A gravity survey on the southern and central parts of the Isle of man

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A GRAVITY SURVEY OF THE SOUTHERN AND CENTRAL PARTS OF THE ISLE OF MAN.

BY

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ABSTRACT

The Bouguer anomalies on the Isle of Man have been calculated from a network of 363 stations. The results of rock density measurements made in the laboratory are stated.

The main features shown by the gravity survey of the southern and central parts of the island are two elongated negative anomalies, centered at Foxdale and Dhoon. They are shown to be shallow in origin and it is suggested that they are due to the presence of two large granite bodies lower in density than the surrounding Manx Slates and only represented at the surface by small outcrops. These two granites are apparently steep sided and lie on a north-east to south-west 'axis' but are not connected. The negative anomaly seen in part in the extreme South-West of the island is probably due to a rise on the Foxdale granite.

The elongated shape of the granites revealed by the survey can be correlated with the zones of metamorphism, the distribution of the mineral veins and the "anticline of cleavage".

Comparing the mass of land above sea level with the mass deficiency due to the granites the southern and central parts of the Isle of Man are found to be under-compensated.

A residual gravity map of the Peel area was prepared and it revealed a negative anomaly which is probably due to the

basin of lower density Peel Sandstones.

The Bouguer anomalies are found generally to be high on the Isle of Man. This emphasises the fact that the Irish Sea seems to be an area of large positive anomalies for gradients have also been observed on the mainland. No definite conclusion has been reached as to the cause of this Irish Sea anomaly or, indeed, that it has only one cause.

C O N T E N T S

CHAPTER 1.

INTRODUCTION AND THE GEOLOGY OF THE ISLE OF MAN.

This thesis is an account of the gravitational investigation of the Isle of Man. It describes the survey procedure and the reduction and interpretation of the results. The work was undertaken from the Geology Department of the Durham Colleges under the supervision of Dr. M.H.P. Bott by Mr. T. Bell and myself.

The Frost Gravimeter and the Bedford Van used for the survey belong to the Durham Colleges Geology Department.

1.1 Introduction.

The Isle of Man is situated in the Irish Sea, midway between the southern part of the Lake District and the Mourne Moutains. The nearest point on the mainland is Burrow Head, Wigtonshire, 17 miles away from the Point of Ayre. The sea around the island is less than 20 fathoms deep with the exception of a trench to the west which reaches a depth of 80 fathoms. Roughly oblong in shape, the island is aligned in a North-North-East to South-South-West direction : the longer axis having a length of 30miles, the shorter 8 to 12 miles and the area of the whole is 227 square miles.

With the exception of the northern plain the island is predominantly upland, the steep but rounded hills rising to between 1500 and 2000 feet. There is a region of particularly high land extending from near Ramsey South-

-westwards to Port Erin, and it is in this area that the hills of South and North Barrule, Slieau Ruy and Snaefell, the highest point on the island, occur. This upland area is divided by the large valley running between Douglas and Peel. The island is bounded by high cliffs.

1.2 Geology

Table 1 gives the geological succession on the Isle of Man. Figure 1 illustrates the major geological features. The sedimentary sequence will be dealt with in chronological order. More emphasis is placed on description of the igneous rocks, especially the granites, since these facts will be more relevant to later discussion.

1.2a Manx Slates

The Manx Slates are a series of slates, grits, breccias, greywackes, tuffs, quartzites and banded strata, occupying about three quarters of the island's area (i.e. c.170 square miles). It has been found to be difficult to subdivide the slates; Gillott listed in 1955 the following beds, based on the lithology in the Sulby Glen - Maughold Head area:-

Cronk Sumark Slates

Sulby Flags

Breccia

Barrule Slates

Banded Beds

Agneash Grits

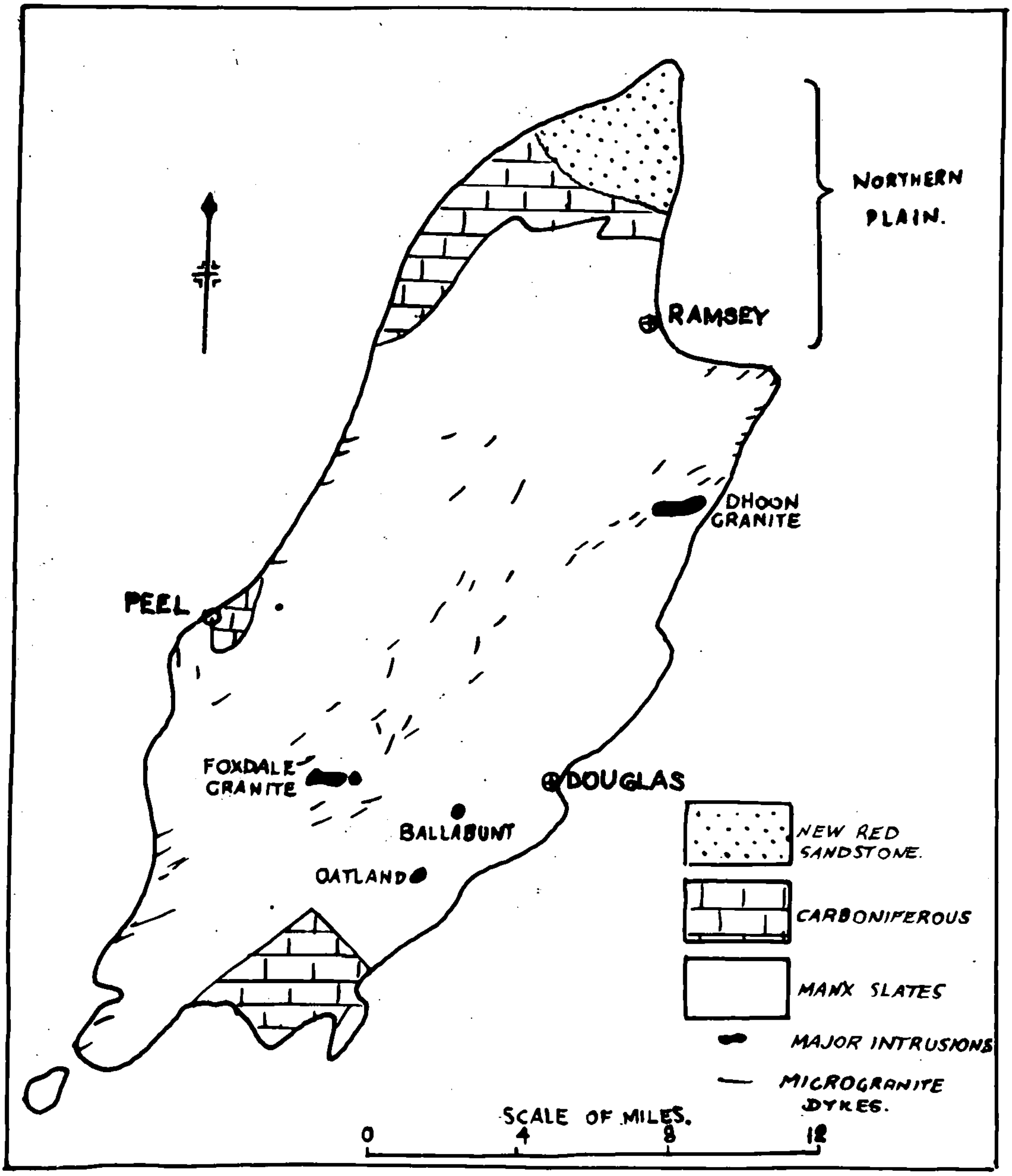
Lonan Flags

Table 1

GENERAL SUCCESSION

RECENT	Blown sand	
	Peat	
	Alluvium	
	Raised beach - marine	
GLACIAL	Late glacial flood gravels	
	Sand and gravel occuring as platforms	
	" " " " " mounds	
	Boulder clay or loam	
TRIASSIC	Red Marls (saliferous)	
	St. Bees Sandstones	
PERMIAN	Lower Marls and Brockram	
CARBONIFEROUS	Limestone Series	
	Basement Sandstones and Conglomerate	
LR. PALAEOZOIC	Manx Slates	
IGNEOUS	Carboniferous	Tuff, agglomerate
		Basalt
	Manx Slates Series	Tuff
	INTRUSIVE	
	Olivine dolerite (Tertiary) dykes	
	Diabase etc., ("Greenstone") dykes.	
	("Altered Greenstone") dykes.	
	Diorite and camptonite dykes.	
	Micro-trap dykes.	
	Micro-granite dykes.	
	Granite	

SKETCH MAP OF THE GEOLOGY OF THE ISLE OF MAN



FROM EASTWOOD "NORTHERN ENGLAND"

Fig. 1.

Thickness. Lamplugh (1903) estimated the total thickness of the Manx Slates visible to be between 1500 and 2000 feet, admitting that "this may be much below the truth". Any estimate of the thickness of such highly folded strata, will necessarily be vague.

Age. The age of the Slates is problematical but what little evidence there is indicates that they are largely Cambrian.

Structure. The Manx Slates have suffered much folding and faulting with some metamorphism and their overall structure has been variously interpreted. Previous to 1903, observers had come to the conclusion that the slates were in the form of a broad anticline but Lamplugh (1903) decided that the main structure was a compound syncline or synclinorium. In sections he prepared (Memoir - page 118) he puts the Barrule Slates in the centre of the syncline, followed outwards by the 'Unseparated Slates', the Agneash Grits and the Lonan and Niarbyl Flags. Stainier (1929) envisaged the structure as two anticlines, inclined towards each other with a narrow syncline between.

Lamplugh also recognised that the latest of the cleavages affecting the Slates had common directions over the whole of the island. The cleavage apparently dips to the North-West in the North-Western part of the island and to the South-East in the South-East. This results in an 'anticline of cleavage', with its crest trending North-East to South-West from near Maughold Head to South-West of Foxdale, which runs parallel to the zones of metamorphism (see Figure 2). The Foxdale granite lies on this anticline but the Dhoon granite is to the South of it.

Metamorphism. Figure 2 illustrates the arrangement of the metamorphic zones as recognised by Lamplugh. The zonation, he says, resulted from 'dyno-metamorphism', the granites playing a minor part by raising the temperature of the rocks. Stainier (1929), however, considered that the granites seen at Foxdale and Dhoon were directly responsible for the metamorphism and, moreover, that they are connected at depth. Gillott (1955) came to the same conclusion.

1.2b Carboniferous

Carboniferous strata lie unconformably on the Manx Slates and are found in two isolated areas, in the extreme South-East around Castletown and in the northern plain of the island where they are covered by drift.

(i) South-east area

Here the succession is as follows:-

		Thickness in ft.	Zone
5	Scarlett Volcanic Series	?	
4	Posidonamya Beds or Black Marble	30-50	D
3	Poolvash Limestone	200	
2	Castletown or lower Dark Limestone	300-400	C_2- S_2
		?	
1	Basement Conglomerate		

The Black Limestone contains goniatites as well as the usual coral-brachiopod fauna and so these strata can be correlated with the basin facies of Lancashire.

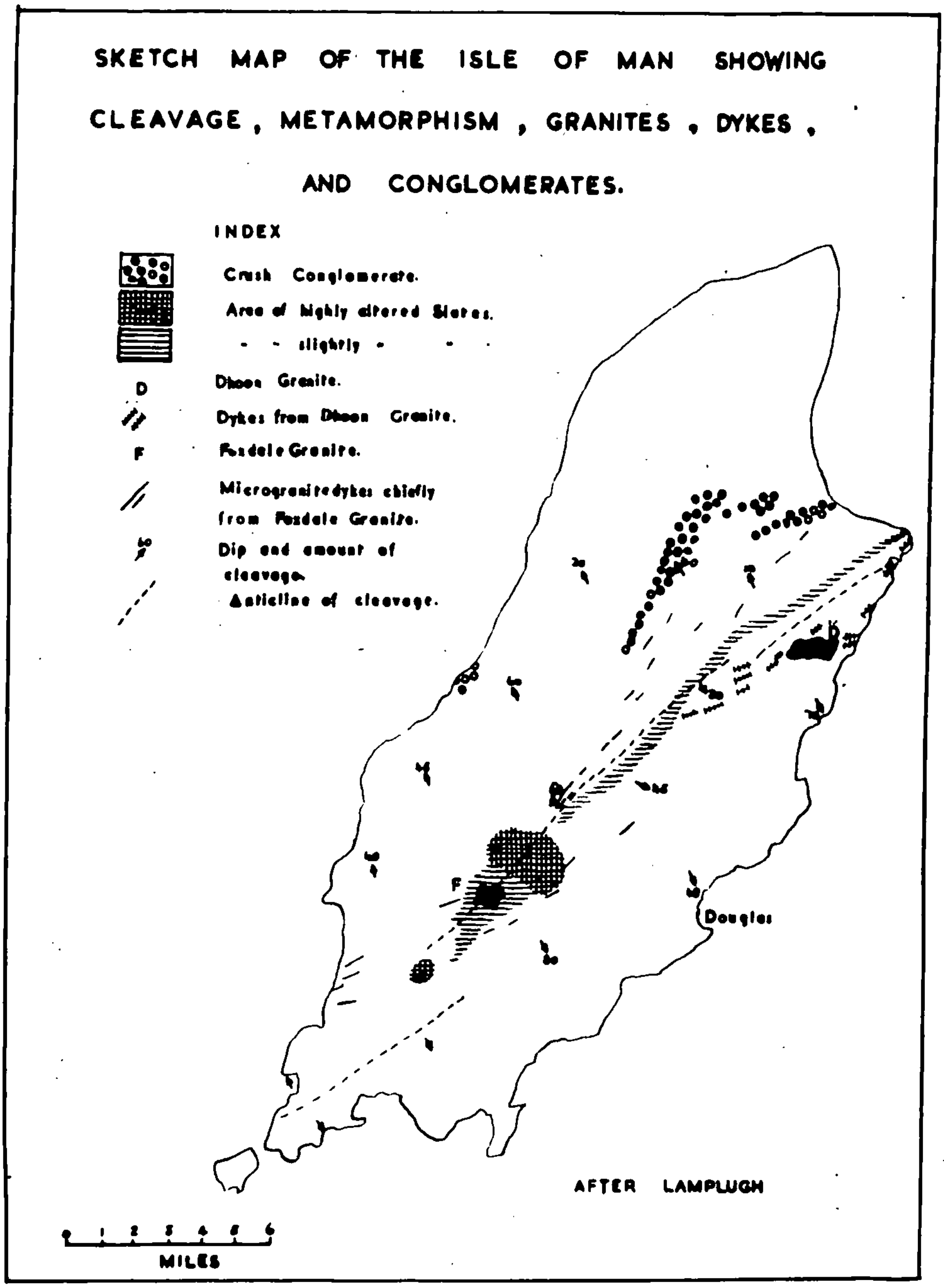

SKETCH MAP OF THE ISLE OF MAN SHOWING
CLEAVAGE, METAMORPHISM, GRANITES, DYKES,
AND CONGLOMERATES.
INDEX
Crush Conglomerate.
Area of highly altered Slates.
- - slightly - - -
D
Dhoon Granite.
Dykes from Dhoon Granite.
F
Foxdale Granite.
Microgranite dykes chiefly
from Foxdale Granite.
Dip and amount of
cleavage.
Anticline of cleavage.
Douglas
AFTER LAMPLUGH
0 1 2 3 4 5 6
MILES

Fig. 2

At Langness the Carboniferous can be seen to overlie the Manx Slates uncomformgably but inland the junction is faulted.

(ii) Northern area

Since the Carboniferous in the North of the island is covered by drift, all information about it comes from boreholes. The succession is as follows:-

	Thickness in feet
Upper Limestone, Sandstones and Shales	500
Main Limestone	800
Conglomerate	100

These strata have been correlated with the succession in Cumberland.

The Carboniferous here again overlies the Manx Slates with marked unconformity. The strata seem to be more disturbed than in the South-East and dip northwards.

Correlation between these two occurences of Carboniferous is not easy and still remains doubtful.

1.2c Peel Sandstones

In the vicinity of Peel there occurs a series of red and mottled sandstones, conglomerates, and thin limestones known as the Peel Sandstones. Various ages have been suggested for them, Lamplugh (1903) considered they are the equivalent of the Carboniferous Basal Conglomerate. They are faulted against the Manx Slates and have a predominantly West-North-West dip. They are only exposed along the coast and at one isolated locality inland.

1.2d New Red Sandstones

Triassic and Permian beds are known only from boreholes in the drift-covered northern plain. The succession, which is similar to that of South Cumberland and Furness, is as follows:-

Red Marls + Rock Salt + Gypsum
Sandstone (Kirklinton Type)
St. Bees Sandstone
Red Marls
Brockram

1.2e Igneous

Granites

Two small Caledonian granites, each less than two square miles in area, outcrop on Granite Mountain (the Foxdale Granite and at Dhoon (the Dhoon Granite). A little granite is also found in the composite intrusion of Oatland.

(i) Foxdale Granite

The Foxdale granite is a moderately coarse-textured grey muscovite granite containing orthoclase and plagioclase (Ab_{7-9}), muscovite, quartz, microcline and a little zircon. Elvans and pegmatites are found in association with the granite

The main outcrop on Granite Mountain is roughly oval in plan. The longer axis, 1400 yards long, extends in an East-West direction and the shorter, North-South axis, is 400 yards in length. There is an isolated patch of similar granite 500 yards east of the main outcrop. This could either be a small boss or a thrust block but there is no evidence for either view.

The Manx Slates at the margin of the granite are altered by contact metamorphism to a limited extent only. The contact is relatively definite and cross-cutting; there is some evidence to suggest that movement of the slates occured during or after intrusion. In plan the margin is very irregular with numerous apophyses and there are many elvans and pegmatites.

According to Lamplugh the granite appears to shelve outwards from the outcrop and is laccolithic in form.

Evidence from mineworkings seems to support this idea for granite was discovered at 300 to 400 feet below the surface at the Cornelly Mines, 1¼ miles north of Granite Mountain. It has been suggested that "this intrusion formed a pipe-like mass inclined westwards" (Lamplugh). This granite is by no means identical with the Foxdale granite "the difference between these, however, is no greater than might occur between different parts of one and the same intrusion" (Lamplugh). An area of high grade metamorphism (See Figure 2) occurs around the Cornelly Mine.

(ii) Dhoon Granite

The Dhoon granite is very distinctive and differs in many ways from that at Foxdale.

The most striking mineralogical characteristic of this granite is the relative abundance of dark minerals (mainly biotite). This is reflected by the high density of the granite (2.71 gm/c.c.). Feldspar (plagioclase Ab_{7-9} and orthoclase), muscovite, quartz, epidote, chlorite, and sphene also occur.

The outcrop is 2,350 yards long and 900 yards wide and is elongated in an East-West direction. The margins are clear cut though very irregular in plan and there is evidence to show that the adjoining Manx Slates have been moved by the granite.

The fact that granite has not been located in the deep glens of Laxey and Dhoon seems to indicate that the intrusion has fairly steep sides. Lamplugh considered it to be pipe-like in form. He also thought the Dhoon granite to be older than the Foxdale granite but gives no evidence.

There has been some controversy about the origin of the Dhoon granite. In his paper, Nockolds (1935) describes two different types of granite at Dhoon.

<u>Type A</u> forms the major part of the intrusion and is, in his opinion , a product of contamination and assimilation resulting from the invasion of a basic intrusion by a granite magma.

<u>Type B</u> has a restricted area and represents part of the partially digested basic intrusion, which originally had a composition similar to the greenstone dykes found in the area.

Reynolds (1947), looking at Nockolds's results, considers on mineralogical and chemical grounds that the Dhoon granite was formed by granitisation and that the 'greenstone' inclusions described by Nockolds as Type B are simply altered inclusions of Manx Slates.

(iii) Small intrusions

The minor intrusions are mainly dykes. Gillott (1954) has distinguished the following types.

a) <u>Greenstone Dykes</u> (diabase, epidiorite and chlorite schist). These are probably of three different ages and show corresponding degrees of metamorphism and lineation. They trend predominantly North-East to South-West, East-West dykes are less common.

b) <u>Microgranite Dykes</u> These are confined to the axial region (i.e. to a north-east to south-west belt from Maughold to Foxdale) and trend parallel to it. They can be correlated to either the Dhoon or the Foxdale granites.

c) <u>The Lamprophyre Dykes</u> These dykes are of very varied composition and were intruded over a period of time. In addition to the dykes there is a number of small boss-like intrusions.

The most important of these is the <u>Oatland Complex</u> at Santon, described by Lamplugh (1903) and Taylor and Gamba (1933). It consists of a central boss of acid rocks (called granitite by Lamplugh and granite by Taylor and Gamba) surrounded by a dark, basic rock (gabbro according to Taylor and Gamba, diorite on the 6 inch Geological Survey map). The granite pierces the the basic rock and sends numerous veins into it.

