BRITISH ANTARCTIC SURVEY

ANNUAL REPORT, 1968–69

Antarctic Activities

THE annual relief of the Survey's Antarctic stations was carried out, more or less according to plan, in spite of renewed volcanic activity at Deception Island in February 1969 and sterngland trouble on R.R.S. *John Biscoe* which necessitated the ship going into dry dock at Montevideo early in the season.

R.R.S. *John Biscoe* and R.R.S. *Shackleton* sailed from Southampton in October 1968. *Shackleton* and H.M.S. *Endurance* arrived at Deception Island at the beginning of December, the station having remained closed throughout the 1968 winter following the volcanic eruptions of December 1967. All seemed to be quiet so the station was re-opened as a summer air facility, and a naval party made a new hydrographic survey around the ash island which had formed in Telefon Bay during the 1967 eruption. Also at this time, a joint Royal Society–British Antarctic Survey party of volcanologists began a 5-week study of the eruption area.

On 10 December, the Survey's new twin-engined Otter aircraft flew south to relieve the Fossil Bluff station, but encountered unexpectedly bad weather and as it was running out of fuel made a forced landing on the Larsen Ice Shelf. After four abortive attempts, two Whirlwind Mk. IX helicopters from H.M.S. *Endurance* managed to fly fuel over the 5,000 ft. [1,525 m.] Antarctic Peninsula plateau to the aircraft, which was then able to return to Adelaide Island. Fossil Bluff was evacuated shortly afterwards. A single-engined Otter aircraft, which had been left crated at South Georgia when Deception Island erupted in 1967, was assembled and flown south to Adelaide Island at the end of January 1969.

M.V. *Perla Dan* was again chartered for the relief of Halley Bay and arrived there on 23 January, having used information from satellite photographs to navigate through the ice of the Weddell Sea. In the next 7 days the ship was able to unload her cargo at a point on the ice shelf only 5 km. from the station, although she had to re-berth several times because the sea ice was breaking up.

Meanwhile, the party at Deception Island found that intermittent tremors were occurring, and during February these increased in frequency and severity. Arrangements were therefore made to evacuate all personnel as soon as possible, but on 21 February, before *Shackleton* could arrive, an eruption of gases occurred—apparently near the unoccupied Chilean station at Pendulum Cove. This was followed by ash, scoriae and mud flows, which destroyed the old hut at the British station and half-filled the new one and the diesel-engine shed. The remains of the old whaling station, two old tractors, the whalers' cemetery and the jetty were also destroyed. The hangar, however, was undamaged except for broken roof-lights. As soon as the eruption started, the Master of *Shackleton* asked the Captain of the Chilean vessel *Piloto Pardo*, which was in the area, if he could pick up the men, and eventually two helicopters from *Piloto Pardo* arrived through the pall of ash and wet snow. Landing back on the ship was extremely difficult, not only because the helicopter domes were completely obscured by ash and snow but also because there was a 30 kt. [15·5 m./sec.] wind and heavy seas. In the words of the Master of *Shackleton:* "The evacuation was a superb example of skilful seamanship and flying carried out in appalling conditions."

The Survey is also greatly indebted to the Argentine Government and Navy for their splendid assistance in an emergency. In mid-August 1968 they succeeded in evacuating a sick man from the Argentine Islands, by helicopter from the Argentine icebreaker *San Martin*, and took him to hospital in Buenos Aires. They had made an earlier attempt to fly him out in a Beaver aircraft but conditions were so difficult that it crashed on take-off, fortunately without injury to the men.

A joint British–American project, in which British surveyors and geologists were transported to the Shackleton Range by a U.S. Navy C130 aircraft, was successfully carried out in the 1968–69 summer. The surveyors were able to establish ground control for existing American

The coastal mountains of northern Marguerite Bay photographed from one of H.M.S. *Endurance*'s helicopters during the rescue flight to the Larsen Ice Shelf. (Admiralty photograph; Crown copyright.)

air photography, in spite of the fact that one of them broke a leg while ski-ing. The Shackleton Range, which lies about 500 km. south of Halley Bay, had been discovered by Sir Vivian Fuchs' Trans-Antarctic Expedition, 1955–58, and visited during their journey to the South Pole. A tractor party also travelled to the area from Halley Bay, a total overland distance of 800 km., to provide support for the air party, if necessary.

During the year, the Natural Environment Research Council decided to replace R.R.S. *Shackleton* with a new ship to be built at Leith at a cost of about £1·75 million. The overall length will be 327 ft. [99·6 m.], the beam 60 ft. [18·3 m.], the draft 21 ft. [6·4 m.], and the cargo capacity 1,800 tons. Two diesel-electric engines will provide 5,000 s.h.p. to a single variable-pitch propeller. Her endurance will be 50 days at full speed, with an economic service speed of about 14 kt. The hull will be all-welded plating of special steel, 1 in. [2·5 cm.] or more thick, and the stem will be cut-away to enable her to ride up on the ice and break it with her own weight. Other features will be an enclosed crow's nest provided with full controls, and a helicopter deck. There will be accommodation on board for 62 expedition personnel and 36 officers and crew. Although primarily designed to carry personnel and cargo, a gravimeter room, a large laboratory and a hydrographic davit have been incorporated for oceanographic and biological research. The cargo-handling gear has been designed for rapid discharge at exposed anchorages. The ship is expected to be ready for service in the Antarctic in the 1970–71 season.

It was also decided that the Survey should re-open a station on South Georgia in the 1969–70 season, replacing the present Government Administration at King Edward Point and taking over some of the existing buildings. The buildings were therefore inspected and some modifications were carried out.

The British Antarctic Survey's station at King Edward Point, South Georgia, with "Shackleton House" in the background.

The stations' radio modernization programme proceeded with the installation of Racal communication equipment and associated Creed teleprinters at Adelaide Island. This equipment had already been installed at the Argentine Islands and Halley Bay.

W. O. Sloman and M. R. Sumner of the Survey's London Office visited the Antarctic stations during the 1968–69 summer and supervised the relief operations. They were accompanied by Professor Lester King of the Geology Department, University of Natal. P. I. Whiteman, also of the London Office, visited the American Antarctic stations as British observer.

Sir Vivian Fuchs and Dr. R. J. Adie represented the United Kingdom at the tenth meeting of SCAR held in Tokyo.

A reception was held in London on Mid-Winter's Day, 21 June, to celebrate the twenty-fifth anniversary of the Survey and the centenary of Captain Scott's birth.

BIOLOGICAL SCIENCES

THE highlight of the year was the second Symposium on Antarctic Ecology, sponsored by the Scientific Committee on Antarctic Research (SCAR) and the International Union of Biological Sciences (IUBS) in collaboration with SCIBP, and held at the Scott Polar Research Institute, Cambridge, during 29 July–3 August 1968. The Symposium was ably organized by the Secretary of the SCAR Working Group on Biology, Dr. M. W. Holdgate, former Senior Biologist of the Survey. There were 101 contributions to the Symposium and of these Survey personnel contributed 14 papers; a further eight papers were contributed by former Survey members and biologists associated with the current activities of the Survey. It is anticipated that the Symposium proceedings will be published as a companion volume to *Biologie Antarctique*, the proceedings of the first Symposium.

For some years now the Survey has actively encouraged summer field work on South Georgia; thus far these activities have been mainly limited to botany, glaciology and geology. However,

with the impending acquisition of the existing buildings at King Edward Point, it will be possible in the future to extend the Survey's scope of research work into various aspects of marine zoology and also introduce year-round botanical and zoological programmes which require overwintering personnel. There has been intensive biological activity at Signy Island for a number of years, and the development of biological work at South Georgia should serve as a basis for many valuable comparative studies.

Botany

FOUR field programmes were undertaken during the year: two representing a development of previous work and two new projects. During the same period, five botanists were writing up the results of field work: three at Birmingham, one at Aberdeen and one at University College London. Work was also continued on some laboratory programmes at Birmingham. As in the past, members of staff of a number of British universities have helped in various ways, while two departments in particular, the Departments of Botany, University of Aberdeen and Westfield College, University of London, have been especially helpful.

An important event at the beginning of the year was the SCAR Symposium on Antarctic Ecology. As well as helping with the organization, four members of the Section contributed papers, four being short articles giving the results of their research, while one was a long review article. Following the conference, Dr. G. A. Llano, Program Director, Antarctic Biology, National Science Foundation, paid a brief visit to the Section.

