

## BRITISH ANTARCTIC SURVEY

### ANNUAL REPORT, 1967-68

ALTHOUGH the British Antarctic Survey has been operating continuously since 1943, this is the first formal Annual Report which has been published. During these 25 years numerous stations have been occupied, some for many years, and then abandoned as the appropriate work has been completed.

During the period 1967-68 six stations were operating, supported by three ships, two aircraft and varying numbers of tractors and dog teams. H.M.S. *Protector*, carrying two helicopters, also assisted the work, both at sea and on land.

The scientific staff, working in numerous fields, were aided by an equal number of technicians and field assistants, who made a very large contribution to the results achieved. The descriptions of the activities in different disciplines are necessarily brief, especially as in many cases the work has not yet been completed. The final results will normally appear either in the *British Antarctic Survey Scientific Reports* or in the *British Antarctic Survey Bulletin*.

#### Antarctic Activities

THE 1967-68 relief of the Survey's stations by R.R.S. *John Biscoe*, R.R.S. *Shackleton* and M.V. *Perla Dan* was interrupted by the unexpected eruption of Deception Island, necessitating the evacuation of all personnel stationed there. The five other main stations were re-supplied and manned as usual. Since February 1944, Deception Island had been occupied continuously as a meteorological station, and since the 1959-60 summer the Survey's main air facility had been situated there. It was therefore impossible to assemble a single-engined Otter which had been shipped south, so that only the Pilatus Porter aircraft was operational to support summer field parties. In spite of long periods of bad weather, the depots necessary for future field work in the Alexander Island-Palmer Land area were established, but the aircraft was irreparably damaged in February during take-off over sastrugi. Emergency repairs were unsuccessful and the pilot and a four-man field party were compelled to overwinter at the Fossil Bluff field station in George VI Sound, 88 km. south of the scene of the mishap.

As a result of the Deception Island eruption, the shipping programme for the early part of the season had to be revised, and at one time it seemed as if some of the summer programmes would have to be cancelled. However, with better ice conditions than usual throughout the area, the relief programme was completed more quickly than anticipated and much of the lost time was later recovered.

An increase in hangar space had been planned for Deception Island but no sooner had the materials been landed than the eruption occurred. Although no damage was done to the installations there, all of the steel for the hangar was buried under several feet of snow and volcanic ash. When the eruption subsided, the station was visited and the buildings tidied and secured. The station was re-visited at the end of the season.

Major extensions to the living quarters at Adelaide Island were carried out. The glass-fibre dormitory building was extended and the living quarters were altered to provide more space.

The voyage into the Weddell Sea was extremely interesting, because satellite photographs were used for navigation for the first time. *Perla Dan* attempted to enter the pack ice along the usual line of long. 11°W., while *John Biscoe*, which was 2 days behind, entered at long. 22°W. which appeared to be the best approach from the satellite photographs. *John Biscoe* had a relatively trouble-free journey, while *Perla Dan* found it impossible to make headway. After some days of fruitless effort she retraced her path northward and then successfully entered the Weddell Sea along the line indicated by the photographs.

The major break-up of the ice shelf at the end of the 1967 relief caused some concern, since the ramp from the sea ice to the top of the ice shelf in Halley Bay broke out. However, on arrival in January 1968 it was found that the ramp in "Emperor Bay" was workable. It was

very steep and cargo had to be relayed up the slope. About 5 km. of sea ice separated the ship from the ramp, and it was a further 5 km. from the top of the ramp to the station site. Recent snowfall resulted in soft surfaces and consequently unloading was slow, but the relief was completed in 7 days.

The re-building of the station at Halley Bay continued throughout the year and, with the exception of the interior of the office block, it was largely completed by Christmas. The standard of workmanship was very high and this station must now rank as one of the most comfortable in the Antarctic. When *Perla Dan* arrived in January 1968, materials for an ionospheric building and a balloon shed were delivered, together with two glass-fibre buildings to house the magnetic instruments. These huts, of monolithic construction, were heavily reinforced with aluminium channel, and it will be interesting to see how they stand up to the weight of the snow that will accumulate on them in future years. A Decca WF2 radar set was also installed.

The Survey's ships visited Bellingshausen, the new Russian station on Fildes Peninsula, King George Island, and Palmer Station on Anvers Island. Previously occupied stations at Admiralty Bay and Port Lockroy were also inspected for damage and deterioration.

In early December 1967, a severely injured man was flown out by a U.S. Navy Hercules aircraft from Halley Bay to New Zealand where he made a complete recovery.

At the invitation of the U.S. Antarctic Research Projects Office, Dr. R. J. Adie visited McMurdo station, South Pole station, "Byrd" station and Scott Base.

Summer visitors to the Antarctic stations included Capt. P. Buchanan, R.N. (H.M.S. *Endurance*), Dr. D. K. Bailey (United States observer), Dr. W. Hermosilla (Chilean observer) and J. Lucas (journalist). D. R. Gipps and P. I. Whiteman, of the London Office, were responsible for supervision of logistics during the Antarctic summer season.

H.M.S. *Endurance*, formerly the Lauritzen Line's *Anita Dan*, was commissioned in June 1968 to replace H.M.S. *Protector*.

## BIOLOGICAL SCIENCES

THE earliest biological observations of value from Antarctic regions date from the botanical and zoological collections and investigations made by the naturalists who accompanied Cook on his second circumnavigation of 1772-75. From then until the early 1920's most biological research in these areas was confined to the collection and identification of specimens, and substantial amounts of material were accumulated in herbaria and museums. The study of these specimens laid the early foundations for present knowledge of the taxonomy and biogeography of the region's plants and animals.

The setting up of the Discovery Committee's biological laboratory on South Georgia in 1928 and the regular sampling of the waters of the southern whaling grounds from its ships opened a new era in scientific investigation of Antarctic regions and for more than a decade marine studies of high quality dominated Antarctic biological research. Of particular importance were the pioneer studies on whales, krill and ecologically important species of the oceanic phytoplankton and zooplankton.

The establishment of the first permanent land-based station in the vicinity of the Antarctic Peninsula in 1944 opened the way to terrestrial studies, particularly of seals and birds. Since the International Geophysical Year, biological studies have been steadily increasing in importance in the programmes of most of the Antarctic Treaty countries, and in 1961 the British Antarctic Survey began to develop its station on Signy Island, primarily for biological studies. Most of the Survey's current biological programmes date from this period.

The appropriateness of and the opportunities for biological research in Antarctic regions by British Antarctic Survey personnel were recently summarized as follows:

- i. The region represents peculiar environmental features, such as the combination of high summer light intensity with low temperatures, often high aridity, a summer photo-periodic gradient from long to continuous day-length, and unique habitats such as the ice shelves and the sea-floors beneath them. It therefore offers opportunities for the study of adaptations and their evolution.

- ii. The Southern Ocean is a region of variable but locally very high productivity and some of its resources that may be of economic importance. Much fundamental research is needed before the consequences of any exploitation can be predicted and the level of harvest adjusted to sustainable yield.
- iii. The Antarctic pack ice is an unusual and highly specialized habitat with indigenous seal species, large avian and seal populations, and unique short food chains. These areas still present a logistic challenge.
- iv. There are opportunities for the analysis of highly adapted, species-poor land and fresh-water ecosystems in which single species are often very abundant, and for the study of the inter-relationships between these and the species-rich productive ecosystems of the surrounding oceans which are the food source for the very large populations of sea birds and mammals.
- v. The Antarctic and sub-Antarctic offer unique opportunities for the study and dispersal of pollen, spores, micro-organisms, and plant and invertebrate species across great expanses of ice and ocean, and for the analysis of the distributions of species in relation to present and past climatic and geographical features.
- vi. Man's physical and biological impact on the environment, flora and fauna of the Antarctic and sub-Antarctic is still relatively slight. Measurements, for example, of plant growth, faunal distribution and trophic relationships could provide a background against which the consequences of increased human activity may be assessed. Also, it is characteristic that large land-breeding vertebrates show little fear of Man and so provide a valuable opportunity for study of their physiology and behaviour.
- vii. Man can be studied under controlled conditions, for a period of one or more years, in isolation in a potentially hostile environment.

