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ABSTRACT

AN area of about 200 square miles, covering Tabarin Peninsula and Duse Bay in the north-eastern part of the Graham Land peninsula, has been surveyed with a vertical intensity magnetometer, with the object of delineating bodies of the Andean Intrusive Suite and determining the nature of the contact between the mid-Miocene James Ross Island Volcanic Group and the ? Carboniferous sediments of the Trinity Peninsula Series. The outcrops of intrusive diorite in the northern half of Tabarin Peninsula are shown to be parts of a single intrusive body, extending over the width of the peninsula and as far south as the volcanic outcrops of Buttress Hill and Brown Bluff and northward at least as far as Mount Taylor and Blade Ridge. Three configurations of the intrusive body which explain the observed magnetic anomalies are given; the most likely form of the intrusion is that of a laccolith. The magnetic anomalies over the volcanic rocks are attributed to basalt lava flows of both normal and reversed magnetizations. Some evidence is given which suggests that the James Ross Island Volcanic Group is at least 4,000 ft. thick, but it has not been possible to determine the nature of the contact between the volcanics and the sediments in southern Tabarin Peninsula or in Duse Bay.

CONTENTS

I. INTRODUCTION

THE aims of the magnetic survey, which was carried out in 1959–60 in north-east Trinity Peninsula (Fig. 1), were:

i. To determine the extent and configuration of the intrusion or intrusions associated with the isolated Andean Intrusive Suite diorite and gabbro outcrops of Tabarin Peninsula.

ii. To determine the position and, if possible, the nature of the contact between the Trinity Peninsula Series and the James Ross Island Volcanic Group in the southern Tabarin Peninsula and Duse Bay areas.

In the northern part of Tabarin Peninsula there are a number of isolated diorite outcrops and two exposures of gabbro. In the past there have been two conflicting interpretations of these outcrops: whether they represent individual small stocks or bosses intruding the Trinity Peninsula Series, or whether they are parts of a major intrusion whose upper surface has been exposed by erosion. The work described in this report has provided substantial evidence in support of the latter interpretation and information on the extent of the intrusion. It was originally hoped that the magnetic survey would be continued into the area north-west of Tabarin Peninsula in order to determine the connection between the granitic intrusions of the Mount Bransfield area and the diorites of Tabarin Peninsula. There was insufficient time to accomplish this part of the programme, which has, however, since been carried out, and will be described in a later report. There is some form of contact between the Trinity Peninsula Series and the James Ross Island Volcanic Group in southern Tabarin Peninsula but it is ice-covered and its precise position and

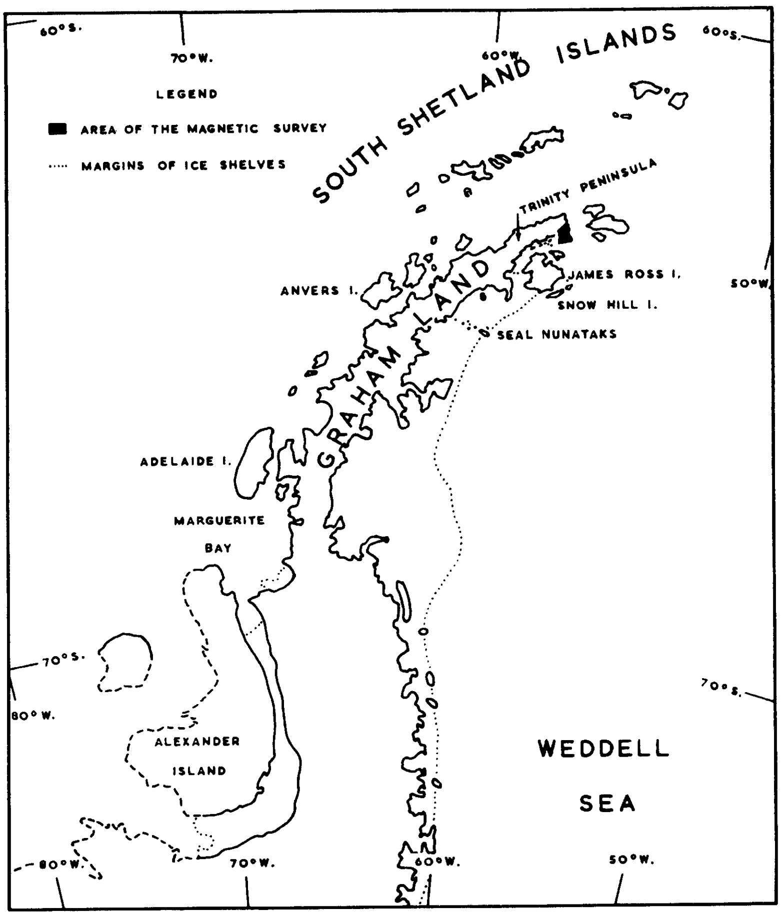

FIGURE 1

Outline map of Graham Land showing the relative position of the area of the magnetic survey (Figs. 7 and 8) (after D.C.S. 960, 1955).

nature have not yet been determined. The longest established opinion is that this contact is a major post-volcanics fault with a downthrow on the southern side and is a northward continuation of a postulated fault line or fault zone governing the position of Prince Gustav Channel. Another interpretation is that the volcanics rest unconformably against a major erosional or tectonic feature in the Trinity Peninsula Series, i.e. either a shoreline scarp or a pre-volcanics fault scarp. The magnetic survey has provided no real evidence on the nature of the contact but it has led to the conclusion that the northern boundary of the volcanics has been determined by the intrusion of the diorite in northern Tabarin Peninsula.

The survey of north-east Trinity Peninsula began at the end of February 1959 and continued intermittently until the beginning of March 1960. About 200 square miles (512 km.^{2}) (outlined in Fig. 2) were surveyed during a total period of 250 days in the field. The reasons for the slow progress of the work were principally the bad weather (on 129 complete days of the field period no work was possible due to the weather) and the difficult nature of the terrain.

In the survey, differences in the vertical component of the Earth's magnetic field were measured between points about 0·75 miles (1·21 km.) apart with an Askania Gfz torsion magnetometer. These differences were evaluated relative to the magnetic field values at 8 base stations which were distributed uniformly within the survey area. The magnetic field values at the base stations were determined by accurately measuring the difference in magnetic field between adjacent base stations and assigning the arbitrary value of + 200 gammas (1 gamma = 10^{-5} oersted) to one of the base stations. In converting the Gfz magnetometer readings into magnetic field values several corrections were necessary; one of these was for the diurnal variation of the vertical component of the Earth's magnetic field. To measure this variation an

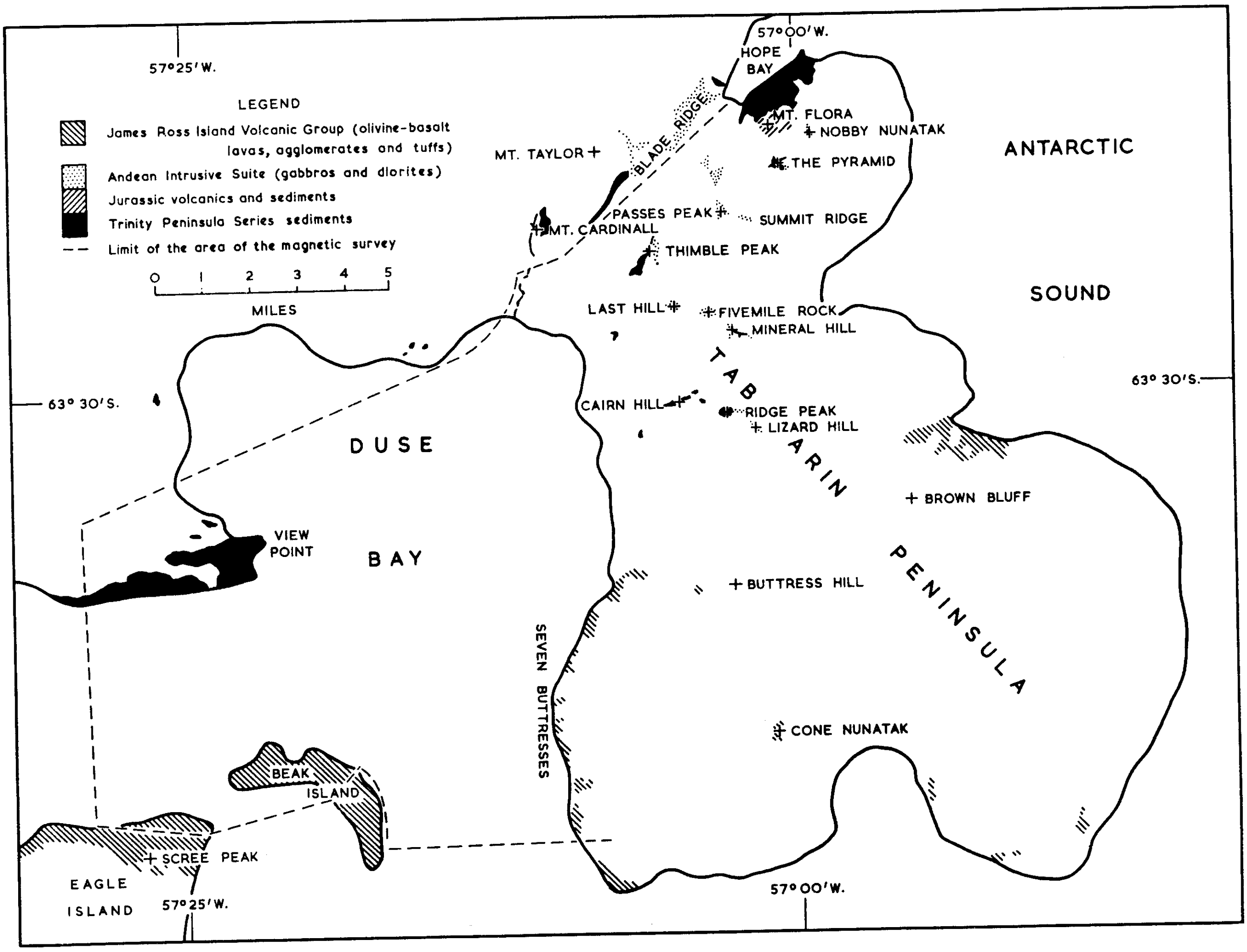

FIGURE 2

Geological sketch map of Tabarin Peninsula and the vicinity of Duse Bay (compiled from F.I.D.S. geological surveys).

Askania Gf6 magnetometer and a Hartmann and Braun recording apparatus were installed in a non-magnetic hut at the Falkland Islands Dependencies Survey Hope Bay station. The construction of this hut and the installation of the recording equipment had to be accomplished before the survey could commence.

For the purpose of determining the magnetic properties of the different rock groups within the survey area, rock samples were collected from most of the outcrops on Tabarin Peninsula, from Seven Buttresses, Beak Island and View Point (Fig. 2).

A magnetic survey is useful for providing information about the geological structure at depth only if the rocks of the different formations have different magnetic properties. If this is so, then the Earth's magnetic field will be distorted in the vicinity of these formations and a measurement of the magnetic distortions (anomalies) at the ground surface, coupled with a knowledge of the magnetic properties of the rock formations, can lead to an interpretation of the geological structure. Only if the magnetic survey is supported by considerable geological knowledge or by supplementary geophysical surveys, e.g. seismic or gravity, can a reliable solution be obtained for the structure.

Geology. The general geology of Graham Land has been described by Adie (1953, 1957*a*). In order that the geological implications of the magnetic survey of Tabarin Peninsula can be better understood the more detailed geology of this area is discussed below. The geology and limits of the area of the magnetic survey are shown in Fig. 2.

The exposures in this area are of five distinct rock groups, namely, the Trinity Peninsula Series sediments, the Middle Jurassic sediments of Mount Flora, the Upper Jurassic Volcanic Group, the Andean Intrusive Suite gabbros and diorites (Adie, 1955) and the James Ross Island Volcanic Group (Table I). North of the Buttress Hill—Brown Bluff area the prominent physiographic features are formed by the intrusive rocks and the sediments of the Trinity Peninsula Series with the one notable exception of Mount Flora, where the Upper Jurassic rhyolites overlie the Middle Jurassic sediments. Intrusive rocks are in contact with the Trinity Peninsula Series sediments at Mount Taylor, The Pyramid, Thimble Peak, Ridge Peak and Mineral Hill, whereas the intrusive rocks form the outcrops of Summit Ridge, Mount Carrel, Five

TABLE I

STRATIGRAPHY OF NORTH-EAST TRINITY PENINSULA

QUATERNARY	Recent Pleistocene	Raised beaches, etc.
TERTIARY	Pliocene ? M. Miocene ? L. Miocene Late Cretaceous to Early Tertiary	Pecten Conglomerate ~~~~ James Ross Island Volcanic Group ~~~~ Seymour Island Series ~~~~ Andean Intrusive Suite (Nobby Nunatak Gabbro and Tabarin Peninsula Diorite)
MESOZOIC	Cretaceous (L.-M. Campanian) U. Jurassic M. Jurassic	Snow Hill Island Series ~~~~ "Andesite-rhyolite volcanic group" "Mount Flora Beds"
PALAEOZOIC	? Carboniferous	Trinity Peninsula Series

Mile Rock, Last Hill, Lizard Hill, Nobby Nunatak and Andersson Nunatak. Cairn Hill, Mount Cardinall and the outcrops in the View Point area appear to be entirely composed of the Trinity Peninsula Series. This series consists mainly of greywackes and shales, and where they are in contact with the Andean intrusive rocks they have been thermally metamorphosed (Adie, 1957*b*). All the outcrops on Tabarin Peninsula south of and including Buttress Hill and Brown Bluff are of the James Ross Island Volcanic Group and Beak, Eagle, Jonassen and Andersson Islands are formed entirely of these volcanic rocks. The unconformity between the James Ross Island Volcanic Group and the Trinity Peninsula Series has not yet been observed in Graham Land. In this area the James Ross Island Volcanic Group is an interbedded succession of olivine-basalt lava flows, tuffs and agglomerates (Adie, 1953). Although the Cretaceous sediments do not occur in this area, they are overlain unconformably by the James Ross Island Volcanic Group at James Ross Island and adjacent islands (Adie, 1953).

The greater part of this report is concerned with the establishment of the non-magnetic hut, the field procedure, the corrections, errors (unless otherwise stated these are *standard errors*) and interpretation of the data. All the field data, the diurnal variation charts and the rock specimens are housed in the Department of Geology, University of Birmingham.

II. ESTABLISHMENT OF THE NON-MAGNETIC HUT AT HOPE BAY

A NON-MAGNETIC hut was built at Hope Bay to house the Askania Gf6 magnetometer and associated recording equipment, which was used to observe diurnal fluctuations in the Earth's magnetic field. The hut was about 150 yd. (137 m.) from the Falkland Islands Dependencies Survey station, on a site where the magnetic gradient was found to be small. The overall dimensions were approximately 12 ft. × 8 ft. (3·65 m. × 2·44 m.) in plan, and the roof sloped from a height of 7 ft. (2·13 m.) at one of the long sides to 6 ft. 6 in. (1·98 m.) at the other. It was divided into two rooms of sizes 8 ft. × 7 ft. (2·44 m. × 2·13 m.) and 3 ft. × 7 ft. (0·91 m. × 2·13 m.) (inside dimensions) by a partition and interconnecting door. The main framework, constructed from 4 in. × 2 in. (10 cm. × 5 cm.) timber, was set in a concrete base made from non-magnetic sand, shingle and "Secar 250" quick-setting cement. In order to give maximum insulation the outside wall and roof sections were built up of the following materials (commencing with the material on the outside):

Ruberoid,
Tongue and groove boarding, 1 in. (2·5 cm.),
Aluminium foil, ~ 0·005 in. (0·013 cm.),
"Stillite" rock-wool insulation, 4 in. (10 cm.),
Aluminium foil, ~ 0·005 in. (0·013 cm.),
Tongue and groove boarding, 0·5 in. (1·3 cm.),
Plywood facing, 0·25 in. (0·64 cm.).

The "Stillite" insulation, a compressed rock-wool, was supplied in two forms: 3 ft. (0·91 m.) square × 2 in. (5 cm.) thick sheets for the walls and roof, and a less compressed roll form for the floor insulation. The floor frame was constructed from 2 in. × 2 in. (5 cm. × 5 cm.) timbers resting directly on the concrete and the space between the 0·5 in. (1·3 cm.) floor boards and the concrete base was filled with the insulation material. Both the partition and the inside doors were of similar construction to the walls but there was only 2 in. (5 cm.) of insulation material between 0·5 in. (1·3 cm.) boarding, which was faced on both sides with plywood. The outside door was of the same construction as the outside walls. The best form of ventilation was found to be a series of 1 in. (2·5 cm.) diameter holes drilled through the wall above the outside door. In the construction of the hut copper nails and brass bolts were used and two 1 in. (2·5 cm.) diameter twisted copper wire cables were used to guy down the hut.

The instruments were placed in the larger room, while a paraffin convector heater in the smaller outer compartment was used for heating. Three small concrete pillars projecting about 4 in. (10 cm.) through the floor, supported the tripod of the Askania Gf6 magnetometer. A 3 ft. (0·91 m.) high concrete pillar supported an astatic magnetometer, an instrument used for determining the magnetic properties of rock samples. The output of the heater was easily sufficient to maintain the temperature of the instrument room in the range of 50–60°F (10–16°C) throughout the year. Since only a very rough temperature control could be effected, i.e. by changing the position of the partition door, a thermograph was installed in the instrument room for recording temperature fluctuations. If the instrument room temperature varied slowly, then the temperature inside the magnetometer varied in a similar manner to the room temperature, and consequently the thermograph recorded the fluctuations in temperature of the magnetometer.

For lighting purposes cables, supplying 18 volt d.c. and 220 volt a.c., were led from the main hut to the non-magnetic hut.

Although recording the diurnal variation was automatic, the apparatus required some maintenance which was efficiently carried out by some of the base personnel. The Gf6 magnetometer was fitted with a special head which contained a small illumination source and a split photocell. Light is reflected onto the split photocell from a magnet which can swing in the vertical plane about a horizontal axis. In a constant magnetic field the magnet assumes a position of equilibrium and therefore the current output of the photocell is constant. As the magnetic field changes the magnet swings into a new equilibrium position and the current output of the photocell changes by an amount proportional to the change in the magnetic field. The varying current output of the photocell is fed to the recording apparatus where it causes a light striker arm to swing across a chart clockwork-driven at a speed of 2 cm./hr. Every half minute the arm strikes down onto an ink band immediately above the chart and leaves a small dot on the chart. By calibrating the movement of the arm in terms of magnetic field the record of the diurnal variation of the Earth's magnetic field is obtained.