Floristic and ecological surveys

An investigation was undertaken on Deception Island into the effects of the 1967 eruption on the island's vegetation. Examination of the two eruption centres, the new island and the land centre, showed the former was bare of macroscopic plant life but around the fumaroles of the land centre colonization of new surfaces had already taken place by a species of the Funariaceae not previously known from the Antarctic. This species was observed to be fruiting extensively and, as a result of the high temperatures and humidity, was spreading rapidly by protonemata. Elsewhere, much of the existing vegetation was buried under ash or washed away by mud flows, and it appears that the sites of the two native phanerogams and the alien grass, *Poa annua*, have been obliterated. Wherever the ash depth was 6 cm. or less, recovery by many species of bryophyte appeared to be possible provided regenerative shoots did not dry out as a result of exposure following re-distribution of the ash. Sample plots, in representative areas, were marked out for future assessment of long-term changes.

Recent records of the distribution of native and alien vascular plants on South Georgia, on the basis of their occurrence in each 5 km. square of the South Georgian grid, have been analysed. It was found that vascular plants are known from 76 out of the 234 squares with land, i.e. from 32 per cent, but that only two squares, one in Stromness Bay and one in Cumberland Bay, have over 30 species recorded out of a possible maximum of 32. Recent records of the distribution of transient aliens have yet to be analysed.

A comprehensive account of an ecological survey of Signy Island has been completed, so that a detailed description is now available of the island's plant communities. In addition, dynamic aspects of the vegetation including colonization, development of communities, and the relationship between pattern and micro-topography have been taken into account.

In an attempt to eliminate the subjectivity involved in any classification of vegetation which is based mainly on an inspection of field data, a normal association analysis was carried out to test the Signy Island results. This analysis gave hierarchical divisions into groups with the strongest associations among the species, the majority of which were found to correspond very closely to those recognized by the inspection method, particularly at the sub-formation and association levels. In collaboration with M. D. Swaine of the School of Plant Biology, University College of North Wales, Bangor, the stands within the main groupings produced by the association analysis, are being ordinated using a principal-components analysis. This should reveal any compositional relationships within each group and should allow a closer correlation with the environmental data than has been possible so far. A second statistical approach, based on tests of homogeneity within successive pairs of stands is being attempted by Dr. A. V. Hall

of the Department of Botany, University of Cape Town, and this should provide a valuable comparison with the results obtained by other methods. A range of soil samples has been analysed by Mr. S. E. Allen and Mr. H. M. Grimshaw of the Merlewood Research Station of the Nature Conservancy.

An introductory account of the vegetation of the South Shetland Islands has also been completed and this has provided two noteworthy contrasts with Signy Island and other parts of the maritime Antarctic. In the first place, optimal development of vegetation appears to be confined to the south or south-east shores of the islands, a result interpreted as being due to the high frequency of gales from the north and north-west, while the virtual absence of the deep *Polytrichum–Dicranum* turves, which produce the extensive peat banks on Signy Island, is also striking. Extensive swards of *Deschampsia antarctica* have been reported from Point Thomas, Admiralty Bay, and a spectacular development of the *Usnea fasciata–Himantormia lugubris* sociation from the raised beach succession at Harmony Cove, Nelson Island.

Plant productivity

Phase I of the Bipolar Botanical Project, which included studies on plant-growth rates and tes of primary production on South Georgia during 1967–68, continued with the processing d evaluation of the materials and data collected during the season's field work. The primary evaluation of the growth-rate results, obtained with seedlings and/or tillers of native and alien crop species, has now been completed. To make this aspect of the programme less time consuming during phase II, a leaf-area meter has been built and successfully tested.

The processing of about 70 area samples (each 25 $cm.^2$), half taken at the beginning and half at the end of season from a well-developed stand of the native *Festuca* grass heath, has been completed and a further 20–25 samples have been analysed by a sub-sampling method. It is hoped that a statistical assessment of the resulting data, being undertaken with Dr. M. C. Lewis of the Department of Biology, University of York, and Dr. A. J. Gore of the Tundra Study Group at the Nature Conservancy's Merlewood Research Station, will yield a satisfactory sampling method for the assessment of short- and long-term changes in this type of community.

Progress can also be reported with the evaluation of the performance of individual species in the South Georgian grassland communities, but many of the results are provisional and will be extended during the field work of phase II.

In order to provide comparative data from an Antarctic locality, growth rates are being determined at a number of sites on Signy Island using seedlings of the same crop species tested on South Georgia. Similar tests are being conducted with seedlings of the island's two native vascular species, *Deschampsia antarctica* and *Colobanthus quitensis* (= *C. crassifolius*), while attempts are also being made to measure their production *in situ* at a number of sites. A range of associated observations and measurements includes vegetative performance in different plant communities, the tolerance of both species to salt water and the effects of artificial environments such as non-limiting media and heated soil. Transplant techniques are also oving valuable.

The search for suitable methods of assessing bryophyte productivity continued, and in a field programme on Signy Island a range of species was examined to see if innate markers could be used to determine annual rates of production. Many species were found to have characteristic growth patterns which appear suitable, i.e. regularity in branching, rhizoidal banding and a succession of horizons of dead apices, but some ecologically important species such as *Chorisodontium aciphyllum* proved recalcitrant in this respect. The use of artificial markers has been tried with species of the latter type and some of the results appear promising. Laboratory experiments on various aspects of growth patterns in bryophytes have also been undertaken.

Micro-climatology

Satisfactory progress has been made with the processing of micro-climate data collected as part of the Bipolar Botanical Project on South Georgia. With the help of members of the Survey's Geophysics Section, these data have now been transferred to magnetic tape and the primary computations have been completed. A full evaluation of the results has still to be made.

An analysis of temperature records covering 12–15 months obtained at plant level in *Polytrichum* turves on Signy and Galindez Islands was completed and has provided comparisons of between-site temperature conditions, as well as plant performance within sites. For example, the temperature regime on Signy Island was found to have been warmer between January and March 1965 than over the same period in the following year. Not only was antheridial development of *Polytrichum alpestre* considerably more successful in 1965 than in 1966, but archegonial development and dehiscence in both *P. alpestre* and *P. alpinum* were advanced by several weeks during the warmer summer. In another study, a comparison was made of conditions within a turf and a carpet community, where differences in moisture content and extent of snow cover were taken into account.

The study of micro-climate at plant level on Signy Island has been extended to include temperature at various levels (above, within and below vegetation), total incoming solar radiation, precipitation and levels of saturation deficits. Long-term measurements are being made at a study site in Factory Cove and similar short-term measurements are being made at various other sites to provide an assessment of variability at plant level.

Bryophyte reproduction

The study of reproductive behaviour in species of *Polytrichum* and *Psilopilum* at various Antarctic sites has been completed. Life-cycle characteristics have been determined for the four species of *Polytrichum* and *Psilopilum antarcticum* on South Georgia, where all five species were found to produce sporophytes freely in the sheltered north-east coastal lowlands. The results suggest, however, that the frequency of sporophytes may decline at high altitudes and in exposed lowland parts of the island. Farther south, *Polytrichum alpinum* and *P. alpestre* are still the only members of the Polytrichaceae known to produce capsules and, since the number of records is few with many of the capsules being small or mis-shapen, it was concluded that it is unlikely that viable spores are often produced.

A study of the reproductive behaviour of *Pohlia nutans* and *P. cruda* from South Georgia has been completed and the results have been compared with a similar analysis of material of the same species from Disko Island (West Greenland) and the United Kingdom. Significant differences in the speed of maturation of both sporophytes and gametophytes were noted, differences which are now being studied under controlled environmental conditions.

A study of reproductive behaviour in *Conostomum pentastichum*, a widespread South Georgian species, has begun with a view to comparing its performance with that of *Polytrichum* and *Pohlia*.

Taxonomy

Work on the Antarctic lichen flora saw the completion of a revision of all material of the genera *Buellia* and *Rinodina*. Studies begun on several new genera have resulted in the first records of species of *Peltigera* from south of the Falkland Islands, three now being known from South Georgia with two of them extending in distribution as far south as the Argentine Islands while the presence of *Stereocaulon ramulosum* on South Georgia, a species known previously from northern Chile and Argentina, was also revealed. Of particular interest was the first collection of lichens from the Theron Mountains, *Omphalodiscus antarcticus* and *O. decussatus* being noteworthy records.

Bryophyte taxonomic studies have been concentrated on the South Georgian flora and a good start has been made on the identification of new material from the island. Some notable additions have been *Holodontium inerme*, *Catagonium politum* and *Campylopus introflexus*, all genera new to South Georgia, while a number of species has been added to existing genera, e.g. *Andreaea* and *Conostomum*. Nomenclatural changes resulting from these studies include the reduction of a number of taxa to synonymy, e.g. *Messia austrogeorgica* to *Philonotis acicularis*.

