water

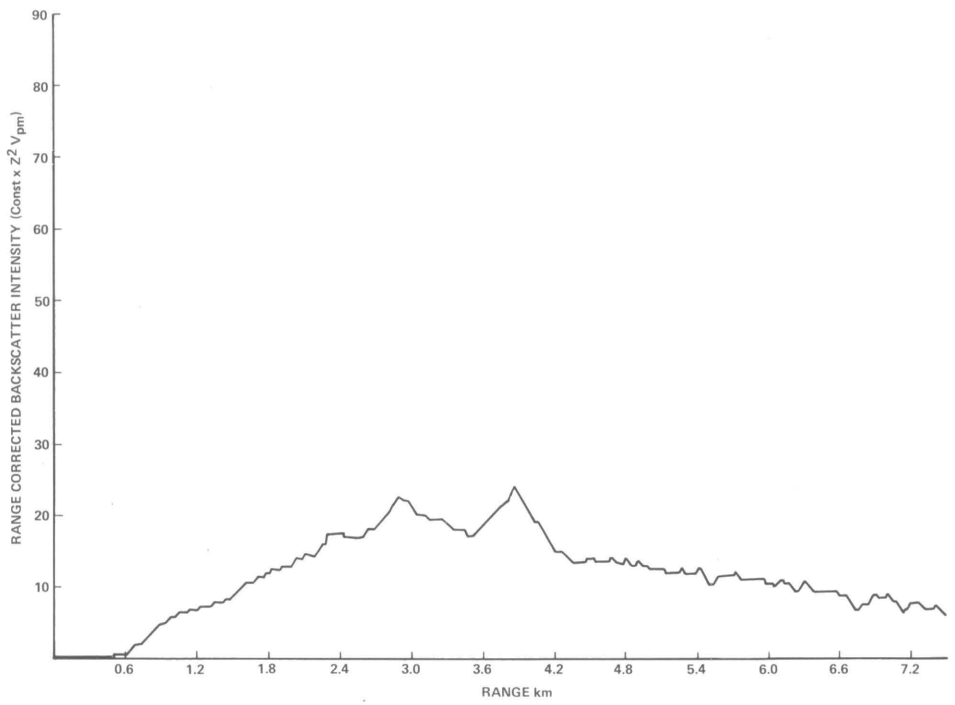

Figure 2. Average lidar return signal from cloud layers at the South Pole on 23 September from 0100 to 0550 Greenwich Mean Time (GMT).

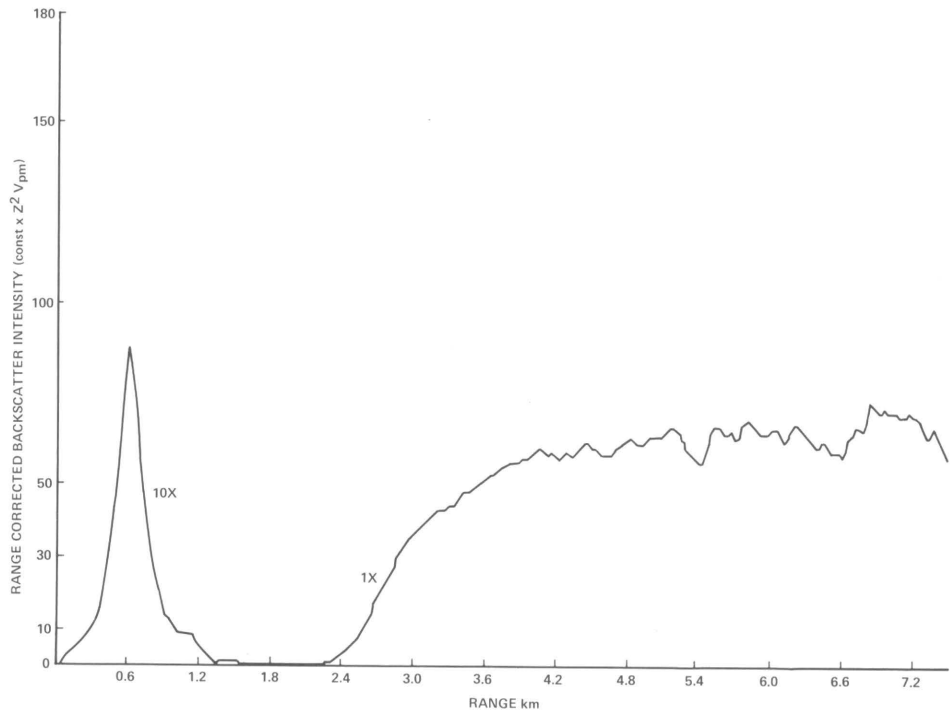

Figure 3. Average lidar return signal from cloud layers at the South Pole on 18 September 1975 from 0200 to 0350 GMT.

vapor concentrations are very low in the polar regions, intense absorption lines must be used to obtain a significant difference in the two signals. Calculations were made of expected lidar returns for intense water lines covered by new infrared laser dyes in the 0.94-micron water band. Figure 4 shows the calculated returns for polar winter conditions for several 0.94-micron lines with laser pulse

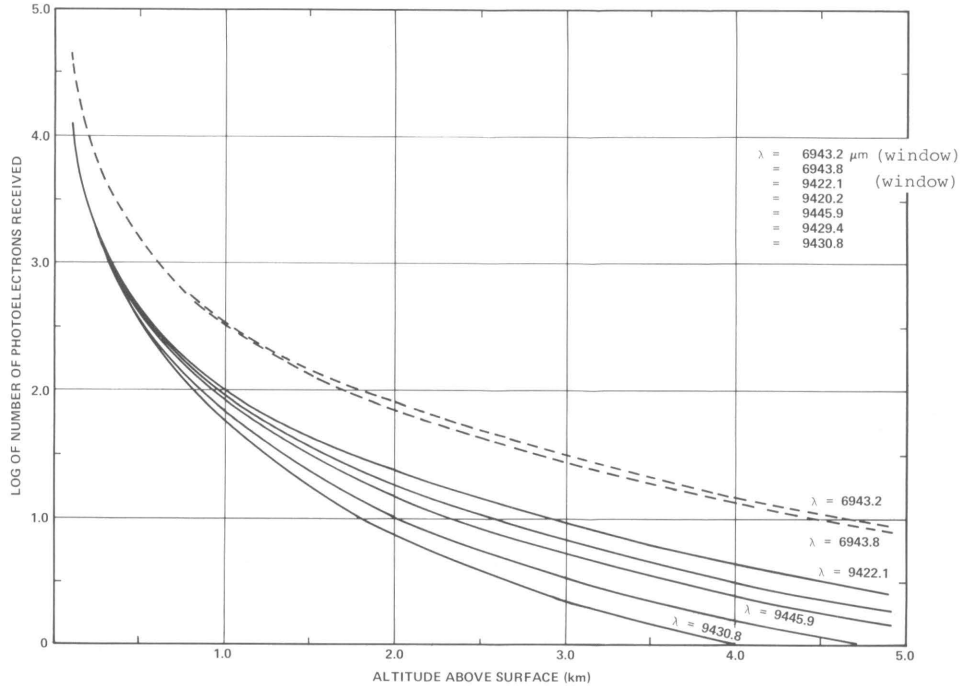

Figure 4. Calculated lidar return for the South Pole austral-winter atmosphere.

energy of 50 millijoules, scattering cell length of 100 meters, receiver aperture of 500 square centimeters, and an S-1 photomultiplier detector. For comparison, figure 4 shows results for a tunable ruby lidar operating at 0.69 micron and having the same specifications as above except for an S-20 photomultiplier. The separation between returns for the ruby lidar is insufficient to permit the use of that system for water vapor measurements in the polar winter.

Analysis of these returns shows that a two-wavelength dye laser lidar should be able to measure water vapor under polar winter conditions to a height of about 3 kilometers with several minutes of integration time.

This project was supported by National Science Foundation grant DPP 74-04990.

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Source of nuclei of atmospheric ice crystals at the South Pole

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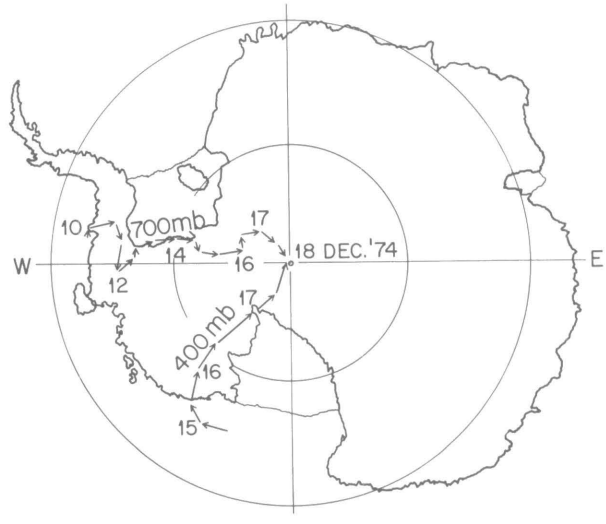
In the last 30 years, meteorologists have used transmission electron microscopes and electron microdiffraction techniques to study the chemical composition of nuclei in cloud droplets and ice crystals. However, because only morphological techniques and electron microdiffraction techniques were applicable, only a few of the droplets and crystals were identified unambiguously as sea salt particles, soil particles, or combustion products. Now the scanning electron microscope, with X-ray analysis, opens a new field in investigating nucleation.

Nuclei of ice crystals collected at the South Pole were examined with a scanning electron microscope and an X-ray energy spectrometer combined to determine their source and their chemical composition. The nuclei were found throughout the crystals—not just at the centers. The table gives the elemental composition (for atomic numbers greater than 10) of nuclei in the crystals, the date of collection, and the shape and size of each crystal. No differentiation is made between centered and randomly located nuclei.

Twelve of 17 ice crystals had high silicon content. Ten crystals had aluminum, always combined with silicon. Two crystals had no detectable chemical elements. Most of the ice crystals taken on 17 and 18 December 1974 had primarily silicon and aluminum. In contrast, 7 of 12 crystals taken on 25 and 26 December had sodium, magnesium, chlorine, sulfur, potassium, and calcium (typical compositions of sea salt) combined with silicon and aluminum.

Air trajectory analyses using 400-millibar flow showed that air arriving at the South Pole normally enters the southwest part of the antarctic continent (90° to 170°W.) from the Pacific Ocean and travels about 1,700 kilometers in 2 to 4 days from the open ocean. So, ice nuclei such as kaolin particles and clay minerals indicating silicon and aluminum possibly are transported from the desert in Australia or from volcanos. (Volcanic ash from the recent volcanic eruption of Augustine Island, Alaska, showed strong nucleation ability in a settling cloud chamber: Ohtake, 1971.)



Air trajectories at 400- and 700-millibar levels arriving at the South Pole at 0000 local time, 18 December 1974. Each arrow indicates air flow every 12 hours.

Chemical elemental compositions (for elements heavier than neon only) of nuclei in individual ice crystals at South Pole.

Collected (Dec. 1974)	Time (local)	Si	Al	Na	Mg	S	Cl	Ca	K	Others	Shape	Size (microns)
17	17:49	+++	++					0			thin pl	150 dia
	17:49	+++	++								column	175×112
	22:30	++	++	0	0			0	0		thin pl	220 dia
18	04:30	++		0							thin pl	470 dia
	14:43			no detectable elements							thin pl	44 dia
25	10:10	+++									column	180×120
	10:10	+++	++	++	++	++	++	++	++	0Fe	plate	100 dia
	10:13	++	++	++	++	+	++				column	260×115
	10:17	++	0								column	167×110
	12:17			no detectable elements							column	140×97
	13:00					+					column	183×127
	13:00	++	+	++	++	++	+	++	++	+Mn	column	157×90
	13:00	+++	+	++	++	++	++	++	++		irreg.	170
26	15:58					++	+				thin pl	33
	15:58	++	+	+	0			0	+	+Mn	column	93×40
	15:58	+++	+++	+	+	++	++		+		column	70×40
	15:58			++	+	+				0Fe	plate	70

Because of the temperature inversion over Antarctica, the air in the lowest several hundred meters is very stable, and we made other trajectory analyses using 700-millibar charts. These analyses were intended to estimate the transport of sea salt particles from the ocean, assuming that the sea salt particles are larger than soil particles and that the flow at 700 millibar is geostrophic. We found that the air stayed over Antarctica before arrival at the South Pole much longer on 17 and 18 December than on 25 and 26 December. This difference may explain why the nuclei of the ice crystals on the latter days contained more sea salt mixed with silicon and aluminum.

This research was supported by National Science Foundation grant DPP 74-04037. I am indebted to Bruce Morley of the University of Nevada, who also collected the ice crystals at the South Pole, and to JEOL (West), Inc., and KEVEX Corporation for making the electron micrographs and X-ray analyses.

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Climatonomy model for the dry valleys with and without snowcover

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The dry valleys of southern Victoria Land near Ross Island are a natural, snowless anomaly immediately adjacent to the East Antarctic Ice Sheet. The valleys' existence suggests that the present snowless climate is stable. However, if the ground were to become snowcovered throughout the summer either by precipitation or by glaciation, would the terrain return to its present snowless state?

A climatonomy model developed by Lettau (1975) is being applied to this problem with the aid of 2 years of data from Vanda Station (Thompson *et al.,* 1971). Although still tentative, early results are presented here.

The model input includes monthly means of flux density of solar radiation absorbed at the ground, $F = (1-a^*)\,G$, where a^* is the surface albedo and G

Table 1. Inputs, parameters, and model-generated heat fluxes (watts per square meter) and surface temperature (°C) for Vanda Station with natural snowless conditions.

	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	mean
a*	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20
G (W/m²)	0	27	104	252	298	281	168	50	0	0	0	0	98.3
(G) (W/m²)	(2)	(14)	(102)	(246)	(289)	(303)	(169)	(33)	(4)	0	0	0	(96.8)
Input													
F (W/m²)	0	22	83	202	238	225	135	40	0	0	0	0	78.7
V (m/sec)	2.3	3.2	4.9	7.2	6.6	6.5	6.1	3.4	1.5	1.9	2.1	4.6	4.19
ΔT (°C)	−13.9	−9.3	0.0	2.6	3.5	3.7	2.5	−6.8	−12.1	−11.1	−11.6	−8.5	−5.1
Parameters													
A*	.38	.28	.23	.37	.42	.37	.31	.29	.23	.27	.31	.42	.323
r_s = 0.48 W/m²			r_q = 1.45 W/m²			t_s = 1.62 month				e* = 0.012			ϵ_s = 0.91
Output													
E (W/m²)	0	0	1	2	3	3	2	0	0	0	0	0	1.0
Q (W/m²)	−46	−28	21	72	89	91	63	−7	−26	−33	−36	−43	9.7
S (W/m²)	−6	3	12	27	15	17	−13	−11	−12	−8	−10	−14	0.0
LWU "	137	166	210	272	309	312	268	200	165	152	149	136	206
LWD "	85	120	161	172	178	198	186	142	127	111	103	79	138
(LW) "	(38)	(48)							(38)	(41)	(43)	(65)	
T_o (°C)	−45	−36	−23	−4	7	8	−5	−26	−36	−40	−41	−45	−23.7
(T_{air}) "	(−39)	(−33)	(−18)	(−7)	(1)	(2)	(−5)	(−18)	(−32)	(−34)	(−36)	(−39)	(−21.5)

Key: a* = surface albedo, G = global radiation, F = global radiation absorbed by surface, V = wind speed, ΔT = temperature at Vanda minus temperature at McMurdo, A* = Angstroem ratio, r_s and r_q = respondances for submedium conduction and eddy heat fluxes, t_s = retention time for submedium conduction, e* = evaporivity, ϵ_s = surface emissivity, flux density for latent heat = E, eddy heat = Q, submedium conduction = S, terrestrial radiation = LWU, and atmospheric radiation = LWD. T_o = surface temperature. Observed quantities are in parenthesis.

is the total global radiation. The latter has been synthesized successfully in an adapted form of shortwave radiation climatonomy (Lettau and Lettau, 1969). Table 1 lists the F values for the natural snowless surface, while table 2 gives F if a* were modified to represent clean snow.

The remaining inputs in table 1 include monthly means of V, the wind speed at Vanda Station in meters per second, and ΔT, the difference in air temperature between Vanda and McMurdo stations in °C. The advection of sensible heat Q′ is expressed as

$$Q' = \overline{Q}\, V(\Delta T - \overline{\Delta T})/\overline{V\,(\Delta T - \Delta T)}$$

where overbars denote annual means and $\overline{Q}$ is tentatively set at 9.7 watts per square meter, implying a net annual export of sensible heat from the valley

Table 2. Surface modification experiment: inputs, parameters, and model-generated heat fluxes (watts per square meter) and surface temperature (°C) for Vanda Station with snowcover.

	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	mean
a*	—	.90	.86	.85	.85	.85	.86	.87	—	—	—	—	.86
G (W/m²)	0	37	137	315	372	348	217	66	0	0	0	0	124.4
Input													
F (W/m²)	0	4	19	47	56	52	30	9	0	0	0	0	18.1
Q′ "	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−10	−9.7
LWD "	85	120	161	172	178	198	186	142	127	111	103	79	138.2
Parameters													
	r_s = 0.16 W/m² °K,				r_q = 0.48 W/M² °K,				t_s = 1.53 months,				e* = 0.15
													ϵ_s = 0.98
Output													
E (W/m²)	0	1	3	7	8	8	5	1	0	0	0	0	2.7
Q "	−20	−14	−7	−1	0	3	−1	−10	−13	−15	−17	−20	−9.7
S "	0	1	6	4	4	6	−3	−3	−2	−3	−3	−6	0.0
LWU "	105	136	178	211	220	235	213	163	142	131	122	104	163.3
T_o (°C)	−59	−48	−33	−21	−18	−12	−20	−38	−46	−50	−53	−59	−38.0

floor. The time series of Q′ reflects the "oasis" effect through the use of ΔT.

Parameters r_s and t_s follow from a theory for heat transfer in nonhomogeneous conductors (Lettau, 1962). Thermal diffusivity is assumed to vary with depth from 0.0048 square centimeters per second at the surface (sand) to 0.0088 square centimeters per second at ½-meter depth (50 percent sand, 50 percent granite). The e* parameter is simply defined $\overline{E} = e^* \overline{F}$ where $\overline{E}$ is a heat flux density equivalent to the annual precipitation. The respondance r_q is tentatively set at a constant 1.45 watts per square meter per °K, although future model development may show that r_q varies depending on the vertical temperature gradient. The Anstroem ratio A* may be parameterized in terms of local cloudiness and precipitable water estimates obtained from balloon soundings at McMurdo Station. The tentative A* values presented here are those necessary to generate the effective longwave fluxes to meet energy balance requirements for each month. The surface emissivity $\epsilon = 0.91$ is typical of sand.

The model appears to generate reasonable monthly surface temperatures and heat fluxes. Net radiation measurements during the sunless period are given as (LW) in table 1. Except in August these compare to within 20 percent with generated LWU-LWD values.

For the surface modification experiment, Q′ is assumed equal to the winter value for the natural surface and r_q is reduced to 0.48 watt per square meter per °K in agreement with studies done for Little America V. Submedium heat flux parameters r_s and t_s are modified to represent conduction through snow. Finally, the flux of atmospheric longwave radiation LWD is assumed equal to values generated for the snowless surface.

Table 2 illustrates the modeled fluxes and surface temperatures for the snowy surface. Despite the assumptions of negative Q′ and unchanged LWD, the effect of the high albedo so drastically reduces F that the surface temperature averages 15°C colder than for the natural surface. In fact, the temperature remains well below freezing even in the summer months. Of course, results are quite tentative and depend on the correct parameterization of LWD and Q, especially in summer, but the initial results suggest that a clean snow surface in the valley could maintain itself.

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Comparison of arctic and antarctic haze

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One of the world's most impressive sights is the Transantarctic Mountains as seen from McMurdo Station. Even though some of the mountain peaks are more than 400 kilometers distant, they can be seen with startling clarity and high contrast.

The excellent visibility in Antarctica implies that there is a very low level of haze there. Indeed, our measurements of the total vertical atmospheric transparency made at the South Pole indicate that the column mass of haze particles is only several milligrams per square meter. This is the cleanest air on earth.

Somewhat surprisingly, measurements made this year in the American Arctic show substantial levels of haze: up to 20 times the amount found at the South Pole. From an aircraft, the haze usually appears to be concentrated in thin layers that sometimes can be seen as dark-colored bands against the sky near the horizon. Trajectory analysis suggests that, at times, industrial pollution from central Europe may be responsible for the haze layers found in the Arctic. It also is possible that the haze is caused by dust transported by winds from the Gobi Desert.

Work is under way to determine the origin and the possible climatic impact of the polar haze.

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Annual temperature and ice condition changes in the Antarctic Peninsula area

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A surveillance of climatic data from stations around the Antarctic Peninsula shows that temperatures have changed remarkably in recent years. From the late 1940s to 1970, temperature variations from year to year on the west side of the Peninsula were related closely to those in the northern Weddell Sea: in every year, the British station Argentine Islands (65.3°S. 64.3°W., in operation since 1947) was colder than the old Argentine station Orcadas (60.7°S. 44.7°W.). Now, each year since 1971, Orcadas indicates lower annual temperatures than Argentine Islands, by about 2°C in the 5-year average, more than 3° in the last five winter half-years (table). The shorter records of Adelaide Island on the western (Bellingshausen Sea) side and three Argentine stations (Matienzo, Petrel, and Esperanza) in the northwestern Weddell Sea and Antarctic Sound confirm the recent change.

Concurrently, ice conditions in Marguerite Bay (about 68.3°S., south and southeast of Adelaide Island) have changed. This bay is the only area on the Peninsula's west side south of the antarctic circle for which a long, though not continuous, series of ice observations exists. Heap (1964) lists 23 summer seasons between 1908-1909 and 1961-1962 in which ships attempted to enter the bay. Only 15 attempts were successful, several taking place as late as March and under considerable difficulty. In contrast, for the five seasons 1971-1972 to 1975-1976 weekly ice maps reveal that the area between Adelaide Island and about 68.5°S., including Marguerite Bay, was essentially free of ice each summer during at least 2 to 3 months.

There were other significant changes in recent years. The pressure differences (at sea level) between Argentine and Adelaide islands were stronger in the last 5-year period than in most previous years, and the same is true for the pressure difference between King George Island (62.2°S. 58.9°W.) and Argentine Islands. This must be interpreted as an increase of the frequency or strength of the northwest component of the surface winds and thus of the advection of warmer air toward the west side of the Peninsula. This increase was most pronounced in June through October, when Marguerite Bay is ice-covered. A detailed analysis of these changes will be published soon; a prediction of future changes, however, is not intended.

Five-year averages of the temperature difference Argentine Islands minus Orcadas.*

Period	1947-1950	1951-1955	1956-1960	1961-1965	1966-1970	1971-1975
Annual values	(−0.7)	−1.8	−2.0	−1.2	−0.6	1.8
Six winter months April-September)	(−0.7)	−2.4	−2.9	−1.6	−0.2	3.4

*In parentheses: the first 4 years. The last 5 months of 1975 for Orcadas were extrapolated using data from the nearest station, Petrel. All temperatures °C.

Data from the Argentine stations were made available by the director general del Servicio Meteorológico Nacional and the chief of the Servicio Meteorológico A.R.A., Buenos Aires. Climatological summaries for the British stations were given by the British Antarctic Survey. Weekly ice maps were provided by the Fleet Weather Facility, U.S. Navy, Suitland, Maryland 20023. This study was supported by National Science Foundation grant DPP 71-04033.

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Solar radiation program aboard ARA *Islas Orcadas*

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Our research during 1975-1976 has been directed toward strengthening our understanding of the solar radiation environment in the South Atlantic Ocean. This knowledge is needed to study

the energetics of the region's biological as well as physical systems. The effort during the past year was twofold: evaluation and diagnosis of solar radiation data that were obtained during two austral summer cruises in 1975; continuation of the measurement program in this data-sparse area during three cruises in the austral winter and spring of 1975.

Measurement program

All related field efforts were conducted aboard ARA *Islas Orcadas*. Incident global solar radiation was measured with four intercalibrated pyranometers (Eppley precision spectroradiometers) exposed on the ship's helicopter pad. Although the immediate aim was to determine the total flux and the photosynthetically active radiation (PAR), the observations permit determination of fluxes associated with four broad spectral bands.

Measurements were made during cruises 3 (12-30 December 1974), 4 (12 January to 24 February 1975), 5 (4 May to 17 June 1975), 6A (4-12 August 1975), 6B (3-13 September 1975), and 7 (31 October to 18 December 1975). Although primary productivity experiments were not made during these cruises, participation was viewed as an excellent opportunity to extend our knowledge of the solar energy milieu of this region.

Results

Thus far we have evaluated data for cruises 3 and 4; these results are summarized here. Both cruises originated in Buenos Aires, Argentina, and terminated in Ushuaia, Tierra del Fuego, Argentina, thus providing a good definition of latitudinal variations.

Cruise 3. This cruise was concentrated in the Drake Passage area. It was temporally centered on the austral summer solstice (22 December), when fluxes of solar energy were at maximum. Clear-sky totals ranged from 700 calories per square centimeter per day at 45°S. to 451 calories per square centimeter per day at 65°S. Corresponding values of PAR were 323 and 232 calories per square centimeter per day. Anomalously low values were found in the cloudy stormtrack zone near 55°S. The influence of cloudiness on solar radiation was well marked by large interdiurnal ranges, by an unequal partitioning of daily energy with respect to local apparent noon (LAN), and by large variations in the quality of the incident flux. In this latter regard, PAR amounted to 46 percent of the total under clear skies, but it was as much as 62 percent under overcast skies. Adjacent to the islands and coastal regions of the Antarctic Peninsula, near 65°S., anomalously high values were observed. This enhancement is associated with lesser cloud amounts and reflection by the snow-covered topographic features.

Cruise 4. Primarily in the Drake Passage and the western Scotia Sea, this cruise was temporally centered more than a month after the solstice when solar fluxes were much reduced. Maximum daily values ranged from 577 calories per square centimeter per day at 45°S. to 303 calories per square centimeter per day at 60°S. Related values of PAR were 300 and 150 calories per square centimeter per day. As with cruise 3, anomalously low values were found along the migratory stormtrack near 55°S., and the dominant role of cloudiness was evident: large interdiurnal variations, diurnal asymmetry with respect to LAN, and modification of flux quality. As a fraction of the total flux, PAR values ranged from a minimum of 46 percent under clear skies to a maximum of 67 percent with overcast conditions.

Comment

For energy budget investigations, biological and physical, the dominant influence of cloudiness on available radiation, its quality and variability, is of prime importance.

For their valuable cooperation, support, and assistance, we are grateful to our Argentine colleagues, especially Angel Abregu, and to Paul Dudley-Hart. This study was sponsored by National Science Foundation grant DPP 76-01121.

FDRAKE, 1976

R/V *Thomas G. Thompson* of the University of Washington and AGS *Yelcho* of the Chilean navy were involved during February, March, and early April of 1976 in the second part of a field experiment within the Drake Passage and the western Scotia Sea entitled the First Dynamic Response and Kinematics Experiment (FDRAKE).

FDRAKE is a component of the International Southern Ocean Studies (Neal, 1974) sponsored by the Office for the International Decade of Ocean Exploration of the National Science Foundation. The program consists of experiments begun during the austral summer of 1974-1975 and scheduled to continue until early 1978. The goals of FDRAKE are (1) to identify and study the energy-containing time and space scales within the Antarctic Circumpolar Current and thus provide information intended to aid in designing an experiment for the long-term monitoring of transport of this current to begin in 1978 when other global atmospheric and oceanic experiments are planned, (2) to describe selected property distributions within the Drake Passage and the western Scotia Sea, and (3) to study the processes involved in the formation of water masses, in particular those processes within the Polar Front Zone involved in the formation of Antarctic Intermediate Water.

Accounts of the field activities during FDRAKE, 1975, appeared in Gordon (1975), Nowlin *et al.* (1975), and Wearn and Park (1975). The following three articles report on the activities and accomplishments during FDRAKE, 1976.

— STEVEN L. PATTERSON

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Contributions of R/V *Thompson* legs 1 and 2 to FDRAKE, 1976

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As a continuation of the First Dynamic Response and Kinematics Experiment (FDRAKE), a part of the

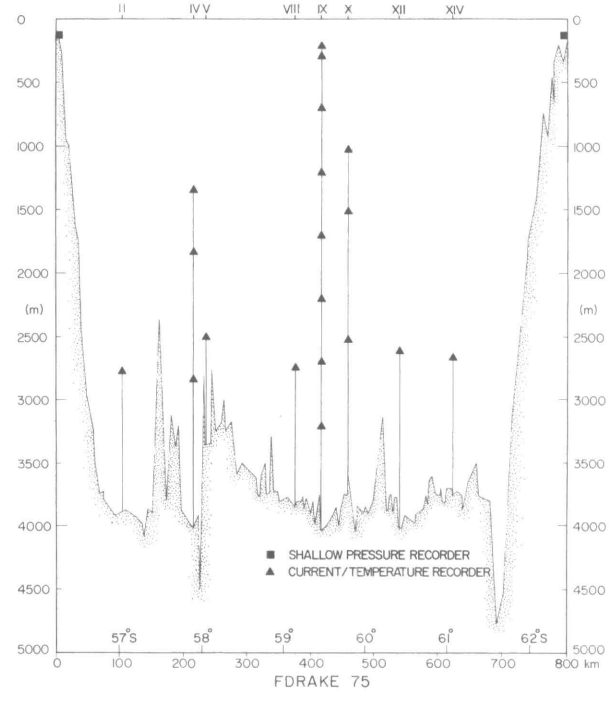

Figure 1a. Long-term array deployed in 1975.

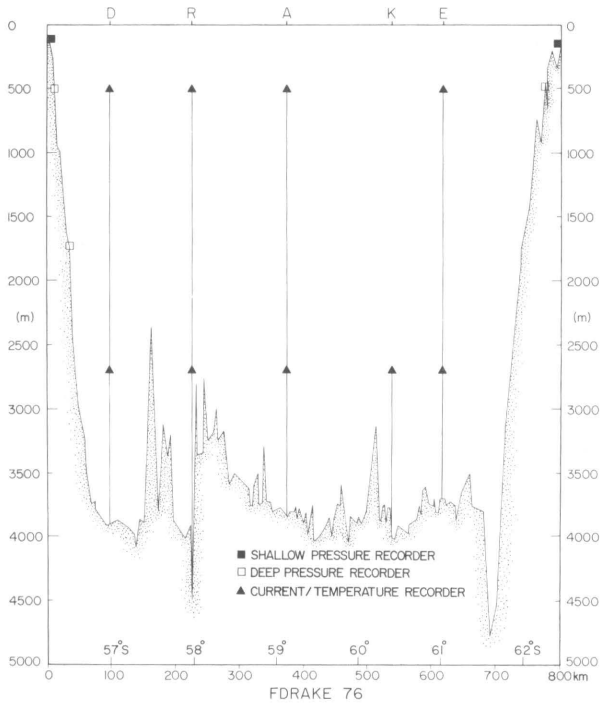

Figure 1b. Long-term array deployed in 1976.