III. DIURNAL VARIATION RECORDS

FIELD work was carried out during 1959 in the periods 20 February to 21 March, 28 May to 1 September, 15 September to 31 December and up to 8 March 1960. The diurnal variation was automatically recorded at Hope Bay during these periods. Plates IIa, b and c illustrate typical recordings for a quiet day, a day of moderate disturbance and a day of severe disturbance, respectively. Each of the intervals between the vertical timing lines on the charts represents half an hour and the separation of horizontal lines represents a magnetic field of about 5 gammas. The accuracy of a corrected field reading is determined, in part, by the accuracy to which the diurnal variation can be read from the chart. However, the accuracy to which a field reading is required depends on the magnitude of the magnetic anomaly of which it is a part, e.g. if the maximum range of an anomaly is 25 gammas, then field readings should be obtained to an accuracy of $\pm$ 1 gamma (in fact this is not possible and the minimum error of $\pm$ 6 to $\pm$ 9 gammas must be tolerated),

TABLE II

CLASSIFICATION OF DIURNAL VARIATION RECORDS ACCORDING TO THE ERRORS WHICH THEY INTRODUCE INTO FIELD READINGS

Error Introduced into Field Readings (gammas)	$\pm$ 5	$\pm$ 10	$\pm$ 20	$> \pm$ 20
Number of days in:				
June 1959	29	1	0	0
July	24	3	1	3
August	23	4	0	3
October	20	10	0	0
November	18	7	3	2
December	15	11	2	3
January 1960	14	13	3	1
February	20	8	0	0

whereas if the magnitude of the anomaly is about 500 gammas an accuracy of ± 30 gammas can be tolerated. These considerations imply that diurnal variation records showing considerable disturbance can be used for correction in some circumstances. In order to present an idea of how much field work is likely to be lost due to the occurrence of magnetic storms in this area, the diurnal variation records have been classified according to the error which they will introduce into a field reading when the latter is corrected for the diurnal variation. The day by day classification (Table II) is shown for errors of up to ± 5, ± 10, ± 20 and greater than ± 20 gammas.

Although monthly records for a complete year were not taken, there is sufficient information in Table II to illustrate the increasing occurrence of disturbances from winter months to summer months. However, the number of intense disturbances, i.e. those introducing the greatest errors, does not show an annual trend and it is on these days that field work is impossible. Table II only gives the classification for those months for which the records are complete and over the entire period that records were taken there were 22 days on which severe magnetic storms occurred. This figure represents the minimum number of days on which work was prevented by magnetic disturbances.

In order to avoid making field observations during magnetic storms, regular radio schedules were held between the Hope Bay station and the field party to give information on the degree of disturbance of the diurnal variation.

IV. FIELD OBSERVATIONS, DERIVATION OF MAGNETIC FIELD VALUES AND ERRORS

THE essential features of the field work were simply reading the magnetometer and fixing the position at which the reading was taken. The points at which magnetic readings were made, known as field stations, were spaced on average about 0·75 miles (1·21 km.) apart but the density of stations was increased where there were rapid changes in the magnetic field. This section deals with the surveying of the field station positions, the procedure in making the magnetometer readings and their conversion into values of relative magnetic field at the field stations. The errors introduced during this conversion are also discussed and summarized.

A. Surveying of the Field Station Positions

The majority of station positions was determined by plane table resection using points with known geographical coordinates. About 150 stations in the southern part of Tabarin Peninsula were fixed by sledge wheel and compass traverses, supplemented where possible with compass bearings on fixed points. The errors in station positions by these two methods were approximately ± 50 yd. (± 46 m.) and ±100 yd. (± 91 m.), respectively.

Heights of the stations in Tabarin Peninsula, south of Ridge Peak, were determined from barometric readings at each station. The error in the heights of stations north of the Brown Bluff—Buttress Hill area is approximately ± 40 ft. (± 12·2 m.) and for those farther south it is ± 60 ft. (± 18·3 m.). The topography of the area north of Ridge Peak has been taken from the latest 1:25,000 map (D.O.S. 310, Hope Bay, 1960), kindly provided by the Directorate of Overseas Surveys.

The depth soundings in Duse Bay and Prince Gustav Channel were made by R.R.S. *Shackleton*. The estimated error in the positions of these soundings is ± 0·25 mile (± 0·40 km.). The error in the soundings is not known but it is considered to be not more than a few fathoms.

B. Field Magnetic Observations, Their Conversion to Relative Magnetic Field Values and Subsequent Errors

As stated on page 3 values of the magnetic field at the field stations were measured relative to the values of the magnetic field at the base stations. On each day of field work two readings were first taken at one of the base stations; two readings were then taken at each of the field stations and the final two readings of the day were again taken at the same base station.

Before reading the magnetometer it was levelled and orientated in approximately the direction of magnetic north. The error introduced by inaccurate levelling depends on the orientation of the instrument with respect to the direction of magnetic north. Levelling was always effected to within half a level division and the orientation of the instrument was usually within 10 degrees of magnetic north. Under these conditions the maximum error introduced by levelling was about ± 3 gammas but the more usual error was assumed to be ± 2 gammas. The error in reading the instrument scale was about ± 1 gamma.

The times of the magnetometer readings were recorded to the nearest half minute.

The operations and corrections described below were carried out to convert the magnetometer readings to relative values of magnetic field.

1. *Calibration of the Gfz magnetometer*

In this type of magnetometer a small magnet is suspended by two horizontal fibres which are perpendicular to the long axis (the magnetic axis) of the magnet. In any magnetic field the magnet rotates until the magnetic couple is balanced by the torsional couple of the fibres and the gravitational couple of the magnet (its point of suspension is slightly offset from its centre of gravity). The fibre system is rotated until the magnet is horizontal and in this position the instrument scale is read. If the magnetic field changes, the fibre system must be rotated by a different amount to bring the magnet into the horizontal position again. The angular difference in the position of the fibre system is a measure of the magnetic field difference. The instrument is calibrated periodically by applying a series of known magnetic fields to the magnet system by means of a pair of Helmholtz coils. The makers of the Gfz magnetometer quoted a figure of 243 gammas/degree of arc for the calibration constant of the particular instrument used, and as this figure was always within the limits of error of the experimentally determined values it was used throughout the survey.

The error in the calibration constant, from eight measurements over a period of 15 months, was ± 0·5 per cent, which does not introduce errors of importance into the field results.

2. *Correction for the diurnal variation*

The difference between the diurnal variation at the time of a field reading and at the time of the base station reading (at the beginning of the day's work) was determined from the diurnal variation chart. This value was either added to or subtracted from the field station reading, depending on whether the Earth's magnetic field had decreased, i.e. become more positive, or increased since the time of the base station reading.

The error introduced by this correction was due to errors in calibration of the Gf6 magnetometer, temperature variation effects on the Gf6 magnetometer and the reading of the diurnal variation charts. The latter involved the accuracy of the time at which a field reading was made. The error due to calibration and temperature effects was ± 3 gammas, and that due to reading the chart varied between ± 2 and ± 15 gammas. The minimum error, therefore, was a combination of the errors of ± 3 and ± 2 gammas, i.e. ± 4 gammas.

3. *Temperature effects on the instruments*

a. *The Gfz magnetometer*. The Gfz magnetometer was adjusted by the makers so that it had a zero temperature coefficient in a vertical magnetic field of − 35,000 gammas. In fields of − 35,000 ± 5,000 gammas the temperature coefficient was ± 0·10 gammas/°C. The vertical magnetic field at Hope Bay is approximately − 36,000 gammas (Slaucitajas, 1956) and the magnetic field over the survey area varies from − 33,000 to − 38,000 gammas, so that the temperature coefficient of the magnetometer varied between + 0·04 and − 0·06 gammas/°C.

The temperature of the instrument varied between about − 30°C and + 5°C. If the magnetometer readings were all corrected to values at a temperature of − 12·5°C then the maximum correction would be ± 1 gamma. For many of the readings the correction was considerably less than ± 1 gamma and so the effects of temperature changes on the Gfz magnetometer are negligible.

b. *The Gf6 magnetometer*. A value of 0·7 ± 0·5 gammas/°F (1·3 ± 0·9 gammas/°C) was determined experimentally from two independent measurements for the temperature coefficient of the Gf6 magnetometer. The range of temperature variation in the non-magnetic hut over the period of a working day rarely exceeded 10°F (5·6°C) and therefore the maximum error in the diurnal variation record was 7 ± 5 gammas. The field readings in the Duse Bay area, corrected for the temperature effect on the diurnal variation (using a value of 0·7 gammas/°F (1·3 gammas/°C) for the temperature coefficient), were plotted as a magnetic contour map which was compared with a map plotted from uncorrected results. The maximum difference in any field station value before and after correction for the temperature effects was 6 gammas, and the contours on the above two maps coincided within the limits over which the contours could be positioned, i.e. the contours from one map could be transferred to the other, where they fitted the results as well as the other set of contours. As the anomalies in Duse Bay were the smallest in magnitude of the whole survey it was considered that the temperature corrections to the diurnal variation records were of negligible importance.

4. *Drift of the Gfz magnetometer*

The first and last readings of a day's work were always taken at the same station, i.e. one of the base stations. After correction for the diurnal variation (also corrected for temperature variations) there was usually a small discrepancy between the two readings; this is referred to as the closing error. The closing error, due principally to instrumental drift, is distributed linearly with time over the period between the first and last readings of the day thus making these readings equal. The average daily closing error for the survey was 9 gammas.

It was assumed that the drift was linear with time, and the estimated error in an individual field station value due to this was ± 2 gammas. The drift has to be considerably different from linear to introduce an error greater than that estimated.

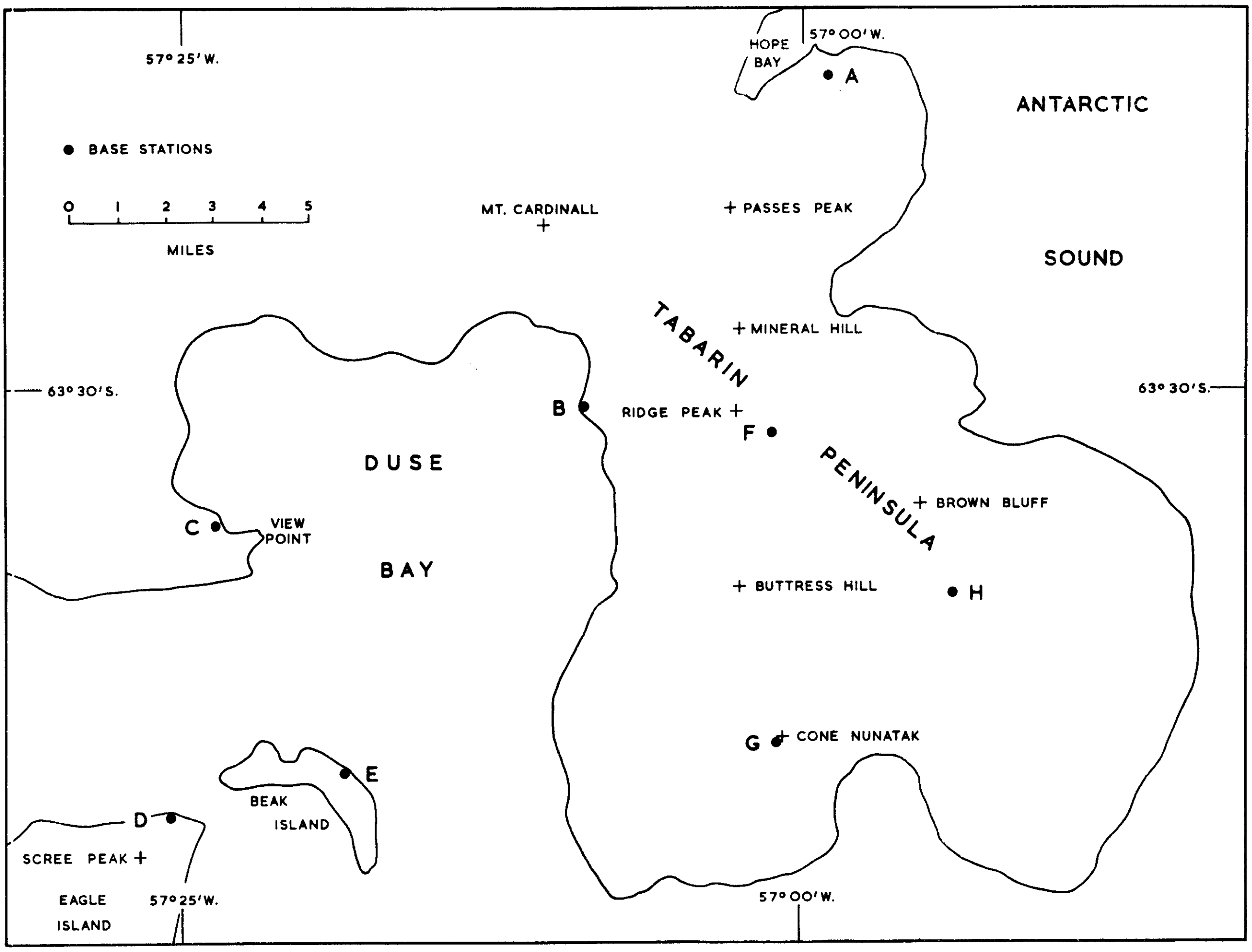

FIGURE 3
The distribution of magnetic base stations (A–H).

5. *Establishment and adjustment of the base station network*

The distribution of base stations in the area surveyed is shown in Fig. 3. The differences in magnetic field between the base stations were determined in a specific manner. As an example of this procedure the method of evaluating the differences between the three base stations, A, B and C (Fig. 4), is given below. The difference between Stations A and B was determined by taking a series of readings at A, consisting of eight readings over a period of about one hour, then a similar series of readings was made at B and again at A. The whole procedure was carried out as quickly as possible to minimize instrumental drift. Series of readings at Stations B, C and B, in that order, and at Stations C, A and C were also taken. After correction of the readings for diurnal variation and instrumental drift the mean differences between Stations A and B, B and C, and C and A were evaluated and should have added algebraically to zero, but a small residual value was usually obtained.

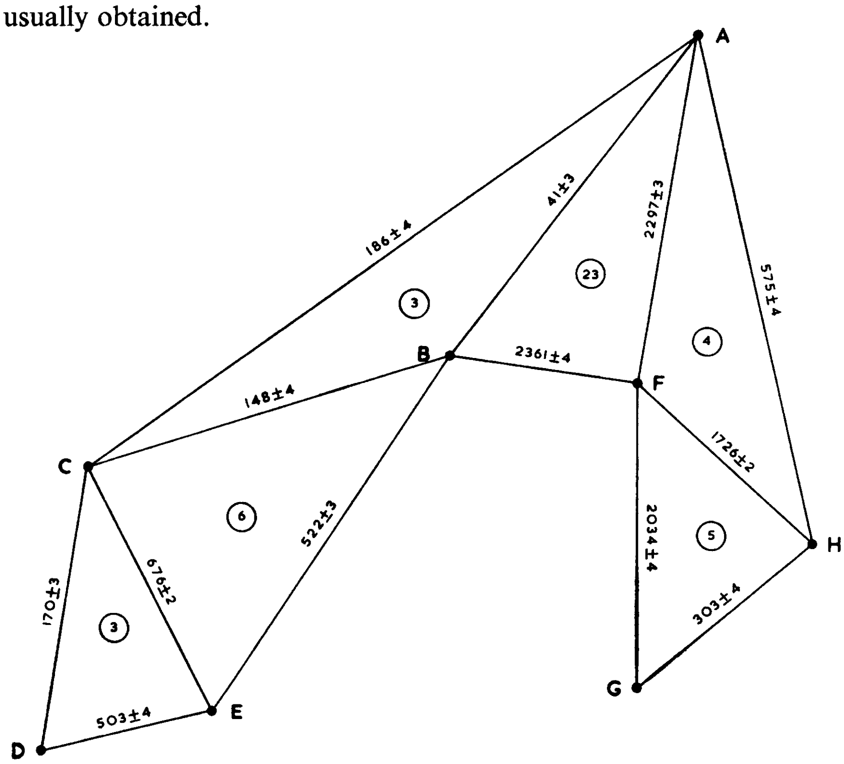

FIGURE 4
Differences in magnetic field in gammas between base stations, and the individual network residual errors in gammas (given in circles).

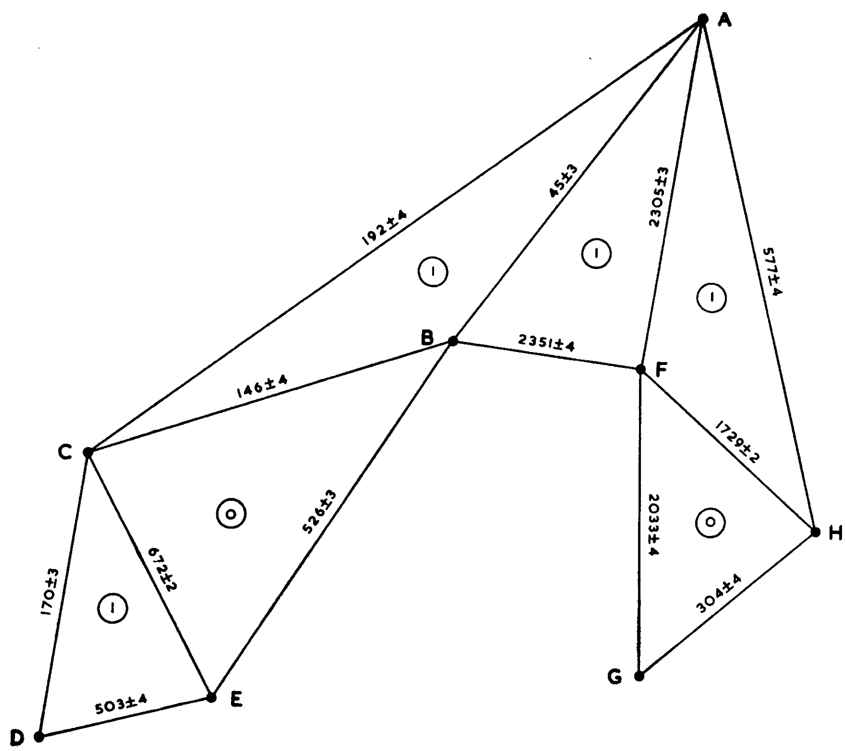

FIGURE 5
Differences in magnetic field in gammas between base stations, and the individual network of errors in gammas (given in circles) after adjustment of the complete network.

Fig. 4 indicates the differences between adjacent stations, and the figures in the centres of the triangles are the residual values obtained by the above procedure for each triangular network. The complete network was adjusted by the least squares method (Smith, 1951) in order to distribute the residual values, and Fig. 5 gives the station differences and residual values after adjustment. By assigning an arbitrary value of + 200 gammas to Station A the values given in Table III were obtained for the other stations.

TABLE III

POSITIONS OF BASE STATIONS AND THEIR MAGNETIC FIELD VALUES

Base Station	*Latitude S.*	*Longitude W.*	*Magnetic Field Value* (gammas)
A	63° 24′ 19″	56° 58′ 55″	+ 200
B	63° 30′ 18″	57° 08′ 53″	+ 155 ± 3
C	63° 32′ 16″	57° 23′ 40″	+ 8 ± 4
D	63° 37′ 40″	57° 25′ 26″	+ 177 ± 5
E	63° 36′ 53″	57° 18′ 31″	+ 680 ± 4
F	63° 30′ 46″	57° 01′ 11″	+ 2506 ± 3
G	63° 36′ 24″	57° 00′ 56″	+ 473 ± 5
H	63° 33′ 44″	56° 53′ 49″	+ 777 ± 4

In Table III the errors quoted for the base station values are their standard errors, which have been derived from the standard errors in the measured differences between the base stations. Base station E can be considered as an illustration of the derivation of the standard error in a base station value. The shortest measured link between Stations E and A was via Station B. The standard error in the difference between Stations E and B, and Stations B and A was ± 3 gammas in each case. The error in the value of Station E was therefore a combination of the two difference errors, i.e. ± 4 gammas.

The field station values were determined relative to the base station values and their errors have been accordingly increased by the errors in the base station values.