From farther south, several additions have been made to the Antarctic moss flora, e.g. *Conostomum perangulatum* from Signy Island. The completion of the study of a collection of hepatics from the South Sandwich Islands, undertaken by Dr. R. Grolle, Sektion Biologie, Friedrich-Schiller-Universität, Jena, has revealed the presence of 11 species new to these islands. Several new bryophyte collections have been received and await study.

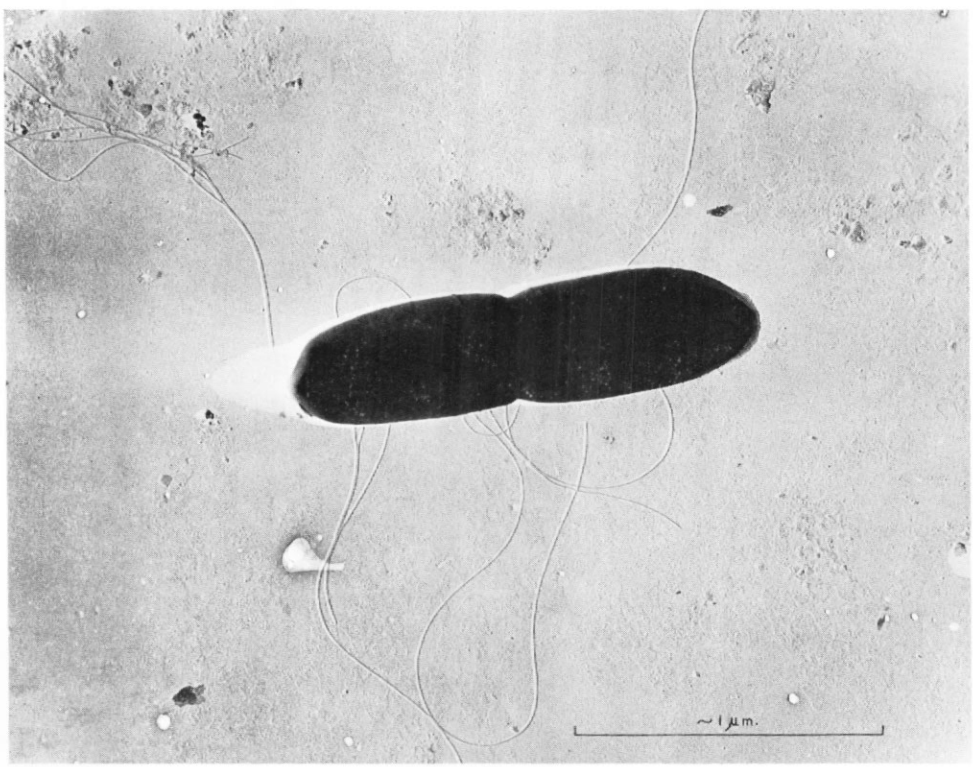
An investigation into the interrelationships of the species of *Acaena* on South Georgia involving an analysis of various morphological and physical characteristics, as well as chromosome complements, the latter in collaboration with Dr. D. M. Moore of the Department of Botany, University of Reading, has resulted in the recognition of naturally occurring hybridization and provided greatly improved descriptions of variation in the taxa. It seems that South Georgian populations of *A. decumbens* (= *A. magellanica* = *A. adscendens*) have $2n = 42$, as on other sub-Antarctic islands, but in contrast to the situation in Tierra del Fuego where only $2n = 84$ is known. The frequent occurrence of dioecious rather than hermaphrodite capitula in South Georgian material was also noted. Comparison of the South Georgian populations with other taxa in South America and elsewhere has involved the relegation of some species to synonymy but the status of others, e.g. *A. tenera*, has been vindicated.

Microbiology

The study of a collection of micro-organisms comprising bacteria, yeasts and filamentous fungi obtained from acid peat developed under many of the plant communities on Signy Island was begun at the Department of Botany and Microbiology, University College London.

Since no freeze-drying equipment was available on Signy Island, the bacteria were transported the United Kingdom on nutrient agar slopes and in frozen aqueous suspensions. Consequently, the major part of the year's work has been devoted to their preservation by lycophilization. A start has been made on their identification, the majority proving to be Gram positive rods. Electron micrographs are being used to determine their flagella patterns.

Work on the yeasts, none of which have yet formed ascospores, has shown that a large number of cultures is psychrophilic, one having a maximum growth temperature below 20° C.



An electron photomicrograph of a bacterium, *Bacillus* sp., which is typical of the micro-flora of a Signy Island peat. The long thin flagellae which propel the organism are clearly visible.

Some have been identified and one appears to belong to a new species, if not a new genus, and has the surprising property of a light-inducible tangerine-coloured pigment which appears to be a carotenoid.

Little work has, so far, been carried out on the moulds but one of them appears to be an obligately psychrophilic species of *Mucor*, a genus not previously known from Signy Island.

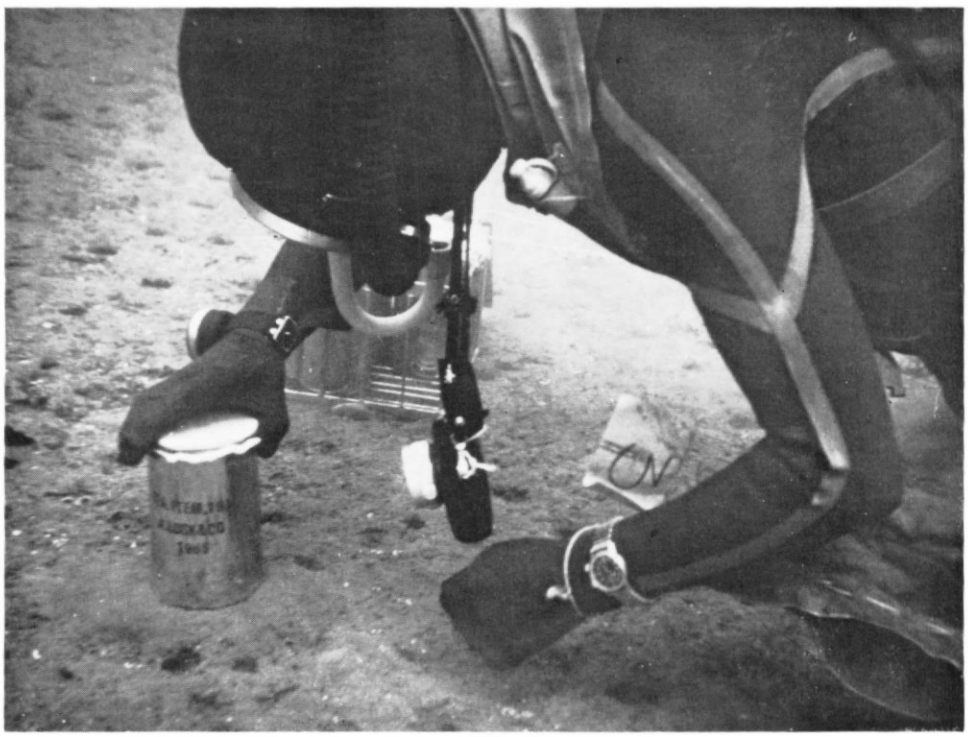
Zoology

Marine ecology

At Signy Island, a study commenced of the polychaetous annelids of inshore waters, particularly the sedentary species *Scoloplos marginatus*. At the same time as sea-bottom cores are taken for distributional and population-density studies, plankton samples are obtained from the water above to elucidate their larval development and food source.

The field work of studying the biological rhythms and life histories of selected sand-dwelling amphipods was completed. Monthly collections of the common inshore amphipod *Bovallia gigantea* were continued at Signy Island during studies of this animal's general biology. Laboratory experiments were also carried out to clarify aspects of the breeding biology and to investigate its respiration rate at different temperatures. Oxygen consumption was found to bear a linear relationship to temperature over the range covered (−1·8° to +3·2° C). Samples of other benthic invertebrates and the stomach contents of certain fish were collected for trophic relationship studies.

As in the past, considerable use was made of Scuba-diving techniques by the marine biologists at Signy Island. This method of study has, in fact, led to the development of a number of sampling devices aimed at producing quantitative estimates of the benthic fauna. This formed the subject of a paper read at the Underwater Association Symposium held in March 1969.