The complex is 1400 yards long and 450 yards wide; its contact with the surrounding Manx Slates has been described as "lit par lit" by Taylor and Gamba. They also consider the intrusion to be laccolithic in form, the granite having stoped its way through the original basic intrusion.

Taylor and Gamba grouped this intrusion with the Dhoon granite because of a similar association of acid and basic rocks. Lamplugh thought that this intrusion was a knob or node on a cluster of dykes.

The largest separate basic intrusion on the island is at Poortown , near Peel. It is a diabase boss at least 1 mile long, which Lamplugh considered as a part of a chain of similar, smaller intrusions trending North-North-East to South-South-West in the area.

At Ballabunt there is a small "boss or dyke" of quartz-diorite.

1.2f. Quaternary

Due to its position in the centre of the Irish Sea the Isle of Man was subjected to extensive glaciation.

The drift covering is extensive and can be divided into

(1) Insular (Grey) Drift restricted to the upland plateau and the deep valleys. It is in the form of a rubbly drift or till.

(2) Extra-insular (Red) Drift makes up the northern plain and is up to 400 feet thick. It consists of stratified and unstratified boulder clay, red clay, sand and gravel.

Table 2 gives the geological history of the Isle of Man.

TABLE 2

GEOLOGICAL HISTORY

The following succession of events is taken from Gillot's Ph.D. thesis. (1954).

1) Sedimentation of the Manx Slates with creep and sliding.

2) Pre-cleavage intrusions of felsite and early basic dykes.

3) North-west to south-east compression folds:- slightly overturned towards the structural axis and 'inverted fan' cleavage. Widespread low grade metamorphism.

4) Early fracture cleavage and the folds modified.

5) Relaxation of compression. Intrusion of the second suite of basic dykes, microgranite dykes along the axial region and plutonic masses.

6) Vertical forces established. Cordierite developed due to continuation of metamorphism and metasomatism after relaxation of stress.

7) Metamorphism outlasted movement at Archallagan. Fracture cleavage.

8) Faulting, jointing and late lineation.

9) Hercynian stress system established forming north-south and east-west fractures filled with economic deposits.

10) Tertiary (?) olivine dolerite dykes.

1.3 Previous geophysical work.

Apart from some magnetic surveying by John Taylor & Sons (London) in connection with mineral exploration little geophysical work has been carried out on the Isle of Man.

In 1958 the Geological Survey (London) included the island in their aeromagnetic survey but the results are not yet available.

1.4 Summary of problems.

A review of the known geology of the Isle of Man suggested the following problems suitable for investigation by a gravity survey.

(1) The deeper structure of the granites. Stainier (1929) and Gillott (1955) had suggested the granites of Dhoon and Foxdale might be connected at depth. Such a granite body would have a north-east to south-west elongation, a feature common to other geological features on the Isle of Man. A gravity surbey would possibly facilitate delineation of the shape of the granites at depth.

(2) Northern plain. All evidence concerning the solid geology under the northern plain comes from boreholes. It was thought that a gravity survey might give a better idea of the geology of the area particularly of the extent of the Manx Slates and the New Red Sandstone.

(3) Sedimentary basins. It was hoped that the survey of the Carboniferous basin of Peel (?) and Castletown would provide additional information of size and depth.

(4) Irish Sea regional anomaly. The relationship between gravity anomalies on the Isle of Man compared with those in the adjoining parts of England, Scotland, Wales and Ireland will be discussed in the thesis.

I shall discuss problems 1,2, and 4 on the following pages.

Mr. T. Bell has dealt with results from the northern plain in his thesis.

CHAPTER II

THE GRAVITY SURVEY AND ROCK DENSITIES.

2.1 The Survey

The survey was completed during four weeks in September 1958 by Mr. T. Bell and myself.

A Frost Gravitymeter was used throughout the survey. Since the heating coils of this meter have to be permanently coupled to a 6 volt car battery, a Bedford van was used for transport. The meter, on its tripod, was set up on the road at the back of the van for reading. This, of course, restricted the survey to roads and tracks accessible to the van.

A total of 363 stations was established giving an average coverage of 1.6 stations per square mile.

2.2 The gravimeter

A Frost Gravitymeter (No. C.2.54) with a calibration factor of 0.0837 milligals per dial division, calculated previously by the Anglo-Iranian Oil Co. Ltd., was used for the survey. Results of the calibration tests are to be found in Report No. K.H.G. 44 published in 1953 by the Anglo-Iranian Oil Co. Ltd.. The probable error in the calibration of this meter is $\pm$ 0.0004 milligals per dial division.

2.3 Base stations

In establishing base stations use was made of the six stations set up by Dr. Bullerwell (Geological Survey) on the

21st of June, 1952.

Dr. Bullerwell has 'tied' these stations to Pendulum House, Cambridge and thus the relative values of gravity are known at each point.

The positions of the original stations are listed below:-

Grid reference	Situation	Values-milligals (+)	
278.689	Ronaldsway (2 stations)	202.45	202.34
383.762	Douglas (2 stations)	215.43	215.40
463.921	On Ramsey-Laxey Rd., 2 miles from Ramsey	192.94	
450.846	The farm Ballamoar - near Laxey	196.28	

We found the Douglas bases to be impractical because of excessive traffic. Similarly the station on the Laxey to Ramsey road was found to be near a bend in the road. We did, however, use the Laxey station as a base.

It was necessary, therefore, to establish our own set of base stations. We first put a base at Ballasalla and tied it in with the Ronaldsway stations, one mile away. Dr. Bullerwell (private communication) found the value at Ronaldsway to be 202.45 milligals higher than the value of gravity at Pendulum House, Cambridge, which was taken to be 981.26500 cm/sec^2 . The absolute value of gravity at the Ballasalla base, with a

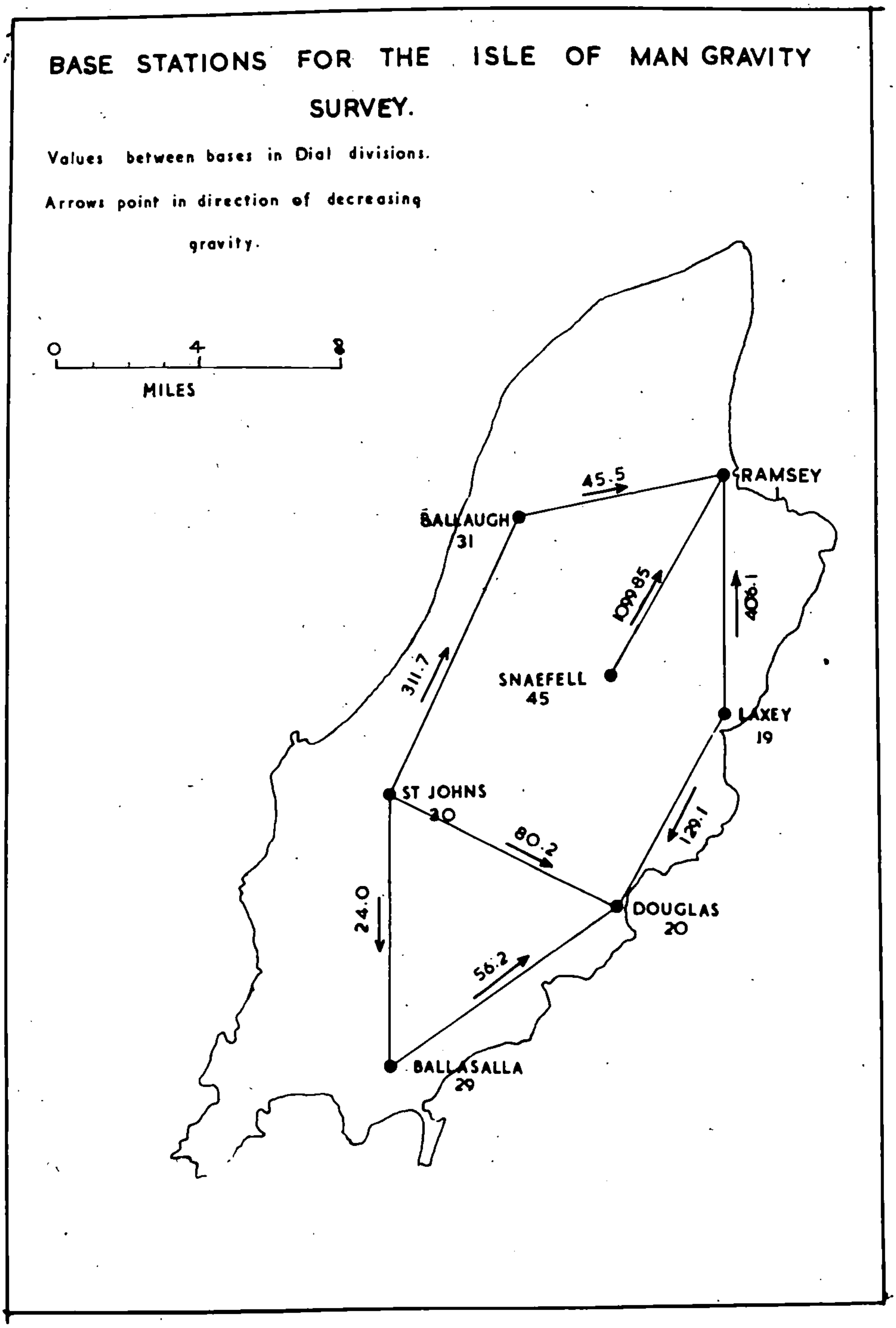

BASE STATIONS FOR THE ISLE OF MAN GRAVITY SURVEY.
Values between bases in Dial divisions.
Arrows point in direction of decreasing gravity.
0
4
8
MILES
RAMSEY
BALLAUGH
31
45.5
1099.85
408.1
SNAEFELL
45
311.7
LAXEY
19
ST JOHNS
30
80.2
120.1
DOUGLAS
20
24.0
56.2
BALLASALLA
29

Fig. 3.

value 0.31 milligal higher than Ronaldsway is therefore 981.4661 cm/sec ^{2}.

Six base stations (including the one at Laxey) were established and 'tied' in by repeated looping, (Station A to Station B-A-B-C-B-C etc). These bases were located at Ramsey, Douglas, St. John's, Ballaugh, Laxey, and Snaefell.

The positions of the base stations are shown on Figure 3. The average closing error is less than 0.05 milligal.

Other details of base stations can be found in the appendix.

2.4 Intermediate Stations

The intermediate stations were occupied on loop runs from base stations. These runs were usually about 2 hours long and never more than 3 hours.

The intermediate stations were restricted to roads where bench marks and spot heights are shown on the six inch to one mile Survey maps. The Isle of Man has an adequate coverage of such roads but the maps have not been revised since publication in 1868. Positions with severe local terrain, such as banks and cuttings, were avoided. We aimed at a regular coverage of stations, at about half mile to three-quarters of a mile interval

The positions of all the stations are shown on Map 1 and also on a one inch to one mile Ordnance Survey map.

By repeating stations the standard deviation of intermediate station readings was found to be about $\pm$ 0.07 milligals.

We prepared a preliminary Bouguer anomaly map (without corrections for terrain) as we proceeded with the survey. From this map we could judge where extra stations were needed and pick out stations needing repetition.

2.5 Reduction of results.

The Bouguer anomaly was calculated as

$$(g_{stn}-g_{ph}) + (g_{ph}-J) + (0.09406-0.01277\rho)h + T \text{ milligals}$$

Measured Gravity Difference	Latitude Correction	Height Correction	Terrain Correction

The anomalies were calculated in the field using assumed densities for height correction and disregarding terrain corrections. Later, all the results were re-calculated and the terrain corrections included. It was found that the calculated densities were sufficiently close to the assumed densities as to make no appreciable change in the height correction.

2.6 Drift

Instrumental drift was checked by repeating base readings every two hours. The drift is simply the difference in the two base readings. It was assumed to be linear and a correction for it was made for each intermediate station.

The average rate of drift during the survey was found to be less than 0.04 milligals per hour.

2.7 Latitude Correction

The latitude of every station was found using a graticule overlay on the six inch to one mile map. This method allowed the latitude to be measured at least to the nearest second. The correction for each station was then simply read off a table prepared from the International Gravity Formula.

The longitude of each station was noted for reference.

2.8 Height Correction

Station heights refer to the Bench marks and spot heights marked on the six inch to one mile Survey maps. Bench marks were used when possible, the actual station heights relative to the mark being found using an Abney Level and staff. Spot heights were used when Bench marks were not available. By this method heights were found at least to the nearest foot. Heights are given relative to sea level at Douglas.

The corrections were calculated using the combined height and free air correction formula:-

Correction in milligals = $(0.09406-0.012770\rho)h$; h being the height of the station above Sea Level in feet.

This correction is likely to be subject to greater systematic error than any other factor in the reduction. For a density uncertainty of 0.1gm/c.c. in the above formula would introduce an error of 1.28 milligals per 1000 foot height change.

2.9 Terrain Correction

Terrain corrections are relatively large over most of the Isle of Man, only on the northern plain are they negligible.

Stations in some of the deeper valleys have corrections of over 4 milligals.

The corrections were calculated by an electronic computer using Bott's (1959) system and programme. The computer used was the Ferranti Pegasus (Ferdinand) belonging to the University of Durham and residing in Newcastle.

The area has to be divided into equal squares, in this case the National Grid 1 Km. squares or groups of them were used. The average altitude of the land in each square is found. The computer will then estimate the correction for each station by summing the incremental contributions from all squares.

The computer programme, however, rejects squares less than 1 Kilometre from the station. The correction for the rejected area must be calculated by the normal Hammer zone chart method, and added to the correction calculated by the computer.

Table 3 compares the terrain corrections worked out by the computer with those done entirely with the zone charts.

2.10 Rock Densities

The density values used in the interpretation are based upon direct density measurements of surface rock specimens. The results are summarised in Table 4. The Manx Slates samples were taken from the various lithological divisions.

Before weighing, the samples were placed in a Winchester jar which was then evacuated. The jar was filled with water and the samples allowed to soak for a day, during which time the air pump was working continuously. The saturated samples

TABLE 3 TERRAIN CORRECTIONS

Station number	Terrain correction by computer. (Milligals)	Terrain correction by Zone Charts. (Milligals)	Difference in Milligals
1	0.589	0.586	-0.003
10	0.165	0.208	+0.043
29	0.206	0.184	-0.022
30	0.882	0.901	+0.019
44	2.337	2.267	-0.070
108	0.565	0.561	-0.004
193	0.052	0.038	-0.014
214	0.980	0.967	-0.013
270	1.600	1.690	+0.090
279	2.290	2.608	+0.318
353	0.522	0.574	+0.052

were then weighed on a normal chemical balance.

This method of finding rock densities is liable to several errors. Weathering at the surface increases pore space, enlarges cracks, joints etc. and decomposes constituent minerals. It is thought that the Manx Slates, being on the whole a fairly compact rock, will not be excessively affected by these factors. Another difficulty lies in the fact that sampling is not random. Theoretically, the number of specimens of each lithology should be proportional to the relative abundance of each lithology within the sequence. This would be almost impossible to carry out with as large a unit as the Manx Slates.

The largest range of density values is found with the Manx Slates. This is to be expected as many different lithologies are involved. It was found, for instance, that the grits (Agneash) tended to be less dense than the flags (Lonan and Niarbyl, etc), as might be expected. An error of 0.06 gm/c.c. in the density of the Manx Slates would introduce a consequent error in the elevation correction for a station at 1000 feet O.D. of 0.75 milligal.

For elevation corrections in the north of the island the density of the drift was taken as 2.00 gm/c.c. Determination of drift density by the above method would be very liable to error but the station heights on the northern plain where the

TABLE 4

ROCK DENSITIES

FORMATION	NUMBER OF LOCATIONS	NUMBER OF SPECIMENS	SATURATED DENSITY
FOXDALE GRANITE	1	22	2.62 ± .02 gm./c.c.
DHOON GRANITE	2	26	2.71 ± .01 gm./c.c.
PEEL SANDSTONE	1	25	2.65 ± .03 gm./c.c.
CARBONIFEROUS LST.	2	38	2.70 ± .05 gm./c.c.
MANX SLATE (various lithologies)	10	113	2.73 ± .06 gm./c.c.
DRIFT (taken as)	-	-	2.00 gm./c.c.

drift occurs, are generally very low.

Values for Triassic and Permian rock densities used for models by T. Bell were taken from Parasnis' paper (1952).

2.11 The Bouguer anomaly map

The Bouguer anomaly map prepared from the results of the survey is shown as Map 1 (Appendix). The map is on a 1 to 63360 (approximately one inch to one mile) scale and the isogals have been drawn at one milligal intervals. The stations are also marked.

There is an adequate number of stations for the purpose of this survey although more information would be desirable for certain areas (e.g. for parts of the upland north of the Peel to Douglas road).

Gravity anomalies range from + 27.2 milligals (station 128 at Foxdale) to + 48.2 milligals (station 243 at Jurby).

CHAPTER III

THE GRAVITY ANOMALIES

There is a number of obvious gravity anomaly changes to be seen on Map I. These can be summarized as follows:-

1) The negative anomaly centered just north-west of the Foxdale granite. This anomaly is elongated in a east-North-East to West-South-West direction and is about 14 milligals below the background anomaly.

2) Another negative is centered approximately north-east of the Dhoon granite. Just over half of the anomaly is visible, the other half being truncated by the coast.

3) The edge of another negative anomaly appears in the extreme south-west of the island (the Calf of Man anomaly).

4) The basin of Peel Sandstone apparently disturbs the general gravity field.

5) There is an extensive positive anomaly north of Ballaugh (the Jurby anomaly).

6) The rapid decrease of gravity approaching the Point of Ayre is apparently part of a large anomaly truncated by the sea. The gravity anomalies drop from + 42 milligals to + 33 milligals in 3 miles.

The last two features occur in the northern plain and are covered by Bell's thesis. I shall concentrate on the anomalies south of a line from Ramsey to Ballaugh.

Figure 4 shows the approximate extent of the anomalies mentioned above.

SKETCH MAP OF THE ISLE OF MAN SHOWING THE MAIN ANOMALIES

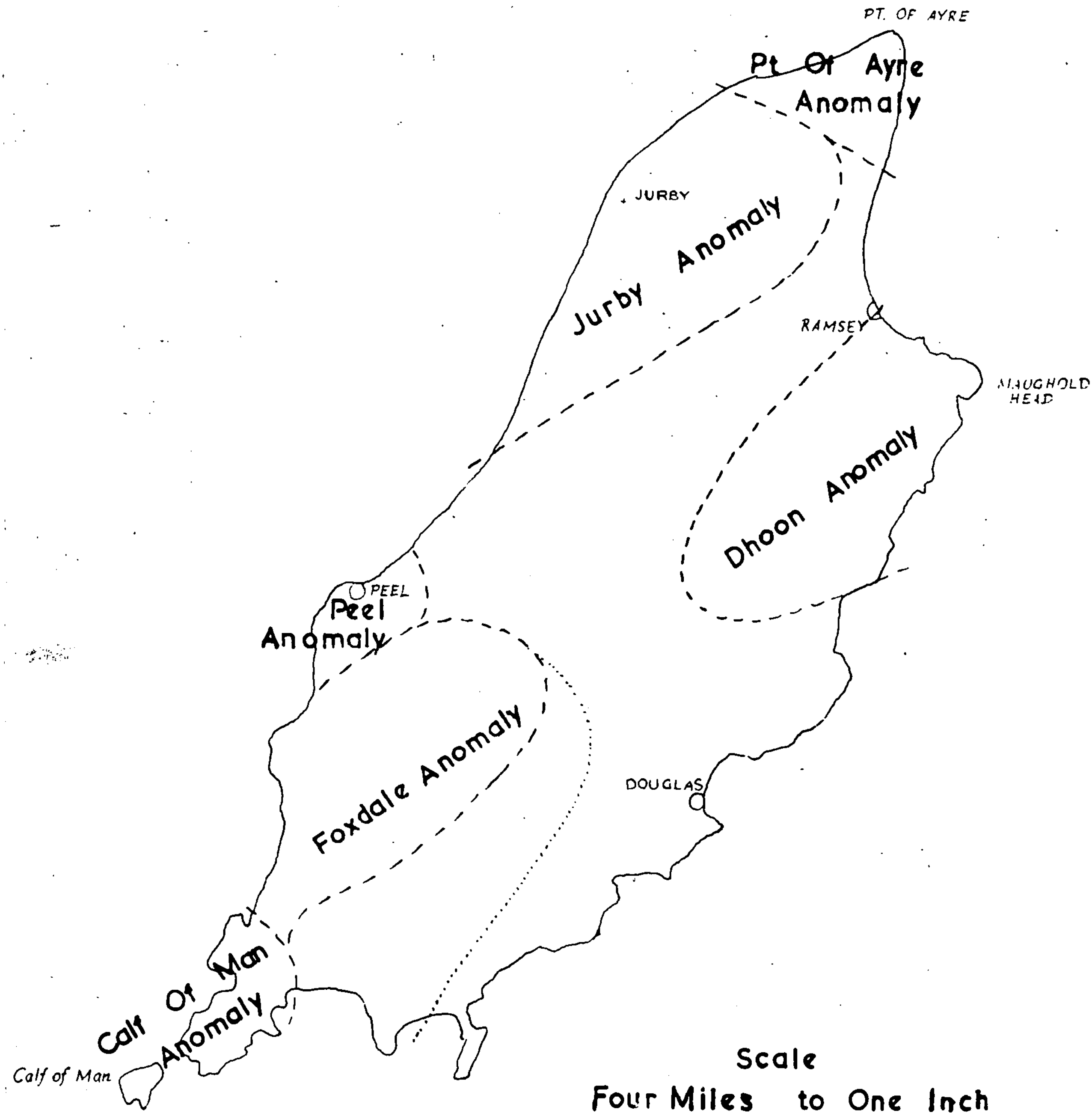


Fig.4.