International Southern Ocean Studies, further field work was carried out in the Drake Passage in February and March 1976. Dr. Nowlin directed the scientific program during legs 1 and 2 aboard R/V *Thomas G. Thompson*. The data on the meso- and large-scale variability of the Circumantarctic Current (also called Antarctic Circumpolar Current) will be used to determine the feasibility of monitoring its transport, with the objective of relating transport variations to the forcing functions caused by oceanic/ice/atmosphere interactions. Specific to FDRAKE, 1976, objectives were (1) to recover an array of current, temperature, and sea-level (shallow pressure) recorders deployed from R/V *Melville* during FDRAKE, 1975, in February and March 1975, (2) to deploy across the Drake Passage an array of current, temperature, and deep- and shallow-pressure recorders to remain for 1 year, (3) to obtain sections of temperature and salinity across the Passage to use with the kinematic measurements to estimate transports and to assess the smallest horizontal scales and spatial statistics of significant baroclinic structure, (4) to obtain density measurements at pairs of stations bracketing the moorings having more than one current meter for use in comparing geostrophic and measured vertical gradients of kinematic quantities, (5) to obtain high precision nutrient measurements for use with those obtained during FDRAKE, 1975, for study of water mass distributions and chemical balances in the Circumantarctic Current, (6) to obtain data in the east-west trending trench at the southern end of the Drake Passage to assess bottom water exchange between Antantic and Pacific, and (7) to launch drogued surface drifters for long-term tracking by satellite.

Thompson departed Punta Arenas, Chile, on 4 February for Cape Horn. The first objective was to recover the long-term array consisting of two shallow-pressure recorders, one mooring with eight General Oceanics winged current meters, and seven moorings with eleven Aanderaa temperature/current recorders (figure 1a) moored between Cape Horn and Hero Bay on the northern side of Livingston Island. All instruments except the pressure recorder off Cape Horn (not found) and the current meter on mooring 5 (run over during recovery) were recovered. With the exception of the two upper meters on mooring 4, which suffered failures of the speed sensors, the Aanderaa instruments performed satisfactorily. The General Oceanics meters gave useful records of up to 150 days duration. The two shallow-pressure recorders had been moored with double anchors separated by a ground line, and the method of recovery was by grappling. Another attempt will be made during the 1977 field operations to recover the recorder off Cape Horn. Mooring and recovery of shallow-pressure recorders and current/temperature recorders were done by an Oregon State University team under Dr. Pillsbury and including Dennis Root, Harry Bryden, and Robert Still, the chief current meter technician.

During the first crossing of the Passage, deep-sea pressure recorders (five sensors on three moorings) were deployed by a University of Washington team consisting of Dr. Baker, Richard Wearn, and Earl Krauss. Figure 2 shows the positions of these three moorings. These pressure recorders are the first to be deployed in an experiment to measure the long-term variation of the change of the barotropic component of mass transport through the Passage.

Approximately 20 hydrographic/salinity-temperature-depth (STD) stations were made during the first crossing of the Passage along the line of the current meter array. At the southern end of the Passage a new shallow-pressure recorder was installed in Hero Bay. Afterwards, seven current meter moorings were deployed on the northward traverse, and another shallow-pressure recorder was set in a sheltered shelf area near Cape Horn (see figure 2). Figure 1b shows the configuration of the nine Aanderaa instruments deployed on the five moorings spanning the Passage. Identical instruments were deployed at nominal depths of 2,700 meters on the moorings labeled 19 and 76 in figure 2 to obtain estimates of coherence for small spatial separations.

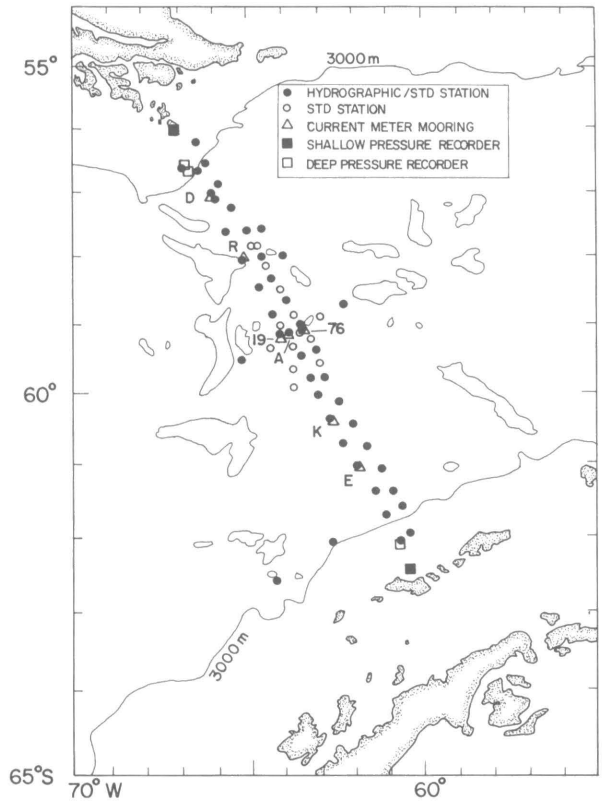

Figure 2. FDRAKE, 1976, mooring and station plan.

Near Livingston Island *Thompson* made a rendezvous with the Soviet research vessel *Professor Viese,* which was making current and hydrographic/STD observations to the west as part of a cooperative program. Visits were made between the vessels; salinity, nutrient, and oxygen standard materials were exchanged; and hydrographic and STD stations were made simultaneously for intercalibration.

The *Thompson* returned to Punta Arenas on 23 February, and the current meter and pressure recorder groups disembarked. Leg 2, lasting from 25 February until 10 March, was concerned mainly with hydrographic and STD stations. During the southward crossing, 24 oceanographic stations were occupied. At the hydrographic stations either one or two Nansen bottle casts were made in conjunction with STD lowering(s) to measure temperature and salinity and to obtain water samples for subsequent analyses for dissolved oxygen and nutrient concentrations. STD profiles were also made at those positions indicated as STD stations in figure 2. The hydrographic operation was under the direction of Dr. Anderson. Chemical analyses with a computer-linked, four-channel AutoAnalyzer II were made for phosphate, silicate, nitrate, and nitrite concentrations by Dr. Gordon, assisted by Wayne Dickinson of Oregon State University. The hydrographic sections showed three regions in which the baroclinic shear evidenced a much stronger eastward surface flow relative to depth than in the surrounding waters—features observed during FDRAKE, 1975. Additional stations were also made in the southern end and across the center of the Passage (see figure 2).

Attempts to launch and track six satellite-tracked surface drifters supplied by the National Data Buoy Office under National Science Foundation contract were partially successful. All buoys were functioning and being received by satellite while aboard the vessel. Due to the light construction and very fragile nature of these drifters, one was damaged and one destroyed during launch attempts. From the four launched successfully, data were obtained only for periods of up to 14 days.

Assisting with the hydrographic and STD work during legs 1 and 2 were Joyce Schmitz, Thomas Whitworth, III, R. V. Pittman, Richard Pittman, James Stasny, and Brady Elliott of Texas A&M University; Susan Patla of Scripps Institution of Oceanography; David F. Paskausky of the Office of Naval Research. Also participating in the data collection and serving as observers were José Gallo from the Argentine Antarctic Institute and Norberto Zuleta from the Chilean Naval Hydrographic Institute.

Throughout the cruise, weather observations were made at 6-hour intervals, supplemented by special observations at hydrographic stations. A total of 131 expendable bathythermographs were deployed. Approximately 1,200 plastic surface drifters were released during the cruise with the hope that some will be recovered and returned in exchange for modest rewards offered. Special water samples were collected at five stations in distinct water masses across the passage for subsequent light hydrocarbon analyses by William Sackett at Texas A&M University.

Acknowledgements. The scientific programs carried out during legs 1 and 2 of FDRAKE, 1976, aboard R/V *Thompson* are part of the International Southern Ocean Studies sponsored by National Science Foundation grants OCE 74-14941, IDO 74-18044, OCE 74-12558, OCE 76-00592, and OCE 75-03961. Ship time was supported by the National Science Foundation. The scientific party sincerely appreciates the cooperation and assistance provided by the officers and crew of R/V *Thompson* under the command of Captain William Clampitt. We thank the National Aeronautics and Space Administration for the use of Applied Technology Satellite 3 for relay of scientific and logistic information during the cruises and those at shore stations who assisted in the transmission of such information; this communication system proved invaluable during FDRAKE.

Observations of the Polar Front Zone during FDRAKE, 1976: R/V *Thompson* leg 3

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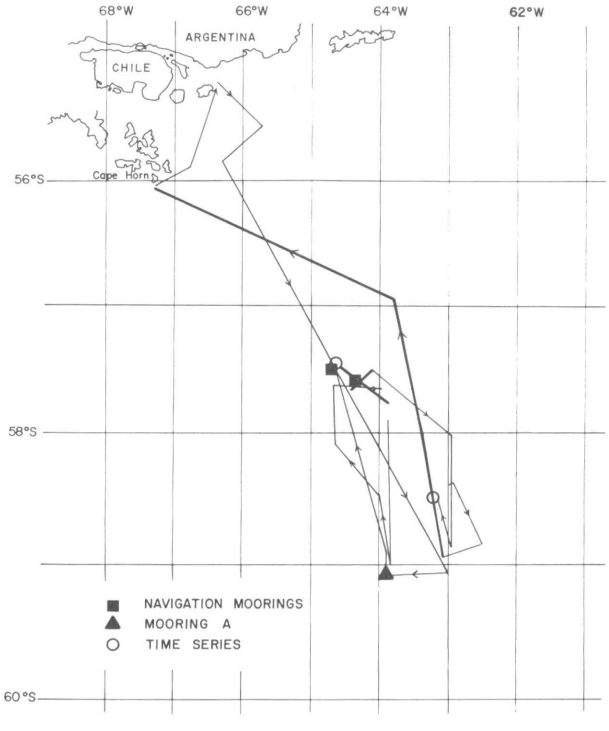
During the 1976 phase of the First Dynamic Response and Kinematics Experiment (FDRAKE) of the International Southern Ocean Studies (ISOS) project we measured scalar fields in the Polar Front Zone. Our vertical and horizontal resolution surpassed previous studies, and we obtained some direct measurements of vertical and horizontal velocities that might reveal various dynamic processes related to scalar variability. The cruise track, showing unbroken runs and principal study sites, is shown in the figure.

Field measurements were made from 12 March to 9 April 1976 during leg 3 of R/V *Thompson* cruise 107. No instruments were lost and no compromising weather was encountered. Consequently, the amount of data is large; and more importantly, its quality is high.

Velocity data were obtained with vertical current meters (VCMs): neutrally buoyant floats equipped with vanes to sense vertical water motion. Five VCMs were built and prepared at Woods Hole and recorded 15 float days of good data during the experiment. A profiling current meter (PCM) was also used: an Aanderaa current meter that slid down the conductivity-temperature-depth (CTD) meter cable at 30 meters per minute and recorded pressure, current speed, and direction. Walter Zenk, Institut für Meereskunde, Kiel, West Germany, provided this instrument. Nineteen profiles were obtained using one of two reference buoys for relative navigation.

Various scalar fields were measured with several instruments: A CTD microprofiler from Woods Hole was equipped with a sensor for continuous measurement of dissolved oxygen at 101 stations. A total of 450 XBTs (expendable bathythermographs) were collected for mapping the thermal structure of the Polar Front Zone and for statistical study of temperature interleaving in the Front; an expanded scale system brought from Lamont-Doherty Geological Observatory was used by Daniel Georgi at 300 of the stations. Light scattering as a function of scattering angle was measured at 48 stations at discrete depths, and continuous scattering was measured at a fixed angle for depths between 0 and 1,000 meters by Gunnar Kullenberg of the University of Copenhagen. Dr. Kullenberg also used a quanta meter (essentially an electronic secchi disk) at 11 stations. Over 950 samples were processed for nutrients using an AutoAnalyzer operated by Clifford Dahm of Oregon State University. Of these, 240 were surface samples collected by the Chilean vessel *Yelcho.* Twenty-eight tritium/helium^3 and 78 oxygen-16/oxygen-18 samples were drawn for isotope analyses. The former will be done at Woods Hole by William Jenkins, and the latter will be made by Louis Gordon at Oregon State University.

In addition to the above, a subsurface mooring was recovered containing instruments belonging to the National Oceanic and Atmospheric Administration's Pacific Marine Environmental Laboratory and the Institut für Meereskunde. During our 4-week study aboard *Thompson,* the Chilean vessel *Yelcho* assisted in defining the mesoscale structure of the Polar Front. A meander in the Circumpolar Current/Polar Front was observed to pinch off, forming an eddy of cold antarctic water that drifted to the northeast in the Circumpolar Current. This rapid evolution of the frontal zone needs to be studied using the combined data sets from *Thompson* and *Yelcho. Yelcho* was in the Drake Passage for



Cruise track of R/V *Thompson* during leg 3. Shown are locations of navigation and current meter moorings, 25-hour time series, and conductivity-temperature-depth sections (heavy lines).

2 weeks before leg 3, and returned during the middle of leg 3 for another 2-week survey. A note on the frontal eddy formation and structure is in preparation. During leg 3 we were able to measure the transfer process at the Polar Front Zone on scales from 50 kilometers horizontal, 2.5 kilometers vertical (cold ring), to 20 centimeters vertical, a dynamic range of over 10^4.

This research was supported by National Science Foundation grant OCE 75-14056. Optical measurements were supported by the Danish Natural Science Council and the Marine Science Panel of the NATO Science Committee. We acknowledge the skill and cooperation of the captain and crew of the R/V *Thompson*. Leg 3 participants were: T. Joyce, N. Bauchmann, J. Dean, M. McCartney, R. Millard, D. Moller, J. Toole, A. Voorhis, and H. Whittemore, all of Woods Hole Oceanographic Institution; W. Zenk, Institut für Meereskunde; G. Kullenberg and H. Hundahl, University of Copenhagen; J. Gallo, Instituto Antártico Argentino; N. Zuleta, Instituto Hidrográfico de la Armada de Chile; D. Georgi, Lamont-Doherty Geological Observatory; C. Dahm, Oregon State University; J. Jolly, Seattle, Washington.

Contributions of AGS *Yelcho* to FDRAKE, 1976

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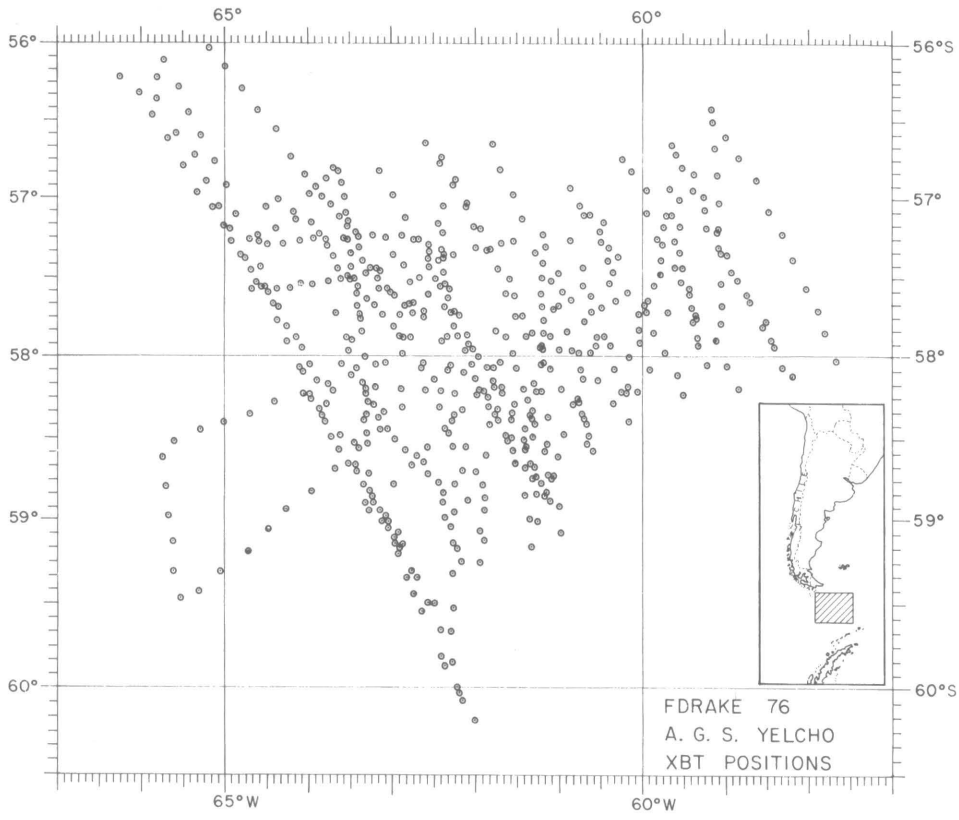
On 27 February 1976 the Chilean naval ship AGS *Yelcho* departed Punta Arenas, Chile, to begin its participation in the second phase of the First Dynamic Response and Kinematics Experiment (FDRAKE 1976) of the International Southern Ocean Ocean Studies. The mission of *Yelcho* was to conduct an expendable bathythermograph (XBT) survey to describe the large-scale thermal structure of the waters in the vicinity of the Polar Front Zone (PFZ) in Drake Passage. This work was done in support of, and in cooperation with, a study of the



Positions of the 571 expendable bathythermograph observations of AGS *Yelcho* obtained during FDRAKE, 1976, in Drake Passage.

small-scale structure of the PFZ done aboard R/V *Thomas G. Thompson* of the University of Washington between 13 March and 9 April (Joyce, 1976).

Scientific operations aboard *Yelcho* were under the direction of Hellmuth A. Sievers, Instituto Hidrográfico de la Armada de Chile, and Steven L. Patterson, Texas A&M University. The remainder of the scientific party consisted of six from the Instituto and two from Texas A&M. Repeated surveys of the PFZ were made during each of two legs aboard *Yelcho*. The first leg lasted from 27 February to 13 March, and the second from 22 March to 8 April. Each began and ended in Punta Arenas.

Preliminary information obtained during leg 1 about the PFZ was passed to scientists aboard *Thompson* before they departed Punta Arenas on 13 March. While at sea the two ships communicated regularly via the Applied Technology Satellite (ATS-3), which is in geostationary orbit over the equator at 70°W.

The figure shows positions of the 571 XBT stations occupied by *Yelcho*. These stations are mostly along and to the east of a line 15 nautical miles northeast of the current meter moorings that were deployed during the first leg of *Thompson* activities (Nowlin *et al.*, 1976). Both T-4 and T-7 type XBT probes, which profile the water temperature to a nominal depth of 450 and 750 meters, respectively, were used in the surveys. The profiles were recorded on a standard Sippican analog recorder and were calibrated with thermometer-determined sea surface temperatures. At most stations surface water samples were collected to be analyzed for salinity and silicate concentration. Standard meteorological observations were made hourly, and bathymetry was continuously monitored using an EDO model 185 echo-sounder. Navigation was by Magnavox model 702A satellite navigation system.

During the 10 days of leg 1 that *Yelcho* was in the survey area, the PFZ remained relatively stationary. It had a west-southwest to east-northeast orientation (centered about an average latitude of 57°40′S.) except for a sharp deflection to the southeast at about 57°50′S. 62°30′W. Between legs 1 and 2 *Yelcho* was absent from the survey area for about 15 days. The initial survey of leg 2 revealed that the deflection, or meander, had grown considerably in size. Subsequently, *Thompson* reported that a cyclonic ring had been shed to the north of the Front. *Yelcho's* first survey of this ring showed that its radius, measured from the cold water (below 0°C) core, located at 57°26′S. 63°38′W., to the 2°C isotherm, ranged from 13 to 22 nautical miles. The feature extended deeper than 750 meters. A survey 3 days later indicated that the ring had grown in size and had become more deformed in shape, with its radius now ranging from 15 to 38 nautical miles. The center had drifted to the north-northeast at approximately 0.2 knots. South of the ring the Front had resumed its west-southwest to east-northeast orientation and was passing within 20 nautical miles to the north of the cluster of three current meter moorings deployed by *Thompson* near 59° 06′S. 63°43′W. These moorings appear to be ideally located to monitor current velocities associated with PFZ.

This research was supported by National Science Foundation grant OCE 74-14941 and the Instituto Hidrográfico de la Armada de Chile. The *Yelcho* and ship support were provided by the Chilean navy. We thank Commander Gaston Droguett and his crew aboard *Yelcho* for their enthusiastic support and cooperation—instrumental in bringing FDRAKE, 1976, operations to a successful conclusion.

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Tidal currents in the sea beneath the Ross Ice Shelf

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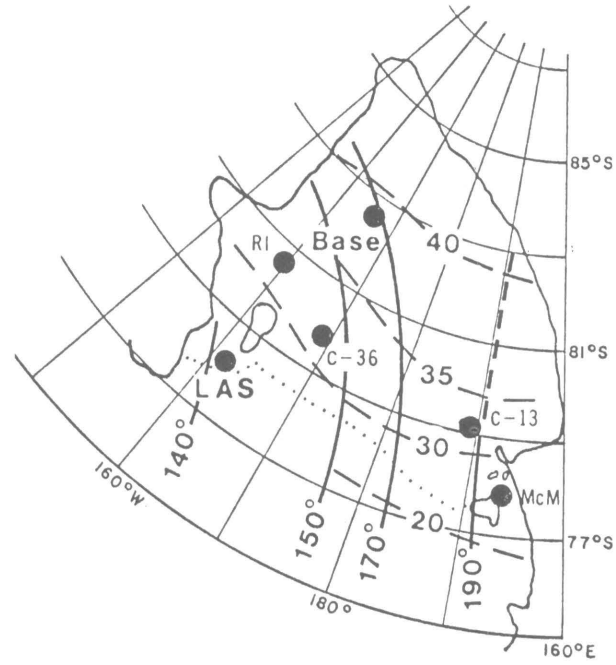
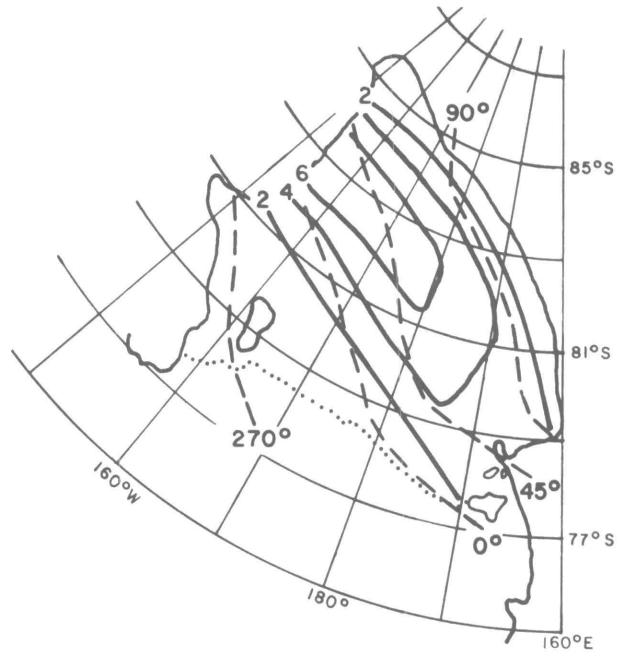
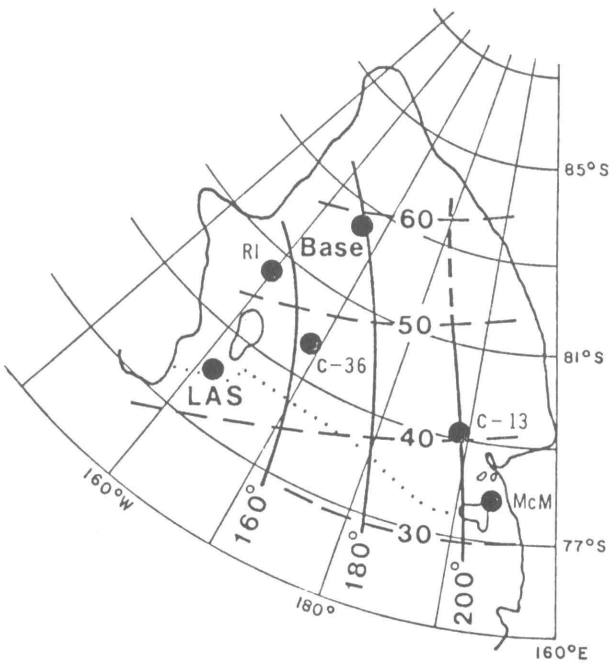
We studied the ocean tide beneath the Ross Ice Shelf in conjunction with the Ross Ice Shelf Project. Robinson *et al.* (1975) report tidal water level fluctuations in the southern part of the Ross Sea for the six locations indicated in figure 1. Interpolated cotidal and corange lines indicate the nature of the principal diurnal constituents O_1 and K_1 P_1 of the ocean tide beneath the Ross Ice Shelf.

The association of tidal water level fluctuation and horizontal components of the tidal current for a particular harmonic constituent is expressed in the Laplace tidal equations (Doodson, 1958). If the







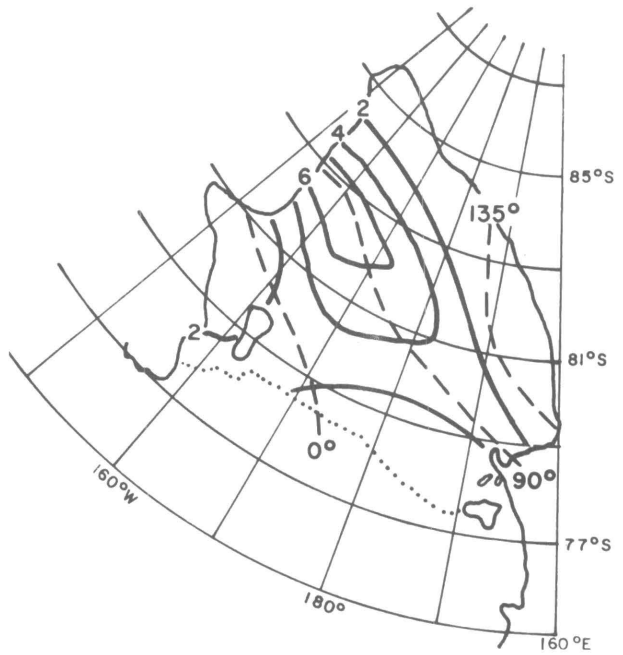


Figure 1. Provisional cotidal-corange charges for the O_1 and K_1P_1 ocean tidal constituents in the Ross Sea. Cotidal angles are relative to the Greenwich meridian. Corange lines express amplitude in centimeters.

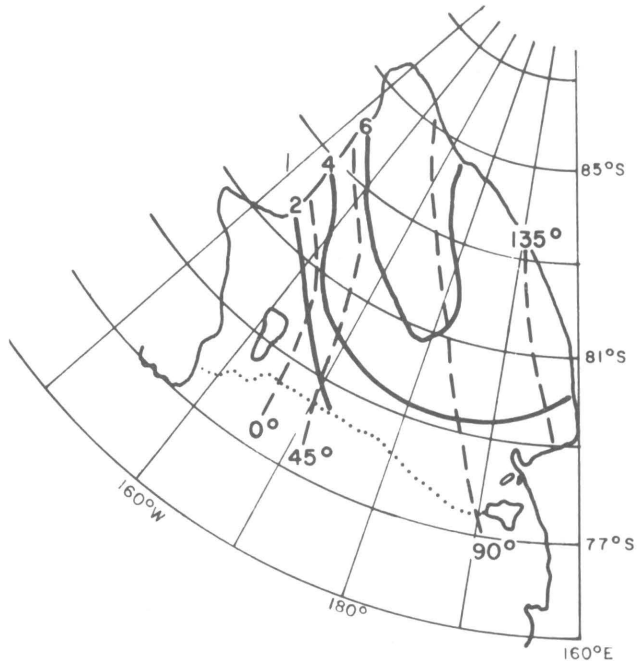
Figure 2. Components of the O_1 tidal current constituent in the Ross Sea. Solid contours indicate current velocity in centimeters per second. Dashed contours indicate phase of the current. South- and east-directed components have phase angles in the ranges of 0° to ±90°. North- and west-directed components have phase angles in the ranges ±90° to 180°.

water level fluctuations are specified at points on a grid, currents can be obtained by using a finite difference method to evaluate these equations (Williams, 1976). Thickness of the water layer and boundaries of the basin must be known to obtain these solutions.

Tidal water level data were interpolated from the charts in figure 1 at points on a grid with spacings of 0.5° latitude and 4° longitude. Thicknesses of the water layer at grid points were taken from Clough and Robertson (1975) and Crary *et al.* (1962). North-south and east-west components of the O_1 and K_1 P_1 tidal current constituents were obtained from these data by finite difference solutions of the Laplace tidal equations at the grid points. Charts in figure 2 illustrate the O_1 current amplitudes and phases. The phase contours are an indication of time relative to the Greenwich meridan. Figure 3 displays similar data for the combined K_1 P_1 constituent.

Diurnal constituents are dominant in the southern Ross Sea and account for more than 80 percent of the water level fluctuation at times of spring tide. Similarly, the diurnal current constituents are the principal cause of tidal water circulation.

This research was supported by National Science Foundation grant DPP 73-05873.



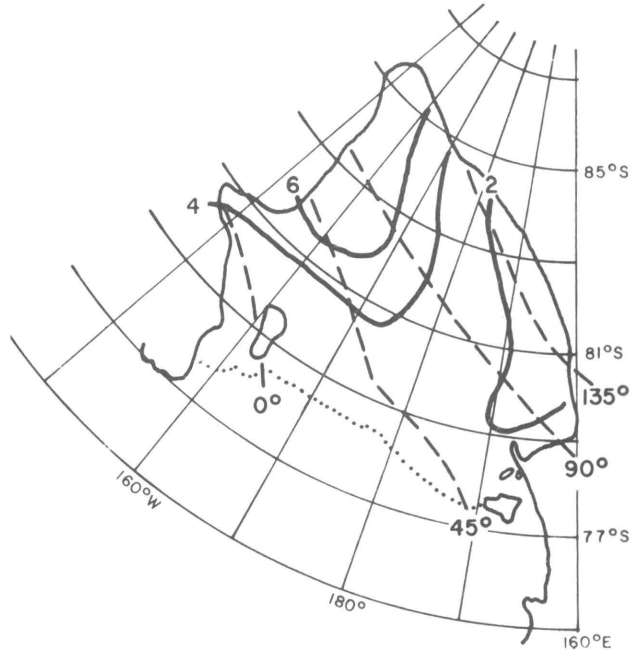


Figure 3. Components of the K_1 P_1 tidal current constituent in the Ross Sea. Effects represented by solid and dashed contours are the same as in figure 2.

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Submarine sedimentary facies at Deception Island, South Shetland Islands

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Substrate samples collected in January 1974 (Lipps and DeLaca, 1974) for a detailed study of Deception Island (62°57′S. 60°38′W.) foraminifera (Finger, 1975) have been analyzed for their grain-size distribution. This information has been related to foraminiferal distributions (Finger, 1976) and may be useful to those investigating other aspects of the Deception Island benthos.