A Scuba diver taking cores in sand. The depressions indicate the positions of the large lamellibranch, *Laternula elliptica*.

The investigation of the role of Isopoda, particularly *Glyptonotus antarcticus*, in the biocoenoses of the epibenthos from material collected at Signy Island, was continued at Monks Wood. 25 specimens of *Serolis ovata* were isolated from some benthos samples and this new material enabled a more comprehensive description of the species.

Fish research

Work on the population dynamics of *Notothenia neglecta* was completed and the results presented in the form of biomass and annual production measurements, and also as an energy budget. The species was shown to have a slow growth rate, which, coupled with the effects of cold adaptation, indicates that only a low percentage of the energy intake is being channelled into production. Even though spawning occurs annually in *Notothenia neglecta*, after the fish reach sexual maturity, the formation of eggs takes 2 years, a phenomenon probably associated with the large size of the eggs when spawned.

Having fully evaluated the results of the initial studies of respiration in some Antarctic fish species, more detailed investigations were initiated. During the 1968–69 summer, experiments were carried out on a large number of individuals of *Chaenocephalus aceratus*. Results indicate that, in contrast to the red-blooded *Notothenia gibberifrons*, the chaenichthyid utilizes a low-pressure large-volume system for both the respiratory water current and the blood circulation. Work began on the accurate experimental determination of the total blood volume of chaenichthyids. A study of the autecology of *C. aceratus* was also initiated and this has been facilitated by the ease and frequency with which they can now be caught.

Research on the biochemistry of fish blood was continued, with results tending to confirm that fish avoid freezing by avoiding contact with ice. Detailed biochemical analyses of blood samples were initiated at the Department of Chemistry, Loughborough University of Technology.

Seal biology

A further collection of jaws, genitalia and alimentary tracts was made from 332 seals, predominantly crabeater, which were killed for dog food. The analysis of material collected previously began at the Department of Anatomy, University of Cambridge. Tagging of Weddell seal pups and adults continued at Signy Island, and observations on the breeding biology and behaviour of this species were also made.

Terrestrial ecology

Two important terrestrial groups were studied at Signy Island during the year. The ecological investigation of nematodes at various contrasting sites was continued. Regular sampling showed a general decline in numbers during winter and at one site where there were bryophytes this was accompanied by an increase in the percentage abundance in the lower layers of the soil. 27 species of free-living nematode have so far been identified, microbial feeders being the most abundant.

A taxonomic survey was carried out as the first step in a 2 year study of the terrestrial protozoa of Signy Island. 95 samples covering a variety of soil types were examined and 141 species of flagellates, Amoebae, testates and ciliates were identified. Species composition and numerical abundance were found to vary considerably between different soils. Work also began on a similar protozoan survey at South Georgia. A result of considerable biogeographical interest is the almost total absence from Signy Island of two protozoan genera, commonly regarded as cosmopolitan and which occur frequently in the soils of South Georgia.

The analysis of data and material collected during an earlier study of arthropod ecology at Signy Island continued at Monks Wood. Culturing of the collembolan *Cryptopygus antarcticus* and other terrestrial arthropods was also continued with a view to determining their respiration rates. To this end, preliminary work has been carried out on the techniques of cartesian diver respirometry using apparatus at the University of Leicester.

Ornithology

Field work at Signy Island was mainly concentrated on the breeding, migration and population dynamics of giant and Wilson's petrels. Parallel observations on both species were

also made at Adelaide Island for comparative purposes. Less detailed ornithological work was carried out at Stonington Island and observations were made at a number of the small islands in Marguerite Bay during the relief of the southern stations. During the combined Royal Society–British Antarctic Survey expedition to Deception Island, a survey was made of the effects of the 1967 eruption on breeding success in bird colonies on the island. Although considerable quantities of ash had been deposited on some chinstrap penguin rookeries, numbers of chicks appeared to be near normal and there was no evidence that the colonies had decreased in size. Cape pigeons on Cathedral Crags seemed equally unaffected by ash build-up on their nesting ledges.

Collection of life-cycle information and ringing-recovery work on selected species was maintained at several of the Survey's stations. At Signy Island, specimens of penguins were collected for anatomical study by specialists in the United Kingdom and a representative collection of bird parasites was made.

In the United Kingdom, accounts of some aspects of the ecology of the cape pigeon, the breeding biology of the black-bellied storm petrel and the embryology of pygoscelid penguins have been completed. Further work on the biology of snow and Wilson's petrels is currently being prepared for publication. The extensive work on petrels in the past few years has revealed that many of the differences between species in their breeding ecology can be related to differences in size and also to vulnerability of nests to snow blockage. As a result of these general studies, several physiological problems suitable for future detailed investigation have now been identified.

Joint Botany/Zoology Project

Limnology

A study of the cyclic activities of *Pseudoboeckella silvestri* (Copepoda, Calanoida) in the pools and lakes of Signy Island was completed. The species is tolerant of a wide range of salinities and

A Wilson's petrel feeding on the sea surface.

of low oxygen concentrations. Pool populations can withstand high and rapidly fluctuating temperatures, and they have an accelerated, univoltine life cycle. Availability and perhaps type of food appear to be the main factors affecting the continuous multivoltine lake populations, controlling maturation rates, longevity, body size and fecundity.

Analysis of field data and material collected during 1963–64 was continued in a comprehensive study on the systematics and ecology of benthic algae being carried out in collaboration with the Freshwater Biological Association.

Field testing of equipment and techniques for a study of primary productivity on Signy Island was successfully concluded at Loch nan Eun in the Cairngorms.

Veterinary Investigations

DURING this period the results gained by the Veterinary Officer, A. R. M. Bellars, in 1967–68 were collated, amalgamated with those obtained by M. F. Godsal in 1963–64, and published in the *British Antarctic Survey Bulletin* under the headings: a survey of the causes of death, osteoarthritis and hereditary disease in the British Antarctic Survey sledge dogs. Useful information continued to come in from the Survey's stations, concerning the deaths and births of the dogs, and in return the stations received advice on many veterinary problems. A more decisive policy regarding the dogs, their breeding and their use was implemented at the stations. It was decided that new breeding stock should be introduced from Greenland in the 1969–70 season.

The Survey's Veterinary Officer gave a lecture to the British Veterinary Radiological Association on the interesting problem of work-induced osteoarthritis in sledge dogs.

Medicine and Human Physiology

DURING the past year, Medical Officers have continued to carry out field experiments in the Antarctic and to follow up this work with laboratory experiments in the United Kingdom.

The increase of urine excretion which occurs in the cold (cold diuresis) was studied at Signy Island, and these investigations have now been followed by experiments in the cold chamber at Hampstead. These were concerned with the relationship between cold diuresis and dehydration. The results obtained indicate that being deprived of water diminishes but does not necessarily abolish the response.

The nutritional study carried out at Halley Bay has now reached the stage at which the serum samples are being analysed at Guy's Hospital. The object of the experiment was to discover the effect of the removal of sucrose from the diet on the level of blood fats and the metabolism of glucose. The sucrose was replaced by glucose and cyclamate. The results obtained so far show that there is an increased ability to absorb large amounts of glucose while living on the sucrose-free diet. The effect on the level of blood fats is not yet known but results from the control subjects, who were eating a normal diet, are similar to those found in previous studies.

Measurements of energy expenditure during normal daily tasks at Signy Island and Halley Bay have revealed that activities which involve walking on snow require about twice as much energy as is needed to do the same task without walking on snow. Also, in the Antarctic there is a greater energy requirement during light activities such as sitting or standing. This is thought to be the result of exposure to the colder environment.

The high-energy cost of sledging has also been studied at Halley Bay. It is already known that cold and hard work cause ketones to be excreted in the urine, and under sledging conditions they were found repeatedly. However, there was no evidence of any decrease in the quantity excreted even after months of sledging, which might have been expected had acclimatization occurred. It was also found that the amount of ketones in the urine was unaffected by the amount of fat in the diet.

In a further study now in progress at Halley Bay, the possible effects of prolonged exercise on temperature regulation are being examined. If, as expected, sledging results in a raised body temperature, for long periods there will probably be some heat acclimatization, and this in turn may affect the level of cold acclimatization. Both aspects are being investigated.

There are now two projects in progress concerning cold acclimatization. The farthest advanced of these, a study of divers at Signy Island, is at the stage of urine samples being

analysed in the laboratory. Divers in wet suits are severely cold stressed and low levels of body temperature have been recorded during the half-hour period after leaving the water. The urinary excretion of the two biological catecholamines, adrenaline and noradrenaline, is a useful indication of the response to cold. Both are excreted in increased amounts during exposure and, if acclimatization occurs, it is expected that the relative amounts of catecholamine excreted will change, so that there would be more noradrenaline than adrenaline in the urine. A project is now being planned for Halley Bay, where cold acclimatization will be studied in terms of the turnover of thyroid hormones in the blood and their relationships to urinary catecholamines.

