A GRAVITY SURVEY

OF THE

STRANRAER SEDIMENTARY BASIN

by

J. Mansfield, B.Sc.

A thesis presented for the degree of Master of Science

in the University of Durham.

Durham. September, 1962.

CONTENTS

SUMMARY

A detailed gravity survey of the Stranraer district of South West Scotland was made by Mr. P. Kennett and the writer. The survey, the subsequent reduction of data and interpretation of the Bouguer anomalies are described.

It was found that a negative gravity anomaly of about 17 milligals is associated with the Carboniferous and New Red Sandstone sedimentary basin at Stranraer. The anomalies show that the basin has a maximum depth of not less than three thousand feet and is possibly closer to four thousand five hundred feet deep beneath Luce Bay.

The possible nature and density of the concealed sediments filling the basin is discussed and the writer suggests that they are probably mainly composed of New Red Sandstones having a density of about 2.3 gm/cm^3.

It is suggested further that the basin is bounded by a normal fault or step faults along the eastern side and was formed by contemporaneous downwarping and sedimentation.

CHAPTER I. INTRODUCTION, STRATIGRAPHY AND STRUCTURE

1. INTRODUCTION, STRATIGRAPHY AND STRUCTURE

1.1 INTRODUCTION

This thesis gives an account of a gravity survey of the Stranraer region of South West Scotland and its geological interpretation. The work was done from the Department of Geology, the Durham Colleges, during 1959 and 1960 as part of an M.Sc. course in geophysics. The initial field survey was made by Mr. P. Kennett and the writer in Autumn 1959, with a further short period in the field during April, 1960.

Stranraer lies on the flat floor of a valley underlain by sediments of Carboniferous, New Red Sandstone, Pleistocene and Recent ages in contrast to the surrounding more hilly country where Lower Palaeozoic rocks crop out. The purpose of the survey was primarily to investigate the shape and magnitude of this sedimentary basin using the gravity method and to compare it with other British New Red Sandstone basins. It was also hoped that the work would throw some light on New Red Sandstone sedimentation and tectonics.

The region has been surveyed by Bullerwell as part of a regional survey of Scotland, (Private communication). His stations were too widely spaced to give detailed information but were sufficient to indicate a negative gravity anomaly of more than 10 mgal and thus the probable interest of further study.

1.2 GEOLOGY OF THE STRANRAER AREA

The Stranraer valley is a broad "U" shaped feature running approximately north west to south east, (Fig. I, Inset). It cuts transversely across the south western end of the belt of Lower Palaeozoic rocks which strike north eastwards across Southern Scotland. It is the lowest in elevation and most westerly of a series of such transverse valleys which form the main drainage pattern of the Southern Uplands, towards the Solway Firth, (Moore, 1849). The floor of the valley is partly submerged; to the north of Stranraer beneath Loch Ryan, and to the south by Luce Bay, while the isthmus between is generally below 100 feet Ordnance Datum. This flat floor is well covered with roads, making possible a detailed gravity survey with a non-portable gravity meter. The adjacent Lower Palaeozoic hills rise steeply to 850 feet O.D. on the north east side and more gently to 600 feet O.D. to the west of the isthmus.

The oldest rocks exposed in the area are cleaved Ordovician and Silurian greywackes and shales which form the hills on each side of the valley. The floor is underlain by sediments of presumed Millstone Grit, New Red Sandstone, Pleistocene and Recent ages, supposedly resting on the Lower Palaeozoic basement rocks, (Fig. I).

1.2.1 STRATIGRAPHY

a) Ordovician

Rocks of Ordovician age crop out over the major part of the area, (Fig I) forming the high hills to the south west and north east

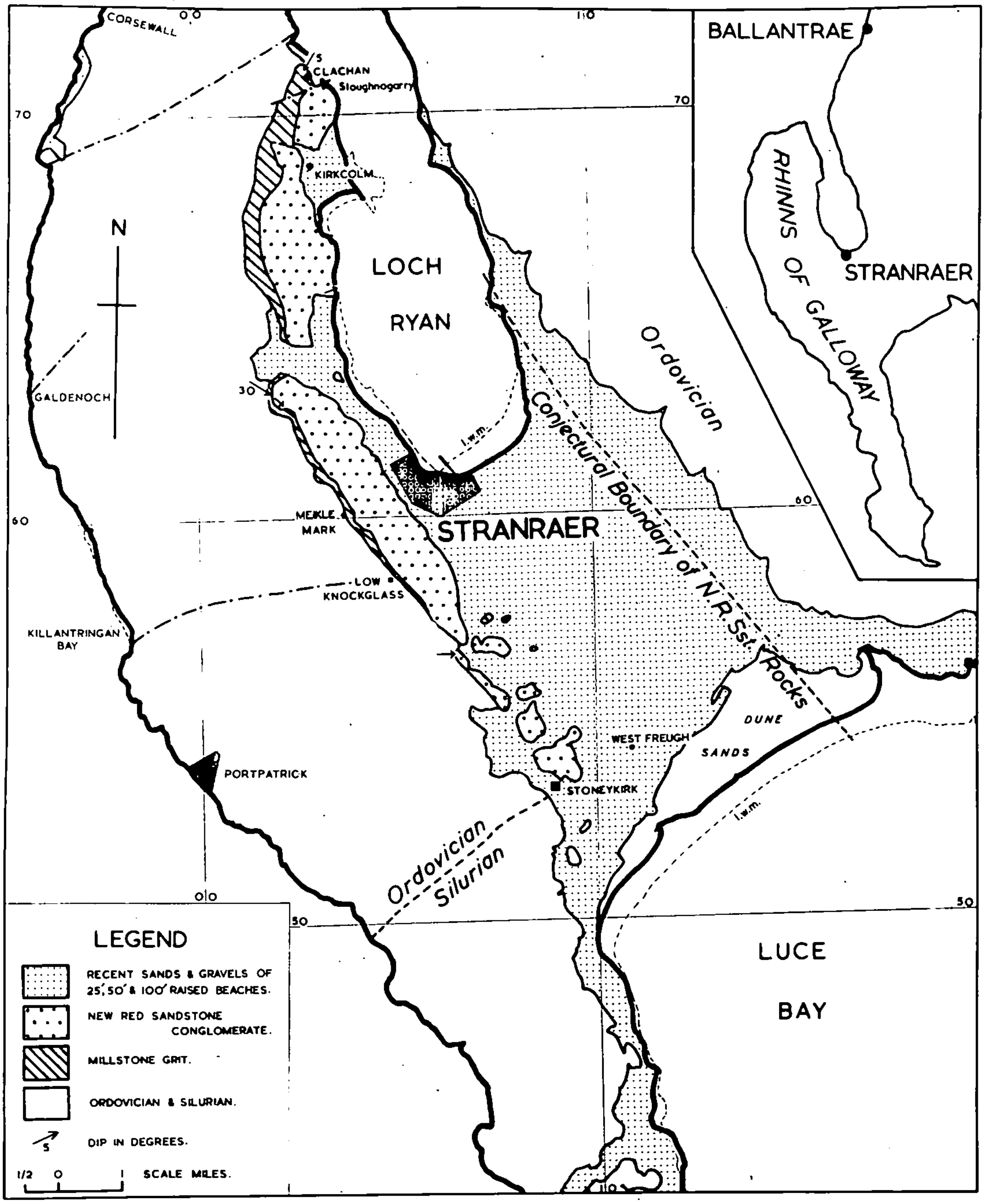


FIGURE 1. GEOLOGICAL SKETCH MAP OF THE STRANRAER DISTRICT

of the valley. They consist mainly of variants of greywacke, flaggy siltstone and mudstones with coarse conglomeratic bands reaching a maximum development at the northern end of the Rhinns of Galloway peninsula, (Fig. I, Inset).