### Botany

If the opportunities for initiating and developing, among other things, long-term field programmes in plant ecology and physiology, are to be fully exploited, then much basic botanical work has still to be accomplished.

It is, for example, clearly essential for the field ecologist to have adequate taxonomic accounts of lichens and bryophytes so that at least the common species or those of ecological importance can be readily identified. In spite of an extensive literature this state has not yet been reached. Since 1960 British Antarctic Survey personnel, including cryptogamic botanists, have been collecting specimens throughout the Antarctic Peninsula sector to be used as the basis for an up-to-date taxonomic account of the region's flora. The study of particularly difficult groups has hardly begun, but it is already clear that satisfactory taxonomic treatment of the problems posed by natural variation, depauperation and sterility will require extensive field survey as well as the study of living plants in cultivation. As the taxonomic basis improves, the present trend towards experimental, ecological and physiological studies can be accelerated to provide an understanding of the behaviour and adaptation of plant species to the unique Antarctic environment.

During this period the Survey undertook three botanical field programmes and three botanists are writing up results of earlier field work. Another scientist spent the year in training for micro-climatological and other studies on Signy Island.

#### *Bipolar Botanical Project*

The major field programme involved five persons and was carried out in South Georgia from November to March, the work forming the southern reconnaissance phase of a Bipolar Botanical Project. This project is sponsored by the International Biological Programme and involves a comparative physiological study of the growth and reproductive characteristics of plants, particularly bipolar species, under Arctic and Antarctic field conditions. Five representative sites, reflecting major differences in habitat factors such as exposure, insolation and moisture were chosen in the vicinity of Grytviken and the characteristics of their vegetation and soils were described. Using portable automatic recorders, the following data were collected every hour, at plant level, to provide a description of the micro-climatic conditions under



*Polystichum mohrioides*, the common South Georgian shield fern.

which the plants were growing—total incoming solar radiation, temperature at various levels above, within and below the vegetation, precipitation and wind speed (by hot-wire anemometer). The data for the primary site, the one with the richest development of vegetation, are continuous for the whole period, but they are less extensive for the secondary sites. Further evaluations of the environment were made by growing seedlings of alien species, oats, radish, turnip and rape on non-limiting media at all the sites and comparing dry weight accumulation as expressed in *relative growth rates*, *net assimilation rates* and *leaf area ratios*. Distinct differences were found between the habitats and again between mid- and end-of-season values. In general, the South Georgian values were lower than comparable results obtained on Disko Island, West Greenland, in August 1967.

Other work undertaken on South Georgia involved estimates of *net primary production* in native *Festuca* grassland; the comparative study of native populations of *Acaena magellanica*, *A. tenera*, *Colobanthus quitensis*, *Deschampsia antarctica* and *Phleum alpinum* at a variety of sites; growth-rate experiments on bryophytes including *Pohlia wahlenbergii* var. *glacialis* and *Tortula robusta*; and measurements of the performance of transplants from the Falkland Islands and West Greenland. Some taxonomic collections were made and some floristic surveys were undertaken at a number of sites along the north-east coast of the island.

#### *Field work on Signy Island*

The second field programme, centred on Signy Island, consisted of a detailed study of the growth and reproductive biology of *Colobanthus quitensis* and *Deschampsia antarctica*. Earlier observations had suggested that both species fail to flower regularly on the island, although both appear to be well established at suitable north-facing sites around its coast. *Relative growth rate* and *net assimilation rate* estimates for both species were obtained under test conditions at two sites, while comparable estimates of performance in natural habitats, including phenological behaviour by the calculation of maturity indices, were also made.





*Festuca-Acaena* grassland, the characteristic sward over much of South Georgia.



*Acaena magellanica*, the Greater Burnet (left) and *Phleum alpinum*, the alpine Catstail (right), two South Georgian species studied intensively during the Bipolar Botanical Project.

The third field programme on Signy Island involved the completion of an ecological study of the composition and seasonal fluctuations of free-living populations of bacteria, actinomycetes, yeasts and filamentous fungi at selected sites. Seasonal variations in the rates of decomposition of bryophyte turfs were also studied. The results of this programme are at present being worked up at University College London.

Other work on Signy Island included the estimation of growth parameters at one site for the same alien seedlings tested on South Georgia, while field tests were also carried out on transplant material from the Falkland Islands and South Georgia grown under rigorously controlled conditions.

#### *Studies in Polytrichum*

At Birmingham, the analysis of data and material collected during earlier field work was continued in the programme involving studies of growth and reproductive characteristics of species of *Polytrichum* at various Antarctic sites. Detailed cycles are now available for *P. alpinum* from South Georgia, while for sites farther south it has been shown that female inflorescences are widespread but that their development is retarded compared to that on South Georgia. Male plants are most common on north-facing sites, but sporophytes are rare. A similar analysis for *P. alpestre* revealed that, although male plants are rare south of South Georgia, females are commonly present; however, sporophytes are rare.

A technique was successfully developed for estimating the *net annual primary production* for samples of *Polytrichum alpestre*, a species which shows distinct annual growth increments. Comparisons made between material from South Georgia, Signy Island and Galindez Island showed the highest rates were obtained on South Georgia and the lowest on Signy Island. It is clear, however, that net productivity in this species is of the order of several hundred g./m.<sup>2</sup>/year even at sites in the maritime Antarctic.

#### *Lichen and moss floras*

Taxonomic studies of Antarctic lichens and mosses were continued. The preliminary analysis of all available unidentified lichen and bryophyte collections from the Antarctic was completed and detailed reviews of some of the material begun. A study of the Usneaceae has greatly increased knowledge of the distribution and general ecology of members of the family, in particular of *Cornicularia epiphorella* previously only known from the Antarctic as a single specimen. A study was also completed of some lichens from Heimefrontfjella. The bryophyte work saw the completion of *Antarctic moss flora: I*, which covers all Antarctic species of the genera *Andreaea*, *Pohlia*, *Polytrichum*, *Psilopilum* and *Sarconeurum*. Some of the most interesting material encountered during this work included specimens of a new species of *Sarconeurum* from a number of localities along the Antarctic Peninsula, as far south as Fossil Bluff on Alexander Island.

#### *Floristic surveys and experimental ecology*

Progress was also made with the writing up of ecological surveys which had been carried out on the South Sandwich Islands, South Shetland Islands and Signy Island. The Signy Island work, which was undertaken at Aberdeen, was based on a detailed field analysis of a very large number of sites; it has resulted in a comprehensive classification scheme which now incorporates all the island's terrestrial plant communities. It was also shown that this scheme could be extended to include parts of the Antarctic Peninsula; consequently a firm basis now exists for evaluation with other vegetation types. The programme of experimental ecology which involved an assessment of water up-take and loss in selected moss species has been extended by further analysis of the results in an attempt to clarify the relationships between plant form and habitat preferences.

### Zoology

THIS period was dominated by the move of the Zoology Section from Queen Mary College, London, to the Monks Wood Experimental Station of the Nature Conservancy, where temporary accommodation was kindly made available by the Director from May until the new building was completed in August. This provides 250 m.<sup>2</sup>, consisting of two main offices, seven research rooms, one large laboratory, a large writing/seminar room and a museum/store area.

### Marine ecology

A study of the breeding biology of the large isopod *Glyptonotus antarcticus* at Signy Island was completed. This is a predator/scavenger of inshore benthos and breeding has been shown to be independent of cyclic changes in primary productivity. Development from egg to hatching takes 18 months and it may take up to 12 years to reach maturity. Because males grow faster than females, they are larger at maturity after the same number of moults. Fecundity varies in proportion to the size of female and, though post-breeding mortality is very high in both sexes, about 2-3 per cent may breed a second time. A new species of marine leech has been described from the exoskeleton of *G. antarcticus* together with two new species of Spirorbinae.