CHAPTER IV

THE FOXDALE AND DHOON ANOMALIES

A preliminary interpretation of the anomalies of Dhoon and Foxdale will be made before each is considered in detail.

4.1 A preliminary interpretation of the Foxdale and Dhoon anomalies

These negative anomalies of Dhoon and Foxdale are the two dominant features on Map 1.

The apparently close relationship of these two anomalies makes it convenient for them to be dealt with together and also to assume that they have similar origins.

a) Background anomaly

The background anomaly is difficult to estimate because of the juxta-position of the various anomalies on the island. For the following interpretations a background value of +42 milligals has been chosen.

b) Depth estimation

The maximum possible depth to the tops of the bodies causing the anomalies can be estimated by considering the maximum anomaly in conjunction with the maximum gravity gradient, using Bott and Smiths' (1958) formula.

For Foxdale, taking the maximum anomaly as 14 milligals and the maximum gradient as 8.7 milligals per mile the maximum depth is 1.48 miles.

For Dhoon, with a 6 milligal anomaly and a gradient of 3.2 milligals per mile the maximum depth is 1.6 miles.

c) The Shape of the anomalies

Both anomalies are approximately oval in shape and have an overall north-east to south-west elongation. The north-eastern side of the Foxdale anomaly has an extremely steep gradient indicating the probability of an almost vertical interface at depth. The Foxdale and Dhoon anomalies have only a slight tendency to merge but the former does decidedly merge with the Calf of Man anomaly.

d) Quantitative geological interpretation

It may be considered that these two anomalies originated in one of five ways.

1) A thickening of the crust.
2) A trough of less dense rocks within or next to the basement.
3) A trough of less dense rocks within the main Manx Slates sequence.
4) A salt dome.
5) An acidic igneous intrusion.

Possibilities 1 and 2 can be ruled out owing to the shallow origin for the anomalous body indicated in b).

The possibility that the anomalies are due to a syncline of less dense rocks (e.g. the Agneash Grits) within the main Manx Slates sequence can be rejected on the following grounds.

a) The density contrasts between the various litholgical units in the Manx Slates are not particularly large.

The contrast between extreme examples is, in fact, unlikely to be more than 0.05 gm./c.c.

b) To cause the observed anomalies, a thickness of at least 2 miles of rock with such a contrast would be necessary. Geological evidence does not support this proposition.

The possibility of the existence of a salt dome is not consistent with the geological evidence.

The remaining possibility, that of two separate igneous intrusions of acidic nature being the cause of the anomalies is accepted on the following grounds.

a) The centres of the two anomalies practically coincide with the exposures of granite at Dhoon and Foxdale. It is assumed that these are the only outcrops of the acidic intrusions.

b) Density measurements have shown that the granites exposed at Dhoon and Granite Mountain (Foxdale) are lighter than the Manx Slates into which they are intruded.

c) The observed shape of the anomalies is consistent with the idea of acid intrusions.

d) The depth estimate is also consistent.

e) Bott and Masson-Smith (1957 and 1958) have shown that comparable negative anomalies elsewhere are apparently due to granite intrusions.

It is therefore concluded that the Dhoon and Foxdale anomalies result from direct density contrasts due to two acidic intrusions.

4.2 The Foxdale anomaly

The geology of the Foxdale granite has been described in 1.2e (a). It is thought that this granite is an apophysis of a larger granite giving rise to the Foxdale anomaly. The Foxdale anomaly will now be discussed in greater detail.

a) The anomaly

This anomaly is by far the largest, both in area and magnitude, on the Isle of Man.
It can be roughly delineated by an oval with its longer axis 9 miles long extending in a north-east to south-west direction, and with the shorter axis, 6 miles long, at right angles. The centre of the anomaly coincides with the centre of the oval.

There is an abrupt and steep increase of gravity outward on the eastern side of the anomaly, gravity increasing by 8 milligals in less than one mile. The gradient on the inner part of the south-eastern side starts off fairly steeply (4 milligals per mile) but flattens out farther away from the centre of the anomaly. The north-western side has a steady gradient of just over 2 milligals per mile. The centre of the anomaly is formed by a peculiarly elongated area with practically no gravity gradient.

Because of the steep gravity gradients found with this anomaly it can be assumed that the Bouguer anomalies reflect variations at the top of the granite.

b) Density contrasts

The calculated densities of the Manx Slates and the Foxdale granite are 2.73 $\pm$ 0.06 gm/c.c. and 2.62 $\pm$ 0.02 gm/c.c. respectively, indicating that there is undoubtedly a density contrast between these rocks which, from these results, is 0.11 gm/c.c. A shallow origin is also indicated for these anomalies (4.1).

It is therefore concluded that the Foxdale anomaly is due to the direct density contrast between the Foxdale granite and the Manx Slates.

c) Mathematical conclusions

A more refined estimate of the maximum depth to the top of the anomalous mass than that given in 4.1 can be made using Smith's (1959) formula. By this method a limiting depth of 0.48 mile is found, if the above density contrast is correct ; this result substantiates the conclusion that the anomaly has a very shallow origin.

The size of the total anomaly (14 milligals) indicates that the granite continues downwards to a great depth. Treating the granite as a cylinder of radius 3 miles with a density contrast of 0.11 gm/c.c. its depth would be 3.7 miles.

d) Model

Figure 5 is a north-west to south-east section through the Foxdale anomaly. On it is superimposed the theoretical anomaly profile calculated from the model shown beneath. The model results were mainly calculated using Bott's (unpublished) programme for an electronic computer with a density contrast of 0.11 gm/c.c. These two dimensional models assume a uniform infinite extent, at right angles to the page.

The most suitable model found from a series of trials is shown on Figure 5. From this it can be seen that the granite is asymmetrical in section. The south-east side falls steeply at about 80° to the horizontal but flattens out about 4 miles down. To the north-west of the outcrop on Granite Mountain the granite is almost horizontal for a distance of 1 mile. This is confirmed by evidence from mining operations on the Great Foxdale Lode, north of the outcrop.

The north-west side is apparently concave and flattens out at a depth of 4 miles. Figure 6 is a copy of Lamplugh's section of the Great Foxdale Lode together with the gravity

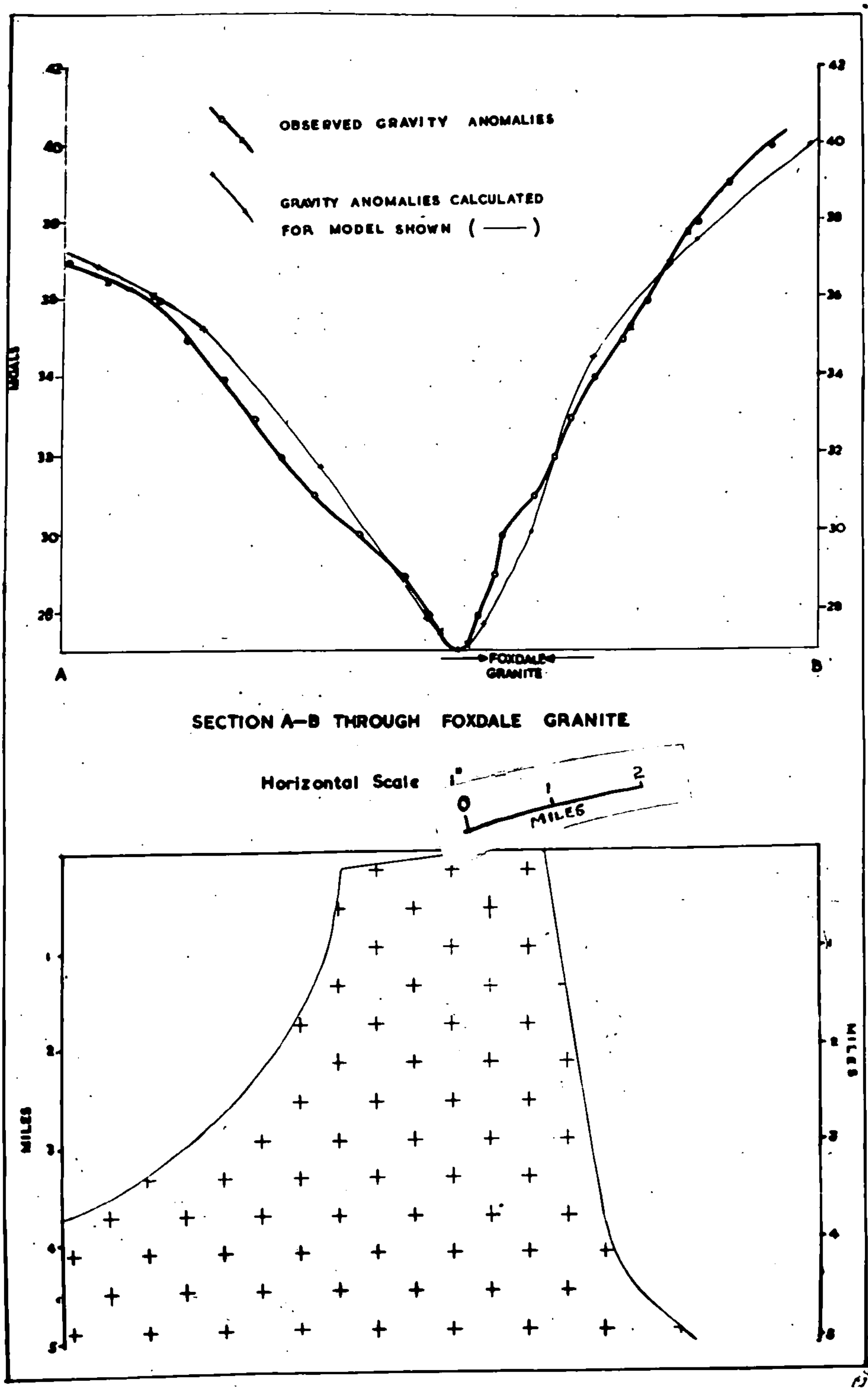

OBSERVED GRAVITY ANOMALIES
GRAVITY ANOMALIES CALCULATED
FOR MODEL SHOWN (——)
MGALS
A
B
FOXDALE GRANITE
SECTION A–B THROUGH FOXDALE GRANITE
Horizontal Scale
0 1 2
MILES
MILES
MILES

Fig. 5.

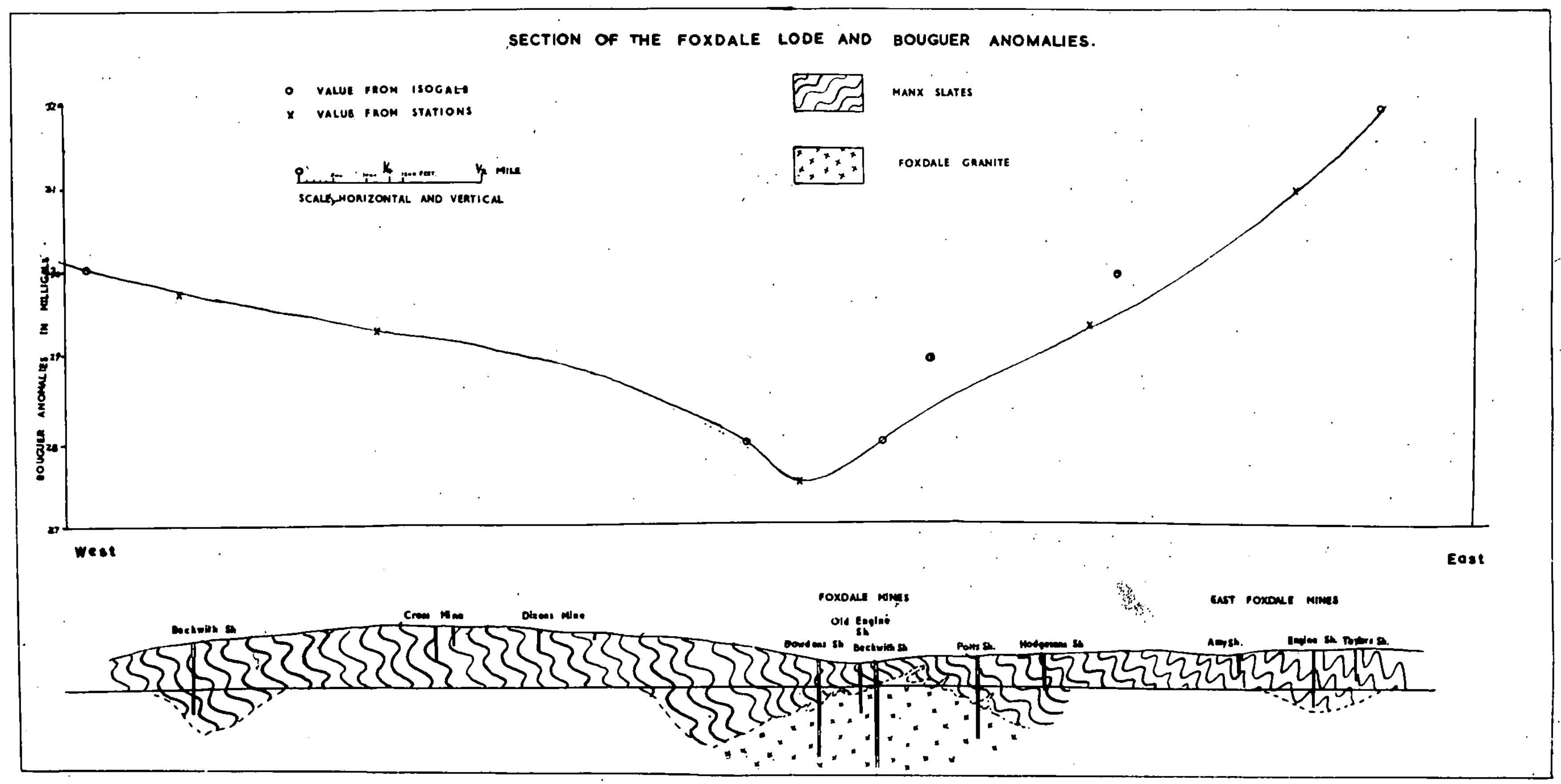

SECTION OF THE FOXDALE LODE AND BOUGUER ANOMALIES.
O VALUE FROM ISOGALS
X VALUE FROM STATIONS
SCALE, HORIZONTAL AND VERTICAL
MANX SLATES
FOXDALE GRANITE
BOUGUER ANOMALIES IN MILLIGALS
West
East
FOXDALE MINES
EAST FOXDALE MINES
Beckwith Sh
Cross Mine
Dixons Mine
Old Engine Sh
Bowdens Sh
Beckwith Sh
Potts Sh.
Amy Sh.
Engine Sh.
Taylors Sh.

Fig. 6.

profile along it.

The assymmetrical shape of the granite accounts for the minimum anomaly being displaced to the north-west of the granite outcrop.

It can be seen that the model profile does not fit exactly the observed profile but it does reproduce the major features.

e) General discussion of the shape of the granite

It is possible to draw conclusions about the general shape of the granite by considering the shape of the anomaly.

It is obvious that there is a discrepancy between the disposition of the isogals in the centre of the anomaly and those forming the margins. The inner isogals probably reflect the shape of the granite near the surface (See 4.2a). It apparently trends in a north-north-east to south-south-west direction and has a broad flat top about 5 miles long and $1\frac{1}{2}$ miles wide stretching from under the Glen Rushen plantation to Archallagan.

As mentioned before the 'bulk' of the granite lies under an area north-west of the granite outcrop. The minimum anomaly was actually recorded at Station 128 on the St. Johns to Castletown road, 450 yards from the outcrop. The granite is nearer the surface at the eastern end than at the western, and there seems to be small 'rise', represented by the + 28 milligal line, under the main road.

respectively. Although the densities of the Dhoon granite specimens we measured were consistent, the Manx Slates, with its many different lithologies, were far from being so.

The contrast between the average densities is 0.02 gm/c.c. Taking into consideration the standard errors of the two samples it is found that this difference is hardly statistically significant.

This is not sufficient evidence to reject the idea of a granite intrusion being the cause of the anomaly for the other facts mentioned in 4.1 still remain. It does mean, however, that the interpretation will not be so straightforward as it was for the Foxdale anomaly and that it will be more hypothetical.

c) Mathematical conclusions

Using Smith's (1959) formula the following estimates have been made for the maximum depth to the top of the anomalous body. The maximum anomaly has been taken as 6 milligals and the maximum rate of change of gravity gradient as 1.4 milligals per mile.

Density (Gm/c.c.) Contrast	Maximum Depth (in miles)
0.025	0.52
0.050	1.04
0.075	1.58
0.100	2.07
0.150	3.10

Considering the intrusion as a cylinder of 2.5 miles radius giving a total anomaly of 6 milligals the following estimates of its depth have been obtained for a variety of density contrasts.

Density Contrast (Gm./c.c.)	Depth to Base (in miles)
0.036	∞
0.050	4.2
0.075	1.7
0.100	1.2

It is suggested that the overall density contrast for the Dhoon granite lies approximately within the limits of 0.035 gm/c.c. and 0.10 gm./c.c.

It must be emphasised here, however, that a weakness in the interpretation of the Dhoon anomaly lies in determining the actual value of the background anomaly. The total size of the anomaly is more difficult to judge here than at Foxdale and a small change (of 2 milligals, for example), would affect the calculations considerably.

d) Model

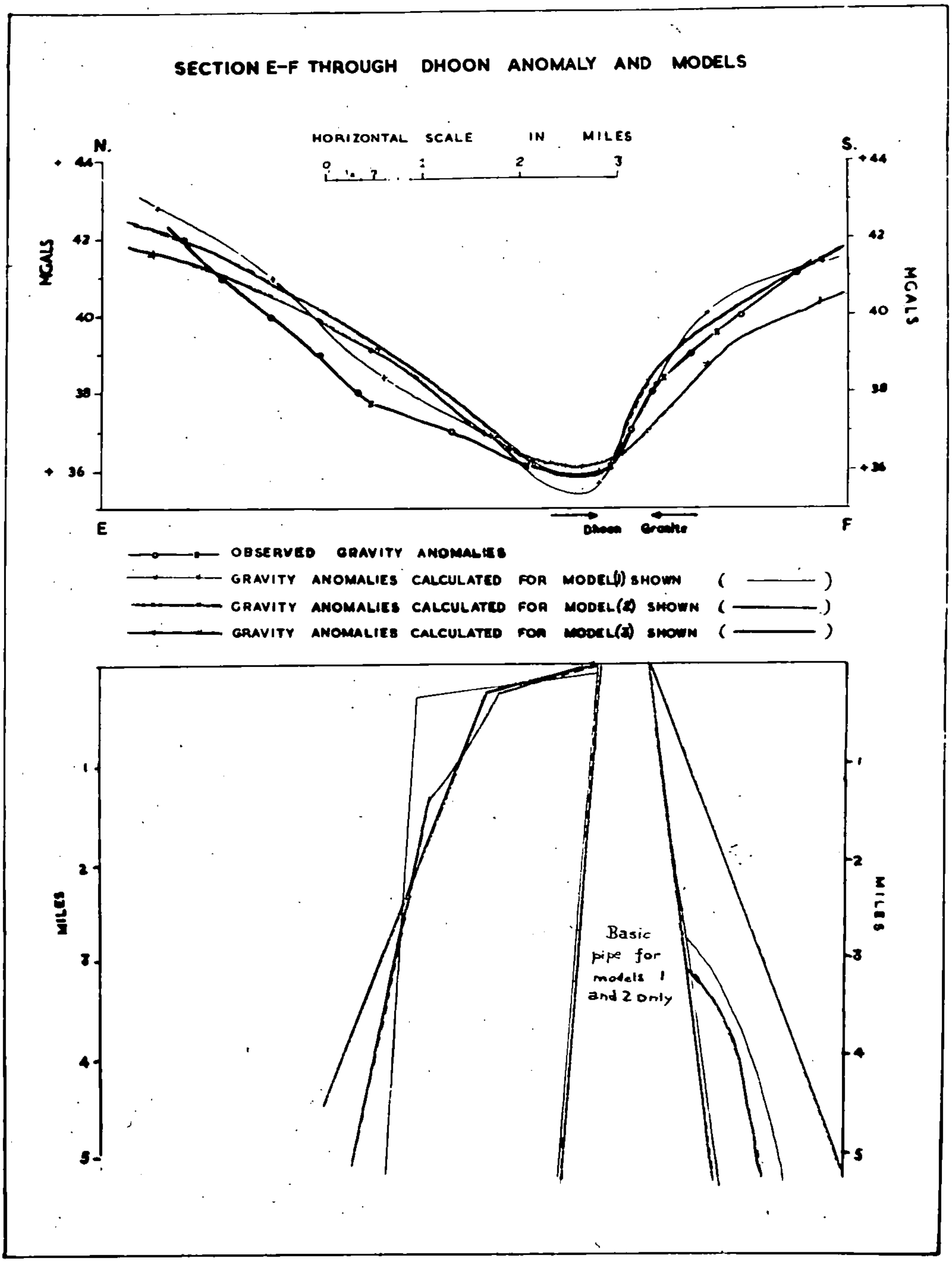
Figure 7 is a north-south section through the Dhoon anomaly.