Following the early work of Moore (1840, 1849, 1856), Peach and Horne (1899) concluded that most of the greywackes and shales were Glenkiln-Hartfell in age, with a facies change northwards from black shales to coarse sediments. Kelling (1961) has recently described the Ordovician rocks of the Rhinns of Galloway in some detail and agrees that the vast bulk of them are of Glenkiln-Hartfell age with some possibly being as late as Birkhill times. He has advanced a stratigraphical succession within the greywackes on the basis of palaeontological and lithological evidence, and using "way up" criteria;- load casts, graded bedding, ripple marks etc., (Table I).

Kelling's three main divisions, the Corsewall, Kirkcolm, and Portpatrick Groups of rocks, each 5000 to 6000 feet thick, are found successively from north of the Rhinns peninsula southwards, and are separated by large faults. The Corsewall Group is flaggy in its lower part and coarse and pebbly above, with thick boulder beds. The Kirkcolm and Portpatrick Groups consist of coarse and medium grained greywackes with finer siltstones and dark mudstones increasing in proportion southwards. These variations in lithology are probably so rapid, and the different lithological units so mixed that the overall rock densities are not much affected.

b) Silurian

Rocks of Silurian age are faulted against the Portpatrick

TABLE I

RECENT AND PLEISTOCENE	Freshwater Alluvium, Dune Sands, and Peat. Raised Beaches and Boulder Clay	
NEW RED SANDSTONE	Conglomerate and Red Sandstone	
CARBONIFEROUS	Sandstone, Shale and Fireclay	
SILURIAN	Grits, Greywackes and Shales with Tarranon & Birkhill Fossils	
ORDOVICIAN	Portpatrick Group	Medium grained greywackes with pebbles, thick siltstones & mudstones
	Galdenock Group	Coarse & medium grained greywackes & siltstones
	Kirkcolm Group	Coarse & medium grained greywackes Siltstone & mudstone.
	Corsewall Group	Coarse greywackes, pebble & boulder beds, siltstone & mudstone

Stratigraphical Succession of the Stranraer District

Group (Kelling, 1961) and form the southern part of the peninsula, (NX 0651). They are greywackes, shales and grits containing Tarranon and Birkhill fossils with bands of black Birkhill Shales occurring in the southern part, (Geol. Surv., 1923).

c) Carboniferous

Carboniferous rocks crop out in a thin strip a few hundred yards wide, running parallel with the west side of Loch Ryan between Clachan (NX 030709) and Low Knockglass (NX 048586), (Fig. I). These rest with strong unconformity on the steeply dipping Ordovician strata. Though contacts are mainly obscured by drift, the thickness is probably less than one hundred feet, decreasing towards the south east. They consist of sandstones, siltstones and clays and include a thin basalt lava flow. The lithological sequence is not easily seen but argillaceous rocks dominate the lower part of the succession and arenaceous ones the upper part, (Fuller, 1954). Where exposed the rocks dip at 25° to 35° towards Lock Ryan.

Moore (1840) stated that these rocks had long been known to exist, noting that they contained Stigmaria ficoides and Calamites remains, and correlated them with the Coal Measures of the Ayrshire Coalfield. Geikie and Irvine (1873) confirmed their Carboniferous age from poorly preserved fossil plants including Alethopteris lonchitica, but provisionally referred them to the lower group of the Calciferous Sandstone Series, the base of the Carboniferous System of Scotland. Peach (1897) considered them to be probably Upper Carboniferous. The occurrence of Alethopteris lonchitica would date these rocks as Lower Coal Measures or Millstone Grit and they are shown as the latter on the Geological Survey map, (1923).

d) New Red Sandstone

The Carboniferous beds are overlain by unconformable strata consisting of red sandstones and conglomerates. They crop out in the one hundred and fifty foot cliff on the west shore of Loch Ryan at Sloughnagarry (NX 034706) where they are almost entirely conglomeratic with thin seams of sandstone, from half an inch to two inches thick marking the lines of stratification, (Irvine, 1873). The conglomerate forms a low drift mantled ridge, about one mile wide, running from Sloughnagarry down the side of the valley to Stoneykirk, (NX 090530), (Fig. I).

Moore (1842) referred to these rocks as "a red breccia", noting that they had no organic remains, and ventured no opinion respecting the period of their formation. They were later shown as Trias on the Quarter Inch Map Sheet 16, Scotland (Geol. Surv., 1904), and as ? Permian on the One Inch Map Sheet 3, Scotland (1923). Fuller (1954) covers both possibilities by referring to these rocks as New Red Sandstone.

The beds dip gently to the east or south east and probably everywhere underlie the superficial deposits of the valley floor, being truncated near the east side by a drift masked fault with a downthrow of about three hundred feet to the south west, (Fuller, 1954). Nearer the centre of the valley at West Freugh (NX 109542) a water borehole penetrated nearly five hundred feet of conglomerate and eighty feet of brown sandstone without reaching the base of the formation, (Craig and Lawrie, 1945), (page 8). A notable feature

West Freugh Borehole

Location;- NX 109542

West Freugh Airfield, 1½ miles E.N.E. of Stoneykirk

Collar;- 50 feet O.D.

Drift	Sand	61
	Clay	6
	Sand	8
	Clay, with large stones at base	59
	Sand and Gravel.. ..	6½
New Red Sandstone	Brown Sandstone ..	9
	Conglomerate, upper part brOken	39
	Conglomerate with thin bands of sandstone	7½
	Conglomerate	414½
	Sandstone	79½
		690

Data from D.S.I.R. Wartime Pamphlet No. 29, Craig and Lawrie, 1945.

to emphasise at this stage is that no previous worker has considered the succession to exceed one thousand feet in thickness. Moore (1849) estimated the combined thickness of Carboniferous and New Red Sandstone rocks to be four hundred feet and Fuller (1954) accords the New Red Sandstone Rocks alone a probable thickness of between five hundred and one thousand feet.

e) Pleistocene and Recent

i) Marine Alluvium

The whole of the valley floor from the shores of Loch Ryan to Luce Bay, is mantled by thick marine alluvium consisting of sands and gravels, into which the twenty five, fifty and one hundred foot raised beaches have been cut. The West Freugh Borehole (with its collar at 50 feet O.D.) passed through one hundred and forty feet of gravels, sands and clays overlying the New Red Sandstone rocks, (Craig and Lawrie, 1945). A small part of the gravity anomaly must thus be caused by these unconsolidated deposits.

ii) Other Superficial Deposits

Boulder clay is widely distributed on the hills on each side of the valley, consisting of unstratified sandy clay with angular and sub-angular stones of greywake, grit, shale, metamorphic rocks and intrusives, (Irvine, 1873). A low ridge of wind blown sand lies across the head of Luce Bay. Freshwater alluvium deposits are small in extent being confined to the larger stream courses. The high ground in the east of the area has considerable accumulations of peat almost completely hiding the underlying glacial drift and rock. The western hills also have numerous peat-filled hollows.

1.2.2 REGIONAL STRUCTURE

During the Caledonian orogeny the Ordovician and Silurian rocks were compressed into complex fold patterns whose axes follow north east - south west directions. Kelling (1961) interprets the folds as a series of north facing assymmetrical anticlines puckered on their southern limbs. He considers the Ordovician rocks of the peninsula as four main structural segments, separated by large faults, (Fig. I). The most northerly segment comprises the Corsewall Group rocks, bounded to the south by the Southern Uplands Fault which strikes N 60° E, north of Clachan (NX 030709) and has a downthrow of 3000 to 4000 feet to the south. South of the Southern Uplands Fault are two segments composed of rocks of the Kirkcolm and Galdenoch Groups, separated by the Galdenoch Fault and bounded on the southern side by the Killantringan thrust zone, striking N 80° E. The fourth segment, of Portpatrick Group rocks, lies south of this thrust zone and is truncated by a further thrust striking N 50° E towards Stoneykirk, and bringing in the Silurian rocks to the south. All of these major faults and thrusts downthrow to the south and are of Caledonian age. Since the lower Palaeozoic rocks have a fairly uniform density these Caledonian structures are unlikely to have more than a minor influence on the gravity ahomalies.