Previous field observations and collections have been extended in studies of the life histories of several common species, especially *Bovallia gigantea*. The eggs of this species develop in the marsupium, hatch in about 7 months and are released in early spring. Maturity in males is reached in 28-29 months after release and in females in 40-41 months. Post-breeding mortality is high, though some females may produce a second brood.

Considerable use is made of the Scuba-diving technique throughout the marine biological programmes and this led to the discovery of a series of submerged beaches at Signy Island. The technique has been operated from a stationary ship, yielding observations and material useful to biogeographical studies without disrupting the ship's routine. Under-water photography has been developed and is now used to provide rapid but permanent records of submarine communities for qualitative and quantitative analysis.

### Fish research

A taxonomic account of Antarctic fish and their larvae has been completed and work on the ecology, population dynamics and reproduction of *Notothenia neglecta*, dealing with biometrics, biomass and annual production, is in progress.

Analyses of the blood of Antarctic fish have indicated a reduced haemoglobin level which may be regarded as a tendency towards the chaenichthyid condition. It has also been shown that the chaenichthyid, though lacking blood pigment, respire at a rate similar to that of red-blooded fish. These observations, and the fact that chaenichthyids have relatively large hearts, are the basis for investigations on the mechanism of oxygen transport in these fish. An attempt has been made to answer the two main questions: "Do active fish have large hearts?" and "Did the chaenichthyid evolve from active forms and thus lose haemoglobin secondarily?" Such studies may throw light on the origin of the Antarctic fish fauna.

It has been found that at Signy Island fish avoid freezing by preventing ice coming into contact with their gills. This appears to contrast with the condition in *Trematomus borchgrevinki* at McMurdo Sound which has an anti-freeze compound in its blood.

### Seal biology

An important collection of jaws, genitalia and alimentary tracts was made from 215 crabeater, Weddell, leopard and elephant seals which had been killed for dog food. The specimens were transported to the United Kingdom in special polythene and fibre-glass tanks installed on R.R.S. *John Biscoe*. The skeletal material complements a collection of about 600 jaws of crabeater and Weddell seals made in previous years. A programme to analyse this material for information on population structure, reproduction and feeding habits has begun in collaboration with the Department of Anatomy, University of Cambridge. Special apparatus has been developed to cut and polish tooth sections for age determination.

Maternal behaviour in Weddell seals has been studied and the recovery of marked females has confirmed that breeding can occur in cows ranging in age from 3 to 20 years.

### Terrestrial ecology

A detailed investigation into the ecology of the terrestrial nematodes of Signy Island has continued. Results from different vegetated habitats have indicated a uniformity of species composition but a considerable variation in number of individuals. The greatest density (>30,000 individuals in 100 g. sample) occurred in a penguin rookery when only one species was present.

Preliminary tests of culture techniques in the United Kingdom for certain terrestrial Antarctic arthropods, in particular the collembolan *Cryptopygus antarcticus*, were successful and this has an important bearing on the feasibility of future respiration experiments on these species. Using a scanning electron microscope in Cambridge, the morphology of *C. antarcticus* was studied and revealed hitherto unobserved details of structure.

An important advance in the field of terrestrial ecology was the decision to establish one or more special long-term study sites on Signy Island. This is aimed at achieving greater integration of the field work and it is consistent with the move towards intensive ecosystem studies.

#### *Ornithology*

As in previous years, ornithological work centred on Signy Island laid particular emphasis on the breeding biology of petrels and observations were also made at the Argentine Islands, Adelaide Island, Halley Bay and South Georgia. One result of these extensive studies was the discovery of a large new breeding colony of Antarctic and snow petrels in the Theron Mountains.

At Signy Island, studies on the breeding biology, migrations and population dynamics of giant and Wilson's petrels continued, while a programme on the relationship of the breeding



Scanning electron microscope photograph of the anterior aspect of the head of the collembolan, *Cryptopygus antarcticus*, showing details of the mouth parts.

biology of the snow petrel to food availability was concluded. Accounts of the breeding biology of the Antarctic skua and of breeding success and moult in smaller Antarctic petrels have been completed. The studies on the embryology of pygoscelid penguins and the breeding behaviour of the blue-eyed shag are continuing.

The routine ring-recovery programme and collection of life-cycle data continued. Specimens of several species were collected for parasitological examination at the University of Hull. At Halley Bay, a programme on the myology and locomotion of the emperor penguin was initiated.

An evaluation of all British Antarctic Survey ornithological material and information collected over the past 20 years has begun. This could lead to the publication of a monograph on the birds of Signy Island, and it would also assist in defining future research programmes.

#### *Organo-chlorine residues*

In the past few years the incidence of organo-chlorine residues in the Antarctic has become an important factor and it remains a subject for collaboration with the Government Chemist. Samples of surface sea-water and from fish, seals, birds and huskies have been taken for analysis.

### Joint Botany/Zoology Project

#### *Limnology*

The recent publication of accounts of the physical and chemical properties of the Signy Island fresh-water lakes has provided the basis for future limnological studies, which are being developed in collaboration with the Freshwater Biological Association and the Department of Botany, Westfield College, London.

Purely zoological topics that have been completed include investigations on the mouth parts and feeding habits of *Parabroteas sarsi* and *Pseudoboeckella silvestri*.

The botanical aspects of this study include the systematic ecology of fresh-water algae and the determination of levels of primary production by the phytoplankton, using such methods as chlorophyll analysis and radiocarbon bio-assay.

Current work has centred on developing techniques for sampling lake water beneath at least 2 m. of snow and ice without disturbing the immediate natural environment or its fauna or flora. Some novel equipment has been devised and, since winter conditions in parts of the Scottish Highlands are similar to those under which the equipment will be operated on Signy Island, thorough field-testing has begun at Loch nan Eun at 915 m. in the Cairngorms. A robust, battery-operated portable solarimeter and recorder, suitable for prolonged and mobile use at different lakes, has been selected.

### Veterinary Investigations

FOLLOWING the discovery of widespread and often severe osteoarthritis in the hip and shoulder joints of 26 out of 34 sledge dogs in 1963-64, another veterinary surgeon visited the Survey's stations in 1967-68 with a portable X-ray set. He was able to show that the condition was not due to any hereditary factors, and concluded that the posture and gait of the husky while pulling, together with the effects of weight-bearing, led to the degenerations seen in the joints.

He also encountered several cases of hereditary disease in the dogs. Four were found to have hereditary entropion (infolded eyelids), and three to have true haemophilia (type A). Whereas this is not an explosive incidence of these disorders, it is hoped that the steps taken at the time to control further spread of the diseases, together with the import of new dogs from the Arctic, will eliminate these troubles.

It is hoped that other veterinary surgeons will have the opportunity of continuing this work, and also of giving advice and assistance with the care of the dogs.

### Medicine and Human Physiology

PHYSIOLOGICAL programmes in the Antarctic are largely carried out by the medical officers but from time to time physiologists undertake specific projects. Two main types of experiment form the programme. There are the experiments concerned with Man in relation to his



environment, in particular the cold, and those which take advantage of the isolation and use the Survey's stations as physiological laboratories where all the outside factors affecting Man are much less complex than in countries such as the United Kingdom.

The occurrence and possible spread of a common skin bacterium, *Staphylococcus aureus*, was studied at Stonington Island. Surprisingly, it was found that few members of the station carried the bacterium, and there was no spread. Serum samples were collected to detect any spontaneous changes in immunity to various viruses, but none was detected.

The well-known increase of urine excretion which occurs when Man is exposed to the cold was investigated at Signy Island. Six members of the station were exposed nude to a temperature of 5° C both during and after a year at Signy Island. Urine flow increased after 20 min. and it became copious and dilute; salt excretion was high even when the urine flow was undramatic. This response was reduced if fluids were withheld for a day before the experiment. Despite an increased tolerance to cold, urine flows, and rectal, skin and extremity temperatures for a given exposure did not change during the year.