The experiments in virology and bacteriology carried out at Stonington Island are being continued. The transport of live viruses was successful and members of the station were infected with a mild coxsackie virus and, later, with an influenza-type virus. This is an important technical achievement and has permitted, for the first time, examination of the response to infection uncomplicated by the many simultaneous contacts which normally occur in a larger society. The antibodies which develop following the infection are measured in the blood and washings from the nose. The measurements show that, although there was a rise immediately after the infection, there were secondary rises apparently unrelated to the intentional infection, and these are as yet unexplained.

A programme to examine the changes in gut bacteria over the course of the Antarctic year is now being pursued at Stonington Island.

EARTH SCIENCES

Survey and Mapping

TOPOGRAPHICAL survey was undertaken from two stations in the Antarctic (Halley Bay and Stonington Island) and two short-term projects were carried out—one party was flown into the Shackleton Range (lat. 80°40′S., long. 26°00′W.) by the U.S. Navy for a period of 9 weeks, and a hydrographic survey party spent 10 days in the Pendleton Strait–Crystal Sound area (lat. 66°23′S., long. 66°30′W.).

At Tolworth, work continued on computations and map compilation.

Further trimetrogon and photography of parts of the Antarctic Peninsula was achieved by the Americans during the 1968–69 flying season, and prints of some of the earlier cover affecting the British Antarctic Survey working areas were purchased.

Halley Bay

In November 1968, a survey/geology party was flown into the Shackleton Range (lat. 80°40′S., long. 26°00′W.) from Halley Bay by the U.S. Navy. An overland party had also reached the mountains, laying supply depots en route. The surveyor's task was to establish mapping control for the American trimetrogon photography of the range. They completed a tellurometer traverse around Fuchs Dome and extended this east towards the Read Mountains (lat. 80°42′S., long. 24°45′W.) before being flown out to Halley Bay in January 1969.

In March and April, astro control points were established for the trimetrogon photography of part of the Brunt Ice Shelf.

Stonington Island

The surveyors' main programme was to continue work on the reconnaissance and observations of the survey framework to link Stonington Island and Fossil Bluff. Control was extended southwards across the sea ice from Stonington Island to Alamode Island (lat. 68°43′S., long. 67°32′W.). Six new survey stations were established and fully observed, and eight tellurometer lines were measured.

Towards the end of the season, a closed tellurometer traverse was measured as part of the local survey of the Stonington Island area; some assistance was also given with large-scale mapping for geological purposes.

A surveyor making astro observations at Depot 36, near Halley Bay.

Seaborne survey

During February, the Royal Navy Antarctic survey party on board H.M.S. *Endurance* assisted the topographical survey programme by making observations to close a major gap in the survey framework along the west coast of the Antarctic Peninsula. A braced tellurometer traverse was run northwards from the northern end of Lallemand Fjord (lat. 67°05′S., long. 66°45′W.) to the Fish Islands (lat. 66°01′S., long. 62°25′W.). The scheme was tied to existing survey stations established in 1958.

United Kingdom

The computation of the survey of the Theron Mountains (lat. 79°05′S., long. 28°15′W.) was continued through this period by the surveyors who had returned from Halley Bay in 1968 and the compilation of the map at a scale of 1 : 40,000 was begun. This compilation incorporated much information provided by the geological and glaciological field parties. Work was also started on the computation of the Brunt Ice Shelf observations in close consultation with the British Antarctic Survey glaciologists at the Scott Polar Research Institute.

The two surveys carried out in Heimefrontfjella in 1966–67 were adjusted to a common datum and a new compilation was forwarded to the Norsk Polarinstitutt.

The surveyor returning from Stonington Island in 1969 completed the preliminary computations of the tellurometer work done in Marguerite Bay in 1969 and in Graham Land in May–June 1968.

Work was also started on the computation of the Shackleton Range survey.

The Directorate of Overseas Surveys began work on four sheets of the regular 1 : 200,000 map series. These are being compiled from air photography and all existing surveys, and cover the Trinity Peninsula and Joinville Island areas.

Geology

THROUGHOUT the past year both the field and laboratory activities have proceeded with vigour. In particular, summer projects have proved to be especially productive and interesting results

Surveyors measuring distances with a tellurometer in the Theron Mountains.

have been obtained. There is no doubt that the further volcanic activity at Deception Island has been the highlight of the year.

Several important aspects of the laboratory work have reached completion and the results have been published. Collaboration with institutions and organizations interested in the Survey's geological programmes has been especially fruitful and will be encouraged in the future.

Field mapping

The main field mapping programmes were centred on north-western Palmer Land and the eastern coast of Alexander Island. A reconnaissance geological survey at a scale of 1 : 100,000 was completed in the Gurney Point–Carse Point area, and further surveys were undertaken in the vicinity of Mount Edgell and in the interior plateau areas, and in the central parts of the west coast of Palmer Land. Wherever possible, mapping at 1 : 50,000 was carried out. Working from the Fossil Bluff field station, detailed stratigraphical and palaeontological work was continued to the south and also extended northwards to Ablation Point. From the field observations, it appears that there is a conformable succession from the Jurassic into the Cretaceous between Belemnite Point and Ablation Point, and this should prove to be stratigraphically important in later interpretation. The vicinity of Ablation Point is structurally complex and more field work needs to be done to resolve the problems of this area.

Detailed mapping in the Neny Fjord area was completed in the latter part of 1968, and further reconnaissance surveys were undertaken in northern Marguerite Bay to link with previous mapping.

During the southern summer of 1968–69 reconnaissance mapping was begun in the western and northern parts of the Shackleton Range. This work was only possible with the logistic support of U.S. Navy Hercules aircraft, and it constitutes the initial stage of a programme which could take several summer seasons to complete. This area is of interest from structural, tectonic and petrological aspects and detailed knowledge of it could contribute a great deal to the understanding of that part of east Antarctica.

Detailed mapping of the Prince Olav Harbour area was continued as part of the programme on the north coast of South Georgia.

Geomorphology

The geomorphological programme carried out on the north coast of South Georgia during the summer of 1967–68 has now reached an advanced stage. The greater part of the final report has been completed and the publication of a five-colour geomorphological map is planned. Further geomorphological studies at South Georgia will be undertaken when there is a suitable opportunity allied to the geological mapping programme.

Volcanology

One of the main centres of geological interest in the Antarctic has proved to be Deception Island, which erupted on 4 December 1967. Although preliminary observations on the results of the volcanic activity were made shortly after the island became quiescent, it was not possible to mount a major effort until the 1968–69 summer. A combined Royal Society–British Antarctic Survey expedition, planned to undertake both geological and biological studies, visited Deception Island in December 1968 and remained there until the end of January 1969. The main geological objectives were to map the centres of activity, prepare a series of detailed isopach maps for ash thickness and particle size, and collect samples representative of the erupted material. In addition, suites of samples from earlier lava flows were collected for palaeomagnetic investigations, petrological and geochemical analysis. Because of excellent planning and logistic support, and the enthusiasm and tenacity of the expedition's members, all of the objectives were achieved beyond expectation.

Within several weeks of the expedition's return to the United Kingdom, a further eruption occurred on 21 February 1969. The expedition was immediately despatched to Deception Island, where it was found that a major fissure almost 5 km. long, nearly 75 m. wide and almost 100 m. deep had opened along the western flank of Mount Pond, extending from just north of Whalers Bay to Pendulum Cove. Ash and bombs had been ejected from localized centres along the fissure, and most of the finer material had been transported by the wind over the southern parts of the island. As a result of the melting of ice by the intense heat generated during the

Fumarolic vapours issuing from the 1969 fissure on the western flank of Mount Pond, Deception Island.

eruption, floods and lahars swept over the lower slopes of Mount Pond into Port Foster and also southwards into Whalers Bay, breaching the outer rim of Kroner Lake. The British station huts, the old whaling factory and the air strip were devastated by the torrents which carried gigantic ice blocks in addition to volcanic mud.