The sediment samples were washed through a 4 phi (230 mesh) screen to remove the mud (silt and clay) fraction. This runoff was collected and then centrifuged at 2,000 revolutions per minute until a clear supernatant was obtained. The muddy concentrate was filtered, oven-dried, and weighed. After separating the foraminifera from the coarser fraction by the carbon tetrachloride flotation method, the dried sand-gravel fraction of each sample was sieved through whole phi intervals from −3 phi to +4 phi for 15 minutes with a mechanical sieve shaker, and the weight of each portion was recorded. Gravel:sand:mud weight ratios were plotted on the triangular graph of Folk (1954), from which appropriate sediment nomenclature was assigned.

Substrate at Deception Island are divided into five geographically separate facies (figure 1). Tongues of gravel and sand extend from the southern slope of Telefon Ridge and the western slope of Mount Pond into Port Foster and are associated with the recent volcanic eruptions at these locations. Closer observation of these patterns (figure 2) reveals a more precise distribution reflecting differential settling of airborne volcanic debris. Concentrations of coarser material decrease away from the eruption sites.

The encircling caldera evidently serves as a sufficient barrier against excessive postdepositional transport to allow finer particles to remain within Port Foster in such high concentrations. The widespread distribution of silt and clay in the bay was probably accomplished while the sediments were still in suspension by aeolian, current, and tidal transport. Most of this area was not showered with coarser pyroclastics, and displacement of such material from its provenance has apparently been minimal. As a result, the interior substrate consists primarily of mud. Thus, the sedimentary facies within Port Foster have been delineated on the basis of volcanic sand and gravel distributions.

Another coarse-grained sedimentary facies is situated in the vicinity of the brackish inlet connected to Fumarole Bay. Fluvial processes have probably transported this material since no erup-

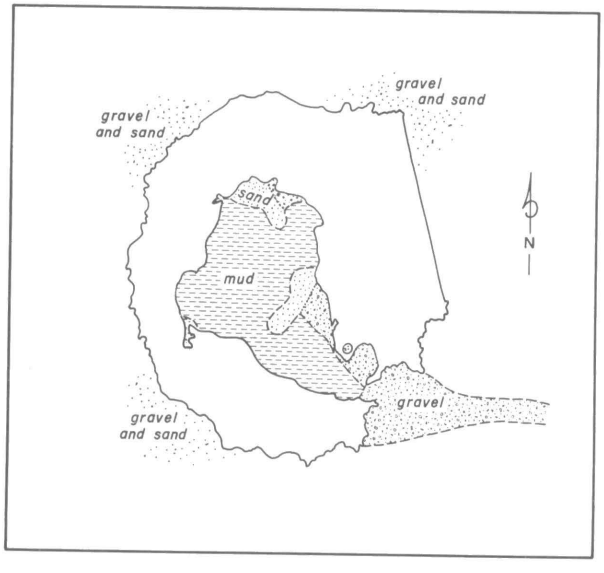

Figure 1. Areal distribution of major sediment types at Deception Island.

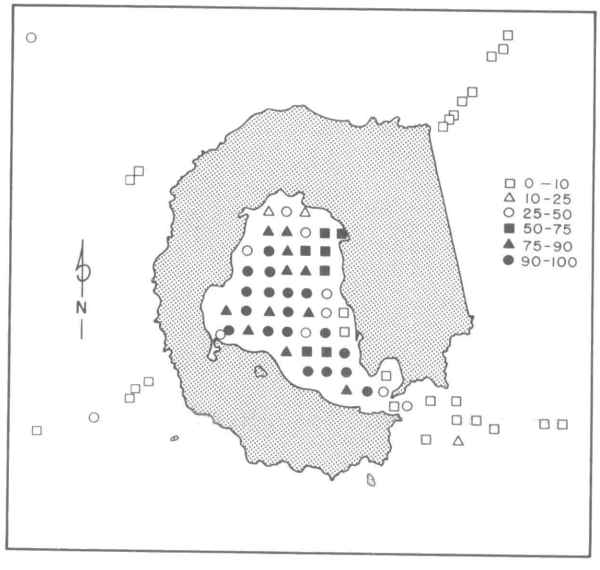

Figure 2. Mud:sand and gravel (percentage mud) distribution at Deception Island sampling localities.

tions have occurred recently in the southwestern section of the island. Drainage through the inlet and into Port Foster must have removed most of the ash before it could settle and accumulate.

A single sedimentary facies has been designated in the region of Bransfield Strait surrounding Deception Island. Winds and currents are probably most responsible for the removal of the finer sediment from the exterior slopes of the land. The distribution of pyroclastics (particularly ash) originating from Deception Island is extensive, ranging as far as King George Island approximately 120 kilometers to the northeast (Baker and McReath, 1971).

This research was supported by National Science Foundation grant GV-31162.

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Geochemical and isotopic study of sediment from unit I, DSDP site 270, Ross Sea

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As part of a study of the chemical composition and strontium isotopic composition of sediment deposited in the Ross Sea (Faure and Bannigan, 1975; Shaffer and Faure, in press), we analyzed samples from unit 1 of Deep Sea Drilling Project (DSDP) site 270 (Hayes *et al.,* 1975). The site is located at 77°26.48'S. 178°30.19'W. This unit extends to about 20 meters below the bottom and consists of unconsolidated silty clay of late Pliocene to Recent age. The upper 20 centimeters of unit 1 is a soupy, diatomaceous, silty clay (labeled subunit 1A) that makes a sharp contact with somewhat more compacted sand-silt-clay sediment (subunit 1B). Hayes *et al.* (1975) report finding rare specimens of the foraminifer *Miliammina arenacea* at the top of core 1 (suggesting a Brunhes age) and *Globocassidulina biora* in the core catcher of core 3 (suggesting a Gauss age). The samples we analyzed are from unit 1B. The table gives the analytical results.

Figure 1 demonstrates that the strontium-87/strontium-86 ratios of the noncarbonate fractions of the sediment increase linearly with the reciprocals of the strontium concentration. This relationship indicates that the sediment is a mixture of two components having differing strontium-87/strontium-86 ratios and strontium concentrations. Faure and Bannigan (1975) identified these components as volcanogenic detritus (low strontium-87/strontium-86, high strontium content) and weathering products of older sialic rocks (high strontium-87/strontium-86, low strontium content). Although the linear correlation of the data points is substantial (correlation coefficient $r = +0.85$), no further quantitative interpretation will be attempted at this time.

Figure 2 contains depth profiles of the parameters listed in the table on the basis of which unit 1B is subdivided as shown. Unit $1B_1$ (extending to 1.35 meters below the bottom) has low concentrations of coarse particles (15.8 percent) and low concentrations of strontium (110.4 parts per million), rubidium (114.3 parts per million), and calcium oxide (1.18 percent). It has a high SiO_2 content (77.3 percent) and a strontium-87/strontium-86 ratio of 0.7241. Unit $1B_2$ is of unknown thickness (due to loss of core) and has higher concentrations of coarse fraction (22.4 percent), strontium (130.6 parts per million), rubidium (124.5 parts per million), and calcium oxide (1.25 percent). Its SiO_2 content is low (73.3 percent), and its strontium-87/strontium-86 ratio is 0.7219. The third subunit ($1B_3$), occurring at the base of unit 1B, has intermediate concentrations of coarse sediment (18.1 percent), strontium (115.4 parts per million), and SiO_2 (75.3 percent). It has a somewhat elevated concentration of rubidium (127.4 parts per million) and calcium oxide (1.26 percent), and its strontium-87/strontium-86 ratio is 0.7249.

The proposed subdivision of the unconsolidated sediments at DSDP site 270 may be useful in correlating sediment layers among piston cores collected elsewhere in the Ross Sea from USNS *Eltanin.* Moreover, such studies provide baseline data for interpretation of sediment cores to be recovered from beneath the Ross Ice Shelf.

Analytical data for sediment from unit 1B, DSDP site 270, Ross Sea.

Sample	Coarse fraction +100 mesh (percent)	Strontium-87 / Strontium-86	Strontium (parts per million)	Rubidium (parts per million)	Calcium oxide (percent)	SiO_2 (percent)
1-1, 110-112	14.1	0.7265	99.3	106.0	1.13	80.0
1-1, 129-130	17.4	0.7217	121.5	122.6	1.23	74.6
1-1, 148-149	22.0	0.7210	130.7	128.7	1.26	72.1
1-2, 20- 21	23.5	0.7228	130.8	126.2	1.33	72.8
1-2, 43- 44	22.9	0.7224	133.9	123.0	1.26	72.8
1-2, 60- 61	23.2	0.7210	135.4	126.9	1.24	74.5
1-2, 82- 83	22.0	0.7221	125.9	120.1	1.22	73.6
1-2, 112-113	20.7	0.7222	127.2	122.3	1.22	74.2
3-1, 101-102	22.4	0.7246	116.2	129.2	1.23	74.1
3-1, 119-120	16.4	0.7251	116.2	128.5	1.26	75.0
3-1, 141-142	15.4	0.7252	113.9	124.6	1.29	76.7

Concentrations of the +100 mesh fractions refer to the total sediment. All other measurements were made on the −100 mesh fractions after removal of carbonate phases by leaching with 2N HCl. The concentrations of strontium, rubidium, calcium oxide, and SiO_2 were determined by X-ray fluorescence using calibrations based on rock standards of the U.S. Geological Survey (Reynolds, 1963).

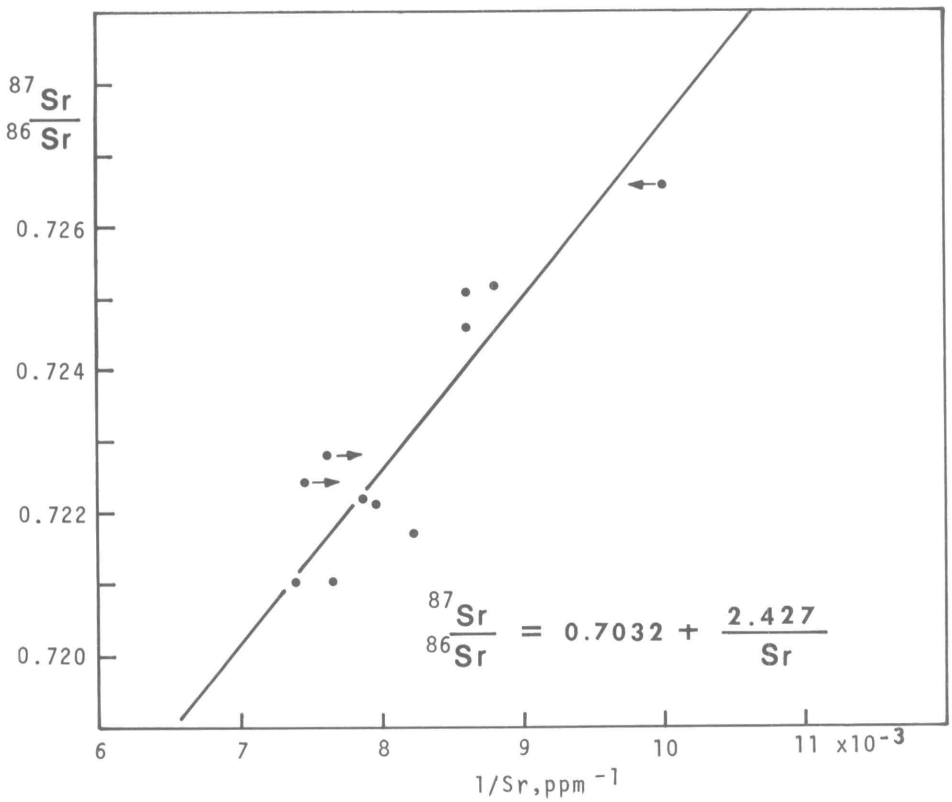

Figure 1. Linear correlation of strontium-87/strontium-86 ratios and the reciprocals of the strontium concentrations of noncarbonate sediment. The line was fitted by least-squares regression after shifting the strontium concentrations of three samples by 2σ as shown.

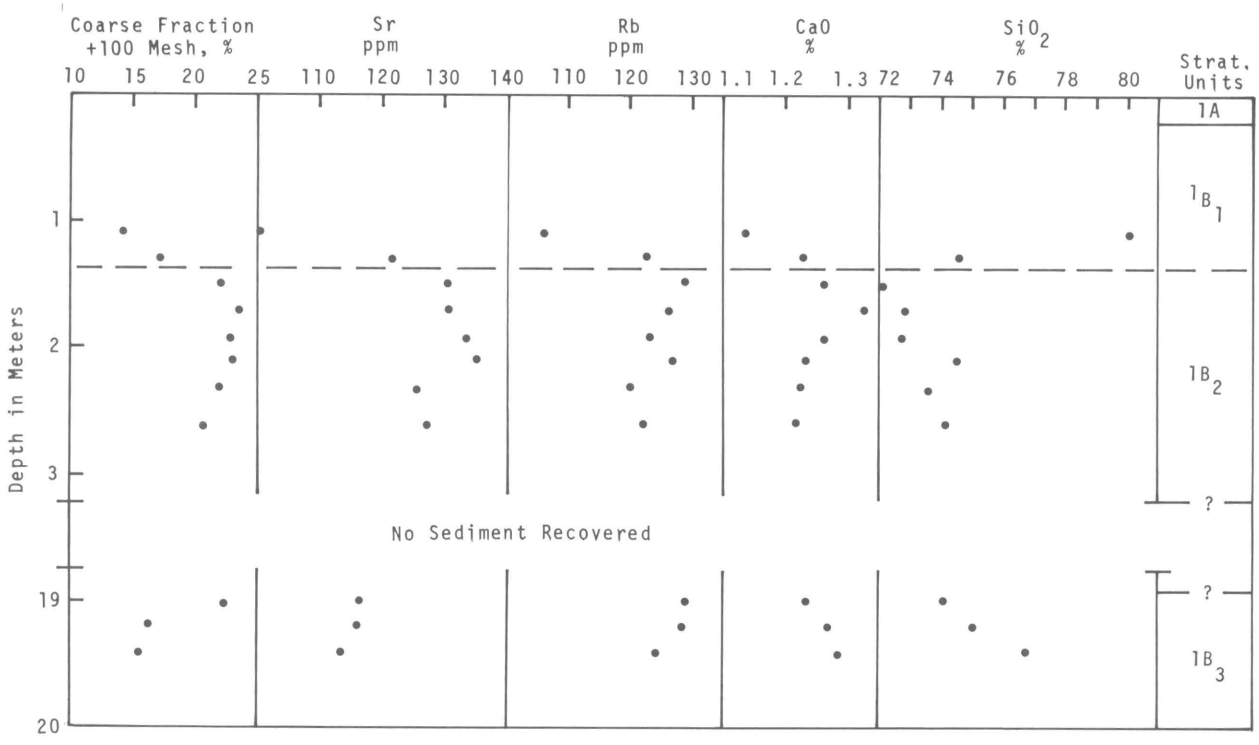

Figure 2. Depth variation of chemical parameters on the basis of which unit IB is subdivided as indicated. Analytical data are explained briefly in the table.

This research was supported by National Science Foundation grant DPP 72-00459. The Deep Sea Drilling Project provided the sediment samples.

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Recent deep-sea benthic foraminiferal distributions in the southeast Indian Ocean

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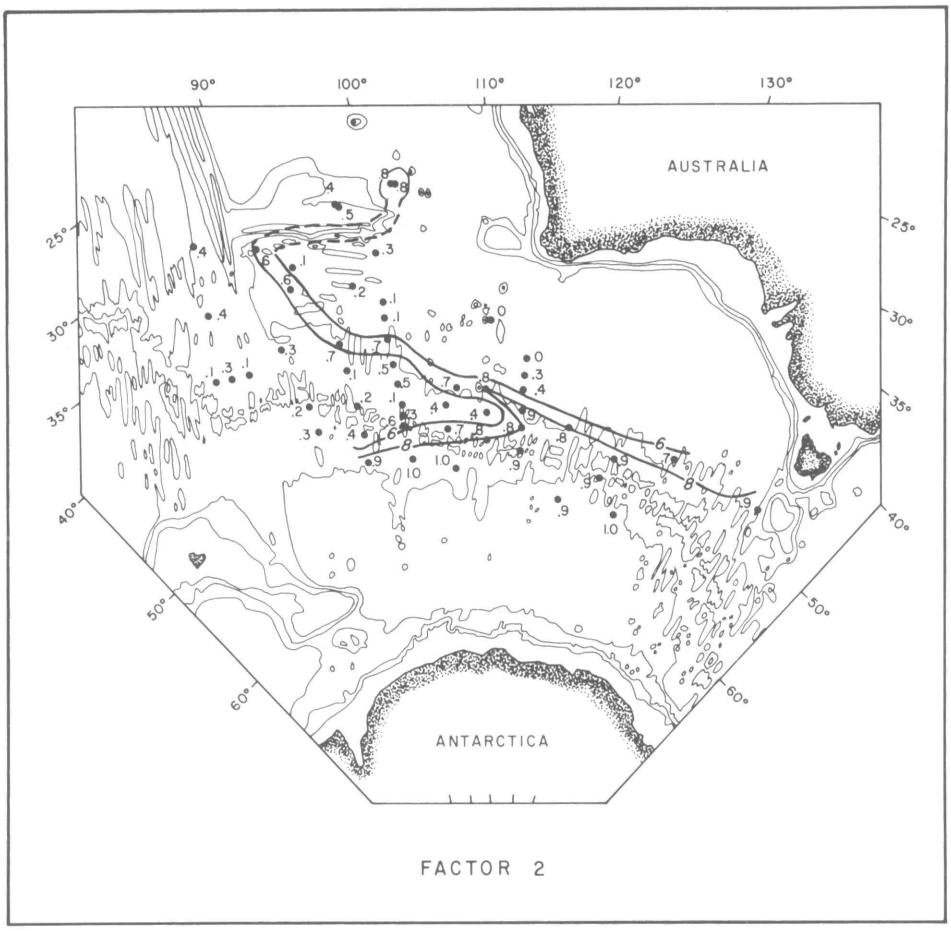
The distribution of deep-sea benthic foraminifera has been examined from Recent surface sediments from USNS *Eltanin* trigger cores in the southeast Indian Ocean between 25° to 50°S. and 80° to 120°E. to evaluate possible relationships with water masses. Two abyssal water masses are present in the area with Antarctic Bottom Water (AABW) found south of the Southeast Indian Ridge and Indian Bottom Water found astride the west-



Map of the southeast Indian Ocean showing the location of USNS *Eltanin* trigger core tops used to determine the distribution of benthic foraminifera. The factor loadings for factor 2 are shown at each sample location. High values reflect dominance of *C. wuellerstorfi, E. umbonifera, G. subglobosa,* and *O. tener,* and are inferred to be areas of Antarctic Bottom Water activity. Low values represent areas of high dominance of *E. exigua* and *Uvigerina* spp. and are areas where Indian Bottom Water is inferred to be present. Bathymetric contours, shown at 2,000, 3,000, and 4,000 meters, are from Heezen *et al.* (1972).

ern ridge crest. Previous work by Streeter (1973) and Schnitker (1974) in the Atlantic demonstrated an association between abyssal water masses and benthic foraminiferal assemblages, with small environmental changes having a large effect upon the distribution of benthic foraminifera. The observed relationships were used to infer paleoceanographic changes during the Quaternary. Factor analysis of species frequencies in the southeast Indian Ocean reveals two faunal assemblages with distinct water mass preferences. The first faunal assemblage is marked by a strong dominance of *Epistominella exigua* (Brady) and *Uvigerina* spp. and is associated with Indian Bottom Water. The second assemblage is marked by several dominant species, the most important of which are *Cibicides wuellerstorfi* (Schwager), *Epistominella umbonifera* (Cushman), *Globocassidulina subglobosa* (Brady), and *Oridorsalis tener* (Brady). These fauna are found in waters with low bottom temperatures and salinities and with high dissolved oxygen content interpreted to be AABW.

Distribution of the second faunal assemblage associated with AABW (figure) suggests that the AABW flows across the Southeast Indian Ridge at 120°E. and then turns westward forming a narrow western boundary undercurrent along the base of the ridge. This direction of bottom water is expected from coriolis forces. The presence of a contour current is supported by the existence of hiatuses and/or very low sedimentation rates in the *Eltanin* piston cores in the region of the inferred current (Kennett and Watkins, 1976; Williams, 1976).

Temperature, salinity, and dissolved oxygen content of the bottom waters do not fully explain the observed faunal patterns and other environmental factors must influence the faunal distributions. A factor that may play an important role as an environmental stress is calcium carbonate undersaturation of the bottom waters. Edmonds (1974) suggested that bottom current activity may enhance the corrosiveness of bottom waters. Hence, the corrosiveness of the waters in the region would be enhanced not only by the cold temperatures of AABW, but also by the current effect.

Biometric analysis of one of the dominant species in the region, *G. subglobosa,* revealed size variation trends that may be associated with water mass distributions. The greatest variation in size is found in

areas of high dissolved oxygen content and low salinity associated with AABW. Two possible explanations are offered for this association. First, winnowing and/or carbonate dissolution related to AABW activity may preferentially dissolve or remove the smaller tests and increase the relative number of large tests within a sample. This concentration of large tests would be reflected by increases in mean size and variability in size. Second, the observed size distribution may result from phenotypic variation in this species with larger test sizes related to high dissolved oxygen and low salinity conditions.

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Oxfordian onychites and a possible decapod microappendage from the Falkland (Malvinas) Plateau

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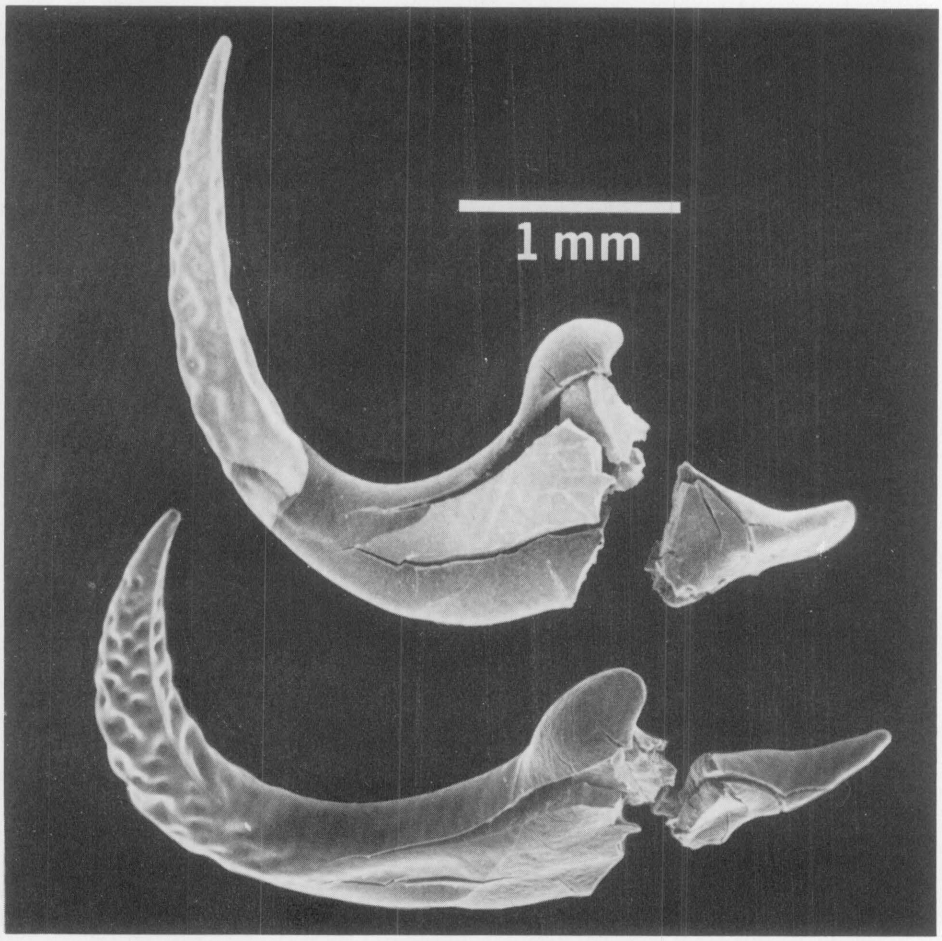
Falkland (Malvinas) Plateau coring over the past 2 years during ARA *Islas Orcadas* cruise 7 and *Glomar Challenger* leg 36 recovered a variety of sediment types ranging from fluvial deltaic and shallow-water continental shelf facies to open marine pelagic, hemipelagic, and glacial marine deposits (Warnke *et al.,* 1976; Barker *et al.,* in press). Most of these units yielded abundant and diverse microfaunas and floras consisting primarily of palynomorphs, foraminifera, coccoliths, radiolarians, silicoflagellates, or diatoms. One unusual microfossil assemblage consisted of tooth and claw-like objects that resemble, superficially, annelid jaw apparatuses (scolecodonts).

Over 150 specimens of scolecodont-like microfossils were recovered from 42 samples taken from a Jurassic sapropelic clay cored at Deep Sea Drilling Project site 330 (50°19′S. 46°53′W.; DSDP cores 330-5 to 330-10, 300 to 414 meters subbottom depth). All samples were determined to be Oxfordian in age using calcareous nannofossils (Wise and Wind, in press) and palynomorphs (Harris, in press). Several of the 10- to 15-milligram samples contained as many as 10 to 12 complete or nearly complete scolecodont-like objects. Complete specimens range in size from less than 0.5 millimeter to nearly 5 millimeters in length. The microfossils are dark brown to black in color, with a dull lustre. Specimens were generally well preserved when taken from the organic-rich sediment. On drying, surfaces of many became crazed and, in time, developed large fissures.

The fauna. Most specimens sufficiently complete for identification can be placed in *Paraglycerites* and *Longuncus,* two genera identified by Kulicki and Szaniawski (1972) as cephalopod arm hooks (onychites). *Paraglycerites* Eisenack (1939) is characterized by a straight to arcuate, long shaft, with spur and uncinus well-developed. *Longuncus* Kulicki and Szaniawski (1972) includes forms described as hooks with long, thin shafts, and a small uncinus and spur.

Additional specimens represent the genus *Accoluncus* defined as small, gently arcuate forms bearing a small spur situated very close to an equally small uncinus. Other specimens appear to represent species of *Deinuncus* Kulicki and Szaniawski (1972) and *Urbanekuncus* Kulicki and Szaniawski (1972). The onychite fauna is described, and new taxa are illustrated in Wind, Dinkelman, and Wise (in press).

One large, well-preserved specimen, illustrated in the figure, bears no similarity to other specimens recovered in these samples, and is unlike all scolecodonts and onychites previously described and illustrated. Although the specimen was originally described by Wind *et al.* (in press) under *Incertae sedis,* it has since been suggested to us (L. G. Abele, 1976, personal communication) that the object is possibly the subchela (distal extremity of a limb



Possible Glypheidae from Deep Sea Drilling Project core 330-6-2 (74-76 centimeters).

developed as a prehensile structure) of a decapod of the Family Glypheidae. This group of crustaceans flourished during the Jurassic and was thought to have been extinct since the Eocene. Forest *et al.* (1976), however, recently reported the discovery of a single specimen dredged live from the South China Sea.

Paleoecology. In addition to the onychites and the single decapod subchela discussed above, belemnite rostra, *Inoceramus* remains, several species of thin-walled pelecypods, agglutinated foraminifera, and plant debris occur in the claystone comprising cores 5 through 10 of DSDP hole 330. Bedding, where evident, is expressed as alternations of light and dark layers reflecting variation in calcareous nannoplankton and carbonaceous content. No apparent bioturbation is visible.

The sapropelic clay that characterizes the Oxfordian interval is believed to be the product of stagnant bottom conditions deficient in oxygen (see Thompson, in press). Euxinic conditions favored the preservation of organic remains and explain the predominance of planktonic and pelagic organisms, whereas the absence of bioturbation suggests a poorly developed or nonexistent infauna. Thus the presence of deoxygenated bottom waters may explain the conspicuous absence of true scolecodonts (such as species of *Ophryotrocha, Glycera,* and *Goniada)* found in the middle and upper Jurassic elsewhere in the world (Szaniawski, 1974). It may also be possible that the pelecypod fauna was more tolerant to generally inhospitable environmental conditions than scolecodont-bearing polychaetes.

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Jurassic to Holocene calcareous nannofossils from the Falkland (Malvinas) Plateau

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A primary limitation on paleobiogeographic studies of calcareous nannofossils has been the lack of an adequate high-latitude coccolith record in the southern ocean. Although the geographic ranges of most modern coccoliths are limited to areas north of the Polar Front, during earlier geologic times when world climates were more equitable (that is, Jurassic, Cretaceous, Paleogene), coccoliths must have been dispersed farther into the higher polar latitudes than they are at present. Outside of single USNS *Eltanin* piston cores from the Kerguelen Plateau (Kaharoeddin *et al.,* 1973) and Naturaliste Plateau (Constans and Wise, 1974), calcareous Mesozoic pelagic material has been unavailable from the southern ocean. Deep sea drilling on the Campbell Plateau (Kennett *et al.,* 1974) and elsewhere in the Pacific sector of the southern ocean failed to obtain calcareous Mesozoic sediments. For this reason, the recovery of Mesozoic and Cenozoic coccolith-bearing sediments from sites at about 50° on the Falkland (Malvinas) Plateau in the Atlantic sector of the southern ocean by *Glomar Challenger* leg 36 and ARA *Islas Orcadas* cruise 7 is significant.

Glomar Challenger raised over 500 meters of drill core from three closely spaced sites on the Falkland (Malvinas) Plateau. Broader core coverage was provided by 22 *Islas Orcadas* piston cores taken in the area of the *Glomar Challenger* (Deep Sea Drilling Project) drill sites. Taxonomic and biostratigraphic studies of coccoliths recovered have been reported by Wise and Wind (in press) and Ciesielski *et al.* (in preparation), whereas Haq *et al.* (in press) discuss the paleobiogeography of the Cenozoic assemblages.

Due to the more equitable climates that existed during Paleogene and Mesozoic times, the diversity of coccoliths from the Falkland (Malvinas) Plateau is greatest for the older assemblages. This is evident in figure 1, which indicates those assemblages sufficiently diverse to be zoned. Even so, definitions of the Cenozoic zones had to be broadened somewhat to permit workable zones to be established. A number of taxa studied are endemic to or flourished in the cooler high latitudes, and these offer some hope for further refinement of a high-latitude coccolith zonation when more is learned of their ranges. At present, endemic cooler water forms such as *Isthmolithus recurvus* Deflandre and *Nephrolithus frequens* Gorka are commonly used for high latitude zonations of the upper Eocene and Maestrichtian respectively. Other such forms common to abundant in the Falkland (Malvinas) Plateau material that should be useful for Southern Hemisphere correlations are:

Tertiary: *Chiasmolithus altus* Bukry and Percival (Oligocene), *Hornibrookina australis* Edwards and Perch-Nielsen and *Heliolithus universus* Wind and Wise (Paleocene).

Cretaceous: *Biscutum dissimilis* Wind and Wise, *Seribiscutum primitivum* (Thierstein), and *Sollasites falklandensis* Wind and Wise.

