South African Antarctic Earth Science Research Programme

SASCAR

Programme developed by the South African Scientific Committee for Antarctic Research (SASCAR)

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PREFACE

South Africa is one of the original signatories of the Antarctic Treaty and South African scientists have been involved in Antarctic research since the early 1960's. Research in the Antarctic is coordinated internationally through the Scientific Committee on Antarctic Research (SCAR) of the International Council of Scientific Unions. The CSIR coordinates the South African Antarctic Research Programme through a national committee called the South African Scientific Committee on Antarctic Research (SASCAR) and represents it on SCAR. The South African Antarctic research programme comprises four main components - biological sciences, earth sciences, oceanographic sciences and upper atmosphere sciences.

This document describes the SA Antarctic Earth Sciences Research Programme which SASCAR has recommended should be undertaken in the subantarctic, Southern Ocean and Antarctic regions by South African research groups. It has been developed in consultation with the scientists and scientific institutions currently active in Antarctic research, with due regard also to international activities in the area. It draws on the knowledge and experience gained during the past two decades, takes into account the manpower, facilities and expertise which are available in the country and concentrates on activities which can be regarded as logical extensions of existing research activities.

The document is intended to direct the efforts of those already involved in the SA Antarctic research programme, be of interest to those not involved, to guide those who may wish to initiate an activity and to guide the policy and decision making bodies in respect of future financial and logistical requirements for this research programme.

ABSTRACT

This document describes the past, current and planned future South African earth science research programme in the Antarctic, Southern Ocean and subantarctic regions. The scientific programme comprises five components into which present and future research activities will fall, viz geodesy and cartography, continental geology and geophysics, continental margin geology, open ocean geoscience and glaciology. The rationale for and main objectives of these components are described. A Bibliography of publications that have arisen from the South African Antarctic Earth Sciences Research Programme is also included.

SAMEVATTING

Hierdie dokument bevat 'n beskrywing van die vorige, huidige en beoogde toekomstige Suid-Afrikaanse Aardwetenskappe-navorsingsprogram in Antarktika, die Suidelike Oseaan en subantarktiese streke. Die wetenskaplike program bestaan uit vyf komponente waaronder huidige en toekomstige navorsingsaktiwiteite sal resorteer, nl. geodesie en kartografie, kontinentale geologie en geofisika, kontinentale rand-geologie, oopsee-geowetenskap en gletserkunde. Die grondbeginsels en hoofoogmerke van die bogenoemde komponente word omskryf. 'n Bibliografie van publikasies wat tot dusver as gevolg van die Suid-Afrikaanse Antarktiese Aardwetenskappe-navorsingsprogram die lig gesien het, is ook ingesluit.

TABLE OF CONTENTS

INTRODUCTION

South African earth scientists have long been interested in Antarctica. When the International Geophysical Year (IGY; 1957/58) ended South Africa acquired the Norwegian IGY base, Norway Station, in western Dronning Maud Land. The first South African National Antarctic Expedition left Cape Town for this base in December 1959, while on 1 December 1959 South Africa joined with 11 other nations to sign the Antarctic Treaty. In 1962 the first South African base, Sanae, was constructed 20 km to the north of Norway Station at position 70°18'S, 02°21'W. By 1971 this base was buried so far beneath the surface that a second Sanae base had to be constructed in the vicinity. This, in turn, was replaced by a third Sanae base in 1980, also nearby at position 70°18'S, 02°26'W. These bases lie on the Fimbul Ice Shelf, the nearest rock exposures being some 115 km to the south.

Field-work continued uninterrupted from the 1960/61 to the 1975/76 summer seasons. By 1975/76 most nunataks reasonably accessible from Sanae and the makeshift Borga and Grunehogna field bases had been geologically studied and mapped by overwintering teams, using oversnow transport. Glaciological studies of the Fimbul Ice Shelf, the inter-nunatak ice sheet and the Jutulstraumen Glacier had also been carried out. Field-work came to a temporary halt in 1976 and the South African Antarctic Earth Sciences Programme went into a 'quiet' period of data analyses and assessment, in anticipation of air support becoming available sometime in the future for summer-only expeditions.

Air support, in the form of two long-range helicopters, materialised during 1980. By this time the basic ground-work for a new national Antarctic Earth Sciences Research Programme had been laid. During the 1980/81 summer season a four-man expedition visited Sanae and some outcrops to the south, to assess further the new research potential arising from the availability of air support. A site for a new field base in the vicinity of Grunehogna (72°02'S, 02°48'W) was also selected. This base was subsequently erected during the 1982/83 summer season. The first full field expedition in the new research programme was undertaken during the 1981/82 summer season, during which a nine-man team of geologists and surveyors spent some 30 days in the field, supported by the helicopters.

This document outlines the direction the future South African Antarctic Earth Sciences Research Programme is expected to take. The programme is not confined to continental research in Antarctica, but also includes work relevant to the main theme of the programme that can be undertaken on the oceanic islands (Gough, Tristan de Cunha, Bouvet, Prince Edward, Marion) south of southern Africa. In addition, a marine geoscience programme focusing on the Antarctic Continental Shelf and on the mid-ocean ridges and associated fracture zones, aseismic ridges, plateaux and rises in this part of the Southern Ocean is included.

The two main themes of this research programme are;

- to obtain a better understanding of the geology of western Dronning Maud Land;

- to obtain a better understanding of the processes involved in continental drift and the manner in which the supercontinent of Gondwana broke up.

The research programme described in this document is not intended to cater for individual academic interests, nor is it based upon such interests. The restrictions placed upon it, financially, logistically and in terms of the manpower and expertise available for it in South Africa, necessitate that it be conducted in a manner which optimises use of resources and focuses these upon objectives that will improve knowledge about the target areas described above, and thus lead to a better understanding of South African geology and global phenomena such as plate tectonic movement.

HISTORY OF SOUTH AFRICAN ANTARCTIC EARTH SCIENCES RESEARCH

ANTARCTICA

Over the period 1960 to 1976, 15 South African earth science expeditions into the Ahlmannryggen and Borgmassivet ranges south of Sanae took place. This involved geologists, geophysicists, glaciologists and surveyors, all of whom were required to overwinter in Antarctica. Initially the Sanae base was used as the overwinter station. In 1969 a small, temporary field base was built at Huldreslottet (72°58'S, 03°48'W) in the Borgmassivet, some 300 km south of Sanae. Teams of two geologists and two support personnel proceeded there in late summer (February/March) where they overwintered. With the onset of spring (September/October) they were able to commence field-work immediately and be back at Sanae about December to accompany the relief voyage home in January/February. The construction of this Borga base, and subsequently another temporary overwintering field base at Grunehogna (72°02'S, 02°48'W), some 195 km south of Sanae in April 1971, greatly increased the time usefully spent in the field by members of these expeditions. The research programme was administered from 1963 by the Geological Survey, with financial and logistical support from the Department of Transport on the advice of SASCAR.

The first oversnow exploration of Dronning Maud Land was by the Norwegian-British-Swedish Antarctic (NBSA) Expedition of 1949-1952. The expedition's geological, glaciological and topographic parties traversed the area between their base Maudheim (71°02'S, 10°55'W), 01°30'E and as far south as 73°37'S. Studies were mainly of a reconnaissance nature, but during the two summer seasons they mapped rock exposures over an area of some 50 000 km^2 and established a stratigraphic column which in broad outline agrees with the present one. Another Norwegian expedition later established the IGY Norway Station in 1957/58 on the Fimbul Ice Shelf, some 315 km west-northwest of Maudheim. This expedition conducted extensive oblique aerial photography over almost all of Dronning Maud Land wherever rock outcrops occurred. Two series of topographical maps (1:500 000 and 1:250 000) were subsequently published by Norsk Polarinstitutt between 1957 and 1964. Soviet field parties operating from their base station Novolazarevskaya (70°46'S, 11°50'E), 520 km east of Sanae, undertook intermittent reconnaissances in the Ahlmannryggen and Borgmassivet between 1959 and 1968. British expeditions based at Halley Bay (75°31'S, 26°56'W) have mapped in the Vestfjella and Heimefrontfjella to the south-west of Sanae.

In the 1967/68 season a South African-Belgian expedition worked in the Borgmassivet and H U Sverdrupfjella regions, supported from the air by Belgian Otter aircraft. Two further joint summer expeditions, mainly for airborne radio-echo sounding by the Belgians, took place in 1968/69 and 1969/70. South Africans, having worked between 71°S and 74°12'S and from 1° to 6°W from 1960 to 1975, have mapped virtually all the exposures in this area, with selected areas being mapped on scales as large as 1:25 000.