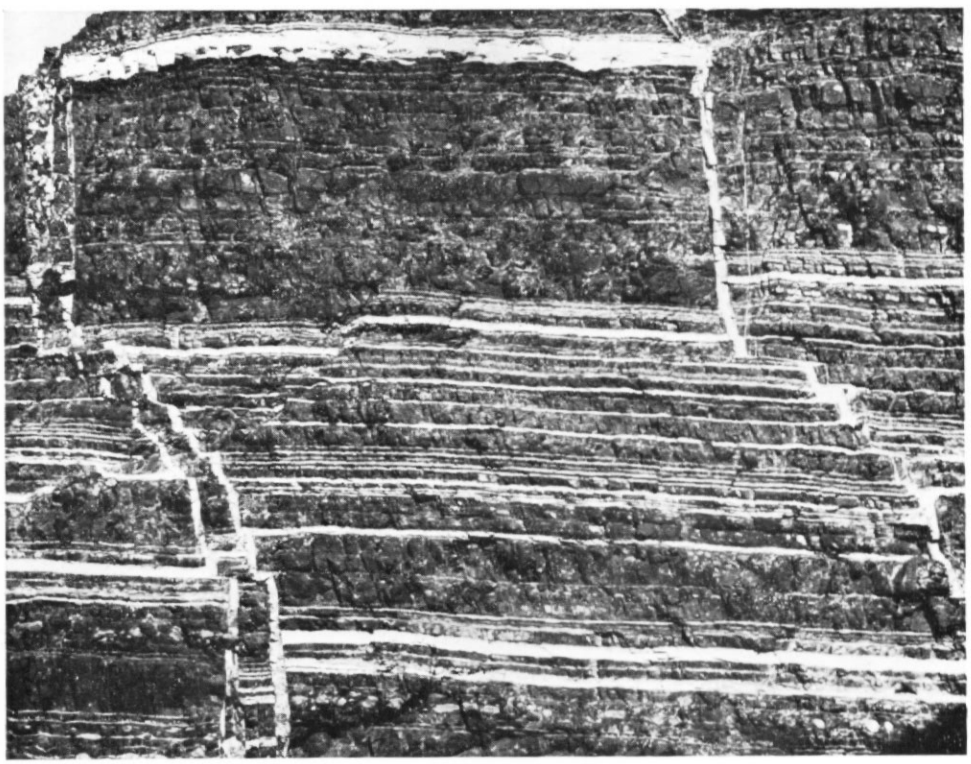
The expedition was able to map the fissure-eruption area and prepare a series of isopach maps comparable to those for the 1967 eruption. Within a few weeks of their return to the United Kingdom, a preliminary account of the 1967 and 1969 eruptions was published in *Nature* and a well-illustrated narrative appeared in the *Geographical Magazine*.

The question posed by these two eruptions within the space of 15 months is "When will Deception Island erupt again?" There is no doubt that both the increased acidity of the 1969 eruption and the occurrence of this activity along a further sector of the caldera rim are indications of future activity. The recurrence of severe shallow earthquakes and elevation of the geothermal gradient are also indicative of energy release in association with a near-surface magma chamber. It would therefore seem unwise to re-occupy the station at Deception Island in view of these circumstances.

Stratigraphy

Most of the stratigraphical work has been associated with the Lower Cretaceous sedim on the east coast of Alexander Island. The careful correlation of measured field sections has continued in association with observations on facies variations and the palaeontology of the fauna in the sediments. The occurrence of concretions in these sediments has been studied both in the field and the laboratory, and a paper on this topic has been prepared for publication. The petrology of these sediments will be examined when the present field work has been completed.

The stratigraphy of parts of the north coast of South Georgia has proved to be a difficult



Sandstone dykes cutting through a thick succession of faulted Lower Cretaceous sediments in south-eastern Alexander Island.

problem, because of the lack of distinctive marker horizons and the apparent absence of fossils in the great thickness of greywacke-facies sediments exposed. It is possible that future laboratory work may reveal methods of correlation.

Palaeontology and palaeobotany

From the palaeontological viewpoint, the Lower Cretaceous sediments of south-eastern Alexander Island have been most productive. A further paper, supplementing a previous account of the ophiuroid and crinoid fauna, has been prepared and other papers on fossil polychaetes, the macrurous decapod fauna, an isopod, the micro-structure of the decapod cuticle and boring thallophytes in decapod cuticles have been completed. In addition, the Gastropoda, inarticulate Brachiopoda and certain aspects of the Ammonoidea from Alexander Island have been described. Preliminary work has begun on a further collection of Ammonoidea from the northern side of Pluto Glacier; this material appears to be of an earlier Cretaceous age than that described previously. Work has also commenced on the belemnites from Alexander Island.

A description of the marine micro-fossils and trace fossils from the Jurassic tuffs of southern Adelaide Island has been published. Work has been undertaken on the description of a small fossil collection made some years ago on Annenkov Island to the south of South Georgia.

The fragmentary palaeobotanical material collected from Powell Island, South Orkney Islands, has been cursorily examined and compared with the Jurassic flora of Hope Bay. A similar but less well-preserved flora from Matthews Island, south-east of Coronation Island, is associated with an apparently younger invertebrate fauna, but further work on this remains to be done.

Large collections of plant macro-fossils and woods of various ages and from different localities still need to be worked on, but the necessary expertise for this task does not seem to be available in the United Kingdom.

Structure and tectonics

Studies on the structure and tectonics of south-eastern Alexander Island have continued, particularly regarding the rift valley of George VI Sound and the relationship of the Alexander Island block to the Antarctic Peninsula mainland. Several papers on the provenance of the Cretaceous sediments and the tectonic environment at the time of their deposition have been published in addition to a palaeogeographical approach to this problem.

The structure of the Prince Olav Harbour area on the north coast of South Georgia has been investigated as part of the continuing field programme there. A preliminary analysis of the structural observations has been made.

An opportunity to visit the Shackleton Range with the logistic support of U.S. Navy Hercules aircraft yielded both structural and tectonic information of considerable importance, and this will be analysed in the near future. Though bad weather hampered the field programme severely, it was possible to examine much of the western part of the Range and also parts of the Herbert and Read Mountains. The great horst of the Shackleton Range is structurally extremely complex and several seasons of work will be required to complete the field work.

Petrology and geochemistry

Much of the laboratory work has been in the fields of petrology and geochemistry. Studies on the metamorphic complex of north-east Heimefrontfjella, the associated pre- and post-Permian dolerite intrusions and the Jurassic basalts have been completed for publication. The geochemical work on the Jurassic basalts and dolerites has shown that there are major differences between this suite and the suite of a similar age already well known from the south Victoria Land sector of the Transantarctic Mountains. It seems that these two suites represent distinct petrological provinces and that the respective magmas may have had quite different histories and evolutionary trends. Further work on the $^{86}Sr/^{87}Sr$ ratios of these rocks is to be undertaken in collaboration with the Laboratory for Isotope Geology and Geochemistry, The Ohio State University, and this should provide conclusive evidence for the origin of the Heimefrontfjella basalts and dolerites.

The geochemistry of the differentiated dolerite sills and dykes of the Theron Mountains has been investigated with the aid of XRF methods. So far, more than 50 analyses of these rocks have been completed and it is expected that approximately 200 will be done eventually. Because of the importance of these dolerites, detailed mineralogical work has been carried out on selected specimens for comparison with similar dolerites from other regions.

Preliminary work has begun on the petrography of collections from the Shackleton Range. For comparison purposes, the Trans-Antarctic Expedition specimen and thin-section collections have been used extensively. It is anticipated that this region will yield important data towards an overall study of the western sector of the Transantarctic Mountains.

The petrology of collections from Powell, Fredriksen and Laurie Islands, South Orkney Islands, has been completed for publication, and further work on Coronation Island and the Robertson Islands is still in progress. The petrology of the Inaccessible Islands has been published.

In the Antarctic Peninsula region, the petrology of two important collections from the Danco Coast has been completed, and further work on the geochemistry of these rocks is anticipated. It has been found that the petrology of the Danco Coast area fits in well with previous work in adjacent areas. Preliminary petrological studies have begun on the north-west coast of Palmer Land, and eventually this work will be linked with previous field work in the southern a[illegible] central parts of Palmer Land.

During the course of the Royal Society–British Antarctic Survey expedition to Deception Island, South Shetland Islands, extensive collections of ejecta from the recent eruptions were made and their petrography has now been studied. Additional collections of earlier lavas were also made and these will be examined both petrologically and geochemically for comparison with the younger lavas and ashes.

Radiometric dating

Collaboration with the Age Group at the University of Leeds has continued and a further programme of K-Ar dating of volcanic and basic intrusive rocks has started. Previously, the main effort was directed towards unravelling the tangle of intrusive phases in the Antarctic Peninsula and dating the metamorphic rocks of the South Orkney Islands.