Numerous experiments were conducted at Signy Island and Halley Bay to measure the energy expenditure involved in all of the commoner tasks, thereby building up a "metabolic map". The samples of expired air collected from subjects in the Antarctic are about to be analysed.

An important nutrition experiment is being carried out at Halley Bay. The object is to find what effect sucrose in the diet has upon the quantity of fat in the blood. To do this, several members of the station have lived on a special diet in which sucrose has been replaced by sweet substances such as cyclamate. Measurements of blood sugar and tolerance of large amounts of glucose made at Halley Bay so far have shown there is little difference between these subjects and those fed on a normal diet. The opportunity of having subjects on a low-sucrose diet is also to be used to study the formation of plaques on teeth.

The isolated community at an Antarctic station forms a good setting in which to study the spread of viral and bacterial infection. As a follow-up to earlier bacteriological work, mild influenza viruses have been taken to the Antarctic. Members of the Stonington Island station are being deliberately infected to study the spread and the development of immunity. In addition, similar lines of investigation are being followed on a bacterium which normally grows in the gut.

Possibly the severest exposure to cold takes place in the divers who swim under the ice at Signy Island while wearing wet suits. Their response, in terms of body temperature and the possible development of cold acclimatization as shown by the excretion of urinary catecholamines, is being investigated.

## EARTH SCIENCES

### Survey and Mapping

THE surveyor's work is basic to that of many other disciplines. His task is to position and record the features of the land so that accurate maps can be produced and these provide the base on which scientific data can be plotted and compared. Nowadays, the features are usually recorded on systematic air photography and the surveyor concentrates on establishing the true position of a framework of features on the ground so that the photography can be correctly scaled and orientated when the maps are plotted in the office. Not all of British Antarctic Territory has yet been photographed from the air, and during this period much of the field work embraced both positioning and recording of the topographic detail; the former was undertaken by tellurometer traversing and triangulation based on astronomical observations, and the latter by ground photography supplemented in places by plane-tableing.

Field survey was undertaken from the Survey's stations at Halley Bay and Stonington Island, and in the United Kingdom maps were compiled from earlier surveys of the South Shetland Islands and of Heimefrontfjella in Dronning Maud Land.

### *Halley Bay*

From Halley Bay plans to commence the systematic survey of the Shackleton Range had to be abandoned because the reconnaissance of a satisfactory overland route to the mountains took up all the available time prior to the surveyors' departure on the 1968 relief ship. The new station site was mapped at a scale of 1 : 1,250 and parts of the Brunt Ice Shelf were surveyed at scales of 1 : 20,000 and 1 : 200,000; these surveys were carried out in conjunction with the glaciologists and they provide considerable information on the complex relief of parts of the ice shelf.

### *Stonington Island*

At Stonington Island the surveyors checked the position of the Survey's station by a new series of astronomical observations, giving a result of lat.  $68^{\circ}11'18''.1$ S., long.  $67^{\circ}00'34''$ W., which is very close to the original results obtained from observations carried out in 1947. Their main programme, however, was carried out in George VI Sound, where five new survey stations were established on its west coast between Fossil Bluff and lat.  $70^{\circ}18'$ S., and three stations established in 1963 on the east coast were checked and rebuilt. The survey framework which had been established south of Fossil Bluff in 1963-64 was extended along the west coast as far north as lat.  $70^{\circ}18'$ S. before the annual flooding of George VI Sound prevented further field work in that area. Towards the end of the season a survey party was landed on the ice shelf north of Blaiklock Island by R.R.S. *John Biscoe* in order to extend northwards the Stonington Island survey work to connect eventually with that observed previously from Dettale Island (lat.  $66^{\circ}52'$ S., long.  $66^{\circ}48'$ W.), but the work was hampered by severe weather conditions and it was only possible on 17 out of a total of 80 days.

### *United Kingdom*

The surveyors who had returned to the United Kingdom from Halley Bay in 1967 and 1968 completed the compilation of a map of the whole Heimefrontfjella at a scale of 1 : 100,000, and copies of the original compilations and of the survey data were supplied to the Norsk Polarinstitut. The computation of the survey of the Theron Mountains (lat.  $79^{\circ}05'$ S., long.  $28^{\circ}15'$ W.) was in hand at the end of the period. The surveyors returning from Stonington Island computed the results of the work in George VI Sound, and computed the survey and compiled a map at 1 : 200,000 of part of north-eastern Palmer Land lying between lat.  $69^{\circ}10'$  and  $71^{\circ}10'$ S., and long.  $62^{\circ}20'$  and  $64^{\circ}40'$ W. as a base map for the geologists; this map is of reconnaissance standard and reveals a number of features that had not previously been mapped.

The Directorate of Overseas Surveys completed the mapping of the South Shetland Islands at 1 : 200,000 from air photography and all existing surveys, and prepared a revised outline map of the Antarctic Peninsula at a scale of 1 : 3,100,000 using satellite photography to check the coastline of the Larsen Ice Shelf.

## **Geology**

SINCE the inception of the Survey in 1943, geology has been one of the main field programmes. Before this time, the geological knowledge of the Scotia arc and the Antarctic Peninsula consisted of disconnected field surveys and reports scattered throughout the literature, but now, mainly through systematic field work and carefully directed laboratory studies, it is possible to state that there is a reasonably clear understanding of the stratigraphy and structural relations of the whole region.

The objectives of the geological investigations are:

- i. To map systematically the whole region at a minimum scale of 1 : 200,000, using all available modern techniques.
- ii. To resolve the stratigraphy and structure of the southerly extension of the South American Andes (i.e. the Antarctic Andes) throughout the Scotia arc and the Antarctic Peninsula region.
- iii. Where possible, to assess the economic potential of the region.

- iv. To attempt to contribute towards the solution of geological problems of broader significance, i.e. related to the whole of the Southern Hemisphere.
- v. To investigate within the region the geological relationship between east and west Antarctica.

All of these objectives fall within the broader scope of the SCAR Working Group on Geology, to which the Survey has made a considerable contribution.

#### *Field mapping*

Since the existing geological map of Signy Island contained a number of incompatible errors, it was decided to re-map the island at a scale of 1 : 10,000 using air photographs. This project has been satisfactorily completed and it is now hoped that new information will be available for laboratory interpretation. Field work in Palmer Land was devoted to the completion of the systematic mapping of the west coast between the Traverse and Batterbee Mountains. Though logistic support was limited, the important stratigraphical, palaeontological and structural work in the immediate vicinity of Ablation Point, Alexander Island, was continued in an attempt to tie it in with existing field data. Where possible, large-scale mapping (1 : 50,000) was undertaken. From Halley Bay, difficult journeys were made southwards to the Theron Mountains to complete the 1 : 100,000 map that was started the previous year.

#### *Geomorphology*

When the 1 : 25,000 geological survey of Deception Island was completed in 1957–58, it was recognized that this island abounded in fascinating volcano-morphological and glacio-morphological phenomena. Therefore, a special project was set up to examine Deception Island during the 1967–68 summer. As the field party was about to arrive at Deception Island, a severe volcanic eruption occurred on 4 December 1967, necessitating the evacuation of the station. By 7 December the eruption centres had subsided sufficiently for a preliminary investigation of the nature of the event, and on 14 December a small party was able to reach the two eruptive centres to make a cursory examination of the topographic modifications which had occurred.

Because conditions were unsuitable for the Deception Island project, the party turned its attention to the north coast of South Georgia. A detailed classification of the topographic features of the area immediately west of Cumberland Bay was undertaken. This also involved accurate ground surveys and an interpretation of the topographic evolution of the whole area. The degree of glacierization was studied in addition to fluctuation in the positions of major glacier snouts and the evolution of glacio-geological features such as terminal moraines and outwash plains. A follow-up study was also made to refine the earlier work on raised beach levels and attempt a correlation with past fluctuations in the glaciers. This whole project proved to be highly successful and will undoubtedly establish a firm basis for future geomorphological studies in South Georgia.