A number of the above have been used to establish new zones or subzones for use in the Falkland (Malvinas) Plateau region. Due to limited diversity, however, little in the way of a coccolith zonation could be applied to the Oligocene through Holocene sequences despite rather close sampling of over 400 meters of section in that interval.

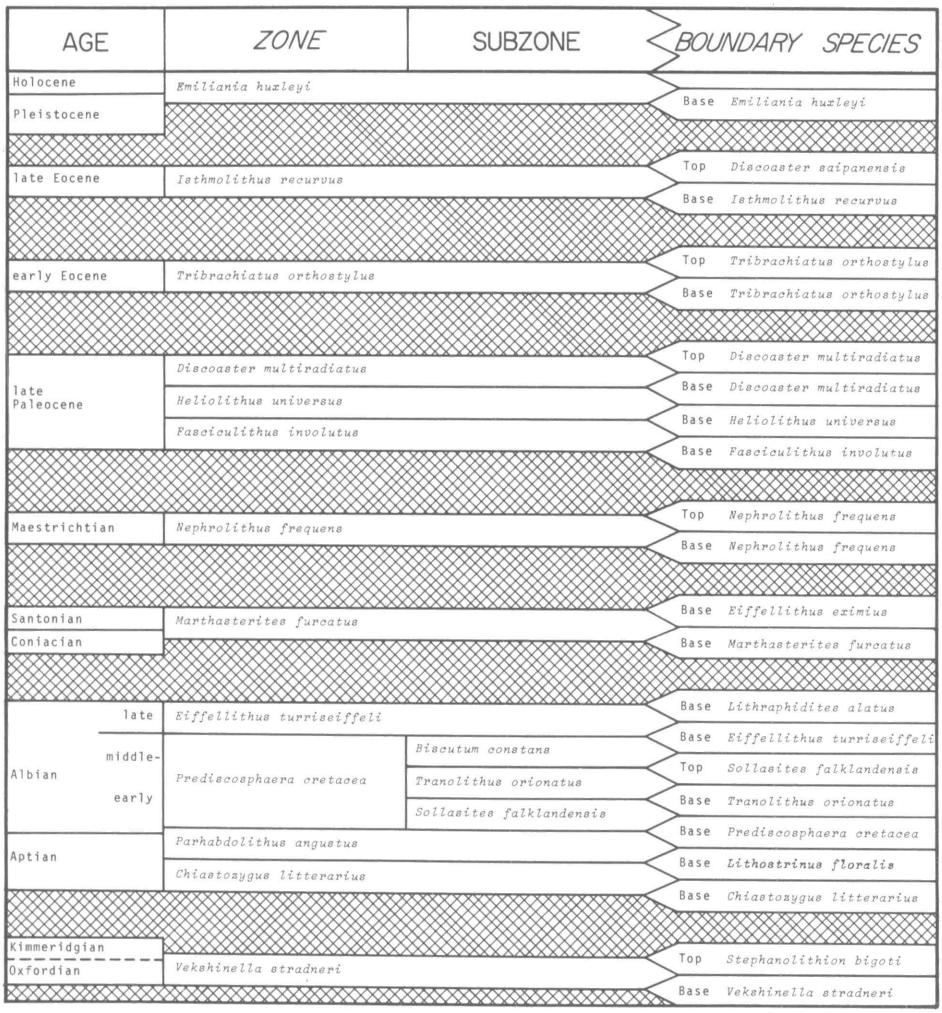

Figure 1. Calcareous nannofossil biostratigraphic zones applied to Falkland (Malvinas) Plateau coccolith assemblages (from Wise and Wind, in press).

Within the Mesozoic, assemblages of Oxfordian, Albian, and Maestrichtian age are diverse and well preserved. Aptian, Cenomanian, and Santonian nannofloras are generally of low diversity and poorly preserved. Most of the latest Jurassic, Neocomian, and Cenomanian-Turonian were not sampled due to hiatuses or to coring gaps. The exceptional preservation of some assemblages, however, particularly those of the Oxfordian, Maestrichtian, and certain levels of the Aptian permitted the identification of 32 new calcareous nannofossil species representing 12 new or existing genera. The majority of these are from the Maestrichtian of Deep Sea Drilling Project hole 327A (50°52.38′S. 46°47.02′W.; water depth, 2,401 meters), where shallow-water deposition, low overburden, and favorable lithology (a moderate biogenic silica and clay content) combined to preserve the nannoflora in a pristine state (figure 2).

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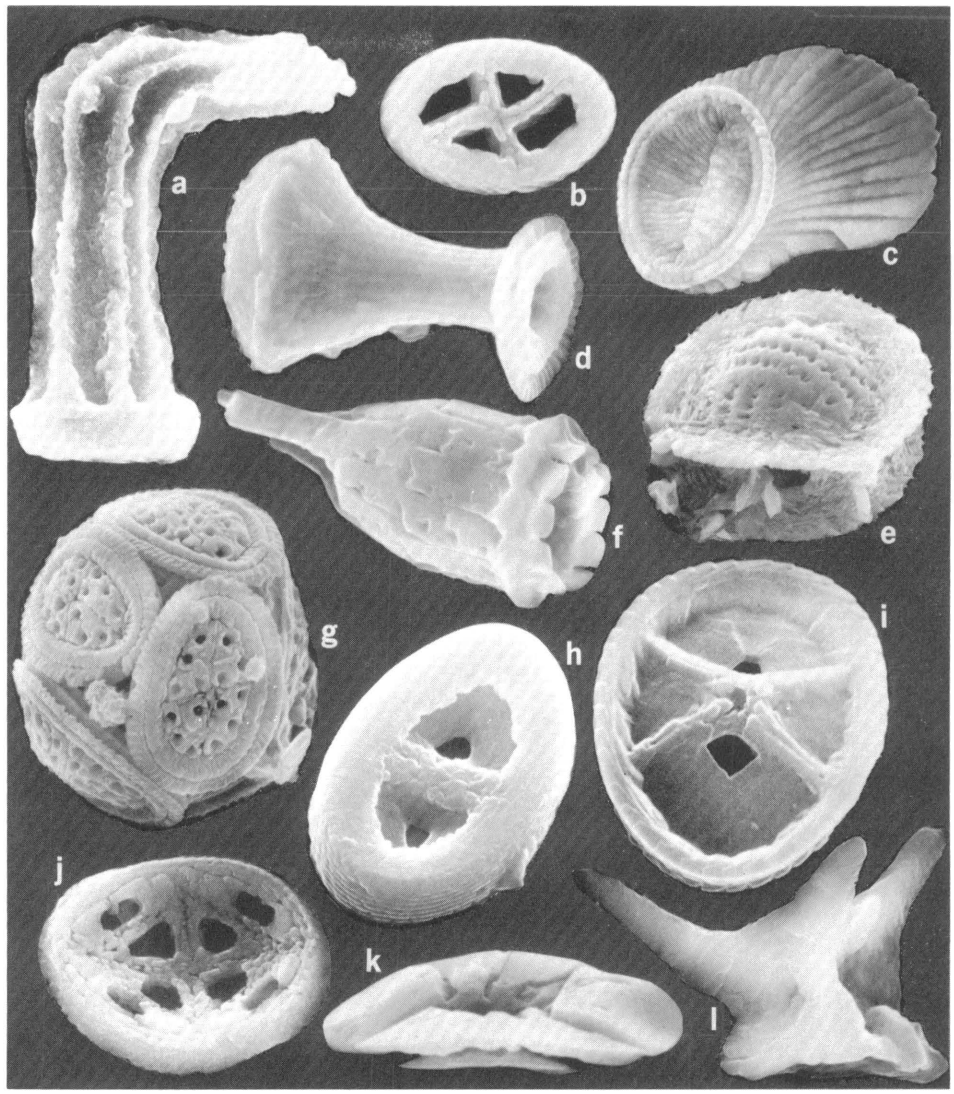

Figure 2. Maestrichtian specimens from Deep Sea Drilling Project leg 36, hole 327A (from Wise and Wind, in press). a. *Lucianorhabdus arcuatus* Forchheimer, X8,500. b. *Chiastozygus propagularia* Bukry, proximal view, X11,000. c. *Kamptnerius magnificus* Deflandre, X7,000. d. *Boletuvelum candens* Wind and Wise, X7,000. e. *Centosphaera barbata* Wind and Wise, X2,000. f. *Lapideacassis mariae* Black emend. Wind and Wise X6,500. g. *Arkhangelskiella cymbiformis* Vekshina, X4,000. h. *Zygodiscus* sp. (*Z. anthophorus* Deflandre?), proximal view, X10,000. i. *Eiffellithus turriseiffeli* (Deflandre and Fert), distal view, X13,500. j. *Monomarginatus quaternarius* Wind and Wise, proximal view, X7,500. k. *Biscutum dissimilis* Wind and Wise, lateral view, X7,400. l. *Micula decussata* Vekshina, X8,500.

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Early Pliocene paleoclimatology and radiolarian biostratigraphy of the southern ocean

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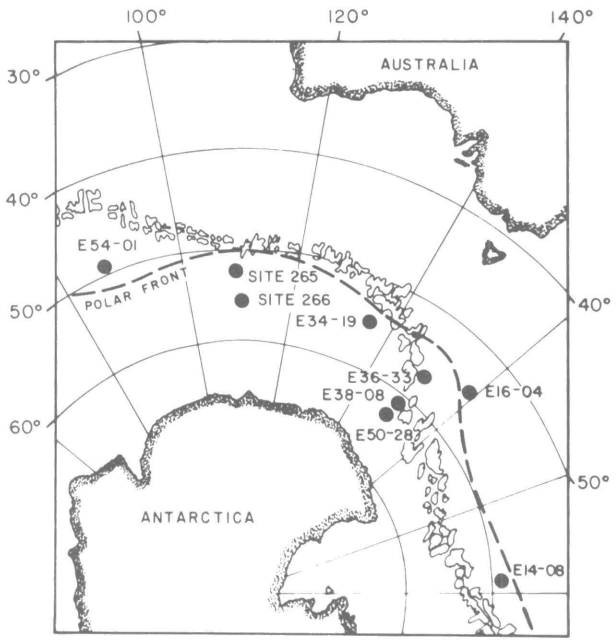
Radiolarian distributions have been studied in a suite of USNS *Eltanin* piston cores and Deep Sea Drilling Sites from the southern ocean (figure). A



USNS *Eltanin* and Deep Sea Drilling Project coring sites in the southern ocean from which radiolarian distributions have been studied in this research.

detailed radiolarian biostratigraphic examination of Pliocene sediments, with particular emphasis on the Gilbert Reversed Magnetic Epoch (3.32 to 5.18 million years before present), has enabled establishment of five new partial range zones (from oldest to youngest): *Anthocyrtidium ehrenbergi* Zone, *Triceraspyris pacifica* Zone, *Lychnocanium grande rugosum* Zone, *Antarctissa longa* Zone, and *Helotholus vema* Zone. These new zones provide increased biostratigraphic control and allow detailed correlation between cores that was not always possible with the previous radiolarian zonations for the southern ocean (Hays, 1965; Hays and Opdyke, 1967; Chen, 1974, 1975). Also, detailed intercore correlations have been aided by a high degree of similarity among frequency changes of radiolarian species and groups.

The three oldest radiolarian zones are defined below the upper limit of the Gilbert "C" event (4.33 million years before present) and have an average duration of 0.3 million years. These zones are marked by warm water radiolarian species (Petrushevskaya, 1973) that are not typical of present-day antarctic faunas. The two younger zones range from the top of the "C" event to the Gauss Matuyama boundary (2.43 million years before present). The *Antarctissa longa* Zone, with a duration of approximately 0.5 million years, contains the first significant abundances of *Antarctissa strelkovi* and *A. denticulata,* the most abundant faunal elements of the present-day antarctic radiolarian assemblages (Hays, 1965; Keany, 1973). The *Helotholus vema* Zone, with an approximate duration of 1.4 million years, is marked by a relatively stable radiolarian assemblage that persists to the Gauss-Matuyama boundary where several of the radiolarian species typical of the antarctic Pliocene sediments become extinct.

Faunal patterns and the rapid succession of faunas in the early Gilbert indicate rapid climatic deterioration in the earliest Pliocene, followed sharply by cool, climatically stable conditions that extended to the latest Pliocene. Further detail of the climatic history of the region, within this general framework, was established by statistical analysis of the total faunal data. Almost all radiolarian species demonstrate distinct frequency oscillations that can be correlated between cores; a high proportion of these are clearly related to paleoclimatic oscillations. This technique has also been successful when applied to planktonic foraminifera in the Gulf of Mexico (Kennett and Huddlestun, 1972). Application of various statistical techniques, including principal component and factor analysis, correlation coefficients, and the Shannon-Weinner diversity index, have greatly aided establishment of detailed relationships among antarctic radiolarian species, including several that are now extinct, and in determining a detailed paleoclimatic curve for the Pliocene.

The increased stratigraphic control resulting from detailed faunal analysis makes it easier to recognize shortened biostratigraphic zones, extreme variations in sedimentation rates, and limits of hiatuses. Definition of these parameters in the study region suggests that early Pliocene climatic deterioration was accomplished by increased current activity. Regional unconformities and scour zones in younger sediments have been described in the southern ocean by Watkins and Kennett (1971) and by Kennett and Watkins (1976), who attributed the increase in current activity to an increase in the production of Antarctic Bottom Water. Apparently a regional hiatus of similar origin is present in the early Pliocene of the southern ocean.

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Cenozoic biogeographic and biostratigraphic development of planktonic microfossils in the Antarctic

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Knowledge of antarctic and subantarctic Cenozoic calcareous and siliceous planktonic microfossils has greatly increased recently by the study of paleomagnetically dated piston cores of Quaternary and Pliocene age and of Deep Sea Drilling Project (DSDP) cores that have, for the first time, provided excellent pre-Pliocene microfossil sequences. General trends are summarized from results of numerous investigations of several microfossil groups.

Present southern ocean biogeography is distinctive from other areas because of differences in species diversity, in species composition, in frequency variation, and in general faunal and floral dominance. Characteristic planktonic assemblages are associated with antarctic, subantarctic, and southern subtropical (temperate) water masses that are separated respectively by the Antarctic Convergence and the Subtropical Convergence. The Antarctic Convergence sharply separates assemblages dominated by siliceous forms (diatoms, radiolaria, and silicoflagellates) to the south from calcareous assemblages (foraminifera, calcareous nannofossils) to the north (Hays, 1965) and essentially marks the southern distribution limit of calcareous nannofossils (Geitzenauer, 1972). This biogeographic provinciality is circumpolar. Diversity is generally low for all groups, with successive decrease associated with increasingly high-latitude water masses. Southward decrease in diversity even continues within the antarctic water mass. Decreased diversity is partly related to increased mixing in surficial water masses and reduction in water mass stratification. The antarctic water mass near the Antarctic Convergence is the principal site of today's siliceous biogenic productivity and sedimentation related to nutrient-rich upwelling of intermediate waters. These biogeographic features were not permanent throughout the Cenozoic, but they have developed in conjunction with the evolution of southern ocean water mass systems.

Cenozoic biogeographic patterns of the high southern latitudes are partly related to two trends. Nearly all evolution of calcareous planktonic microfossils takes place outside of the region, with subsequent migration into these water masses. Thus, there is virtually no endemism among calcareous microfossil groups at these latitudes. In contrast, evolution has been very conspicuous within the siliceous groups especially during the Neogene (Chen, 1975; Petrushevskaya, 1975; McCollum, 1975). Although Paleogene siliceous assemblages are still not well known, endemism in the siliceous groups seems much less apparent in the Paleogene, especially during the Eocene when assemblages seem to have a much more cosmopolitan aspect. The low diversity of antarctic calcareous microfossils throughout the Cenozoic makes them only broadly useful for correlation. Higher diversity in the Subantarctic makes them much more useful, although appearances and disappearances are often clearly diachronous with warmer regions and are climatically controlled (Edwards and Perch-Nielsen, 1975).

During the Eocene (55 to 38 million years ago), sediments contain abundant calcareous microfossils even adjacent to the continent (Burns, 1975a). Antarctic planktonic microfossil assemblages are relatively diverse compared with today, but they still are lower than those of middle and high latitudes. Faunas may still be dominated by only one or two species (Burns, 1975a, 1975b). Subantarctic Eocene planktonic foraminifera more closely resemble temperate faunas (Jenkins, 1975). Biogeographic differences exist between different sectors of the southern ocean as a result of separation by high-latitude land masses (Jenkins, 1974). Subantarctic planktonic foraminifera have slightly higher diversity in the Early Eocene. Calcareous nannofossils range southward to the continent and contain low-latitude elements (Burns, 1975b). In

the Subantarctic, Paleocene and Eocene calcareous nannofossils exhibit higher diversity than in the Oligocene and Neogene. Antarctic radiolaria contain forms with relatively close affinities to tropical forms (Chen, 1975). A major change occurs in antarctic biogeography near the Eocene-Oligocene boundary. Since then, planktonic foraminifera have had a characteristically polar aspect (Kaneps, 1975). This event is considered to be linked to the initiation of widespread glaciation (although not ice cap formation) of Antarctica and to sea-ice formation (Kennett and Shackleton, 1976). The antarctic faunal and floral provinces that begin to develop at this time are related to the evolution of the southern ocean as Australia moved northward from Antarctica and perhaps to the opening of the Drake Passage.

During the Oligocene (38 to 22 million years ago), diversity is relatively low in all groups throughout the world's oceans. In the Antarctic, the early Oligocene planktonic foraminiferal fauna is monospecific; in the later Oligocene, though, two species are recorded. In the Subantarctic, Oligocene planktonic foraminiferal faunas show much higher diversity compared with the Antarctic, and the biostratigraphic succession is similar to temperate regions. Early and middle Oligocene faunas show the lowest diversity for the entire Cenozoic, with increasing diversity commencing again in the late Oligocene.

The Paleogene-Neogene transition is marked by a major change in the world's planktonic biogeography. The development of modern patterns took place at this time, creating a consistently steep diversity gradient between tropics and poles even during the most frigid climatic episodes (Kennett *et al.,* 1972). This was not the case in the early and middle Oligocene, when assemblages were more cosmopolitan and had relatively low diversity even in low-latitude areas. We suggest that the permanency of the steep diversity gradient and the distinct latitudinal provinces during the Neogene and Quaternary resulted from the development of the Antarctic Circumpolar Current during the Oligocene, which permanently isolated the equatorial and southern polar planktonic assemblages.

During the Neogene, when the antarctic water mass remains cold, antarctic calcareous assemblages are of consistently low diversity and faunas are often dominated by single species. In contrast, subantarctic assemblages are much more diverse. Antarctic siliceous faunas begin to become particularly important in the early Neogene, and siliceous biogenic productivity increases as the Antarctic Convergence develops and intensifies (Kennett *et al.,* 1975). Radiolaria begin to show distinct endemism (Chen, 1975; Petrushevskaya, 1975). The early and middle Miocene (22 to 11 million years ago) show relatively higher diversity in both planktonic foraminifera and calcareous nannofossils related to a climax in Cenozoic warming (Jenkins, 1975). Discoasters are conspicuous in the early Miocene of the northern Subantarctic (Edwards and Perch-Nielsen, 1975), while planktonic foraminiferal faunas reach highest diversities in the middle Miocene of both the Antarctic (about four species) and the Subantarctic (average of about 13 species). Silicoflagellates also reach high diversities in the early to middle Miocene (Ciesielski, 1975).

The late Miocene (11 to 5 million years ago) shows a marked northward movement of the Antarctic Convergence, resulting from antarctic cooling, and shows a corresponding expansion of the antarctic planktonic province (Hayes and Frakes, 1975). This resulted in lower diversity of calcareous faunas and floras.

Pliocene (5 to 1.8 million years ago) and Quaternary biostratigraphic events have been placed in a chronological framework using paleomagnetic stratigraphy and thorium dating. In subantarctic sequences, the Pliocene and Quaternary have been divided into zones based on upward sequential disappearance of planktonic foraminifera (Kennett, 1970), upward sequential disappearance of radiolarians (Hays and Opdyke, 1967), and stratigraphic succession of other groups. Pliocene planktonic foraminifera are essentially monospecific in both antarctic and subantarctic sequences.

During the Quaternary (1.8 million years ago to the present), the antarctic water mass shows its greatest northward expansion, and siliceous biogenic productivity, associated with the Antarctic Convergence, reached its maximum (Hayes and Frakes, 1975; Kennett *et al.,* 1975). In the Subantarctic, planktonic foraminiferal diversity is much higher than in the Pliocene. Although calcareous nannofossil diversity may be high, only three to five species are very abundant (Geitzenauer, 1972), while sometimes the floras are almost monospecific. Large northward shifts of antarctic and subantarctic water masses occurred, but there were no southward penetrations much beyond those of today. Several radiolaria and foraminiferal species disappear or appear close to paleomagnetic reversals such as the Brunhes-Matuyama boundary (690,000 years ago) and do not seem closely related to major climatic events (Hays and Opdyke, 1967; Hays and Donahue, 1972; Kennett, 1970).

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Diatom investigations in the South Atlantic

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Diatoms from six Deep Sea Drilling Project (DSDP) sites (table 1) and six USNS *Eltanin, Vema,* and *Robert Conrad* piston cores from the southwest Atlantic (table 2) have been investigated in detail. Neogene diatoms were encountered at nine of the Atlantic sites, commonly occurring as thin veneers of diatomaceous ooze overlying older sediments. Thick accumulations of Miocene to Recent diatomaceous sediments were penetrated at two sites: DSDP site 329 on the Maurice Ewing Bank, and DSDP site 328 in the Malvinas (Falkland) Outer Basin. The section at site 329 consists of nearly 400 meters of middle to late Miocene nannodiatom ooze that exhibits much reworking. This accumulation is thought to have resulted from the eddying of sediments carried by bottom currents flowing over the Falkland (Malvinas) Plateau. A relatively undisturbed Miocene to Recent section of clayey and silty biosiliceous ooze was recovered at site 328.

Table 1. Locations of leg 36 drill sites.

Hole	Latitude (°S.)	Longitude (°W.)
326	56°35.00′	65°18.20′
327	50°52.28′	46°47.02′
328	49°48.67′	36°39.53′
329	50°39.31′	46°05.73′
330	50°55.19′	46°53.00′
331	37°53.00′	38°06.92′

Table 2. Piston cores used in this study.

Core	Latitude (°S.)	Longitude (°W.)
RC 15-84	50°28.6′	44°43′
V 18-112	51°40′	48°29′
V 17-107	51°08′	54°22′
RC 12-237	47°45.7′	57°38.5′
E 6-9	53°59′	55°58′
V 31-60	51°07′	53°04′

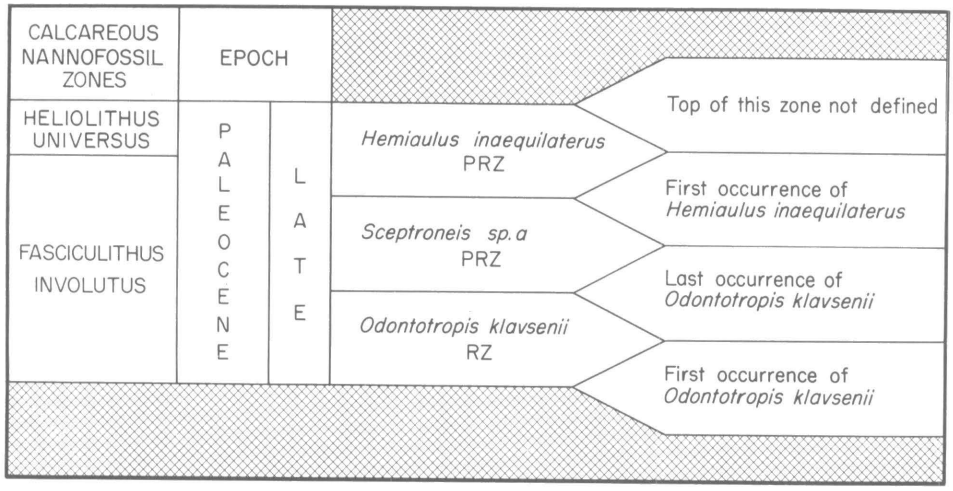

Figure 1. Definition of late Paleocene diatom zone from the south Atlantic Ocean (from Gombos, 1976). Reference section is Deep Sea Drilling Project site 327 in the Malvinas (Falkland) Outer Basin. PRZ, partial range zone; RZ, range zone. Calcareous nannofossil zones are from Wise and Wind (in press).

This section was dated and zoned using diatom zonations established in the Pacific sector of the southern ocean.

Four late Eocene to late Oligocene zones and one early Miocene diatom zone were established on the basis of evolutionary datums identified in the late Paleogene to early Neogene section at site 328. From late Eocene to early Miocene, these zones are: *Pyrgupyxis eocena/Pterotheca aculeifera* Concurrent Range Zone; *Hemiaulus incisus* Partial Range Zone; *Melosira architecturalis* Partial Range Zone; *Pyrgupyxis prolongata* Partial Range Zone; *Bogorovia veniamini* Partial Range Zone. Three late Paleocene diatom zones were similarly established for the section at site 327. These are: *Odontotropis klavsenii* Range Zone; *Sceptroneis sp. a* Partial Range Zone; *Hemiaulus inaequilaterus* Partial Range Zone. The late Paleocene diatom zones have been correlated to calcareous nannofossil zones.

Figures 1 and 2 summarize the new Paleogene diatom zones. A more detailed treatment of the diatoms recovered in cores from DSDP leg 36 is in Gombos (in press).

Six piston cores from the Falkland (Malvinas) Plateau containing Paleogene diatoms were chosen to test the new zones (table 2). It was possible to correlate four of these cores with the reference sections at sites 327 and 328. The remaining two piston cores contained either a poorly preserved diatom assemblage or too short a Paleogene section for reliable correlation. A more detailed treatment of the diatoms of these piston cores is in Gombos (1967).

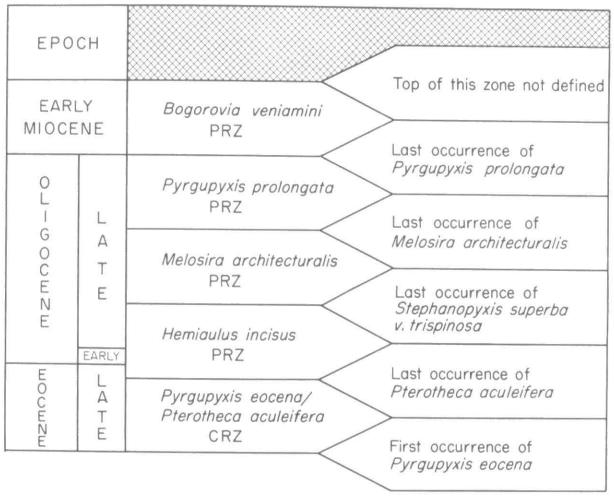

Figure 2. Definition of late Eocene and Oligocene diatom zones from the south Atlantic Ocean (from Gombos, in press). Reference section is Deep Sea Drilling Project site 328 on the Falkland (Malvinas) Plateau. PRZ, partial range zone; CRZ, concurrent range zone.

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Size variations in *Globigerina bulloides* d'Orbigny as a Quaternary paleoclimatic index in the southern ocean

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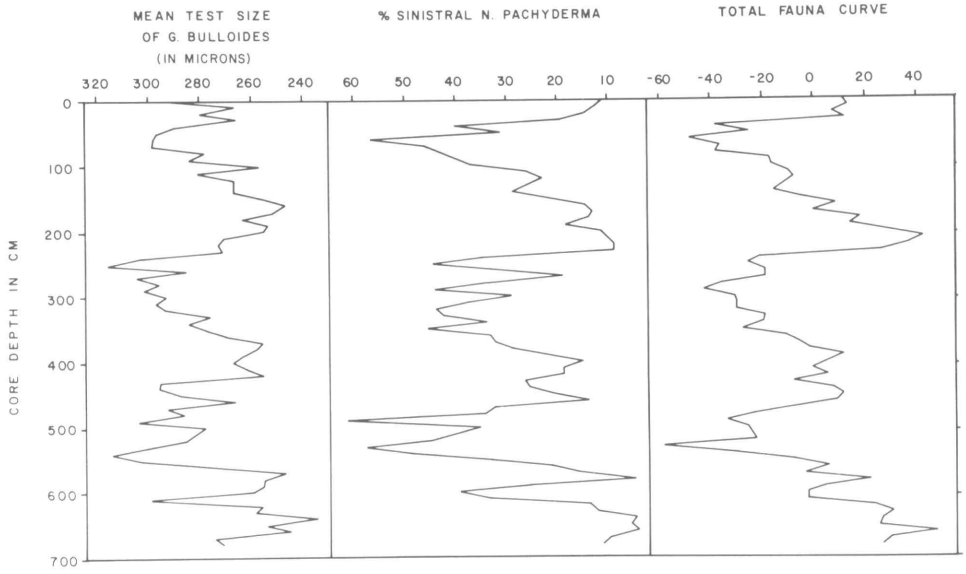
Malmgren and Kennett (1976) show that average test size and coiling direction in modern assemblages (surface sediments of USNS *Eltanin* cores) of the planktonic foraminifera *Globigerina bulloides* d'Orbigny show clear relationships with the distributions of southern subtropical to northern antarctic waters of the southern Indian Ocean (30° to 53°S.). The species attains largest test sizes in cooler waters (average widths of about 350 microns) and decreases gradually in size with increasing surface-water temperature (to a minimum average of about 210 microns). Highest percentages of sinistrally coiled forms (about 70 percent) occur in cooler waters decreasing to about 55 percent sinistral coiling in warmer waters. We are studying *G. bulloides* in late Quaternary *Eltanin* cores from subantarctic waters to determine if average test size and coiling direction changes parallel paleotemperature curves established using other methods. The other methods include those based on frequency variations in single species or groups of species, coiling directions, and oxygen isotopic variations.

Study of one core is complete (*Eltanin* 48-22A; 39.90°S. 85.41°E.; water depth 3,378 meters). The result indicates that mean test size variations in *G. bulloides* closely follow paleotemperature variations (figure). The size oscillations show a significant overall correlation (r=0.65) with paleotemperature curves based on coiling ratios of the planktonic species *Neogloboquadrina pachyderma* and factor analysis of entire planktonic foraminiferal assemblages (figure). Three major climatic coolings are marked by large average mean sizes (between about 280 and 315 microns), and four major warming episodes are reflected by small mean sizes (between about 235 and 280 microns).

Coiling direction of *G. bulloides* does not show any relationship to the paleotemperature curves despite relationships exhibited between temperature and coiling direction in surface sediments.

In Recent assemblages a correlation also exists between test size and percentages of *G. bulloides*, with highest frequencies generally being found in southern subantarctic waters. It is therefore possible that water temperature itself is not the primary factor controlling test size, but that largest growth occurs in the optimum environmental conditions for this species (as indicated by highest frequencies). The observed correlation between test size and water temperature may thus be a secondary consequence of the relationship between water temperature and percentages of *G. bulloides* in the area of study. Agreement between optimum adaptation and optimum growth environments in *G. bulloides* would be in accordance with a general model for the growth of planktonic foraminifera proposed by Hecht (1976).