Of greatest importance in the present programme are the widespread Jurassic volcanic rocks of the Antarctic Peninsula which are invariably altered by adjacent Andean intrusions and therefore give spurious ages by the K-Ar method. A careful survey of all available material has yielded several specimens worthy of dating, and these have given initial average ages of ~156 m. yr. for this phase of volcanism. Further material still has to be dated, and it may be necessary to make special field collections to confirm this age.

Doleritic sills and dykes, and basic volcanic rocks, from Heimefrontfjella and the Theron Mountains have also been dated, since they are complementary to information already available from the Transantarctic Mountains. The dolerites from the Theron Mountains give ages ranging between 155 and 170 m. yr., whereas some of the dolerites and the basaltic lavas from Heimefrontfjella have ages of ~170 m. yr. One of the known pre-Permian dolerites fro[illegible] Heimefrontfjella has an age of 455 m. yr., which is probably far older than expected. Even older doleritic rocks from Mannefallknausane fall in the age range of 560–580±100 m. yr. Specimens of doleritic intrusions from the Shackleton Range will be dated in due course.

The olivine-basalts of James Ross Island and the Seal Nunataks have also been investigated. Numerous problems have arisen because much of the material collected in the field has proved to be unsuitable due to its vesicularity and hence the possibility of argon loss. From field observations, the James Ross Island olivine-basalts were suspected as being of Upper Miocene age, and K-Ar dating has given ages ranging from 4·6 to 1·4 m. yr. The petrologically and chemically similar olivine-basalts of the Seal Nunataks have proved to be extremely difficult to date by this method. So far, none of these rocks has yielded radiogenic argon and therefore they have been assumed to be younger than 1 m. yr. Further investigations are proceeding.

An attempt has been made to use the Rb-Sr isochron method on a suite of selected metamorphic rocks from the South Orkney Islands, but the results are not yet to hand. If this is successful, it might yield the true age of these rocks which have been dated by the K-Ar method at 190 m. yr. (i.e. indicating the last release of argon).

In collaboration with the Department of Geology, University of Birmingham, a number of ^{14}C dates has been completed on carbonaceous materials collected from the raised beaches of the South Shetland Islands. These results have been discussed in relation to the late Pleistocene history of this region and they have given quantitative significance to the field observations.

Geophysics

Field programmes

Land geophysics

Regional magnetic and gravity surveys in Alexander Island, George VI Sound and Palmer Land have supplemented the existing coverage and have yielded valuable information on the structure of this complex region. In contrast, large-scale geophysical surveys have been undertaken in northern Marguerite Bay in order to extend the existing work.

In the United Kingdom, the computation of all available magnetic and gravity data for the whole of Graham Land has been completed. With the introduction of radio-echo sounding from aircraft, accurate ice-thickness data have become available, and these have enabled all the gravity observations to be recalculated with a higher precision. In collaboration with F. J. Davey of the Sub-Department of Geophysics, University of Birmingham, both land and marine gravity observations have been used to prepare a Bouguer anomaly map for the Scotia Sea and Graham Land regions. More than 200 identified rock samples from the Antarctic Peninsula have been measured for density to assist in the accurate interpretation of the gravity data.

Using a third-order three-dimensional polynomial fitting, a regional total magnetic intensity map of Graham Land has now been prepared. In comparison with previous estimates of the regional magnetic field derived from extrapolation of marine and observatory observations, there is good correlation over this region. For the area south of lat. 68°S., a cross-correlation technique has been applied to two land magnetic traverses completed in 1966–67. This has indicated that there is close correlation on both of the traverses between detected magnetic anomalies trending north-west to south-east and separated by up to 40 km. An extension of this method to a Project Magnet flight 55 km. farther east suggests a possible continuation of this trend. Vertical magnetic anomaly maps have been prepared for the area north of the Seal Nunataks, and these are being compared with the total magnetic field maps for the Graham Land east coast from Hope Bay to Mobiloil Inlet for an overall interpretation.

The computer facilities of the University of Birmingham have proved invaluable in the processing and interpretation of the vast quantities of gravity and magnetic data.

Palaeomagnetism

The established programme of palaeomagnetic investigations, in collaboration with the Sub-Department of Geophysics, University of Birmingham, has continued. Further field collections have been made to supplement the already extensive suites of material held in Birmingham. Special attention was directed to the collection of samples from selected lava flows on Deception Island, where there have recently been volcanic eruptions.

Marine geophysics

The marine geophysics programme of the geophysics section of the Department of Geology, University of Birmingham, was continued during the 1968–69 Antarctic season. As in previous years, the British Antarctic Survey provided facilities on board R.R.S. *Shackleton*. This work receives the support of the Natural Environment Research Council. Its aim is to determine crustal structure in the Scotia Sea and over the Scotia Ridge, and hence to see how this region fits into the world pattern of sea-floor spreading.

Detailed examination of restricted areas was made physically possible for the first time as a result of the acquisition by the Natural Environment Research Council of a satellite-navigation receiver which was installed in R.R.S. *Shackleton*. Strip surveys, consisting of three or more parallel lines spaced at between 5 and 10 miles [8 and 16 km.] apart, were also measured across the Scotia Sea to map magnetic lineations and aid in the correlation of anomalies with the

magnetic reversal time-scale. Some success has been achieved but this area is clearly a complex one. In all, about 14,000 km. of magnetic and bathymetric profiles were obtained, mainly in Drake Passage.

A detailed magnetic survey was also made in the vicinity of Elephant and Clarence Islands. A number of seismic refraction lines was also shot over the ridge in this area. As a result of this and former surveys, it is hoped that it will be possible to throw some light on the mutual relations between the various parts of the ridge in this area, since it is believed that there has been considerable relative movement between the various "blocks".

An experiment was carried out with a long array in an effort to obtain reflections from the base of the crust. 32 shots were fired at near vertical incidence, and these data are now being processed.

Work has continued throughout the year in Birmingham on the interpretation of gravity data.

As a result of the past season's survey and earlier work, a fair amount is now known about the form and structure of the ridge between the South Shetland and South Orkney Islands. Large areas of both the Scotia Ridge and the Scotia Sea still remain unsurveyed but, nevertheless, progress has been made and the essence of the structural history is now emerging.

Observatory programmes

At Halley Bay there were interruptions in most of the programmes while instruments were transferred from the old station to the new one. The sledge huts for auroral, ozone and V.L.F. observations were brought into use early in the winter, but the rapid deterioration in living conditions at the old station precluded any attempt to obtain an overlap of magnetic records at the two stations. Recording ceased at the old station in March 1968 and was begun at the new one in October 1968.

A local survey of the total magnetic field showed that the new station was west of the I.G.Y. position; preliminary calculations suggest that the movement of the ice shelf has been uniform (on a yearly basis, in the vicinity of the station) since 1960.

At the Argentine Islands, the routine observations were continued satisfactorily throughout the year. From January 1969, *K*-indices have been sent out monthly by radio. These are passed on to Paris, where they are used in the calculation of K_s, the Southern Hemisphere index of magnetic activity. Separate indices, K_N and K_S, for the respective hemispheres are now prepared and they replace the older planetary index K_P.

The Geophysical Section in Edinburgh has developed computer programmes to facilitate the processing of data. Satisfactory methods are now available for dealing with geomagnetic, radiation and wind records, and for the analysis of the auroral all-sky camera film. Considerable progress has been made in transferring earlier data to magnetic disc storage; when completed, this will greatly facilitate climatological and solar-cycle analyses. The introduction of new machines at the Edinburgh Regional Computing Centre has meant that much effort has had to be devoted to translating programmes and data, but the situation should now remain stable for some years.

The British Antarctic Survey Meteorological Service staff in Stanley has been greatly reduced. It has been agreed in principle that the meteorological work in the Section at Edinburgh should be extended, and that the Section will eventually assume responsibility for climatological publications.

Glaciology

SINCE 1962, the Survey has been co-operating with the Scott Polar Research Institute in the development of a radio-echo sounding technique for glaciers. It is now possible to measure the thickness of glaciers and ice sheets from aircraft flying over them, and many thousands of kilometres have already been flown on sounding runs over Antarctica. The principal task since 1967 has been the reduction and analysis of the large volume of data obtained. Navigational information stored on a flight-recorder trace has been processed in the University of Cambridge Titan computer to obtain, in digital form, the track of the aircraft and thus the geographical positions at which soundings were made. In the first place, a dead-reckoning track was prepared on the basis of aircraft heading and speed information stored by the flight recorder. This track

was compared in the computer with known fixes and adjusted to give a best-fit version of the path followed by the aircraft. The coordinates of the track were stored on magnetic tape and finally plotted on a transparent-paper overlay at the same scale as published topographic maps. The computer was also used to bring measured ice thicknesses together with the positional information in the form of contour maps and fence diagrams.