6. *Removal of the regional gradient*

It is not possible to derive the regional gradient, i.e. the gradient of the Earth's normal magnetic field, from the survey results, because the area surveyed is not large enough. The value of the gradient has therefore been taken from the magnetic maps given by Vestine *et al* (1947) for 1945. In the Hope Bay area the Earth's field increases, or becomes more negative, in a southerly direction at a rate of 14·80 ± 0·30 gammas/mile (8·75 ± 0·19 gammas/km.) and also increases to the west at a rate of 1·74 ± 0·04 gammas/mile (1·09 ± 0·03 gammas/km.). The secular variation of the Earth's magnetic field in this area is about 100 gammas/yr. (according to Vestine *et al.* (1947)) but it is consistent over the whole area surveyed. Accordingly, it has been assumed that, although the amplitude of the Earth's magnetic field has changed since 1945, the gradient has not changed.

The regional correction at Station A (Hope Bay) has been taken as zero and all the other stations have been corrected by a corresponding amount depending on their distances from Station A. The maximum regional correction, at the extreme south-western part of the survey, was − 262 gammas.

The error introduced into a field station magnetic value by this correction depends on the distance of the field station from Station A. The error is directly proportional to this distance and consequently the maximum error, ± 5 gammas, is in those stations at the greatest distance from Station A.

7. *Summary of the errors*

A standard error cannot be given for all the field values, because the error varies considerably with the character of the diurnal variation for which the field reading has been corrected and it also depends on the distance of the field station from Station A. However, minimum errors of ± 6, ± 7 and ± 8 gammas were determined for stations whose field values were relative to base stations with errors of ± 3, ± 4 and ± 5 gammas, respectively. These errors do not include the errors introduced by the removal of the regional gradient. The increase in the minimum error introduced by the error in the calibration constant of the Gfz magnetometer was ± 1 gamma, if the field value was between 600 and 1,000 gammas different from the base station value to which it was relative.

The above considerations have led to an estimated error of between ± 6 and ± 9 gammas in the results for Duse Bay, where the anomalies are at a minimum. In the highly anomalous areas of Tabarin Peninsula and the vicinity of Beak and Eagle Islands the error in some values was as high as ± 15 gammas.

V. DETERMINATION OF THE MAGNETIC PROPERTIES OF ROCK SPECIMENS

ROCK samples were collected from almost all of the exposures on Tabarin Peninsula, from Seven Buttresses, Beak Island, View Point and Corry Island, for the determination of the remanent magnetization and the susceptibility of the rock formations encountered in and around the survey area. Specimens for which the remanent magnetization was required were on average about 4 in. × 4 in. × 4 in. (10 cm. × 10 cm. × 10 cm.) in size, while those required purely for susceptibility measurements were somewhat smaller. All the samples were taken *in situ* where an effort was made to obtain samples of fresh rock.

1. *Measurement of the remanent magnetization*

Most of the rock samples collected were orientated, i.e. marked with the horizontal plane and the direction of magnetic north while still *in situ*. This provided a convenient reference system so that the direction of remanent magnetization could be later determined in the laboratory and related to the original orientation of the rock specimen.

Both igneous and volcanic rocks acquire a thermo-remanent magnetization during solidification, when their temperatures have fallen below a "critical temperature". This critical temperature is the ferromagnetic Curie Point of the ferromagnesian mineral constituent of the rock. Most rocks contain a number of ferromagnesian minerals each with different Curie Points, and the remanent magnetization is only completely acquired when the rock has cooled to a temperature below the lowest Curie Point. The direction of magnetization of the rock is parallel or antiparallel to the direction of the Earth's magnetic field in which the rock has cooled. These two cases are respectively referred to as *normal* and *reversed thermo-remanent magnetization.*

Sediments can also acquire a thermo-remanent magnetization if they are heated to a temperature above the Curie Points of the individual ferromagnesian constituents. They may also exhibit a remanent magnetization which is the result of alignment of individual grains in the sediment with the magnetic field during deposition under calm conditions. In certain cases remanent magnetization can be acquired during the crystal growth of the rock.

Laboratory measurements of the remanent magnetization were made on cylindrical cores (1·9 cm. in diameter and length) drilled from the rock samples. Before drilling the rock was set up in Plaster of Paris in the same plane in which it was sampled, i.e. the horizontal plane. The cores were drilled vertically and before extraction were marked with the direction of magnetic north at the sample locality. They were then cut to size and their magnetizations were measured with either a spinning type magnetometer (Griffiths, 1955) or an astatic magnetometer (Blackett, 1952) depending on the magnitude of the magnetization. Measurements were made on three cores from each sample.

Storage tests were carried out on 12 samples to determine the short term stability of the direction of remanent magnetization. The direction of remanent magnetization of each sample was first determined and then the samples were stored for a period of 17 days with their directions of magnetization in a plane at right angles to the plane of the present Earth's magnetic field. After the storage period the directions of magnetization were again determined and compared with those obtained prior to storing. If there was a difference in the directions for any sample then that sample possessed a very unstable remanent magnetization. Of the rock samples collected during this survey only the diorite from Lizard Hill showed such instability; Dr. D. J. Blundell observed the same effect for the diorite of Ridge Peak.

TABLE IV
VALUES OF REMANENT MAGNETIZATION (FIG. 6)

Rock Type	*Locality*	*Number of Samples*	*Intensity of Magnetization*		*Direction of Magnetization*	
			Range of Values (e.m.u. /cm.^{3} × 10^{-6})	*Mean Value* (e.m.u. /cm.^{3} × 10^{-6})	*Declination*	*Inclination*
Olivine-basalt	West of Buttress Hill	5	2990–6800	5130 ± 1170	177°	71° **DOWN**
	Beak Island	5	570–1340	1100 ± 270	185°	80° **DOWN**
	Brown Bluff*	2	14100–27400	19000 ± 2000	169°	78° **DOWN**
	Corry Island	4	2400–5860	3760 ± 1480	350°	63° **UP**
Agglomerate	Beak Island	2	25–140	47 ± 47	40°	60° **DOWN**
	Seven Buttresses	1	50		213°	62° **DOWN**
Diorite	Mineral Hill*	1	1540		353°	76° **UP**
	Lizard Hill	4	95–545		**UNSTABLE**	
	Summit Ridge*	4	901–3410	1660 ± 880	6°	75° **UP**
	Fivemile Rock*	4	576–2760	1740 ± 250	8°	72° **UP**
	Ridge Peak*	3	141–291		**UNSTABLE**	
Gabbro	Nobby Nunatak*	4	2–100	60 ± 30	342°	74° **UP**
Sediments	Cairn Hill	7	10–2240	430 ± 595	129°	84° **UP**
	Ridge Peak	3	150–1180		**VARIABLE**	Both **UP** & **DOWN**
	Mineral Hill	5	20–3900	55 ± 32 (excl. 3900)	85°	87° **UP**
	The Pyramid*	5	< 1			
	Hope Bay*	6	< 1			

*Specimens collected and measured by Dr. D. J. Blundell, Department of Geology, University of Birmingham.

The results of these measurements are given in Table IV. The declination is measured clockwise from geographical north and an inclination of say 71° **DOWN** means that the magnetization is in the approximate opposite sense to the southern hemisphere magnetic field and inclined at an angle of 71° to the horizontal plane. The directions of remanence of the olivine-basalt, the diorite and the sediment samples are illustrated in the stereograms of Fig. 6, in which the lines marked N indicate the azimuth of geographical north.

The mean values of the directions of remanence, given in Table IV, have been submitted to Fisher's (1953) statistics to test their validity. The results, except those for the sediments and agglomerates, are very reliable and agree well with the present direction of the Earth's dipole magnetic field (the fundamental component of the Earth's normal magnetic field), which has a declination of 0° and an inclination of 76° **UP** in this area.

2. *Measurement of the induced magnetization*

Any rock containing ferromagnesian minerals will acquire an induced magnetization when it is placed in a magnetic field. The induced magnetization, I per unit volume, is given by

$$I = kH,$$

where k is the volume susceptibility of the rock and H is the magnetic field. Since the value of the Earth's magnetic field is known, it is only necessary to determine k to calculate the value of induced magnetization.

An apparatus similar to that described by Bruckshaw and Robertson (1948), which measures susceptibilities by use of an alternating magnetic field of peak value 0·5 oersted, was used for the determination of k. Values of susceptibility down to 10^{-5} c.g.s. units/cm.^{3} could be measured and this was sufficiently accurate for the present purpose. Measurements were made on cores, small fragments and powdered samples of the rock specimens and the results are presented in Table V.

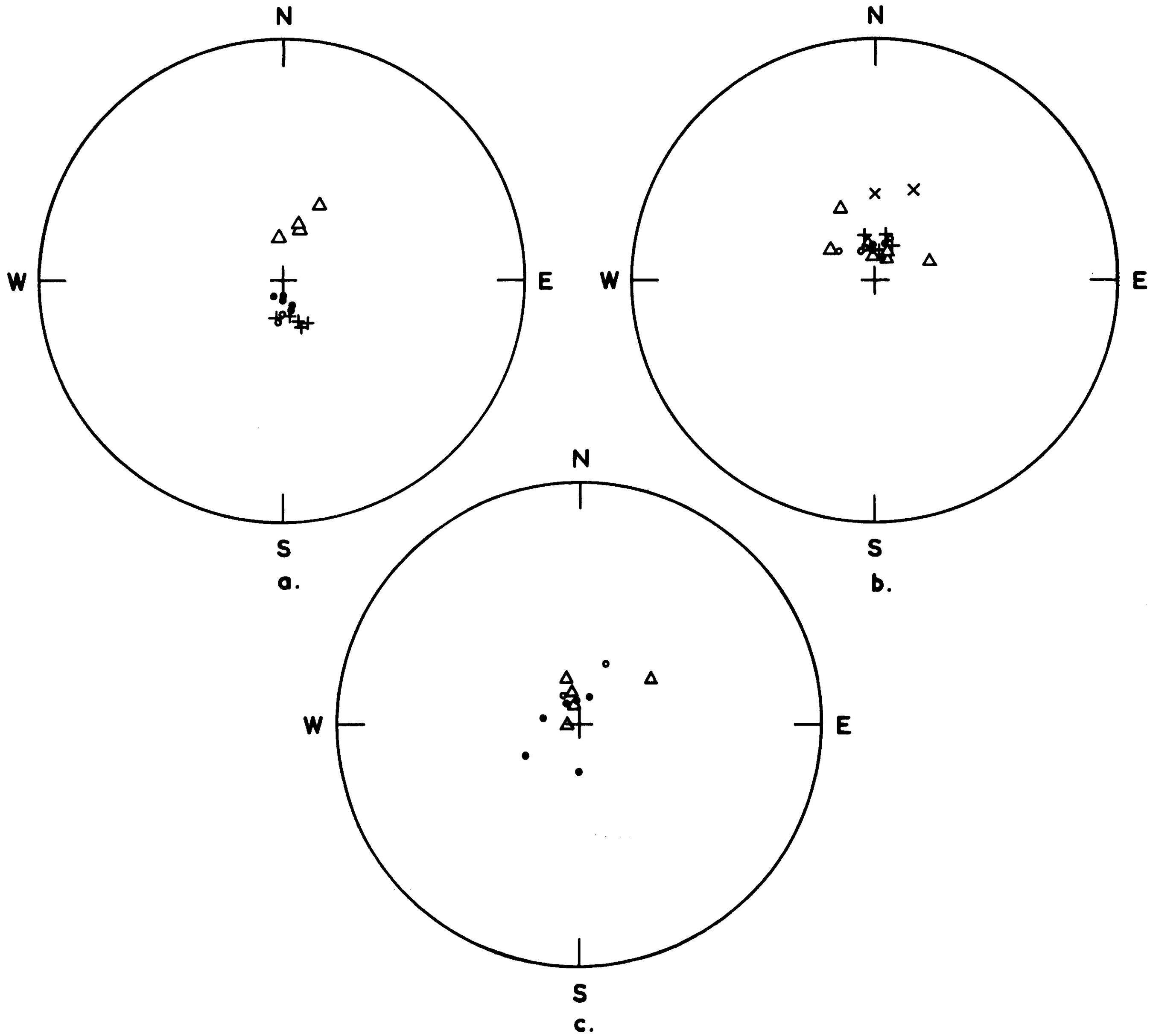

FIGURE 6

Stereograms showing directions of remanent magnetization of rock samples.

a. Olivine-basalt lavas of the James Ross Island Volcanic Group from:
- △ Corry Island (projections of the north-seeking poles on the upper hemisphere)
- ● Beak Island
- ○ Brown Bluff*
- + West of Buttress Hill

(projections of the north-seeking poles on the lower hemisphere)

b. Diorites and gabbros of the Andean Intrusive Suite from:
- △ Mineral Hill*
- ● Summit Ridge*
- ○ Nobby Nunatak*
- + Fivemile Rock*
- × Last Hill*

(projections of the north-seeking poles on the upper hemisphere)

c. Sediments of the Trinity Peninsula Series from:
- △ Mineral Hill
- ● Cairn Hill
- ○ Ridge Peak

(projections of the north-seeking poles on the upper hemisphere)

* From measurements made by Dr. D. J. Blundell.

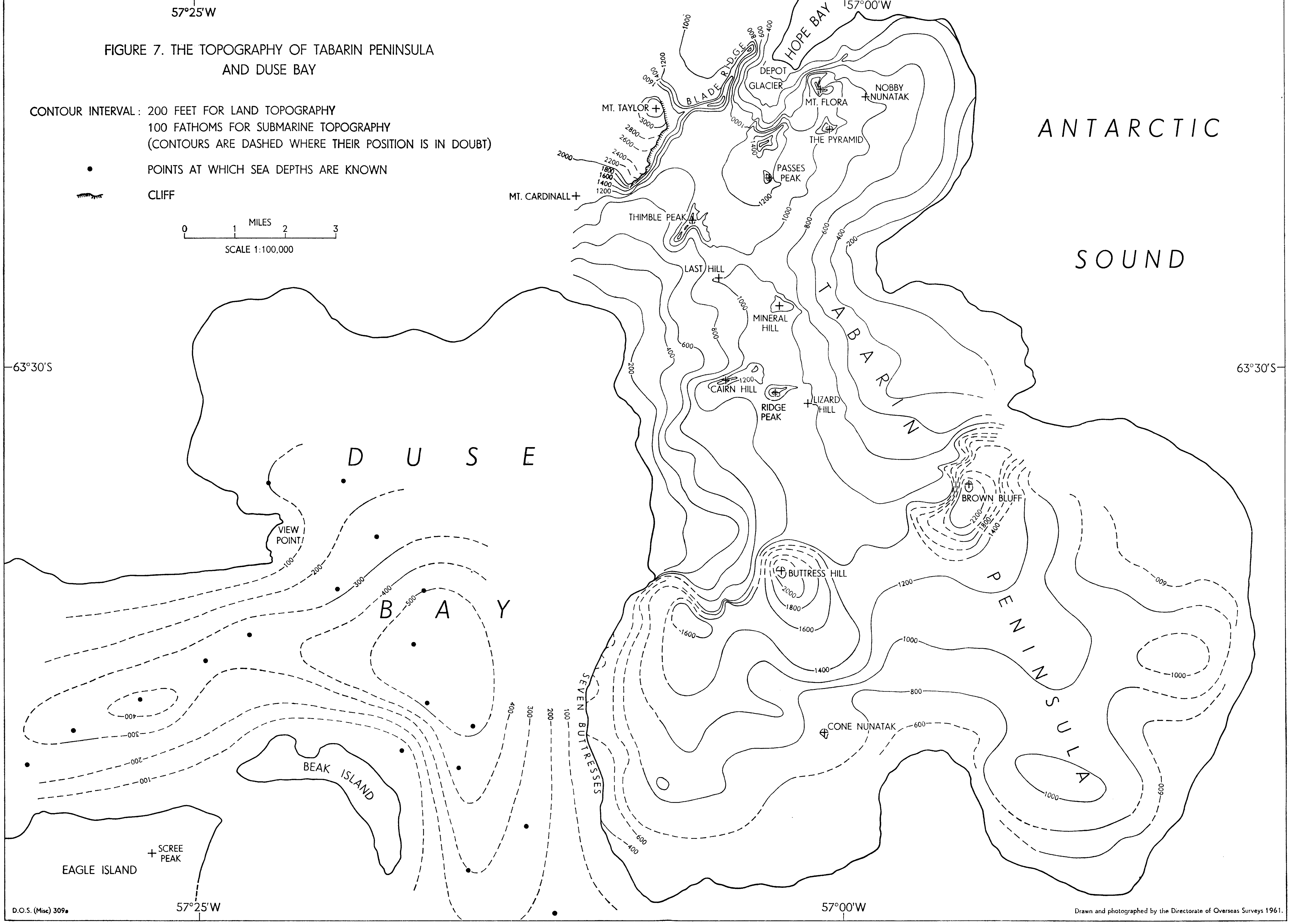

FIGURE 7. THE TOPOGRAPHY OF TABARIN PENINSULA AND DUSE BAY

TABLE V
VALUES OF VOLUME SUSCEPTIBILITY

Rock Type	*Locality*	*Number of Rock Fragments, Etc. Measured*	*Volume Susceptibility*	
			Range of Values (c.g.s. units /cm.³ × 10^{-6})	*Mean Value* (c.g.s. units /cm.³ × 10^{-6})
Olivine-basalt	West of Buttress Hill	13	509–1000	716 ± 143
	Beak Island	13	10–65	43 ± 12
	Brown Bluff	3	87–104	99 ± 7
	"Various"	20	26–131	63 ± 34
Agglomerate	Beak Island	10	14–20	23 ± 9 (Beak Island, Seven Buttresses, Cone Nunatak)
	Seven Buttresses	18	17–40	
	Cone Nunatak	9	10–41	
Diorite	Mineral Hill	4	2292–3640	1730 ± 1015 (Mineral Hill to Fivemile Rock)
	Lizard Hill	12	1110–2910	
	Summit Ridge	5	40–2070	
	Last Hill	6	527–2910	
	Fivemile Rock	4	104–890	
Gabbro	Nobby Nunatak	6	36–40	37 ± 1
Sediments	Cairn Hill	17	12–159	45 ± 43
	Ridge Peak	12	10–93	39 ± 29
	Mineral Hill	19	10–160	46 ± 43
	The Pyramid	1	< 11	15 ± 6 (The Pyramid to Below Last Hill)
	Hope Bay	9	0–14	
	View Point	5	10–22	
	Cardinall Ridge	2	20, 23	
	Below Last Hill	3	22–25	

The olivine-basalt samples listed in the locality column as "Various" are fragments of basalt from the agglomerates of Beak Island and Seven Buttresses. The only rocks with susceptibilities of any significance are the basalt from west of Buttress Hill and the diorites from all localities on Tabarin Peninsula.

3. *Combination of the remanent and induced magnetizations*

The remanent magnetization of the olivine-basalts and the diorites is important in relation to the interpretation of the magnetic data. This must be combined with the induced magnetization of these rocks to obtain the resultant magnetization (Green, 1960). The resultant magnetization of the Tabarin Peninsula diorites is 2,457 ± 521 × 10^{-6} e.m.u./cm.³ with a direction which has a declination of + 6° and an inclination of 69° **UP.** By dividing the resultant magnetization by the value of the Earth's magnetic field an equivalent susceptibility of 5,680 ± 1,200 × 10^{-6} c.g.s. units/cm.³ is obtained.

The only other magnetizations which need to be combined are those for the basalt samples from west of Buttress Hill. The resultant intensity of magnetization is 4,825 ± 1,440 × 10^{-6} e.m.u./cm.³, which has a declination of + 16° and an inclination of 73° **DOWN.** The equivalent susceptibility is 11,150 ± 2,550 × 10^{-6} c.g.s. units/cm.³.

VI. INTERPRETATION

IT has already been stated (p. 4) that the magnetic method alone cannot give a unique solution to a geological problem. The value of any solution obtained can be estimated from the reliability of the intensity of magnetization data, the accuracy of the topography (this is particularly important if the body producing the magnetic anomaly is near the surface), and the consistency of the solution in relation to the known geology.