We thank Douglas Williams for allowing us to use



Variation in mean test size of *Globigerina bulloides* in USNS *Eltanin* core 48-22A (39.90°S. 85.41°E.) from the southern Indian Ocean (close to the Subtropical Convergence) compared to paleotemperature curves derived from coiling ratios of *Neogloboquadrina pachyderma* and factor analysis of total planktonic foraminiferal assemblages (from Williams, in press). Size curve is significantly correlated (r=0.65) with paleotemperature curves.

his oxygen isotope data and coiling directions of *N. pachyderma* from core 48-22A. This research was supported by National Science Foundation grant DPP 75-15511.

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Morphologic variations in *Hannaites,* a Paleogene silicoflagellate

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We have continued our studies of surface ultrastructure and morphology of *Hannaites* (Mandra *et al.,* 1975). In this paper the following are illustrated and described for the first time: three- and five-sided *Hannaites* (figures 1, 5, and 6*) and gross morphology of new four-sided specimens (figures 2, 3, and 4). Also, a correlation is presented between some morphologic terms of earlier workers and our current terms for surface morphology and ultrastructural detail (figures 7, 8, and 9) as described in 1975.

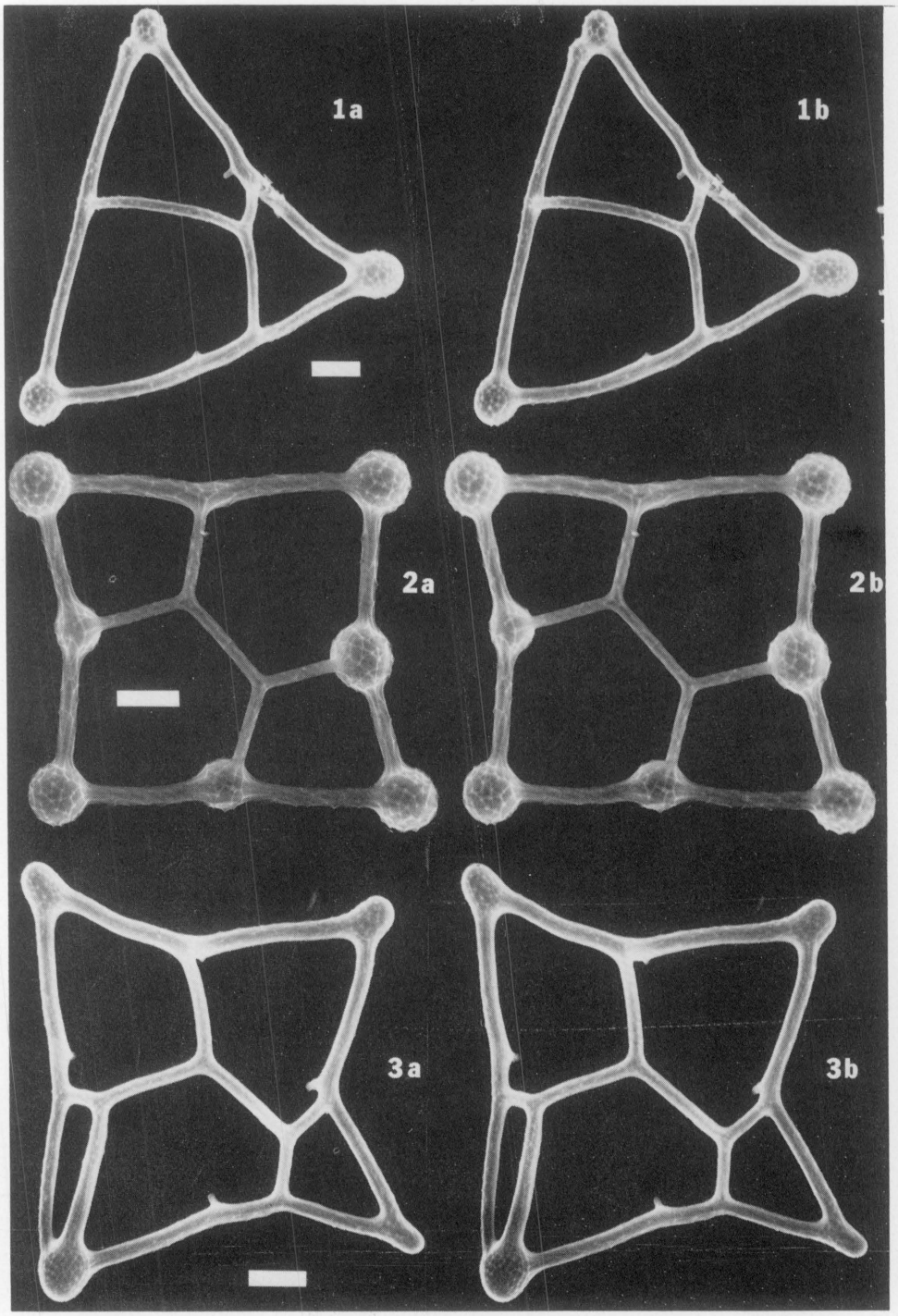
The three levels of morphology reported in 1975 for the four-sided *Hannaites* are also present in the three- and five-sided *Hannaites.* It now appears that these three levels of morphology are present in many, but not all, silicoflagellates of other genera. Similarly, three- and five-sided forms also have: surface morphology with reticulations and "flow lines" (figure 8) and ultrastructural morphology with nanodivides, nanopeaks, and nanovalleys (figures 7, 8, and 9).

The gross morphology of *Hannaites* includes three-, four-, and five-sided forms that have a basal ring and an apical bridge system comparable to the apical system and basal ring of the genus *Dictyocha.* However, the protuberances (swellings) of *Hannaites* distinguish it from *Dictyocha.* Our prior papers on *Hannaites* report the protuberances only at the corners of specimens. Here we illustrate (figure 2) a specimen having protuberances not only at each of the four corners but also in the middle of three sides of the four-sided basal ring. These midside protuberances are at three of the four apical bridge-to-basal-ring intersections. Therefore, this four-sided *Hannaites* has seven protuberances.

In most specimens two tubes radiate from each corner protuberance, either in or nearly in the plane of the basal ring. These two corner radiating tubes are oriented about 45° to 90° to each other. There are exceptions, one of which is a specimen with one corner protuberance having three radiating tubes (figure 3). Protuberances on the sides have three radiating tubes because they join the basal ring to the apical system. In plan view (figure 2), these tubes are usually oriented at about 0°, 90°, 180°. The apical tube is always inclined to the plane of the basal ring. Usually two tubes radiate from an area close to the equatorial (basal ring) plane of the protuberances. However, some protuberances with three radiating tubes have tubes almost tangential to the sphere-like swelling (figure 2, left central protuberance).

Figure 4 illustrates a four-sided *Hannaites* with basal ring tubes that do not meet at one corner. In stereo one sees that these tubes are displaced from each other normal to the page. The terminal parts of these two tubes have small, clublike swellings at the corner region, and the two tubes apparently just miss forming a corner protuberance. The adjacent corner protuberance to the right has clear-cut lobes

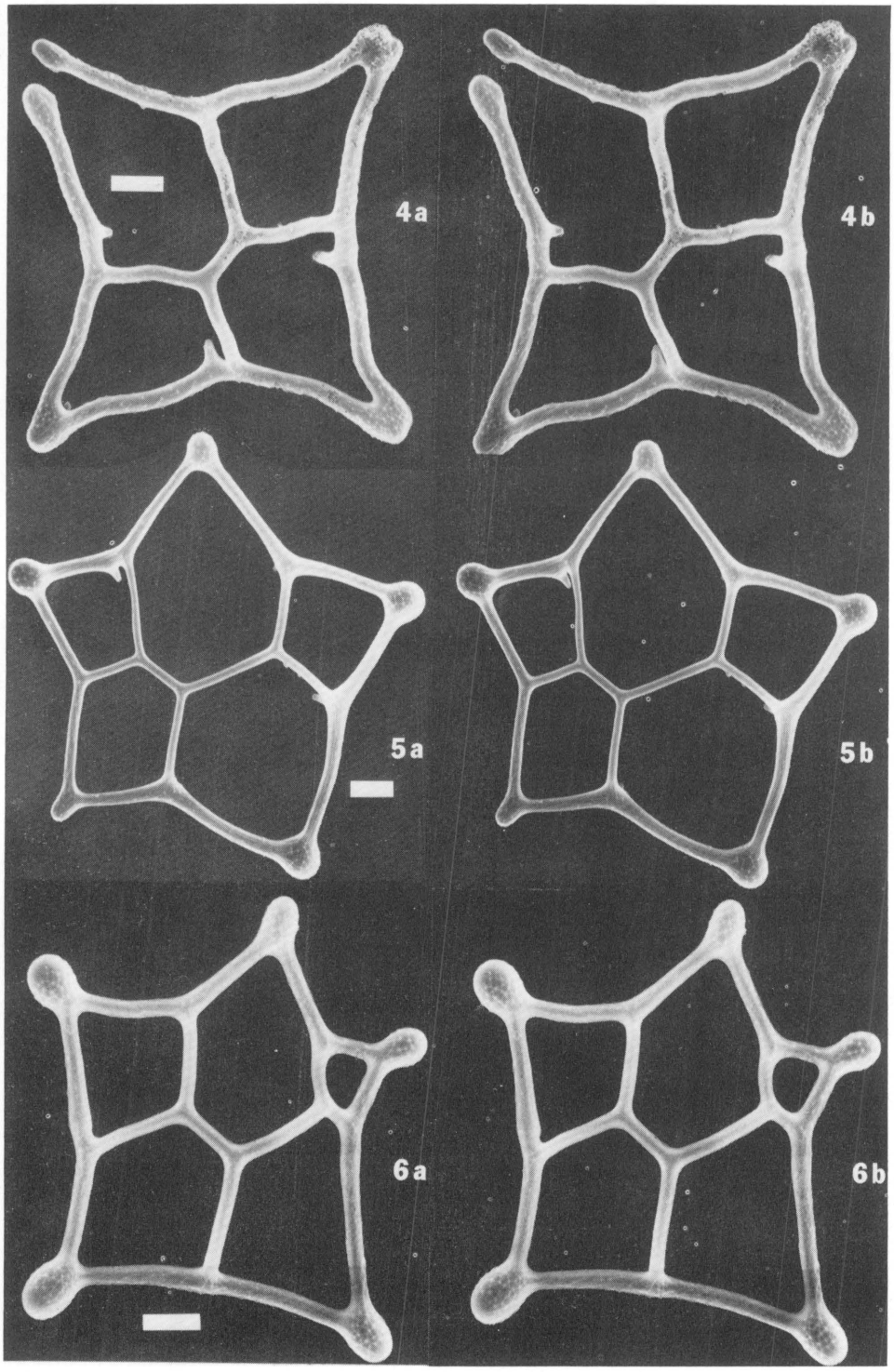
*Illustrations are stereograms. All stereograms have one specimen at 0° and the second at 8° tilt, except figures 9a and 9b, which were 34° and 42° tilt. In all cases the accelerating voltage was 25 kilovolts. Bar scales = 10 microns.



Figures 1a, 1b. Three-sided *Hannaites* with one corner protuberance having two lobes. Figures 2a, 2b. Four-sided *Hannaites* with seven protuberances. Figures 3a, 3b. Four-sided *Hannaites* with one corner protuberance with three radiating tubes.

that look as if the corner was formed by the swollen ends of two tubes coalescing. Each corner of this specimen could represent a different stage in the formation of corner protuberances: stage 1 (upper left corner of specimen), tubes not quite meeting; stage 2 (upper right corner of specimen), tubes just meeting and "blending" together; stage 3 (lower right corner of specimen), loss of much of the identity of the two individual tubes that were joined; stage 4 (lower left corner of specimen), complete loss of identity of two tubes that were joined. Figure 7, a corner of a three-sided form, appears to be another example of stage 2.

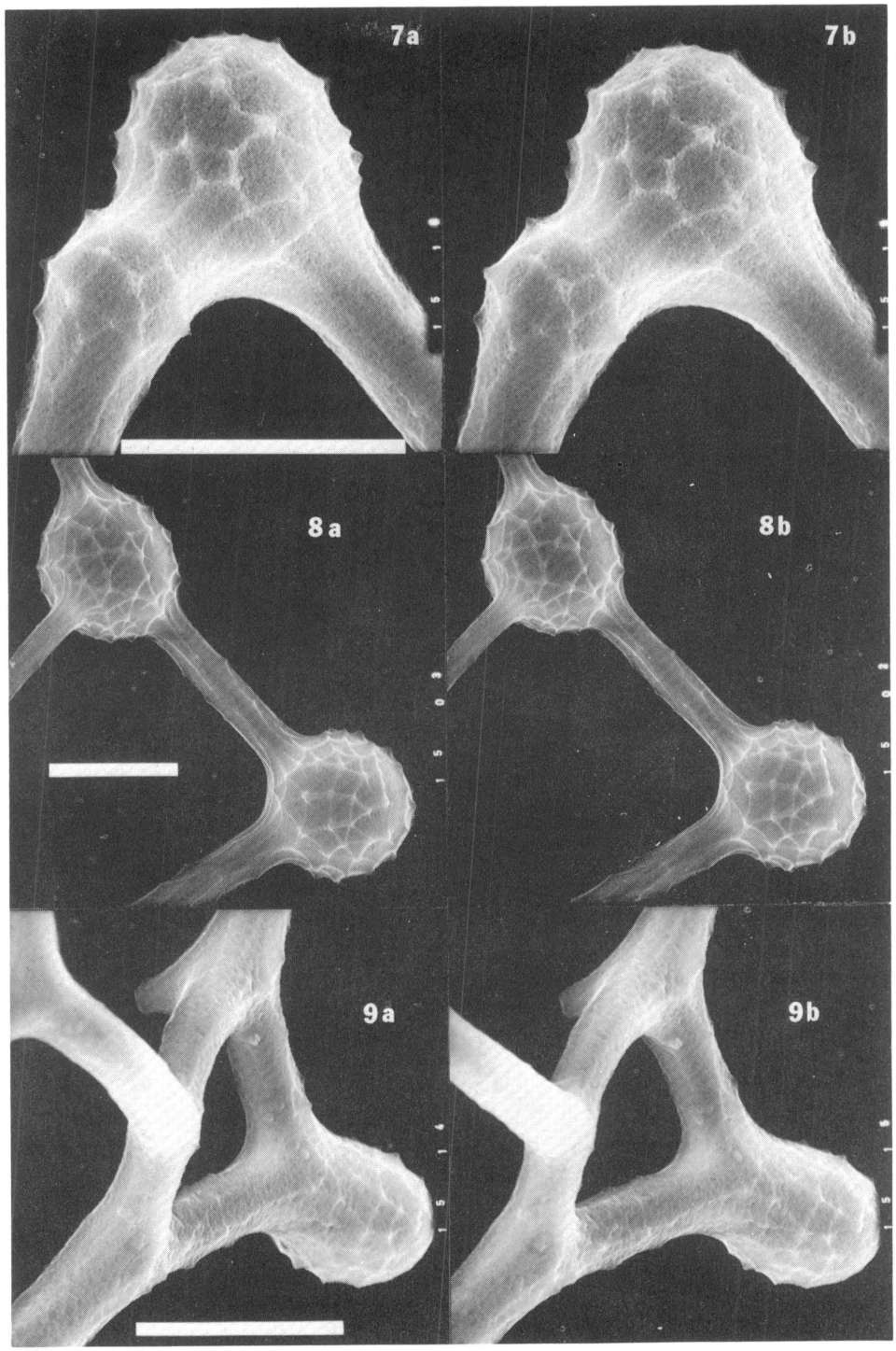
The shapes of protuberances vary from almost perfect spheres to distorted spheres that could be described as "boudinage-shaped" (figure 9) (we use



Figures 4a, 4b. Four-sided *Hannaites* with one corner open. Figures 5a, 5b. Five-sided *Hannaites* with five apical windows approximately equal in size. Figures 6a, 6b. Five-sided *Hannaites* with one apical window considerably smaller than the others.

the term "boudinage-shaped" as it is used in structural geology); or squarish-shaped with rounded corners and edges (figure 4, upper right corner); or cylindrical (figure 6, top central corner) with a rounded extremity and an axis sometimes more than twice the length of the diameter; or "joined ends" (figure 1, top corner) as described in the preceding paragraph.

This study of three- and five-sided forms of *Hannaites* indicates that surface morphology consisting of reticulations and "flow lines" does not differ



Figures 7a, 7b. Ultrastructural details of top corner protuberance of three-sided *Hannaites* (figure 1) with nanopeaks, nanodivides, and nanovalleys. Figures 8a, 8b. Ultrastructural details of the lower right corner and the middle right protuberance; the connecting portion of the basal ring of four-sided *Hannaites* (figure 2). The straight tubes show the nanopeaks,which were called thorns. Both protuberances show the nanopeaks, nanodivides, and nanovalleys, all three of which were treated as one phenomenon and called reticulations. Figures 9a, 9b. Ultrastructural details of the boudinage-shape upper right corner of protuberance of five-sided *Hannaites* (figure 6).

from that of four-sided forms reported by Mandra *et al.* (1975).

A correlation between the earlier silicoflagellate morphologic terms "thorn" and "reticulation" and our current terms for surface morphology and ultrastructural detail can now be demonstrated. Most thorns are nanopeaks formed by the intersection of two nanodivides. Reticulations are clusters of nanodivides, nanopeaks (usually formed by three or more intersecting nanodivides) and nanovalleys concentrated in a particular area of the specimen. The gross, overall patterns of the nanodivides constitute surface morphology. The details of those patterns constitute the ultrastructure.

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Ecology of fishes and echinoderms during ARA *Islas Orcadas* cruise 8[1,2]

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The objectives of our biological program aboard ARA *Islas Orcadas* during cruise 8 (February and March 1976) were similar to those of cruise 5: to investigate the food habits and feeding behavior, the distribution, the abundance, the taxonomy, and the general biology of demersal fishes and certain echinoderms. Our plan was to repeat some of the work previously done at South Georgia Island to obtain comparable data at a different season of the year (late summer as opposed to late fall) and to sample in the South Orkney and southernmost South Sandwich islands to fill in our geographic coverage of the Scotia Arc islands and for comparison with the more northern islands.

The South Orkney Islands are free of commercial fishing pressure and are relatively unknown. They lie approximately 360 nautical miles south of South Georgia and are south of the Weddell Sea Confluence, which is the boundary between water originating in the Weddell Sea and that from the southeastern Pacific (Gordon, 1967). The South Sandwich Islands and associated shallow banks lie south of the Weddell Sea Confluence, but extend some 240 nautical miles in a north-south direction. They were sampled very little prior to *Islas Orcadas* cruise 5. South Georgia lies northwest of the Weddell Sea Confluence, and because its fish fauna is distinct enough from that found near the coasts of Antarctica it is recognized as a separate region of the glacial district of the Antarctic Zone (DeWitt, 1971). The South Sandwich and South Orkney islands are considered transitional areas between the low antarctic region (South Georgia) and the high antarctic region (Antarctica) of the glacial district. We hope that our selection of sampling areas will allow a better understanding of faunal relationships and limits as well as comparisons of several aspects of the biology of the species found in separate geographic localities.

The University of Maine party consisted of Drs. DeWitt and McCleave as coprincipal investigators; Timothy E. Targett and William F. Taylor, graduate students; and John T. Konecky, biological technician and ichthyologist. Bruce A. Daniels, Smithsonian Oceanographic Sorting Center (SOSC), whose special interest was leeches, joined our party to assist with the echinoderm studies and was responsible for collecting other invertebrates for SOSC under a cooperative arrangement with the University of Maine.

Three factors caused cruise 8 to be less successful than anticipated. Several periods of rough weather caused cancellation of some work and longer than expected running time between stations, which necessitated further reductions in station time. Two early losses of wire required moving deepwater stations to areas shallower than about 1,000 fathoms. Most damaging, however, was the failure of one main alternator engine on the morning of 3 March, which resulted in cancellation of all

[1]This is contribution 95 of the Ira C. Darling Center for Research, Teaching and Service, University of Maine at Orono, Walpole, Maine 04573.

[2]Operation of ARA *Islas Orcadas* (formerly USNS *Eltanin*) is a 5-year cooperative effort between Argentina and the United States to complete the circumpolar oceanographic survey begun by *Eltanin* in the early 1960s (*see* January/February 1974 *Antarctic Journal,* page 30). Publication of *Islas Orcadas* preliminary cruise reports in *Antarctic Journal* is a U.S. contribution to the project. The first report in this series appeared in the July/August 1975 issue (page 141).

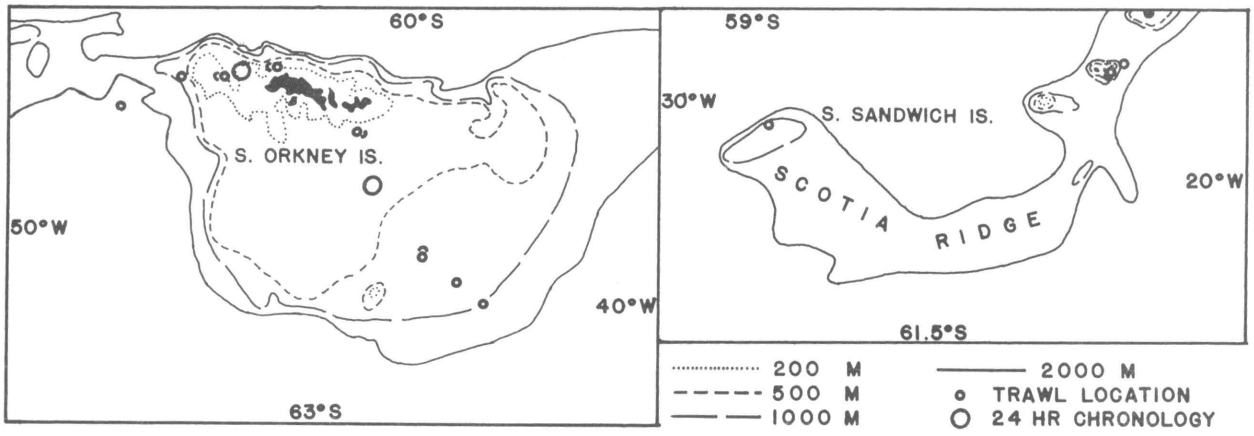

Figure 1. Locations of tows made with the 10-foot Blake trawl during ARA *Islas Orcadas* cruise 8. The 24-hour study locations consist of six tows.

further work. This meant the loss of all our planned work at South Georgia, amounting to more than 40 percent of our station time, and vitiated much of our seasonal studies of food and reproductive habits since we were unable to repeat any of our earlier late-fall stations. Our total accomplishments thus were few compared to those of cruise 5.

Twenty-eight successful tows were made with the 10-foot Blake trawl; 24 were in the vicinity of the South Orkney Islands, and four were in the vicinity of the Southern Thule group of the South Sandwich Islands (figure 1). From the tows 3,378 fishes were obtained, of which 1,460 were preserved for further study at the University of Maine. Total lengths were measured on 1,639 specimens, including random samples of the more common species (*Notothenia gibberifrons* and *N. larseni*), and all specimens of the less common and rarer forms. Fresh weights were recorded for the total catches by species, and 506 specimens were selected for individual weights to calculate estimates of length-weight relationships. The stomachs of 941 specimens were examined for food contents, and food items were found in 854 of the stomachs. The latter, together with the contained food, were preserved for further analysis in Maine. Otoliths were taken from 262 specimens for possible use in taxonomic and age studies.

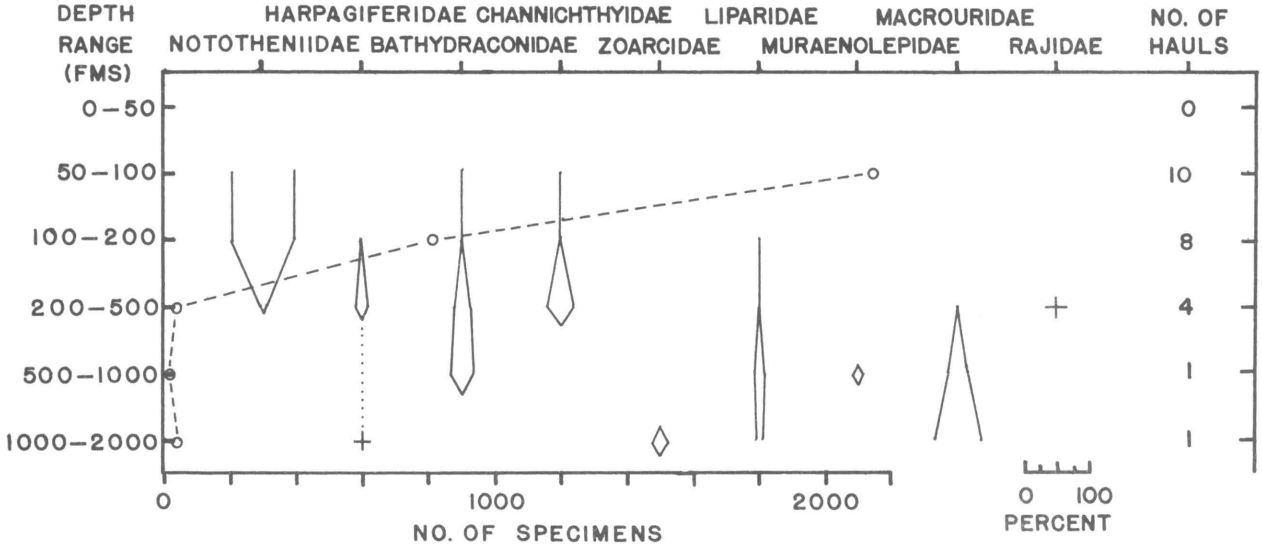

Figure 2. Depth distribution and relative abundance (as percent) of nine families of fishes near the South Orkney Islands, together with number of hauls and specimens taken in each of six depth ranges. The width of each diagram indicates percent of numbers: single line or cross, less than 4 percent; dotted line, depth interval with no catches between two intervals with catches; dashed line joins the total number of specimens captured in each depth interval.

The collections made near the South Orkney Islands are adequate to characterize the fish fauna found there. It resembles fauna of the Antarctic Peninsula region in the presence of several genera *(Pleuragramma, Pogonophryne, Racovitzia, Prionodraco, Gymnodraco,* and *Chionodraco)* and species *(Trematomus eulepidotus, T. scotti, T. newnesi, Artedidraco skottsbergi,* and *Bathydraco marri),* and therefore differs significantly from that of South Georgia. Families represented at South Georgia and absent from our South Orkney collections are the Moridae and Bothidae. Figure 2 shows that the depth distributions of the families present at the South Orkneys are closely similar to those of South Georgia (DeWitt *et al.,* 1976). The Nototheniidae dominate in shallow waters and the Macrouridae dominate in depths over 1,000 fathoms.

The echinoderm studies emphasized the feeding and reproductive biology of astrozoans. The stomach contents of many species were examined for prey items, particularly good data being obtained for the asteroids *Psilaster charcoti* and *Labidiaster annulatus,* and the ophiuroid *Ophionotus victoriae.* Several specimens of brooding asteroids were obtained, and these have been shipped to Maine for analysis of brood effort and juvenile nutrition. One South Orkney station and two at Southern Thule yielded large numbers of *Ophionotus victoriae.* These samples will enable a study of population structure, annual growth rates, and differences in reproductive timing between localities. Specimens of several astrozoan species were frozen for electrophoretic analysis of genetic homogeneity within breeding populations, and about 300 preserved specimens have been shipped to the University of Maine for morphological studies and species identification.

We thank all who participated in cruise 8 for their help in making it so successful despite difficult weather and unforeseen problems. We especially thank Capitan Pedro Sanjurjo, commander, for his efforts and interest in our program and for his aid in planning the cruise. His knowledge of the English language more than made up for our want of Spanish. To Teniente Roberto Parodi, chief oceanographic officer, and the oceanographic group of the Argentine Naval Hydrographic Service, we are indebted for excellent handling of our over-the-side gear. We thank Aldo Tomo, chief scientist of the Argentine Antarctic Institute, for his efforts to coordinate our program with that of his institution. We thank all of our Argentine colleagues for their efforts in making our stay pleasant. Finally, we express our appreciation to Paul Dudley-Hart for again making life smoother aboard ship. This research was supported by National Science Foundation grant DPP 74-08565 to the University of Maine, Orono.

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Biological oceanographic investigations during *Marion-Dufresne* cruise 8

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Through a cooperative arrangement between the National Science Foundation and the Territoire des Terres Australes et Antarctique Françaises, two students (D. Stockwell and H. Reheim) and I were invited to participate in cruise 8 of the French vessel *Marion-Dufresne* in the southwestern Indian Ocean (figure 1). The cruise provided an excellent opportunity to continue my circumantarctic study of phytoplankton ecology and primary productivity of the southern ocean. Since the Indian sector of the Antarctic and Subantarctic is still recognized as the least studied region of the southern ocean, our participation in cruise 8 was a welcome opportunity to fill in some of the huge gaps in our knowledge of that sector.