It is necessary to give the anomalous mass a definite density contrast, before theoretical anomaly profiles can be calculated from models. We get no help for this from the measured densities. Therefore three models and their anomaly profiles have been taken. It is worth bearing in mind the fact that there is a wide variety of model shapes with different combinations of density contrasts which will give anomaly profiles identical to that observed. The examples shown are therefore just three of a very large number of possibilities.

It is impossible to construct a model with an overall density contrast of less than 0.036 gm/c.c. with a profile at all comparable with that observed.

1) Models one and two are based partly upon Nockolds' (1931) conception of the Dhoon granite as being the result of the invasion of an original basic intrusion by a granite. The basic intrusion, pipe-like in form, now has a density of 2.71 gm/c.c. owing to alteration by the invading granite. The latter, is represented by the more extensive intrusion with a density contrast of 0.11 gm/c.c.

2) Model three gives the idea of the shape of an intrusion with an overall density contrast of 0.05 gm/c.c. This model is based on the idea of the granite having a variable density (e.g. 2.71 gm/c.c. near and at the surface) but resulting in a general density of 2.68 gm/c.c. Changes are still necessary



SECTION E-F THROUGH DHOON ANOMALY AND MODELS
HORIZONTAL SCALE IN MILES
0 1 2 3
N.
S.
MGALS
44
42
40
38
36
E
F
Dhoon
Granite
OBSERVED GRAVITY ANOMALIES
GRAVITY ANOMALIES CALCULATED FOR MODEL(1) SHOWN
GRAVITY ANOMALIES CALCULATED FOR MODEL(2) SHOWN
GRAVITY ANOMALIES CALCULATED FOR MODEL(3) SHOWN
MILES
1
2
3
4
5
Basic pipe for models 1 and 2 only

Fig. 7.

to make the profiles fit exactly.

e) General discussion on the shape of the granite

From a general consideration of the shape of the anomaly it is possible to suggest the approximate shape of the granite irrespective of its density contrast.

The granite is again assymmetrical with the steeper sides on the south. The north side trends in a north-east to south-west direction and apparently turns somewhat abruptly around to the south-east under Slieau Lheau (425877).

The main bulk of the granite lies to the north-east of the outcrop at Dhoon and, like Foxdale, it seems to have a broad, flattened top.

There is some indication that the granite, at depth, extends in a south-westerly direction towards Foxdale but it is doubtful whether they actually coalesce.

4.4. The Calf of Man anomaly

a) The anomaly

The negative anomaly is confined to the extreme south-western peninsula of the Isle of Man.

Approaching the Calf of Man from the north-east the gravity anomalies gradually decrease by three milligals in about three and a half miles. The isogals, when drawn, appear to be part of an oval trending north-east to south-west, truncated on three sides by the coast.

The Foxdale and Calf anomalies merge but there is a 'saddle' under station 217. The north-east to south-west elongation of the Calf anomaly and the part of the Foxdale anomaly nearest to it is very marked.

The minimum value observed was + 30.0 milligals at station 324. (i.e. about 12 milligals below background value).

b) The origin of the anomaly

There is no indication at the surface of any feature which might give rise to the anomaly.

Some idea of the maximum depth to the top of the anomalous body can be achieved using Bott and Smiths's (1958) formula. Taking the maximum anomaly as 12 milligals and the maximum gradient as 4 milligals/mile the top can not be more than 2.6 miles deep.

Referring to the possibilities for the origin of the Dhoon and Foxdale anomalies (4.1) one must again come to the conclusion that the anomaly is probably due to an acidic intrusion at depth. The following points are in favour of this origin;-

1) A relatively shallow origin is indicated.
2) The merging of the Foxdale and Calf of Man anomalies suggests a common origin. This being so it would be reasonable to conclude that the acidic intrusion under the Calf of Man is a granite probably similar to the Foxdale granite.
3) The north-east to south-west elongation is common to the

Calf of Man anomaly and to the major part of the Foxdale anomaly.

4) The shape of the anomaly is consistent with the idea of an acid intrusion.

5) The Foxdale granite apparently underlies the whole of the south-western part of the Isle of Man. The Calf of Man anomaly lies directly over this granite.

The Calf of Man anomaly is therefore probably due to a granitic intrusion, not exposed at the surface.

c) The Shape of the Granite

The Calf of Man granite is apparently an oval rise on the south-western extension of the Foxdale granite with a north-east to south-west elongation and probably rises nearest the surface off the coast near the Calf of Man.

It is separated from the granite rising to the surface at Foxdale by the saddle under station 217. It has been estimated that the saddle lies at less than two-thirds of a mile from the surface, the top of the Calf of granite may then lie within half a mile of the surface.

4.5 General Conclusions

Interpretation of the Foxdale Dhoon and Calf of Man anomalies has resulted in these conclusions.

a) The Foxdale anomaly is due to a granite body which underlies practically the whole of the south-west corner of the Isle of Man.

b) The Dhoon anomaly is due to another granite of smaller size and evidently of a more complicated form than the Foxdale granite.

c) The Calf of Man anomaly is due to an elongate 'rise' on the main Foxdale granite.

These three bodies lie approximately on a roughly north-east to south-west axis. Figure 8 is included to show the variation of gravity anomalies in this direction, the profile coinciding approximately with the crest of Lamplughs 'anticline of cleavage'.

4.6 General discussion of implications

In the following discussion the word 'granite' refers to the granites revealed by the gravity survey and not necessarily to the outcrops at Dhoon and Foxdale.

a) Structural features

i) Inter-relationship of the granites

The Foxdale and Dhoon granites have striking differences at the surface and at depth too they are apparently dissimilar. The question arises as to whether they are connected at depth. I do not think any definite answer can be reached but the

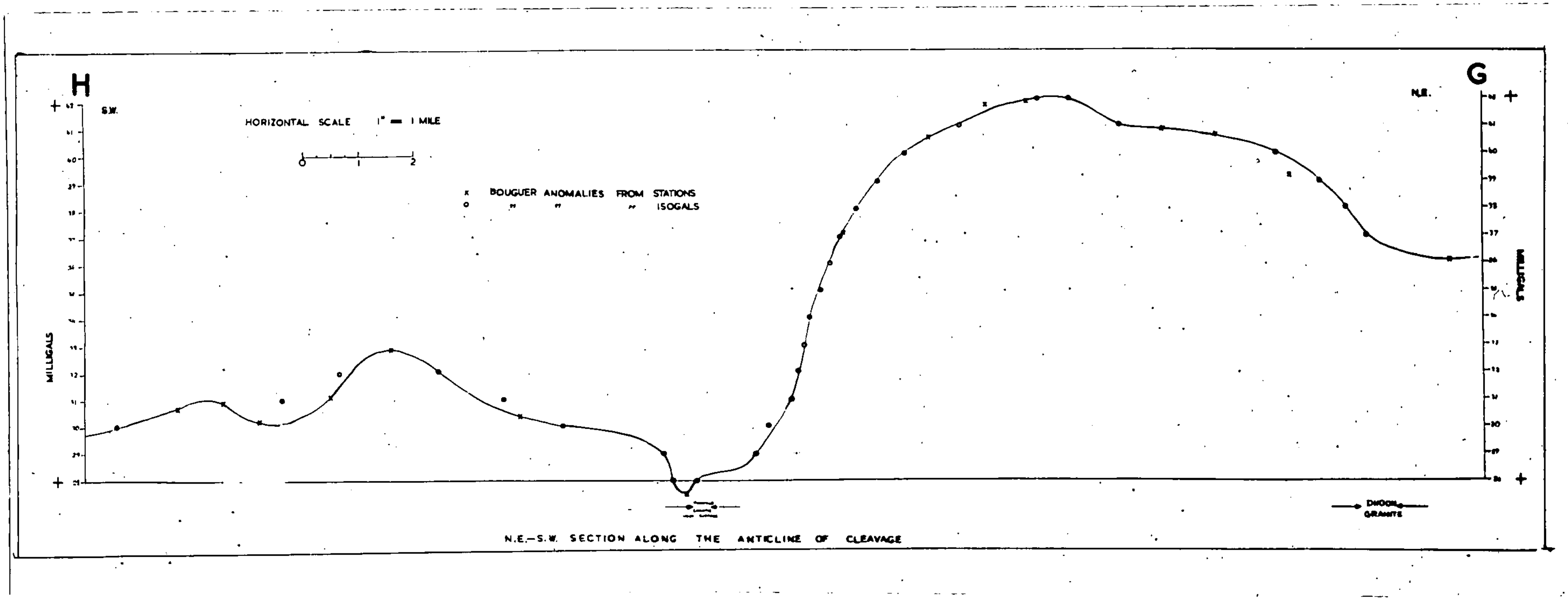

H
G
S.W.
N.E.
HORIZONTAL SCALE 1" = 1 MILE
0
1
2
x BOUGUER ANOMALIES FROM STATIONS
o " " " ISOGALS
MILLIGALS
MILLIGALS
DHOON GRANITE
N.E.–S.W. SECTION ALONG THE ANTICLINE OF CLEAVAGE

Fig. 8.

following facts are of interest.

a) On the Bouguer anomaly map the 41 milligal lines on the Foxdale and Dhoon anomalies are elongated towards each other. The 42 milligal line, however, shows that the gravity gradient must be practically non-existent in this area between the granites.

b) The density of the Dhoon granite is 2.71 gm/c.c. and the Foxdale Granite 2.62 gm/c.c. It has been shown (4.3) that a less dense granite must exist under Dhoon to cause the anomaly. This granite may be similar to that of Foxdale.

c) Both granites lie on the north-east to south-west axis of the Isle of Man.

d) The side of the Foxdale granite facing Dhoon is steep and also reaches a relatively great depth.

If they are not connected the elongation of the granites seems to be such that they probably approach within 3 miles of each other.

The Foxdale and Calf of Man granites are undoubtedly joined and were probably formed simultaneously.

ii) Relationship to Manx Slates

The three granites lie parallel to the strike of the Manx Slates on the Isle of Man (i.e. north-east to south-west).

The 'anticline' of cleavage (Lamplugh) (1.2a) lies almost directly above the centres of the three granites (Figure 2).

and it coincides with the north-east to south-west 'axis' of the granites. This cleavage was post granite in age, according to Lamplugh, and was the last to affect the Manx Slates. It has been disturbed around the Foxdale intrusion but Lamplugh states (p.168) "hence the Foxdale granite may be coincident with rather than the cause of the deviations" in advocating a post granite age for it. The granite and micrograntes are affected by the cleavage. The direction of the cleavage seems to indicate a Caledonian age for its origin.

The coincidence of the anticline of cleavage with the axis of the granites is remarkable. It seems likely that there is some relationship in their origins, in which case there are two possibilities. If, as Lamplugh states, the anticline is the later of the two it is possible that the granites formed a stable block against which the Manx Slates were crushed. Alternatively if the granites were later, the anticlinal crest might mark a line of structural weakness or a place where the vertical forces were at a maximum, thus facilitating the formation of the granite in this position.

As for the origin of the granites little can be said except that there are signs of forcible intrusion.

iii) General relationship

Geological evidence gives the Foxdale and Dhoon granites a Caledonian age, although they were not necessarily simultaneous. Their north-east to south-west trend is typically Caledonian, this and their general environment if not their size make them comparable with the granites of Leinster, Criffel, Cairnsmore, Mourne and Donegal. Like them the Isle of Man granites were formed just after the acme of the Caledonian movements but not before movements had ceased entirely.

The Manx Slates are comparable in structure and lithology with the Ordovician and Silurian strata of adjoining areas on the mainland in the Lake District, the Southern Uplands, and County Down.

b) Metamorphism and metasomatism of the Manx Slates.

Most of the work on the metamorphism of the Manx Slates has been done by Lamplugh (1903) and Gillott (1955).

Lamplugh recognised a striking tendency for the metamorphic 'zones' to be elongated in a north-east to south-west direction. This is shown in Figure 2. His twofold classification of the degrees of metamorphism is necessarily simple and is as follows;

1) Zone of most intense metamorphism found at Archallagan and around the Castletown Waterworks where mica schists and quartzose schists are found respectively.

2) Zone of less intense metamorphism;- this is in the form of a narrow band almost coinciding with the anticline of cleavage.

Lamplugh thought the metamorphism resulted from differential movements, the granites "played their part in raising the temperature of the rock mass".

Using Lamplugh's evidence, Stainier (1928) suggested that the linear arrangement of the metamorphic zones could be due to a continuous granite underlying the affected slates.

Gillott (1954) recognised and listed the following metamorphic facies in his Ph.D. thesis.

1) The Amphibolite facies - developed only near Archallagan & Foxdale.

2) The Biotite - chlorite sub-facies - covering an extensive area, and demarcated by the biotite isograd.

3) The Muscovite - chlorite sub-facies- marked by the presence of leucoxene laths.

The extent of these facies is shown on Map 1; the elongation of the sub-facies (2) and (3) is a notable feature on this map.

Gillott suggests that the above facies were formed by metamorphism and metasomatism due to regional invasion of a granite magma. The granite would be in the form of an elongated body rising to the surface at Dhoon and on Granite Mountain.

The metasomatic minerals, such as tourmaline, leucoxene and cordierite are largely confined to the axial region overlying the highest parts of the granite.

Interpretation of the gravity anomalies has shown that the Foxdale and Dhoon granites are far more extensive at depth than would be imagined from the size of the surface outcrop. Lamplugh's 'zone of less intense metamorphism' coincides with the elongation of the granites and lies approximately over the highest parts of these granites. The same applies to Gillott's' sub-facies.

This coincidence of the linearly arranged metamorphic zones with the large granites revealed by the gravity survey is strong evidence in favour of Gillott's view.

The more intense metamorphism and metasomatism would be expected to occur where the granite is nearest the surface, as it does at Archallagan (granite at 300-400 feet). The fact that there is no high grade metamorphism in the Dhoon district can possibly be explained by the smaller size of the Dhoon Granite.

c) Mineralisation

Map 1 shows the main productive veins on the Isle of Man. It can be seen that most of the veins are confined to the north-east to south-west 'axial region'. The veins themselves, however, have mainly a north-south, east-west direction.

Lamplugh discovered that the veins were unaffected by the earth movements which crushed the granites and the microgranite dykes. This, with other evidence, lead him to conclude that the mineralisation was post granite-intrusion and therefore independent of the granites.

In his PH.D. thesis Gillott says that whereas the general north-east to south-west distribution of the veins suggested a Caledonian origin, the north-south east-west lineation of the veins was probably caused by the Hercynian stress-system. He therefore concludes that the continuous granite body he had earlier suggested might exist (to explain the metamorphism) could have had some influence upon the distribution of the veins (by setting up structural weaknesses over the granite?). The actual formation and mineralisation of the veins, however, did not take place until the Hercynian movements.

Reference to Map 1 indeed shows that the mineral veins are largely confined to an elongated area overlying the granites. Lamplugh pointed out that many of the more important veins (such as at Bradda, Snaefell and the Foxdale Lode) were far from the visible granite. However, these veins can be seen to be related to the underlying granite as shown by the anomaly map. The Bradda veins overlie the Calf of Man granite, the Great Foxdale Lode passes right over the flat top of the Foxdale granite and the Snaefell mines lie over the south-western elongation of the Dhoon granite. It would seem logical to conclude, on the grounds of coincidence, that the veins were formed by hydrothermal action during the intrusion of the granites.

If the metalliferous veins are post-granite in age, Gillott's suggestions seem acceptable. The granites can be envisaged as weakening the directly overlying rock, making it more susceptible to the formation of open veins at a later date than areas to the north-west and south-east. This would not explain the origin of the veins but it would explain their distribution.

d) Minor intrusions

The greenstone and microgranite dykes make up the largest part of this category.

The greenstone dykes on the Isle of Man belong to several suites. These are generally irregularly disposed along the coast but in the centre of the island a predominant north-east to south-west trend becomes apparent. They are pre-granite in age.

The microgranite dykes, however, are confined (see Figure 1) to the north-east to south-west axial region. They obviously originated from both the Foxdale and Dhoon granites and were formed towards the end of the intrusion of these granites.

The distribution of some of the greenstone dykes and the microgranite dykes clearly illustrates the configuration of the stress system before and during the formation of the granites. For the dykes to have a north-east to south-west lineation the intermediate pressure must have been in the same direction. The greatest pressure would be directed approx -imately vertically and the least pressure would be found at right angles to the intermediate pressure (i.e. in a north-west to south-east direction) directed horizontally. The general elongation of the granites suggests that this stress system influenced the form of the granites as well.

e) The bearing of the granites on isostatic compensation

Bott (1959) has suggested "that the gravitational body forces necessarily arising from the existence of a body of low density granite magma within the denser country rocks around were partly responsible for the mechanism of the granite emplacement". The gravity survey of the Isle of Man has shown that the negative anomalies are probably due to the presence of granite lower in density than the surrounding country rock. Gravitational body forces therefore must still exist and are possibly counteracted by a crustal load in the form of relatively high ground;in effect,an isostatic mechanism.

The idea that an isostatic mechanism is responsible for the uplift of the Isle of Man can be roughly tested by comparing the mass deficiency below sea level (the granites) with the mass of the land above. In the estimation all the island south of the 94N grid line was taken into consideration.

It was found that the mass deficiency was in the order of 4.0×10^{16} gm. and the mass of land above sea level 1.7×10^{17}gm. The Isle of Man is therefore considerably under compensated. This may be due to either an error in the calculation of the mass deficiency or in averaging the height of land above sea level .

f) General Conclusion

In discussing the general implications of the granites revealed by the gravity survey, one striking fact has emerged. That is, the close association of the linearity of a number of geological features with the elongation of the granites. These featutes are as follows:-

1) Some greenstone dykes.
2) The metamorphic zones.
3) The micrrogranite dykes.
4) The anticline of cleavage.
5) The distribution of the mineral veins.

Two of these features undoubtedly owe their origin to the granites, while with 4) and 5) the coincidence suggests some connection even though this is difficult to demonstrate in practice.

The greenstone dykes were formed some time before the granites and the reason they have a north-east to south-west trend near the axial region is difficult to explain unless, again, we regard the 'axial region' as an area of structural weakness.

The granites are therefore intimately involved and of great importance in the general geology of the Isle of Man. The north-east to south-west trend common to all these features and to the granites results from their formation during the Caledonian earth-movements but the strip of land known as the 'axial region' was the centre of most of the activity.

4.7 Other intrusions

The igneous intrusions of Dhoon and Foxdale are associated with appreciable gravity anomalies suggesting that they have a far greater extent at depth than would be imagined from their size at the surface. The intrusions at Poortown and Oatland, although their outcrops are comparable in size with the above, give rise to no appreciable anomalies. It is perhaps of interes to suggest reasons for this.

Oatland complex

The Oatland complex (Santon) has been described in 1.2e (iii). A slightly high reading was recorded at station 56, adjacent to the intrusion, but it is doubtful if this is significant.

The basic component of the complex would be expected to have a density of about 2.90gm/c.c. and the acid, about 2.60-2.65 gm/c.c. The overall density would therefore be in the order of 2.75 gm/c.c.;that is,approximately the same as the Manx Slates, the country rock. The density contrast is therefore not appreciable.

The Dhoon granite, however, has an observed density contrast of only 0.02 gm/c.c. and Taylor and Gamba suggested (1933) that the two intrusions had a similar origin. If this is the case the proportion of less dense acid rock must be far less at Oatland than at Dhoon or alternatively the Oatland complex must be of very limited size.