1.2.3 New Red Sandstone and Carboniferous Structure

The basin containing the New Red Sandstone and Carboniferous rocks is similar in several respects to others in the Southern Uplands since it cuts across the north easterly strike of the folded and faulted Lower Palaeozoic rocks and the infilling deposits thicken towards the centre, (West Freugh Borehole Data), cf. Dumfries and Lochmaben Basins, (Bott and Masson-Smith, 1960).

Fuller (1954) considers that the New Red Sandstone and Carboniferous rocks lie in a syncline pitching south eastwards along an axial line through Kirkcolm, (NX 029688). Only the western limb and the northern extremity of the syncline are exposed. Tectonic dip is consistently east or south east except near Sloughnagarry where it is horizontal or southwesterly. Fuller, considering the dip and thickness of the Carboniferous and New Red Sandstone strata on the west side of Loch Ryan, states that there is not sufficient space beneath the loch to accommodate the eastern limb of a symmetrical fold. He therefore postulates a hidden fault running parallel with the east shore cliff line and truncating the east limb of the syncline, with a downthrow in the region of 300 feet. It will be seen later that the gravity anomalies give new light on this problem of the existence and extent of an eastern boundary fault.

CHAPTER 2 THE GRAVITY SURVEY

2. THE GRAVITY SURVEY

During four weeks spent in the field 380 new gravity stations were occupied. A Frost North American gravity meter was used for the measurements and transported in a Bedford van.

2.1 THE FROST GRAVITY METER

The Frost gravity meter consists essentially of a horizontal beam pivoted at one end, loaded at the other and suspended by springs. Beam deflection is not used directly to measure gravity changes, but the beam is restored to an arbitrary zero position by an auxiliary spring having a micrometer screw tension adjuster. The auxiliary spring is adjustable over a range of about 120 mgal so that the main spring only required resetting at the beginning of each survey period. The instrument has built in barometric compensation and the temperature is regulated by mercury thermoregulators and relays which control heating coils in the double, insulated casing. A thermometer and levels are fitted in the casing. Power for heating coils and illumination of the levels and scale is provided by an external six volt car battery.

2.2 OPERATION OF THE GRAVITY METER

The meter was carried by van in a doubly sprung container to minimise road shocks. For several days before and continuously during the survey period current was supplied to the instrument to maintain the temperature at operation level of 96° Fahrenheit. Operation procedure is as follows:-

1) Place the tripod on the spot chosen for the gravity station, usually near a convenient bench mark or spot height. Roughly level the tripod head using the bulls-eye level. (On tarmacadam or unmade roads it was necessary to put small pieces of slate under the tripod legs to prevent them sinking.)

2) Place the levelling plate on the tripod head and lift the gravity meter onto it. Check the previous scale reading to ensure that it has been accurately recorded.

3) Adjust the levelling plate thumbscrews until the instrument is accurately level.

4) Gently unclamp the gravity meter beam. Turn the micrometer dial until the cross hair, viewed through the telescope, appears exactly at the null point on the illuminated scale.

5) Check that the meter is still level.

6) Re-clamp the beam and record the reading of the micrometer dial. Replace the gravity meter in its container and the tripod in the van.

7) Plot the station position and number on the Six Inch map.

8) Measure the height of the station from the bench mark or spot height, using an Abney Level and rule for short distances or a telescopic level and staff for longer ones. Record the height of the station and time of reading the gravity meter.

2.3 CALIBRATION OF THE GRAVITY METER

It was not possible to calibrate the instrument before the survey so the previously determined value of some years standing, (0.0837 mgal per dial division) was used in the reduction of data. The gravity meter was recalibrated after the survey by Messrs. Kennett, Scott, Smith and the writer.

2.3.1 METHOD OF CALIBRATION

Gravity meter readings were taken at Geological Survey gravity base stations of known large gravity difference, at Newcastle-upon-Tyne, Durham, Northallerton and York. Their gravity values relative to the value at Pendulum House, Cambridge are as follows;-

Newcastle-upon-Tyne ..	241.51 mgal	(Bullerwell, private communication)
Durham	228.64 "	(")
Northallerton	181.58 "	(")
York	149.86 "	"

The gravity meter was taken by road from base to base recording the scale reading and time at each. The looping procedure was used so that the drift of the instrument could be calculated. Three calibration runs were made in all:- Durham to York via Northallerton, Durham to Newcastle-upon-Tyne and Durham to Northallerton via an intermediate station at Darlington. The calibration factor was derived from the overall differences of dial reading and gravity values between York and Newcastle-upon-Tyne.

$$\text{i.e.}\ \frac{\text{Gravity Value-Newcastle - Gravity Value York}}{\text{Drift Corrected Dial Difference, York - Newcastle}}\ \text{mgal/dial division}$$

The new calibration factor is 0.0832 mgal per dial division

2.4 GRAVITY VALUES

Gravity values were determined with respect to the Geological Survey Gravity Base Station at the gates of Loch Inch Castle on the A.75 road. This station with a gravity value of 981.25571 cm/sec^2 is connected by the Geological Survey gravity network to Pendulum House, Cambridge which has an assumed gravity value of 981.265 cm/sec^2, (Bullard & Jolly, 1936).

2.5 GRAVITY BASE STATIONS

Two further base stations were set up at Portpatrick and Sandhead (Fig. 1). They were connected to the Loch Inch base and to each other giving a triangular loop. The closing error was 0.45 dial divisions (0.038 mgal), giving a standard error of 0.02 mgal for each of the two bases with respect to Loch Inch base. The values were closed by inspection, (Fig. 2).

2.6 INTERMEDIATE GRAVITY STATIONS

Intermediate gravity stations were occupied along pre-planned traverses, keeping them as far as possible perpendicular to the axis of the valley. The average distance between stations on a traverse was less than half a mile. Base readings were normally taken at intervals not exceeding two hours so that the drift of the gravity