#### *Patterned-ground studies*

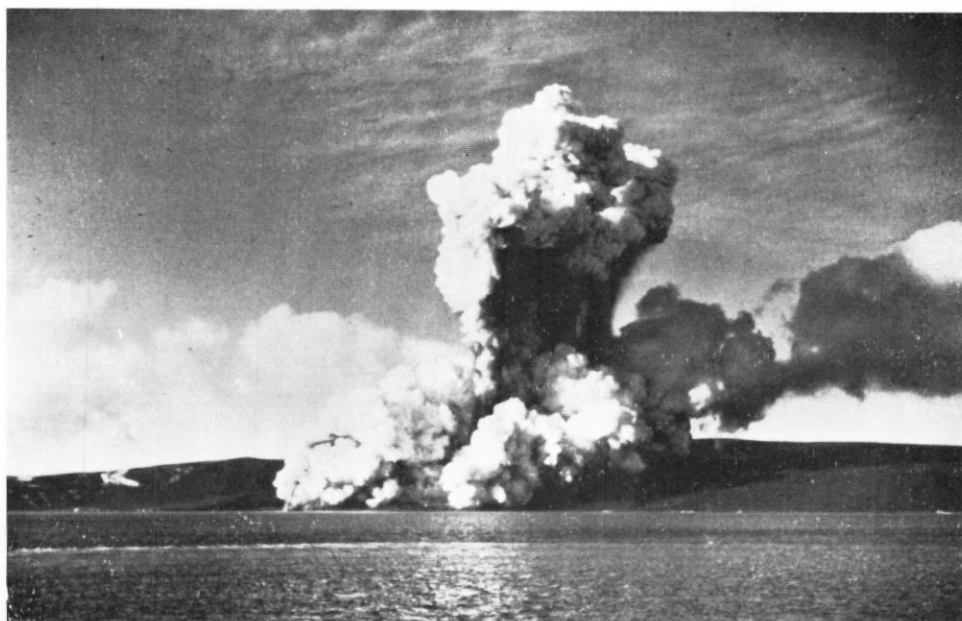
Many parts of Antarctica that have lost their ice cover in relatively recent times have revealed magnificent examples of undisturbed fossil patterning which had undoubtedly formed in a less severe climatic environment. Cryoturbation phenomena of many species have been discovered not only in the Antarctic Peninsula but also on the islands of the Scotia arc. A carefully devised study of these phenomena was begun at Signy Island in 1962–63, and it was accompanied by a series of experiments to test the mode and degree of upheaval by frost-action in that climate. Numerous novel ideas emerged from these initial observations and short-term experiments, but the longer-term data were undoubtedly of more general significance. After a duration of several years, a further set of observations was made in 1967–68 on the experimental plots and mass-flow marker stakes to give a broader interpretation of this widespread feature of periglacial conditions. These sites are to be preserved for future programmes on the rates of growth of sorted circles, and the origin of stone stripes and various polygons in a metamorphic terrain.

### *Volcanology*

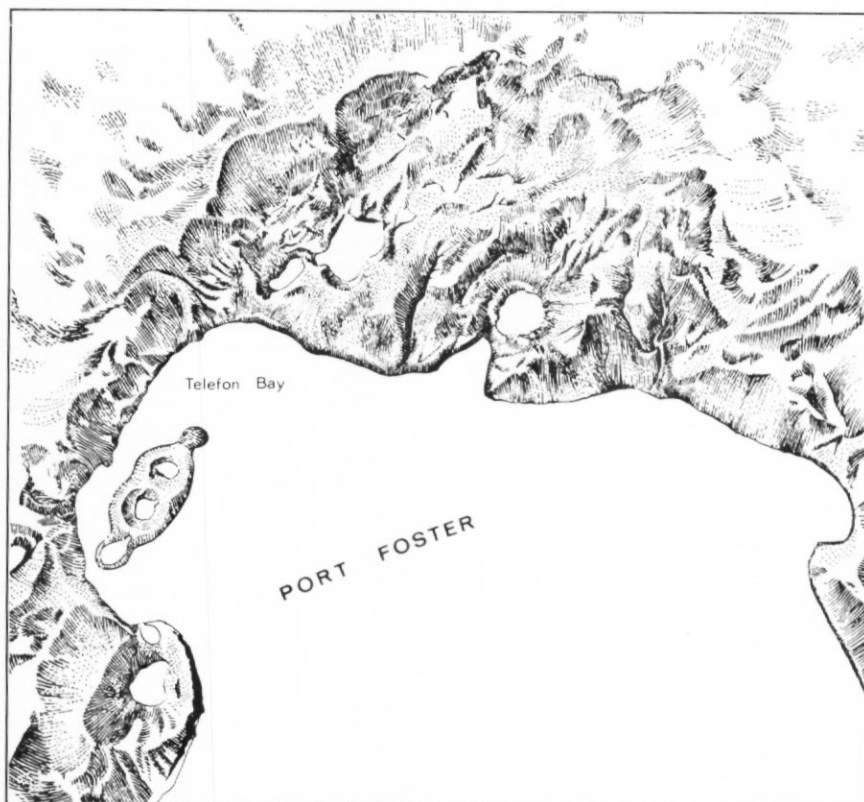
It is seldom that Nature provides such a scientifically interesting phenomenon as a volcanic eruption in the Antarctic. The early morning of 4 December 1967 was indeed such an occasion at Deception Island. From their dangerously near grandstand, the occupants of the Chilean station at Pendulum Cove witnessed the slow upheaval of the sea ice in Telefon Bay, and the ejection of a column of ash from the turbulent sea accompanied by earth tremors, loud explosions, tidal waves, rising clouds of steam, ash showers, thunder, lightning and a severe hailstorm. Such was the initial stage of an eruption that had not been previously experienced by Man in the Antarctic. The severity of the explosions and ash showers increased in intensity to such a degree that all occupants of the island had to be evacuated as soon as possible. Apparently, within several hours a second centre on the land not far north of Pendulum Cove began erupting, and also emitted ash and steam. The final stages of the eruption were only observed from afar, but it is known that the power of the explosions carried ash over 9,000 m. into the air. Reconnaissance by boat on 7 December revealed that a new island with five main centres of eruption had been formed in Telefon Bay and that the land centre north of Pendulum Cove had been breached by the sea. In spite of the intensity of fumarolic activity and the emission of fumes, the landing party was able to prepare contoured maps of the new island and the land centre, and make a satisfactory collection of specimens from these new features. An interesting fact of this eruption, in contrast to other recent eruptions in the South Atlantic Ocean, was the total absence of lava and the presence of a high intensity of fumarolic activity. Because of logistic difficulties, it was not possible to carry the investigations further at this stage, but a combined Royal Society/British Antarctic Survey expedition to Deception Island to carry out a thorough study of the results of the eruption and its effects has been planned for the 1968-69 summer.

### *Stratigraphy*

One of the most important localities in the Southern Hemisphere for the Lower Cretaceous has turned out to be the south-eastern coast of Alexander Island. Though the sediments are overthrust, faulted and folded in places, the abundance of invertebrate fossils has proved to be



One of the last ash eruptions from the centre north of Pendulum Cove, Deception Island; 7 December 1967. (Photograph by M. J. Cole.)



The northern part of Deception Island, showing the new island in Telefon Bay and the crater centre to the north-east which resulted from the volcanic eruption of 4 December 1967. (Reproduced by courtesy of *The Geographical Magazine*, London.)

of great importance in stratigraphic correlation. Much work has been done on the correlation of measured field sections, both on facies and palaeontological grounds. The occurrence of camptonite and sandstone dykes in the sediments has been investigated and has proved to be most interesting. Further studies are in progress and these should lead to a thorough understanding of the depositional conditions.

The stratigraphy of the Lower Permian terrestrial sediments of the Theron Mountains has also been examined. Their most important feature is the presence of the *Glossopteris* flora, which is also known from north-east Heimfrontfjella and the Whichaway Nunataks to the south.