Marion-Dufresne cruise 8 was a multidisciplinary cruise. Its main objective was to contribute to knowledge of the biological oceanography of the southwestern Indian Ocean, with special emphasis on the study of the benthic fauna of the subantarctic islands of Marion, Prince Edward, and Crozet. Although the fauna of the two former islands were first studied by the *Challenger* Expedition in 1873 during its brief visit to the islands, these studies were never completed. The objectives of cruise 8 thus were:

(1) carry out a systematic inventory of the benthic fauna (both vertebrates and invertebrates) in the study areas;

(2) estimate the biomass of fishes, lithodid crabs, and cephalopod;

(3) study the biology, distribution, and abun-

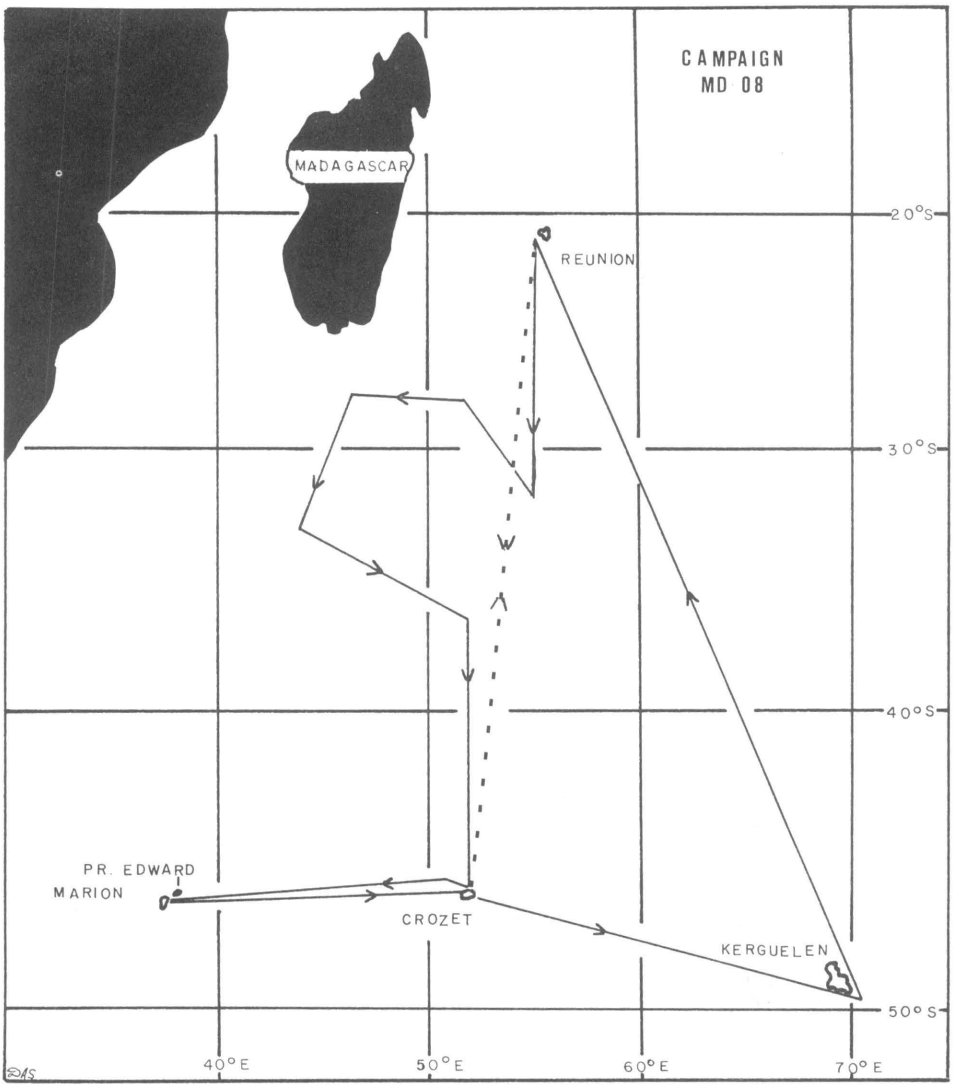

Figure 1. Track of *Marion-Dufresne* cruise 8 (8 March to 26 April 1976). Solid line, first leg; broken line, second leg.

dance of the lithodid crab species *Lithodes murrayi,* and incidentally those of *Paralomis aculeata,* and cephalopod populations;

(4) study primary productivity and ecology of the phytoplankton population;

(5) study the biomass and species composition of zooplankton;

(6) take a census of the oceanic birds, and study their feeding behavior and relate their distribution to the water masses traversed;

(7) study the hydrographic conditions of the water masses, and correlate the distribution of the biota with such physical features as the Subtropical Convergence and Antarctic Convergence, pycnoclines and nutriclines.

During this cruise a detailed study of the continental shelf off the Crozet Islands was made. Data from several stations occupied around these islands confirmed earlier observations regarding the abundance of the litholid crab *Lithodes murrayi* in the American Bay (Possession Island). The catch of another crab *Paralomis aculeata,* however, was small. Attempts to estimate the population of *L. murrayi* at the American Bay were made by the tag/recapture technique. Unfortunately, the number of tags recovered was too small to estimate that population.

Study of the bottom fauna in the vicinity of the Marion and Prince Edward islands also yielded interesting results. Data from cruise 8, together with data gathered from earlier cruises in the vicinity of

P. M. Arnaud

Figure 2. *Marion-Dufresne* at Crozet Island (Ile de l'Est in the background).

the Kerguelen Islands, revealed that biogeographically the continental shelves of the Marion-Crozet-Kerguelen islands can be grouped tentatively under the "Kerguelenian Province." Additional observations are needed to confirm this view.

The phytoplankton program centered on the study of the distribution of the standing crop, primary productivity (using the *in situ* method), estimates of the rates of dark-assimilation of carbon-14, contribution of nannoplankton (<20 microns), ATP (adenosine triphosphate), and species composition. At the seven stations occupied off Marion Island we encountered one of the richest phytoplankton populations found during the cruise; indeed, the standing crops at these stations were as high as any of the other rich areas I have found in the southern ocean. Interestingly, the phytoplankton catch at these stations was mainly (95 to 99 percent) composed of the diatom *Chaetoceros flexuosus*.

Marion-Dufresne logged about 10,772 nautical miles during this 50-day cruise; 79 stations were occupied. The ship (figure 2), a luxurious 3,500 metric tons, was built and run by the Compagnie des Messageries Maritimes for the sole use of the Terres Australes et Antarctiques Françaises. It essentially is a transport/supply ship for the subantarctic islands of Kerguelen, Crozet, Saint Paul, and Amsterdam.

The scientific complement (22) was headed by the two co-chief scientists, J. C. Hureau and P. M. Arnaud, and was composed of several professors, graduate assistants, technicians, and a "patron de pêche"; they represented several universities and institutions in France, the United States, the Republic of South Africa, and Portugal and Canada. My research aboard cruise 8 was supported by National Science Foundation grant DPP 75-09288.

Subtidal survey of the Strait of Magellan in the vicinity of the *Metula* oil spill

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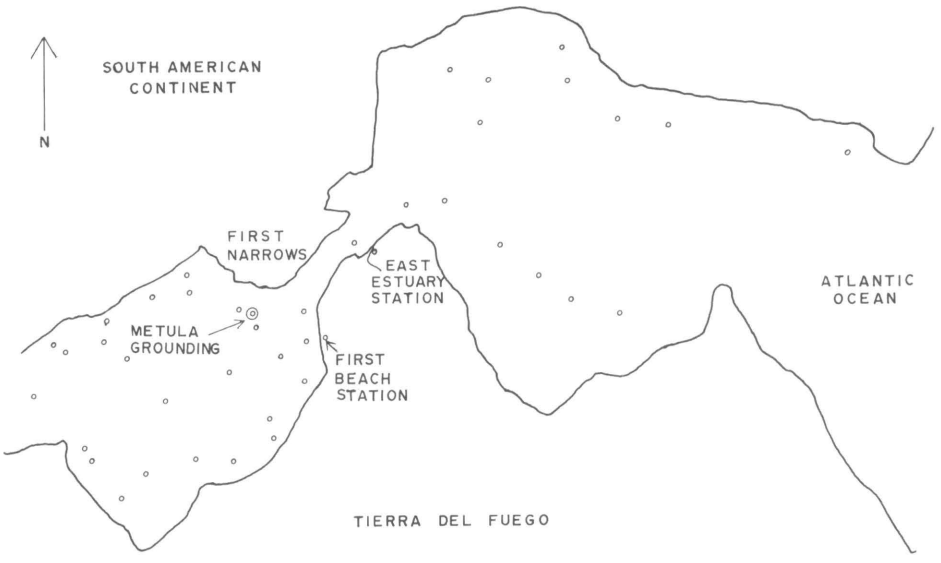
On 9 August 1974 the oil tanker *Metula* ran aground on the Satellite Bank (52°33.8'S. 69° 42.1'W.) immediately west of the First Narrows (figure) in the Strait of Magellan (Gunnerson and Peter, 1976). The ship spilled an estimated 52,300 metric tons of Arabian light crude and 2,000 tons of bunker C fuel oil into the strait. Most of the oil was rapidly driven onto the beaches. No attempt was made to disperse the spilled oil or to remove it from the shoreline.

We surveyed subtidal benthic communities and sediment oil contamination from the National Science Foundation's research ship *Hero* during 5-13 April 1976. Accompanying us in the scientific party were Jorge Castillo, Universidad de Concepción, Chile, and Italo Campodonico and Demitirio Diaz, Instituto de la Patagonía, Punta Arenas, Chile. Forty-four benthic grab, beach, and trawl stations were occupied (figure). Benthic specimens will be identified and enumerated under U.S. Environmental Protection Agency (EPA) grant R804514 to the Universidad de Concepción. Description of spatial variations in benthic community structure in the vicinity of the spill will be a collaborative effort between U.S. and Chilean scientists. Donald Baumgartner of EPA's Corvallis Environmental Research Laboratory will analyze petroleum hydrocarbon contamination of sediments.

We encountered a great diversity of subtidal benthic habitats. Sediment types ranged from clays to boulders, and benthic communities appeared to be equally heterogeneous. Quantities of oil were still on the beaches. We found a 25-centimeter-thick oil "mousse" layer 45 centimeters below the surface of the upper intertidal zone at the first beach



Site of the *Metula* grounding and benthic sampling stations in the Strait of Magellan.

station (figure). Oil in the east estuary on the southern shore of First Narrows extended from the main channel to the supralittoral zone where it affected *Lepidophylum* and *Salicornia* plant communities. The beaches and inlets appear to be a continuing source of oil pollution in the Strait.

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Marine mammals and birds in the southwest Atlantic Ocean: R/V *Hero* cruise 75-5

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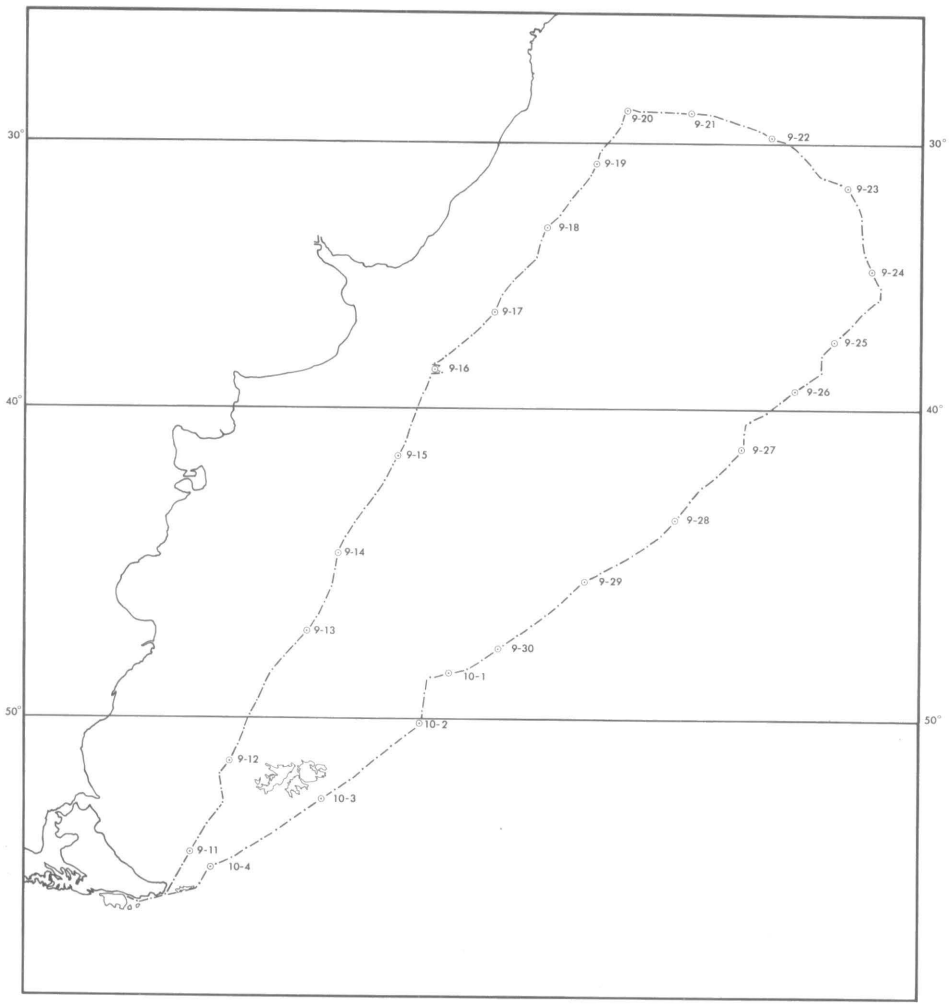
R/V *Hero* cruise 75-5 departed Ushuaia, Argentina, on 11 September 1975 and ended at the same port on 6 October 1975 after systematic observations of marine mammals and birds in the southwest Atlantic Ocean. In addition to the author, the scientific complement comprised the following: E. D. Mitchell and V. M. Kozicki, Arctic Biological Station, St-Anne de Bellevue, Quebec, Canada; A. Kawamura, Whales Research Institute, Tokyo, Japan; Saint-claire Bechtinger Simon, superintendencia do Desenvolvimento da Pesca, Rio de Janeiro, Brazil; M. A. E. Rumboll, Museo Argentino de Ciencias Naturales, Buenos Aires, Argentina; F. Addison, Washington, D.C.

Ship's track. After leaving the Beagle Channel and rounding Cape San Diego, Tierra del Fuego, *Hero* went north-northeast for 9 days, traversing waters outside the continental shelf. On reaching the most northern point of the cruise (28°40′S. 44°00′W.) on 20 September, the course was changed to easterly, and we continued toward Bromley Plateau. The ship crossed the plateau from northwest to southeast in 2½ days, after which it began the return leg of the cruise. The most eastern point of the trip (33°50′S. 32°00′W.) was reached on 24 September after 1 day of a south-southeast course. *Hero* was then put on a southwest course and passed east of the Falkland Islands (Islas Malvinas) and Staten Island and then west to the entrance of the Beagle Channel (figure).

Marine mammal observations and research. Teams made up from the scientific staff kept watch for marine mammals during all daylight hours. Few large whales were sighted. They include, in descending order of abundance: sperm whales, *Physeter catodon;* sei whales, *Balaenoptera borealis;* and minke whales, *B. acutorostrata.* Observations were recorded on the following small cetaceans: southern bottlenose whale, *Hyperoodon planifrons;* long-finned pilot whale, *Globicephala melaena;* hourglass dolphin, *Lagenorhynchus cruciger;* Peale's dol-



Track of R/V *Hero* cruise 75-5 (September and October 1975).

phin, *L. australis;* and southern right whale dolphin, *Lissodelphis peronii.* Two species of pinnipeds were observed during the cruise: South American fur seal, *Arctocephalus australis;* and South American sea lion, *Otaria flavescens.*

One sperm whale approximately 12 meters in length was tagged at 37°20'S. 33°52'W. by Kozicki on 25 September (Canadian sperm tag number FRBC/5584).

Detailed data were compiled on the coloration and behavior of all the small cetaceans encountered during the cruise.

Seabird observations and research. This program was directed by Joseph R. Jehl, Jr., Natural History Museum, San Diego, California. Dr. Rumboll conducted all the field research. Using standard techniques, he censused seabird numbers at specified periods throughout the day. Although seabird populations were low at this season, presumably because breeding birds had moved southward into the vicinity of nesting islands, Dr. Rumboll was able to gather valuable quantitative data from this little-studied area. He also obtained new distributional data for several species. The most unexpected discovery was the sighting of three juvenile emperor penguins, *Aptenodytes forsteri,* off the coast of Northern Argentina (approximately 40°S. 54°W.). Previously this species had not been discovered away from the pack ice, and Dr. Rumboll's observations thus suggest that its range may be more extensive than we currently recognize.

Data were compiled on the feeding habits, the associations, and the ecology of seabirds. When possible, specimens were collected for stomach contents. Mallophaga recovered from bird specimens were sent to the University of Canterbury, Christchurch, New Zealand, for identification and study. In addition, Rumboll made daily plankton tows; the samples were deposited in the Museo Argentino de Ciencias Naturales in Buenos Aires and are being studied there by N. Maldagi.

Conclusions. Unfortunately, observations of large cetaceans were few, in part because of rough seas

throughout most of the cruise. The almost complete absence of minke whales was a disappointment, as the ship's track had been planned to traverse waters believed to be frequented by minkes at the time of the cruise. The absence of minkes indicates that current ideas of the seasonal distribution of these whales must be refined.

The cruise constituted an important U.S. contribution to the International Decade of Cetacean Research of the International Whaling Commission.

The master of R/V *Hero,* Pieter Lenie, and his crew provided excellent assistance to our program. This research was supported by National Science Foundation grants DPP 75-19724 and DPP 75-19221, and by Environment Canada.

David G. Ainley

Figure 1. Subadult elephant seal present at Cape Crozier on 18-21 December 1974 and on 18-27 January 1975.

Southern elephant seals in the Ross Sea

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Southern elephant seals, *Mirounga leonina,* are circumpolar in distribution. All their breeding localities, primarily subantarctic islands, as well as all sightings have been summarized by Erickson and Hofman (1974: plate 7*). The southernmost records are from McMurdo Sound or nearby points on Ross Island (Golden, 1974, *in* Erickson and Hofman, 1974; Kooyman, 1964; Schlatter and Sladen, 1971; Wilson, 1907). These records were of five immature seals and one adult male, the latter collected in January 1904 at Cape Royds (77°33′S.) (Wilson, 1907).

At least one subadult male (figure 1), estimated to be 5 to 6 years of age based on size and morphology, was observed in the Ross Island vicinity during the 1974-1975 austral summer. It was at Cape Crozier (77°31′S.) 18 to 21 December 1974, disappeared for a time, and was next seen 18 to 27 January 1975. When observations were discontinued on the latter date it had not begun its annual molt. Possibly two different animals occurred, but we believe it was the same animal during both

Janet L. Boyd

Figure 2. Adult male elephant seal present near Scott Base and McMurdo Station on 10-18 February 1975.

*The reference for record number 298 of *M. leonina* from the Ross Sea is incorrect. It deals only with Beauchene Island, which is south of the Falkland Islands (Islas Malvinas).

periods. This represents the fourth elephant seal recorded for Crozier during 12 recent austral summers when biologists were present for extended periods (1961-1962 to 1970-1971, 1974-1975, and 1975-1976; see references above). During the same summer, on about 10 February 1975, two other males hauled out on the opposite (south) side of Ross Island, about 0.5 kilometer south of Scott Base (77°51′S.). Based on morphology, particularly the presence of well developed chest shields (figure 2), these animals were approaching or had already reached adulthood. They had not yet begun their molt. One of the two, which measured 4.5 meters, remained in the Scott Base and nearby McMurdo Station area until 18 February.

The elephant seal breeding locality nearest Ross Island is MacQuarie Island, approximately 2,400 kilometers to the northwest, where mature males begin their molt in late January or February (Carrick and Ingham, 1962). The complete moulting process takes about 18 days, and individual seals haul out for up to 2 weeks before molt and 3 weeks after (Carrick and Ingham, 1962).

We thank Daniel H. Morton, III, Robert Boyd, and Janet L. Boyd for their observations and photographs of the seals at Scott Base. This is contribution 132 of the Point Reyes Bird Observatory.

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Lake Bonney ecosystem: mathematical model

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After three field seasons of research at Lake Bonney (77°43′S. 162°25′E.) (figure 1), Taylor Valley, we have produced a data base that, although still lacking in some areas, will provide a reasonably solid basis for testing our mathematical models during the coming year. Among the more interesting findings during our investigation of the Lake Bonney ecosystem are:

(1) discovery, characterization, and measurement of photosynthesis of an extensive algal mat community in the east lobe of the lake;

(2) indirect evidence suggesting that cobalt and phosphorus deficiency or toxic levels of boron may limit growth of the microbial communities;

(3) phytoplankton algal counts and productivity rates significantly higher than those of earlier studies;

(4) among the planktonic heterotrophs, yeasts dominate during the early austral summer, then give way to bacteria, which dominate during the summer peak;

(5) more than 40 species or genera of algae are known to occur in the lake and its associated glacial melt streams;

(6) evidence of springs or underground water entering the east lobe during two consecutive austral summers;

(7) discovery and characterization of dihydrohalite at the bottom of the east lobe of the lake.

The scenario for Lake Bonney's austral summer begins with increasing solar radiation, producing a November peak in primary productivity. The increase in photosynthesis begins immediately below the 4 meters of clear ice and progresses to a depth of about 12 meters. A productivity peak subsides in early December, presumably in response to nutrient depletion. As solar radiation continues to increase, glaciers melt. The Sollas and Lacroix gla-

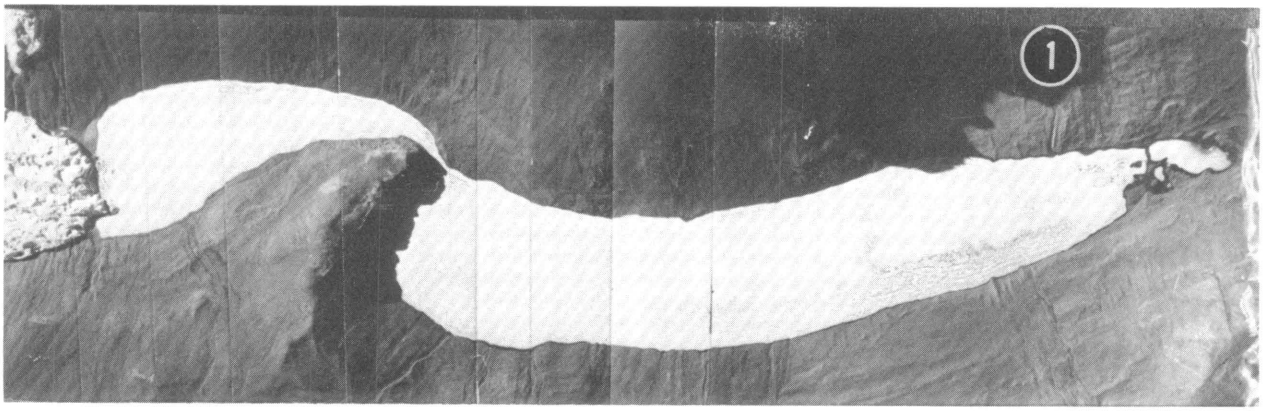

Figure 1. Composite aerial photography of Lake Bonney on 12 January 1975. The arrow marks the approximate location of our primary sample site on the east lobe.

ciers east of the lake contribute meltwater that passes several kilometers over soil and permafrost, ultimately bringing phosphorus, ammonium, and nitrate, as well as algae and other microorganisms, into the east lobe. Following dispersion and biological response, a second peak in productivity occurs in late December or early January. We believe the photosynthetic production in Lake Bonney accompanies the release of significant amounts of dissolved organic matter that may provide a carbon energy reservoir for the prolonged darkness of the antarctic winter.

A model for the ecostructure of Lake Bonney is being developed. Figure 2 shows the variables to be included and their relationships. Each arrow in the figure represents a submodel that must be developed and put into a prediction equation for the variable touching that arrow. The resulting 13 equations will be solved by computer, giving predictions for each variable.

Many of the needed submodels are in the literature, although only the most efficient and up-to-date ones will be used. Submodels not in the literature will be developed by using data from Lake Bonney. We hope enough data from Lake Bonney will be left for us to verify the model.

Our modeling intentions are to create a general model of a polar lake. The parameters used in the model will of course be appropriate to Lake Bonney, but with minor modification our model should be applicable to many polar lakes.

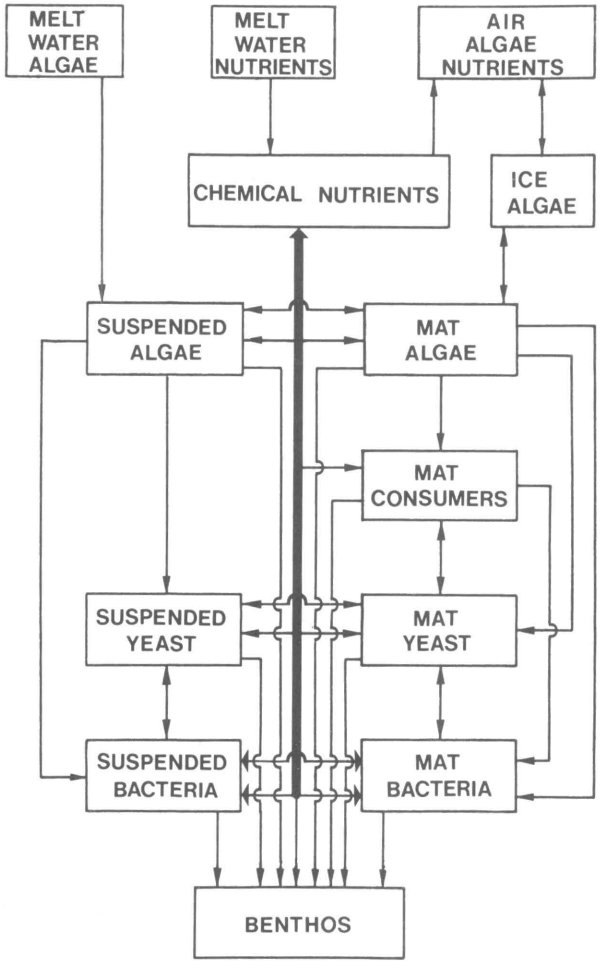

Figure 2. Idealize word model for Lake Bonney, representing a much simplified version of the models being developed.

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Cooperative systematic studies

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Investigators from numerous organizations, with the support of the U.S. Antarctic Research Program (USARP), have been collecting antarctic organisms for about 13 years. Enormous quantities were collected during the incomplete circumpolar expeditions of USNS *Eltanin* (now ARA *Islas Orcadas),* and considerably more came from operations of the research ship *Hero* and from land stations. Under an arrangement with the National Science Foundation (NSF), the Smithsonian Oceanographic Sorting Center (SOSC) processes and distributes these collections to scientists for study and systematic analyses.

The extensiveness of the collections has often exceeded the numbers and resources of specialists in particular taxa. As one means of further expediting the scientific analyses and of reducing the usual time between collection activities and having useful reports in hand, SOSC began a program called Cooperative Systematic Studies in Antarctic Biology about 10 years ago. The studies are designed to provide systematic data in an economical and scientific manner to complement all polar biological studies, particularly ecosystem research requiring species determinations. This program provides for studies which are not included in regular NSF proposals. Specialists prepare reports in 1 or 2 years depending on the quantity of specimens to be examined.

SOSC has negotiated contracts with individual scientists for production of about 25 manuscripts on discrete groups of organisms; this includes monographs and numerous other scientific reports. Results of a number of these studies have appeared in the *Antarctic Research Series* (American Geophysical Union) and the *Antarctic Map Folio Series* (American Geographical Society of New York). Additionally, five reports are in press, four are being reviewed or revised, two large and long-term projects are under way, and five newer ones are to be completed by December. Groups included in recent reports and other studies in progress are: bacteria, fungi, Ciliata, Octocorallia, Bryozoa, Solenogartres, Polychaeta, Halacaridae, planktonic Ostracoda, two families of Copepoda, Cirripedia larvae, Isopoda, and Rhodophyta.

The program has proved that limited support often can enable a specialist to undertake a study that might at best be long delayed after the time of collection. We anticipate that other groups of major importance in polar ecosystems will be studied. There is still much to be done with groups such as the polychaet worms, the copepods (primary herbivors), and most of the coelenterata. Investigators interested in these or other groups should contact SOSC to determine the availability of specimens and support.

The cooperative systematic studies are supported under National Science Foundation grant DPP 74-12303.

News and notes

U.S. Antarctic Research Program, 1976-1977

Planned field research projects

Below are summaries of U.S. science projects scheduled to take place in Antarctica during 1976-1977. Project titles (in **boldface**) are followed by names of principal investigators and their institutions (in *italics*).

Antarctic Peninsula

Scotia Arc tectonics project. *Ian W. D. Dalziel, Lamont-Doherty Geological Observatory of Columbia University.* This season we will continue our study of the processes involved in the creation of the Antarctic Peninsula Cordillera, the submarine subantarctic Scotia Ridge, and the southernmost Andes. This work should help us to further understand the breakup of southwestern Gondwanaland, a process that is still poorly understood. This year's work in the South Orkney Islands will complete our study of the Paleozoic rocks of the southeastern Pacific margin, providing an insight into the nature of the old Pacific Ocean basin and the processes along its margin by which Antarctica developed.

Mesozoic and Cenozoic depositional basins of the northern Antarctic Peninsula and the South Orkney Islands. *David H. Elliot, The Ohio State University.* This austral summer we will assess the Mesozoic geologic history of the South Orkney Islands and the relationships to the evolution of the northern Antarctic Peninsula and the Scotia Arc. We will study the stratigraphy, the sedimentary petrology, and the paleontology of clastic sediments cropping out adjacent to Lewthwaite Strait (60°42′S. 45° 07′W.). Detailed stratigraphic sections will be measured, conglomerate and sandstone samples will be collected for petrographic and provenance studies, and paleontological collections will be made to establish the age of the rocks. Michael Thompson, British Antarctic Survey, will participate in this project.

Effect of ice facies on small-scale oceanographic phenomena. *Robert J. Barsdate and Vera Alexander, University of Alaska, Fairbanks.* We will study the nearshore oceanographic environment around Palmer Station, Anvers Island, this austral summer, with special emphasis on the ice/water interface. Ice margin areas are thought to enhance biological productivity at several trophic levels, and antarctic nearshore areas are very productive in relation to contiguous oceanic systems. In this first year we will gather data primarily on the microscopic, free-floating algae that form the base of the antarctic food web, and we also will study chemical and physical factors that govern growth and distribution of these plankton algae. Data will

include primary productivity and plankton biomass, nutrient and trace metal chemistry, carbon dioxide system chemistry, salinity, temperature, oxygen, and light penetration.

Marine bird studies. *Joseph R. Jehl, Jr., San Diego Society of Natural History.* We will use the U.S. Antarctic Research Program's R/V *Hero* (cruise 77-2) to extend previous studies of the distribution and abundance of sea birds to the areas of the Falkland Islands (Islas Malvinas) and South Georgia. Birds will be observed and collected, and their feeding habits will be examined with respect to distance from land, underwater topography, and oceanic conditions. Plankton tows will be made along the ship's route to get an estimate of local productivity. These data, with other information, can be used to model the energetics of sea bird communities. The Museo Argentino de Ciencias Naturales "Bernardino Rivadavia" will cooperate in this study.

Structure of antarctic marine bird communities. *David G. Ainley, Point Reyes Bird Observatory.* This austral summer we will compare sea birds of the antarctic pack ice to cetaceans and pinnipeds in terms of their number, density, and biomass. We also will study the distribution of higher antarctic vertebrates, and we will note how various types of pack-ice cover affect these animals and which species are likely to be present with other species. This research is basic to understanding how marine resources are allocated among antarctic vertebrate communities. The data will help to determine what happens to some vertebrate populations (for example, birds) when other populations (for example, whales) are reduced. The Pacific sector of the Antarctic, particularly the Ross Sea, will be our area of study from aboard a U.S. Coast Guard icebreaker.

Ecological and behavioral adaptations to antarctic environments. *David F. Parmelee, University of Minnesota, Minneapolis.* Dr. Parmelee will observe the ecology and behavior of American sheathbills, brown skuas, and antarctic terns at South Georgia Island this austral summer. David R. Neilson, a University of Minnesota graduate student, will continue studies of hybridization in brown and south polar skuas at Palmer Station at the same time. A new graduate student will work with Mr. Neilson and then will remain at Palmer during the 1977 austral winter to continue year-round bird observations. Use of a radar unit at Palmer should greatly enhance our knowledge of the migration of a large number of birds that takes place during the winter. Our banding program will be expanded this year in light of the remarkable recoveries, as far away as in Mexico and Greenland, of young south polar skuas banded at Palmer in 1974-1975 *(see* June 1976 *Antarctic Journal,* page 111).

Behavioral and ecological adaptations of pygoscelid penguins. *D. Muller-Schwarze, State University of New York, Syracuse.* Studies of Adélie, chinstrap, and gentoo penguins will be conducted this austral summer along the Antarctic Peninsula where the three species are sympatric. This season's project will be an analysis of food and habitat utilization by the three species, with emphasis on the relationship between utilization of these resources and the penguins' chick-rearing abilities. This information is needed to understand the role of the penguins in the marine antarctic ecosystem and to evaluate potential disturbances to that system by such human activities as commercial krill fishing.