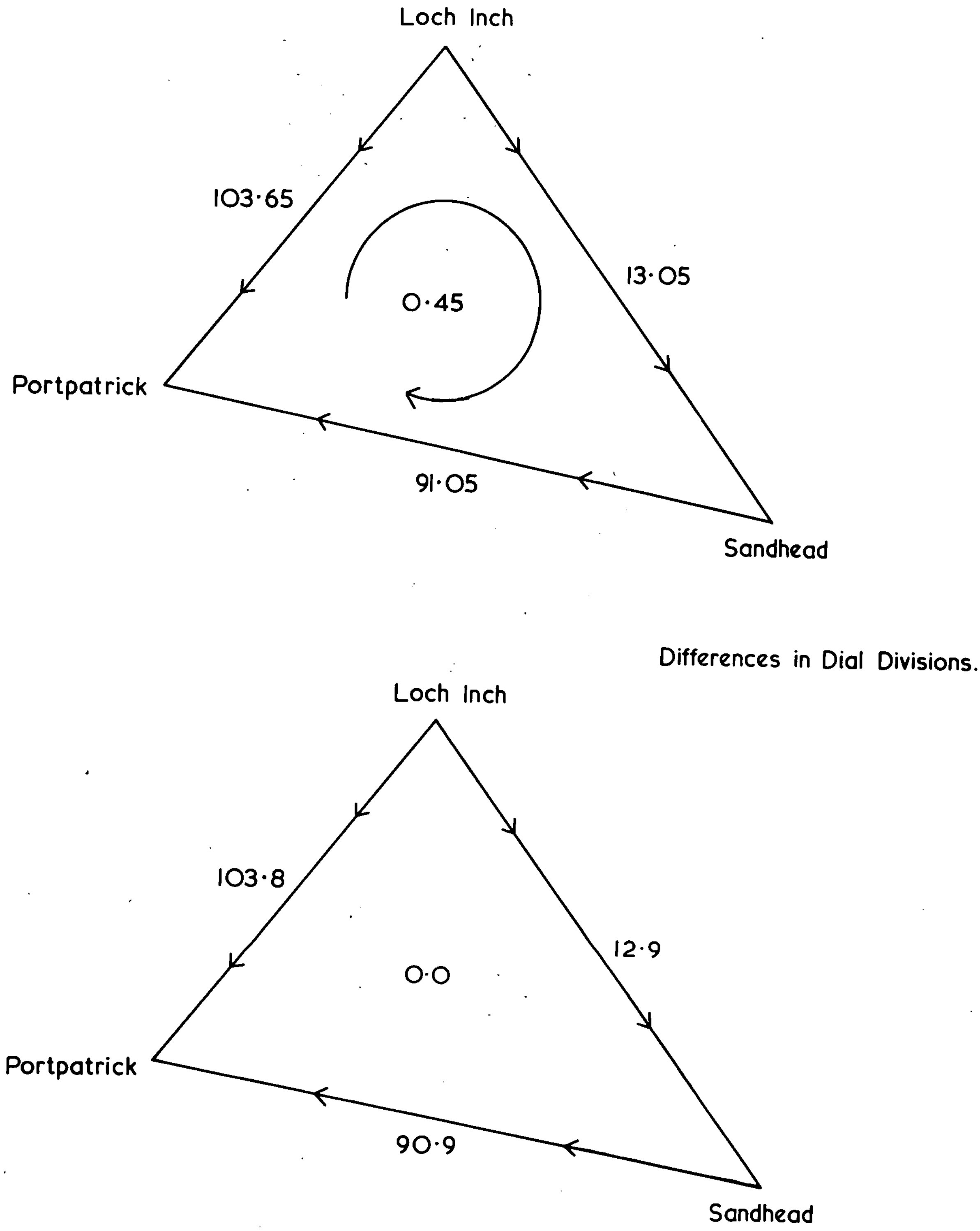


FIGURE 2 UNCLOSED AND CLOSED GRAVITY BASE STATION LOOP.

meter was known. When readings were taken along Luce Sands, four hours elapsed between base readings. Three readings made during 1959 were reread in April, 1960. The values agreed to within 0.1 mgal. Their standard deviation was 0.03 mgal.

2.7 REDUCTION OF DATA

Dial readings must be corrected for instrument drift and multiplied by the calibration factor to give gravity values in milligals. These values then represent gravity at the points at which the readings were taken relative to Pendulum House. They are partly dependant on the latitude, elevation and type of terrain in the vicinity of the station. Correction for each of these factors is necessary before geological interpretation can proceed. The corrected values are termed Bouguer Values and are the basis for subsequent interpretation. The corrections necessary to obtain Bouguer Values are as follows:-

2.7.1 DRIFT CORRECTION

Base station readings were plotted graphically against time. The drift of the gravity meter was assumed to be linear between base readings and corrections for intermediate station readings were read directly from the straight line graphs.

2.7.2 CONVERSION OF DIAL READINGS TO GRAVITY VALUES

The drift corrected scale readings were multiplied by the old calibration factor of the gravity meter (page 14) and related to the gravity value in milligals of the Loch Inch base station and hence to Pendulum House.

2.7.3 ELEVATION CORRECTION

Gravity values vary with elevation and must therefore be corrected to a datum level. In this case the readings were corrected with respect to Ordnance Datum or mean sea level at Newlyn. The elevation correction consists of two parts, the Free-Air Correction, which is very nearly constant, and the Bouguer Correction. The Free-Air Correction is + 0.09406 mgal per foot, and the Bouguer Correction is -0.01276 ρ mgal per foot, where ρ is the density of rocks between the gravity station and the datum level. The two corrections may be combined and added to the observed gravity value.

viz:- Total Elevation Correction = +h (0.09406 - 0.01276ρ) mgal.

where h is the height of the gravity station above the datum.

In this survey the total elevation corrections used were as follows:-

Ordovician & Silurian Rocks	(Density 2.73 gm/cm^3)	- - 0.05922mgal/ft.
New Red Sandstone Rocks	(Density 2.33 gm/cm^3)	- - 0.06433mgal/ft.

Where the rock type was uncertain because hidden by drift the correction was calculated for both types and two Bouguer values were plotted on the gravity map, the less likely value in parentheses.

2.7.4 LATITUDE CORRECTION

The International Gravity Formula (Cassinis, Doré and Vallarin, 1937) gives the normal gravity value for any given latitude, and is based on a spheroid of equatorial and polar radii of 6,378,388 and 6,356,909 metres respectively. The International Gravity Formula is as follows:-

$$G_0\varphi = 978.049 \ (1 + 0.0052884 \sin^2\varphi - 0.0000059 \sin^2 2\varphi)$$

where $G_0\varphi$ is the normal gravity value at latitude φ and 978.049 is the normal gravity value at the equator.

Tables of normal gravity calculated from the International Gravity Formula (Nettleton, 1940) were used to compile a table of normal gravity differences between a datum latitude (Pendulum House), and the latitudes within the survey area. An interpolation formula (Nettleton, 1940) was used to give values to single minutes, and a further table to give values to single seconds of latitude. In this area the latitude correction amounted to - 1.42 mgal per minute or approximately 1.2 mgal per mile.

Most station latitudes were measured to the nearest second using Six Inch maps and a latitude graticule. A few marginal stations were measured on the One Inch map.

2.7.5. TERRAIN CORRECTION

Correction needs also to be made for the uneven topography in the vicinity of a gravity station. Any hump or hill near a station exerts an upward attraction causing a reduction in the observed gravity value. A hollow also causes a low reading since it represents absence of rock which was assumed to be present in making the Bouguer correction. Terrain corrections are therefore positive.

Terrain corrections were calculated using the computer method developed by Bott, (1959). It is unnecessary to describe the method here except to say that the computer programme used makes no correction for terrain very close to a station. Hammer Zone Charts and tables were used to work out the contribution to the terrain corrections of the innermost zones c,d,e,f,g, working on the Two and a Half and Six Inch Scale maps.

2.8 BOUGUER VALUES

A table of Bouguer Values is given in Appendix 2. The Bouguer Values were plotted on a map of Two and a Half Inches to One Mile and isogals drawn at one mgal intervals. Values at Geological Survey stations were plotted as well as values measured at sea in Luce Bay by Bott et al, (Private Communication).

2.9 ERRORS IN THE BOUGUER VALUES

2.9.1 BASE STATION ERRORS

The errors in the values of the Portpatrick and Sandhead base stations was mentioned in 2.5. The Standard Error of each base was 0.02 mgal with respect to the Loch Inch base station.

2.9.2 OBSERVATIONAL ERRORS

Observational errors arise from reading the micrometer dial wrongly and from inaccurate levelling of the gravity meter. Both of these were minimised by double checking. The micrometer was checked before setting up at a subsequent station and the levelling was re-checked before finally recording a reading.

2.9.3 DRIFT ERRORS

Errors are made in assuming that the instrument drift is linear between base readings. The errors are reduced by taking base readings at frequent intervals, normally two hours or less. The maximum rate of drift detectable from base readings was 0.14 mgal per hour. The average drift rate calculated from all the base readings was less than 0.04 mgal per hour. The standard deviation of three readings which were repeated six months after first reading was 0.03 mgal.