The rocks of the Ahlmannryggen and Borgmassivet comprise, in part, the oldest platform deposits yet found in Antarctica. These relatively undisturbed sedimentary-volcanic rocks of low metamorphic grade are probably more than 3 km thick. To the east of these rocks and separated from them by the Penck-Jutul rift, which is exploited by the largest outlet glacier - the Jutulstraumen - in western Dronning Maud Land, lie the repeatedly remobilised high-grade metamorphic rocks of the East Antarctic crystalline basement. In the extreme south-eastern part of the Kirwanveggen, a folded sequence of quartzites and conglomerates, probably of early Palaeozoic age, occurs in tectonic contact with rocks of the metamorphic complex. These rocks are in turn unconformably overlain by about 100 m of flat-lying conglomerates and sandstones of probably Permian age, followed comformably by more than 3 000 m of Jurassic basaltic lavas.

The earth sciences programme in Antarctica is aimed at studying these features, as well as the Fimbul Ice Shelf. Much of the work done during the previous programme (1960-1975) was of a reconnaissance nature, due to the limitations of the slow, oversnow transport that was available and the great distances involved. The necessity for expedition research staff to overwinter in Antarctica, often in the small field bases far south of Sanae, also influenced the programme insofar as the availability of suitably trained or qualified scientists and/or technicians was concerned. Nevertheless, much pioneering work over the whole region was achieved. The new programme is aimed at conducting in-depth studies of particular features or in particular areas of special interest.

SUBANTARCTIC ISLANDS

The islands which fall within the sphere of interest of the South African Antarctic Earth Sciences Research Programme are Bouvet Island (54°25'S, 03°21'E), the Prince Edward islands comprising Marion

(46°55'S, 37°45'E) and Prince Edward (46°38'S, 37°57'E) islands, Gough Island (40°19'S, 09°56'W) and the Tristan da Cunha group. Marion Island, being a South African possession and the largest of the islands, has attracted by far the greatest attention. Prior to 1965 the available information on this island, and nearby Prince Edward Island, was in general scant. It comprised mainly laboratory studies on rock samples collected by visitors.

The first important contribution to the geological knowledge of the Prince Edward islands, primarily Marion Island, was that made by the South African biological and geological expedition of 1965/66, under Prof E M van Zinderen Bakker Sr. The topography and geology of the islands were mapped and the geology, with particular emphasis on volcanological features, was described. Subsequently, the geochemistry of the lavas was investigated, potassium-argon dates on some of the lavas were determined and some palaeomagnetic studies were also conducted. Among the more interesting results was the discovery of glacial pavements on Marion Island, indicating that the island was already in existence during the Pleistocene Ice Age. In view of the far-reaching implications this had for biological, particularly palaeo-ecological studies, work on the glacial geology and geomorphology was undertaken from 1975 to 1978. During 1980 an unexpected volcanic eruption occurred on Marion Island, hitherto considered to be extinct. This event emphasised how little was really known about the geology of the islands and provided the impetus for a renewed research effort.

The geology, glaciology and topography of Bouvet Island have received intermittent attention since the early 1960's by Norwegian, British, American and South African scientists. Resulting in part from South African expeditions in 1964, 1966 and 1981, but mainly from Norwegian expeditions in 1976/77 and 1978/79, aspects of the island's geology, glaciology, geochemistry and seismicity have been studied and its topography mapped. Due to the island's isolated position and inhospitable terrain and climate, relatively few scientists have worked there. When this has happened, time available on the island has usually been very restricted, except in the case of the two Norwegian expeditions of 1976/77 and 1978/79 during which three to six weeks were spent on the island each time. Detailed geochemical studies on available samples from these expeditions have been carried out but it is hoped that in the future earth scientists from South Africa and other nations will be able to continue studies there during the course of the Sanae relief voyages.

The first scientific expedition to Gough Island was undertaken in the summer of 1955/56 by a team of British scientists led by J B Heaney. This visit led to the completion of the only detailed topographic and geological maps of the island available even today, and the first comprehensive collection and description of the volcanic rocks found there. Their samples formed the basis of all subsequent studies of the Gough Island lavas until 1978, when a South African geological party visited the island and made an extensive collection of volcanic rocks. This new suite of lavas has been the subject of extensive geochemical investigation and K-Ar dating. The results have highlighted the extremely complex geological history of the island and a significantly younger age of the lavas than previously thought, necessitating a re-evaluation of the stratigraphy of the island and providing impetus for further study.

The nearby Tristan da Cunha group was visited by a British Expedition in 1961 during an active volcanic period. Reconnaissance work on some of these samples indicate an urgent need to carry out more detailed geochemical investigations.

RESEARCH IN THE SOUTHERN OCEAN

Marion, Prince Edward and Bouvet islands are of particular interest in a global context because of their proximity to the world-encircling mid-ocean ridge system. The bathymetry, magnetic anomalies and tectonics of the ocean floor in these areas, as well as the mid-ocean areas between these islands and Sanae, have been studied since the early 1970's by South African marine geoscientists. The plate tectonic theory of ocean basin evolution provided a coherent framework for understanding these observations. This theory will be briefly outlined in this document, when the scientific rationale of the national Antarctic earth sciences research programme is reviewed.

Very detailed mapping of magnetic anomalies and fracture zones has been undertaken with the ships RSA and SA AGULHAS. These studies established the geometry of sea-floor spreading between South Africa and Antarctica during the past 150 million years. Because the plate-tectonic theory successfully integrated such observations with similar data from the south Atlantic, south Indian and Southern Oceans, it proved possible to reconstruct the form of the supercontinent of Gondwana in detail. An international workshop with the motif 'Reunite Gondwanaland' was held in Johannesburg in 1979, at which the participants agreed on the production

of a 1:10 million geological map of Gondwanaland, which they hope to publish in colour in 1984. This map should provide a basis for understanding many of the geological features and earth resources of Antarctica and relating them to the geology of the continents which once abutted against Antarctica.

During the period 1976 to 1983 much activity has focused on the investigation of the mid-ocean ridge systems and associated fracture zones in the Southern Ocean. Dredging from the RV ISLAS ORCADAS (1976), RV ATLANTIS II (1980), RV MELVILLE (1980-81) and from the SA AGULHAS (1979, 1981, 1983), has allowed extensive sampling of igneous rocks from the America-Antarctica Ridge, from the South-West Indian Ridge and the southern Mid-Atlantic Ridge.

Detailed petrographic and analytical studies have been and are being made of the now substantial collection of basalts and related rocks from the ridge systems. Petrologic modelling of near-surface, crystal-liquid fractionation processes have led to explanations for the diversity of rock types present on the ridge, and for the distinctions between ridge and fracture zone basalts. The precise modelling of these low pressure fractionation trends has allowed investigators to see through near-surface processes, in order to distinguish differences in rock chemistry that reflect the nature of the source materials and thus provide clues to the nature of the underlying mantle.

Summary

South African geoscientists have been active in Antarctica (western Dronning Maud Land), the Southern Ocean (south of Southern Africa) and at accessible subantarctic islands (in particular the Prince Edward islands) since the early 1960's, but particularly over the past decade. They have made significant contributions to the scientific literature focusing on these regions (see Bibliography), and such gains are expected to continue.

A volume entitled "Geological Investigations in western Dronning Maud Land, Antarctica - a synthesis", by L G Wolmarans and L E Kent, published as a special supplement to the South African Journal of Antarctic Research (Suppl. 2, 1982), describes the work carried out by South African geologists in Antarctica from 1961 to 1976 and the knowledge gained therefrom. Included in this volume is a set of three geological maps of western Dronning Maud Land, the geology having been

superimposed onto a computer-enhanced mosaic of Landsat imagery of the area.

The topography, geology and geochronology, and the geochemistry of some lavas have been described for the Prince Edward islands in a book entitled "Marion and Prince Edward islands: report on the South African biological and geological expedition, 1965-1966", by E M van Zinderen Bakker, J M Winter-bottom and R A Dyer (A A Balkema, 1971). Included in this volume are topographic and volcanological maps of both Marion and Prince Edward islands.

The above two publications are listed in the bibliography at the back of this document.

INTERNATIONAL REPRESENTATION AND CONTACT

South Africa has been a member of SCAR (Scientific Committee on Antarctic Research) of the International Council of Scientific Unions (ICSU) since its inception in 1958. Although the Prince Edward islands do not fall within the Antarctic Treaty "area" (south of 60°S), they are included in SCAR's area of interest and South Africa voluntarily conducts its affairs at, and manages these islands in the spirit of the Antarctic Treaty. Bouvet and Gough islands, neither of which fall in the Antarctic Treaty area, are Norwegian and British possessions respectively. Both Norway and the United Kingdom are members of SCAR and, like South Africa, are Consultative Parties to the Antarctic Treaty, being among the 12 original signatory nations.