In preparation for more airborne work during the 1969–70 season, there has been some re-designing of the sounder itself. The 1967 Scott Polar Research Institute Mk. 2 instrument was not capable of recording weak echoes from the bottom of the ice when strong surface echoes were present. The new version (SPRI Mk. 4), which has been designed with aircraft installation in mind, has a greater dynamic range and should be able to measure ice thickness in places where the Mk. 2 instrument was unsuccessful. In addition, Mk. 4 is more flexible in operation and it automatically annotates the record with time, position and attenuator information. These improvements should speed the analysis of the mass of data that will be collected.

Ice-shelf studies

Two of Antarctica's floating ice shelves are larger than the British Isles. Radio-echo sounding profiles have shown that they are from 100 m. to as much as 1,300 m. thick, yet they rise and fall with every tide. The Halley Bay station is built on an ice shelf that is moving westwards at the rate of 348 m./yr. The measured rate of movement of the station itself towards the sea is a by-product of a 4 year research programme aimed at an understanding of the dynamic response of a floating ice sheet to the steady precipitation of snow on its surface. The mass balance of any glacier can be described with a knowledge of the rate at which snow accumulates on its surface, the rate at which the ice is deforming and the rate of loss or gain of mass beneath the glacier.

There is little or no surface melting on most Antarctic ice shelves and accumulation rates can be measured easily by repeated observations of the length of stakes planted in the surface. Since the surface is generally flat or gently undulating, accumulation rates vary little over large areas. Snow accumulation has been measured on the Brunt Ice Shelf at Halley Bay through every year since 1955. Triangulation measurements completed in 1968 have been processed to provide a complete velocity and surface-strain profile along a 55 km. flow line from the inland ice sheet through the Halley Bay station to the ice front. A beacon in the middle of a locally grounded area, the McDonald Ice Rumples, was included in the scheme and used as an assumed fixed point. The observed rate of movement at Halley Bay during 1966 and 1967 relative to the grounded ice was found to be 348 ± 1 m./yr. This result cannot be reconciled with astronomical observations repeated regularly since 1955, which gave an average rate of movement of 396 ± 15 m./yr. The difference between these values is most probably explained by movement of the grounded ice amounting to about 50 m./yr., but it could also be due to an accumulation of unknown errors in the astronomical observations or to variations with time in the velocity of the ice. Experiments have since been made to establish whether or not there are variations with time in the rate of ice movement.

Observed velocities of the stakes marking the triangulation scheme allow the computation of principal strain-rates at many points spread over the area surveyed. Strains measured on the surface of an ice sheet resting on a virtually frictionless medium are assumed to be representative of those within the mass of ice. When values of the vertical displacement of the ice surface are available, it will be possible to compute the rate of thinning of the ice shelf at all points along the stake line, and hence the rate of bottom melting. Preliminary figures for the Halley Bay station area indicate bottom melting at the rate of about 1·3 m. ice/yr.

Precise optical levelling has been used since 1967 to measure not only the surface profile of the ice in the direction of flow but also the slow vertical displacement as the ice shelf creeps forward. A principal levelling profile was run along one side of the main triangulation scheme from the inland ice sheet to the ice front, and a second line of similar length was set out across it. The ice-surface levels were linked to sea-level in two places. When these profiles have been levelled twice with an interval of 1 year or more, it will be possible, by combining the levelling results with snow-accumulation measurements, to establish the trajectory of ice particles in a vertical plane.

The main profile has yielded new information on the surface features of ice shelves. Shortly

after the ice sheet flows from the land on to the sea its surface is disturbed, with variations in level of 10 m. or more over short distances. Farther out on the ice shelf, the surface profile takes an approximately sinusoidal wave form with a wave-length of the order of 500 m. in the direction of flow and a wave height of about 6 m. Approaching the ice front, the wave-length has increased to 1,500 m. and the wave height has decreased to about 3 m. Comparison of these figures in detail with the measured strain pattern and with ice-thickness data may indicate the cause of wave-like surface features, which occur on all ice shelves but which remain largely unexplained.

Very few places on the coast of Antarctica are farther from land, in the sense of bare rock, than is Halley Bay. The nearest nunatak is 360 km. away. Thus it was a rare surprise to find a small quantity of morainic debris sitting on the surface of the Brunt Ice Shelf only 50 km. south-east of Halley Bay. Where did it come from and how did it get there? All of the fragments are from metamorphic rocks similar to those which crop out in Heimefrontfjella, 400 km. to the east. But owing to the general direction of flow of the ice sheet, they could not have been carried from the east. Neither could they have come from the Theron Mountains far to the south of Halley Bay. Instead, the parent rock must lie somewhere beneath the inland ice sheet at an unknown distance to the south-east of the place where they were found. How they were brought to the surface is another mystery, since most things on an ice shelf are progressively buried by snow. There is one place in Antarctica where rocks are raised to the underside of an ice shelf by anchor ice, but material could only be brought to the upper surface by a complete reversal of the downward particle paths generally associated with floating glaciers.

Local glacier studies

Certain glacier measurements are co-ordinated internationally under the programme of the International Hydrological Decade. One of three priority chains of glaciers used for detailed studies extends from arctic Alaska through the Rocky Mountains, the Andes and the Antarctic Peninsula to the South Pole. The biggest gap in the whole chain of stations already established has been between the Andes and the South Pole. Since the United Kingdom is the only country maintaining a permanent research station in Alexander Island, it was decided to select, as part of the chain, a glacier in the vicinity of Fossil Bluff. The chosen glacier occupies a well-defined niche in a highly dissected sedimentary massif that is bounded on one side by the main western escarpment of George VI Sound. This area is accessible by oversnow vehicle from the Fossil Bluff station which lies 40 km. farther south. It is hoped that glaciologists can work here at intervals during the next few years to measure heat, mass and water balances for comparison with those of similar glaciers in other parts of the world. Accurate topographic and levelling surveys should allow us to establish within a few years whether, and to what extent, contemporary climatic fluctuations may be causing changes in the size of such glaciers. While it is known that some coastal glaciers of Antarctica are in retreat, it is still not known whether the ice sheet away from the sea is responding at all, or indeed whether—as some have suggested—it may be responding in the opposite sense by growing.

Sea-ice distribution

For the second year in succession the Survey received regular satellite photographs of the whole of British Antarctic Territory throughout the summer period. Supplied by the U.S. Environmental Science Services Administration (ESSA) from their National Environmental Satellite Center, the photographs have been used principally to observe the distribution of pack ice to facilitate the passage of the Survey's ships to Antarctic stations. ESSA satellites are launched into Sun-synchronous orbits inclined about 80° to the Equator. This means that they always cross the Equator at the same local Sun time, giving proper illumination for photography. With an orbital period of 115 min., ESSA-7 covered every point on the Earth's surface at least once a day. Overlapping coverage of the whole area south of lat. 60°S. and between long. 20° and 80°W. was represented by an average of 16 photographs/day. During the 1968–69 shipping season, the photographs were examined once each week in Cambridge, after which radio reports were prepared describing the route that appeared least likely to encounter heavy concentrations of ice. The vessels reported their positions with a description of the actual ice conditions. When

The mountains of Alexander Island in lat. 71°S. An air photograph from a height of 6,000 m. over George VI Sound, looking west. The valley glacier in the foreground has been chosen as a representative glacier basin for detailed studies under the programme of the International Hydrological Decade. (Photograph by the U.S. Navy for the U.S. Geological Survey.)

the ice conditions as seen in the photographs agreed with conditions being encountered by the ships, fairly detailed suggestions were made as to the best route to avoid close pack ice. In January 1969, there was almost no ice in the Weddell Sea east of long. 20°W., and M.V. *Perla Dan* was given a routing from South Georgia to Halley Bay which appeared from the photographs, and also proved to be, almost ice-free. But there was plenty of ice farther west, and the icebreaker U.S.C.G.C. *Glacier* found "very heavy ice" in long. 40°W. Though a mariner surrounded by ice floes may never again feel quite so lonely as he did in the past, no satellite is likely to replace the quite special skill that is required to handle a ship in ice.

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* Resigned during the year.

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‡ Relief for part of the season.