2.9.4 ERROR IN CALIBRATION

Calibration of the gravity meter subsequent to the survey showed that the calibration factor used in converting dial readings to gravity values was too large by 0.0005 mgal per dial division. This causes a maximum error of +0.25 mgal between the highest and lowest values of the survey.

2.9.5 LATITUDE CORRECTION ERRORS

The great majority of station latitudes were read to the nearest second from Six Inch Scale maps. An error of one second of latitude causes an error in the gravity value of 0.024 mgal. The latitude of each station was checked by a second observer so accidental errors are unlikely.

2.9.6 ERRORS IN HEIGHT CORRECTION

A discrepancy of one foot leads to an error of 0.094 mgal in the free air correction, and 0.03 mgal in the Bouguer Correction for a rock density of 2.33 gm/cm^3. These corrections are opposite in sign and therefore give a combined error of 0.064 mgal per foot. One Hundred and Twenty of the gravity stations were levelled from bench marks, using bench mark lists issued by the Ordnance Survey. These stations are probably measured accurately to ± 0.2 feet. The remainder of the stations were sited on spot heights recorded on the Six Inch Ordnance Survey maps. These are probably accurate to ± 1 foot. The maximum error in height correction is therefore ± 0.064 mgal.

2.9.7 ERRORS IN ROCK DENSITIES

A density value in error by 0.1 gm/cm^3 causes an error in the Bouguer Correction of 0.0013 mgal per foot. It is unlikely that the densities used in reduction are wrong by more than 0.20 gm/cm^3 so the maximum error is ± 0.0026 mgal/foot.

2.9.8 ERRORS IN TERRAIN CORRECTION

The computor method used for calculating terrain corrections is accurate to within 5% if the zone chart method is assumed to give correct values (Bott, 1959). The maximum terrain correction in this survey was 2.35 mgal so the maximum error is ± 0.12 mgal. The great majority of stations had terrain corrections of less than 0.5 mgal so the normal error must be less than 0.025 mgal.

2.9.9 TOTAL ERROR

The maximum total error in the Bouguer values is possibly as great as 0.5 mgal. Of this error a large part is systematic and known, being the calibration error. As a result the maximum anomaly is in error by + 0.25 mgal. The remaining error is uncertain but is probably ± 0.1 mgal.

CHAPTER 3. DETERMINATION OF ROCK DENSITIES

3. DETERMINATION OF ROCK DENSITIES

Knowledge of the rock densities is required both in the reduction of gravity readings and in the interpretation of the Bouguer anomalies. All but a few of the density values used in this survey were determined by other workers. All of the determinations however were made using the laboratory method described below. No measurements were made on the New Red Sandstone rocks of the Stranraer area, since, in the few places where they are exposed they consist almost entirely of a coarse breccia which is too heterogeneous to be measured by the method described. The density could not be determined by the gravity traverse method because all of the area underlain by New Red Sandstone rocks has anomalous gravity values. For reduction purposes the density of these rocks was assumed to be the same as that of the New Red Sandstone rocks of Dumfries and Lochmaben, (Bott and Masson-Smith 1960).

3.1 METHOD

Sixteen small unweathered specimens of Ordovician shale and greywacke were collected from quarries and road cuttings in the area. They were placed in a tank which was sealed and evacuated. After several hours sufficient water to cover the specimens was introduced while the vacuum was maintained. They were left to soak for twenty-four hours so that the pore spaces filled with water. Each specimen was then weighed twice, first suspended in water, and second, after blotting off surface moisture, in air. The latter was the saturated weight, and the difference of the two weights was the volume of the specimen. The saturated density was obtained as follows:-

$$\text{Saturated Density} = \frac{\text{Saturated Weight in Air (gm.)}}{\text{Sat.Wt.in Air(gm.) - Sat.Wt. in Water (gm.)}} \text{ gm./cm}^3$$

3.2 ROCK DENSITIES

Saturated rock densities of specimens collected from the Stranraer, Dalbeattie and Dumfries areas are given in Table 2. These suggest that the density of Lower Paleozoic rocks is 2.71 ± 0.05 gm/cm^3 and of New Red Sandstone rocks 2.33 ± 0.04 gm/cm^3. The density contrast between these rocks is therefore of the order of 0.4 gm/cm^3.

The density contrast between Lower Paleozoic and Carboniferous rocks is probably 0.15 - 0.2 gm/cm^3 (Bott & Masson-Smith, 1957) while the unconsolidated surface deposits probably have a density of 2.0 - 2.1 gm/cm^3 (Jakosky, 1950, Birch, 1942, Nettleton, 1940) and contrast with the Lower Palaeozoic rocks by 0.7 gm/cm^3.

When the reductions of gravity values were made the rock densities were assumed to be 2.73 and 2.33 gm/cm^3 for Lower Palaeozoic and New Red Sandstone rocks respectively (page 17). The value used for Lower Palaeozoic rocks was therefore in error by 0.02 gm/cm^3, causing an error in the Bouguer correction of 0.13 mgal at the station at the highest elevation of five hundred and eleven feet O.D.

Any estimation of the density of the New Red Sandstone rocks, which are presumed to underlie the major part of the valley floor, must be mainly conjectural at this stage. There are several possibilities.

(a) The rocks could be entirely composed of breccias as where they are exposed along the west side of the valley, (1.2.1. d). Fuller

TABLE 2

Rock Type	Locality	No. of Specimens	Saturated Density gm/cm	Determined by:-
Silurian Shale	5 Localities S. Uplands	27	2.714±0.049	Bott & Masson Smith (1960)
Silurian Greywacke	7 Localities S. Uplands	63	2.706±0.055	
New Red Sandstone	Dumfries Basin Locharbriggs Surface	II	2.25 ± 0.05	
	200ft Depth	22	2.33 ± 0.04	
	Lochmaben Basin	14	2.32 ± 0.04	
Silurian Shale	Haugh of Urr	5	2.71 ± 0.004	Kennett (M.Sc. Thesis unpublished)
Silurian Greywacke	"	9	2.71 ± 0.002	
"	Dundrennan	14	2.72 ± 0.006	
Permian Red Sandstone	Mauchline Ayrshire	17	2.28 ± 0.03	A. C. McLean (1961)
L. Palaeozoic Sediments & Spilites	Ayrshire	68	2.72	"
Ordovician Greywacke & Shale	Stranraer District	16	2.704 ± 0·05	Writer

Saturated Densities of Rocks from S.W. Scotland

(1954) considers at least ninety-nine per cent of the boulders in the breccia to be variants of greywacke and slate which could have been derived from the Local Lower Palaeozoic rocks. The breccia, therefore, probably has a density of 2.5 - 2.6 gm/cm^3. In this case the adoption of a density value of 2.33 gm/cm^3 by analogy with the Dumfries and Lochmaben sandstones would be quite invalid.

(b) The breccia which outcrops could be a large lens occurring in the main formation of sandstone, as lenses of brockram occur in the Penrith Sandstone of north west England. In this case other lenses of breccia might occur in the other parts of the valley. These would possibly be indicated by relatively positive areas in the generally negative gravity field.

(c) The deposit may consist of interbedded breccias and sandstone. (Sandstone does occur beneath the valley as shown by the West Freugh borehole (Fig. 1) where at least eighty feet of sandstone is overlain by nearly five hundred feet of breccia). In this case the density would probably lie between 2.33 and 2.5 gm/cm^3 depending upon the relative proportions of sandstone and breccia.

These uncertainties made it necessary to interpret the gravity anomalies for a range of density contrasts to cover different possibilities (Chap. 5).