#### *Palaeontology and palaeobotany*

Detailed collecting in the Lower Cretaceous sediments of south-eastern Alexander Island has yielded a wealth of invertebrate material which will take some years to work up properly. Already the echinoids, cirripedes and trace fossils have been published, and now work is proceeding on the decapods, gastropods and ammonites. From a stratigraphical viewpoint, the latter are very important since they provide a means for correlation with South American stratigraphy.

One of the most promising discoveries of recent years is the occurrence of Triassic plants at Livingston Island in the South Shetland Islands. These are the first plants of this age to be found in west Antarctica and therefore they may be useful in tracing the evolution of the Jurassic species already known from Hope Bay and several parts of east Antarctica. Further work has been done on the fragmentary plants collected from Powell Island, South Orkney Islands, and it seems they are probably of the same age as the renowned flora of Hope Bay.



*Structure and tectonics*

South-eastern Alexander Island, particularly south of Fossil Bluff and in the hinterland, has yielded structural and tectonic information which will ultimately give the clue to the formation of the great north-south rift valley of George VI Sound and possibly of the Antarctic Peninsula plateau itself. Tectonic features on all scales have been studied in the field and in the laboratory, especially from a geometrical standpoint. Clearly, the understanding of the stratigraphy is directly linked with both the structure and the tectonic environment. Allied to these studies is the provenance of the Lower Cretaceous sediments and their depositional environment, detailed information on which is now emerging.

*Petrology and geochemistry*

The main laboratory work has been concentrated in the fields of petrology and geochemistry. The remaining areas of the Foyn and Bowman Coasts have been completed, and additional work on central Palmer Land (Éternity Range area), Horseshoe and Pourquoi Pas Islands has reached an advanced stage. The metamorphic complex of north-east Heimfrontfjella and the dolerite intrusions of the Theron Mountains have been studied in detail. Not only has the petrology of previous collections from Signy Island, the Inaccessible Islands, the James Ross Island area and South Georgia been worked on and written up for publication, but a new programme on the Danco Coast rocks has been initiated.

More than 60 chemical analyses of rocks from these areas have been completed by classical, rapid and XRF methods. These samples have been carefully selected to tie in with petrological, radio-isotope and palaeomagnetic studies, and it is now clear that the results yield valuable information. One interesting mineralogical study on feldspars from the Bowman Coast has given data on the temperatures of formation of the rocks, and by using this it has been possible to differentiate between acid intrusions which are both petrologically and chemically similar.

The results of the present petrological and geochemical work fit in admirably with earlier investigations, and it therefore seems there is little discrepancy of thought on the overall geological column for the Scotia arc and the Antarctic Peninsula.

*Radio-isotope dating*

For the past 3 years there has been close collaboration between the Survey and the Age Group of the Department of Geology and Mineralogy, University of Oxford, in a programme of radio-isotope dating of representative samples from the Scotia arc and the Antarctic Peninsula. K-Ar and Sr-Rb techniques have been used thus far and attention has been primarily directed towards determining the intrusive sequence in the Antarctic Peninsula. The age of the main orogeny in this region has been another aspect of the work. In all, about 90 samples have been dated by K-Ar determination and a further 20 Sr-Rb determinations have been done. Rigorous checks by both methods on the same samples have been adopted where necessary.

New K-Ar dates on metamorphic rocks from the South Orkney Islands (mainly Signy Island) have confirmed the age of the last release of argon as 190 m. yr. Age determinations on a wide selection of samples of basic to acid intrusive rocks from the Antarctic Peninsula have revealed six phases of igneous intrusion: 370, 160-180, 130-140, 90-110, 70-75 and 45-60 m. yr., respectively. The two latest phases of intrusion constitute the previously known Andean Intrusive Suite; this has confirmed what has been suspected from other field evidence. Radio-isotope age determinations have been responsible for broadening the scope of the field mapping and the laboratory work, and they have enabled more accurate correlation with South America to be undertaken. They have also added vastly to the value of the palaeomagnetic work done thus far.

This important programme is to be continued in collaboration with the Age Group at the University of Leeds, and a specific attempt will be made to resolve the existing problem of the ages of volcanic and minor intrusive rocks in the Antarctic Peninsula. Modifications of existing techniques are being used in an attempt to pass beyond the blank wall of the last orogeny and the deleterious effects of the Andean intrusions.

## Geophysics

### *Field programmes*

#### *Land geophysics*

The use of magnetic and gravity surveys in conjunction with geological field mapping has proved to be a great asset to the geologist, enabling him to "see" beneath the ice- and snow-covered areas of the Antarctic Peninsula. This technique has been used successfully in following beneath the ice contacts, unconformities and tectonic features exposed elsewhere, and for the interpretation of structure.

Geophysical surveys on a broader scale have been conducted in George VI Sound to establish the precise nature of this feature and its relationship to Palmer Land and Alexander Island. Large-scale local surveys have also been done to solve specific geological problems, e.g. to establish the location of an important contact at Horseshoe Island.

#### *Palaeomagnetism*

Palaeomagnetic investigations are of considerable interest to the field geophysicists and the geologists. To continue the long-established programme in this field, the collection of suites of orientated samples has become a routine matter. The laboratory work is being undertaken in the Sub-Department of Geophysics, University of Birmingham.

#### *Marine geophysics*

Since 1959 the British Antarctic Survey has provided facilities on board R.R.S. *Shackleton* and sea time for a marine geophysics group of the Sub-Department of Geophysics, University of Birmingham. This work is supported by a N.E.R.C. grant. The group is engaged on a study of the crustal structure and origin of the Scotia arc.

Available sea time was less than in recent years, mainly as a consequence of the volcanic eruption on Deception Island, but much useful work was done.

Both the two-ship seismic refraction experiments (with H.M.S. *Protector*) and the sonobuoy work concentrated on the section of the south Scotia Ridge which lies between the South Orkney Islands and Elephant and Clarence Islands. Together with further work planned for next season, these measurements will relate the double ridge to the structures already observed in the areas at either end of the ridge.

To provide a firm foundation for this work, the magnetic survey of Bransfield Strait was extended eastward, to the limits of the ship's ability to obtain good radar fixes from Elephant and Clarence Islands.

Further magnetic and bathymetric profiles were obtained on north-south tracks, 48 km. apart, across the Scotia Sea to extend eastward the adequate reconnaissance coverage of the Drake Passage area.

Processing and interpretation is keeping pace with the field work. Crustal structure studies in the South Shetland Islands area and on the South Orkney Islands continental block are now complete and will be published shortly. A summary of work done on the large number of magnetic and bathymetric profiles obtained in the deep-water areas of the Scotia Sea over the past few years is also being prepared. It seems likely that these data contain the essence of the recent structural history of the whole region.

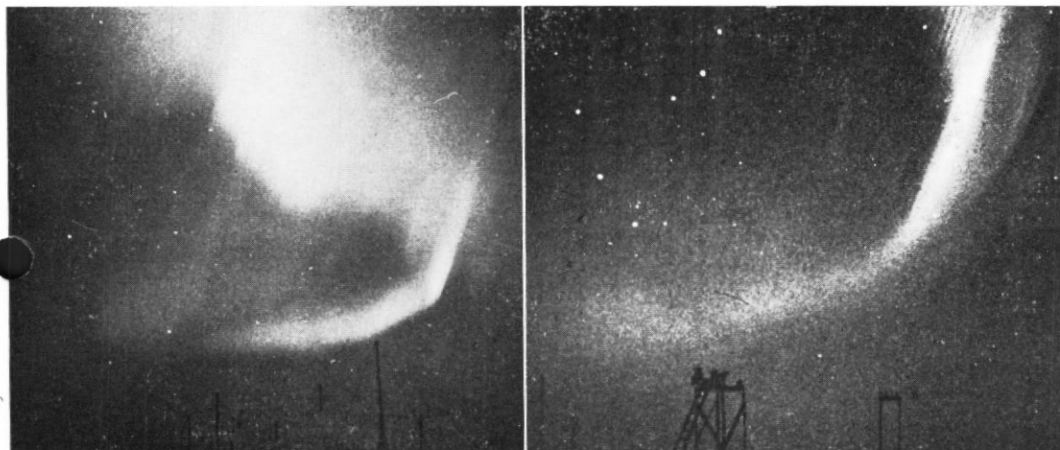
The results to date seem to show that the greater part of the Scotia Sea has been formed over the last 30 m. yr. by the separation of South America and Antarctica along a north-west to south-east line, and before that time the Scotia Ridge was a cusped marginal orogenic belt similar to those along the western margin of the Pacific Ocean. However, many crucial details are still missing and it is hoped that the close survey which will be possible with the new satellite navigation system will provide these during the next few years.