Poortown Diabase

The Poortown (Peel) diabase, described in 1.2e (iii) apparently has no effect upon the gravity anomalies. Diabase would be expected to be about 0.2 gm/c.c. more dense than the

Manx Slates, unless it had been very extensively altered. With such a density contrast less than 400 feet of diabase would cause an anomaly of 1 milligal. It seems, therefore, that either the intrusion is of restricted thickness (less than 400 ') or that it is greatly attenuated at depth.

CHAPTER 5

THE PEEL ANOMALY

The part of the Foxdale anomaly which lies south of Peel has evidently been influenced by some feature other than the Foxdale granite. On the Bouguer anomaly map (Map1) the isogals in this area seem to be deviated from the general regional pattern and there is also a 'valley' trending north-west to south-east.

A residual gravity anomaly map was prepared but owing to the difficulty in deciding the regional gravity gradient it is not likely to be very reliable. It did, however, show a negative anomaly of between 3 and 5 milligals with minimum values at the coast just west of Peel. The anomaly is apparently truncated by the coast and is elongated west-north-west to east-south-east.

Examining the geology of the area and the conclusions so far reached in this thesis, this anomaly may be due to either:-

a) an elongation of the Foxdale granite at depth, or

b) a basin of lower density rocks within the Manx Slates.

It has been mentioned (1.2c) that the town of Peel lies on a down-faulted basin of sandstones, conglomerates, etc. with uncertain boundaries. From our density measurements the Peel Sandstones have been found to be, on average, 0.08 gm/c.c. less dense than the Manx Slates.

It therefore seems more likely that the Peel anomaly is due to the basin of relatively lower density rocks, known as the Peel Sandstones.

The residual anomaly map, inaccurate as it may be, suggests that the Peel Sandstones are thickest at the coast and that their extension inland is greater than that shown on the one inch to one mile Geological Survey Map. Approximately 4000 feet of Peel Sandstones, with a density contrast of 0.08 gm/c.c. would be needed to give an anomaly of 4 milligals.

CHAPTER 6

THE IRISH SEA ANOMALY

6.1 Introduction

The gravity survey of the Isle of Man has shown that the values of the Bouguer anomalies are entirely positive and relatively large, ranging from + 28 milligals to + 47 milligals. This emphasises the fact that there is a tendency for gravity anomalies to become increasingly positive as the Irish Sea is approached. Surveys in Wales and Ireland particularly have shown this.

The results of gravity surveys of areas adjacent to the Irish Sea have been combined in Map 2.

6.2 Previous literature

The regional increase of gravity approaching the Irish Sea has been commented on by Thirlaway (1950) and Powell (1956).

Thirlaway took into consideration the gravity gradient in south-east Ireland and Central Wales and also the submarine station which recorded - 35 milligals midway between Arklow and Aberystwyth. He came to the conclusion that the increase of gravity in these districts was due to two geosynclines of Lower Palaeozoic sediments at a relatively shallow depth.

The sediments, he considered, were generally 0.1 gm/c.c. denser than the underlying Basement and a geosyncline 15,000 feet deep under Aberystwyth would give the 25 milligal anomaly observed there. There would be another geosyncline under south-east Ireland but the two would be separated by a rise in the Basement or a granite intrusion resulting in the reading of - 35 milligals mentioned above.

Powell (1956) seems to agree with Thirlaway on this interpretation but states that "the increase of gravity approaching Anglesey from the south-east may be due to a crustal flexure. "If the crust were arched under the area so that the intermediate layer and substratum were about 10,000 feet nearer the surface under Menai that under Holyhead and Bala, then the gravity gradients of 1 milligal per mile and 0.75 milligals per mile could be explained." Gravity anomalies in this area are difficult to interpret, however.

6.3 Interpretation

Thirlaways and Powell's' interpretations can be checked by finding the maximum depth to the top of the anomalous body. The difficulty here lies in the fact that the regional increase of gravity can not easily be distinguished from the local effects of the geology.

In the Aberystwyth area the maximum depth using Bott and Smiths' (1958) and Smiths' (1959) formula is respectively about 4½ miles and 1 mile. The latter result is uncertain because of the approximation used for the rate of change of gradient and our lack of knowledge of the true density contrast. This, however, seems to indicate that Thirlaway's idea is feasible.

In North Wales, the anomalous mass lies at less than 3½ to 4 miles from the surface, but again this value is doubtful. This does not entirely invalidate Powell's idea of a crustal upwarp since he considers the base of the Granite layer to be only about 4 miles deep. Owing to insufficient detail it was not possible to apply Smith's (1959) more accurate formula for maximum depth but an even shallower origin for the anomaly is suspected. Thirlaway's interpretation does not seem possible here since the increase of gravity coincides with the rise of the Pre-Cambrian rocks.

These interpretations, of course, only deal with two areas and they are far from being conclusive. It is still uncertain whether the Irish Sea anomaly is systematically positive since there is no interrelating evidence, For the sake of simpligity it would obviously be satisfactory to find a common origin, because, as mentioned above, the presence of positive anomalies seems fairly general around the Irish Sea. But before we can come to definite conclusions further gravity and seismic work in the Irish Sea would be necessary.

The following points need to be considered in discussing the anomaly:-

1) The gradients and large positive anomalies are largely confined to areas where Pre-Cambrian and Lower Palaeozoic rocks outcrop.

2) Powell's rock density measurements show that there is an overlap between Lower Palaeozoic and Basement densities in North Wales. Thirlaway's assumption that the former are consistently 0.1 gm/c.c. more dense than the Basement seems to be the great weakness in his argument.

3) The gradients observed in Wales seem to indicate a shallow origin for the anomaly. The possible causes of an extensive positive anomaly are as follows, (remembering that if the high anomalies recorded on the Isle of Man have a different origin to the gradients on the surrounding mainland any one of these, except 4) and 5) may be responsible):-

1) Crustal Upwarp

An upwarp in the crust as envisaged by Powell under the Irish Sea would account for the gradients on the mainland and the positive anomalies on the Isle of Man, but the gradients observed seem to indicate a shallower origin.

2) Rise of a denser Basement

In many areas around the Irish Sea the Pre-Cambrian

Basement is thought to be at a fairly shallow depth.

This must particularly be the case for the Isle of Man. However, it has yet to be clearly demonstrated that the Basement is consistently more dense than the Lower Palaeozoic, even though this would be expected to be the case. In reverse this applies to the ~~next~~ point 4.

3) Basic intrusion

It would be interesting to see if the positive anomaly due to the basic intrusion under the Slieve-Gullion-Carlingford area was elongated eastwards to the Isle of Man.

4) Basin of denser Lower Palaeozoic

This could be geologically possible in some areas but definitely not in all (e.g. Isle of Man and Anglesey).

5) Density contrast between Ordovician and Silurian.

In Wales the positive anomalies can be roughly correlated with the outcrop of the Ordovician. For the Ordovician to cause an anomaly it would have to be consistently more dense than the Silurian. This has not yet been demonstrated by density measurements but possibly the contemporaneous igneous rocks of the Ordovician have increased the overall density. As stated above more information will be necessary before we can reach a conclusion as to interrelationship of the positive anomalies and to the cause or causes.

It does seem possible however, that the positive anomalies are due in part, at least, to the presence of dense Pre-Cambrian and Lower Palaeozoics near the surface in the area in question in contrast to the less dense Upper Palaeozoic and Post-Palaeozoic rocks.

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GRAVIMETER SURVEY : *GRAVITY DATA SHEET*

FILE REF. :-

1 OBSERVERS STATION NUMBER	2 LATITUDE N.	3 LONGITUDE (E. or W.)	4 ELEVATION feet (Newlyn O.D.)	5 STATION TO WHICH CONNECTED	6 GRAVITY DIFFERENCE MEAN VALUE (milligals)	6 DEVIATION	7 TOTAL GRAVITY MEAN VALUE	7 DEVIATION	8 FREE AIR ANOMALY (milligals)	9 BOUGUER ANOMALY ON I.G.F. (milligals)	10 DENSITY VALUES USED IN BOUGUER REDUCTION	11 TERRAIN CORRECTION (milligals)	11 ZONE	12 REMARKS	13 G.S.M. REFERENCE NO. OF STATION
1	54 19 21	4 23 17 W	17.0	BASE			230.03			43.51	2.0	0.59			
2	54 20 02	4 23 36 W	70.0	1			229.02			44.81	"	0.25			
3	54 20 28	4 24 12 W	73.9	1			230.24			45.64	"	0.21			
4	54 20 53	4 24 49 W	74.0	1			230.42			45.17	"	0.15			
5	54 19 15	4 24 15 W	44.3	1			228.29			44.07	"	0.88			
6	54 18 34	4 24 33 W	114.0	1			220.63			42.74	2.75	2.55			
7	54 19 51	4 24 46 W	28.0	1			231.52			44.87	2.0	0.42			
8	54 19 52	4 25 52 W	21.0	1			232.16			45.01	"	0.43			
9	54 20 09	4 26 36 W	32.0	1			232.05			45.13	"	0.31			
10	54 20 53	4 26 33 W	40.0	1			232.90			46.34	"	0.17			
11	54 20 53	4 25 41 W	58.6	1			231.35			45.06	"	0.16			
12	54 24 54	4 22 10 W	31.0	1			226.79			32.74	"	0.04			
13	54 24 31	4 21 54 W	25.0	1			228.79			34.85	"	0.04			
14	54 24 15	4 21 44 W	21.0	1			229.88			36.08	"	0.04			
15	54 23 59	4 21 43 W	25.0	1			230.65			37.48	"	0.05			
16	54 23 45	4 21 54 W	38.3	1			230.70			38.83	"	0.06			
17	54 23 31	4 22 25 W	31.0	1			231.74			39.69	"	0.06			
18	54 23 10	4 22 55 W	82.0	1			228.98			40.95	"	0.08			
19	54 13 58	4 22 41 W	403.3	1			196.04			40.72	2.75	1.49			
20	54 09 37	4 29 05 W	157.5	19			206.85			42.09	"	0.32			
21	54 09 62	4 28 02 W	22.0	19			215.78			43.15	"	0.80			
22	54 10 24	4 27 24 W	227.5	19			204.67			43.05	"	0.45			
23	54 11 01	4 26 28 W	296.0	19			200.43 201.47			42.80	"	0.78			
24	54 11 37	4 25 30 W	307.0	19			~~201.38~~ 201.35			42.87	"	0.53			
25	54 12 04	4 24 43 W	310.0	19			~~202.60~~ 202.60			42.40	"	0.65			
26	54 12 44	4 24 20 W	299.0	19			~~[illegible]~~			42.33	"	0.93			
27	54 13 20	4 23 48 W	209.5	19			207.43			41.74	"	1.65			
28	54 18 24	4 26 13 W	824.0	1			179.98			43.05	"	1.40			
29	54 05 54	4 37 [illegible] W	85.3	20 & 30			202.14			38.25	2.70	0.21			
30	54 11 51	4 37 57 W	142.5	29			[illegible]			[illegible]	[illegible]	[illegible]			

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31	54 18 32	4 32 35 W	106.0	1 & 30			226.23			47.07	2.00	0.68			
32	54 14 26	4 24 34 W	308.7	19			201.32			40.35	2.75	2.09			
33	54 14 48	4 24 43 W	552.0	19			186.61			39.16	"	1.78			
34	54 15 08	4 25 44 W	587.2	19			183.15			39.94	"	4.42			
35	54 15 20	4 26 19 W	774.0	19			172.99			40.04	"	3.96			
36	54 15 02	4 24 59 W	658.0	19			179.33			39.32	"	3.31			
37	54 16 53	4 23 52 W	961.9	19			163.15			37.98	"	2.87			
38	54 18 01	4 32 05 W	173.0	31			220.23			45.88	"	1.83			
39	54 17 21	4 30 25 W	943.2	31			171.27			42.88	"	1.41			
40	54 16 50	4 31 03 W	1,003.2	31			166.47			42.79	"	1.65			
41	54 16 05	4 31 01 W	780.0	31			178.98			42.35	"	0.99			
42	54 15 51	4 31 26 W	820.6	31			176.18			42.84	"	1.56			
43	54 15 04	4 32 21 W	1044.0	31			159.24			40.29	"	1.66			
44	54 14 53	4 28 29 W	1398.0	31			138.57			41.45	"	2.34			
45	54 14 35	4 28 13 W	1388.9	1			137.97			40.48	"	2.08			
46	54 20 37	4 23 02 W	66.1	1			230.11			44.94	2.00	0.39			
47	54 21 08	4 22 59 W	51.0	1			231.78			44.60	"	0.15			
48	54 21 35	4 23 07 W	95.6	1			229.20			44.39	"	0.11			
49	54 21 08	4 23 55 W	86.5	1			224.59			44.84	"	0.13			
50	54 09 08	4 30 35 W	92.0	20			210.58			42.67	2.75	0.34			
51	54 08 32	4 32 00 W	208.0	20			202.64			42.54	"	0.45			
52	54 08 15	4 33 16 W	445.0	20			186.90			41.09	"	0.37			
53	54 07 45	4 34 00 W	402.0	20			188.83			41.16	"	0.32			
54	54 07 17	4 33 34 W	297.0	20			196.21			43.56	"	0.28			
55	54 07 56	4 31 48 W	302.6	20			196.63			42.89	"	0.38			
56	54 08 23	4 30 29 W	153.0	20			205.75			42.57	"	0.40			
57	54 08 23	4 24 20 W	380.0	20			191.41			42.29	"	1.05			
58	54 09 17	4 32 25 W	340.0	20			194.70			41.18	"	0.34			
59	54 10 02	4 31 02 W	103.0	20			209.62			41.54	"	[illegible]			
60	54 10 39	4 32 53	[illegible]	1 & 30			203.10			40.24		0.33			

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61	54 11 05	4 34 01 W	181·0	20 & 30			203·16			38·21	2·75	0·83			
62	54 11 34	4 35 22 W	177·0	20 & 30			199·90			35·24	″	2·04			
63	54 11 52	4 36 56 W	166·0	20 & 30			200·09			33·17	″	0·88			
64	54 11 03	4 38 24 W	262·0	30			189·60			30·28	″	1·68			
65	54 10 10	4 39 16 W	446·0	30			175·35			27·54	″	1·04			
66	54 10 12	4 37 05 W	524·0	30			173·24			29·36	″	0·40			
67	54 9 53	4 35 38 W	586·0	″			173·72			34·13	″	0·60			
68	54 9 16	4 34 13 W	485·0	″			183·70			39·05	″	0·62			
69	54 10 05	4 33 39 W	197·0	″			202·09			39·11	″	0·44			
70	54 12 48	4 37 50 W	192·0	30 & 31			203·55			37·45	″	1·50			
71	54 13 27	4 37 02 W	282·6	″			201·67			41·86	″	3·40			
72	54 14 09	4 36 42 W	571·5	″			189·50			43·04	″	0·69			
73	54 14 55	4 35 23 W	521·0	″			194·25			44·25	″	1·23			
74	54 15 50	4 34 42 W	285·0	″			2,1·15			46·05	″	1·57			
75	54 16 41	4 34 57 W	207·9	″			217·33			45·98	″	0·88			
76	54 17 35	4 34 33 W	129·0	″			223·27			46·97	2·00	0·61			
77	54 18 12	4 33 43 W	118·0	″			225·85			47·94	2·00	0·64			
78	54 19 28	4 25 24 W	56·0	″			227·35			45·05	″	1·83			
79	54 19 09	4 26 33 W	61·0	″			227·52			45·82	″	2·10			
80	54 19 18	4 27 31 W	62·0	″			228·17			45·49	″	1·26			
81	54 19 39	4 28 16 W	49·0	″			230·43			45·60	″	0·45			
82	54 20 17	4 28 08 W	42·1	″			232·51			46·03	″	0·25			
83	54 20 53	4 27 28 W	62·3	″			232·2[illegible]			46·19	″	0·16			
84	54 21 41	4 27 22 W	81·0	″			231·53			45·56	″	0·10			
85	54 21 51	4 26 22 W	83·0	″			231·51			45·43	″	0·09			
86	54 21 24	4 25 04 W	69·8	″			231·42			45·48	″	0·11			
87	54 18 30	4 21 00 W	51·0	″			222·37			39·99	2·75	0·83			
88	54 18 10	4 19 57 W	204·0	″			212·36			38·40	″	0·60			
89	54 18 50	4 22 21 W	82·3				222·61			41·29	2·00	1·37			
90	54 21 53	4 23 21 W	100·0	″			229·33			44·23	″	0·10			

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91	54 22 26	4 23 35 W	142.2	1			227.13			44.35	2.00	0.15			
92	54 22 53	4 22 23 W	100.0	"			229.43			42.10	"	0.14			
93	54 23 01	4 23 21 W	170.0	"			223.82			42.37	"	0.31			
94	54 23 20	4 24 24 W	120.0	"			228.36			42.81	"	0.20			
95	54 22 52	4 24 54 W	181.0	"			223.66			43.27	"	0.50			
96	54 21 45	4 24 14 W	96.0	"			230.00			44.97	"	0.10			
97	54 22 34	4 24 53 W	150.0	"			226.77			44.34	"	0.16			
98	54 12 06	4 39 01 W	103.8	30			204.03			34.08	2.75	1.85			
99	54 12 14	4 40 22 W	100.1	"			206.88			35.71	"	1.04			
100	54 12 26	4 41 34 W	85.0	"			209.38			36.49	"	0.50			
101	54 12 54	4 41 46 W	100.8	"			209.62			37.10	"	0.63			
102	54 13 22	4 41 40 W	37.6	"			214.78			37.67	"	0.40			
103	54 13 10	4 40 33 W	137.0	"			208.42			37.52	2.65	0.30			
104	54 12 52	4 38 21 W	182.2	"			205.59			37.89	2.75	0.58			
105	54 12 38	4 38 23 W	215.0	"			201.89			36.70	"	0.82			
106	54 09 24	4 38 15 W	680.0	"			162.89			29.84	"	0.91			
107	54 08 34	4 38 14 W	636.0	"			168.27			33.77	"	0.87			
108	54 07 58	4 38 14 W	507.0	"			177.79			36.25	"	0.57			
109	54 08 10	4 37 11 W	379.0	"			186.04			36.44	"	0.38			
110	54 08 44	4 36 29 W	393.0	"			184.88			35.35		0.40			
111	54 09 40	4 36 27 W	432.0	"			180.25			31.73	"	0.44			
112	54 10 59	4 37 39 W	590.2	"			169.97			29.07	"	0.63			
113	54 09 55	4 39 44 W	900.0	30 & 39			148.99			29.28	"	1.43			
114	54 09 17	4 36 41 W	983.5	"			143.52			29.56	"	1.84			
115	54 08 47	4 41 00 W	1000.0	"			142.08			30.59	"	2.72			
116	54 08 07	4 41 20 W	829.0	"			153.89			32.03	"	1.53			
117	54 07 26	4 41 08 W	607.0	"			167.84			33.40	"	1.02			
118	54 06 38	4 40 51 W	349.0	"			184.58			35.54	"	0.49			
119	54 16 10	4 36 29 W	134.0	31 & 30			221.17			46.28	"	0.95			
120	54 15 26	4 37 28 W	238.8				212.70			43.34	"	1.25			

