# GEOPHYSICAL INVESTIGATIONS IN THE SCOTIA ARC AND GRAHAM LAND

*By* D. H. Griffiths*

In 1959 the Falkland Islands Dependencies Survey agreed to collaborate with the geophysics section of the Department of Geology, University of Birmingham, by providing facilities for carrying out geophysical surveys in the areas of Antarctica and the surrounding waters in which they operated. The Survey had already begun magnetic surveying in north-east Trinity Peninsula, mainly as an aid to geological mapping, but the proposed investigations were to be on a larger scale, and were mainly intended to obtain information about the structure and composition of the Earth's crust, particularly in the Scotia Arc.

A start on this programme was made in the Antarctic season of 1959–60. Using a Worden gravimeter (No. 14, loaned by Professor G. P. Woollard, University of Wisconsin), gravity differences were measured between the various Survey bases, and a connection was established between this network of stations and a gravity station at Buenos Aires (Ezeiza international airport), where the absolute value is known. The connection was made by sea via Port Stanley in the Falkland Islands and Montevideo.

In the Antarctic territories measurements were made wherever possible by landing from a small boat. During the first season (1959–60) both R.R.S. *Shackleton* and R.R.S. *John Biscoe* took part in this survey. In the following seasons (1960–61 and 1961–62) the gravity measurements at the Survey bases and the link with Buenos Aires were repeated whenever possible to improve the accuracy of the network. More secondary stations were also occupied. (A new Worden Master gravimeter, No. 556, belonging to the Survey, was used.)

In 1959–60 a proton precession magnetometer loaned by Imperial College, London, was towed behind R.R.S. *Shackleton* and a number of magnetic profiles were obtained across the Bransfield Strait. Unfortunately, a lot of time was lost due to leaks developing in the casing of the towed detector, but this was remedied before the next season, during which the instrument worked satisfactorily and a number of long traverses were measured. In 1961–62 the magnetometer was replaced by a new instrument manufactured by Bruce Peebles Ltd. of Edinburgh, and loaned to us by the Department of Scientific and Industrial Research. This instrument has been continuously operated since, whenever the ship has been on passage in open water.

Five short seismic refraction lines were surveyed during the 1961–62 season with the help of H.M.S. *Protector*, which acted as firing ship, R.R.S. *Shackleton* receiving. A much longer traverse across the Scotia Sea has been successfully surveyed in the 1962–63 season.

A summary of the work done so far is given in the following sections.

## Gravity Survey

Fig. 1 shows the principal area covered by the gravity survey in the South Shetland Islands and Graham Land region. A number of stations have also been occupied in the South Orkney Islands, South Sandwich Islands and in South Georgia, and at present the survey is being extended down the east coast of Graham Land as far south as the Churchill Peninsula. In all about 150 stations have been occupied, all in coastal regions, either on the mainland or on islands, and most of them are within a few feet of sea-level. The stations have a reasonably uniform distribution. Those at the occupied Survey bases have been clearly marked and can be reoccupied. With the exception of a few outlying stations the gravity differences measured between points on the Graham Land coast, the adjacent islands and the South Shetland Islands are likely to be correct to within a few tenths of a milligal. The absolute values of gravity for these stations depend on the quality of the link between Antarctica and South America. The estimated standard error of this link is less than 2 mgal, but a rough comparison with gravity values measured by the Argentinians, based on pendulum measurements at "Esperanza" [Hope Bay], shows a discrepancy of about 10 mgal. Since our values depend on two long links measured by a Worden gravimeter carried on a ship, they may have a large