Contact and cooperation with other nations within the framework of SCAR has been and continues to be stimulating, especially in the SCAR Working Groups. South Africa has representatives on the SCAR Working Groups on Geology, Geodesy and Cartography, and Solid Earth Geophysics. No representation presently exists on the SCAR Working Group on Glaciology, mainly because the South African glaciological research effort in Antarctica is undeveloped.

Persons participating in the SA Antarctic Earth Sciences Research Programme are encouraged to develop and maintain close liaison with colleagues throughout the world who are involved in similar research. Participants in the programme are strongly encouraged to develop projects designed to complement each other and contribute towards the attainment of goals outlined in this document. Development of research proposals which involve cooperation or even joint participation with scientists involved in other national Antarctic research efforts is also encouraged, provided the work contributes to the goals described here.

Participants in the South African Antarctic Research Programme are encouraged, and may be supported financially, to attend the international SCAR Symposia on Earth Sciences which are held from time to time.

THE SCIENTIFIC RATIONALE FOR SOUTH AFRICAN EARTH SCIENCE RESEARCH IN ANTARCTICA, THE SUBANTARCTIC AND THE SOUTHERN OCEAN

ANTARCTICA

Earth science research in Antarctica has reached a stage when problem-oriented research can be undertaken. Present understanding of the theory of plate tectonics has indicated that particular aspects in Antarctic geology can contribute significantly to the global perspective. The relative positions of Antarctica and southern Africa in the Gondwana reconstruction suggest that both areas had a similar, perhaps common geological evolution at least between 700 and 200 Ma ago. Antarctica and southern Africa were thereafter the focus of magmatic and tectonic phenomena related to the fragmentation of the Gondwana supercontinent. Both areas therefore play key roles in understanding the deep-seated processes responsible for this disruption.

Currently accepted reconstructions of the Gondwana supercontinent have perforce been based largely on a few restricted and detailed studies. That part of Antarctica (Dronning Maud Land) in which South African earth science research has been concentrated, is believed to have lain adjacent to the east coast of southern Africa prior to the break-up of Gondwana. Whereas this general model is probably correct, uncertainty prevails concerning the precise juxtaposition of the two continental masses. High-grade metamorphic rocks cropping out to the east of the great Jutulstraumen (Jutul glacier) have yielded isotopic ages of ± 1 000 Ma, overprinted by a later low-grade thermal episode at ± 500 Ma. It could be interpreted that Antarctica was so positioned that this metamorphic terrane represents a continuation of the Namaqua-Natal tectono-thermal province. This reconstruction raises a problem with respect to the relative positions of the Archaean granitoid basement in Antarctica and northern Natal. An alternative interpretation suggests that rotation of Antarctica may have occurred during drift, in which case the metamorphic terrane may represent a southerly prolongation of the Mozambique tectono-thermal event. Resolution of this problem by means of detailed petrologic, structural, geochronologic and fission track methods would be a major contribution to understanding the process of Gondwana fragmentation.

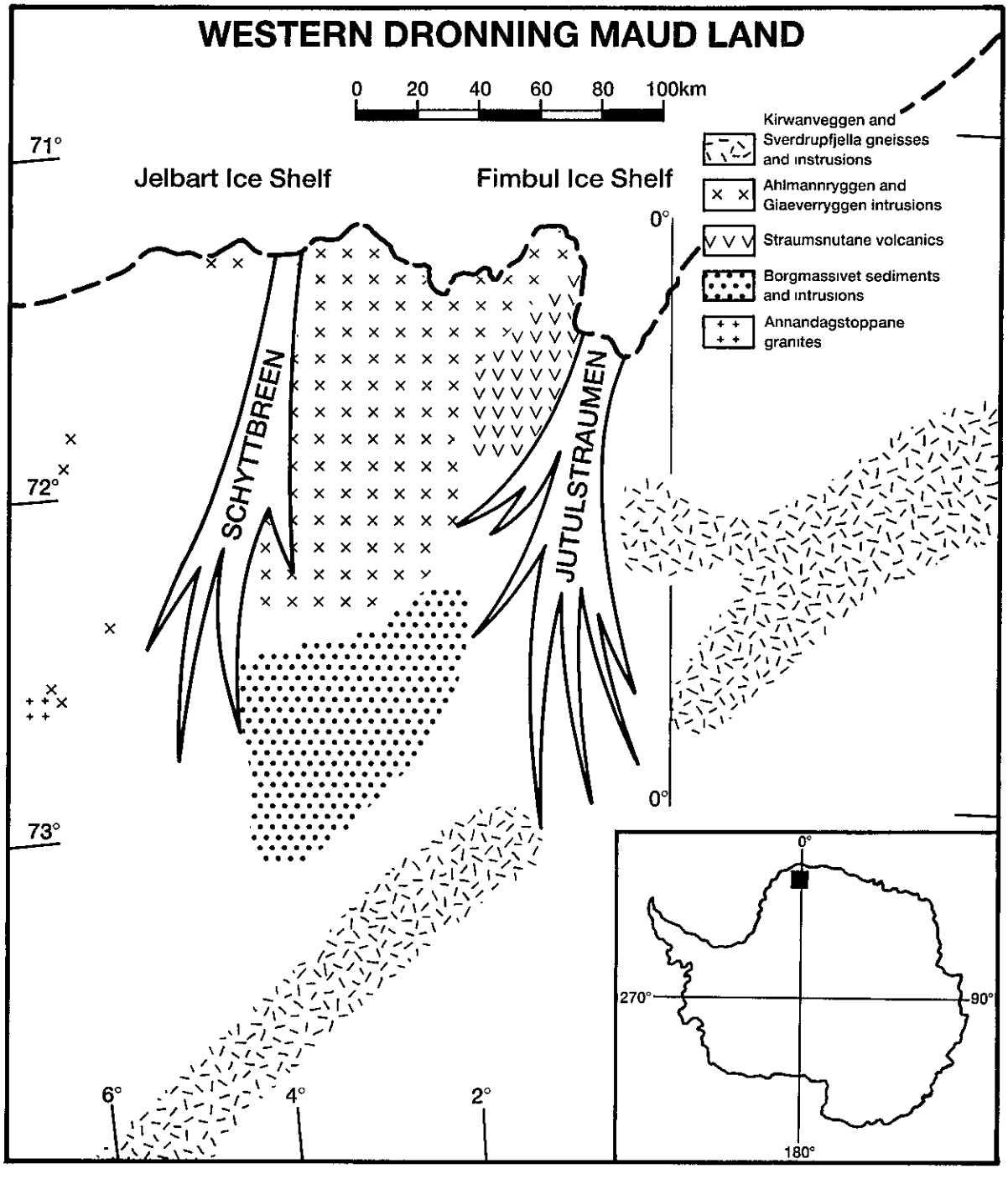

FIGURE 1. The simplified geology of western Dronning Maud Land, Antarctica.

The Jutulstraumen is a vast outlet glacier that apparently occupies a major rift-like structure, known as the Penck-Jutul Trough, that separates the high-grade metamorphic terrane lying to the east of the

Greenwich meridian from the low-grade, flat-lying sedimentary-volcanic sequences in the west. Geophysical and fission track studies across this feature would contribute to the better understanding of the structure of the trough, its sub-ice topography, and the timing of its formation. There are a number of rift structures, similar to the Penck-Jutul Trough in Antarctica, which have a radial disposition. These rifts are regarded as mantle-tapping fractures that are a fundamental feature of the structure of Antarctica. If this is so, it is important to know what role these rifts played in the evolution of the Antarctic plate.

The Jutulstraumen and the extensive Fimbul and Jelbart Ice Shelves surrounding Sanae provide opportunities for glaciological studies, including mass ice budget calculations. These investigations would be of significance to biologists and meteorologists. Variations in the mass ice budget could be used by these specialists with respect to the behaviour of species, ecosystems and climate.

The Fimbul and Jelbart Ice Shelves float out over part of the Antarctic Continental Shelf. Geophysical studies over these shelves have a special significance with respect to potential Antarctic mineral resources and would complement similar investigations by other nations of the largely ice-free areas (during summer) of the Antarctic Continental Shelf.

Rock outcrops account for only about one per cent of the surface area of Dronning Maud Land. Despite this sparsity of outcrop, the quality of those available for study provides excellent opportunities for detailed examination of a wide range of sedimentary, metamorphic and igneous rocks, which can be divided into three geological domains;

- to the east of the Greenwich meridian lies a high-grade metamorphic terrane that has suffered polyphase deformation. A basement-cover relationship can be identified and several generations of granitoid, gabbroic and syenitic magmas intrude this domain. Elucidation of the structural and metamorphic history of this terrane, together with its temporal evolution, is critical to identifying its possible correlatives on the southern African continent. In addition, such studies will provide critical information, in conjunction with geophysical investigations across the Penck-Jutul Trough, as to the nature of the boundary between this terrane and the stable cratonic domain to the west.