CHAPTER 4 METHODS OF INTERPRETATION

to scale and then use a graticule. Recently computer methods have been used for calculating gravity anomalies.

4.3 TWO DIMENSIONAL METHODS

In a case where the body causing a gravity anomaly is linearly elongated, a fair approximation of the cross - sectional shape may be calculated by assuming that the body extends to plus and minus infinity in the direction of its long axis. A small underestimate of the depth of the cross - section is involved in this method due to the end effect. The error increases with the depth of the body.

4.4 COMPUTER METHODS

a) A digital computer method is available (Talwani et al) which makes possible the calculation of the theoretical gravity anomaly across any specified two dimensional model bounded by a polygonal series of straight lines. The method is based on the formula for the gravitational effect of a horizontal, semi-infinite slab bounded by a sloping end surface, (Fig. 4c). The formula given by Heiland (1946) is as follows;-

$$g = 2G\rho\left\{(D\theta_2 - d\theta_1) - (x\sin i + d\cos i)\left[\sin i \log_e \frac{r_2}{r_1} + \cos i(\theta_2 - \theta_1)\right]\right\}$$

where g is the gravitational effect of the semi-infinite slab at point P, G is the gravitational constant, and ρ is the density contrast between the slab and surrounding material. The remaining symbols are shown in Fig. 4c.

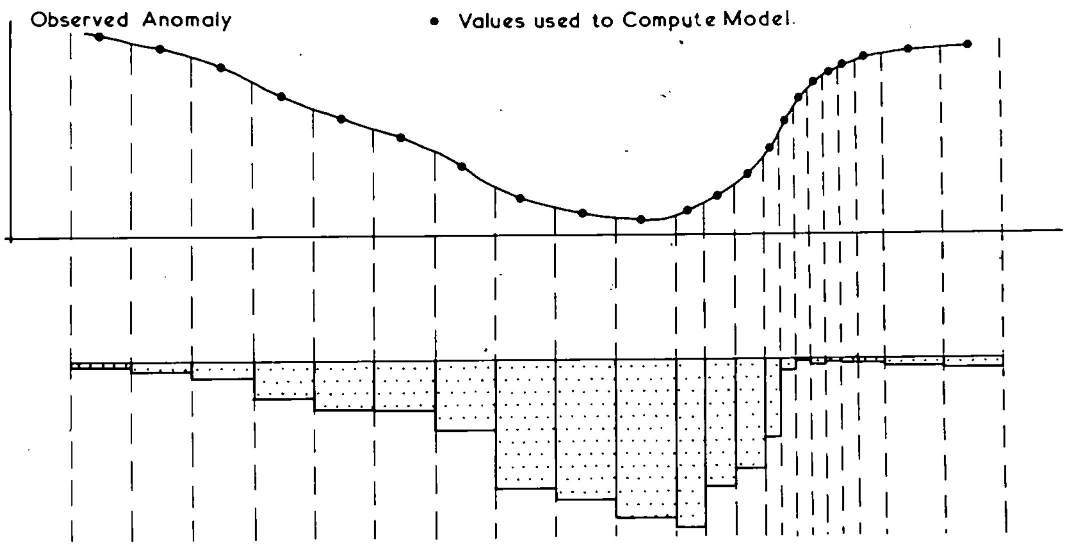


Fig. 4a.

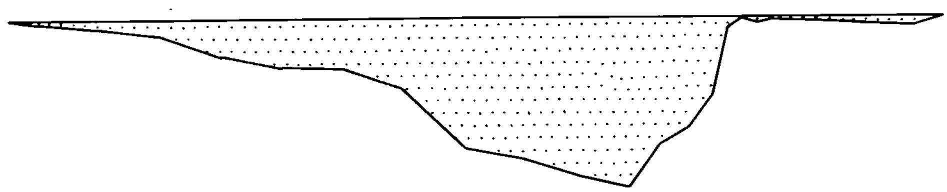


Fig. 4b.

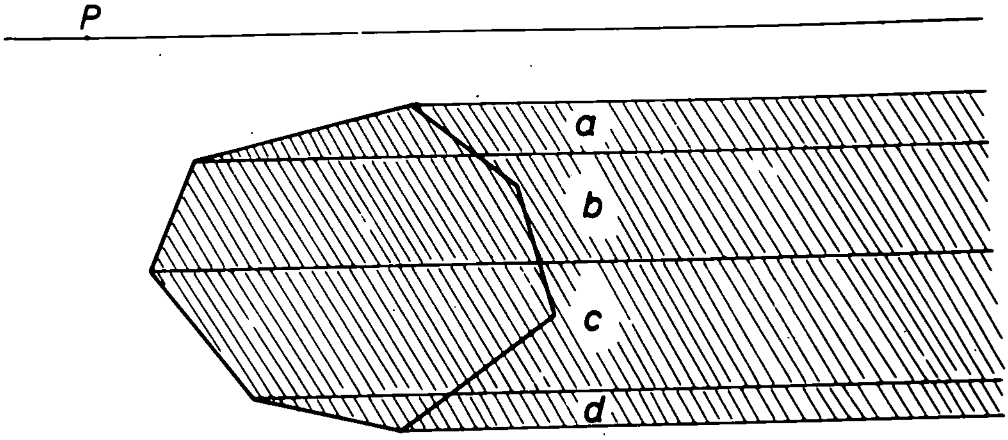


Fig. 4 d(1).

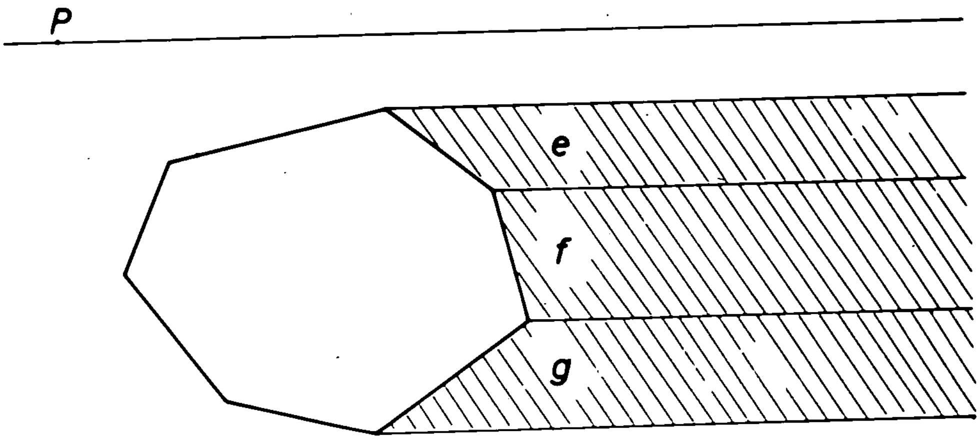


Fig. 4 d(2).

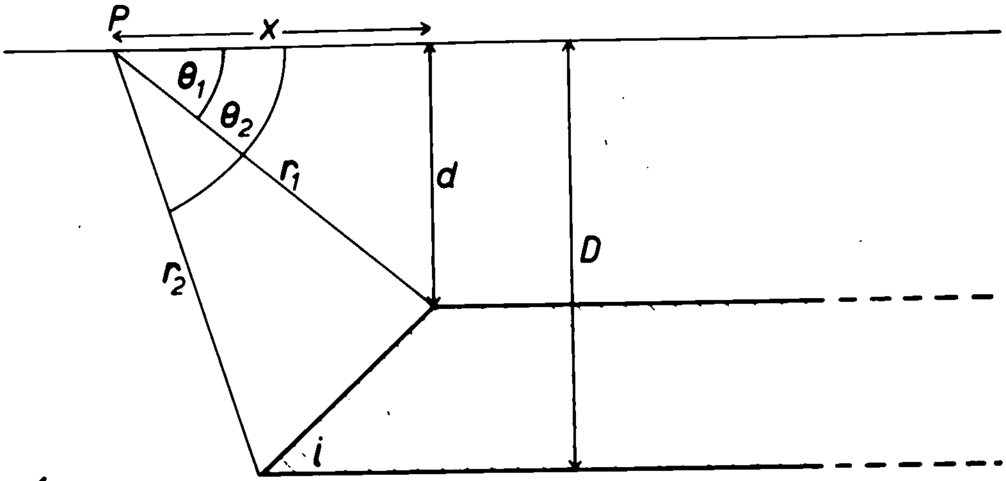

P
x
θ1
θ2
r1
r2
d
D
i

Fig. 4c.