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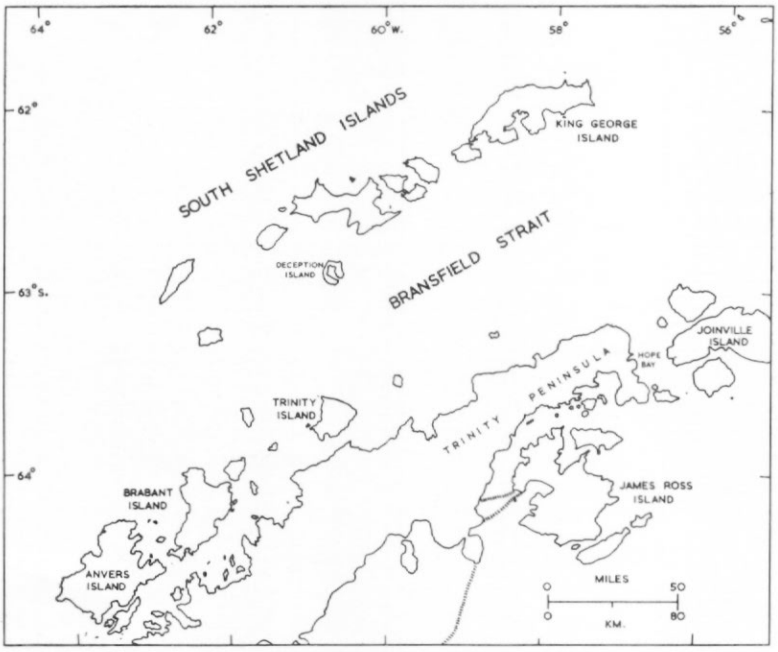


Fig. 1. Sketch map showing the principal area covered by the gravity survey.

systematic error, but there seems no reason why this should be so, particularly because there is agreement between measurements taken in different years with two different instruments.

In the northern part of Graham Land and the South Shetland Islands the general pattern of the Bouguer anomalies appears to be simple. The contours follow a trend which is similar to that of the main geological structure, the regional gradient being from the south-east to the north-west. The values are all positive, and culminate in a high of greater than 100 mgal over the South Shetland Islands.

## Marine Magnetic Survey

A considerable amount of the time spent by R.R.S. *Shackleton* in Antarctic waters is employed relieving Survey bases. For this reason most of the magnetic measurements have been made in the course of the ship's regular duties. However, deviations from normal routes, often considerable, have been made to obtain better cover of the area, and it has been possible to carry out systematic surveying in a few areas of particular interest. A bathymetric record has been kept at all times.

It has not been possible to make any correction for diurnal variation, but the data have been corrected for secular change mainly using measurements made at the magnetic observatory in the Argentine Islands.

Fig. 2 shows the major traverses along which magnetic measurements have been made. Traverses in the Bransfield Strait and off the north coast of the South Shetland Islands are relatively numerous, and it has been possible to draw a contour map of this area showing the major anomalies.

Traverses across the Scotia Sea show magnetic features typical of oceanic regions. There is often a regular succession of anomalies with peak to trough amplitudes of as great as 400 gammas and wave-length of about 10 miles (16 km.). A few areas, such as the Burdwood Bank, are magnetically smooth, and no marked anomalies have been observed in crossings of the deep trenches associated with the island arc, for example, the Meteor Deep.

Individual traverses were rarely closer than 40 miles (64 km.) and it has not been possible to correlate individual anomalies from one traverse to the next. However, it has been found