- at the south-western end of the Kirwanveggen, basalts of Jurassic age are preserved together with outcrops of Palaeozoic sedimentary sequences. The basalt pile thus provides an opportunity to compare its geochemical characteristics and evolution with rocks of comparable age in South Africa.

- outcrops to the west of the Greenwich meridian are composed mainly of flat-lying sediments with interbedded volcanic and volcaniclastic units. Volcanic rocks are dominant in the Straumsnutane. Some of these Proterozoic sequences are possibly, in part at least, time-equivalents of the Waterberg Group in the Transvaal. Confirmation of this correlation would contribute to the reconstruction of the palaeogeography of the Waterberg depositional basin. Detailed sedimentological studies aimed at identifying transport directions, depositional environments and provenance would assist in establishing the relative orientations of Antarctica and South Africa in addition to providing information on the older history of the Antarctic continent. A large proportion of South Africa's mineral wealth is won from sedimentary basins, the distribution and type of mineralisation being controlled by depositional environments that prevailed from time to time. The spatial association of Antarctica and southern Africa until the mid-Phanerozoic implies that studies contributing to a better understanding of palaeogeographic and depositional environments in these ancient sedimentary basins could have relevance to the identification of exploration targets within South Africa.

The relatively undisturbed sedimentary and volcanic piles are intruded by a variety of dioritic, gabbroic and noritic sheets and sills. These intrusions which are of possibly three generations will provide, through geochemical and isotopic studies, information on the nature and composition of the subantarctic mantle if the possible role of crustal contamination of the mafic rocks can be eliminated. These studies linked to those on the Jurassic volcanics and the intrusions in the metamorphic terrane will contribute to the understanding of mantle processes throughout a broad time-span. The presence of intrusions of similar ages on the southern African continent will permit comparisons to be made with this and other areas. Noting that the isotopic signatures of Jurassic rocks from opposite sides of Gondwanaland - namely South Africa as compared with Tasmania - are markedly different, it may be particularly rewarding to study the manner in which this change occurs.

The three diverse geological domains in western Dronning Maud Land thus provide opportunities for the study of a wide spectrum of phenomena that have relevance to the broader problems of Antarctic and global geology.

FIGURE 2. Highly deformed metasedimentary unit cropping out at Brekkerista nunatak, H U Sverdrupfjella, east of the Jutulstraumen. Width of photograph = 1.5 m (Photograph by A R Allen).

FIGURE 3. Several ages of dyking in strongly deformed porphyroclastic granite, Brekkerista nunatak. (Photograph by A R Allen).

Because of the very small percentage of the surface area of Dronning Maud Land which is occupied by rock outcrop, indirect methods of investigation that will permit key formations to be traced below the ice - especially such geophysical methods as aeromagnetics and radio-echo sounding - are expected to play an invaluable role.

ANTARCTICA'S MARGINS AND DRIFTING

A full understanding of the geology of the Antarctic continental margins can only be attained where the regional geology is interpreted in the context of Gondwanaland separation. The nature of the rocks on the continental margin and the sedimentation patterns initiated on continent separation influence the nature of the Antarctic shelf. This is an area of intense interest where shelf studies will add greatly to our understanding of the earliest stages in th evolution of the Southern Ocean basins. Knowledge of the sedimentary succession and structure of the shelf adjacent to the Antarctic continent will be invaluable in assessing the processes involved in Gondwanaland disruptions. Such knowledge is also important for current discussions involving Antarctica's resources.

Present knowledge of the geology of Antaractica's continental margins lacks a detailed framework for understanding the rifting between Antarctica and the continental masses of Africa, Madagascar and India. The available models cannot explain the particular sites of the rifts, their timing, or the deep- seated processes which brought about rifting. An improved understanding of these matters requires at least three kinds of research: first, detailed mapping of the Vine-Matthews anomalies and fracture zones near the edge of the Antarctic continent, the results of which should define the time and kinematics of rifting; second, a collation of 'on-shore' information (including fission track dates) regarding the Mesozoic geology of the eastern Weddell Sea and Dronning Maud Land (on the one hand) and the contiguous parts of Gondwanaland on the other; and third, research which focuses on the deep-seated foundations for the rifting of Antarctica from the rest of Gondwanaland, where the timing of Jurassic volcanism, geochemistry isotopic character and petrogenesis of Jurassic volcanism, mantle metasomatism, mantle degassing, uplifts of plateaux, etc all supply constraints on the deep physical and chemical processes.

THE SOUTHERN OCEAN

During the past 20 years geological science has undergone revolutionary change, because of the powerful new concepts of sea-floor spreading and plate tectonics. These concepts have arisen from studies of the floor rocks beneath the oceans. The rocks are usually covered by a very thin veneer of sediment, which can be penetrated by a drill rig mounted on a ship. Below the sediment there is basalt. The basalts are always young by geological standards (the oldest are about one-twentieth of the age of the oldest rocks on the continents). These facts, and the body of observations made in the ocean basins around Antarctica, are placed in a simple coherent framework by the theory of plate tectonics.

The revolution in the earth sciences began with the concept of 'sea floor spreading', where attention is focused on the long mid-ocean ridges, such as the ridge midway between South Africa and Antarctica. New hot material is continually rising to the surface at the ridge crest. The colder sea floor on the north side moves away northwards from the ridge and Africa is carried passively northwards, as if it was firmly fixed to a conveyor belt. Similarly, the sea floor on the south side moves southwards and the Antarctic continent is carried passively southwards. Most of the rock of the deep ocean floor was initially formed by volcanism at the ridge, and is termed MORB (Mid-Ocean Ridge Basalt). Elsewhere on the planet there are subduction zones, where the ocean floor plunges steeply down towards the earth's interior. The rate of destruction of sea floor, in these zones, equals the rate of creation of new sea floor at the ridges.

The volcanic rocks which form the bedrock below the sea are all very young, because the global rate of turnover (in the continued rifting, passive translation and plunging just described) is fast. The lower density continents carry rocks which are 10 to 20 times older, because they always float passively on the conveyor-belt and never plunge downward in a subduction zone. The theory of plate tectonics states that the global pattern of conveyor-belt motions can be simplified into the cap-like movements of about 20 rigid plates.

The period of revolutionary change in our basic concepts of geological processes may not be over, as there are major gaps in our knowledge, including our knowledge of the processes of generation of magma in the sub-oceanic mantle and the subsequent generation of the new oceanic crust by volcanic activity. The most abundant volcanic rocks, the mid-ocean ridge basalts, are generated in great quantity along divergent

oceanic plate boundaries, such boundaries also being the loci for hydrothermal vents from which mineral-rich solutions emerge. In contrast, the basalts and related rocks from oceanic islands, such as Marion, Bouvet and Gough, are chemically and isotopically distinct from the mid-ocean ridge basalts. These oceanic islands are located above mantle 'hot spots' that may occur within or marginal to the plates and which appear to be decoupled from plate movement. The distinctive chemistry associated with volcanism above mantle 'hot spots' has been detected in mid-ocean ridge basalts in the North Atlantic, in regions of the ridge adjacent to 'hot spots' such as the Azores. A chemical gradient in ocean ridge basalts away from such 'hot spots' has been interpreted as an indication of mixing between the two types of volcanism, with the generation of intermediate lava types. In the southern oceans there is no evidence of such mixing and, where the two types of lava occur in close proximity, their distinctive chemical characteristics are preserved. Such observations indicate that modifications are required to the prevailing models of oceanic volcanism, and these modifications should lead to a better understanding of the construction of new lithosphere from the underlying weak asthenosphere, a process which occurs at the ridge crest and at the base of the cooling plates. There is an intensive search for the mechanisms of volcanic emplacement in ridge systems and around mantle 'hot spots'. In addition, geoscientists want to understand whether the distribution of these two types of volcanism over the region may be interpreted in terms of relative motions of the African, American and Antarctic plates, and of the several 'hot spots' since the break-up of Gondwanaland and the subsequent evolution of the Southern Ocean.

SUBANTARCTIC ISLANDS

The scientific importance of geological research on the subantarctic islands derives from several factors:

Bouvet, Gough, Tristan da Cunha, Marion, and Prince Edward are probably situated above mantle 'hot spots', which appear to be decoupled from the horizontal motion of the lithospheric plates. The global family of 'hot spot' islands - which includes Hawaii, Iceland and Réunion - exhibits four striking features;

(i) as plates move relative to 'hot spots', the plates carry a trail of extinct volcanic islands or seamounts;

(ii) the 'hot spots' lie on a hypothetical frame of almost fixed geometry, so that they maintain constant angular distances from one another;

(iii) the 'hot spots' show alternating episodes of eruption and quiescence;

(iv) the 'hot spots' have a geochemical and isotopic character which is quite distinct from MORB.