In the present case almost the entire area surveyed is ice-covered and a knowledge of ice thickness is useful, since it places a limit to the position of the upper surface of an anomaly-producing body. Values of ice thickness have been calculated from ice movements (Koerner, 1961) using an empirical formula derived from measurements on Alpine glaciers (Perutz, 1950). An approximate value for the thickness of the snout of Depot Glacier is known from the height of the snout and the adjacent sea depth. This value is consistent with the result obtained from applying the formula to known movement rates of the glacier near the snout. Seven ice thickness values, determined within an area of radius 5 miles (8 km.) from Hope Bay, range from a maximum of 157 m. at the head of Depot Glacier to a minimum of 48 m. for the ice sheet to the east of Nobby Nunatak. These results indicate that the ice thickness varies considerably, as would be anticipated from the topography of the area (Fig. 7), and provide some information on an otherwise completely unknown quantity.

From the intensity of magnetization data it is apparent that of the rocks exposed at the surface only the intrusive diorites, the olivine-basalt lavas and some of the thermally metamorphosed sediments will produce appreciable magnetic anomalies. The magnetizations of the agglomerates and the remainder of the sediments are effectively zero. A three-dimensional interpretation of the anomalies has been made using a method devised by Pirson (1940), but the theory presented by Pirson has been revised to give a more accurate solution. A brief description of the calculation of the anomalies by this method is given below.

A circular chart, divided into segments by concentric circles and radial lines, was drawn on a sheet of "Perspex" to a size suitable for use with 1:50,000 topographic maps. A map of the assumed topography of the upper surface of the body producing the particular anomaly was then drawn to a scale of 1:50,000 (all the original work was done on this scale but the maps accompanying this report have been reduced to a convenient size for publication). The chart was placed on this map with its centre at the point (X) where the anomaly was required to be calculated. The average height difference between the surface of the body and the elevation of point X, i.e. the elevation of the ice surface at point X, was estimated for each segment of the chart.

A set of graphs was constructed which gave the vertical magnetic effect at the centre of the chart of a vertical prism, magnetized by the vertical component of the Earth's field, of cross-section equal to that of one of the chart segments for varying distances of the top of the prism below the centre of the chart,

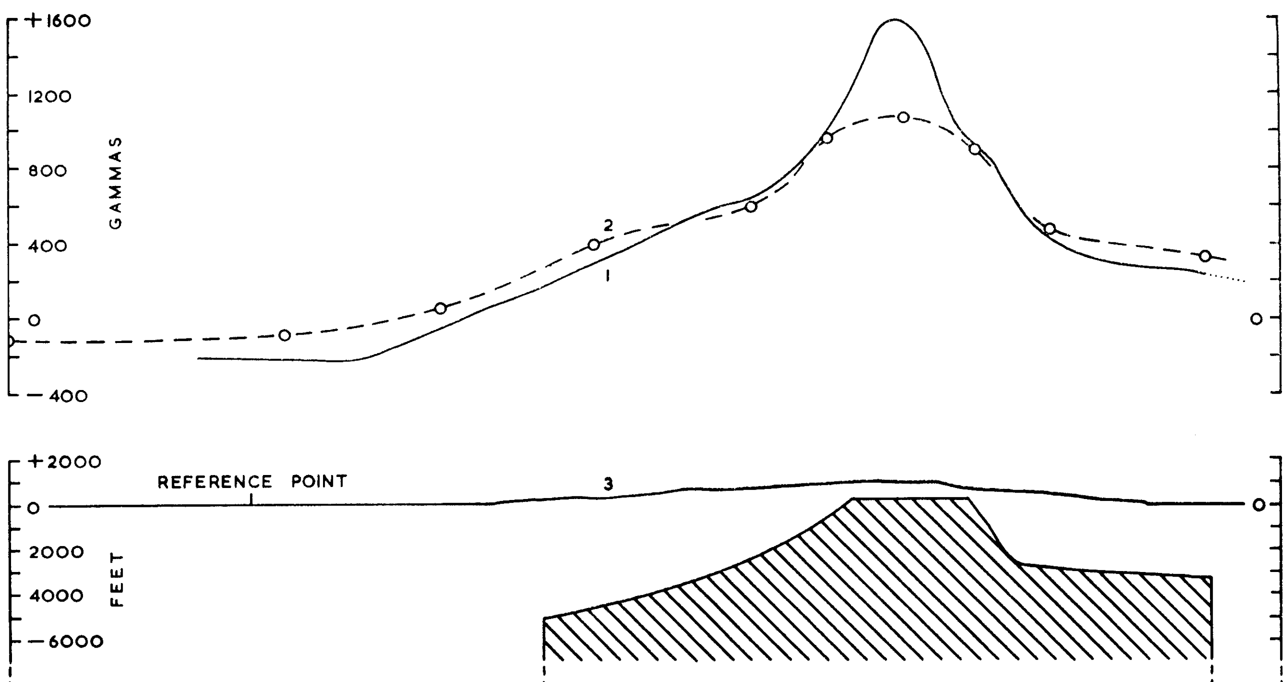

FIGURE 9

Profile A (Fig. 11) for Solution 1 of the intrusion anomaly. 1. Observed magnetic anomaly. 2. Calculated magnetic anomaly for the upper surface of the intrusion. 3. Land surface.

Cross-section of the intrusion.

o Points for which the magnetic field values have been calculated.

(Scale 1:100,000; vertical scale=horizontal scale)

assuming a value for the magnetization of the prism. The base of the prism extends to infinite depth and the cross-section of the prism, i.e. one of the segments of the chart, increases with horizontal distance from the centre of the chart. By using these graphs in conjunction with the chart the magnetic anomaly produced at the centre of the chart from all the segment contributions was evaluated. The same procedure was followed for the determination of the anomaly produced by the base of the body and therefore the total anomaly could be calculated. Various configurations of the body were used until one which produced an anomaly very similar to the observed anomaly was obtained.

In the following interpretation it has been assumed that only magnetization by the vertical component of the Earth's magnetic field contributes to the observed vertical magnetic anomalies. This is quite a reasonable assumption particularly when calculating the magnetic effects of a body whose remanent magnetization is its dominant magnetization, since most of the measured remanent magnetizations (Table IV) are near vertical.

The variation of the vertical component of the Earth's magnetic field over the survey area is shown in Fig. 8 (where the density of field stations was high, i.e. in the area between Beak and Eagle Islands and in the neighbourhood of Lizard Hill, the field station positions have not been indicated).

The principal anomalous area of the survey is that of Tabarin Peninsula, which, on the basis of the character of the anomalies, can be divided into two smaller areas by an east-west line just north of Buttress Hill and Brown Bluff. The large anomaly in the northern part of the peninsula is referred to as "the intrusion anomaly" and its interpretation will be treated first. The interpretation of the anomalies in the southern part of Tabarin Peninsula and in the Duse Bay area will then be discussed. All the calculated anomalies are numerically 120 gammas greater than the observed anomalies but in the following diagrams they have been decreased by this amount for ease of comparison with the observed anomalies.

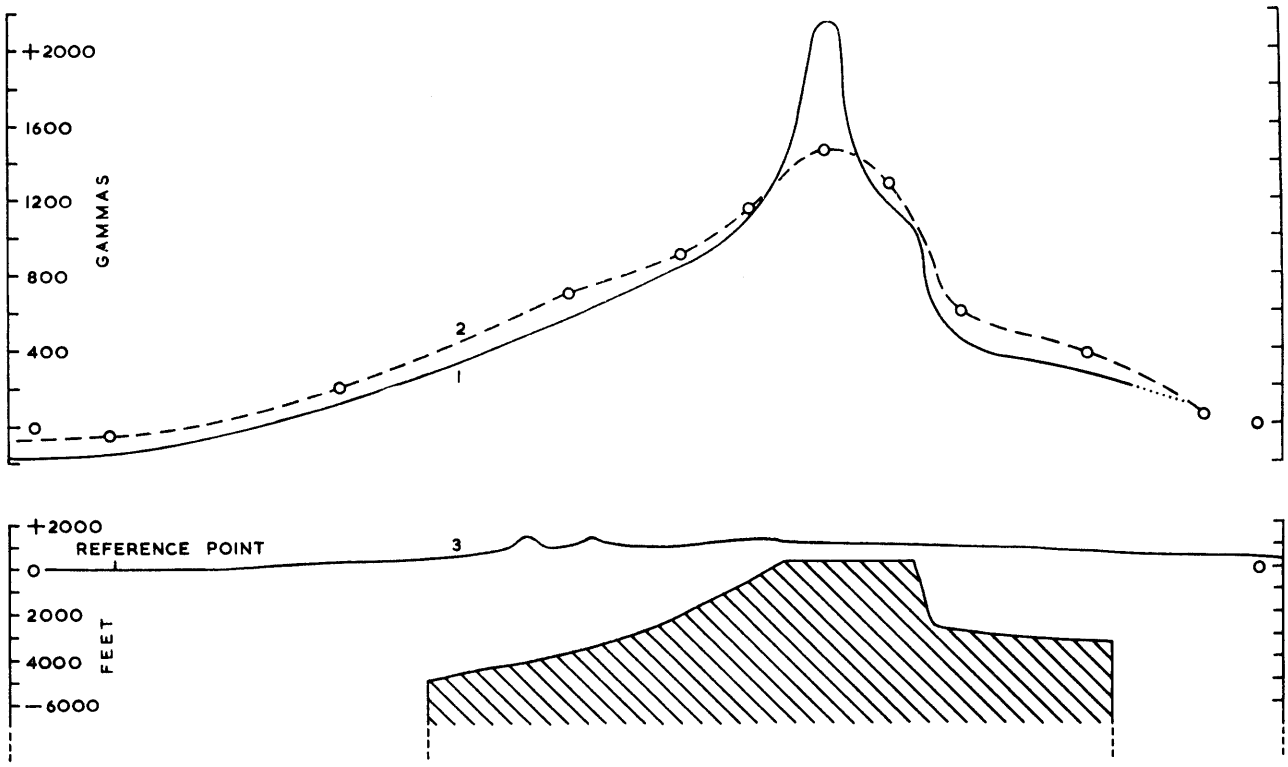

FIGURE 10

Profile B (Fig. 11) for Solution 1 of the intrusion anomaly. 1. Observed magnetic anomaly. 2. Calculated magnetic anomaly for the upper surface of the intrusion. 3. Land surface.

Cross-section of the intrusion.

o Points for which the magnetic field value have been calculated.

(Scale 1:100,000; vertical scale=horizontal scale)

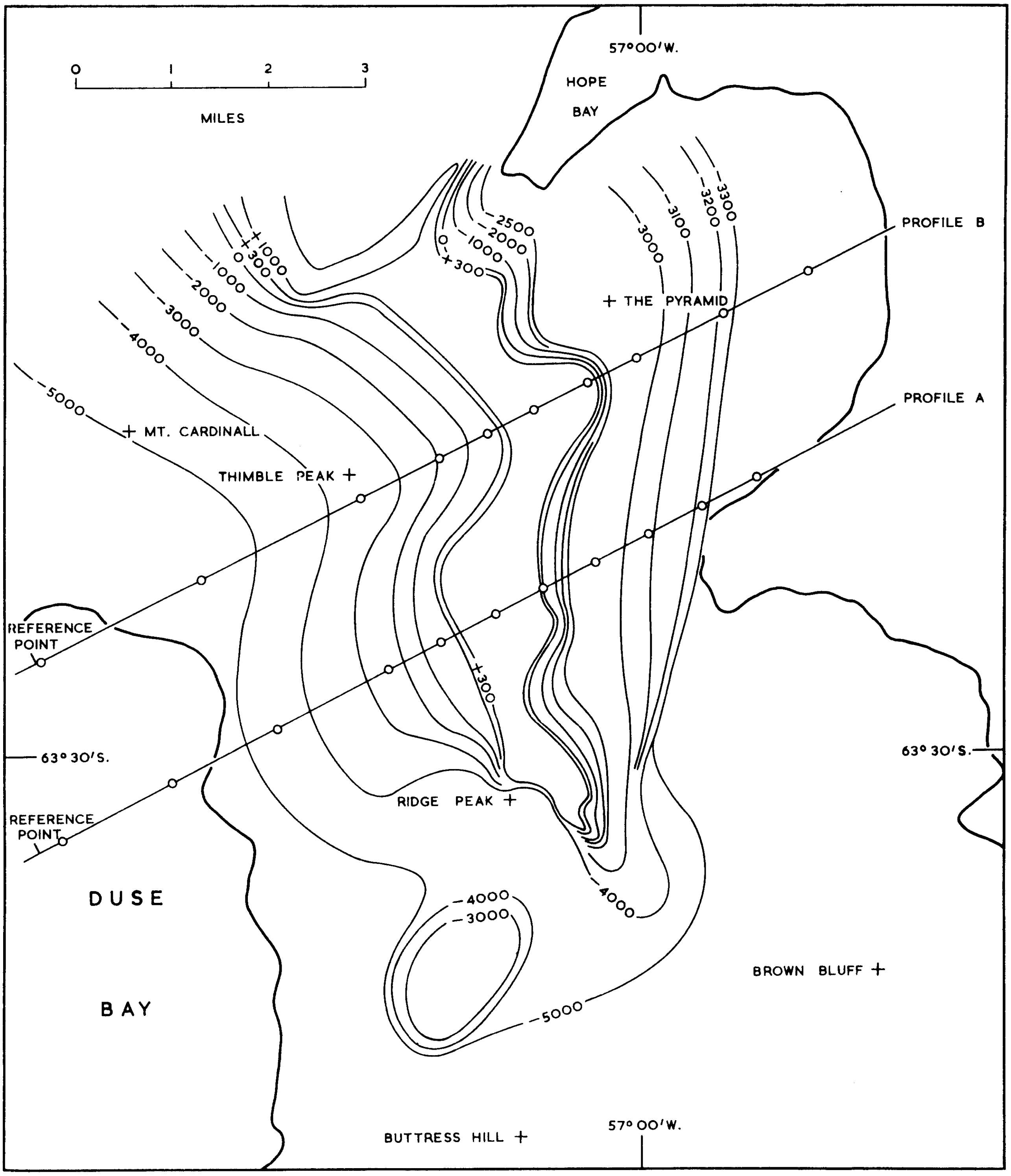

FIGURE 11

The topography of the upper surface of the intrusion for Solution 1 of the intrusion anomaly. The positions of Profiles A (Fig. 9) and B (Fig. 10) are shown.

o Points at which the magnetic field values have been calculated.

(Scale 1:100,000; contours are in feet)

1. *The intrusion anomaly*

The interpretation has been carried out by determining the anomaly along profiles rather than by calculating the anomaly at points distributed over the area. All the profiles used in the calculations are marked on the magnetic contour map (Fig. 8). The measured value of the apparent susceptibility for diorite has been used in the following solutions.

Figs. 9 and 10 show the observed and calculated anomalies for Solution 1 along Profiles A and B for a form of intrusion whose upper surface is illustrated in the contour map (Fig. 11). This mass has vertical sides and its base is effectively at infinite depth, i.e. the base makes no contribution to the observed anomaly, which implies that it is at a depth of at least 40,000 ft. (12,190 m.) below sea-level. No attempt has been made to find an exact solution for the highest parts of the anomalies, because a solution for the broad features of the intrusion is considered to be of prime importance. However, these high local anomalies superimposed on the broad features of the intrusion anomaly can be accounted for by bringing small areas of the intrusion closer to the surface. It is doubtful whether the local anomalies are caused by masses of diorite of anomalously high magnetization, because the value of magnetization used in the interpretation is that of the masses of diorite exposed at the surface along the central part of the intrusion.

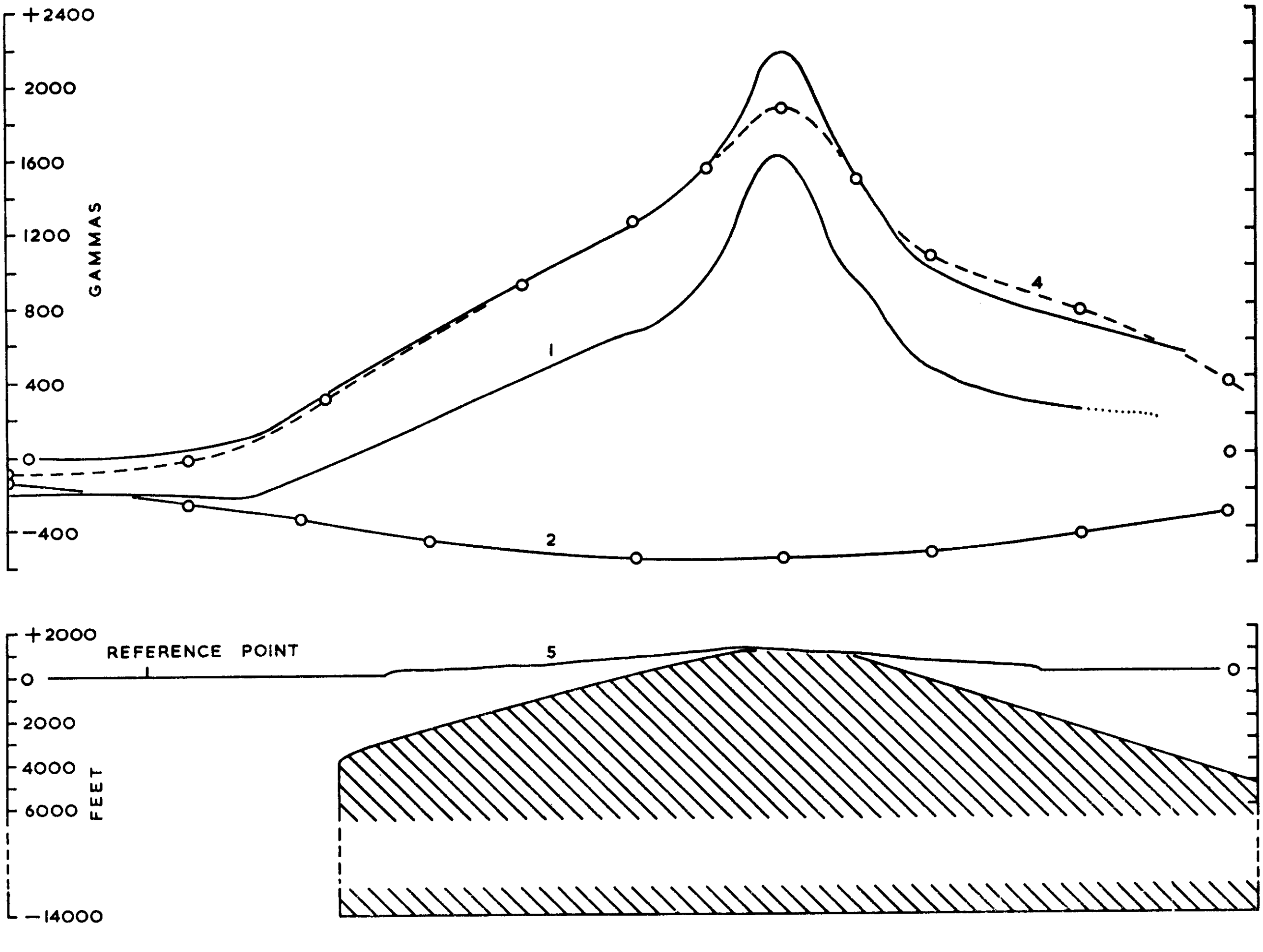

FIGURE 12

Profile A (Fig. 13) for Solution 2 of the intrusion anomaly. 1. Observed magnetic anomaly. 2. Calculated magnetic anomaly for the base of the intrusion. 3. Observed magnetic anomaly minus the calculated magnetic anomaly for the base of the intrusion. 4. Calculated magnetic anomaly for the upper surface of the intrusion. 5. Land surface.

