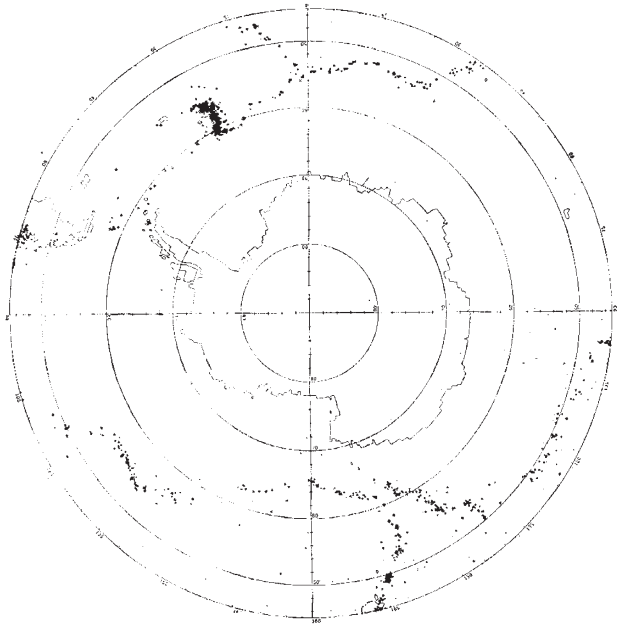
NORTH AMERICA

Progress in Geophysics

from our Geomagnetism Correspondent

ACCORDING to the National Science Foundation, the United States research effort in Antarctica during the past year has been one of consolidation, principally recording and mapping, rather than of spectacular new discovery. The annual reviews of projects begun, or in progress, during 1968–69 (*Antarctic J.*, **4**, 91 and 167; 1969) show that fifty-one projects in the Earth sciences, biology, topography and upper atmosphere physics involved about 200 scientists and technicians in addition to the logistic support provided as usual by the US Navy. The operational highlight of the season was the arrival at the Antarctic Peninsula of the NSF's new research vessel Hero. Within two months she had proved her worth as a base for scientists studying the volcanic eruption which occurred with little advance warning on Deception Island in February.

But there were also disappointments. First, ice prevented the retrieval of submerged buoys placed by the International Weddell Sea Oceanographic Expedition in 1968 to record data on Antarctic bottom waters. Second, an attempt to drill into bedrock at the bottom of the 2,164 m hole drilled through the ice at Byrd Station the previous season failed when the drill became trapped in the ice. Another casualty in the same borehole was an instrument designed to measure the age of the ice at various levels using small samples. This instrument, designed by C. C. Langway (US Army Cold Regions Research and Engineering Laboratory) and H. Oeschger (University of Berne), was a remotely controlled melt-extraction system able to make collections of carbon dioxide (for carbon-14 dating) in either liquid-filled or dry boreholes. At the time of the accident, caused by a motor failure, the probe and extraction lines were still being tested, although enough experience was gained to enable an improved model to be constructed for use during the current austral summer season.



Distribution of earthquake epicentres south of 45° S latitude during 1957–1969. Crosses are pre-1961 centres located graphically; asterisks are 1961 and later centres determined by computer.

The continuing programme of regional earthquake recording at the Byrd and South Pole Stations (J. F. Lander, ESSA) was more successful. Since 1957, 1,058 earthquake epicentres have been located south of 45° S. Most of them occur in segments of the mid-oceanic ridges which form the circum-Antarctic belt; but the increasing density of data points has not only shown up the zones of low seismic activity but brought out the fine structure within the active zones. Of particular interest is the trend of epicentres from the southern end of the Scotia Arc across the South Atlantic Ocean, which suggests the presence of a ridge not yet mapped. Observations of earthquake epicentres are increasing at the rate of about 150 a year, though since at least 1957 none has been located south of 65·8° S.

During the past two years the South Pole and Byrd Stations have recorded three earthquake episodes on Deception Island. The first comprised six shocks, each greater than Richter magnitude 4, on December 4, 1967. The second was apparently a single event of magnitude 4·9 on September 17, 1968. But in the third, tremors began on February 14, 1969, and built up to an earthquake of magnitude 5·2 on February 21 which was accompanied by a volcanic eruption (P. L. Williams, US Geological Survey). Volcanic activity began as a cloud of steam rising to a height of 3,000 m. Ash, pumice and scoria were then ejected from a fissure 4·5 km long and 120 m wide trending about N 20° W in the eastern part of the island, despite an ice cover at least 100 m thick. At the northern end of the fissure several hundred thousand cubic metres of bombs and blocks up to 3 m long totally destroyed the Chilean base, while meltwater resulted in the partial destruction and abandonment of the British base near the southern end of the fissure. The fact that both bases were built on alluvial slopes at the base of ice-covered and apparently dormant volcanic mountains suggests some useful lessons for future Antarctic camp builders.