In 1971 Morgan proposed that these features could be reconciled if each 'hot spot' was the surface expression of an ascending plume located in a rigid 'mesosphere', below the weaker asthenosphere which permits the plates to slide. As this simple model pointed to some fundamental deep processes occurring below the asthenosphere, it has been intensively investigated and increasingly detailed studies are currently undertaken on the composition and character of oceanic island volcanics. South African geoscientists have two additional incentives in this field - first, there is evidence of some kinship between 'hot spots' and kimberlites, and second, a combination of systematic intensive studies on the 'hot spot' islands and nearby dredged MORB samples - especially closely spaced suites located near islands such as the Prince Edward group - are likely to constrain theories of the earth's evolution. All available techniques, including trace elements, isotope ratios, volcanic gas analyses and magnetic field surveys need to be employed.

- the causes of the diversity of igneous rocks is a problem central to the science of petrology. In this respect there are striking differences among the islands under consideration - Bouvet lavas include the entire range from basalts to rhyolites but have a transitional character between alkaline and sub-alkaline; on Gough the lavas are more restricted in composition from basaltic to trachytic; Marion and Prince Edward represent a narrow range of basaltic compositions. The exact nature of the processes of partial melting, fractionation and differentiation responsible for these differences is still to a large extent unknown. Oceanic islands remote from the continents enable the petrologist to study problems of magma genesis in isolation, uncomplicated by the effects of a sialic crust.

- on Marion and Prince Edward islands exposures exist that are likely to provide a more complete terrestrial record of Upper Pleistocene chronology than anywhere else in the southern

hemisphere. Knowledge of climatic changes during the last 500 000 years is of fundamental importance to earth science but is mainly based on research in Europe and North America, and on the interpretation of deep-sea drilling. Before extrapolation to the whole earth, this knowledge should be tested and extended wherever possible. The escarpments of Marion and Prince Edward islands contain numerous datable lava flows interlayered with deposits of possible glacial and periglacial origin as well as recognisable plant remains. By combining geochronology with paleomagnetism this stratigraphic succession could also contribute to refining the Pleistocene geomagnetic polarity time scale.

- the renewal of volcanic activity on Marion Island in 1980 created a potential hazard to all forms of life including human habitation. Investigations aimed at predicting the time, location, magnitude and character of future eruptions have thus become of practical importance. In addition, South African scientists are afforded their only opportunity of studying and monitoring an active volcano on South African territory. Observation of an eruption, coupled with the detection of ground deformation and seismic events between eruptions can lead to a better understanding of the mechanisms of volcanic eruptions and ultimately of their causes.

Summary

The rationale for the extension of South African earth sciences research in Antarctica is, overall, strongly associated with the development of a better understanding of the history of the Gondwana supercontinent. Because South Africa was a constituent part of this supercontinent for about half of the geological time scale, many aspects of local geology can only be comprehended in the context of Gondwana geology. If South African scientists are enabled to retain their position as leaders in Gondwana studies through expanding their activities in Antarctica and over its margins, in the Southern Ocean south of Southern Africa and the islands which lie in this region, this will be of considerable long-term value not simply to our earth science community, but also to our understanding of Southern African geology.

COMPONENTS OF THE RESEARCH PROGRAMME

The main components of the research programme outlined below offer opportunities for a variety of research activities in Antarctica, the subantarctic, and the ocean floor in the Southern Ocean south of southern Africa. The research programme, current and envisaged, is primarily of an exploratory nature, designed to improve knowledge about these regions and thus obtain a better understanding of southern African geology and also of global phenomena such as plate tectonic movement.

For many of these components certain prime objectives have been identified. This research programme is therefore not intended to be an open effort catering for individual research interests - the restrictions placed on it, financially and logistically, necessitate optimum use of resources including manpower to work in a coordinated, multi-disciplinary manner towards these pre-selected goals.

1. Geodesy and Cartography

This component is primarily concerned with providing a service for researchers of the South African National Antarctic Research Programme who need maps of particular areas in their studies.

Prior to 1976, surveying activities in Antarctica were confined to the observation of strain traverses for glaciological research, and sun and star azimuths for navigational purposes and geomagnetic research.

The period 1976 to 1980 was devoted to planning and preparing the projects in which the newly acquired long-range helicopters were to play a major role.

The basic projects which are now being pursued are the production of 1:250 000 LANDSAT maps and 1:10 000 ORTHOPHOTO maps. The 1:250 000 maps will be used for planning and for navigation, whereas the 1:10 000 mapping will be confined to smaller areas where geologists have specific research interests;

- in western Dronning Maud Land, the 1:250 000 maps will be based on images relayed to remote sensing centres by the earth-orbiting satelite LANDSAT. They will cover the area between approximately 08°W to 08°E longitude and 70°S to 74°S latitude.

- the 1:10 000 maps for western Dronning Maud Land and the subantarctic islands, will assume a similar format to the 1:10 000 maps of the South African national map series. Aerial photographs taken from helicopters to which vibration-damped camera mountings have been custom-fitted will provide the source material for these maps.

A basic requirement for the production of reliable maps is the establishment of horizontal and vertical control points in the area to be mapped. This entails visiting the points on the ground in order to take the required survey measurements. The deployment of receiver sets tuned to signals received from the United States Navy navigation satellites is a most effective method of providing primary control in remote areas such as Antarctica. Three JMR-1 receivers are being made available by the Directorate of Surveys and Mapping for this purpose. Once these fundamental points have been fixed additional denser control for the larger scale mapping will be provided by surveyors using classical survey techniques such as triangulation and traversing.

Surveyors from the Directorate of Surveys and Mapping of the Department of Community Development organise these activities and lead the survey teams operating in the Antarctic.

2. Continental Geology and Geophysics

A number of priority research activities have been identified in this field, each with its own specific objectives. These are:

(i) Stratigraphical and Sedimentological Studies - the Ahlamannryggen and Borgmassivet are underlain by thick, relatively undeformed piles of Precambrian, clastic sediments which are intercalated with a variety of pyroclastic and volcanic rocks. The majority of these sections are exposed in vertical or steep cliff faces, but it is possible to measure accurate profiles in many places. Stratigraphic relationships are well-established in specific groups of nunataks, but there is less general agreement on correlations across longer distances.

The Urfjell and Lagfjella nunataks are composed of sedimentary sequences of Palaeozoic age. There is a need, amongst others,for the collection of sedimentological, petrographical, geochemical and isotopic data that are required for basin analysis, palaeogeographic reconstruction and

identification of provenance areas and depositional environments in both the Precambrian and Palaeozoic sediments.

The location of Mesozoic and Cenozoic sediment basins on the continental shelf will have been controlled by the presence of various basement features. It will be necessary, therefore, to identify and map onshore trends and structures which potentially could have influenced basement subsidence patterns offshore, in particular the relationship of Phanerozoic sedimentary basins to older structures. This will emphasise continuity in the geology of the whole continental margin including both onshore and offshore areas.

The main objectives are:

- to identify the provenance of the lithic fill in the sedimentary basins and the environments of deposition.

- to identify the relationships in time and space of different depositional environments in specific depositional basins.

- to identify the nature and source of pyroclastic beds in the sedimentary strata and to establish their relationship, if any, to contemporaneous volcanism.

- to establish the possible extent of the sedimentary basins.

- to identify correlations, if any, with comparable sedimentary strata in South Africa.

- to use isotopic data on sedimentary rocks to monitor the evolution of the Antarctic continental crust.

- to establish the structural and stratigraphic relationships of sedimentary basins on the continental shelf to structures on the adjoining land area.

(ii) Petrological and Geochemical Studies of Volcanic and Intrusive Rocks - these studies can be conveniently considered under three sub-sections:

(a) Areally extensive, mafic and ultramafic intrusions with minor acid to intermediate components are present in the sedimentary sequences of the Ahlmannryggen and Borgmassivet. Preliminary geochronological data suggest that there were perhaps three

periods of emplacement. Petrological and geochemical studies, undertaken in collaboration with geochronological studies, are required to identify the sequence of intrusive events and their geochemical evolution through time. Volcanic rocks of dominantly andesitic composition crop out in the Straumsnutane in addition to those that are interbedded with the sediments. Archaean granitoids form the basement on which these sediments were deposited.

(b) Thick sequences of basaltic lavas crop out in the nunataks at the south-western end of the Kirwanveggen. These rocks are of Jurassic age and could thus be related to the extensive post-Karoo volcanism in South Africa. Little is known of their detailed petrology and chemistry or of their similarity, if any, to South African basalts of Jurassic age.

(c) The area to the east of the Jutulstraumen is a crystalline, high-grade metamorphic terrane into which plutonic rocks have been intruded. These include various granitoids, syenites and layered gabbro-anorthosite massifs. Some of these intrusive magmas were generated in the mantle but others are the products of partial melting of crustal rocks. This part of Dronning Maud Land provides unrivalled opportunities for the study of the genesis and evolution of these intrusive magmas. Geochronological studies will be a requirement to complement the petrological and geochemical investigations.