▧ Cross-section of the intrusion.

o Points for which the magnetic field values have been calculated.

(Scale 1:100,000; vertical scale=horizontal scale)

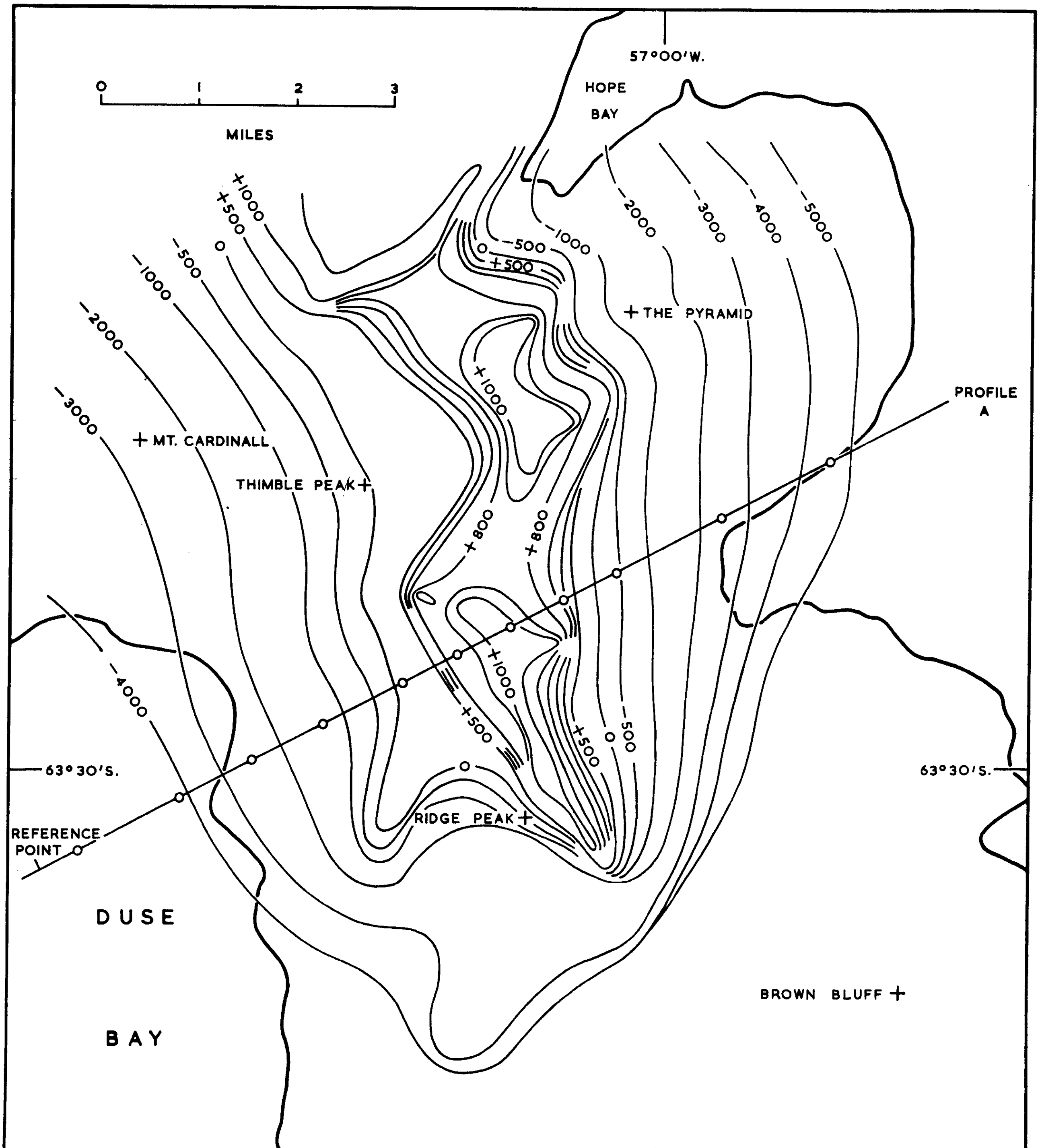

FIGURE 13

The topography of the upper surface of the intrusion for Solution 2 of the intrusion anomaly. The position of Profile A (Fig. 12) is shown.

○ Points at which the magnetic field values have been calculated.

(Scale 1:100,000; contours are in feet)

It would be useful if limits could be placed on the position of the margin of the intrusion for a solution of the form presented here. This is possible for the western margin of the intrusion, where the magnetic anomaly is well defined. If the intrusion extends westwards as far as the reference point (Profile A), i.e. a westerly extension of 2·3 miles (3·7 km.), and the margin of the intrusion is at a depth of 10,000 ft. (3,048 m.) below sea-level, then the anomaly at the reference point would be + 220 gammas. If the margin is at a depth of 20,000 ft. (6,096 m.), the anomaly would be + 100 gammas, while the observed anomaly at this point is about − 200 gammas. Even if the margin is at a depth of 40,000 ft. (12,190 m.) below sea-level the anomaly would be − 50 gammas. Considerations of this sort limit the position of the western margin of the intrusion to within ± 0·75 mile (± 1·21 km.) of its present position, allowing for the limits of error

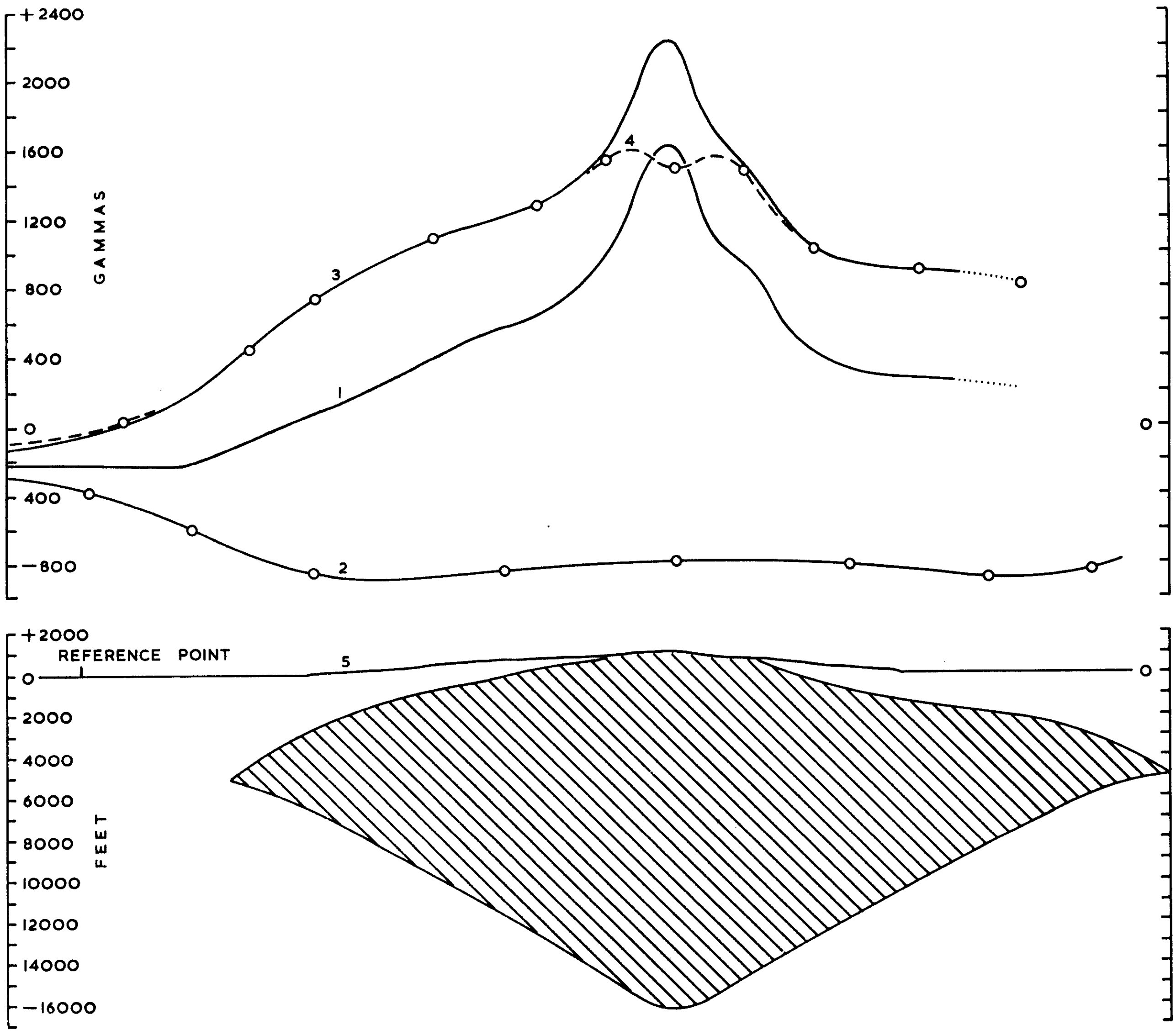

FIGURE 14

Profile A (Figs. 17 and 18) for Solution 3 of the intrusion anomaly.

1. Observed magnetic anomaly. 2. Calculated magnetic anomaly for the base of the intrusion. 3. Observed magnetic anomaly minus the calculated magnetic anomaly for the base of the intrusion. 4. Calculated magnetic anomaly for the upper surface of the intrusion. 5. Land surface.

▧ Cross-section of the intrusion.

o Points for which the magnetic field values have been calculated.

(Scale 1:100,000; vertical scale=horizontal scale)

of the calculated anomaly which are discussed later. The calculated anomaly is very susceptible to changes in the shape of the central part of the intrusion and this cannot be changed laterally or vertically by more than a few hundred feet.

Solution 2 for Profile A is shown in Fig. 12, while Fig. 13 gives the topography of the upper surface of the intrusion for this solution. In this solution the intrusion has vertical sides and a horizontal base at a depth of 14,000 ft. (4,270 m.) below sea-level. The object in obtaining a solution for the intrusion anomaly by a configuration such as this was to gain some idea of the minimum depth extent of the intrusion. If the base of the intrusion is brought too near the ground surface the observed magnetic anomaly cannot be accounted for without increasing the magnetization of the intrusion. In Solution 2 the base, which is not at the minimum depth extent, can be within the limits 14,000 $\pm$ 2,000 ft. (4,270 $\pm$ 610 m.) below sea-level and the intrusion would produce an anomaly which would fit the observed anomaly within the limits of error of the calculated anomaly. The minimum depth of the intrusion, assuming that its upper surface is close to the ground surface, is probably between 7,000 and 11,000 ft. (2,135 and 3,453 m.).

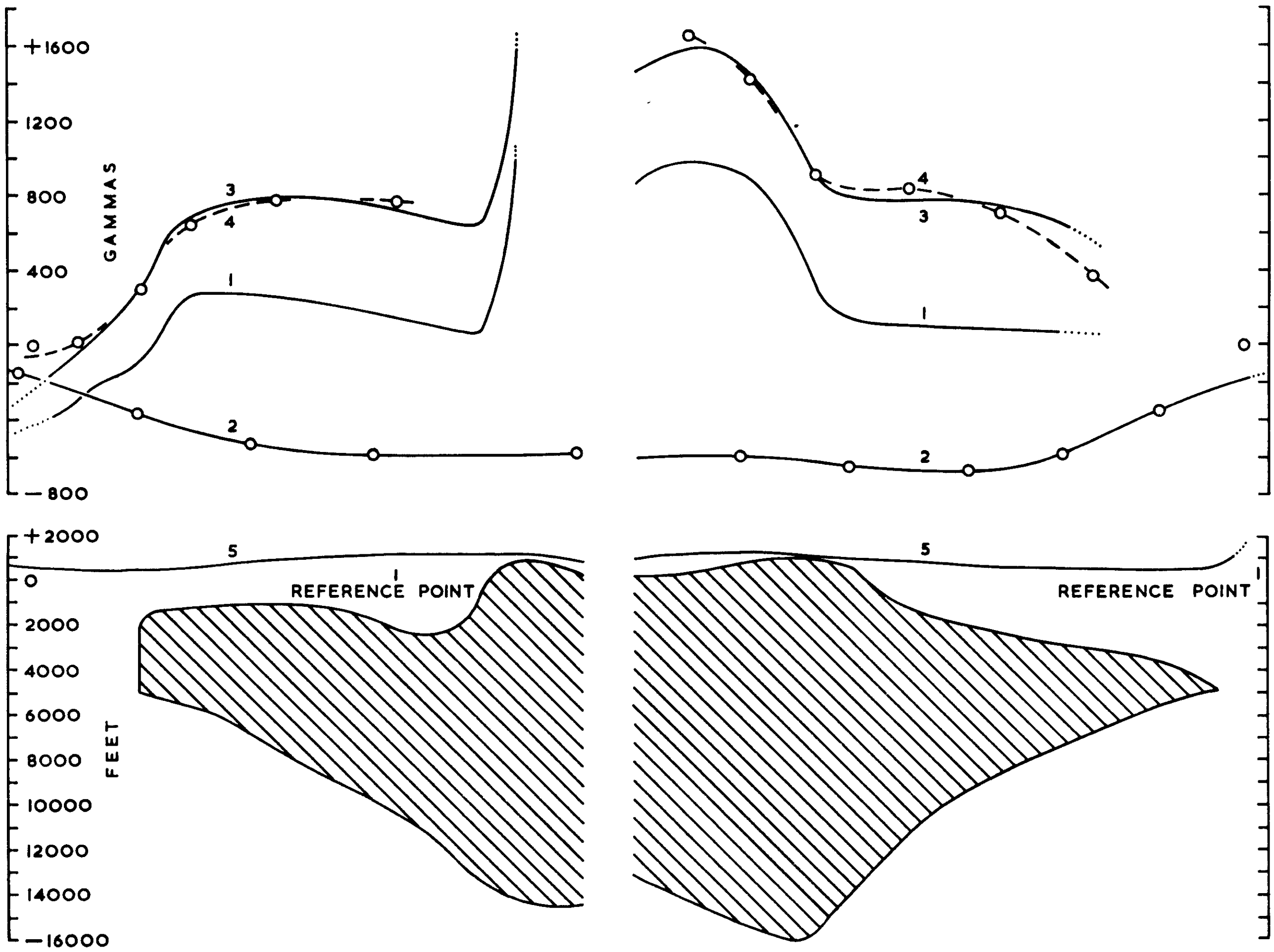

FIGURE 15

Profile C (Figs. 17 and 18) for Solution 3 of the intrusion anomaly.

FIGURE 16

Profile D (Figs. 17 and 18) for Solution 3 of the intrusion anomaly.

1. Observed magnetic anomaly. 2. Calculated magnetic anomaly for the base of the intrusion. 3. Observed magnetic anomaly minus the calculated magnetic anomaly for the base of the intrusion. 4. Calculated magnetic anomaly for the upper surface of the intrusion. 5. Land surface.

▧ Cross-section of the intrusion.

○ Points for which the magnetic field values have been calculated.

(Scale 1:100,000; vertical scale = horizontal scale)

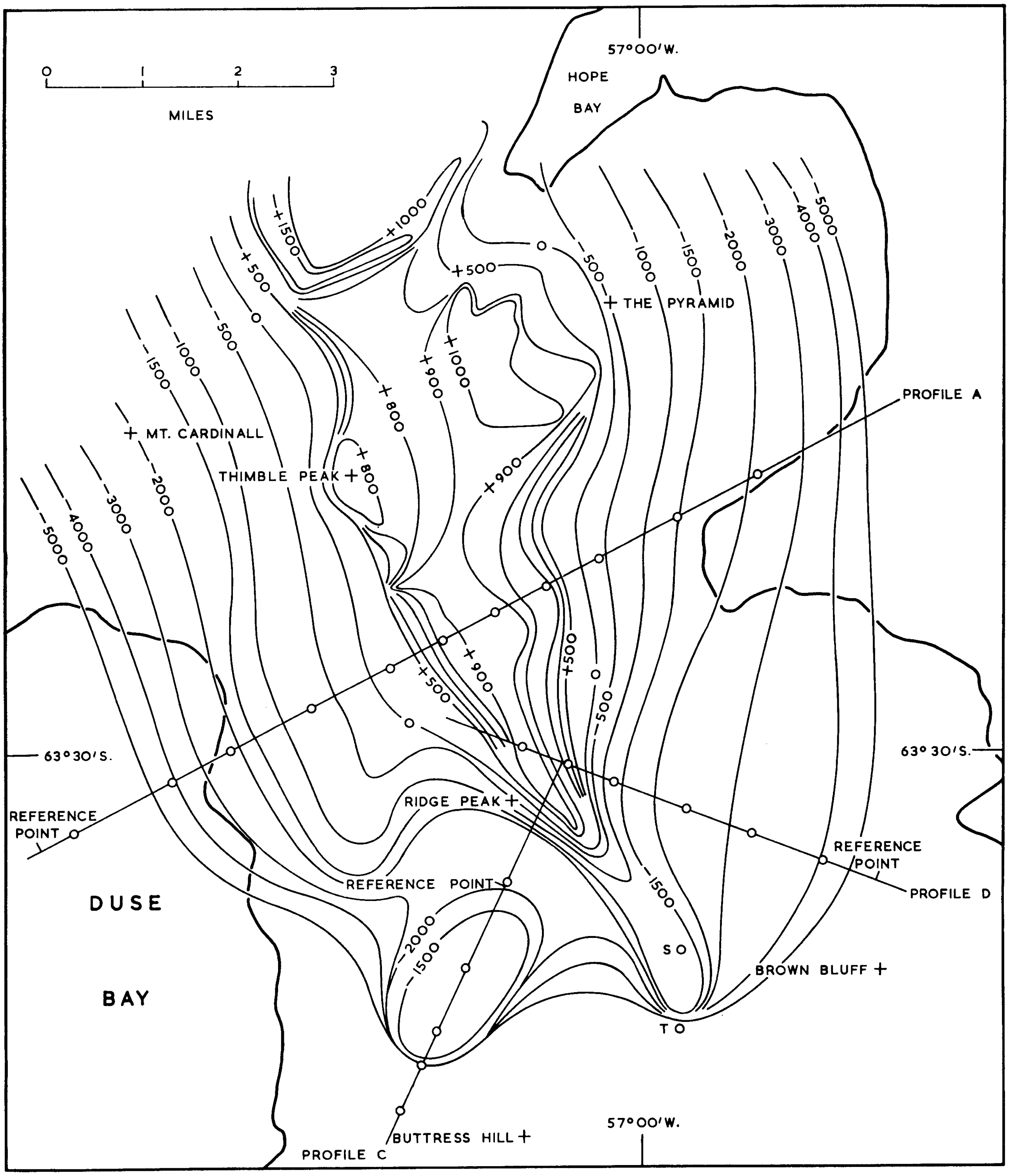

FIGURE 17

The topography of the upper surface of the intrusion for Solution 3 of the intrusion anomaly. The positions of Profiles A (Fig. 14), C (Fig. 15) and D (Fig. 16) are shown.

○ Points at which the magnetic field values have been calculated.