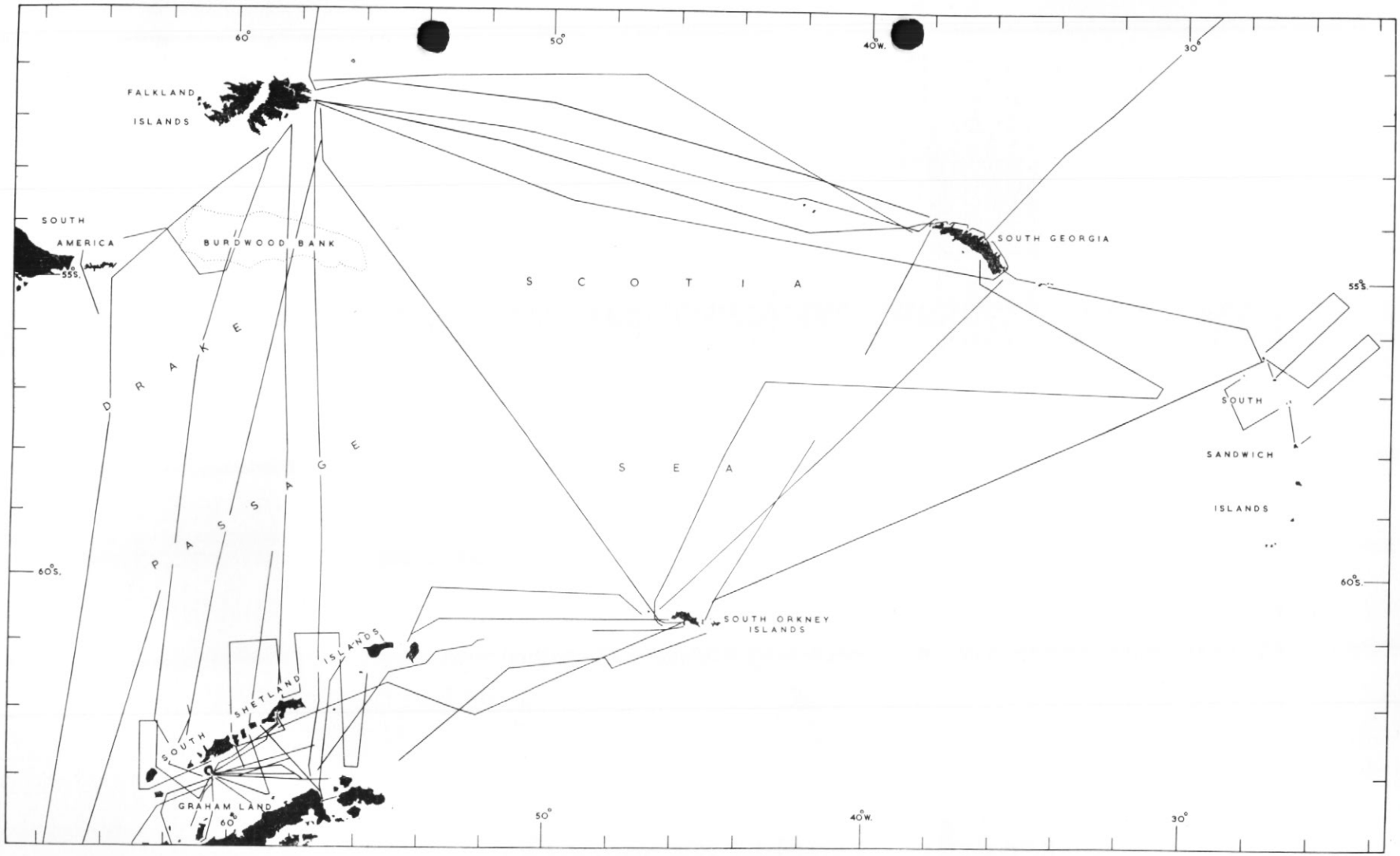


Fig. 2. Sketch map of the Scotia Arc showing the main traverses along which magnetic measurements have been made.

that the character of groups of anomalies on a particular traverse could be correlated with those of adjacent runs, and by this means it has proved possible to divide the region into areas of different and sometimes sharply contrasting type. The character of an anomaly has been defined by three measurements, its peak to trough amplitude, the horizontal distance between these peaks, and a "depth index" defined as the horizontal distance between the points of half-maximum gradient. The possibility of correlation by this method probably depends to a considerable extent on the traverses correlated having the same general direction and roughly constant relationship to the geological structure. The fact that in the open oceans the lithology and structure of the sea floor is likely to be relatively uniform over large areas is probably also important.