### *Observatory programmes*

The Survey maintains two geophysical observatories situated at Halley Bay on the east coast of the Weddell Sea, and at the Argentine Islands 1,600 km. to the west, off the Antarctic Peninsula.

The programmes at these observatories include continuous observations in meteorology (surface and upper air), including solar radiation and ozone, geomagnetism, aurora, ionospherics and whistlers. In addition, seismological events are recorded at the Argentine Islands.

All the standard observations continued satisfactorily throughout the period. In particular, a very low frequency goniometer receiver system was introduced at Halley Bay to record the amplitude and direction of the arrival of very low frequency emissions. Special periods of observation were also chosen to coincide with the transit of Ariel-3 at Halley Bay and at the



Examples of auroral displays observed at Halley Bay. The all-sky camera can be seen in the foreground of the right-hand photograph. (Photographs by G. Blundell.)

conjugate point. This satellite contained a University of Sheffield very low frequency experiment. The results obtained were remarkable and demonstrated that the site of Halley Bay is particularly favourable for future work.

At the Argentine Islands the standard ionosonde vertical incidence soundings were amplified by special observations to study travelling disturbances. The results of this work have yet to be completed.

In the United Kingdom the reduction of the various observations continued and these were passed to the appropriate World Data Centres as they were completed.

### Glaciology

ICE covers about one-tenth of the Earth's surface and influences the environment in all latitudes. 90 per cent of the world's ice is in the Antarctic, and the changing mass of ice is one of the principal factors controlling mean sea-level off the coasts and seaports of Britain. Scientific interest in the Antarctic ice sheet arises because all branches of Antarctic research are dominated more by the ice environment than by any other factor; because the study of ice sheets offers a means of understanding processes which took place on other continents during former ice ages; and because the Antarctic ice sheet provides a unique area of deposition and preservation of atmospheric precipitation which is almost free from local sources of contamination. These points require a theoretical understanding of the growth and maintenance of continental ice sheets based on adequate measurements of the processes taking place on the Antarctic ice sheet and associated with it. Existing estimates even of the amount of ice are subject to large errors.

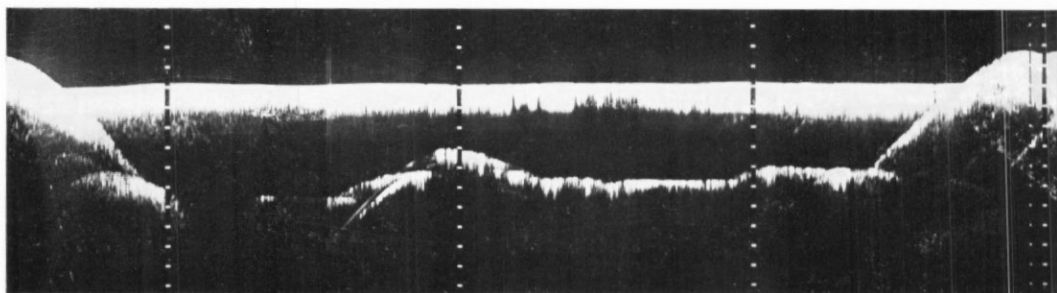
#### *Radio echo-sounding techniques*

It is now possible to measure the thickness of glaciers and ice sheets from an aircraft flying over them. Instruments developed at the Scott Polar Research Institute provide a continuous

record of the ice thickness in the same way that a ship's echo-sounder provides a continuous profile of the sea bed. A pulsed radar operating at a frequency of 35 MHz uses aeriels suspended beneath the wings or tail-plane of large or small aircraft. Echoes from the ice surface and also from the glacier bed are displayed on a cathode-ray tube. A slowly moving photographic film integrates the rapidly changing traces to provide a continuous profile.

The Survey in co-operation with the Scott Polar Research Institute was first, in March 1965, to use continuous recording of ice depth on an Antarctic journey, and also first in Antarctica to operate the system from an aircraft. A year after it was used aboard one of the Survey's Otter aircraft in the Antarctic Peninsula, the equipment was installed in a 4-engined Super Constellation of the U.S. Navy. During December 1967 much was done under a co-operative arrangement between the Scott Polar Research Institute, the Survey and the U.S. National Science Foundation. Some 25,000 km. of radio echo profiling in 94 hr. flying time yielded more ice-depth measurements than the sum total measured by seismic sounding over the last 30 years. A four-man party led by the Director of the Scott Polar Research Institute installed and operated the equipment. Correlation with the aircraft navigation system was provided by a flight recorder which carried air speed, pressure altitude, outside air temperature, heading and terrain clearance traces, and the same time marks and event marks as the radio echo film.

The longer flights were made with the principal purpose of discovering the practical limit of depth penetration for a wide range of ice-temperature conditions. Longitudinal and transverse sections were made of several of the valley glaciers that feed the Ross Ice Shelf, and



Radio-echo record of a flight across Nimrod Glacier. The top surface of the ice is represented by the upper edge of the top white line, and the bottom surface by the upper edge of the bottom white line. The vertical scale marks are 2  $\mu$ sec. apart (equivalent to  $169 \pm 2$  m. of ice); thus towards the left end of the crossing the ice is 900 m. thick. The glacier is 18 km. wide; the record therefore approximates a cross-section with a vertical exaggeration of 2.4 times.

considerable attention was paid to the Ross Ice Shelf itself. On land glaciers, bottom reflections were generally continuous where the ice depth was less than 2,000 m. but intermittent where the depth was greater than this. Much greater depths were recorded in the cold high plateau areas where surface elevations exceed 3,500 m. than in the warmer ice near "Byrd" station. The maximum depth measured was 4,200 m. near "Sovetskaya". Surprisingly strong echoes were observed from layers within the top 2,200 m. of ice. The layers were deeper and more extensive than had previously been reported. Over the greater part of the ice sheet the layers deformed uniformly over the bottom topography, indicating stream-line ice flow. But in some regions of considerable bottom relief the internal echoes suggest a different type of flow with faulting taking place to considerable depths.

On floating glaciers, bottom reflections were much stronger than on land glaciers, and no difficulty was found in making continuous profiles to the greatest ice depth encountered, which was 1,300 m. at the southern extremity of the Ross Ice Shelf. It was also found possible to study the extent of brine penetration in ice shelves, since brine gives total reflection of radio waves at the frequency used.

Equipment performance was up to the standard of the best surface studies by the same system. Observations appear to fit predictions of the absorption of radio waves in ice but there were considerable variations in the reflection coefficient along the profiles. The 4,200 m. ice

depth can best be explained by the presence of a water layer of 1 m. or more beneath the ice to give the maximum reflection coefficient. In this respect it is significant that early in 1968 an American drilling team penetrated the ice sheet at "Byrd" station and found a film of water beneath the ice at a depth of 2,164 m. The radio echo-sounder had, incidentally, been able to predict the depth at which their drill would reach the glacier bed.

The tremendous task of analysing this material has only begun but an automated system of track plotting by computer is being developed to speed the work. Many of the profiles obtained show large mountains, escarpments and valleys beneath the ice. One result is that now for the first time it will be possible to compare landscapes beneath contemporary ice sheets with those in countries that were once glaciated, as for example the British Isles. Another result after more sounding will be a much better estimate of the amount of ice on the Earth than could be obtained by any other method. The Antarctic ice sheet represents 90 per cent of the total volume of ice and its fluctuations are therefore of special significance to mankind.