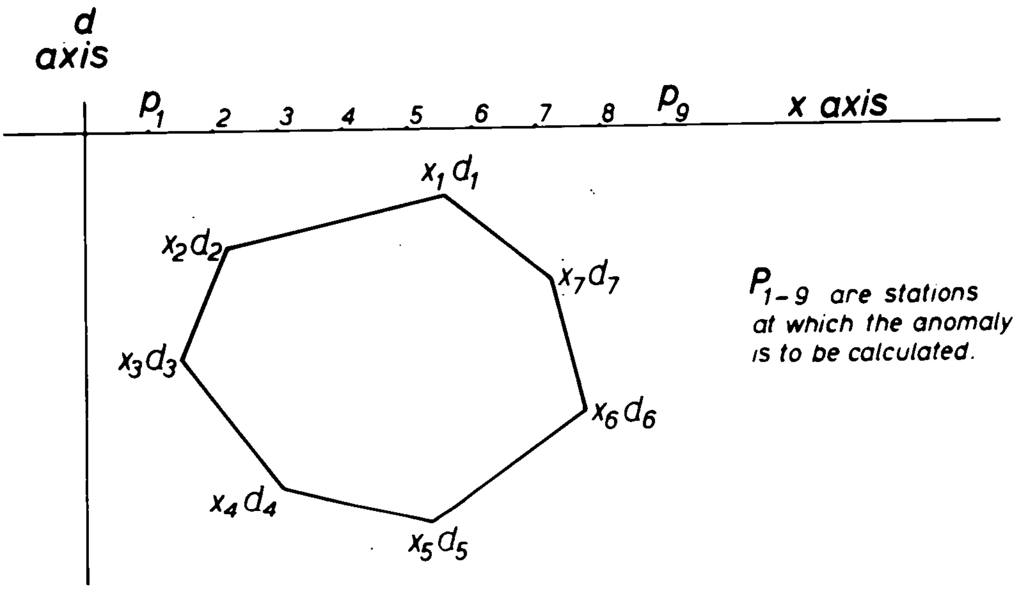

d
axis
P1
2
3
4
5
6
7
8
P9
x axis
x1 d1
x2 d2
x3 d3
x4 d4
x5 d5
x6 d6
x7 d7
P1-9 are stations at which the anomaly is to be calculated.

Fig. 4e.

Any polygon can be represented by a series of sloping ended slabs bounded by horizontal surfaces. Fig. 4d (1) shows a polygonal body divided into horizontal slabs a, b, c, d, whose thicknesses are determined by the sloping surfaces of the left hand side, and extending to infinity on the right. Fig. 4d (2) shows a series of semi-infinite slabs e, f, g, based upon the sloping surfaces of the right hand side of the body. If the gravitational effect at P of slab a is A, and of slab b is B etc., the gravitational effect of the whole body will be A + B + C + D - E - F - G.

The computer method works on the above principle. In practice a station tape is prepared giving the position of each point for which the calculated anomaly is required, (Fig. 4e). A second tape gives the distance (x) and depth (d) co-ordinates of each surface of the polygonal model, and the density contrast. The programme deals with each sloping ended slab in turn, starting from the top of the model and proceeding anti-clockwise, (Fig. 4e). If the second depth co-ordinate of a slab is greater than the first the effect is made positive and vice-versa. The calculated anomalies are plotted alongside the observed gravity values to show the residual anomalies.

b) A second computer method allows the calculation of the shapes of two dimensional sedimentary basins, of known density contrast, from their gravity anomalies, (Bott, 1960). It is a logical development of the method just described having the additional facility of constructing the model, comparing the calculated and observed gravity values, and altering the shape of the model in the direction indicated by the residual anomalies. When a gravity anomaly can be entirely attributed to a continuous sedimentary basin and the density contrast between the sediments and county rocks is known, then the conditions set out earlier (4.1) are fulfilled and the shape of the basin can be determined. The method is as follows;-

First, from the map of Bougøuer values a gravity profile is drawn across the width of the sedimentary basin, which is then divided into a series of vertical, two dimensional columns, (Fig. 4a). The object is to find the thickness of sediment beneath each column, which would cause the observed gravity profile. The computer is supplied with details of the co-ordinates, half width, density contrast and the regionally corrected gravity anomaly at the centre point of each column. The first model is constructed by making the thickness of sediment beneath each column equal to the thickness of a horizontal infinite slab of the given density contrast, required to give the observed anomaly at the centre of the column. The calculated anomaly for this model is obtained by considering the sediments beneath each column to be a two dimensional rectangular block, and by summing the contribution of all the blocks for each position on the profile. The calculated anomalies for the model are subtracted from the observed values to give the residual anomalies. The depth of each block of sediments is then altered in the direction indicated by the residuals, and the anomaly recalculated and compared again with the observed values. This process of progressive approximation is usually repeated ten times or until the residuals are smaller than the observational error. This method is subject to the end effect error mentioned in 4.3, (Two Dimensional Methods).

4.5 APPLICATION

Both computer methods were used in interpreting the Bouguer anomalies. First the shape of the sedimentary basin was calculated in terms of a series of rectangular blocks (4.4b, Fig. 4a). The model was then redrawn making the lower boundary polygonal, (Fig. 4b). The theoretical gravity anomaly for this polygonal model was then calculated using the first computer method (4.4a) and compared with the observed Bouguer anomaly as a check on the accuracy of the calculated shape of the basin. In each case the calculated anomaly correlated well with the observed gravity values.

CHAPTER 5. DESCRIPTION AND INTERPRETATION OF BOUGUER ANOMALY

5. DESCRIPTION AND INTERPRETATION OF BOUGUER ANOMALY

5.1 DESCRIPTION OF BOUGUER ANOMALY

The contour map of Bouguer values (Appendix 1) shows a negative gravity anomaly coinciding with the Stranraer valley. The background values on each side of the valley are of the order of +29.5 to +30.5 mgal falling to +12 to +20 mgal over the valley floor. The anomaly is linear, parallel to the valley and asymmetrical in cross section. From south west to north east the gravity values fall fairly steadily over the west side of the valley and the valley floor and then increase rapidly over the eastern side to background level. This steep gravity gradient is a marked feature running the length of the valley's eastern side. The maximum gradient is of the order of 17 mgal per mile. The lowest gravity value recorded was +11.6 mgal on the northern shore of Luce Bay. The nearest undisturbed area has a value of +28.5 mgal giving a maximum anomaly of 17 mgal. The linear trough shaped anomaly is apparently closed to the north and more recent measurements at sea in Luce Bay by Bott et al (private communication) show that the anomaly also closes to the south.