(Scale 1:100,000; contours are in feet)

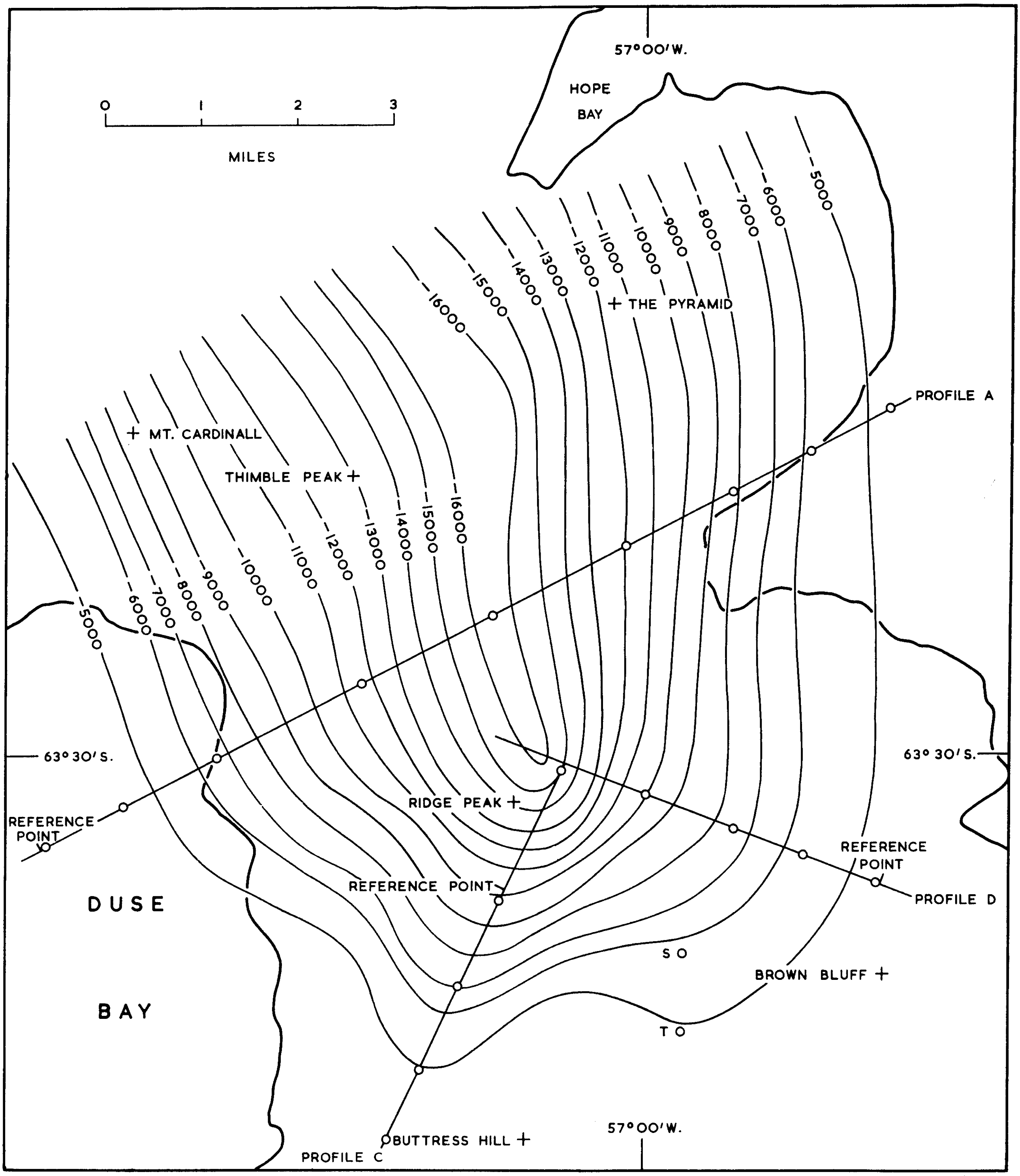

FIGURE 18

The topography of the lower surface of the intrusion for Solution 3 of the intrusion anomaly. The positions of Profiles A (Fig. 14), C (Fig. 15) and D (Fig. 16) are shown.

o Points at which the magnetic field values have been calculated.

(Scale 1:100,000; contours are in feet)

The western margin of the intrusion can be varied within $\pm$ 1,500 ft. ($\pm$ 458 m.) of its present position and the observed anomaly will lie within the limits of error of the calculated anomaly, while the eastern margin will satisfy this condition, if it lies within about 0·5 miles (0·8 km.) west and about 2 miles (3·2 km.) east of its position given in this solution.

A successful attempt was made to find a solution in which the intrusion does not have vertical sides while its upper surface is as close as possible to the ground surface and includes the outcrops of diorite. This is Solution 3 of the intrusion anomaly. The solutions for Profiles A, C and D are given in Figs. 14, 15 and 16. Figs. 17 and 18 show the topography of the upper and lower surfaces of the intrusion.

A configuration of the intrusion such as that given here places rather narrow limits on the position and depth of the margin of the intrusion, if the shape of the base is not varied over a wide range. For example, the configuration of the intrusion in this solution was derived by varying the depth of the margin of the intrusion between 2,000 and 6,000 ft. (610 and 1,829 m.) below sea-level and its position over a distance of 1·5 miles (2·5 km.), varying the maximum depth of the base between 13,000 and 16,000 ft. (3,962 and 4,877 m.) below sea-level and varying the slope of the base between 20° and 30° from the horizontal. Within these limits Solution 3 gives the one configuration which will produce the observed magnetic anomaly. The limits of error of the calculated anomaly allow a variation in the position of the western margin of the intrusion of $\pm$ 1,500 ft. ($\pm$ 457 m.) and a variation of a few hundred feet in the depth of the margin.

In all these solutions the influence of the thermally metamorphosed sediments, which definitely lie on the exposed parts of the intrusion and presumably also on the unexposed upper surface, has not been considered. The remanent magnetization of these sediments can be as high as 2–4 $\times$ 10^{-3} e.m.u./cm.^{3}, which is approximately equal to the resultant magnetization of the diorite. Using the maximum value of magnetization for the sediments the upper surface topography given in the above solutions represents the upper surface of the metamorphosed sediments whose thickness, say x ft., is unknown. If the remanent magnetization of the sediments is either less than or greater than the magnetization of the diorite, then the upper surface of the intrusion will be at a distance less than or greater than x ft. below the upper surfaces given in the above solutions. The directions of remanent magnetization of the more intensely magnetized sediments agree with the direction of the remanent magnetization of the diorite, which suggests that the sediments have acquired a thermo-remanent magnetization as a result of heating by the diorite-gabbro mass when the latter was injected. If this is so, an estimate of the thickness of sediments which has been raised above the Curie Point of magnetite can be gained from the work of Jaeger (1957). He has calculated that an intrusive sheet of thickness D and infinite extent in the horizontal plane will heat the country rock within a distance of $0{\cdot}04D$ of its margin to a temperature above the Curie Point of magnetite. This figure is not greatly affected if the sedimentary cover is as low as $0{\cdot}5D$. None of the solutions for the Tabarin Peninsula intrusion are sheet-like masses, nevertheless some idea of the thickness of sediments having a thermo-remanent magnetization can be gained for Solution 3. In this solution the average width of the intrusion is 42,000 ft. (12,802 m.) and the thickness varies from a few feet at the margins to 16,000 ft. (4,877 m.) at the centre. A sheet-like mass of thickness 16,000 ft. (4,877 m.) would be covered by 640 ft. (195 m.) of sediments having a thermo-remanent magnetization and this is certainly a considerable overestimate of the thickness of such sediments overlying the intrusion of Solution 3. If the average thickness of the intrusion is assumed to be 8,000 ft. (2,438 m.), i.e. one-fifth the average width of the intrusion, then the intrusion is one to which Jaeger's result can be applied. In this case there would be about 300 ft. (91 m.) of sediments which would exhibit a thermo-remanent magnetization.

These considerations demonstrate a source of error of up to a few hundred feet in the height of the upper surface of the intrusion given in the solutions for the intrusion anomaly. A further source of error is the contribution to the anomaly of the horizontal magnetization of the intrusion, which has been neglected in these solutions. An estimate of its magnitude for a mass of similar shape to that used in Solution 3 but having infinite extent in both northern and southern directions has been made. The maximum effect of the horizontal magnetization is approximately 100 gammas; its effect for the intrusion of Solution 3 will be somewhat less than this value and for the intrusions of Solutions 1 and 2 it will be less than 60 gammas. The error in the resultant magnetization of the diorite is $\pm$ 21 per cent, which implies a similar error in the calculated anomaly. In consequence of this error it has not been considered necessary to calculate the exact contribution of the horizontal magnetization.

The best-defined part of the intrusion is its western margin, which varies in position over a distance of

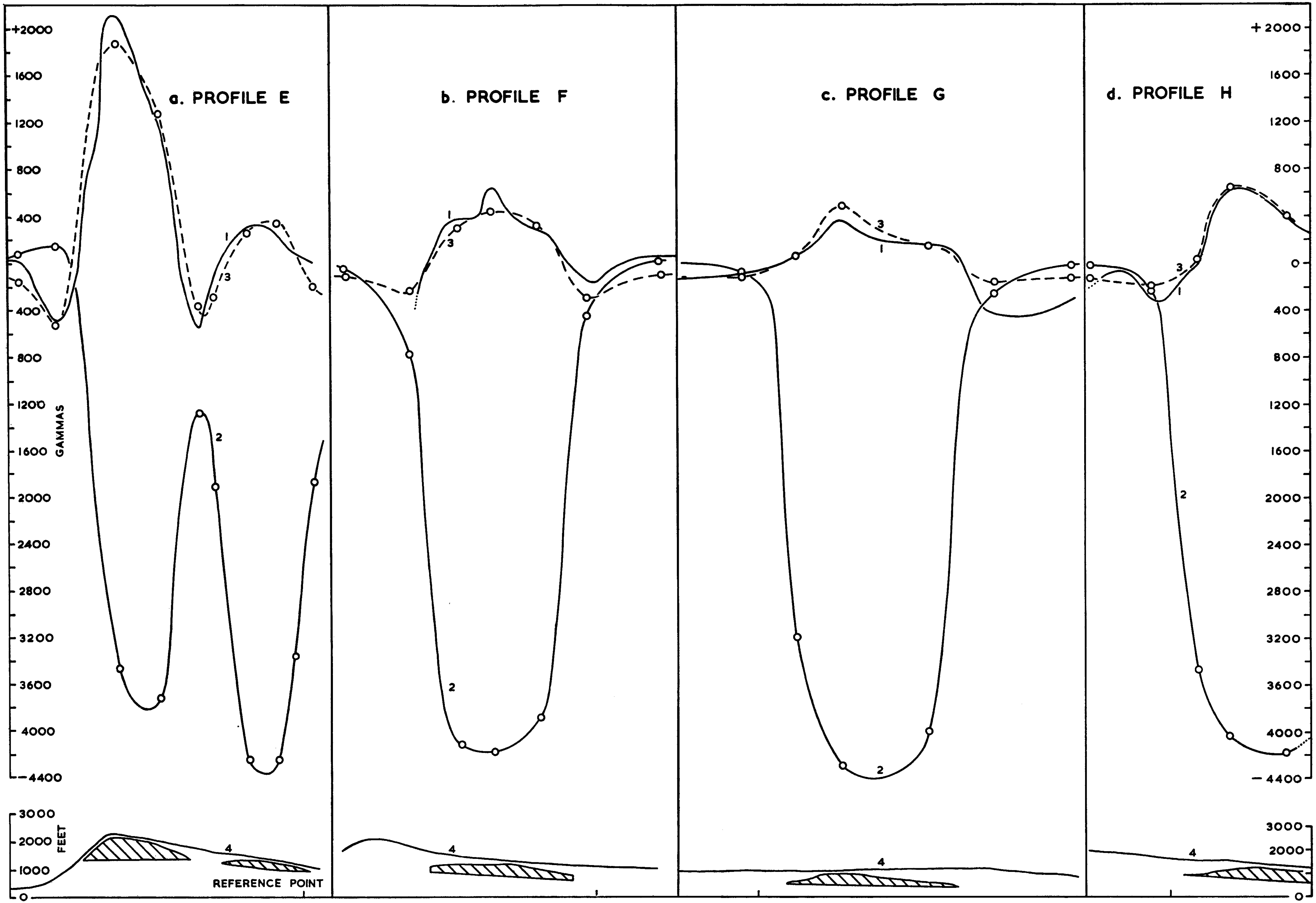

FIGURE 19

Solution for the magnetic anomalies along Profiles E, F, G and H (Figs. 20 and 21)

Cross section of the lava flow

only 1·5 miles (2·4 km.) in the three solutions. The eastern margin has been defined on the assumption that the anomaly decreases to below 0 gammas just off the eastern edge of the peninsula. It is conceivable that the intrusion extends farther south than the position given in Solution 3 but, if this is so, it must then be at considerable depth or otherwise its presence would be detectable in the area between Buttress Hill and Brown Bluff, as the anomalies over the latter features fall off very quickly with distance. The anomalies calculated at points S and T (Figs. 8, 17 and 18) for Solution 3 are respectively + 75 and − 100 gammas.

Solution 3 is considered geologically to be the most feasible of the three solutions presented for the intrusion anomaly. The question of how the intrusion was fed now arises. Some further magnetic results from the area north and north-west of Tabarin Peninsula have been made available by A. Allen and these suggest that the intrusive mass extends in a northerly and north-westerly direction from Tabarin Peninsula. The part of the intrusion on Tabarin Peninsula could therefore have been fed from the north. Alternatively, a fissure-like feed under the central part of the intrusion is quite possible and could be incorporated in the given solutions with a negligible effect on the calculated anomalies, unless it is more than 2,000–3,000 ft. (610–914 m.) wide.

No information can be given about the relationship between the Nobby Nunatak gabbro and the Tabarin Peninsula diorite as the gabbro has a very low susceptibility and a very low remanent magnetization.

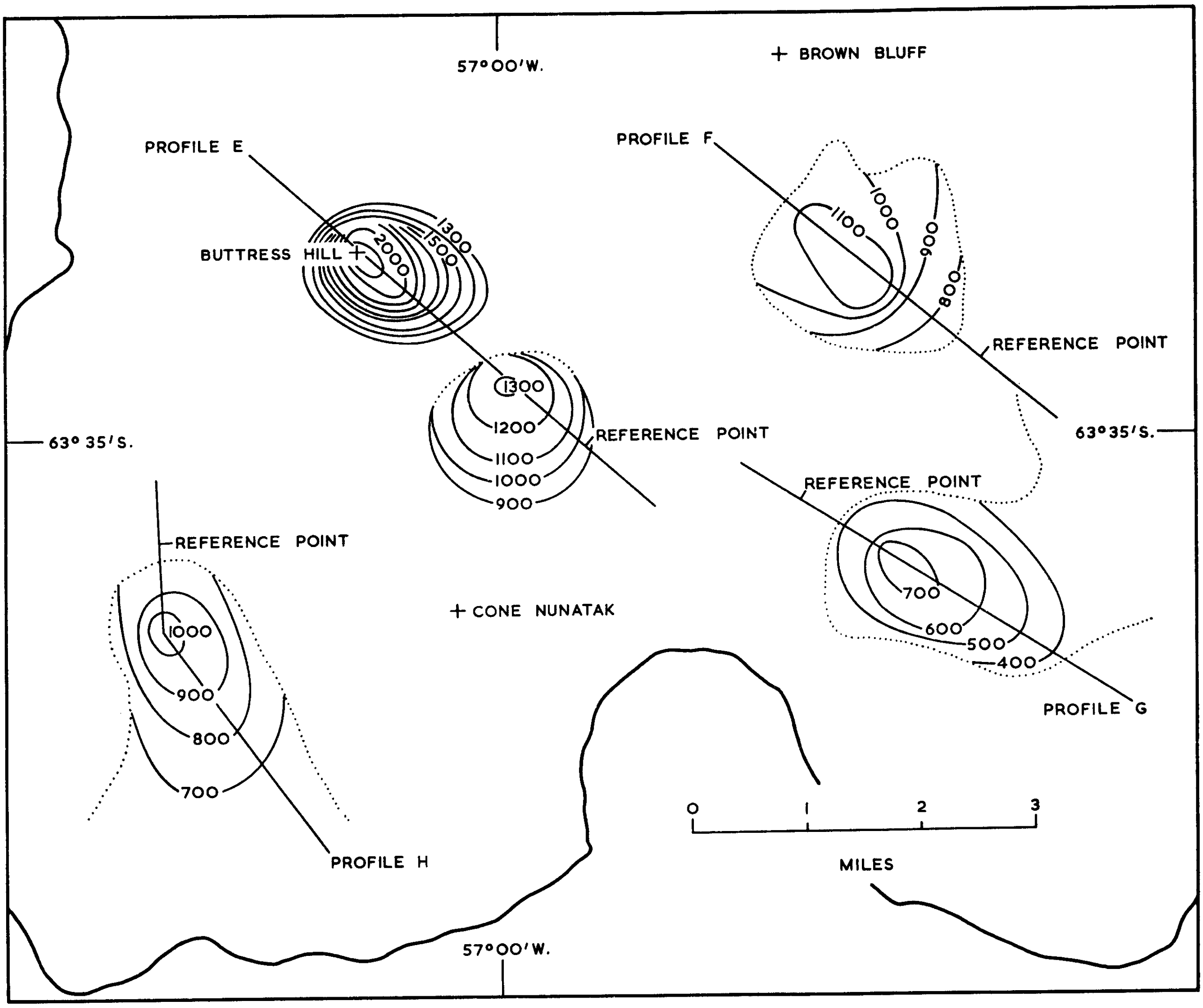

FIGURE 20

The topography of the upper surfaces of the lava flows for solutions along Profiles E, F, G and H (Fig. 19).
. . . . . . Boundaries of the lava flows.
(Scale 1:100,000; contour interval 100 feet)

2. *The anomalies on southern Tabarin Peninsula*

An interpretation of five of the positive anomalies in this part of Tabarin Peninsula (south of and including Buttress Hill and Brown Bluff) has been achieved along the Profiles E, F, G and H (Fig. 8). Some comments are made on the large negative anomalies over Brown Bluff and Seven Buttresses.

a. *Profiles E, F, G and H.* No rock samples were taken from Buttress Hill; some olivine-basalt lava samples, collected from an outcrop immediately to the west of Buttress Hill, have a reversed remanent magnetization. If Buttress Hill, which is composed of volcanic material, is capped by the same lava flow as that from which the samples were taken, then a negative anomaly should be observed over it. The olivine-basalt agglomerates have both reversed and normal remanent magnetizations of widely scattered directions and it is impossible, judging from the measured values of their intensity of magnetization and susceptibility, for them to produce the positive anomaly observed over Buttress Hill. The most likely explanation is that the hill is capped by a normally magnetized lava flow, although no such flows have been sampled on Tabarin Peninsula. The results from the Corry Island olivine-basalt lava flow (Table IV) prove the existence of normally magnetized lava flows within the James Ross Island Volcanic Group. This flow has an equivalent susceptibility of approximately 9×10^{-3} c.g.s. units/cm.[3], while the reversely