#### *Ice-shelf investigations*

Two of Antarctica's floating ice shelves are larger than the British Isles and, as shown by radio echo-sounding, from 100 m. to as much as 1,300 m. thick, yet they rise and fall with every tide. A 2-year study of the deformation of the ice shelf at Halley Bay has now been completed. The purpose of the study was to determine the trajectory of snow particles from the time that they fall on the surface to the time, some hundreds of years later, when the same particles finally reach the sea. Field work involved the solution of quite unusual survey problems posed by the complete absence of stationary reference points and the significant deformation of the ice mass even during the relatively short periods in which measurements were being made. While this work has determined the trajectory of particles in a horizontal plane, other experiments are in progress to establish the trajectory in a vertical plane.

#### *Pack-ice distribution and ice navigation*

Throughout the summer season the Survey received regular photographs of the whole of British Antarctic Territory as seen from the American satellite ESSA-3. With an orbital period of 115 min., ESSA-3 covered every point on the Earth's surface at least once a day. In the long term the photographs will be of immense significance in climatology, since distinct cloud patterns continually reveal weather systems that cannot be identified from observations coming only from the sparse network of meteorological stations in Antarctica. But our immediate purpose was to observe the distribution of pack ice to facilitate the passage of the Survey's ships to its stations. After examining the photographs in London, radio reports were prepared describing the route that appeared least likely to encounter heavy concentrations of ice. When *Perla Dan* was brought to a standstill by ice she was advised as to the best escape route, along which she was able to proceed without further incident. Interpretations of the photographs tallied closely with actual conditions in the Weddell Sea as reported by the ships. The captain of R.R.S. *John Biscoe* wrote afterwards of the "enormous help" that was afforded by the satellite reports. Since ice conditions, like weather conditions, vary from year to year, there is no doubt of the value of the assembled photographs as a permanent record of the range of variation. This is particularly important in our case as no other organization in Europe receives satellite photographs covering the Antarctic Peninsula area.

Another quite unexpected use of satellite photography has been in plotting the seaward boundary of the Larsen Ice Shelf. The Directorate of Overseas Surveys was able to map the ice front more accurately than was possible from the available terrestrial survey data.



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\* Resigned during the year.

### Antarctic Personnel

Since the period covered by this report includes the summer season and consequently the relief of Antarctic stations, the personnel listed below include summer visitors and those wintering at stations during both calendar years.

#### Field Scientists

##### Visiting scientists (summer)

*Signy Island:* Dr. M. J. G. Chambers, Dr. W. Hermosilla. *South Georgia:* Dr. C. M. Clapperton, Mrs. D. Greene, Dr. S. W. Greene, D. W. H. Walton.

##### Botanists

*Signy Island:* J. H. Baker, J. A. Edwards.

##### Zoologists

*Signy Island:* J. R. Beck, D. G. Bone, P. K. Bregazzi, J. W. H. Conroy, R. N. Smith, V. W. Spaul, M. G. White.

##### Medical officers and human physiologists

*Stonington Island:* Dr. M. J. Holmes, Dr. R. A. Williams. *Signy Island:* Dr. J. A. Ball, Dr. E. R. Hillier.<sup>†</sup>  
*Halley Bay:* Dr. J. R. Brotherhood, M. Burgin, A. J. Fry, Dr. A. M. Roberts.

##### Veterinary officer

A. R. M. Bellars.

##### Surveyors

*Stonington Island:* R. A. Boulding, H. M. Fielding, D. Postlethwaite, P. Wainwright. *Halley Bay:* A. Johnston, M. M. Samuel.

##### Geologists

*Stonington Island:* C. G. Smith, L. E. Willey. *Signy Island:* P. J. Rowe. *Adelaide Island:* M. H. Elliott. *Halley Bay:* D. Brook, P. D. Clarkson, M. K. Skidmore.

##### Field geophysicist

*Stonington Island:* I. F. Smith.

##### Glaciologists

*Halley Bay:* P. H. Coslett, R. H. Thomas, A. C. Wager.

##### Physicists and ionosphericists

*Argentine Islands:* J. R. Dudeney,<sup>†</sup> B. G. Gardiner, B. D. Gilbert, C. J. S. Jefferies, R. I. Kressman, P. C. Mitchell, P. D. Morgan. *Halley Bay:* J. A. Chalmers, D. C. Groom, J. H. Jamieson, W. R. Laidlaw, G. McWilliam, P. T. Pitts.

##### Meteorologists

*Deception Island:* P. G. H. Myers,<sup>†</sup> S. M. Norman. *Argentine Islands:* P. J. Cotterill, R. S. Hesbrook, L. N. Philp, I. S. Tyson. *Signy Island:* D. W. Brown,<sup>†</sup> S. P. Finigan, L. A. Graves, L. U. Mole, W. Taylor. *Adelaide Island:* J. Barlow, R. B. Ledingham, D. F. Salter, E. B. Sheldon, F. W. A. Wilkinson, I. M. Willey. *Fossil Bluff:* R. B. Ledingham,<sup>†</sup> M. J. Bramwell. *Halley Bay:* M. J. Durrant, D. E. French, P. S. Mountford, F. C. E. Platt, C. M. Read, A. R. Williams, C. M. Wornham.

### Winter Support Personnel

*Deception Island:* J. R. Ayers, N. O. S. McLaren, D. J. McLoughlin, R. V. M. Perren, G. D. Seear, R. P. Vere. *Stonington Island:* A. J. Collings, W. M. Dawson, J. T. Donaldson, K. C. Doyle, R. England, D. Horley, W. A. Keith, A. H. McArthur,<sup>†</sup> G. K. McLeod, E. C. Madders, J. R. B. Noble, S. M. Norman, I. A. Sykes.

*Argentine Islands:* D. J. Biggadike, D. N. Bravington, P. R. S. Burns, R. W. Davidson, R. R. Diamond, A. Feenan, G. M. Jones, K. J. Portwine, B. Swift.<sup>†</sup>

*Signy Island:* D. N. Bravington, R. E. Liddall, A. Losh, S. A. O'Shanohun, G. Pearce, D. A. Spencer, H. Taylor.

*Adelaide Island:* J. D. G. Beard, A. Bottomley,<sup>†</sup> D. Bowen, A. J. Collings, D. W. Darroch, B. Gibson, A. D. McKeith, F. G. Meeds, D. S. Parnell,<sup>†</sup> D. J. D. Y. Rinning.

*Fossil Bluff:* J. R. Ayers, J. C. Walsh.

<sup>†</sup> Base commander.

*Halley Bay:* A. Baker, M. Baring-Gould, D. C. Blossom, J. F. Carter, E. J. Chinn,<sup>†</sup> R. H. Docchar, W. A. Etchells, N. J. Fothergill, K. J. Gainey, J. M. Gallsworthy, C. J. Gostick, K. W. Halliday, D. J. Hill, C. McM. Hodson, C. L. Jones, G. McKerrow, D. S. MacLennan, A. S. MacQuarrie, N. Mathys, P. H. Noble, J. F. Porter, N. W. Riley, L. J. Shirtcliffe, A. Smith, G. Smith, C. C. R. Sykes,<sup>†</sup> P. Wharton, T. H. Wiggans, A. B. Wilson.

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T. Woodfield (captain), M. Phelps, S. Culshaw, R. MacKean, C. Elliott (officers), H. Ward, W. Hibbert, H. Manison (engineers), H. M. O'Gorman (radio officer), G. Lewis (electrician), G. Cutland (chief steward).

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D. H. Turnbull (captain), M. J. Cole, E. P. J. Genochio, B. Bromby (officers), J. Richardson, J. F. Glover, I. Curphey (engineers), A. Little (radio officer), D. Borthwick (electrician), M. Siddy (chief steward).

<sup>†</sup> Base commander.