Biota of antarctic pack ice. *Donald B. Siniff, University of Minnesota, Saint Paul.* This project will use the U.S. Antarctic Research Program's R/V *Hero* this austral summer to study seals of the pack ice in the vicinity of the Gerlache Strait along the Antarctic Peninsula. The research will be carried out in October 1976, which is the period of crabeater seal pupping in this area. Data will be collected on the social organization and behavior of the crabeater. To aid these studies, radio transmitters will be attached to adult seals that accompany pups so we can relocate family groups. The growth rate of pups and the weight loss of adults will be measured. Also, changes in the social organization and behavior that occur before and after weaning will be documented. Interactions among the antarctic seal species and other species such as the killer whale probably play an important role in the population dynamics of these major vertebrate species, and our data should further understanding of these interactions.

Comparative aquatic biology of endotherms. *Gerald L. Kooyman, Scripps Institution of Oceanography, University of California, San Diego.* At South Georgia and elsewhere, we will investigate diving behavior of fur, Weddell, and Ross seals, emperor and king penguins, and diving petrels. Also, we will analyze ventilation and breathhold physiology while the animals are diving. Central to our work is a new depth-time recorder, developed by us, that weighs 0.65 kilogram and can record the depths of a diving animal for up to 21 days. The U.S. Antarctic Research Program's R/V *Hero* will provide logistics as part of cruise 77-2. The work at South Georgia will be done in cooperation with the British Antarctic Survey.

McMurdo Station and vicinity

High-latitude ionospheric absorption. *Hugh J. A. Chivers, University of California, San Diego.* This austral summer we will install and then maintain year-round riometers and associated antennas at Amundsen-Scott South Pole, Siple, and McMurdo stations. We will continue to measure ionospheric absorption at different latitudes caused by energetic electrons and protons precipitated by solar activity. Our project includes measurements at the conjugate location in Roberval, Quebec, and at Frobisher Bay, Northwest Territories, Canada.

Cosmic ray intensity variations. *Martin A. Pomerantz, Bartol Research Foundation of the Franklin Institute.* During 1976-1977 we will continue year-round measurements of cosmic ray intensities at McMurdo and Amundsen-Scott South Pole stations to further our understanding of how the sun controls interplanetary "weather" and the earth's immediate environment. The observations with ground-based detectors, in combination with similar data from arctic observatories, provide unique information about the directions of galactic and solar cosmic ray streaming. A new cosmic ray detector to be installed at South Pole Station this austral summer will be the most sensitive of its kind in the world.

Antarctic atmospheric infrasound. *Charles R. Wilson, University of Alaska, Fairbanks.* During 1976-1977 we will measure the natural spectrum of atmospheric infrasonic waves in the period range from 10 to 100 seconds with an array of microphones located at Windless Bight, about 30 kilometers southeast of McMurdo Station on the Ross Ice Shelf. Auroral infrasonic waves (AIW) will be recorded at the very high geomagnetic latitude of Windless Bight to determine their morphology deep within the auroral oval. This research is an attempt to explain how AIW's are generated by auroral electrojet motions.

Aerosol measurements in the stratosphere. *D. J. Hofmann and J. M. Rosen, University of Wyoming.* Stratospheric chloroflurocarbon samples will be taken this season at McMurdo Station to assess the global extent of this possible ozone-destroying agent. Also, the vertical distribution of condensation nuclei at Amundsen-Scott South Pole Station will be studied to assess the possible importance of these nuclei in clear-sky precipitation phenomena and in the formation of stratospheric aerosols.

Geodetic satellite observatory, *Arnold J. Tucker, The University of Texas, Austin.* The geodetic satellite observatory at McMurdo Station operates year-round to record scientific data from several earth-orbiting satellites. Doppler data are recorded to establish orbital parameters of these satellites in conjunction with polar-wander studies. Also, these data are used in studies of ionospheric scintillations occurring between the satellites and the ground observatory. Magnetometer data are recorded aboard the satellites and are transmitted to the observatory for use in locating the auroral oval.

Volcanic rocks of the McMurdo Sound area. *Samuel B. Treves, University of Nebraska, Lincoln.* This austral summer we will map, sample, and otherwise investigate volcanic rocks of the McMurdo Sound area to determine their origin and distribution, and to learn more about the area's geologic history. Our work will center on acid volcanics of the ice-free valleys of southern Victoria Land, and on the basaltic and trachitic rocks of Mount Discovery (78°23′S. 165°00′E.), Mount Morning (78°30′S. 163°32′E.), Minna Bluff (78°32′S. 166°30′E.), and Brown Peninsula (78°05′S. 165°25′E.).

Subsurface measurements of the McMurdo Ice Shelf. *Austin Kovacs and Anthony Gow, U.S. Army Cold Regions Research and Engineering Laboratory.* We will examine the process of brine soaking of the McMurdo Ice Shelf by using an impulse radar profiler to monitor the continuity and the lateral extent of brine infiltration. We also will obtain ice core samples for measurement of firn temperature, density, and brine volume, and for chemical and stable isotope analysis. The radar profiler will be used on the Koettlitz Ice Tongue to examine the process by which a glacial ice tongue transforms into sea ice of great thickness.

Seismic anisotropic investigations in the Minna Bluff area. *Hugh F. Bennett, Michigan State University, East Lansing, and Roger M. Turpening, The Environmental Research Institute of Michigan, Ann Arbor.* This field season we will test the application of the sonic petrographic method to the definition of stress fields in ice. This work will aid our evaluation of the potential use of shear waves in glaciological studies. We hope to obtain information on ice thickness, ocean bottom depths, ocean bottom slopes, and perhaps subbottom layering of the Ross Ice Shelf just east of Minna Bluff (78°32′S. 166° 30′E.).

Benthic communities of McMurdo Sound. *Paul K. Dayton, Scripps Institution of Oceanography, University of California, San Diego.* During 1976-1977 we will continue scuba diving in McMurdo Sound adjacent to McMurdo Station and New Harbor to examine structural and functional components of shallow-water benthic communities. The predictable physical nature of the antarctic marine environment suggests that biological processes rather than physical (or abiotic) stresses exert the most influence on population evolution. Our objectives are to: (1) continue and expand research on the sponge community; (2) study the adaptive value of reproductive and defense strategies of selected sponges; (3) investigate the hypothesized biological structuring mechanisms of soft-bottom communities. Species composition and distribution patterns and abundance of soft-bottom invertebrates will be studied in areas subject to natural and experimental perturbations, enrichment, and pollution. This work will eventually contribute to understanding the selective pressures and population responses to stresses within a biologically accommodated marine community.

Colonial behavior of antarctic marine mammals. *Donald B. Siniff and Douglas P. DeMaster, University of Minnesota, Saint Paul.* This project examines factors that affect the population of Weddell seals in the McMurdo Sound region. These factors will be incorporated into a model that will predict future population trends and hopefully suggest mechanisms that are important in regulating this seal population. Our research concentrates on two questions: (1) What factors contribute to the nonproductive status of almost half of the adult female population? (2) What level of subadult survival is needed to maintain this population?

Cardiovascular and metabolic response to diving and endocrinology of the Weddell Seal. *Warren M. Zapol, Massachusetts General Hospital.* This austral summer we will study the regional blood flow and biochemical adaptation of the Weddell seal in collaboration with researchers from Canada and New Zealand. This large mammal is capable of extremely long and deep diving due to many unique modifications of its biochemistry and physiology. Using a balloon-tipped catheter, we will study blood circulation to the lungs during simulated diving. Blood flows to all parts of the body will be measured with radioactively tagged microspheres. The metabolism of food and hormones will be studied. By placing plastic catheters in fetal seal umbilical vessels, oxygen, carbon dioxide, hormones, and other important blood concentrations will be studied during pregnancy and birth in undisturbed seals and during simulated diving. Studying the adaptations of the Weddell seal may give insight into improved therapy for clinical shock and asphyxia.

Establishment of a permanent penguin breeding colony and exhibit. *Frank S. Todd, Hubbs/Sea World Research Institute.* A total of 100 Adélie and 40 emperor penguins will be collected in the Ross Sea region during the 1976-1977 austral summer and transported to the United States under permit from the U.S. Department of Agriculture. The penguins will be placed in special containers and flown directly to San Diego, California, in the company of Sea World, Inc., staff. The airplane will be maintained at $-5°$ during the flight, and other precautions will be taken to insure safe and transport of the birds. In San Diego the penguins will be further acclimated. Long-range plans are to establish a self-sustaining breeding colony in a permanent, temperature-controlled environment at Sea World for research and education.

Newcastle disease and avian influenza viruses in antarctic birds. *Robert P. Hanson and Bernard C. Easterday, University of Wisconsin, Madison.* As a preventive measure before about 140 live Adélie and emperor penguins are collected and transported this austral summer to Sea World, Inc., San Diego, California, we will take trachael and cloacal swabs and blood samples from a statistically representative sampling of penguins and skua gulls at Cape Crozier, Ross Island. These samples will be used to determine whether Newcastle disease and avian influenza viruses are present in antarctic birds. Newcastle disease is of economic importance to the U.S. poultry industry; in 1971, for example, over $50 million was spent to eradicate virulent Newcastle disease that had entered southern California through international traffic in non-antarctic wild birds. Our antarctic data may also provide information on whether Newcastle disease is transmitted between resident and migratory bird populations of the Antarctic.

Viral etiology and epidemiology of respiratory infection. *Elliot C. Dick, University of Wisconsin Medical School.* We will determine whether winterers at McMurdo Station are more susceptible to respiratory infections than are new arrivals at the station on "Winfly" (winter fly-in) in early September, and whether there is a difference in illness severity between the two populations while they are isolated together before the main field season begins in early October. We also will identify which

viruses cause respiratory illness during this transition period from winter to summer personnel at McMurdo. Viruses will be isolated from nasal specimens taken at Christchurch, New Zealand, and at McMurdo, and these will either be inoculated directly into tissue culture or frozen for later study in the United States. Serum specimens will be taken from all persons at McMurdo at the beginning and the end of this transition period. Also, we will study how viruses are transmitted from person to person. Transmission studies will involve taking nasal specimens from persons with respiratory infections and determining the amount of virus present, and by keeping records of contacts among personnel. Careful study of interpersonal spread of respiratory viruses in this isolated population ultimately will give clues to methods by which the chain of infection may be interrupted.

Remote projects

Geology of the Dufek intrusion. *Arthur B. Ford, U.S. Geological Survey, Menlo Park, California.* At least five geologists will begin detailed geological mapping this austral summer of a very large layered igneous complex that was mapped in preliminary reconnaissance studies in the 1965-1966 summer. This body, known as the Dufek intrusion, makes up the northern third of the Pensacola Mountains (82°30′S. 57°W.) and underlies all of the Dufek Massif and the Forrestal Range and adjoining ice sheets. Detailed stratigraphic sections will be measured and samples will be collected for studies in our home laboratory of processes by which this complex formed.

Geological and geophysical reconnaissance of Marie Byrd Land. *F. Alton Wade, Texas Tech University.* We will conduct an airborne reconnaissance of Marie Byrd Land this season in preparation for a multidisciplinary field project in 1977-1978 to obtain detailed geological and geophysical data and rock specimens. These data and specimens will be used to develop a geologic history of West Antarctica. This season's reconnaissance will investigate several sites for the establishment of two field camps during 1977-1978. The field team will be accompanied by U.S. Navy personnel to select sites convenient to our areas of scientific interest that are suitable for aircraft operations.

Geological test of whether the West Antarctic Ice Sheet is disintegrating. *George H. Denton, University of Maine, Orono.* This austral summer we will continue to study the history of the marine-based West Antarctic Ice Sheet by systematically examining ice-free areas in the Transantarctic Mountains, on islands in the Ross Sea, and on nunataks in Marie Byrd Land. Our results from earlier seasons have shown that west antarctic ice expanded onto the Ross and Weddell continental shelves during glaciations, and receded during interglaciations. This recession probably was completed during the last interglaciation, about 120,000 years ago. Our research now focuses on the chronology of recession during the present interglacial: is the West Antarctic Ice Sheet disintegrating? If so, at what rate? What effect would this have on world sea levels?

Circumantarctic biological productivity. *Sayed Z. El-Sayed, Texas A&M University.* Our research this austral summer will again be in collaboration with French scientists aboard *Marion-Dufresne,* which is under the auspices of the Territoire des Terres Australes et Antarctiques Françaises. *Marion-Dufresne* cruise 12 (February 1977) will be devoted to primary productivity and related studies of antarctic and subantarctic waters of the Indian sector of the southern ocean. Since this sector is recognized as one of the least studied regions of the southern ocean, this French cruise allows us to complete our circumantarctic studies of phytoplankton productivity in these waters. It will also afford an opportunity to cooperate in studying the food chain dynamics of the southern ocean begun during USNS *Eltanin* cruises 46 and 51. Similar studies will be made from aboard a U.S. Coast Guard icebreaker in the Weddell Sea in February and March 1977. Our study in the Indian and Atlantic sectors with its emphasis on primary productivity and the factors governing such production comes at a time when considerable attention is being given to the exploitation of antarctic marine living resources. Realistic figures on the primary productivity of antarctic waters should be obtained before these resources are exploited commercially.

Antarctic sea ice interactions with the atmosphere and the ocean. *Stephen F. Ackley, U.S. Army Cold Regions Research and Engineering Laboratory.* From aboard a U.S. Coast Guard icebreaker in the Weddell Sea this season we will obtain data on the following properties of sea ice: surface snow cover, thickness and roughness, and salinity. These data are necessarily as "ground truth" in interpreting satellite imagery of this region for studies of variations in sea ice extent and heat and mass exchange between the atmosphere and the ocean. Our data may be extrapolated for use in other sea ice areas where ground information is not available.

Transfer of organochlorine pollutants to antarctic ecosystems. *Robert W. Risebrough, University of California, Berkeley.* In this second year of our project we will profile the deposition of synthetic organic compounds over recent years in antarctic snow. The profile will help to determine how the rates of deposition of these pollutants from the atmosphere to the snow have changed during this period. Data on these changes will eventually be used to formulate global mass balance equations of synthetic organic pollutants in marine environments. This phase of our antarctic work will give the necessary baseline data on the Southern Hemisphere, and will be conducted at the dome C field camp (74°30′S. 123°10′E.) in East Antarctica.

Ross Ice Shelf

Coordination of the Ross Ice Shelf Project (RISP). *John W. Clough, University of Nebraska, Lincoln.* Staff from the RISP Management Office will be in the field this austral summer to coordinate science activities on the Ross Ice Shelf. The main focus of activity will be the drilling of a hole through the shelf about 475 kilometers from the open Ross Sea. Over 60 persons representing eight nations plus the United States will visit the RISP drill site to study the shelf ice, the sea beneath the ice, and the ocean floor. Sampling through the shelf is scheduled to begin in late December. In addition to the drillhole activity, the Ross Ice Shelf Geophysical and Glaciological Survey (RIGGS) will continue this season. Two contract Twin Otter airplanes will assist RIGGS in its third field season. Four small camps will also be occupied for other RISP projects studying tidal fluctuations of the shelf and snow and ice chemistry.

Geophysical survey of the Ross Ice Shelf. *C. R. Bentley, University of Wisconsin, Madison.* Our field party this season will survey ice thickness, water depth, sediment thickness, crustal structure, seismic wave velocity, e-m wave velocity, and electrical resistivity in and under the western half of the Ross Ice Shelf. Also, we will conduct sonic logging in the main Ross Ice Shelf Project drillhole, and we will make wave velocity measurements of core samples from the hole.

South Pole doppler data and geoceiver support of the Ross Ice Shelf Project. *William R. MacDonald, U.S. Geological Survey, Reston, Virginia.* For the fifth year the U.S. Geological Survey (USGS) will collect year-round doppler data at Amundsen-Scott South Pole Station to support studies of ice movements, polar motion, and earth's spin axis. Combined with doppler data from McMurdo Station, South Pole is a master translocation station for roving teams of USGS engineers using geoceivers to track doppler satellites and thereby to derive accurate positions for mapping and for navigation. During the 1976-1977 austral summer, USGS geoceivers will support the Ross Ice Shelf Project (RISP). Geophysical study sites established during the 1974-1975 field season on Roosevelt Island (79°30′S. 162°00′W.) will be reobserved, and new positions will be established at other RISP sites.

Surface glaciology of the Ross Ice Shelf. *R. H. Thomas, University of Maine, Orono.* Stake rosettes that were planted during the 1974-1975 season at 35 stations in the northeast quadrant of the Ross Ice Shelf will be remeasured this season to give surface strain rates. Also, about 80 new rosettes will be planted in the western half of the ice shelf. Data already collected from the southeast quadrant reveal an apparent thickening with time of the ice shelf in this region. This may be due to comparatively recent grounding of the ice rise at grid 7°S. 1°W. To check this hypothesis, we will attempt to remeasure strain networks that were planted on this ice rise in 1973-1974. Data from this austral summer's work will reveal whether ice shelf thickening is widespread along the eastern margins of the ice shelf. This would imply an advance of the West Antarctic Ice Sheet onto the Ross Ice Shelf. Future measurements of the rosettes in the western half of the ice shelf will test the behavior of glaciers that drain the East Antarctic Ice Sheet. The Ross Ice Shelf strain rates, with other information from Ross Ice Shelf Project activities, will provide test data for a finite element computer model of the ice shelf that will be a first step toward finite element modeling of glaciers, ice streams, and ice sheets.

Ross Ice Shelf Project (RISP) **drilling operations.** *John H. Rand, U.S. Army Cold Regions Research and Engineering Laboratory.* In support of the 1976-1977 RISP field program we will drill four holes through the Ross Ice Shelf in the vicinity of the main RISP camp at site J-9. The first will be a water well for the camp and for drilling requirements, the second and third will be 16-centimeter holes to obtain 6-centimeter core for later study, and the fourth will be the main RISP access hole that will be 30 centimeters in diameter. Through this main hole RISP investigators hope to sample sub-ice waters and sediments and to observe any marine life that may exist beneath the Ross Ice Shelf. We

also will operate a hoist on the drill to lower scientific instruments into the main hole, and we will operate a heating cable to control refreezing of the main hole.

Physical oceanographic interactions of the Ross Sea and the Ross Ice Shelf. *S. S. Jacobs and A. L. Gordon, Lamont-Doherty Geological Observatory of Columbia University.* As part of the Ross Ice Shelf Project, physical oceanographic measurements (salinity, temperature, dissolved oxygen, nutrients, geochemistry, and year-long deep current observations) will be made north of the Ross Ice Shelf to define interactions among the ice shelf, the water in the continental shelf, and the water just north of the continental shelf. Similar measurements will be made through the main Ross Ice Shelf Project access hole. Bottom photographs and light scattering studies will provide data on physical processes beneath the ice shelf and will aid in the search for marine organisms.

Ross Ice Shelf oceanography. *Theodore D. Foster, Scripps Institution of Oceanography, University of California, San Diego.* We will take physical oceanographic measurements for the Ross Ice Shelf Project (RISP). Continuous, high-resolution temperature and salinity measurements will be made in the water column beneath the shelf, and geothermal heat flux measurements will be made on the sea floor. These measurements are aimed at settling questions about the influence of the shelf on the adjacent ocean, the melting or freezing rate of the shelf, and the vertical convection and transport of heat and salt in the sea beneath the shelf.

Ocean tides beneath the Ross Ice Shelf. *Edwin S. Robinson, Virginia Polytechnic Institute and State University.* We will record tidal variations of gravity on the Ross Ice Shelf at two sites (J-9 and C-24) and on bedrock at McMurdo Station to obtain data for deducing ocean tidal amplitude and currents in the Ross Sea.

Mass balance and heat flow at the ice/water interface beneath the Ross Ice Shelf. *Olav Orheim Norsk Polarinstitutt (Norway).* In a cooperative project with T. Kvinge of the University of Bergen (Norway), we will lower equipment through the main Ross Ice Shelf Project access hole to measure the mass balance and heat flow at the ice/seawater interface beneath the Ross Ice Shelf. We will be the last group to use the access hole during the 1976-1977 season, and our instruments will remain under the shelf during the 1977 austral winter to transmit data to a tape recorder on the surface. The recorder, and hopefully the instruments, will be recovered early in the 1977-1978 field season.

Heat and mass transfer below the Ross Ice Shelf. *Peter Schwerdtfeger, Flinders University of South Australia.* This austral summer we will measure the transfer of heat, salt, and momentum in seawater immediately below the Ross Ice Shelf as part of the Ross Ice Shelf Project. Measurements of water temperature, salinity, and currents near the ice/water interface will help to better understand local transfer processes that affect nearby and surrounding water masses.

Borehole measurements on the Ross Ice Shelf using impulse radar. *Rexford M. Morey, Geophysical Survey Systems, Inc.* Our major goal this austral summer as part of the Ross Ice Shelf Project (RISP) is to measure the velocity of propagation and absorption rate of very high frequency (30- to 300-megahertz) radio waves in firn and ice and to correlate these electromagnetic results with measured physical properties (that is, temperature, density, and crystal fabric). The test site will be in and near the 300-meter deep hole at the RISP J-9 drill site. Our data will help to interpret airborne radio-echo soundings of ice masses and to better understand internal layering in glaciers.

Ross Ice Shelf Project (RISP) isotope studies. *Hans Oeschger, University of Bern (Switzerland).* Our RISP fieldwork this season in isotope geophysics will involve (1) down-borehole extraction of gases, particulates, and ions for radioactive dating of ice using such radioisotopes as carbon-14 and argon-39 (radioactive isotope dating may be the only way of determining the age of ice at different depths), (2) collection of water samples from below the Ross Ice Shelf for isotope studies (carbon-14, argon-39, krypton-85, hydrogen-3, oxygen-18, and deuterium), and (3) interpretation of data in terms of ocean circulation. Other studies will investigate gas content and composition in ice cores and water samples.

Physical and chemical investigations of 1976-1977 Ross Ice Shelf Project (RISP) core. *Chester C. Langway, Jr., State University of New York, Buffalo.* We will log, process, handle, and transport to the United States the 500-meter RISP ice core to be drilled this season. Field studies will involve measurements of density and recording stratigraphic phenomena. Pits will be dug in the vicinity of the main RISP camp for mesoscale and microscale

chemistry collections. We also plan to auger core to 100-meter depths on Roosevelt Island and in the vicinity of site C-7 on the Ross Ice Shelf using the highly portable "Swiss" drill. All cores and surface samples will be returned to our central storage facility, where redistribution of samples will be made to approved investigators.

Isotope analyses of Ross Ice Shelf cores. *W. Dansgaard, University of Copenhagen (Denmark).* As part of the 1976-1977 Ross Ice Shelf Project, we will drill 10- to 15-meter firn cores for later isotope analyses in our Copenhagen laboratory. These analyses are for measurements of accumulation rates on the Ross Ice Shelf.

Logging and curating geologic material from the Ross Ice Shelf Project. *P. N. Webb, Northern Illinois University, De Kalb.* We will log and curate geologic materials obtained this austral summer during the Ross Ice Shelf Project (RISP), and we will prepare these materials for transport to the United States. Some preliminary geological analyses will be made *in situ.* Detailed logging will be done in the United States during the northern spring of 1977. Soon thereafter, reports will be available for circulation to interested researchers.

Biology of the water column beneath the Ross Ice Shelf. *O. Holm-Hansen, F. Azam, A. F. Carlucci, and P. M. Williams, University of California, San Diego.* Our biological and biochemical studies this season in the water column beneath the Ross Ice Shelf, as part of the Ross Ice Shelf Project (RISP), will determine types, numbers, and distributions of microbial and planktonic organisms. Using the 25-centimeter-diameter RISP access hole, we will gather information on the energy source at the base of the food chain and on the flux of organic carbon through the food chain's major components. Plankton will be compared physiologically and chemically to similar organisms from the open Ross Sea, which is over 400 kilometers distant. Also, we hope to obtain baseline chemical data (radiocarbon, tritium, and various trace metals) from organisms and water samples to identify water transport rates beneath the ice shelf and any possible effects of pollution from elsewhere in the world.

Is there life under the Ross Ice Shelf? *Jere H. Lipps, University of California, Davis.* As part of the Ross Ice Shelf Project (RISP), we will study the structure and history of benthic communities that may live beneath the ice shelf. Life probably will be found that is either similar in species and abundance to open Ross Sea assemblages of equal depth (±600 meters) or that is similar to oligotrophic deep-sea assemblages. Using the 25-centimeter-diameter RISP access hole drilled through the Ross Ice Shelf this austral summer, we will study whatever community may exist. We will employ television and still photography to assess megafauna; sphincter samples will be taken to acquire undisturbed benthic samples, gravity cores will be obtained to compile a stratigraphic record enabling us to decipher the history of the communities, and fish and other mobile organisms will be caught using traps and fishing lines. We have four objectives: (1) document the species found, including their abundance; (2) determine their ecologic relationships; (3) assess the genetic variability of several populations; (4) infer the history of the communities. Collaborators in this project will be from the University of California, Davis and Los Angeles, and from Scripps Institution of Oceanography.

Influence of precipitation-forming mechanisms on the chemistry of the Ross Ice Shelf. *Joseph A. Warburton, Desert Research Institute, University of Nevada System.* This austral summer we will (1) determine the effects of principal precipitation processes on the accumulation of chemical substances on the Ross Ice Shelf, (2) determine the relationships between chemical accumulation and precipitation processes as a function of distance from the ocean, and investigate possible relationships to the extent of sea ice, and (3) determine the relative contributions of oceanic and continental aerosols to the chemistry of the Ross Ice Shelf. Earlier results suggest two chemical zones on the shelf, the boundary of them being around 400 to 500 kilometers from the Ross Sea coast.

Siple Station

Active and passive probing of the magnetosphere using very low frequency (VLF) techniques. *R. A. Helliwell, Stanford University.* During 1976-1977 the Siple Station VLF transmitter will be used in a quantitative investigation of wave-particle interactions in the magnetosphere. Special wave functions, such as short and long pulses and frequency ramps, will be used to produce wave growth,

emissions, and various wave-wave interactions. Precipitation of energetic electrons induced by the Siple signals and by natural whistlers and emissions will be investigated on paths near the plasmapause. The transmitter will also be used in support of VLF direction-finding experiments near Siple's conjugate station in Roberval, Quebec, Canada. A Leavitt DV tracker and a goniometer will be used in experiments on a variety of natural and artificial whistler-mode signals. Triangulation measurements involving data from recorders at antarctic stations Halley Bay (United Kingdom) and General Belgrano (Argentina) will be made, and in conjunction with the International Magnetospheric Study we will make intensive VLF broadband transmissions in June and July 1977 for worldwide correlative studies of plasmapause position and plasmapause dynamics.

Conjugate magnetic studies near L=4. *L. J. Lanzerotti and A. Hasegawa, Bell Laboratories.* A three-component fluxgate magnetometer with digital data acquisition will gather year-round data at Siple Station in 1977. These data will be used with data from four similar magnetometers placed in the northern conjugate area at L=4.4, 4.0, 3.5, and 3.2, plus a fifth mobile station around L=3.5. (Magnetic lines of force that pass the Equator at an altitude of, for example, 3.5 earth radii come to the earth in the Northern and Southern Hemispheres at areas called L=3.5.) The data will be used in studies of geomagnetic conjugacy, of magnetohydrodynamic wave modes in the magnetosphere, of effects of the ionosphere on transmission of ultra low frequency waves from the magnetosphere to the ground, and of changes in conjugacy with magnetic disturbances.

Micropulsation detections. *Laurence J. Cahill, University of Minnesota, Minneapolis.* During 1976-1977 we will determine the generating region and propagation characteristics of magnetic micropulsations. Of particular interest are pulsations near 1 hertz in frequency.

Auroral radar studies. *B. B. Balsley and W. L. Ecklund, National Oceanic and Atmospheric Administration, Boulder, Colorado.* A 50-megahertz very high frequency (VHF) radar system will be established at Siple Station this austral summer to examine echoes returned from electron density irregularities in the ionospheric E-region. Studies of the morphology of these irregularities will yield data on the morphology of the auroral electrojets and the associated magnetospheric/electric fields. Correlative studies with concurrent Siple observations will help to understand auroral ionospheric processes.

Rocket soundings of the upper atmosphere. *Norman E. Peterson, Jr., National Aeronautics and Space Administration, Greenbelt, Maryland.* This austral summer we will install equipment at Siple Station in preparation for the planned launches of three Nike Tomahawk rockets from Siple during the 1977-1978 austral summer. University of Maryland payloads aboard the rockets are to investigate electron precipitation triggered by very low frequency radio wave emissions.

Amundsen-Scott South Pole Station

Atmospheric electric measurements. *William F. Cobb, National Oceanic and Atmospheric Administration, Boulder, Colorado.* Basic atmospheric electric measurements at the surface and aloft will continue, with emphasis on measurement of the air-earth conduction current by balloon-borne radiosonde. Our project's purpose is first to establish an environmental benchmark of electrical measurements that index the amount of particulates in the atmosphere, and second to investigate the origin of the electrical current that flows continuously between the earth and the ionosphere and the hypothesis that this current is maintained and controlled by everpresent, worldwide thunderstorms.

Auroral photometry. *S. B. Mende, Lockheed Palo Alto Research Laboratories.* We will monitor faint aurora and airglow at Amundsen-Scott South Pole Station. Precipitating particles generate detectable signatures in optical emissions. These signatures can be interpreted in terms of magnetospheric structures. South Pole is close to the cusp during the magnetic midday period, and therefore is a suitable site from which to observe these phenomena.

Midday auroras. *Syun-Ichi Akasofu, University of Alaska, Fairbanks.* All-sky photographs from Amundsen-Scott South Pole Station and DMSP satellite photos will be used to study large-scale auroral activity. The all-sky camera will operate at the South Pole throughout the 1977 austral winter.

Atmospheric processes and energy transfers at the South Pole. *John J. Carroll and Kinsell L. Coulson, University of California, Davis.* This austral summer a skylight polarimeter will be reinstalled at Amundsen-Scott South Pole Station to measure surface reflection. Measurements will be made through January 1977 by replacement winterover

personnel. Several sensors in our energy balance system at South Pole Station will be replaced to allow Stateside recalibration. Upon completion of a new clean air facility, the present energy balance system will be checked and relocated near the new facility for its third and final year of operation.

Atmospheric acoustic echo sounding. *Freeman F. Hall, National Oceanic and Atmospheric Administration, Boulder, Colorado.* Using acoustic sounding techniques, we will continue year-round research on the turbulence structure of the planetary boundary layer and its coupling to the free atmosphere.

Atmospheric radiation studies. *Glenn E. Shaw, University of Alaska, Fairbanks.* Our objective is to derive physical properties (size distribution, columnar concentration, and refraction index) of atmospheric particulates at Amundsen-Scott South Pole Station from multiwavelength measurements of sun and sky radiation. Particulate properties will be related to climatic effects. We also will determine the source and method of particulate transport to Antarctica.