It has not been possible to identify the source of the anomalies with any certainty, but a study of the major anomalies in the Drake Passage area, where the traverses appear to run at right angles to the structures, suggests that they may be interpreted as due mainly to a sub-bottom topography of basic igneous rocks, possibly lavas, buried by sediments. Making the reasonable assumption that the topography is limited to about 0·75 miles (1·2 km.) in height, this implies that the rocks have an intensity of magnetization of about $5 \times 10^{-3}$ c.g.s. units. The alternative acceptable interpretation is that the anomalies are due to very widespread intrusion of the crustal layers by bodies with steep sides and an average width of about 2 miles (3·2 km.).

## Seismic Surveys

In the 1961-62 season very simple equipment was used for seismic surveys. An arrangement of four hydrophones was suspended at intervals of 200 ft. (61 m.) from a buoyant cable. The hydrophones were arranged to have neutral buoyancy and to float at a depth of about 150 ft. (46 m.). The output from each was taken to a transistor amplifier, three of these having a response of approximately 5–300 cycles. These were used to detect the ground wave. The fourth channel had a higher frequency response and was specifically designed for receiving the water wave, though in practice it was found that this was adequately recorded on the other channels. A conventional galvanometer camera, loaned by the British Petroleum Co. Ltd., was used for recording. Shots were made up from naval demolition charges of T.N.T. and were electrically fired, the shot instant being relayed from H.M.S. *Protector* to R.R.S. *Shackleton* by radio. The noise level of the equipment was relatively high; the reason for this, it is thought, was partly due to unsatisfactory suspension of the hydrophones and partly to ship noise. Using the maximum charge that could be reasonably handled (200 lb.; 91 kg.), this restricted the firing range to about 15 miles (24 km.) even in fairly calm weather.

In the 1962–63 season the amplifiers have been replaced by a GTR-200 Transistor Amplifier System (made by Dresser Electronics, U.S.A.), and an ultra-violet paper recorder (made by New Electronic Products Ltd.) was used for recording. Although more attention has been paid to hydrophone suspension, the noise level is still comparatively high, but by using 300 lb. (136 kg.) T.N.T. depth charges a range of 36 miles (58 km.) has been achieved in calm weather.

Fig. 3 shows the location of the seismic lines surveyed so far. The letter "R" against the line indicates that it has been shot from both ends. A few lines were shot in the Bransfield Strait with the recording apparatus on land. These are marked with the letter "S" indicating the position of the shore stations. These results are being interpreted at the present time and will be published shortly as a *British Antarctic Survey Scientific Report*.

## Future Work

The seismic surveys will be extended, using two ships whenever possible. As only R.R.S. *Shackleton* will be available for much of the season, she is being equipped for single-ship working. A Sonobuoy system, which is expected to be operating in the 1963–64 season, is being designed and built to our specification by G. & E. Bradley Ltd. of London. The main aim of the seismic investigations will be to obtain further information on crustal structure in the Scotia Sea and across the Scotia Arc. As more magnetic and seismic data become available it is hoped that the geological significance of the magnetic measurements will become apparent.