The main objectives are:

- to establish the extent and number of intrusive events in the Ahlmannryggen and Borgmassivet.

- to identify their geochemical evolution and relationship, if any, to the volcanic rocks and draw conclusions concerning mantle compositions with time beneath Antarctica.

- to study mechanisms of intrusion into wet sediments and the chemical interactions between magma and sediment under these conditions.

- to establish the age and genesis of the Archaean granitoid basement.

- to establish the processes by which the granitoid, syenitic and mafic magmas, intrusive into the high-grade terrane, were generated.

- to establish the time-sequence of these intrusive events and their relationship to the metamorphic and structural history of the high-grade terrane.

- to trace the petrological and geochemical evolution of the Jurassic volcanic rocks.

- to identify, if possible, mantle processes responsible for the disruption of Gondwana in relation to the Jurassic volcanism.

(iii) Structural and Metamorphic Studies - the flat-lying sediments of the Borgmassivet are separated from the high-grade metamorphic terrane by the rift-like Penck-Jutul Trough. Polyphase deformation has affected the metamorphic rocks. A major tectono-thermal event, identified in the southwestern Kirwanveggen, affected the metamorphic rocks at ± 1 000 Ma, and there is also evidence of a later resetting of their biotite Rb-Sr isotopic systematics at ± 480 Ma. The 1 000 Ma event post-dates the deposition of the Precambrian sediments lying to the west of the Penck-Jutul Trough. Mild deformation has affected these sediments which show evidence of low-grade metamorphism adjacent to the Penck-Jutul Trough. Cataclastic rocks in the high-grade metamorphic terrane adjacent to the eastern flank of the Penck-Jutul Trough are reported to show regressive metamorphism at ± 590 Ma (K/Ar). Structural and metamorphic studies, complemented by geophysical investigations and fission track studies, are necessary to attempt to resolve the nature of the boundary between the highly deformed metamorphic rocks and the sediments.

Within the metamorphic terrane there is evidence for a basement-cover relationship. Detailed structural and metamorphic studies are required to establish the significance of this relationship.

The main objectives are :

- to attempt to establish the nature of the boundary between the mobile and stable crustal fragments. Biotite ages can aid recognition of distinct metamorphic provinces. These can possibly be related to distinct micro-plates in ancient accretion zones.

- to identify the timing of the formation of the Penck-Jutul Trough and its significance with respect to the crustal evolution of Antarctica.

- to establish the sequence of metamorphic events east of the Jutulstraumen and the temporal relations of the various intrusive events to the metamorphic events.

- to attempt to establish the original nature of the metamorphic rocks to determine whether they could represent tectono-thermally reworked equivalents of any of the sediments and associated volcanics.

- to trace geochemical changes accompanying prograde and retrograde metamorphism.

- to establish the structural evolution of the high-grade terrane.

- to compare and contrast the tectono-thermal history of the high-grade terrane with possible equivalents in South Africa.

(iv) Geophysical Studies - the goal of these studies will be a fundamental understanding of the principal geological features and events within the various geological domains of western Dronning Maud Land. The significance of the boundaries between the main crustal sectors will receive concentrated study. The geophysical studies should also improve insights regarding the principal glaciological features of the region.

The main components of the planned geophysical programme are:

- Isotope geophysics - radiometric age measurements on the various strata occurring to the south of Sanae have been referred to several times in regard to stratigraphic, geochemical, structural and metamorphic studies. Knowledge of the time of formation of various major rock units is important, not only for these individual disciplines but also for a broad understanding of the geological evolution of Dronning Maud Land as a whole. These isotopic studies should be carried out in an integrated manner, involving isotope geophysics and the other components listed below.

- Aeromagnetic mapping - this is expected to provide information on the delineation and interpretation of geological structure, demarcation of margins between major geological domains, ice thickness, location of new intrusions, and will generally facilitate geological mapping in ice-covered areas. An important product of aeromagnetic surveys will be a group of contoured (and coloured) maps of the magnetic field intensity, which would provide the basis for interpretation. The surveys should extend across the ice-shelf to the edge of the continental shelf, in order to delineate the magnetic character of the continental shelf and margin.

- Palaeomagnetic studies - the existing base of palaeomagnetic knowledge needs to be greatly extended by systematic sampling of the principal stratigraphic units. Such data are essential for accurate interpretation of the aeromagnetic maps. When used together with the age measurements, the data should permit deduction of 'apparent polar wander plots' which are in the vanguard of current earth science research. These data will also greatly facilitate geological correlation and are essential in tracing the assembly and break-up of the former supercontinent of Gondwanaland.

- Radio-echo soundings - conducted in a regular grid pattern such that maps of sub-ice topography can be compiled. This is essential for glaciological research (dealt with under Section 5 of this chapter).

- Gravity - gravity data are of particular use in delineating bedrock topography in areas, such as Antarctica, where the overburden is of uniform density and shows large contrast with the bedrock. Such data would therefore be a valuable supplement to ice-thickness determined aeromagnetically or from radio-echo soundings. Regional gravity surveys are invaluable for the location and study of the boundaries between crustal blocks of different character.

  In addition, local gravity surveys will be of value in delineating the structure and size of dense geological units such as the intrusive suites.

- Seismology - the location of the Sanae seismological observatory is ideal for recording earthquakes in the seismologically active mid-ocean ridge region of the south Indian and Atlantic Oceans.

The establishment of a second observatory on Marion Island would greatly add to the recording potential. The possibility of mounting an additional observatory at Grunehogna to record relatively small events within the crust due to major ice movement (eg along the Jutulstraumen) or other causes should also be considered.

In some areas ice thickness may exceed the limits of the radio-echo sounding method. The possibility of utilising explosion-based seismic refraction or reflection techniques should be investigated.

3. Continental Margin Geology

At present, South African research workers are active on the land area of Antarctica, and in the adjacent parts of the Southern Ocean. However, no systematic work is being done on the intervening continental shelf of Antarctica in the vicinity of Sanae, although other SCAR nations have made preliminary surveys.

For a full understanding of the post-Permian geological history of Antarctica, and in particular its relative location within and subsequent separation from other parts of Gondwanaland, a knowledge of its continental shelf and slope area is essential. To do this, a detailed bathymetric map must be constructed and a systematic geophysical survey of the continental shelf, slope and immediately adjacent ocean floor carried out. Because of extensive glacial debris cover of the sea floor, geophysical surveys must be made before meaningful geological sampling can be attempted. Ideally, these surveys will consist of multichannel seismic profiling, magnetometry and gravimetry, but in practice single channel seismics and magnetometry are all that can be realistically planned with present facilities.

Apart from documenting the structure and sedimentary succession of the continental margin between, say 10°W and 10°E, the initial scientific targets will consist of identifying the nature of the continental edge (ie sheared, or pull apart) to test various palaeogeographic refits of Gondwanaland. For example, it is possible that west of 0°, the margin could be structurally analogous to the Agulhas Fracture Zone (SE Africa), whereas east of 0° structures similar to those off SW Africa (Namibia) may occur. This knowledge is vital to proceed further with models for reconstructions that locate this part of Antarctica to SE Africa and the Falkland Plateau.

At the same time, work would be aimed at identifying specific structural features that correlate with analogues on the west Gondwana side of the refit. Information gained in this work would also assist in understanding the structure and geological history of continental and oceanic features off southeast Africa.

The main objectives are :

- to delineate Mesozoic sedimentary basins and establish an acoustic stratigraphy for the succession. If possible to relate this to the sedimentary history of the continental shelf.

- to delineate the main structural and basement features under the continental shelf and, where possible, correlate these with onshore analogues in Antarctica.

- to delineate the continent/ocean boundary (COB) and establish the relationship of structures adjacent to the COB to features on adjacent ocean crust, and their role in continental separation.

4. Open Ocean Geoscience

This component has two interrelated goals. The first goal is to trace accurately the history of the sea-floor spreading which took South America, Africa, Madagascar and India away from their former positions contiguous to Dronning Maud Land. The second goal is to use this dispersal history to develop a more comprehensive understanding of the physical and chemical processes at the ridge crest. A consistent model for the generation and dynamics of 'hot-spots' will also be sought. In this respect, special emphasis will be given to studies on the Prince Edward, Gough and Bouvet islands. There will be a concerted attempt to reconstruct the geological and petrological history of these islands, from the time that the first volcanic rocks were deposited above sea level to the present.

In summary the main objectives are :

- to reconstruct the geology of the former supercontinent of Gondwanaland

- to interpret variations in velocities and rotation poles for the spreading ridges involved, throughout the Mesozoic and Cenozoic Eras.