Optical atmospheric phenomena. *Robert Greenler, University of Wisconsin, Milwaukee.* This season at Amundsen-Scott South Pole Station we will attempt to observe and to photograph optical effects in the sky that result from reflection and refraction of sunlight by atmospheric ice crystals. These effects include solar halos, arcs, and pillars, as well as some less familiar phenomena. In cooperation with other investigators, ice crystals will be collected and photographed both from the ground and at different altitudes in the atmosphere. Computer simulation will determine the optical effects that arise from different shapes and sizes of ice crystals. The simulation will be compared with the observed effects, and the collected ice crystals will be compared with the crystal forms used in the simulation. These optical effects may be a useful remote indicator of the atmospheric ice crystal population.

Origin of ice crystals in South Pole precipitation. *V. Smiley and J. A. Warburton, Desert Research Institute, University of Nevada System.* This austral summer we will collect lidar (optical radar) data on ice crystals in the troposphere and use replication techniques to collect data on sizes and habits of precipitated crystals. Growth layers and mechanisms for crystal growth will be determined from these data. The field lidar will be modified to permit ice/water discrimination. Also, laboratory work using a two-wavelength lidar will determine water vapor in the atmosphere.

Ice crystal precipitation in the antarctic atmosphere. *Takeshi Ohtake, University of Alaska, Fairbanks.* Our objectives are to study formation mechanisms and the physical properties of ice crystal precipitation in the antarctic atmosphere. Experimental work at Amundsen-Scott South Pole Station this year will include measuring the vertical distribution of ice crystals with a balloon- and kite-borne replicator, and collecting ice crystals at the surface. The profile of meteorological factors (temperature, pressure, and humidity) will be measured simultaneously; a humidity sensor in low temperatures will be calibrated by dry ice seeding. Also, an all-sky motion picture camera, an ice crystal concentration recorder, and an ice crystal precipitation recorder will operate for 2 months this austral summer.

Analysis of halocarbons. *R. A. Rasmussen and E. Robinson, Washington State University, Pullman.* The concentration distribution pattern of halocarbons in the antarctic atmosphere and snow and ice will be measured this summer. The potential role of Antarctica in removing or modulating global halocarbon (Freon) levels is unknown, but there is evidence that polar atmospheric and precipitation processes can remove these trace gases from the atmosphere.

Aerosols of the polar regions. *Austin W. Hogan, State University of New York, Albany.* This field season we will continue our research on the interaction between atmospheric aerosols (particles in the air) and cloud drops and ice crystals over the South Pole. Antarctica is unique for this study because of the absence of pollution and frequent low-level clouds. We also will make several airplane flights to measure ozone water vapor and aerosol concentration and basic meteorological phenomena.

Geophysical monitoring for climatic change. *Kirby J. Hanson, National Oceanic and Atmospheric Administration, Boulder, Colorado.* Two 1977 austral winter personnel will continue our project of geophysical monitoring for climatic change by measuring trace atmospheric constituents. Three summer-only personnel will move our instruments and those of other cooperative projects from a temporary hut to a new facility constructed on stilts near Amundsen-Scott South Pole Station.

Meteorological observations at the South Pole. *W. Schwerdtfeger, University of Wisconsin, Madison.* A. F. Kapela, University of Wisconsin, Madison, will make routine meteorological observations at

Amundsen-Scott South Pole Station this austral summer in support of summer activities (including airplane flights) in the station vicinity.

Search for the pendulum mode of the earth's inner core. *L. B. Slichter, W. Smythe, and T. Yogi, University of California, Los Angeles.* During 1976-1977 at Amundsen-Scott South Pole Station Dr. Yogi will use gravimeters to continue our year-round observations of the vertical components of earth tides and of the earth's free modes. A new project for observing the two horizontal components will also begin. This will require operation of long, string-supported pendulums in boreholes in the ice. Success should greatly increase chances of detecting the pendulum mode of the earth's inner core. This would supply information on the viscosity of the surrounding fluid and on the density difference at the boundary between the inner and outer core.

Human adaptations to south polar stresses. *Harold G. Muchmore, Oklahoma Medical Research Foundation.* Year-round studies of immunologic changes in people who winter at Amundsen-Scott South Pole Station will continue throughout 1976-1977 in collaboration with researchers of the University of Otago (Dunedin, New Zealand) and the University of Wisconsin, Madison. These studies are designed to evaluate any loss of immunity (resistance to infections) that may result from prolonged isolation during the polar winter. Cellular immunity studies will be carried out on live leukocytes derived from peripheral blood. Lymphocytes will be processed from transformation studies, and T and B enumeration and neutrophil functions also will be studied. Specimens for immunoglobulins will be collected, and specimens for virus isolation will be obtained to isolate and identify the respiratory virus responsible for postpolar infections. These viruses will be utilized as reagents in the assay of immunity changes during isolation. Baseline data on these parameters from persons scheduled to spend the 1977 austral winter at the South Pole were gathered before they left for Antarctica. Radioactive material (tritium) will be used in these studies, which are reviewed and approved annually by the Human Experimentation Committees of the Oklahoma Medical Research Foundation and of the Oklahoma University Health Sciences Center.

Southern Victoria Land

Borehole logging and ground magnetism study. *L. D. McGinnis, Northern Illinois University.* As a follow-up to Dry Valley Drilling Project (DVDP) fieldwork, which ended during the 1975-1976 season with a final borehole in McMurdo Sound, this austral summer we will do electric and gamma logs in DVDP hole 5 (Don Juan Pond) and in all other DVDP holes in southern Victoria Land that are still open. We also will provide ground magnetic control on igneous extrusions along flanks of Taylor Valley to compare ground and airborne magnetic fields. Borehole logging data will enable geologists to compare geophysical measurements down the hole with observations of core extracted from the hole. The logs will establish, with high precision, depths to the various strata penetrated, and they will aid in the correlation of strata between holes. Magnetic measurements over the igneous outcrops will permit geologists to confirm their deep-seated origin or to identify them as glacial erratics. Since much of the glacial history of the dry valleys has been interpreted from isotopic ages measured on these rocks, it is necessary to establish their mode of emplacement.

Quantitative paleoclimatic analysis of Ross Sea continental shelf sediments. *Thomas B. Kellogg, University of Maine, Orono.* Our field work this austral summer will be in two areas. Holocene marine sediments will be collected during mid-December from the McMurdo Ice Tongue between Black Island (78°12′S. 166°25′E.) and the ice/shelf margin. These sediments result from the action of anchor ice beneath the ice shelf and should provide a record of oceanographic conditions during the last 7,000 years. Sediments of the Pecten Formation will be collected from Wright Valley near Bull Pass (77°28′S. 161°43′E.) during December. The microfossils will be studied to resolve a recent controversy concerning their depositional environment and age, questions important to the early climatic history of the Ross Ice Shelf.

Search for meteorites in Antarctica. *William A. Cassidy, University of Pittsburgh.* According to recent Japanese findings, certain ice conditions in Antarctica may concentrate meteorites laterally and/or through time so that many can be found on the ice within relatively small areas. This austral summer we will search for meteorites in modern terminal moraines along meltfaces in the dry valleys of southern Victoria Land and in areas of ice deflation within helicopter range of McMurdo Station. Identification of areas with meteorite concentrations could provide new meteoritic material for study, may lead to collection of rare types of meteorites that are preserved under antarctic conditions, permit better estimates of average meteorite com-

position, lead to information on the relative age of antarctic ice, and result in discovery of previously unknown types of meteorites or lunar ejecta.

Radioactivity survey using airborne gamma-ray spectrometry. *Edward J. Zeller, University of Kansas.* This austral summer we will survey the radioactivity of rocks in the ice-free valleys of southern Victoria Land. The data will be useful for assessing the potential for uranium and thorium resources of these areas. Ground traverses will be made to determine precise radioactivity profiles of outcrops. Counting apparatus will then be transferred to a helicopter for calibration over the surveyed outcrops before undertaking an aerial reconnaissance.

Lake Bonney modeling and environmental impact studies of the Dry Valley Drilling Project. *Bruce C. Parker, Virginia Polytechnic Institute and State University.* This is our final year of limnological data collection at Lake Bonney, which is in Taylor Valley, southern Victoria Land. Our field teams also will continue postaudit studies of Dry Valley Drilling Project sites in the McMurdo Sound region.

Endolithic algae as primary producers in an antarctic desert ecosystem. *E. Imre Friedmann, Florida State University, Tallahassee.* Recent study of rock samples from the dry valleys of southern Victoria Land revealed the presence of endolithic blue-green algae under the surface of some samples. Both the organisms and the type of growth are similar to those we have found in hot deserts. This is the first evidence of primary producers in the cold antarctic desert ecosystem. We plan to do a more extensive survey of the dry valleys this austral summer for endolithic algae. Micrometeorological measurements will be made, and samples will be shipped frozen to the laboratory for study of any living organisms.

International cooperation

In addition to a few of the projects described above, at least five other 1976-1977 antarctic projects will involve U.S.-foreign nation interactions in personnel and support services. Projects in this category follow:

Japan visiting scientist program (McMurdo Station, Ross Ice Shelf). *Takesi Nagata, Japan National Institute of Polar Research.*

U.S.S.R. visiting scientist program (McMurdo Station, Ross Ice shelf). *A. F. Treshnikov, Arctic and Antarctic Scientific Research Institute.*

Meteorological observations (Amundsen-Scott South Pole Station). *John DeLisle, N.Z. National Weather Service.*

Argentina-United States ARA *Islas Orcadas* **circumantarctic oceanographic survey.**

Logistic support activities (Palmer Station, Ross Ice Shelf). *Richard M. Laws, British Antarctic Survey.*

U.S. Antarctic Research Program science and support personnel, winter 1976

During the 1976 austral winter, 14 scientists—including one Soviet exchange scientist and two N.Z. meteorologists—and 76 support personnel are wintering at three U.S. antarctic stations. Also, one U.S. researcher is at the Soviet Union's Vostok Station (78°55'S. 83°55'W.) with the 21st Soviet Antarctic Expedition.

Participants in the 1976 winter U.S. Antarctic Research Program are listed below and on the next page. The support units of U.S. Naval Support Force, Antarctica, and Holmes & Narver, Inc., are abbreviated NSFA and H&N.

Amundsen-Scott South Pole Station

Fesler, Ronald B., H&N
Graser, William F., *doppler research,* U.S. Geological Survey
Hinely, John A., Jr., *doppler research,* U.S. Geological Survey
Holloway, Donald P., H&N
Jackson, Bruce S., *meteorology,* University of California, Davis
Jackson, Robert W., *meteorology,* University of

California, Davis
*Jefferson, C. Michael, *geophysics,* University of California, Los Angeles
Jones, Timothy C., H&N
Jordon, James R., *meteorology,* National Oceanic and Atmospheric Administration
Lemieux, Mark A., H&N
Maguire, Bernard V., *meteorology,* N.Z. Meteorological Service
McConnell, Todd A., *biomedicine,* Oklahoma Medical Research Foundation, and *station physician,* H&N
McEwen, Bernard S., H&N
Morton, Daniel H., III, H&N, *station manager*
Potter, Barry J., *meteorology,* N.Z. Meteorological Service
Seeley, Dennis E., H&N
Szwarc, Valentine S., *meteorology,* National Oceanic and Atmospheric Administration
Zimmer, Stephen J., H&N

McMurdo Station

Affeldt, James A., NSFA
Baumgartner, Robert A., NSFA
Berg, Michael L., NSFA
Blaum, Jeffrey D., NSFA
Bock, Terry L., NSFA
Boothby, Richard L., NSFA
Borcher, David G., NSFA
Brower, Howard W., NSFA
Brown, Thomas R., NSFA
Cantu, John J., NSFA
Carpenter, Gerald G., NSFA
Combs, Darrell H., NSFA
Deck, Ervin C., NSFA
Dutile, Gregory A., NSFA
Elarton, Dennis E., NSFA
Fearer, Raymond L., NSFA
Flynn, Timothy C., NSFA, *medical officer*
Gholson, Walter C., NSFA
Goepfert, Eric R., NSFA, *officer in charge*
Green, John B., NSFA
Hager, Michael K., *geodesy and upper atmosphere,* University of Texas, Austin
*Hall, Douglas W., *upper atmosphere,* Bartol Research Foundation
Hansen, Robert C., NSFA
Henry, Jeffrey J., NSFA
Hernandez, Efrain, NSFA
Hogan, Dennis L., NSFA
Jones, John I., III, *geodesy and upper atmosphere,* University of Texas, Austin
Kent, Randolph E., NSFA
Kelly, Brian F., NSFA
Keranen, Jason A., NSFA
Larocque, Armand, NSFA
Leek, Bobby J., NSFA
Lovgren, Frank L., NSFA
Lysakov, Edward P., *meteorology,* Arctic and Antarctic Research Institute (U.S.S.R.)
Maffin, John S., NSFA
Marx, Roland M., NSFA
McGrath, Michael G., NSFA
McClain, Howard L., NSFA
Morante, Apolinario F., NSFA
Miller, Kenneth G., NSFA
Morgan, Walter F., Jr., NSFA
Ney, Daniel S., NSFA
Orris, Michael J., NSFA
Owen, Robert F., NSFA
Para, Marion A., NSFA
Patterson, Robert G., NSFA
Polacek, James F., NSFA
Pratt, Andrew J., NSFA
Pritchett, John P., NSFA
Reiff, Gregory L., H&N
Reiff, Michael L., H&N
Rich, William L., NSFA
Rippe, Gene E., NSFA
Rodriguez, Bryan K., NSFA
Rohleder, Donald L., NSFA
Schornick, Clearence F., III, NSFA
Shaw, Norman D., NSFA
Sheets, Barry L., NSFA
Spurlock, James A., NSFA
Stander, Ernest E., NSFA
Stanhope, Paul K., NSFA
Tolleson, Steven L., NSFA
West, Richard L., NSFA
Williams, Russell J., NSFA
Williams, Willie L., NSFA
Wilson, John C., NSFA

Palmer Station

Bertram, Craig W., H&N
*Fraser, William R., *biology,* University of Minnesota
Frenaye, Thomas W., H&N
Hankel-Shepherd, Peter W., H&N
Miyoda, Edward M., H&N
Miyoda, Larry W., H&N, *station manager*
Wood, Frank A., H&N

Vostok (Soviet Union)

Johnson, Ralph N., *geophysics,* U.S. Geological Survey

*Station science leader.

President sends midwinter message

On 16 June 1976 President Gerald R. Ford telegraphed the following message to those of all nations who are wintering in Antarctica this year:

"Discovery and scientific exploration of the Antarctic account for one of the most remarkable legacies of the past two hundred years.

"In the United States, we take special pride during our Bicentennial observance in this nation's dynamic role in antarctic exploration and in the accomplishments of great Americans like Nathaniel Palmer, Charles Wilkes and Richard Byrd. In the best tradition of these famous explorers, the members of the international scientific community wintering in the Antarctic expand even further our knowledge of this magnificent region. We are equally proud of the fellow citizens who are part of this rewarding international effort.

"Mindful that we are a nation of nations whose diverse ancestral heritage binds us in a unique way with the other participating countries, we invite all who winter in Antarctica this year to join in celebrating the two hundredth birthday of United States Independence. We hope this will be an especially productive and satisfying year for each of you. We are confident that the new findings and new friendships which will result will both benefit all mankind. Gerald R. Ford."

Antarctica Service Medals available

Under Public Law 86-600 (reprinted below), U.S. citizens and foreign nationals who participate in antarctic activities sponsored by the U.S. Government may be eligible to receive the Antarctica Service Medal of the United States.

Regulations for presenting the medal are prescribed, subject to the approval of the Secretary of Defense, by the Department of the Navy. The current eligibility requirements, as set forth in Secretary of the Navy Instruction 1650.1D (31 May 1973) and in Commander, Naval Support Force, Antarctica, Instruction 1650.2A (5 November 1975), for award of the Antarctica Service Medal to civilians are summarized as follows:

(1) Any person who, under the sponsorship of a U.S. Government agency, participated in an operation in Antarctica or any area south of latitude 60°S. during the period between 1 January 1946 and 31 May 1973, and who made a significant contribution to the U.S. scientific or support program in Antarctica, is eligible to receive the medal.

(2) Any person who, under the sponsorship of a U.S. Government authority, on or after 1 June 1973 participated in operations in Antarctica or any area south of latitude 60°S. for a period of at least 30 days is eligible to receive the medal. Days do not have to be consecutive, and each day of duty at an outlying station on the antarctic continent will count as 2 days when determining eligibility.

(3) Only one award of the medal is authorized per individual.

The National Science Foundation is responsible for identifying and for recommending most of the awards of the medal to *civilians*. The increased number of civilians in the U.S. antarctic program in recent years, however, combined with the difficulty of maintaining valid addresses for many of these persons, has made it impractical for the Foundation to process awards to many qualified persons.

Civilian participants in the U.S. program who have not received the medal and who believe that they are eligible for it should write to the Division Director, Division of Polar Programs, National Science Foundation, Washington, D.C. 20550. The letter should state beginning and ending dates and locations of each period in the Antarctic, name and correct address of sponsoring organization (university, agency, or other institution), and present nationality. Letters will be promptly acknowledged.

86th Congress
Public Law 600
July 7, 1960

To provide for the presentation of a medal to persons who have served as members of a United States expedition to Antarctica.

Be it enacted by the Senate and the House of Representatives of the United States of America in Congress assembled, That each person who serves, or has served, as a member of a United States expedition to Antarctica between January 1, 1946, and a date to be subsequently established by the Secretary of Defense shall be presented a medal with accompanying ribbons and appurtenances, under regulations to be prescribed by the Secretary of the Military Departments under whose cognizance the expedition falls, such regulations to be subject to the approval of the Secretary of Defense. The regulations may include provisions for award to civilian as well as uniformed members and for posthumous awards.

Members of the Armed Forces of the United States who are presented the medal referred to in the first section of this Act may wear such medal and the ribbon symbolic of such medal in such manner as shall be prescribed by regulations approved by the Secretary of Defense.

Translation of Soviet bulletin ceases

With the translation into English and publication of issue 90 of the *Soviet Antarctic Expedition Information Bulletin,* a 16-year project by the American Geophysical Union and Scripta Technica, Inc., has come to an end. Partially funded by the National Science Foundation, the project began in 1962 with issue 31 of the *Bulletin.* Issue 90 ($7.50) and back issues may be purchased from the American Geophysical Union, 1909 K Street, N.W., Washington, D.C. 20036.

Rising costs for translation and publication, plus a small readership, forced the Foundation to end its support of the project.

Issues 1 through 30 were translated by Scripta Technica in cooperation with the University of Wisconsin—also with support from the Foundation. Elsevier Publishing Company published these 30 issues in three volumes in 1964 and 1965.

Staff changes

Benson T. Fogle became program manager for polar atmospheric sciences in the National Science Foundation's Division of Polar Programs (DPP) on 28 June 1976. Formerly associate climate dynamics program director in the Foundation's Division of Atmospheric Sciences, Dr. Fogle succeeded Raymond R. Heer, Jr., who retired from Federal service on 3 January 1976. Mr. Heer, a Federal employee since 1949, had been with the Foundation since March 1964 as program manager for polar atmospheric physics.

On 2 August, U.S. Navy Captain Darrel E. Westbrook, Jr., became DPP staff associate for polar planning and coordination. His predecessor, Navy Captain Joe F. Lasseter, Jr., left DPP in November 1975 upon his retirement from the Navy. Captain Westbrook was previously assigned to the Naval War College, Newport, Rhode Island.

Bernhard Lettau, on a 2-year leave from the State University of New York, Albany, became DPP program associate for polar ocean sciences on 16 August. John J. Kelley, on leave from the University of Alaska's Institute of Marine Science, had been DPP program associate for polar meteorology and ocean sciences from 11 July 1974 to 30 June 1976, and now is with the National Oceanic and Atmospheric Administration's Environmental Research Laboratories, Boulder, Colorado. Drs. Fogle and Lettau will share responsibility for DPP's arctic and antarctic meteorological programs.

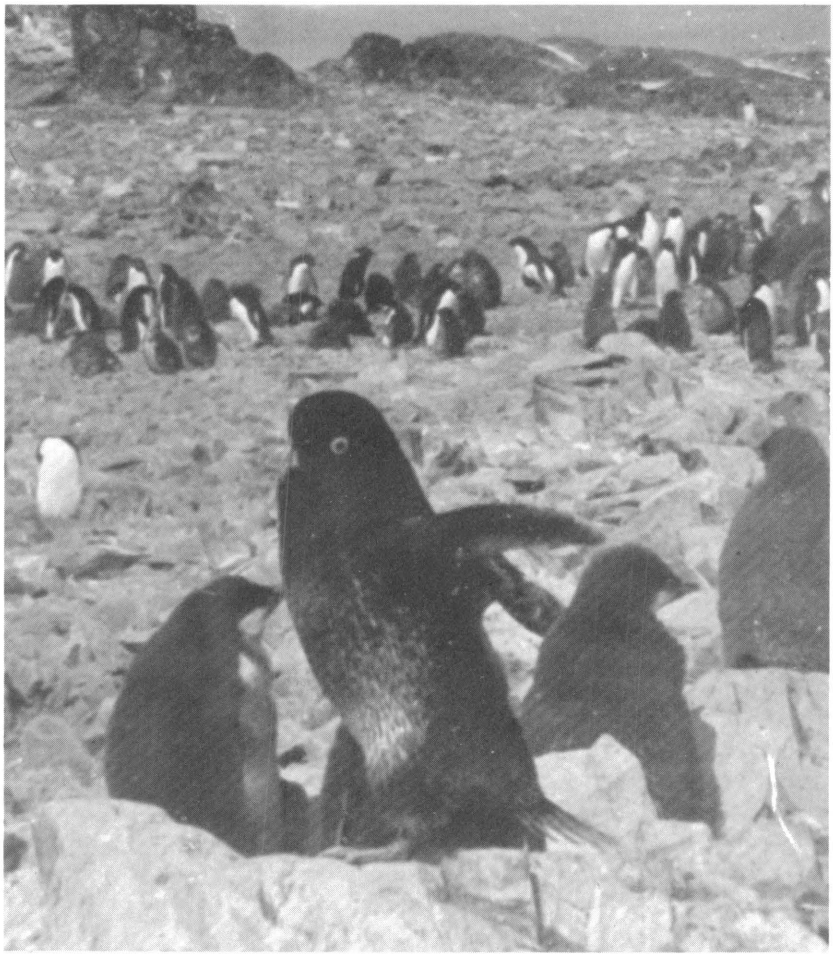
For the record

A minimum temperature of −74.4°C was recorded at Amundsen-Scott South Pole Station on 23 May 1976, breaking the previous May temperature minimum for the station, −73.6°C, set in 1957.

Corrections

Average sky cover for Amundsen-Scott South Pole Station in November and December 1975 and January 1976 ("Monthly climate summary," March 1976 *Antarctic Journal,* inside back cover) is in eighths. The same values for McMurdo Station are correctly given in tenths.

In "ARA *Islas Orcadas* cruise 7" (Warnke *et al.,* June 1976 issue), the islands off the east coast of southern South America (map, page 71) should be labeled Falkland Islands (Islas Malvinas). Also, on page 72 (right column, lines 24 and 25) the core recovery figures are corrected as follows: 288 meters of piston and 9 meters of trigger.



Jere H. Lipps

All-black Adélie penguin banded during the 1974-1975 austral summer on Torgersen Island (64°46′S. 64°05′W.), near Palmer Station. The cover of the March/April 1974 *Antarctic Journal* featured an albino chinstrap penguin also sighted by U.S. investigators along the Antarctic Peninsula.

Foundation awards of funds for antarctic projects

1 April to 30 June 1976

Below are listed National Science Foundation awards made in the fourth quarter of fiscal 1976 for antarctic projects. This list completes the listing of fiscal-1976 antarctic awards that begins on pages 42-44 of the March 1976 *Antarctic Journal* and continues on pages 113 and 116 of the June 1976 issue.

Amounts listed are for antarctic program funds only. A few investigators with bipolar projects are funded using both antarctic and arctic funds, and the full amounts of their awards are shown in parentheses. Very large awards, as to the Department of Defense for logistics and support, often are made incrementally throughout a fiscal year, so the amounts shown here may not reflect the annual rate. Nearly all research awards are for a 1-year period.

Biology

DeGoes, Louis. National Academy of Sciences. International conference on marine living resources of the southern ocean. C-310. $39,600.

Weller, Milton W. University of Minnesota. Waterfowl ecosystem studies on subantarctic islands. DPP 76-20058. $5,000.

Geology

Craddock, Campbell J. University of Wisconsin, Madison. Analysis of geologic collections. DPP 76-11867. $70,000.

McMahon, Beverly. University of Texas, Dallas. Paleomagnetism of Dry Valley Drilling Project cores. DPP 75-22385. $5,000.

Siegel, Frederick R. George Washington University. Antarctic contribution to sediments off South America. DPP 73-09317. $11,100.

Wade, F. Alton. Texas Tech University. Geology of Marie Byrd Land and Ellsworth Land. DPP 75-19130. $23,700.

Webb, P. N. Northern Illinois University. Late Cenozoic micropaleontology and biostratigraphy. DPP 74-22894. $13,000.

Webers, Gerald F. Macalester College. Paleontology of fossil faunas from the Ellsworth Mountains. DPP 73-05819. $3,800.

Glaciology

Bull, Colin. Ohio State University. Microparticle variations in a 101-meter ice core from the South Pole. DPP 76-07745. $15,700.

Clough, John W. University of Nebraska, Lincoln. Management of the Ross Ice Shelf Project. DPP 72-02685. $190,300.

Langway, Chester C. State University of New York, Buffalo. Ice core study. DPP 75-03499. $59,700.

Oeschger, Hans. University of Bern, Switzerland. Geochemical and isotope borehole studies as part of polar ice-drilling projects. DPP 73-05933. $57,300.

Raymond, Charles F. University of Washington. Numerical calculation of glacier flow by finite element methods. DPP 74-19075. $15,000.

Thomas, Robert H. University of Nebraska, Lincoln. Surface glaciology of the Ross Ice Shelf. DPP 74-00475. $56,900.

Meteorology

Lennenbom, V. J. Department of the Navy. Automatic weather station. DPP 76-09124. $10,000.

Schwerdtfeger, Werner. University of Wisconsin, Madison. Meteorological research. DPP 76-05702. $39,500.

Ocean sciences

Watkins, Norman D. University of Rhode Island. Glacial history recorded in sediments of the southern ocean. DPP 75-19222. $51,500.

Wise, Sherwood W. Florida State University. Circumpolar bottom sediment survey with paleontologic and sedimentologic studies of piston cores. DPP 74-20109. $73,700.

Upper atmosphere physics

Helliwell, Robert A. Stanford University. Active and passive probing of the magnetosphere using VLF techniques at Siple Station. DPP 74-04093. $187,700 ($250,500).

Matthews, David L. University of Maryland. Rocket investigation of electron precipitation triggered by VLF emissions. DPP 75-03516. $85,600 ($125,000).

Mende, Stephen B. Lockheed Missiles & Space Company, Inc. Photometric experiment. DPP 71-01668. $32,200 ($57,500).

Pomerantz, Martin A. Franklin Institute. Cosmic ray intensity variations. DPP 74-00042. $80,000.

Rosenberg, Theodore J. University of Maryland. Naturally and artificially induced electron precipitation near the plasmapause. DPP 74-01704. $26,100 ($70,100).

Services and Support

Davis, Allan S. Department of the Navy. Rations for U.S. Antarctic Research Program personnel. DPP 69-01177. $70,000.

Elsner, Robert W. University of Alaska. Conceptual design of a polar research ship. OCE 76-10089. $20,000 ($80,400).

Johnson, James R. Holmes & Narver, Inc. Station operation and other support. C-793. $1,368,573.

Johnson, James R. Holmes & Narver, Inc. Operation of Palmer Station and research ship *Hero*. C-852. $124,531.

Kinter, George. Department of State. Scope and costs of an environmental impact statement for mineral exploration/exploitation (partial support). DPP 76-15669. $10,000.

Nicoletti, Frank T. Department of the Army. Standard geographic nomenclature. DPP 69-01151. $33,200.

Nordhill, Claude H. Department of Defense (U.S. Navy). Logistics and support. CA-165. $230,000.

Van Reeth, Eugene W. Department of Defense (U.S. Navy). Logistics and support. CA-165. $2,623,000.

Vicente, Calixto E. Government of the Argentine Republic. Operation and use of the research ship *Islas Orcadas*. DPP 74-12163. $75,000.

International travel

Angino, Ernest E. University of Kansas. Sydney, Australia, August 1976, for 25th International Geological Congress. DPP 76-15427. $560.

Bentley, Charles R. University of Wisconsin. Moscow and Leningrad, July-August 1976, for 23rd International Geographical Congress. DPP 76-14298. $1,130.

Parmelee, David F. University of Minnesota. Cambridge, England, May 1976, for Scientific Committee on Antarctic Research working group on biology. DPP 76-17087. $776.

Teichert, Curt, University of Kansas. Sydney, Australia, August 1976, for 25th International Geological Congress. DPP 76-15425. $438.

Monthly climate summary

Feature	May 1976 McMurdo (date)	May 1976 Palmer* (date)	May 1976 South Pole (date)	June 1976 McMurdo (date)	June 1976 Palmer* (date)	June 1976 South Pole (date)	July 1976 McMurdo (date)	July 1976 Palmer* (date)	July 1976 South Pole (date)
Average temperature (°C)	−26.8	−5	−56.7	−27.3	−9	−56.5	−21.2	−12	−60.8
Temperature maximum (°C)	−14.4 (5/8)	4 (5/9	−38.9 (5/7)	−15.6 (6/27)	0 (6/15)	−39.8 (6/1)	−8.2 (7/31)	0 (7/2)	−50.0 (7/19)
Temperature minimum	−43.3	−20	−74.4	−41.1	−23	−73.1	−38.4	−26	−71.5
Average station pressure (mb)	988.83		672.6	990.52		678.2	987.81		679.5
Pressure maximum (mb)	1008.13 (5/21)		684.3 (5/21)	1004.06 (6/3)		692.7 (6/25)	1004.40 (7/26)		696.1 (7/24)
Pressure minimum (mb)	976.30 (5/8)		658.7 (5/31)	976.63 (6/13)		666.9 (6/1)	963.43 (7/6)		664.8 (7/9)
Snowfall (mm)	170.2		Trace	38.1		Trace	647.9		Trace
Prevailing wind direction	90°		90°	135°		70°	115°		70°
Average wind speed (m/sec)	7.0		4.2	6.2		6.3	7.5		4.8
Fastest wind speed (m/sec)	28 90° (5/27)		16 30° (5/31)	33° 180° (6/19)		17 25° (6/1)	34 135° (7/19)		15 0° (7/6)
Average sky cover	5.7/10		2.2/8	4.2/10		2.1/8	6.6/10		6.7/8
Number clear days	10		20	16		14	8		24
Number partly cloudy days	10		5	10		9	7		6
Number cloudy days	11		3	4		7	16		1
Number days with visibility less than 0.4 km	0		4	1		5	2		6

*Temperature data unverified.

The Director of the National Science Foundation has determined that the publication of this periodical is necessary in the transaction of the public business required by law of this agency. Use of funds for printing this periodical has been approved by the Director of the Office of Management and Budget through 30 September 1979.

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