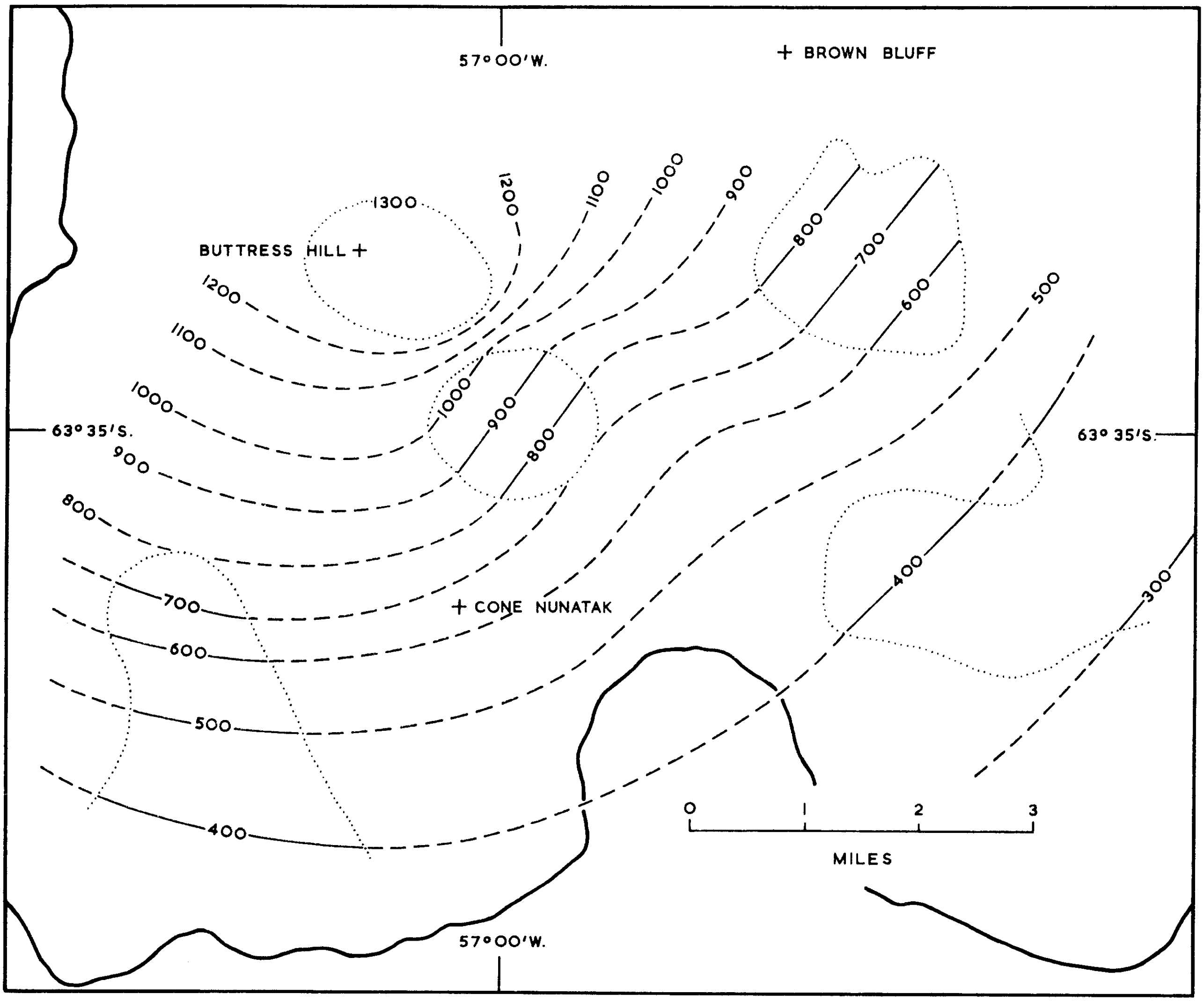

FIGURE 21

The topography of the lower surfaces of the lava flows for solutions along Profiles E, F, G and H (Fig. 19).
. . . . . . Boundaries of the lava flows.
– – – Interpolated contours.

(Scale 1:100,000; contour interval 100 feet) magnetized olivine-basalt lava flow capping Brown Bluff has an equivalent susceptibility of about 40×10^{-3} c.g.s. units/cm.^{3}, thus illustrating the wide range in the magnetic properties of the olivine-basalts within the James Ross Island Volcanic Group.

Solutions have been obtained for the Buttress Hill anomaly and the positive anomaly immediately south of Buttress Hill, in terms of a normally magnetized lava of equivalent susceptibility 21×10^{-3} c.g.s. units/cm.^{3}, i.e. a resultant intensity of magnetization of $9{\cdot}1 \times 10^{-3}$ e.m.u./cm.^{3}. The solution for Profile E is illustrated in Fig. 19a, while Figs. 20 and 21 show the topography of the upper and lower surfaces of the lava flow. The ice thickness on the top of Buttress Hill is about 100 ft. (30·5 m.) according to this solution. The negative anomalies surrounding Buttress Hill are accounted for and the limited lateral extent of the anomaly is indicated. The influence of the olivine-basalt agglomerates underlying the lava is assumed to be negligible.

The other positive anomalies in this part of the peninsula are explained as being due to small masses of lava of the same magnetic properties as that of Buttress Hill. Solutions for these anomalies have been calculated by assuming that the average ice thickness in this area is about 200 ft. (61·0 m.) and that the ice rests directly on the lava. Figs. 19b, c and d show the observed and calculated anomalies for three of the positive anomalies. Contour maps of the upper and lower surfaces of the lava masses are given in Figs. 20 and 21. It is strongly suggested from Fig. 21 that, on the above interpretation, the small lava masses are the remnants of an original lava flow which covered most or all of this part of the peninsula and which has since suffered considerable glacial erosion. The easternmost positive anomaly, which is only partly delineated, has not been interpreted, because it is not clear whether it is an anomaly in its own right or whether it is associated with some anomaly in the unsurveyed area to the south. Although olivine-basalt agglomerates crop out at Cone Nunatak, the positive anomaly there suggests that olivine-basalt lavas are present at no great distance from the surface.

In the above solutions the effect of the agglomerates has again been assumed to be negligible.

b. *The Brown Bluff anomaly*. The lava flow capping Brown Bluff can be seen in a north-facing cliff exposure and its thickness, and also the thickness of the ice above it, have been measured by observing the vertical angles subtended by the upper and lower margins of the flow and by the upper surface of the ice at a point of known position. Measurements at three different points along the flow indicate a thickness of about 120 ft. (36·6 m.) of olivine-basalt overlain by about 120 ft. (36·6 m.) of ice. A reversely magnetized lava flow in the form of a flat disc of radius 3,000 ft. (914 m.) and thickness 200 ft. (61·0 m.) would produce an anomaly of nearly − 1,000 gammas at a point 100 ft. (30·5 m.) above its centre, if the apparent susceptibility of the lava is 43×10^{-3} c.g.s. units/cm.^{3} (intensity of magnetization approximately 19×10^{-3} e.m.u./cm.^{3}). The anomaly on top of Brown Bluff decreases to almost − 1,200 gammas but the disc anomaly could be increased in magnitude by adjusting the shape of the disc.

The above considerations are sufficient to indicate that the anomaly observed over Brown Bluff is produced by a reversely magnetized lava flow and is consistent with the known physical properties of this flow. The density of stations over Brown Bluff does not warrant a more refined solution.

c. *The anomalies above Seven Buttresses*. A lava flow, 50–100 ft. (15·3–30·5 m.) thick, is exposed at the top of Seven Buttresses at a height of about 700 ft. (213·5 m.) a.s.l. and the outcrop west of Buttress Hill, at a height of about 1,400 ft. (427 m.) a.s.l., is probably part of the same flow. The latter is reversely magnetized and the lava flow could therefore produce the observed negative anomalies above Seven Buttresses. No interpretation of these anomalies has been undertaken as the topography in the area of these anomalies is not yet accurately known.

3. *Anomalies in the Duse Bay area*

The part of Beak Island west of the large bay on the north coast is capped by a reversely magnetized horizontal olivine-basalt lava flow of estimated thickness 150–200 ft. (45·8–61·0 m.). The lava rests on agglomerates which form the bulk of the island, and numerous dykes are intruded through the agglomerates. The susceptibility of the lava is small and hence the resultant magnetization is virtually the remanent magnetization, i.e. $1{\cdot}1 \times 10^{-3}$ e.m.u./cm.^{3}, which gives an equivalent susceptibility of about 3×10^{-3} c.g.s. units/cm.^{3}. The extent and thickness of the flow are known approximately but the observed anomaly cannot be explained unless the susceptibility value is raised to 12×10^{-3} c.g.s. units/cm.^{3}. The magnetic effect of the rocks beneath the lava is assumed to be negligible.

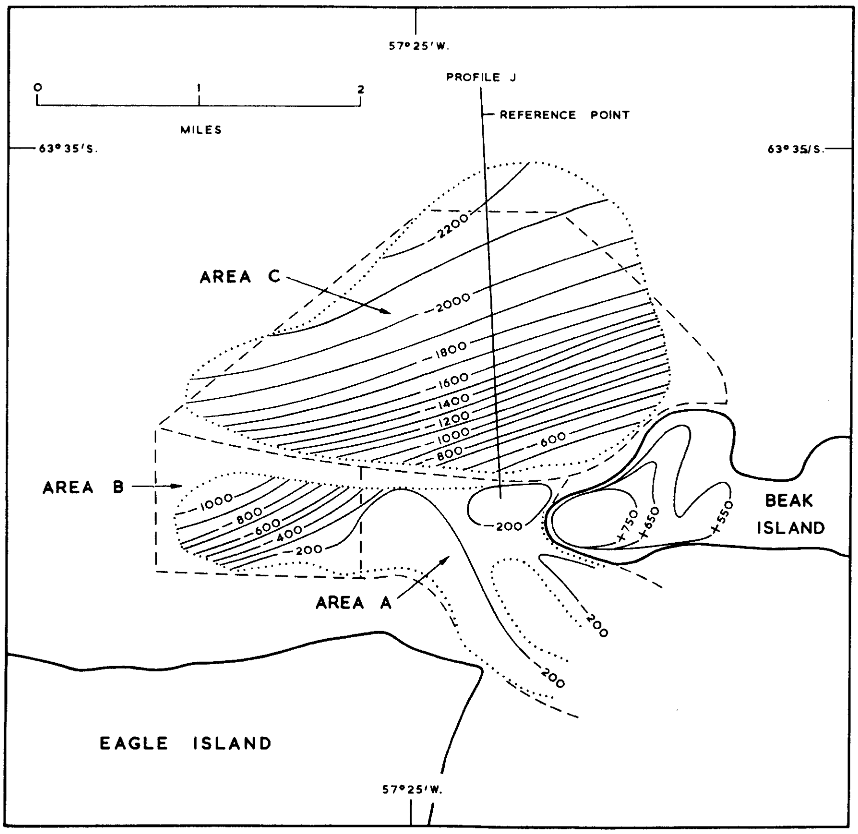

FIGURE 22

The topography of the upper surfaces of the lava flows on and in the vicinity of Beak Island. The position of Profile J (Fig. 23) is shown.

...... Boundaries of the lava flows.

– – – Boundaries of the areas A, B and C.

(Scale 1:75,000; contour interval 100 feet)

TABLE VI

LAVA FLOW PARAMETERS FOR SOLUTION OF THE MAGNETIC ANOMALY IN AREA A (FIG. 22)

Susceptibility (c.g.s. units/cm.^{3} $\times$ 10^{-3})	*Depth of Lava Flow below Sea-level* (ft.)	
	Upper Surface	*Lower Surface*
12	50	200
12	100	260
12	150	330
12*	200*	410*
5	100	560
3	100	600
3	300	1200

The assumption that the large negative anomalies in the area between Beak and Eagle Islands are due to a reversely magnetized lava flow is inevitable and it is further assumed that its properties are similar to those deduced for the Beak Island flow. The depth of the sea in this area is not accurately known and therefore various approximate solutions are presented. A reversely magnetized lava flow at some distance below sea-level will not produce a positive anomaly at sea-level and hence the positive anomalies in this area must be caused by a mass of different magnetic properties, probably a normally magnetized lava flow.

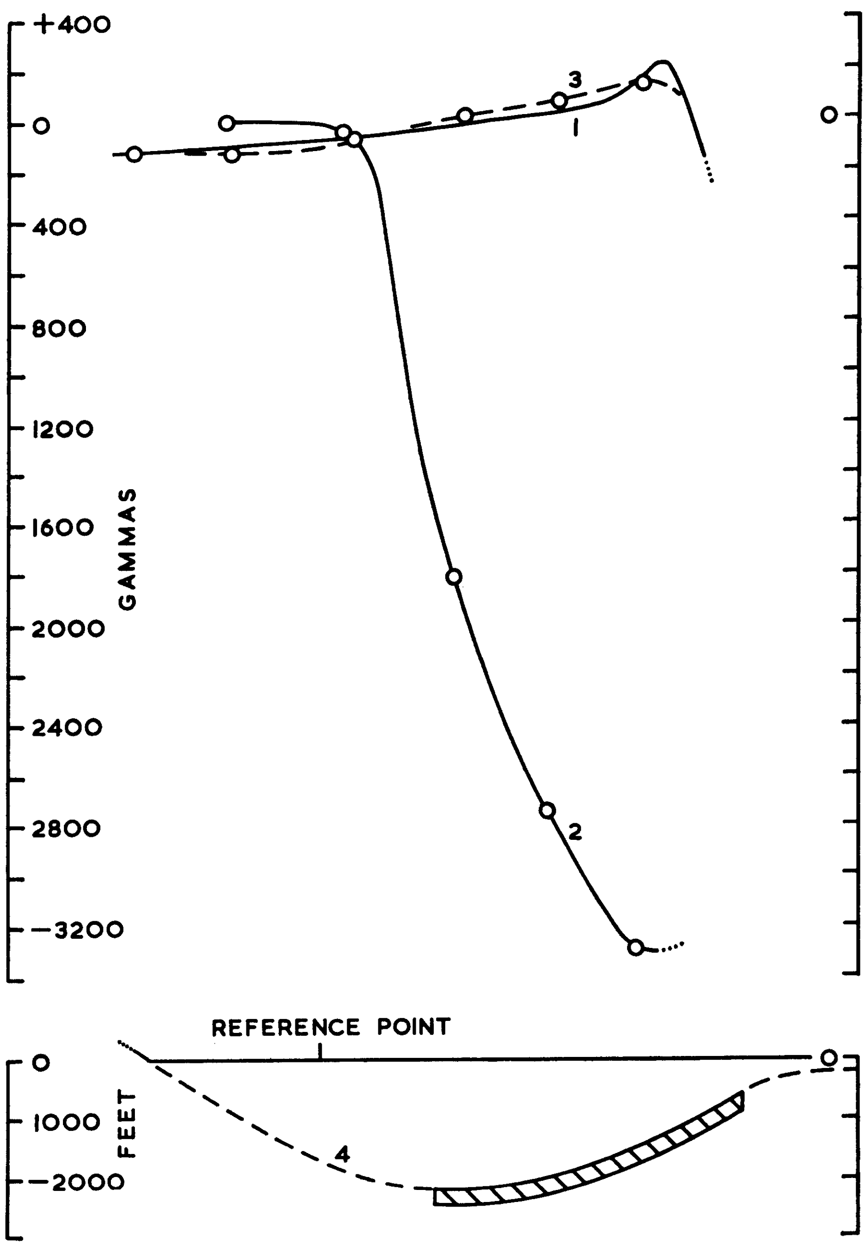

FIGURE 23

The solution of the magnetic anomaly along Profile J (Fig. 22).

1. Observed magnetic anomaly. 2. Calculated magnetic anomaly for the base of the lava flow. 3. Calculated magnetic anomaly for the upper surface of the lava flow plus the calculated magnetic anomaly for the base of the lava flow. 4. Approximate submarine topography.

Cross-section of the lava flow.

(Scale 1:75,000; vertical scale=2×horizontal scale)

Fig. 22 illustrates the extent and upper surface topography of the reversely magnetized lava flow indicated by an asterisk in Table VI. For Area A, where the depth to the sea bed is probably a minimum for the area, a horizontal lava flow with any of the parameters given in Table VI will produce an anomaly of − 1,500 gammas at sea-level.

For Area B (Fig. 22) the sea depth may be as much as 150 fathoms (275 m.) and, if the lava crops out on the sea bed, then its thickness must be 140 ft. (42·7 m.) to produce an anomaly of − 500 gammas at sea-level. If the value for sea depth in this area is correct, then it is certain that the James Ross Island Volcanic Group is present at a depth of about 1,000 ft. (305 m.) below sea-level.

The lava flow on Beak Island will produce a positive anomaly at sea-level but only within a distance of about 0·25 mile (0·40 km.) of the island. An explanation of the positive anomaly in Area C (Fig. 22) must therefore be sought in terms of another mass; presumably the volcanics extend northward into this area. A study of the topographic map (Fig. 7) in conjunction with the magnetic map (Fig. 8) indicates that the positive anomaly extends northward into this area between the 400 fathom (732 m.) contours. One solution of the anomaly is presented in Fig. 23, where the calculated anomaly for a normally magnetized lava flow of thickness 300 ft. (91·4 m.) and susceptibility 21 × 10^{-3} c.g.s. units/cm.^{3} is given. The fit between observed and calculated anomalies is not particularly good. Since information on the sea depth in this area is poor and the susceptibility value is assumed, a more exact solution would not necessarily be of more value than the present one. The solution suggests that the volcanics are present at a depth of at least 300 fathoms (548 m.) below sea-level. An important point arising from the above solution is that a mass of lava of

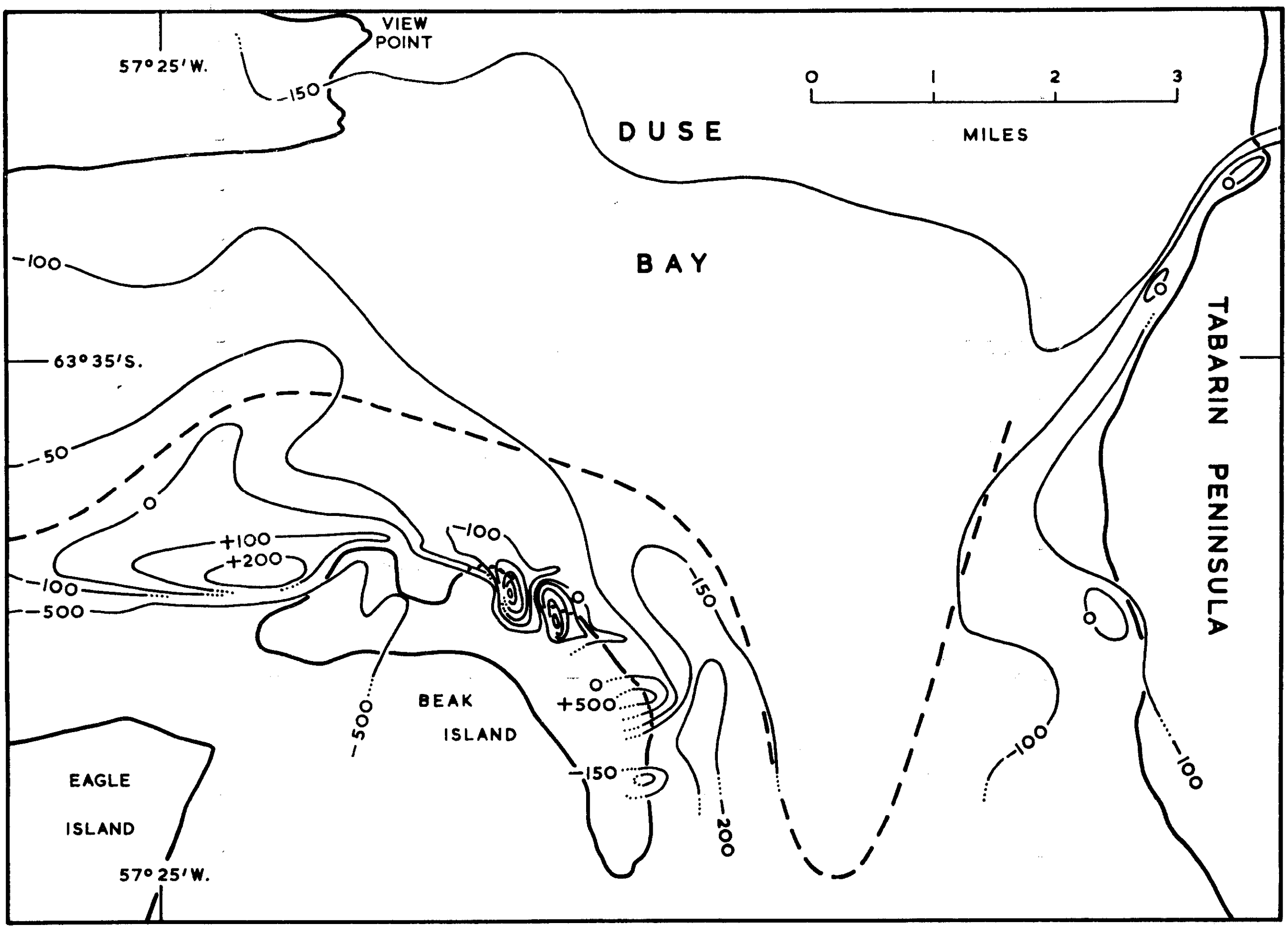

FIGURE 24

The position of the postulated northern boundary of the James Ross Island Volcanic Group in relation to the magnetic anomalies.