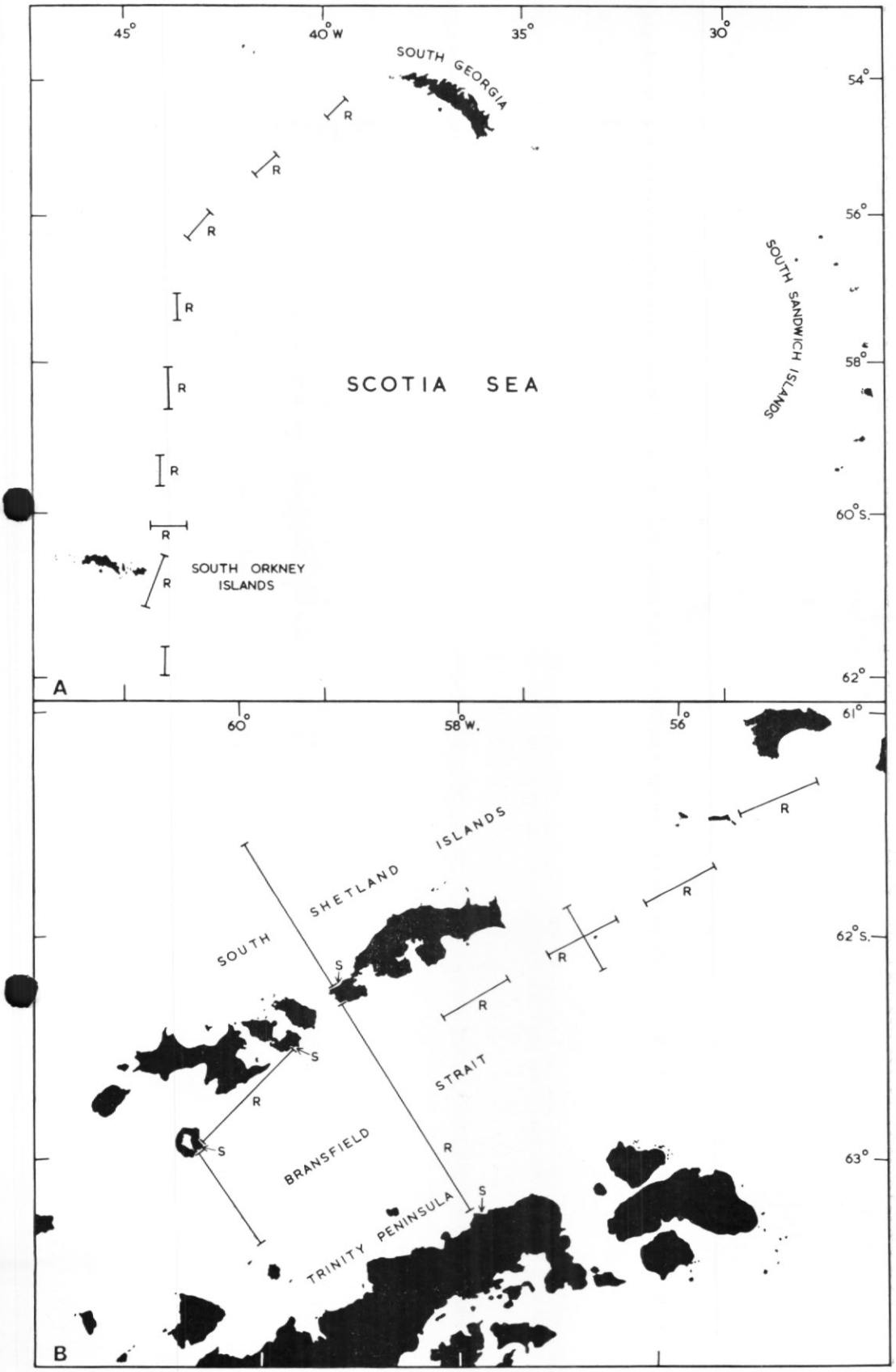


Fig. 3. Seismic refraction lines surveyed in the 1961–62 and 1962–63 seasons:
A. Eastern Scotia Sea; B. Bransfield Strait area.
R. Reversed refraction line.
S. Shore-based recording station.

If this proves to be so, it should be possible to use the magnetic survey to interpolate the geological structure between the seismic lines.

The gravity survey will be extended down the east and west coasts of Graham Land and it may be possible at some future date to increase the station density in the region of the Bransfield Strait and the South Shetland Islands. Measurements of gravity at sea in this area are urgently required, but at present there is little prospect of fitting R.R.S. *Shackleton* with a gravimeter.

It is also anticipated that an investigation into the heat flow through the ocean floor will be started in the 1963–64 season and apparatus for this purpose is being prepared.

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