GRAVIMETER SURVEY : GRAVITY DATA SHEET

FILE REF. :-

1 OBSERVER'S STATION NUMBER	2 LATITUDE N.	3 LONGITUDE (E. or W)	4 ELEVATION feet (Newlyn O.D.)	5 STATION TO WHICH CONNECTED	6 GRAVITY DIFFERENCE MEAN VALUE (milligals)	6 DEVIATION	7 TOTAL GRAVITY MEAN VALUE	7 DEVIATION	8 FREE AIR ANOMALY (milligals)	9 BOUGUER ANOMALY ON I.G.F. (milligals)	10 DENSITY VALUES USED IN BOUGUER REDUCTION	11 TERRAIN CORRECTION (milligals)	11 ZONE	12 REMARKS	13 G.S.M. REFERENCE NO. OF STATION
121	54 14 53	4 38 17 W	219.0	31 & 30			212.76			44.94	2.75	1.17			
122	54 14 19	4 38 46 W	234.1	"			209.21			42.98	"	0.96			
123	54 13 52	4 39 51 W	99.3	"			214.19			40.28	2.65	0.54			
124	54 13 35	4 40 35 W	173.0	"			208.33			39.06	"	0.35			
125	54 12 53	4 40 50 W	93.0	"			208.40			35.27	"	0.31			
126	54 12 32	4 40 02 W	94.0	"			206.93			35.09	2.75	0.65			
127	54 10 38	4 38 29 W	303.9	"			186.10			29.49	"	1.30			
128	54 09 52	4 38 08 W	579.0	"			166.91			27.20	"	0.88			
129	54 11 47	4 41 52 W	206.0	30			199.76			35.39	"	0.93			
130	54 11 05	4 42 10 W	281.8	"			193.39			34.44	"	0.90			
131	54 10 39	4 43 13 W	269.0	"			193.67			34.63	"	0.95			
132	54 10 00	4 43 57 W	177.0	"			198.46			35.17	"	1.19			
133	54 09 29	4 42 37 W	707.0	"			162.01			30.92	"	1.40			
134	54 09 00	4 42 10 W	683.0	"			161.76			29.78	"	1.23			
135	54 10 25	4 39 43 W	714.7	"			162.27			29.90	"	1.00			
136	54 10 32	4 35 35 W	501.0	"			174.73			29.04	"	0.45			
137	54 09 11	4 35 41 W	400.0	"			185.64			35.84	"	0.36			
138	54 09 54	4 34 35 W	300.0	"			194.31			37.70	"	0.48			
139	54 10 27	4 34 23 W	300.0	"			194.87			37.49	"	0.49			
140	54 13 23	4 38 11 W	449.0	30 & 31			192.42			40.06	"	0.91			
141	54 13 55	4 37 35 W	565.0	"			188.54			41.98	"	0.64			
142	54 14 47	4 36 53 W	604.0	"			189.35			44.13	"	0.94			
143	54 08 09	4 39 43 W	672.0	29 & 30			165.17			33.24	"	1.06			
144	54 07 40	4 40 00 W	450.0	"			173.37			33.99	"	0.66			
145	54 08 30	4 39 07 W	700.0	"			163.26			33.15	"	1.39			
146	54 07 20	4 38 23 W	322.0	"			188.86			37.06	"	0.32			
147	54 06 45	4 38 32 W	227.0	"			194.31			37.74	"	0.34			
148	54 06 09	4 38 32 W	164.0	"			197.27			37.84	2.70	0.21			
149	54 04 [illegible]	4 38 39 W	29.0	29			203.44			38.00	"	0.11			
150	54 04 34	4 37 28 W	15.0	"			206.11			39.96	"	0.09			

GRAVIMETER SURVEY : *GRAVITY DATA SHEET*

FILE REF. :-

1 OBSERVER'S STATION NUMBER	2 LATITUDE N.	3 LONGITUDE (E. or W)	4 ELEVATION feet (Newlyn O.D.)	5 STATION TO WHICH CONNECTED	6 GRAVITY DIFFERENCE MEAN VALUE (milligals)	6 DEVIATION	7 TOTAL GRAVITY MEAN VALUE	7 DEVIATION	8 FREE AIR ANOMALY (milligals)	9 BOUGUER ANOMALY ON I.G.F. (milligals)	10 DENSITY VALUES USED IN BOUGUER REDUCTION	11 TERRAIN CORRECTION (milligals)	11 ZONE	12 REMARKS	13 G.S.M. REFERENCE NO. OF STATION
121	54 14 53	4 38 17 W	219.0	31 & 30			212.76			44.94	2.75	1.17			
122	54 14 19	4 38 46 W	234.1	"			209.21			42.38	"	0.96			
123	54 13 52	4 39 51 W	99.3	"			214.19			40.28	2.65	0.54			
124	54 13 35	4 40 35 W	173.0	"			208.33			39.06	"	0.35			
125	54 12 53	4 40 50 W	93.0	"			208.40			35.27	"	0.31			
126	54 12 32	4 40 02 W	94.0	"			206.93			35.09	2.75	0.65			
127	54 10 38	4 38 29 W	303.9	"			186.10			29.49	"	1.30			
128	54 09 52	4 38 08 W	574.0	"			166.91			27.20	"	0.88			
129	54 11 47	4 41 52 W	206.0	30			199.76			35.39	"	0.93			
130	54 11 05	4 42 10 W	281.8	"			193.39			34.44	"	0.90			
131	54 10 39	4 43 13 W	269.0	"			193.67			34.63	"	0.95			
132	54 10 00	4 43 57 W	177.0	"			198.46			35.17	"	1.19			
133	54 09 24	4 42 37 W	707.0	"			162.01			30.92	"	1.40			
134	54 09 00	4 42 10 W	683.0	"			161.76			29.78	"	1.23			
135	54 10 25	4 39 43 W	714.7	"			162.27			29.90	"	1.00			
136	54 10 32	4 35 35 W	501.0	"			174.73			29.04	"	0.45			
137	54 09 11	4 35 41 W	400.0	"			185.64			35.84	"	0.36			
138	54 09 54	4 34 35 W	300.0	"			194.31			37.70	"	0.48			
139	54 10 27	4 34 23 W	300.0	"			194.87			37.49	"	0.49			
140	54 13 23	4 38 11 W	449.0	30 & 31			192.42			40.06	"	0.91			
141	54 13 55	4 37 35 W	565.0	"			188.54			41.98	"	0.64			
142	54 14 47	4 36 53 W	604.0	"			189.35			44.13	"	0.94			
143	54 08 09	4 39 43 W	672.0	29 & 30			165.17			33.24	"	1.06			
144	54 07 40	4 40 00 W	450.0	"			173.37			33.99	"	0.66			
145	54 08 30	4 39 07 W	700.0	"			163.26			33.15	"	1.39			
146	54 07 20	4 38 23 W	322.0	"			188.86			37.06	"	0.32			
147	54 06 45	4 38 32 W	227.0	"			194.31			37.74	"	0.34			
148	54 06 09	4 38 32 W	164.0	"			197.27			37.84	2.70	0.21			
149	54 04 40	4 38 39 W	29.0	29			203.44			33.00	"	0.11			
150	54 04 34	4 37 28 W	15.0	"			206.11			39.96	"	0.09			

GRAVIMETER SURVEY : *GRAVITY DATA SHEET*

FILE REF. :-

1 OBSERVER'S STATION NUMBER	2 LATITUDE N.	3 LONGITUDE (E. or W)	4 ELEVATION feet (Newlyn O.D.)	5 STATION TO WHICH CONNECTED	6 GRAVITY DIFFERENCE MEAN VALUE (milligals)	6 DEVIATION	7 TOTAL GRAVITY MEAN VALUE	7 DEVIATION	8 FREE AIR ANOMALY (milligals)	9 BOUGUER ANOMALY ON I.G.F. (milligals)	10 DENSITY VALUES USED IN BOUGUER REDUCTION	11 TERRAIN CORRECTION (milligals)	11 ZONE	12 REMARKS	13 G.S.M. REFERENCE NO. OF STATION
151	54 04 54	4 36 49 W	19.0	29			207.12			40.76	2.70	0.12			
152	54 03 55	4 37 09 W	33.5	"			205.03			40.97	"	0.13			
153	54 04 06	4 39 44 W	17.5	"			202.75			37.44	"	0.11			
154	54 04 47	4 39 55 W	27.3	"			202.59			36.89	"	0.11			
155	54 05 35	4 40 25 W	61.3	"			199.97			35.39	"	0.22			
156	54 05 39	4 39 24 W	67.8	"			201.87			37.46	"	0.21			
157	54 05 12	4 39 01 W	48.1	"			202.30			37.27	"	0.13			
158	54 05 52	4 41 13 W	81.0	"			199.39			35.58	2.75	0.42			
159	54 05 46	4 42 18 W	90.9	"			197.57			34.38	"	0.32			
160	54 05 26	4 43 41 W	86.5	"			195.33			32.42	"	0.38			
161	54 05 42	4 45 05 W	96.0	"			194.19			31.73	"	0.65			
162	54 05 07	4 45 17 W	61.0	"			194.26			30.22	"	0.30			
163	54 05 06	4 42 44 W	50.0	"			198.62			33.87	"	0.21			
164	54 05 00	4 41 12 W	41.0	"			200.45			35.31	2.70	0.16			
165	54 04 28	4 40 57 W	27.0	"			200.87			35.72	"	0.17			
166	54 18 16	4 23 16 W	682.0	18 45			185.62			41.18	2.75	2.07			
167	54 17 47	4 24 12 W	1019.0	"			163.66			40.44	"	3.33			
168	54 17 29	4 24 42 W	1166.0	"			154.19			40.64	"	3.30			
169	54 16 57	4 25 42 W	1254.6	"			147.68			40.32	"	3.52			
170	54 16 43	4 26 17 W	1318.0	"			144.20			39.78	"	2.39			
171	54 16 14	4 26 40 W	1381.4	"			139.87			39.78	"	2.28			
172	54 15 42	4 26 55 W	1369.0	"			139.00			40.17	"	3.51			
173	54 15 02	4 27 44 W	1346.0	"			141.05			40.24	"	1.94			
174	54 10 46	4 28 13 W	431.0	20 & 45			192.22			42.19	"	0.57			
175	54 10 29	4 29 23 W	234.8	20			203.24			41.91	"	0.43			
176	54 10 45	4 30 21 W	255.0	"			202.18			41.60	"	0.37			
177	54 10 58	4 31 38 W	371.9	"			194.45			40.44	"	0.41			
178	54 11 14	4 32 56 W	405.0	"			191.55			39.65	"	0.90			
179	54 14 54	4 22 18 W	602.0	19 & 1			181.81			38.43	"	3.05			
180	54 15 26	4 22 16 W	541.3	"			185.18			36.06	2.71	1.44			

GRAVIMETER SURVEY : *GRAVITY DATA SHEET*

FILE REF. :-

1 OBSERVERS STATION NUMBER	2 LATITUDE N.	3 LONGITUDE (E. or W)	4 ELEVATION feet (Newlyn O.D.)	5 STATION TO WHICH CONNECTED	6 GRAVITY DIFFERENCE MEAN VALUE (milligals)	6 DEVIATION	7 TOTAL GRAVITY MEAN VALUE	7 DEVIATION	8 FREE AIR ANOMALY (milligals)	9 BOUGUER ANOMALY ON I.G.F. (milligals)	10 DENSITY VALUES USED IN BOUGUER REDUCTION	11 TERRAIN CORRECTION (milligals)	11 ZONE	12 REMARKS	13 G.S.M. REFERENCE NO. OF STATION
181	54 16 00	4 22 36 W	493.0	1 & 19			189.00			36.32	2.75	1.75			
182	54 16 54	4 22 21 W	425.6	"			195.20			37.11	"	1.60			
183	54 17 35	4 22 01 W	522.3	"			191.20			37.72	"	1.47			
184	54 18 01	4 21 46 W	523.1	"			192.76			38.95	"	1.71			
185	54 18 36	4 29 24 W	118.2	1 & 45			223.34			45.38	"	2.28			
186	54 18 06	4 29 01 W	158.0	"			217.02			43.67	"	3.82			
187	54 17 29	4 29 21 W	205.0	"			210.77			43.03	"	5.78			
188	54 16 46	4 29 19 W	380.0	"			200.97			42.81	"	4.03			
189	54 16 20	4 29 52 W	644.1	"			187.11			43.01	"	1.90			
190	54 15 55	4 28 52 W	1027.0	"			162.95			41.85	"	1.72			
191	54 15 25	4 28 29 W	1181.9	"			151.93			41.83	"	2.87			
192	54 23 46	4 24 22 W	38.8	|			232.82			40.95	2.00	0.06			
193	54 24 07	4 24 34 W	19.0	"			233.14			39.40	"	0.05			
194	54 23 16	4 25 32 W	115.0	"			228.39			42.51	"	0.11			
195	54 23 14	4 26 44 W	76.9	"			230.90			42.34	"	0.06			
196	54 23 42	4 26 36 W	50.0	"			233.03			42.03	"	0.06			
197	54 23 11	4 27 21 W	79.0	"			230.55			42.30	"	0.09			
198	54 23 28	4 28 31 W	98.0	"			228.13			40.84	"	0.15			
199	54 17 55	4 19 00 W	207.8	"			210.70			37.39	2.75	0.67			
200	54 17 36	4 19 52 W	99.5	"			216.57			37.35	"	0.67			
201	54 17 50	4 20 56 W	255.0	"			207.38			37.62	"	1.31			
202	54 07 05	4 32 20 W	323.0	20 & 29			193.44			42.25	"	0.51			
203	54 06 43	4 34 27 W	172.3	"			201.07			41.25	"	0.25			
204	54 06 12	4 33 51 W	100.0	"			205.24			41.94	"	0.29			
205	54 06 07	4 35 34 W	263.6	"			194.10			40.81	"	0.54			
206	54 06 26	4 36 20 W	212.0	"			196.41			39.86	"	0.27			
207	54 05 26	4 36 27 W	101.3	29			202.86			40.72	~~2.75~~ 2.70	0.21			
208	54 07 13	4 34 51 W	258.3	"			196.41			40.99	2.75	0.29			
209	54 08 00	4 34 59 W	325.7	"			192.52			40.00	"	0.33			
210	54 07 36	4 36 08 W	372.0	"			188.43			39.16	"	0.28			

GRAVIMETER SURVEY : *GRAVITY DATA SHEET*

FILE REF. :–

1 OBSERVERS STATION NUMBER	2 LATITUDE N.	3 LONGITUDE (E. or W)	4 ELEVATION feet (Newlyn O.D)	5 STATION TO WHICH CONNECTED	6 GRAVITY DIFFERENCE MEAN VALUE (milligals)	6 DEVIATION	7 TOTAL GRAVITY MEAN VALUE	7 DEVIATION	8 FREE AIR ANOMALY (milligals)	9 BOUGUER ANOMALY ON I.G.F. (milligals)	10 DENSITY VALUES USED IN BOUGUER REDUCTION	11 TERRAIN CORRECTION (milligals)	11 ZONE	12 REMARKS	13 G.S.M. REFERENCE NO. OF STATION
211	54 06 58	4 36 45 W	291.0	29			192.09			38.92	2.75	0.25			
212	54 06 30	4 37 22 W	249.5	"			192.97			38.16	"	0.39			
213	54 06 54	4 39 45 W	357.8	"			185.55			36.56	"	0.40			
214	54 07 06	4 42 29 W	456.9	"			176.72			33.86	"	0.98			
215	54 06 16	4 42 06 W	255.0	"			190.22			36.11	"	0.43			
216	54 06 27	4 42 58 W	400.0	"			179.65			33.98	"	0.58			
217	54 06 52	4 43 28 W	550.0	"			169.88			32.86	"	0.99			
218	54 06 12	4 43 41 W	505.6	"			171.62			33.07	"	1.12			
219	54 11 53	4 28 25 W	582.7	18 29			184.46			42.07	"	0.86			
220	54 12 37	4 28 24 W	918.0	"			164.96			41.98	"	1.55			
221	54 13 51	4 28 11 W	1220.5	"			147.22			40.65	"	1.86			
222	54 14 46	4 30 37 W	1349.0	"			142.59			42.37	"	1.97			
223	54 13 25	4 25 10 W	522.2	19			189.41			41.38	"	0.99			
224	54 12 34	4 27 26 W	821.0	"			172.17			43.20	"	1.21			
225	54 12 56	4 26 39 W	856.0	"			168.61			41.27	"	1.30			
226	54 12 28	4 25 47 W	686.0	"			178.03			41.32	"	1.29			
227	54 11 41	4 26 33 W	542.0	"			186.74			42.12	"	0.75			
228	54 11 51	4 23 41 W	300.0	"			200.57			41.62	"	0.93			
229	54 13 58	4 24 18 W	130.0	"			211.88				"	2.24			
230	54 18 45	4 31 26 W	93.0	31			226.24			46.56	2.00	1.37			
231	54 19 04	4 30 02 W	63.0	"			228.55			46.18	"	1.16			
232	54 19 18	4 28 50 W	62.0	"			228.63			45.44	"	0.77			
233	54 19 44	4 29 33 W	50.0	"			231.21			46.17	"	0.36			
234	54 20 32	4 29 56 W	34.6	"			234.15			46.74	"	0.19			
235	54 20 38	4 31 20 W	35.0	"			235.04			47.27	"	0.15			
236	54 20 16	4 32 13 W	33.0	"			234.56			47.74	"	0.17			
237	54 19 48	4 33 13 W	19.0	"			234.40			46.97	"	0.19			
238	54 19 02	4 33 44 W	130.0	"			225.34			46.97	"	0.45			
239	54 19 08	4 32 01 W	68.0	"			230.21			47.32	"	0.42			
240	54 14 28	4 32 37 W	56.5	"			231.58			47.26	"	0.26			

GRAVIMETER SURVEY : *GRAVITY DATA SHEET*

FILE REF. :-

1 OBSERVER'S STATION NUMBER	2 LATITUDE N.			3 LONGITUDE (E. or W)				4 ELEVATION feet (Newlyn O.D)	5 STATION TO WHICH CONNECTED	6 GRAVITY DIFFERENCE MEAN VALUE (milligals)	6 DEVIATION	7 TOTAL GRAVITY MEAN VALUE	7 DEVIATION	8 FREE AIR ANOMALY (milligals)	9 BOUGUER ANOMALY ON I.G.F. (milligals)	10 DENSITY VALUES USED IN BOUGUER REDUCTION	11 TERRAIN CORRECTION (milligals)	ZONE	12 REMARKS	13 G.S.M. REFERENCE NO. OF STATION
241	54	19	54	4	31	32	W	43.0	31			233.67			47.81	2.0	0.26			
242	54	19	26	4	30	59	W	38.0	"			232.32			46.97	"	0.45			
243	54	20	30	4	32	52	W	64.0	"			233.60			48.22	"	0.16			
244	54	21	05	4	32	19	W	80.0	"			233.24			48.08	"	0.12			
245	54	21	33	4	31	40	W	90.0	"			231.99			46.84	"	0.11			
246	54	22	15	4	30	49	W	81.9	"			232.21			45.49	"	0.09			
247	54	22	54	4	29	38	W	35.0	"			234.49			43.70	"	0.16			
248	54	22	32	4	28	49	W	61.7	"			232.96			44.45	"	0.08			
249	54	22	18	4	27	51	W	69.5	"			232.31			44.66	"	0.08			
250	54	21	50	4	28	29	W	42.0	"			234.36			45.51	"	0.10			
251	54	21	53	4	29	58	W	74.0	"			232.76			46.02	"	0.09			
252	54	21	26	4	30	48	W	83.0	1 & 31			232.06			46.59	"	0.10			
253	54	21	00	4	31	15	W	63.2	"			233.02			46.84	"	0.13			
254	54	20	49	4	29	11	W	39.0	"			233.97			46.42	"	0.16			
255	54	22	17	4	25	41	W	90.0	"			230.90			44.68	"	0.08			
256	54	22	22	4	26	31	W	71.0	"			232.52			44.89	"	0.08			
257	54	22	46	4	26	47	W	66.5	"			231.98			43.45	"	0.07			
258	54	23	00	4	28	11	W	119.0	"			227.37			42.22	"	0.18			
259	54	22	54	4	29	02	W	128.0	"			227.71			43.30	"	0.17			
260	54	21	58	4	32	03	W	52.6	"			234.22			46.05	"	0.24			
261	54	18	07	4	34	43	W	85.0	"			227.18			46.95	"	0.46			
262	54	07	30	4	43	46	W	658.0	30			163.36			33.24	2.75	2.43			
263	54	08	16	4	42	19	W	1160.3	"			132.45			31.46	"	3.03			
264	54	16	06	4	35	28	W	272.3	31 & 45			212.96			46.59	"	1.21			
265	54	14	04	4	35	16	W	504.3	"			192.68			43.27	"	1.59			
266	54	14	35	4	34	50	W	650.0	"			186.55			44.62	"	1.21			
267	54	15	10	4	34	37	W	756.8	"			180.83			45.31	"	2.16			
268	54	14	53	4	33	50	W	874.5	"			171.90			44.02	"	2.45			
269	54	14	46	4	33	00	W	1015.0	"			163.11			42.77	"	1.56			
270	54	14	40	4	31	42	W	1266.0	"			147.74			42.44	"	1.60			