- to interpret the detailed movement of triple junctions and 'hot-spots', and improve on the understanding of these features in global tectonics

- to obtain an understanding of the geochemical evolution of Southern Ocean lithosphere and asthenosphere since the break-up of Goldwanaland,

- to make use of the gains in the above four objectives, in seeking the basic mechanics for the break-up of Gondwanaland.

The studies needed to achieve these goals can be grouped as follows:

(a) Study of the composition of basalts dredged from a great length of the circum-Antarctic ridge system (18°W to 25°E), from the southern end of the Mid-Atlantic Ridge and from ocean islands and associated sea mounts in the Southern Oceans. A wide range of geochemical and isotopic tracer elements can be used to evaluate the geochemical nature and evolution of the Southern Ocean Lithosphere and associated mantle plumes.

(b) study of the palaeomagnetic parameters of the basalts referred to above.

(c) mapping of the magnetic field intensity, with bottom and sub-bottom topography, from the ridge crest to the margins of the Gondwanaland continents.

(d) study of the Pleistocene succession at the Prince Edward islands, the first step being the measurement of stratigraphic sections along coastal and inland escarpments in order to establish the number and thickness of units like lava flows, tills, tephra layers, peat and palaeosol. Special efforts need to be made to reach the deepest and therefore oldest possible level of the pile, and to effect a correlation between sections at different localities. Sampling of as many lava flows as possible with a view to K-Ar dating, palaeomagnetic determinations and geochemical analysis will compromise an important component of this study, as will geological observations that would help in deciding whether the flows were subaerial, submarine or subglacial, or perhaps intrusive rather than extrusive. The sedimentology of the intercalated fragmentary deposits also require detailed study in order to deduce their origin.

Since fluvial erosion did not play a significant role in the sculpturing of these islands, the existence of vertical exposures must be properly explained - whether they are due to marine erosion, glaciation, tectonic movement or any combination of the three. If the escarpments represent radial and perhaps even concentric faults, as has been suggested, their actual and relative displacements should be determined and the events placed in correct chronological order. The effects of isostatic adjustment and eustatic changes of sea level must be taken into account.

The numerous black lava flows and their associated scoria cones belonging to the Holocene epoch have only been mapped on a reconnaissance scale and placed in four preliminary age groups. As soon as accurate topographic base maps become available it will be necessary to prepare a detailed volcanological map on which each individual flow is distinguished. Methods for dating these flows should be tested and applied if possible (eg the method based on secular magnetic variation). A detailed geochemical study of these lavas and their comparison with the older volcanics are likely to reveal subtle differences and evolutionary trends that could be of fundamental importance.

(e) Integration of data from (a), (b), (c), (d) above, in order to develop a general model for the physical and chemical processes at the ridge crest and at 'hot spots', which is consistent with other world-wide data relevant to these problems.

(f) Collation of phenomena which are precursive to, or synchronous with, separation of continental masses from Dronning Maud Land and analysis of data relevant to mechanics of disruption.

In dealing with the Triassic and Jurassic Periods, particular attention should be given to developing a model in which the volcano-tectonic evolution of the eastern part of southern Africa (Nuanetsi, Lebombo and Stormberg provinces), the evolution of the continental shelf basins, the early "leaky transform" stage of the Mozambique Ridge and the early rifting of the Dronning Maud Land coast can be understood.

In dealing with the Late Jurassic, Cretaceous and Tertiary Periods, particular attention should be given to those ocean floor tectonic features which provide decisive evidence concerning the presence or absence of fracture zones and 'hot

spots' and also to the development of a model in which these features and alkalic provinces on the southwestern fringe of Africa, in Madagascar, on Kerguelen and on the fringe of Antarctica can be comprehended in an integrated way.

The detailed gravity field for the oceanic regions is expected to be a valuable adjunct for the above studies.

(g) Mapping of the character of the sediment and crust in the deep sea through seismic reflection measurements. Interpretation of these reflection profiles in the framework delineated under (e) and (f) above.

5. Glaciology

The main purposes of glaciological studies are to determine the sub-glacial topography of accessible sectors of the Fimbul Ice Shelf and the movement of this shelf and the Jutulstraumen and its tributary ice streams. By measuring certain aspects of bottom roughness, it is now possible to draw conclusions about the bottom geology. It is also possible to contribute to the knowledge of the mass ice balance of this part of Antarctica by studying the mass transport of the ice streams. Radio-echo sounding is the main technique involved in these studies.

The main objectives are:

- to continue the mass budget studies of the Fimbul Ice Shelf and the inland ice, with particular reference to the Jutulstraumen and its tributary ice streams.

- to continue the determination of sub-glacial topography, especially beneath the Fimbul Ice Shelf.

ORGANIZATION AND ADMINISTRATION OF THE RESEARCH PROGRAMME

Research in the Antarctic is coordinated internationally through the Scientific Committee on Antarctic Research (SCAR) of the International Council of Scientific Unions (ICSU). The Council for Scientific and Industrial Research (CSIR) adheres to SCAR on behalf of South Africa and coordinates the South African Antarctic Research Programme through the South African Scientific Committee for Antarctic Research (SASCAR).

The SASCAR Subcommittee on Earth Sciences guides and coordinates the Antarctic Earth Science Research Programme. It comprises the leaders of the various 'suites' of projects which constitute the research programme, a number of other non-participating experts in the fields of research being undertaken, representatives of the Department of Transport (Antarctic Section) and the Scientific Coordinator and secretarial staff from the 'SASCAR office' of the CSIR. Financial and logistical support are provided by the Department of Transport, on the advice of SASCAR and its Subcommittee on Earth Sciences.

SCIENTIFIC COORDINATION

The overall research programme is managed by a Scientific Coordinator at the Cooperative Scientific Programmes (CSP) unit of the CSIR. The institutions which participate in the programme are themselves responsible for project budgeting and the internal administration of their research personnel and allocated funds.

Participants in the South African Antarctic Earth Sciences Research Programme are expected to maintain close liaison with each other. Laboratory, domestic and field facilities, available at Marion island, at Sanae and Grunehogna and aboard the SA AGULHAS, are shared by all participants.

Maintenance of research standards and progress is largely the responsibility of the project leaders. SASCAR, on the advice of its subcommittees, have a degree of guardianship over these aspects as well and can withdraw support from projects if it is felt that suitable progress and sufficient standards are not being maintained.

Local workshops and symposia on selected topics can be arranged, participants are sent to international SCAR or SCAR-related workshops, symposia and conferences when appropriate, and when possible overseas experts are brought to South Africa to visit researchers in the field or at their home bases.

PARTICIPATION IN THE PROGRAMME

Participation in the South African National Antarctic Research Programme is not confined to any particular research groups. Individuals or groups of researchers from any academic or scientific organisation in South Africa are free to submit research proposals, provided they are designed to contribute towards the main objectives described in this document. These are considered by the SASCAR Subcommittee on Earth Sciences in free and fair competition with each other and in terms of the needs of the programme as a whole. If approved, projects are funded for fixed periods - normally between three to five years - provided satisfactory progress and standards are maintained.

New projects are incorporated into the programme as and when funds become available. Usually, this occurs when current projects are brought to completion.

Research proposals are submitted annually to CSP through the proposer's own research administration, by 30 June. The proposal is prepared on the CSP NP10 form, obtainable from the Scientific Coordinator or from university Registrars. Proposals take two forms - the first and original "project proposal", describing the objectives, intended duration, techniques to be used, cost analysis, motivation and work plan of the project, and "follow-up proposals" submitted in each subsequent year of the project's duration.

New proposals may be sent out for review and are then considered by the SASCAR Subcommittee on Earth Sciences, usually about September each year. The recommendations of this subcommittee are then referred to SASCAR which meets annually, usually in October/November, for final approval.

Applicants are subsequently informed of the amounts they have been awarded for their projects, if any, usually in December/January. Funding is based on the financial year 1 April to 31 March. New or follow-up proposals submitted in June are therefore considered for

funding from 1 April the following year to 31 March the year after. Funds are budgeted for and allocated on a yearly basis and cannot be carried over into the next financial year. An audited financial statement for the previous financial year is required by the Department of Transport.

Proper preparation of new and follow-up proposals is essential. Participants are advised to consult with the Scientific Coordinator prior to their preparation, particularly with regard to the preparation of budgets and work plans. Proposals that indicate insufficient familiarity with past and current work or with the objectives for future work set out in this document, and a lack of attention to experimental design, key questions, duration and costing, will not be accepted for consideration.

A handbook, known as the "Antarctic Programme Manual", detailing procedures to be followed by project leaders with respect to the selection and appointment of research staff, salary scales, payment of bonuses and daily allowances and general financial administration is available from the General Section (Antarctic Division) of the Department of Transport. This manual is updated periodically as procedures change and salary scales are reviewed. Project leaders are expected to operate according to these procedures.