— — — Boundary of the volcanics.

——— Magnetic field contours in gammas.

(Scale 1:100,000)

susceptibility 21×10^{-3} c.g.s. units/cm.^{3} and thickness 300 ft. (91·4 m.) produces a very small anomaly at a point 2,000 ft. (610 m.) above its surface. Volcanics could therefore be present in the deepest part of Duse Bay and their presence need not be apparent from the magnetic results.

It is interesting to suppose that the base of the volcanics is horizontal and at a depth of 300–400 fathoms (548–732 m.) below sea-level and then to trace the position of the boundary of the volcanics in Duse Bay. Fig. 24 shows this boundary in relation to the magnetic anomalies. The boundary follows approximately the trend of the − 100 gammas contour and there are significantly higher magnetic values to the south of the boundary than to the north. The negative anomaly to the east of Beak Island appears to be an anomaly in its own right, i.e. it is not caused by the mass of Beak Island, thus suggesting that the volcanics extend to the east of Beak Island. The boundary of the volcanics, as shown in Fig. 24, is not incompatible with the magnetic results but a quantitative analysis of the results is restricted by the quality of the topographic map and reliability of the intensity of the magnetization data. However, there is some evidence to suggest that the volcanics are present to a depth of at least 2,000 ft. (610 m.) below sea-level and, as they are exposed on Eagle Island at a height of 1,840 ft. (561 m.) a.s.l., the James Ross Island Volcanic Group is probably at least 4,000 ft. (1,220 m.) thick.

VII. SUMMARY

THE outcrops of the Andean Intrusive Suite diorite in the northern part of Tabarin Peninsula have been shown to be exposed parts of one large intrusion which extends from near Buttress Hill in the south to at least Blade Ridge in the north. Geologically, the most feasible of the three configurations presented for this intrusion is that of Solution 3, in which the intrusion approximates in form to a laccolith. It has been assumed that this mass, or that represented by Solution 2, has been intruded into the Trinity Peninsula Series sediments and that either these sediments or rocks of low magnetic properties now underlie the intrusion. When the laccolith was intruded it most probably produced uplift of the sediments in the northern part of Tabarin Peninsula. These uplifted sediments have since been eroded to expose the central part of the upper surface of the intrusion at Mineral Hill, Ridge Peak, Summit Ridge, etc. Had this laccolith not been intruded in this area then that part of Tabarin Peninsula south of and including Buttress Hill and Brown Bluff might now be an island, which would conform morphologically with the present island distribution of the volcanics.

The limits to the position of the western margin of the intrusion are defined, to within a few hundred yards, by the positions given in Solutions 1 and 2, i.e. the margin may vary in position over a distance of approximately 1·5 miles (2·4 km.). Elsewhere the extent of the intrusion is not so well defined, because in the eastern part of Tabarin Peninsula the magnetic survey may not extend over the margin of the intrusion and to the south the magnetic anomalies are influenced by the volcanic masses of Buttress Hill and Brown Bluff. The actual form of the intrusion could most probably be decided by carrying out a gravity survey over the northern part of Tabarin Peninsula.

Because of the negligible contrast in the magnetic properties of the sediments of the Trinity Peninsula Series and the agglomerates and tuffs of the James Ross Island Volcanic Group, it has been impossible to obtain definite information on the contact between these two groups of rocks. The measured values of volume susceptibility and remanent magnetization both indicate that magnetic anomalies will only be observed over the volcanics where olivine-basalt lava flows are present. Although the magnetization of the lavas is high, the lava flows must be of considerable thickness to produce observable magnetic anomalies at points 2,000–3,000 ft. (610–914 m.) above their surfaces. Consequently, if the lava flows within the volcanics group are thin, and none thicker than 100–200 ft. (30·5–61·0 m.) have been observed, they could be present beneath Duse Bay at a depth of 300–500 fathoms (549–914 m.) and not be detected, magnetically, at sea-level. Contrary to these considerations, the northern boundary of the volcanics given in Fig. 24 is based on the assumption that wherever volcanic rocks are present beneath Duse Bay they will produce a magnetic anomaly at sea-level. Even if this assumption is true, it is impossible qualitatively to position the boundary precisely in respect of the magnetic anomalies. The difficulty in determining the nature of the contact between the volcanics and the sediments of, presumably, the Trinity Peninsula Series will now be apparent, and it is doubtful whether a magnetic survey on any scale could provide the solution to this problem.

In the interpretation all the anomalies over the volcanics have been attributed to olivine-basalt lava flows; at least two such flows have been distinguished on the southern part of Tabarin Peninsula. The topography of the base of a normally magnetized lava flow has been indicated in Fig. 21. The reversely magnetized lava flows exposed near the top of Brown Bluff and to the west of Buttress Hill may be parts of the same flow and certainly do not belong to the normally magnetized lava flow mentioned above.

VIII. ACKNOWLEDGEMENTS

MY thanks are due to Dr. R. J. Adie for advice on the preparation of this report, and to Drs. D. H. Griffiths and R. F. King of the Department of Geology, University of Birmingham, for most helpful discussions during the course of the work. I should like to thank Professor F. W. Shotton for providing the laboratory facilities for this study. I am indebted to the personnel of the Falkland Islands Dependencies Survey station at Hope Bay for their co-operation. Particular mention must be made of R. Tindal, who accompanied me throughout the greater part of the field work, was responsible for much of the rock sample collection and for the construction of the non-magnetic hut; M. D. Rhodes, D. MacCalman and T. Richardson efficiently maintained the equipment in the non-magnetic hut while I was in the field.

I am grateful to the Directorate of Overseas Surveys for providing topographical information on Tabarin Peninsula and also for preparing the topographical map (Fig. 7) and the magnetic contour map (Fig. 8).

Mr. L. W. Vaughan very kindly prepared the plates.

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APPENDIX

THE BEHAVIOUR OF THE INSTRUMENTS IN LOW TEMPERATURES AND SOME SUGGESTIONS FOR IMPROVEMENT IN DESIGN

Plates Ib, c and d illustrate the magnetometers and the recording equipment. This appendix is a brief account of the performance of the equipment and the faults which developed during its operation. Some suggestions are made for eradicating these faults.

1. *The Gfz magnetometer*

This instrument was used in temperatures down to −30 °F (−34 °C) and the only trouble experienced was with the clamping mechanism. At temperatures below about 0 °F (−18 °C) the clamping mechanism became very stiff and was difficult to operate. This may have been due to differential contraction of the components of the mechanism and a low temperature lubricant might be a possible remedy.

The clamping knob (Plate Ib) could be better designed for use in cold climates where it is necessary to operate the instrument with gloved hands. The small arm of the knob, which is used for rotating the knob between its clamped and unclamped positions, and the knob itself should be considerably larger in size.

The instrument head is attached to the tripod by three screws. For safety reasons the head was always detached from the tripod and carried in its padded container when travelling between field stations. In low temperatures the procedure of securing the instrument head to the tripod by turning the screws with a screwdriver is irksome and it would be a great improvement if the screws were to be fitted with knurled knobs and the number of screws reduced from three to two.

In the present construction of the tripod the distance to which the legs will splay out is limited. If work is carried out in winds of up to 20 knots (10·3 m./sec.) there is a tendency for the tripod to be blown over unless the ground surface is firm enough to grip the ends of the tripod legs. Many snow surfaces do not provide sufficient grip and the instrument would be safer if the tripod legs splayed out to a greater distance.

In every other way the instrument worked satisfactorily.

2. *The diurnal variation recording equipment*

The Gf6 magnetometer, equipped with its photocell head (Plate Ic), was perfectly satisfactory.

The mechanism of the recording apparatus, outlined on p. 6, developed several minor faults during its operation. The ink band of the Hartmann and Braun recorder did not function properly at temperatures below about 35 °F (2 °C) and at these temperatures the trace on the chart was faint or indistinguishable. This was, however, rarely a cause for concern as the temperature inside the non-magnetic hut only infrequently fell below 50 °F (10 °C).

The recording apparatus was run almost continuously for 13 months. The clockwork motor gradually slowed down so that at the end of this period the chart speed was approximately 0·17 mm./hr. less than its original speed of 20 mm./hr. There is no mechanism on the motor by which its speed can be adjusted and therefore the apparatus could be improved by the inclusion of such a mechanism.

Another addition to the recording apparatus which would be a considerable advantage is a take-up spool for the chart. It was necessary to cut off the length of used chart every two days, otherwise the chart became fouled in the spiked wheels which advance the chart.

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PLATE I

a. Using the Askania Gfz magnetometer on Tabarin Peninsula.

b. Close-up view of the Askania Gfz magnetometer.
1. The clamping knob. 2. One of the screws used for attaching the instrument head to the tripod.

c. Close-up view of the Askania Gf6 magnetometer.
1. The photocell head. 2. The Helmholtz coils.

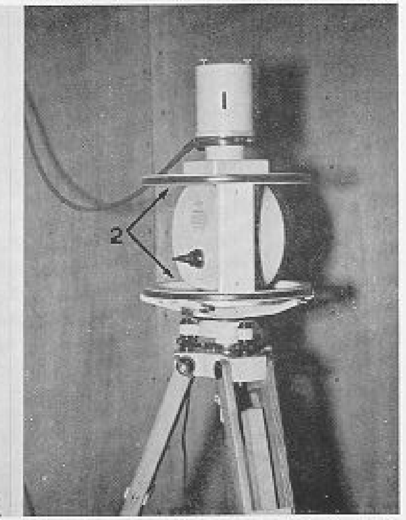
d. The recording equipment.
1. The Hartmann and Braun recorder. 2. The thermograph. 3. The apparatus used, in conjunction with the Helmholtz coils, for calibrating the Askania Gf6 magnetometer.

e. The astatic magnetometer.

PLATE I

a

b



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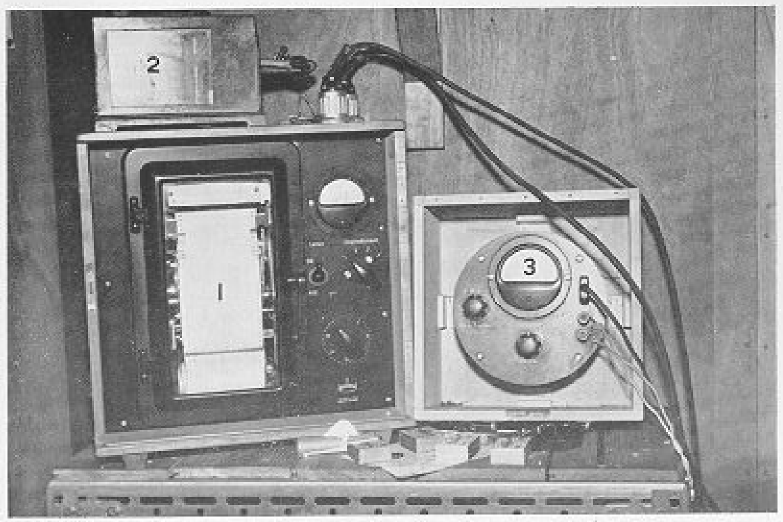

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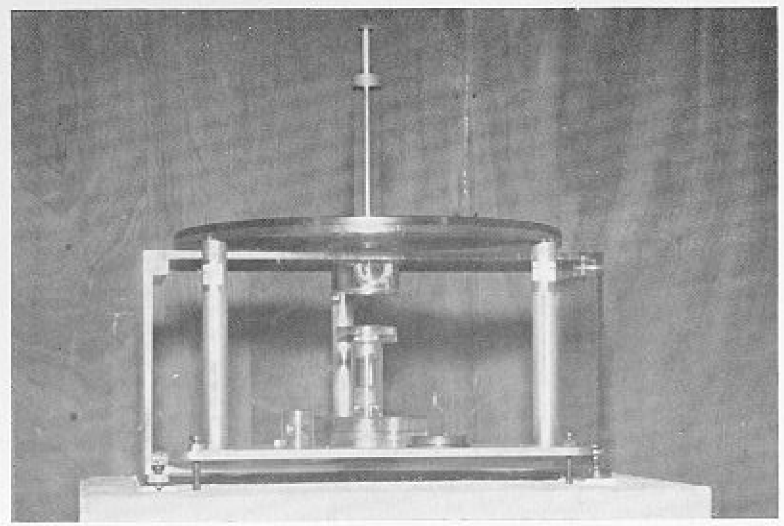


e

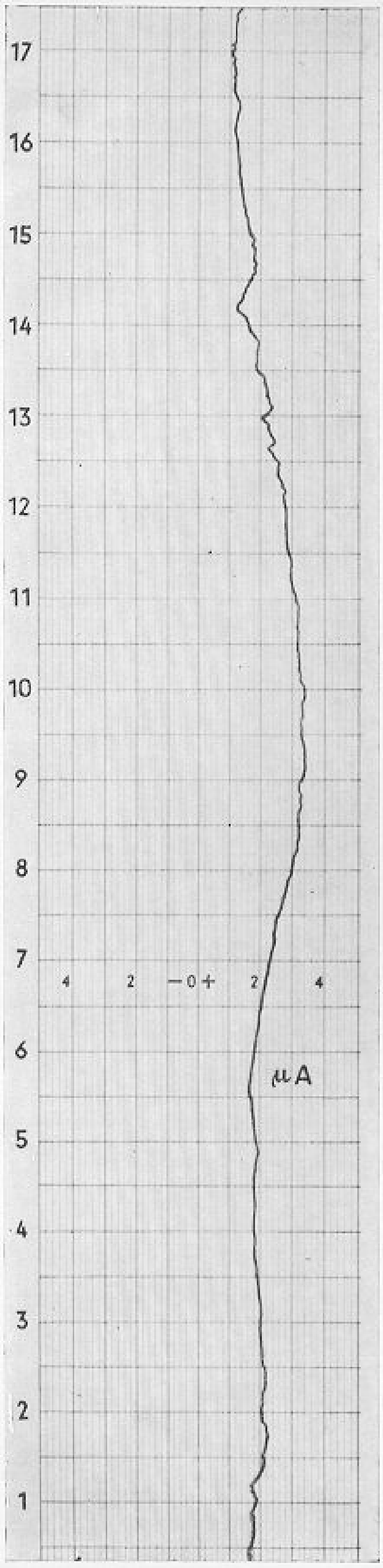
PLATE II

Examples of diurnal variation records from Hope Bay, 1959–60.

a. A quiet day.

b. A day of moderate disturbance.

c. A day of severe disturbance.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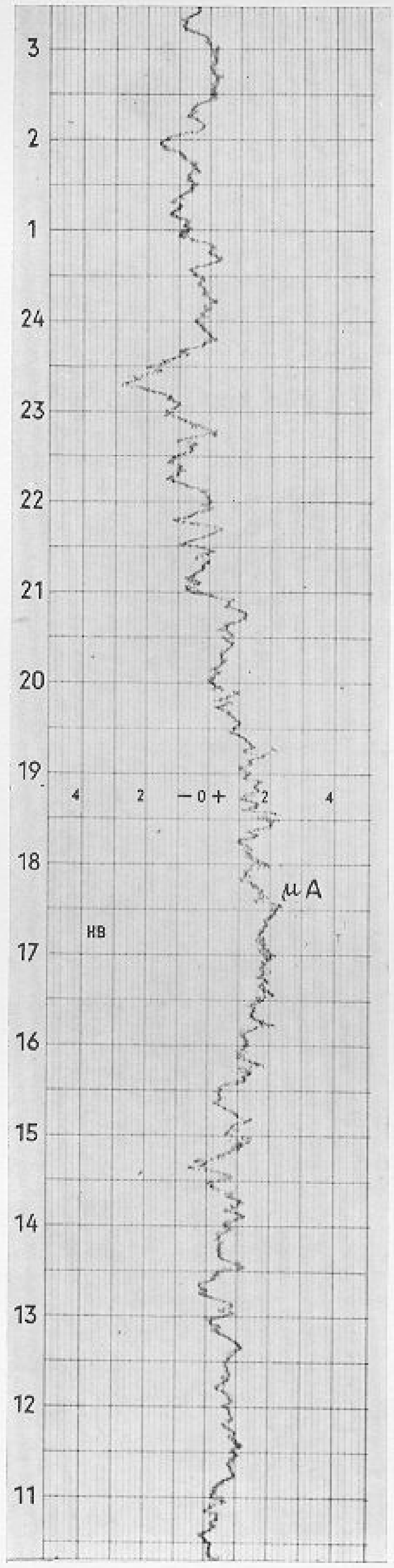
a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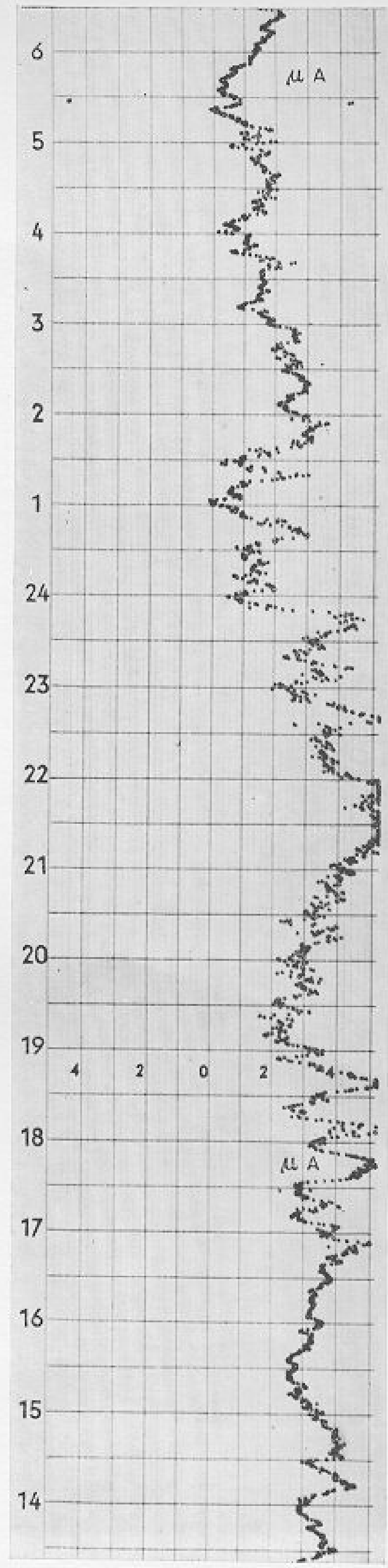
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c