GRAVIMETER SURVEY : *GRAVITY DATA SHEET*

FILE REF. :-

1 OBSERVER'S STATION NUMBER	2 LATITUDE N.	3 LONGITUDE (E. or W.)	4 ELEVATION feet (Newlyn O.D.)	5 STATION TO WHICH CONNECTED	6 GRAVITY DIFFERENCE MEAN VALUE (milligals)	6 DEVIATION	7 TOTAL GRAVITY MEAN VALUE	7 DEVIATION	8 FREE AIR ANOMALY (milligals)	9 BOUGUER ANOMALY ON I.G.F. (milligals)	10 DENSITY VALUES USED IN BOUGUER REDUCTION	11 TERRAIN CORRECTION (milligals)	ZONE	12 REMARKS	13 G.S.M. REFERENCE NO. OF STATION
271	54 11 48	4 33 57 W	500.0	20 & 45			185.46			37.14	2.75	1.71			
272	54 11 35	4 31 33 W	281.4	"			200.92			40.27	"	0.74			
273	54 12 24	4 31 18 W	361.0	"			197.54			41.75	"	1.27			
274	54 12 58	4 31 04 W	476.8	"			191.58			42.09	"	1.55			
275	54 13 50	4 31 13 W	594.0	"			185.55			43.02	"	2.84			
276	54 14 10	4 31 50 W	1042.6	"			159.82			41.99	"	1.57			
277	54 12 37	4 30 16 W	402.0	45			195.26			41.86	"	1.56			
278	54 13 16	4 29 44 W	600.0	"			185.10			42.50	"	1.61			
279	54 13 47	4 29 25 W	650.6	"			180.35			40.99	"	2.29			
280	54 12 02	4 30 44 W	288.1	"			201.86			41.02	"	1.17			
281	54 11 27	4 30 03 W	332.0	"			198.51			41.71	"	0.62			
282	54 11 15	4 28 52 W	400.0	"			194.74			42.82	"	1.20			
283	54 16 58	4 20 07 W	332.8	"			200.95			36.94	"	1.24			
284	54 16 25	4 20 41 W	330.0	"			200.03			36.25	"	0.86			
285	54 17 01	4 21 12 W	336.2	"			201.14			36.89	"	0.86			
286	54 16 08	4 21 21 W	210.0	18 & 19			201.13			31.56	"	1.74			
287	54 15 51	4 20 48 W	34.6	"			216.37			36.79	"	1.68			
288	54 14 36	4 23 20 W	688.2	"			178.80			39.50	"	1.62			
289	54 13 39	4 26 19 W	510.0	19			190.22			41.69	"	1.54			
290	54 14 08	4 26 12 W	579.2	"			185.85			40.71	"	1.53			
291	54 13 53	4 25 16 W	467.0	"			192.64			40.80	"	1.09			
292	54 11 04	4 25 42 W	200.0	"			207.00			42.83	"	0.49			
293	54 10 47	4 25 07 W	182.0	"			207.44			42.60	"	0.47			
294	54 11 20	4 24 45 W	281.0	"			201.62			41.81	"	0.45			
295	54 18 53	4 28 33 W	133.8	18 & 20			223.40			45.31	"	1.63			
296	54 11 18	4 26 59 W	400.0	"			195.11			42.59	"	0.67			
297	54 11 52	4 27 11 W	500.0	"			189.55			42.20	"	0.72			
298	54 11 30	4 27 45 W	400.0	"			194.92			42.19	"	0.75			
299	54 08 31	4 34 20 W	571.4	20			178.11			39.68	"	0.67			
300	54 08 56	4 34 54 W	385.0	"			189.07			38.72	"	0.35			

GRAVIMETER SURVEY : *GRAVITY DATA SHEET*

FILE REF. :-

1 OBSERVERS STATION NUMBER	2 LATITUDE N.	3 LONGITUDE (E. or W.)	4 ELEVATION feet (Newlyn O.D.)	5 STATION TO WHICH CONNECTED	6 GRAVITY DIFFERENCE MEAN VALUE (milligals)	6 DEVIATION	7 TOTAL GRAVITY MEAN VALUE	7 DEVIATION	8 FREE AIR ANOMALY (milligals)	9 BOUGUER ANOMALY ON I.G.F. (milligals)	10 DENSITY VALUES USED IN BOUGUER REDUCTION	11 TERRAIN CORRECTION (milligals)	11 ZONE	12 REMARKS	13 G.S.M. REFERENCE NO. OF STATION
301	54 08 24	4 35 52 W	321.0	20			191.14			37.76	2.75	0.32			
302	54 10 01	4 36 15 W	535.0	"			174.03			31.14	"	0.50			
303	54 09 28	4 35 03 W	502.0	"			180.90			37.05	"	0.71			
304	54 08 56	4 33 37 W	556.0	"			180.01			40.24	"	0.84			
305	54 08 50	4 28 33 W	17.0	"			214.55			42.71	"	0.41			
306	54 10 28	4 30 47 W	203.0	1 & 20			203.12			39.81	"	0.31			
307	54 11 56	4 32 37 W	600.0	"			181.72			40.59	"	1.18			
308	54 12 17	4 32 30 W	500.0	"			188.05			41.03	"	1.65			
309	54 11 33	4 40 50 W	362.7	30			188.33			33.85	"	1.37			
310	54 10 43	4 41 40 W	237.4	"			191.62			32.67	"	3.00			
311	54 10 22	4 41 15 W	381.4	"			180.62			30.61	"	2.94			
312	54 10 04	4 40 38 W	644.2	"			165.68			29.72	"	1.07			
313	54 09 57	4 38 49 W	941.0	"			146.46			29.20	"	2.08			
314	54 10 30	4 37 40 W	563.0	"			170.80			28.83	"	0.47			
315	54 09 30	4 43 39 W	212.4	29 & 30			193.67			33.58	"	1.59			
316	54 09 03	4 43 04 W	785.7	"			156.54			31.33	"	2.02			
317	54 08 40	4 42 53 W	927.2	"			147.86			32.03	"	2.50			
318	54 07 43	4 43 02 W	1000.0	"			139.94			31.22	"	3.97			
319	54 04 54	4 43 33 W	65.0	29			194.63			31.05	"	0.21			
320	54 04 27	4 43 15 W	56.5	"			195.56			32.40	"	0.48			
321	54 04 27	4 45 22 W	348.7	"			176.54			31.00	"	0.87			
322	54 04 13	4 45 53 W	467.4	"			168.78			30.78	"	1.08			
323	54 04 04	4 46 37 W	311.0	"			178.10			30.68	"	0.67			
324	54 03 50	4 47 28 W	70.2	"			191.34			30.04	"	0.65			
325	54 04 37	4 45 56 W	382.0	"			174.53			30.86	"	1.01			
326	54 05 40	4 46 28 W	350.0	29 & 30			177.61			31.35	"	1.82			
327	54 06 15	4 45 06 W	123.3	"			192.42			31.35	"	1.22			
328	54 06 04	4 43 20 W	300.0	"			182.01			31.13	"	0.73			
329	54 01 38	4 40 14 W	960.0	"			145.28			29.24	"	1.75			
330	54 18 38	4 33 44 W	136.3	1 3 31			225.25			47.72	2.00	0.32			

GRAVIMETER SURVEY : *GRAVITY DATA SHEET*

FILE REF. :–

1 OBSERVERS STATION NUMBER	2 LATITUDE N.	3 LONGITUDE (E. or W.)	4 ELEVATION feet (Newlyn O.D.)	5 STATION TO WHICH CONNECTED	6 GRAVITY DIFFERENCE MEAN VALUE (milligals)	6 DEVIATION	7 TOTAL GRAVITY MEAN VALUE	7 DEVIATION	8 FREE AIR ANOMALY (milligals)	9 BOUGUER ANOMALY ON I.G.F. (milligals)	10 DENSITY VALUES USED IN BOUGUER REDUCTION	11 TERRAIN CORRECTION (milligals)	11 ZONE	12 REMARKS	13 G.S.M. REFERENCE NO. OF STATION
331	54 19 27	4 31 54 W	50.0	1 & 31			231.94			47.29	2.00	0.34			
332	54 24 50	4 21 49 W	33.0	"			227.41			33.64	"	0.09			
333	54 24 42	4 22 28 W	33.0	"			228.41			34.79	"	0.04			
334	54 18 16	4 24 59 W	176.0	"			215.22			43.03	2.75	4.16			
335	54 18 34	4 27 13 W	600.0	"			195.29			44.67	"	1.16			
336	54 18 12	4 27 08 W	850.0	"			178.58			43.42	"	1.36			
337	54 17 46	4 31 22 W	504.0	31			199.16			44.55	"	1.69			
338	54 15 24	4 31 53 W	850.0	"			173.59			43.13	"	2.06			
339	54 16 19	4 34 07 W	437.2	"			202.37			45.90	"	1.70			
340	54 20 28	4 31 46 W	37.0	1			234.85			47.67	2.00	0.16			
341	54 16 10	4 22 03 W	327.7	1 & 19			198.97			36.14	2.75	1.59			
342	54 16 02	4 21 02 W	105.3	"			211.58			36.10	"	1.86			
343	54 15 45	4 22 30 W	620.2	"			186.89			36.39	"	1.96			
344	54 14 27	4 22 21 W	503.2	"			189.05			39.62	"	2.18			
345	54 13 41	4 39 00 W	250.0	30 & 31			205.48			40.83	"	0.80			
346	54 13 05	4 40 11 W	120.6	"			209.57			37.92	2.65	0.39			
347	54 12 17	4 40 49 W	78.2	"			209.05			36.16	2.75	0.69			
348	54 12 19	4 36 10 W	500.0	30			184.06			36.88	"	1.56			
349	54 12 46	4 36 01 W	750.0	"			171.26			38.14	"	1.53			
350	54 11 20	4 34 38 W	161.3	"			202.92			37.07	"	1.47			
351	54 10 37	4 35 00 W	500.0	"			180.34			34.67		0.64			
352	54 10 58	4 36 42 W	500.0	"			176.69			30.51	"	0.68			
353	54 10 40	4 37 03 W	600.0	"			168.67			28.70	"	0.52			
354	54 11 01	4 39 53 W	850.0	"			159.87			35.14	"	1.50			
355	54 09 42	4 30 22 W	59.0	1 & 30			212.61			42.21	"	0.61			
356	54 12 02	4 29 17 W	500.0	"			159.02			41.61	"	0.93			
357	54 13 42	4 27 15 W	700.0	"			165.64			40.95	"	2.45			
358	54 09 04	4 38 18 W	723.3	30			161.78			31.74	"	0.90			
359	54 09 21	4 36 24 W	362.0	"			185.65			33.46	"	0.45			
360	54 09 50	4 37 23 W	600.0	"			168.27			30.64	2.62	0.67			

GRAVIMETER SURVEY : *GRAVITY DATA SHEET*

FILE REF. :-

1 OBSERVERS STATION NUMBER	2 LATITUDE N.			3 LONGITUDE (E. or W.)				4 ELEVATION feet (Newlyn O.D.)	5 STATION TO WHICH CONNECTED	6 GRAVITY DIFFERENCE		7 TOTAL GRAVITY		8 FREE AIR ANOMALY (milligals)	9 BOUGUER ANOMALY ON I.G.F. (milligals)	10 DENSITY VALUES USED IN BOUGUER REDUCTION	11 TERRAIN		12 REMARKS	13 G.S.M. REFERENCE NO. OF STATION
										MEAN VALUE (milligals)	DEVIATION	MEAN VALUE	DEVIATION				CORRECTION (milligals)	ZONE		
361	54	08	28	4	41	29	W	1053.0	29 & 30			139.05			30.40	2.75	1.98			
362	54	05	27	4	45	34	W	1250	-			191.16			30.63	"	0.51			
363	54	14	53	4	32	09	W	1169.0	45			154.04			42.68	"	1.60			

GEOL. DEPT. (DURHAM COLLEGES) SURVEY

~~GEOLOGICAL SURVEY AND MUSEUM~~

GRAVITY BASE STATION NO. 1

TOWN: RAMSEY

COUNTY: ISLE OF MAN.

1" MAP: Sheet 87

6" MAP: 5

DESCRIPTION

Bircham Avenue (off Ballaugh road) by entrance to car park. Level with end wall of no.19, 3′ from pavement edge.

GRAVITY 230.03

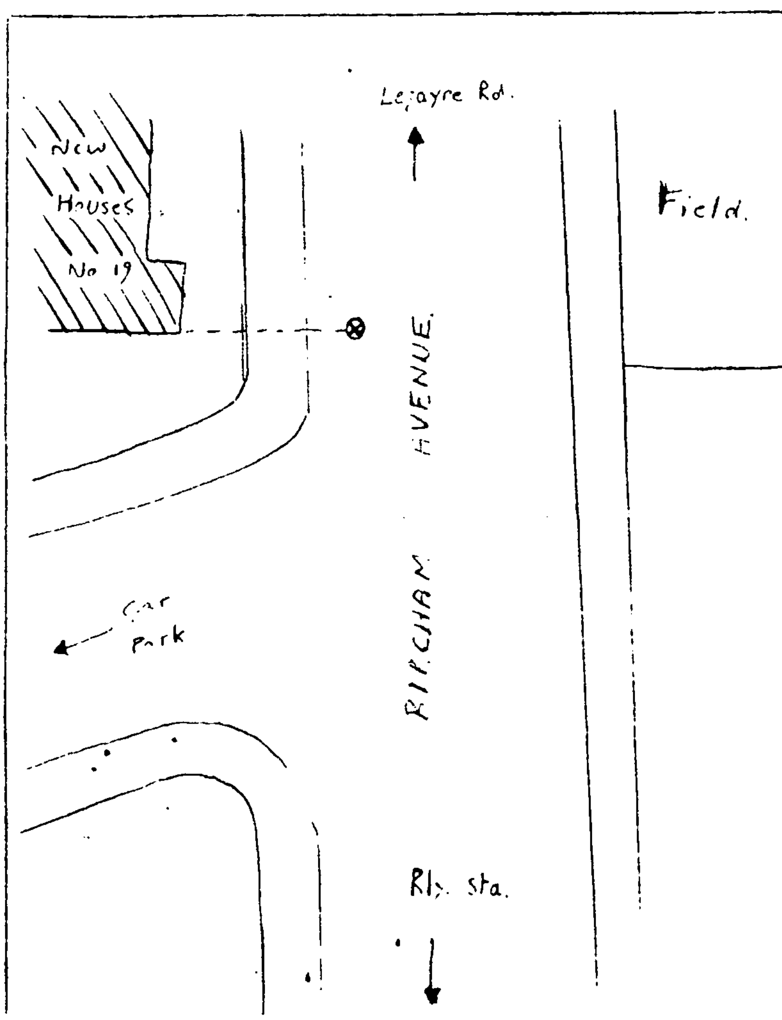
ELEVATION 17.0'

LATITUDE 54° 19' 21" N

LONGITUDE 4° 23' 17" W

DATE 6th September, 1958.

OBSERVER T. Bell & J.D. Cornwell.



GEOL. DEPT.(DURHAM COLLEGES) SURVEY

[redacted]

GRAVITY BASE STATION NO. 19

TOWN: LAXEY **COUNTY:** ISLE OF MAN

1" MAP: 87 **6" MAP:** 11

DESCRIPTION

Meter in line with wall and 4' from corner. Settlement named "Ballamoar" on 6" map. Approximately 200 yards north of milestone (Douglas 9)
This station corresponds with the Geological Survey's Gravity Base Station No. 311.

GRAVITY 196.04

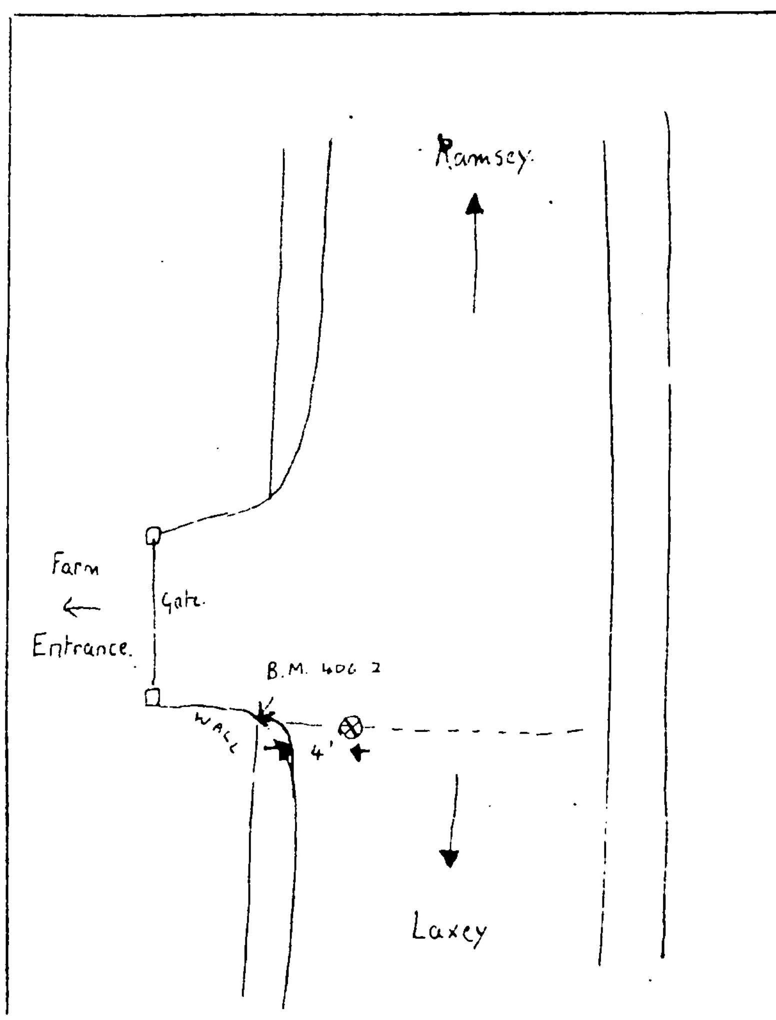
ELEVATION 403.3'

LATITUDE 54° 13' 58" N

LONGITUDE 4° 22' 41" W

DATE 8th September 1953.

OBSERVER T.Bell & J.D.Cornwell.



GEOL. DEPT.(DURHAM COLLEGES) SURVEY
[redacted]

GRAVITY BASE STATION NO. 20.

TOWN: DOUGLAS. **COUNTY:** ISLE OF MAN.

1" MAP: 87 **6" MAP:** 13.

DESCRIPTION

On main road in Douglas between "House of Keys" and "School" on 1" map. Opposite house named "Beverly Mount", level with southern wall on western side of road 3' from pavement.

GRAVITY 206.35

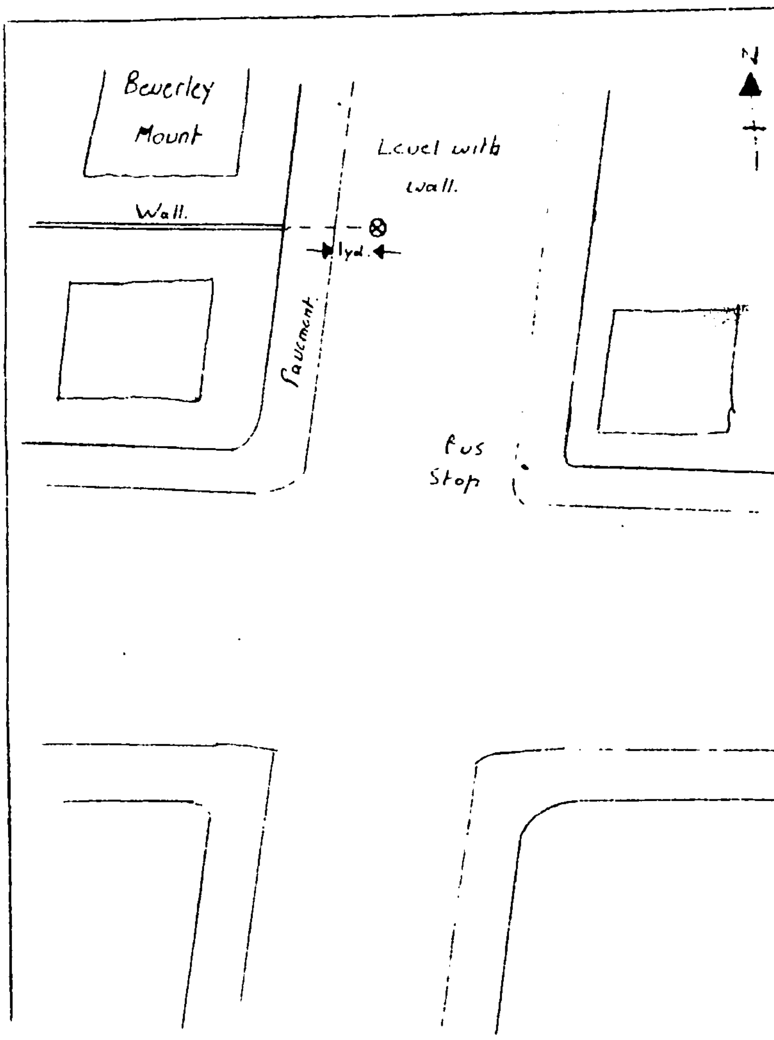
ELEVATION 157.5

LATITUDE 54° 09' 37" N

LONGITUDE 4° 29' 05" W

DATE 8th September 1953.

OBSERVER T.Bell & J.D.Cornwell.



GEOL. DEPT. (DURHAM COLLEGES) SURVEY

~~[illegible]~~

GRAVITY BASE STATION NO. 29

TOWN: Ballasalla. COUNTY: ISLE OF MAN.

1" MAP: 87 6" MAP: 16.

DESCRIPTION

On road to Port Erin, just out of village centre, on south side of road. Level with west wall of white house (opposite church) 3' from pavement.

GRAVITY 202.14.