PROGRESS REPORTS

Progress reports, covering the previous 12 months from July to June, are required with each follow-up proposal. They provide a means to assess scientific progress over the previous year and are therefore important supporting documents. A set of guidelines for the preparation of these reports is available from the Scientific Coordinator.

All progress reports submitted to SASCAR are distributed to participants in the South African Antarctic Research Programme and to members of SASCAR and its subcommittees, in the form of an annual volume of "Progress Reports to SASCAR". These volumes provide participants with an insight into all research projects in the National Antarctic Research Programme.

LOGISTICS

The General Section (Antarctic Division) of the Department of Transport is responsible for administrative control and financial and logistical support for the national Antarctic research effort. The research funds allocated by SASCAR are obtained from this Department. Provision and maintenance of laboratory equipment and special scientific supplies are the responsibility of the participating researchers. The Department of Community Development is responsible for the construction and/or maintenance of base station buildings.

The South African Antarctic research/supply ship, the MV SA AGULHAS, based in Cape Town, usually visits Marion Island twice annually. The first and longest visit, usually lasting three to six weeks, takes place in autumn (April/May) and is the annual relief voyage. The second visit, generally of much shorter duration, usually takes place in spring (August/September) or summer (November/December). The ship visits Gough Island once annually for the relief exercise, usually in early summer (October/November) and the visit lasts three to six weeks. In December/January each year it sails to Antarctica for the annual relief of the Sanae station (70°18'S, 02°24'W) on the Fimbul Ice Shelf, Dronning Maud Land and the voyage lasts from six to 10 weeks. Following the off-loading of expedition personnel, construction/maintenance personnel, observers and supplies at a base station, the ship then normally proceeds on oceanographic surveys. On completion of this work, it returns to the base to collect homeward-bound personnel and then proceeds back to Cape Town.

The outward and inward voyages between the research stations and Cape Town are in themselves valuable opportunities for field-work. Occasionally special research cruises, which do not detour via any of these base stations, can be arranged for specific purposes. Due to the ship's base station relief schedule, such cruises are normally confined to the winter period between May and August. The SA AGULHAS is the only platform regularly available to South African scientists for field-work in the Southern Ocean.

Researchers and field assistants intending to stay at the stations between relief voyages are required to undergo medical examination and aptitude and adaptibility tests before their appointment can be confirmed. They are also required to attend an orientation course prior to departure. These courses take place in February/March (for Marion Island), August/September (for Gough Island) and November/December (for

Sanae). The Department of Transport organizes these courses. Those visiting the stations for the duration of the relief periods only are not normally required to undergo the selection tests but they are advised to undergo a medical examination for their own benefit. For the members of the summer earth science expeditions to Antarctica, the Antarctic Research Officer (geology), together with the Department of Transport and the South African Air Force, organizes pre-departure training in climbing, first-aid, radio communications, helicopter procedures, maintenance of skidoos and other useful field techniques.

A field base at Grunehogna (72°01'S, 02°47'W), erected during the 1982/83 summer season for the earth sciences programme, provides a staging base for researchers. This base is some 200 km inland from Sanae and lies in the Ahlmannryggen. Field workers are flown into the base from Sanae to collect their field equipment and skidoos, which are stored there over winter, and they are then either airlifted or travel oversnow by skidoo to their target areas for the season. Periodically they can be re-supplied by air or brought back for a rest to Grunehogna. At the end of the season the field base is closed. Field-workers with their samples (and field equipment in need of repair) are then flown back to Sanae where they join the ship and return to South Africa.

TITLES OF CURRENT PROJECTS

Department of Geology, University of Natal, Pietermaritzburg

- Geochemistry and petrology of the Ahlmannryggen, ending March 1985.
- Study of the metamorphic and plutonic rocks of the Sverdrupfjella, ending March 1987.

Department of Geology, University of Stellenbosch, Stellenbosch

- Sedimentologic-stratigraphical investigation of the Högfonna, Raudberget and Fassettfjellet formations in the Borgmassivet, ending December 1984.
- The Pleistocene stratigraphy and volcanology of Marion Island,ending March 1985.
- Sedimentologic and stratigraphical investigation of the sedimentary formations in the Ahlmannryggen, ending December 1985.

Departments of Geochemistry and Geology, University of Cape Town, Cape Town

- Southern Ocean lithosphere project, ending March 1986.
- The geochemistry of Jurassic basalts of the Kirwanveggen, Dronning Maud Land, and their significance for Gondwana volcanism in relation to plate rectonics.

Bernard Price Institute of Geophysical Research (BPI), University of the Witwatersrand, Johannesburg

- Investigation, by the fission track dating method, of Gondwanaland break-up and the spreading of Antarctica from southern Africa, ending March 1986.
- Geochronologic and isotopic investigations of crust-mantle evolution in Queen Maud Land, Antarctica and in subantarctic islands, ending March 1984.
- A study of the Africa-Antarctica plate boundary, ending March 1986.
- The palaeomagnetic and aeromagnetic interpretation of the areas surrounding the Jutulstraumen, Queen Maud Land, Antarctica - a feasibiity study, ending March 1984.

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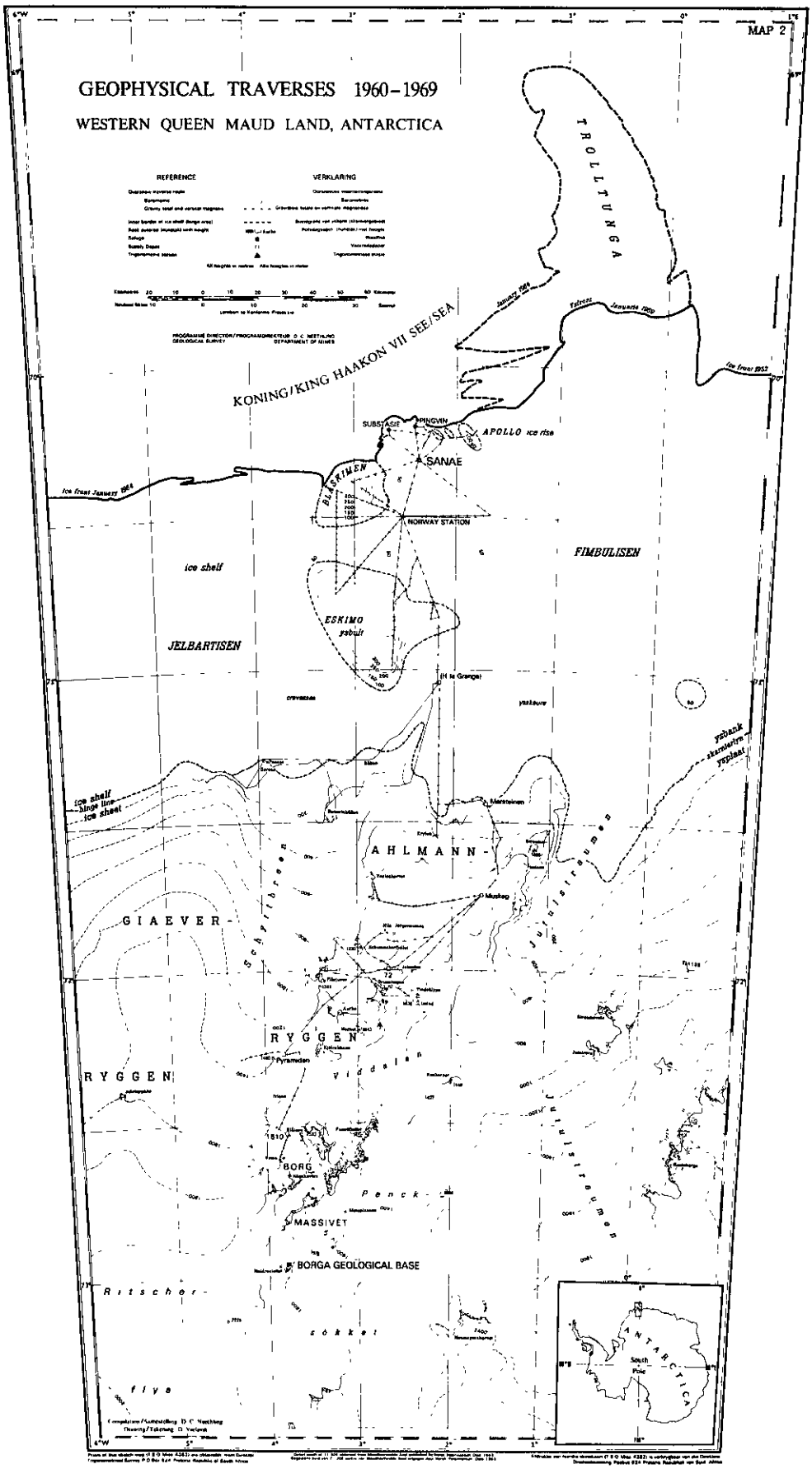

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