Earth tides require instruments of higher sensitivity for their detection than do earthquakes; but a polar location has some unique advantages for the observation of long-period tides. For one thing, the recordings are free from the large semi-diurnal and diurnal variations present in mid-latitudes. Second, the South Pole Station's mid-continental position means that the correction for distant oceanic tides is extremely small and reliable. Then there is the simple relationship that long period tides at the pole have maximum amplitude which is twice that of the minimum at the equator. Finally, observations at the pole give a global mean independent of longitude. Even so, highly sensitive gravimeters are required measuring to 0·25 μgal. This is 1 per cent of some tidal amplitudes

and 7 per cent of the residual but only about 4×10^{-9} of the total local gravity field. Despite this seemingly impossible accuracy, under Antarctic conditions to boot, C. L. Hager (University of California, Los Angeles) and R. V. O'Connell (United States Coast and Geodetic Survey) have managed to obtain some beautiful records of gravity tides with typical peak to peak amplitudes of 50 μgals and periods of fourteen days.

Antarctica also possesses a natural advantage for geomagnetic measurements (J. V. Hastings, ESSA). The ice thickness, about two miles at the South Pole Station, effectively removes the magnetographs from sources of crustal magnetic anomalies and structural geological materials with varying induction properties. The three orthogonal components of the Earth's magnetic field have now been recorded at the Byrd and South Pole Stations for more than eleven years, which puts these two stations among the Coast and Geodetic Survey's fourteen most reliable sources of geomagnetic observations. The data gathered are thus of the quality necessary for accurate determination of secular variation; and this will be reflected in better polar coverage for the 1970 issue of the five-year World Magnetic Charts.

Palaeomagnetism, on the other hand, suffers badly in Antarctica because of limited accessibility to samples. Nevertheless, L. Sharon (Washington University) and his colleagues have, during the past few years, managed to build up an impressive collection of samples from exposed regions. Measurements show that virtual geomagnetic poles from East Antarctica are displaced significantly from those in the West, which seems to suggest that East and West Antarctica are unrelated geologically or structurally. This fits in with Schopf's analysis of sea floor spreading (*Science*, **164**, 63; 1969) which indicates that the reconstruction of Gondwanaland "would be simplified if West Antarctica is not regarded as part of the ancient Antarctic crustal unit", and also with Hamilton's tectonic analysis (*Tectonophys.*, **4**, 555; 1967) which leads to a similar conclusion.

Commonsense on Environmental Pollution

THE most level-headed analysis so far of the problems of the environment seems to have been produced by a committee of the American Chemical Society under Dr F. A. Long of Cornell University (*Cleaning Our Environment. The Chemical Basis for Action.* American Chemical Society, $2·75). The lasting value of the report will no doubt lie in the detailed recommendations which it contains for future research programmes aimed at removing some of the uncertainties which at present abound in the assessment of environmental hazards. The committee begins, however, by drawing attention to the way in which environmental problems must necessarily involve both governments and people, to the international character of a great many problems of pollution (such as the spread of long-lived pesticides) and to the need that governments should be concerned not merely with legislation but with support of research.

The committee says that in the long run, "the cost of pollution and its control will be borne by the citizen", both in taxes and in prices. But people have already elected to pay for certain important controls of sources of pollution—automobile engines, for example. "A parallel value judgment" is involved in the current discussion of the control of water quality, but, the report says, comparatively little has so far been done to deal with solid rubbish. On some occasions, there may be direct money saving in methods of control, but on other occasions the benefits are less tangible.

The scientific problems that the committee has identified for solution by others include the effect of low doses of pollutants on living things, the fact that understanding of the effects of pollutants on ecology is in an "even more primitive condition", and that the analytical methods available for the monitoring and control of these phenomena "are not as good as they ought to be". The committee's recommendations on air pollution should be a powerful stimulant to research and development. The committee points to the areas in which ignorance and even frank disagreement are rife and says that what little is known of the problems of air pollution "has been worked out in the teeth of formidable scientific odds"—chiefly the small concentrations of atmospheric contaminants which must be investigated. The committee points out, however, that the United States is at present producing atmospheric pollutants at the rate of 142 million tons a year (in 1965)—72 million tons of carbon monoxide, 26 million tons of sulphur oxides, 19 million tons of hydrocarbons, 13 million tons of nitrogen oxides and 12 million tons of solid particles. Automobiles are the worst offenders, and are responsible for 86 million tons of pollutants a year, most of it as carbon monoxide.

Whether there has been a secular increase of the amounts of the various contaminants is an open question, chiefly because of the uncertainties of monitoring. Measured sulphur dioxide concentrations in various cities of the United States in the first half of the sixties show a fluctuating pattern, with concentrations ranging from 0·21 (in Denver, Colorado) to 0·13 (in Chicago, Illinois). The committee was, however, impressed with the way in which the removal of sulphur compounds from the atmosphere by means of rain increased the acidity of rainfall over Europe in the early sixties until, by 1966, rainfall over central Sweden had a *p*H of 4·5 and until the *p*H of Lake Vanern in Sweden fell from 7·3 at the beginning of 1965 to about 6·8 two and a half years later. The committee says, however, that the long term importance of sulphur pollution in the air "is essentially unknown" although the possibility that sulphur compounds as particles might have geophysical consequences cannot be ruled out.

The committee considers that what scanty evidence there is shows that the concentration of airborne particles is increasing, and that there could in the long run be geophysical consequences. The long term effects of carbon monoxide in the atmosphere are