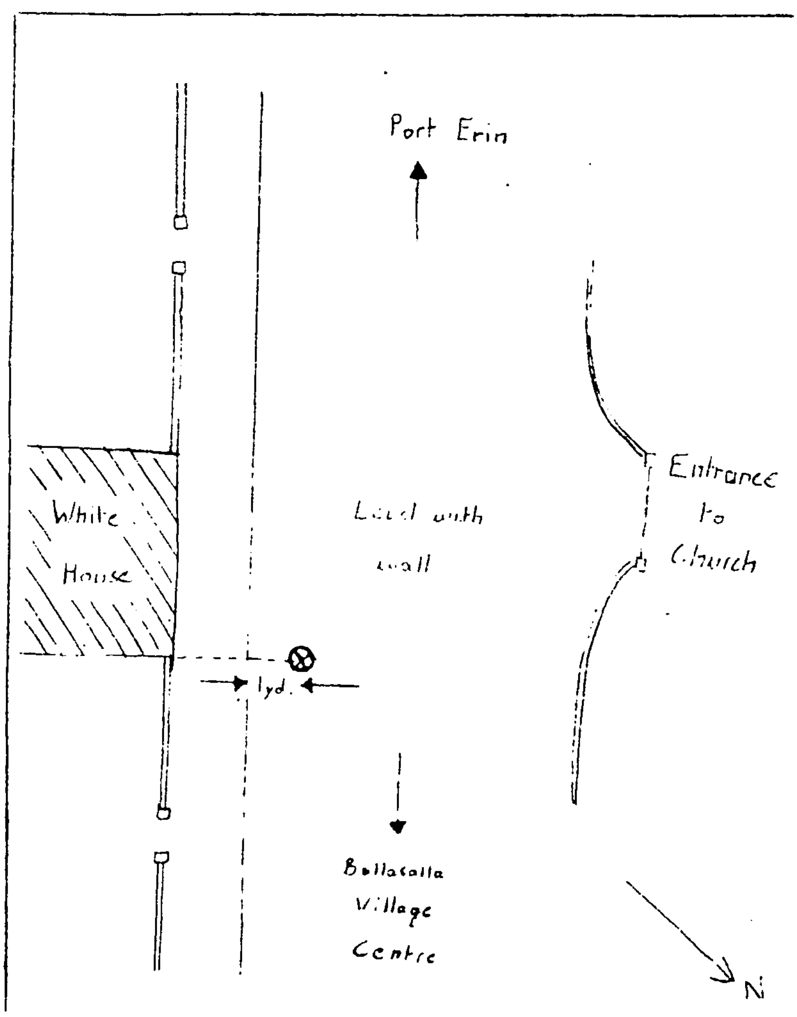
ELEVATION 33.3'

LATITUDE 54° 05' 54" N

LONGITUDE 4° 37' 52" W

DATE 9th September 1958.

OBSERVER T.Bell & J.D.Cornwell.



GEOL. DEPT. (DURHAM COLLEGES) SURVEY

[illegible]

GRAVITY BASE STATION NO. 29

TOWN: Ballasalla. COUNTY: ISLE OF MAN.

1" MAP: 87 6" MAP: 16.

DESCRIPTION

On road to Port Erin, just out of village centre, on south side of road. Level with west wall of white house (opposite church) 3′ from pavement.

GRAVITY 202.14.

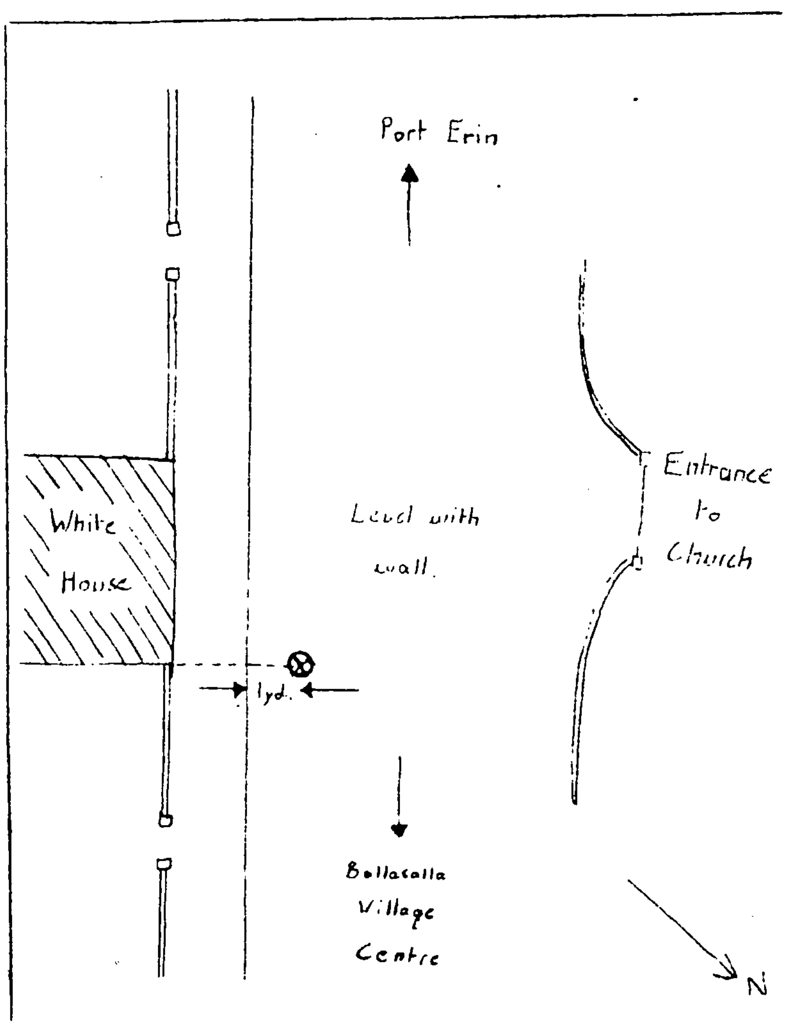
ELEVATION 33.3'

LATITUDE 54° 05' 54" N

LONGITUDE 4° 37' 52" W

DATE 9th September 1953.

OBSERVER T.Bell & J.D.Cornwell.



GEOL. DEPT. (DURHAM COLLEGES) SURVEY

~~GEOLOGICAL SURVEY AND MUSEUM~~

GRAVITY BASE STATION NO. 36

TOWN: St. JOHNS COUNTY: ISLE OF MAN

1" MAP: 87 6" MAP: 9

DESCRIPTION

On west side of Foxdale-St. Johns road south of level crossing. Near cottage on west side of road, level with northerly gatepost. 3 from pavement edge.

GRAVITY 200.13

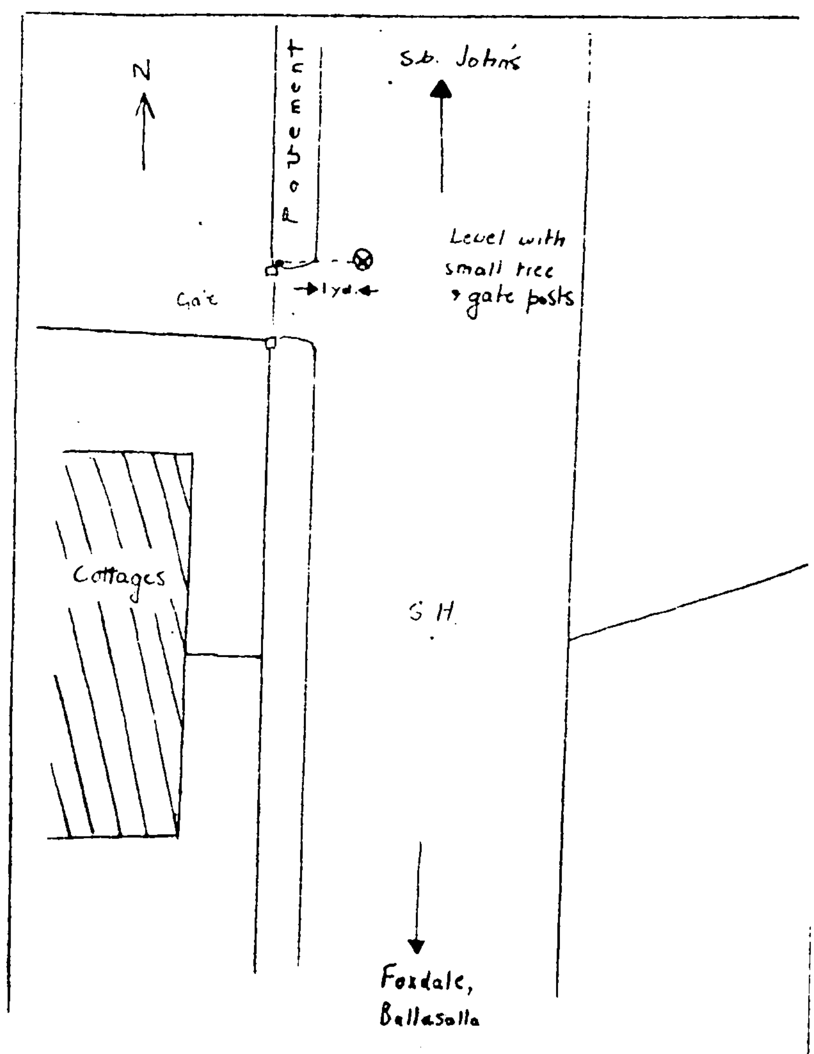
ELEVATION 142.5

LATITUDE 54° 11' 51" N

LONGITUDE 4° 37' 57" W

DATE 9th September 1958.

OBSERVER T. Bell & J. D. Cornwell.



GEOL. DEPT. (DURHAM COLLEGES) SURVEY.

~~GEOLOGICAL SURVEY AND MUSEUM~~

GRAVITY BASE STATION NO. 31.

TOWN: BALLAUGH

COUNTY: ISLE OF MAN

1" MAP: 87

6" MAP: 4

DESCRIPTION

On Peel - Ballaugh road just west of Ballaugh bridge. level with Sycamore tree on south side of road, 3' 7" from hedge, 19' 3" from gatepost.

GRAVITY 226.23

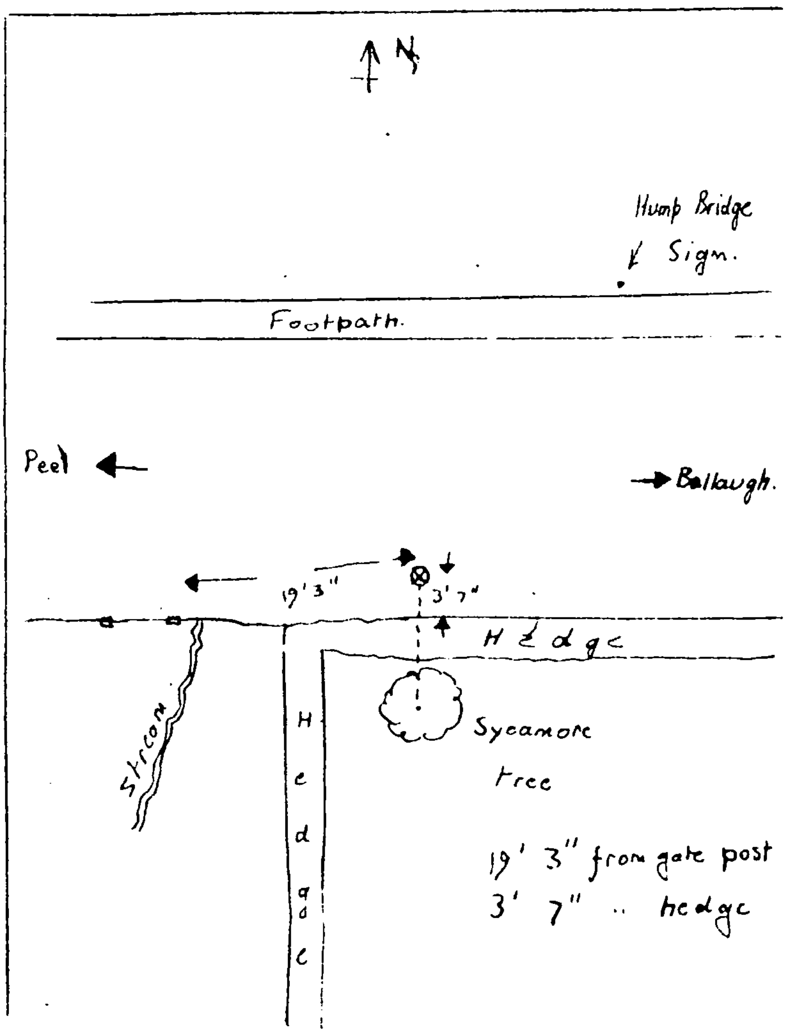
ELEVATION 106.0'

LATITUDE 54° 13' 32" N

LONGITUDE 4° 32' 35" W

DATE 10th September 1958.

OBSERVER T.Bell & J.D.Cornwell.



GEOL. DEPT. (DURHAM COLLEGES) SURVEY.

~~GEOLOGICAL SURVEY AND MUSEUM~~

GRAVITY BASE STATION NO. 45

TOWN: SNAEFELL COUNTY: ISLE OF MAN

1" MAP: 87 6" MAP: 7

DESCRIPTION

On Kirk Micheal road by junction with mountain road between Ramsey and Douglas. On nearside of road going West. Level with fourth concrete post east of gate , four feet from roadside.

GRAVITY 137.97

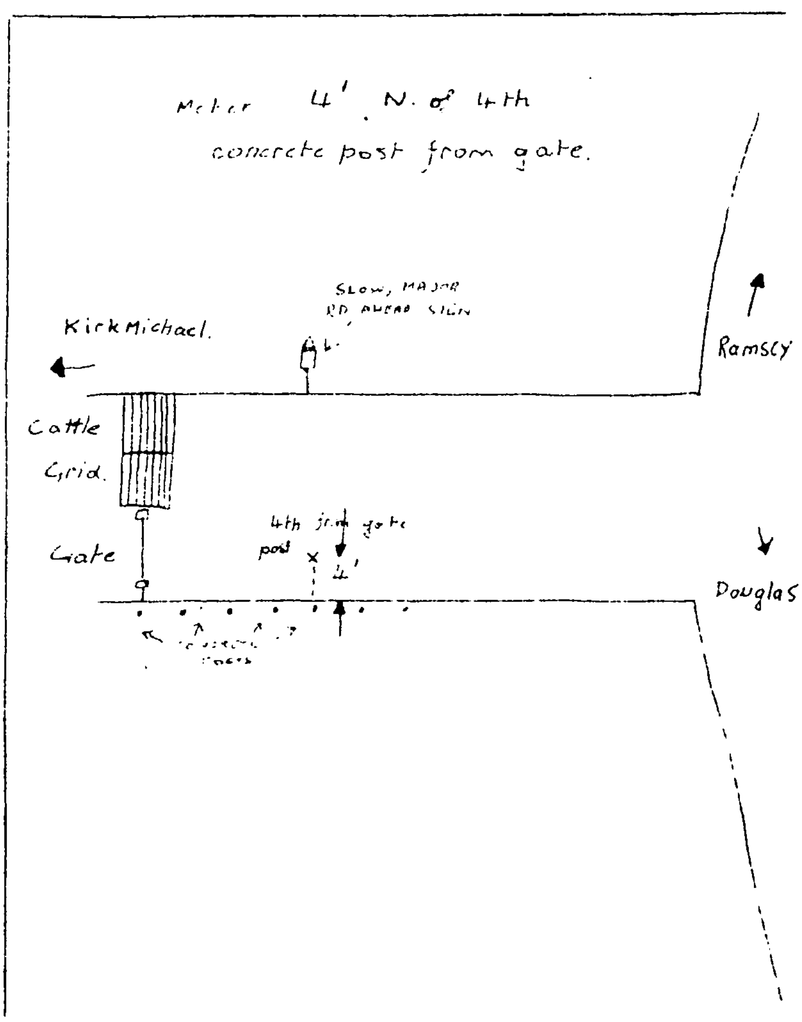
ELEVATION 1388.9'

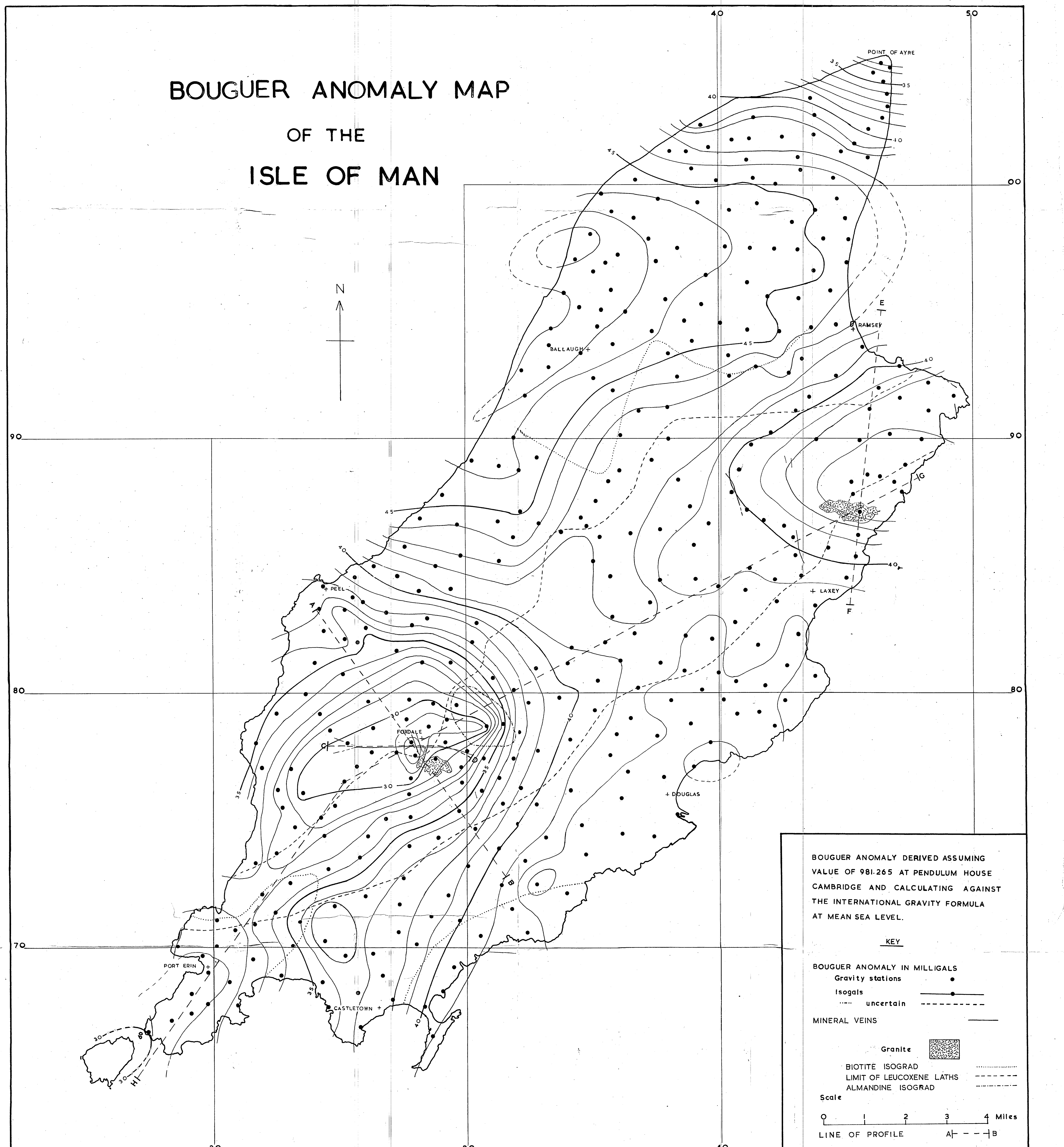
LATITUDE 54° 14' 35" N

LONGITUDE 4° 28' 13" W

DATE 15th September 1958.

OBSERVER T.Bell & J.D.Cornwell .




BOUGUER ANOMALY MAP
OF THE
ISLE OF MAN
N
POINT OF AYRE
RAMSEY
BALLAUGH
PEEL
LAXEY
FOXDALE
DOUGLAS
PORT ERIN
CASTLETOWN
BOUGUER ANOMALY DERIVED ASSUMING VALUE OF 981.265 AT PENDULUM HOUSE CAMBRIDGE AND CALCULATING AGAINST THE INTERNATIONAL GRAVITY FORMULA AT MEAN SEA LEVEL.
KEY
BOUGUER ANOMALY IN MILLIGALS
Gravity stations
Isogals
uncertain
MINERAL VEINS
Granite
BIOTITE ISOGRAD
LIMIT OF LEUCOXENE LATHS
ALMANDINE ISOGRAD
Scale
0 1 2 3 4 Miles
LINE OF PROFILE A—B

MAP 2

BOUGUER ANOMALY MAP OF THE AREA SURROUNDING THE IRISH SEA.