5.2 PHYSICAL INTERPRETATION

Some facts may be deduced about the cause of the anomaly on purely physical grounds.

a) The negative gravity anomaly must be caused by some body of lower density than the country rocks. A quantitative estimate of the thickness of the body can be made. The minimum possible thickness for a body causing the anomaly is given by the formula for the gravitational effect of a horizontal infinite slab, of maximum density contrast.

$$\text{i.e.} \quad \text{Anomaly} = 2\pi G \rho t$$

where G is the gravitational constant, ρ is the density contrast and t is the thickness of the body. For this anomaly of 17 mgal and for a maximum possible density contrast of 0.5 gm/cm^3 the body must have a thickness greater than 2650 feet.

b) The body must be elongated north west to south east to cause such a linear anomaly.

c) The steepness of the gravity gradient and the rapid changes of gradient suggest that the body causing the anomaly is not far below the ground surface. A limiting depth formula (Smith, 1959, Theorem 3) may be used to find the maximum possible depth to the top of the body.

$$\text{i.e.} \quad \text{Depth} = \frac{2.70 \times G \rho_{max}}{A''_{max}} \quad (\text{c.g.s.u.})$$

where A" is the rate of change of gravity gradient. A"max taken from profile C-C' is ~~1.8~~ 2.4 mgal / thousand feet / thousand feet and gives a maximum depth to the top of the body of ~~5000~~ about 1,200 feet for a density contrast of 0.5g/cm³.

d) The as~~s~~ymmetry of the anomaly shows that the body must also be as~~s~~ymmetrical in cross section.

5.3 GEOLOGICAL ASPECTS OF THE GRAVITY ANOMALY

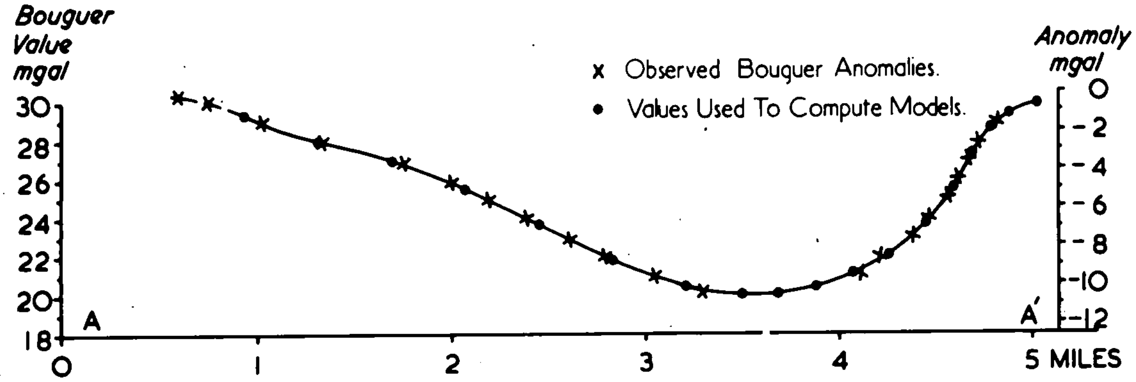
5.3.1 THE CAUSE OF THE ANOMALY

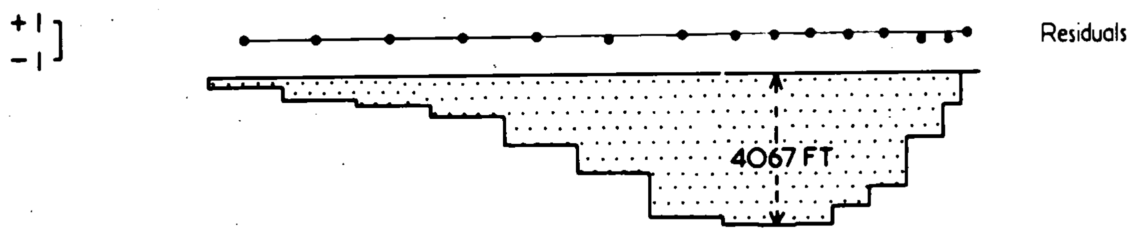
The geographic coincidence of relatively low Bouguer values and the valley sediments is immediately apparent. It is known from the exposed rocks in the north west (Sloughnagarry NX 034706) and the borehole at West Freugh (NX 109542) in the centre of the valley, that New Red Sandstone rocks thicken towards the south east. The negative anomaly also increases in the same direction. It is supposed that the New Red Sandstone rocks are bounded to the east by a hidden fault, (Fuller, 1954). This would correlate with the very steep gravity gradient running approximately parallel to the supposed fault line. The New Red Sandstone rocks are covered only by drift deposits as shown in the borehole and it has already been shown (5.2c) that the cause of the gravity anomaly is not deep-seated. Thus it would seem highly reasonable to assume that the low density sediments within the valley (Carboniferous, New Red Sandstone rocks and drift) are the cause of the gravity anomaly.

5.3.2. THE SHAPE OF THE BASIN

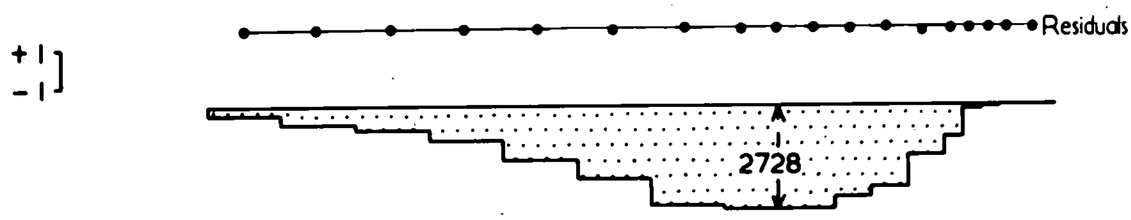
Assuming that the sedimentary trough is the cause of the anomaly, the interpretive procedures set out in Chapter 4 can be used to calculate the two-dimensional profiles of the trough. Bouguer Anomaly profiles are plotted along the section lines A-A′, B-B′, C-C′ and D-D′ (Appendix I) and corrected where necessary for the regional gravity gradient. Depth profiles are computed using density contrasts between the Lower Palaeozoic basement and sediments of 0.3, 0.4 and 0.5 gm/cm^3, for each line of section. The models derived by the computer are shown in figures 5A to 5D The anomalies have been recalculated from similar but polygonal models and found to agree quite closely with the observed values. One example of a polygonal model and its residual anomaly is given in Fig. 5P

All the models derived from the Bouguer Anomaly profiles have a similar basic shape and differ significantly only in depth according to the density contrasts. They show that the sediments thicken steadily from the south west reaching a maximum depth beneath an axial line two thirds to three quarters of the distance across the valley, and then thin very rapidly to the eastern margin. It appears from the models A, B and C that the eastern boundary is steep and thus probably a normal fault as supposed by Fuller (1954), or a series of closely spaced normal step faults. This eastern boundary is shown to be a little more easterly than the conjectural boundary in Fig. 1 which is taken from the Geological Survey One Inch Map, Sheet 3, Scotland, (1923). The models based on the Bouguer Anomaly profile D-D′ do not show such a steep boundary on the eastern side, indicating that step faults possibly occur here.

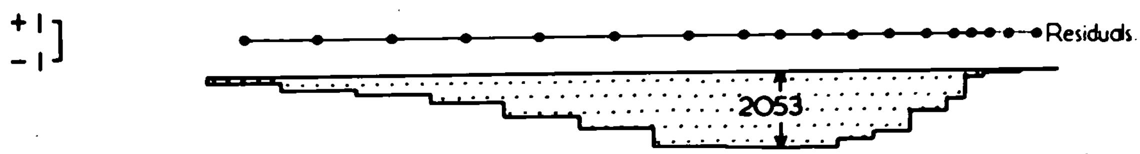




MODEL A.1 Density Contrast 0·3 gm/cm³.



MODEL A.2 Density Contrast 0·4 gm/cm³.



MODEL A.3 Density Contrast 0·5 gm/cm³.

FIGURE 5A

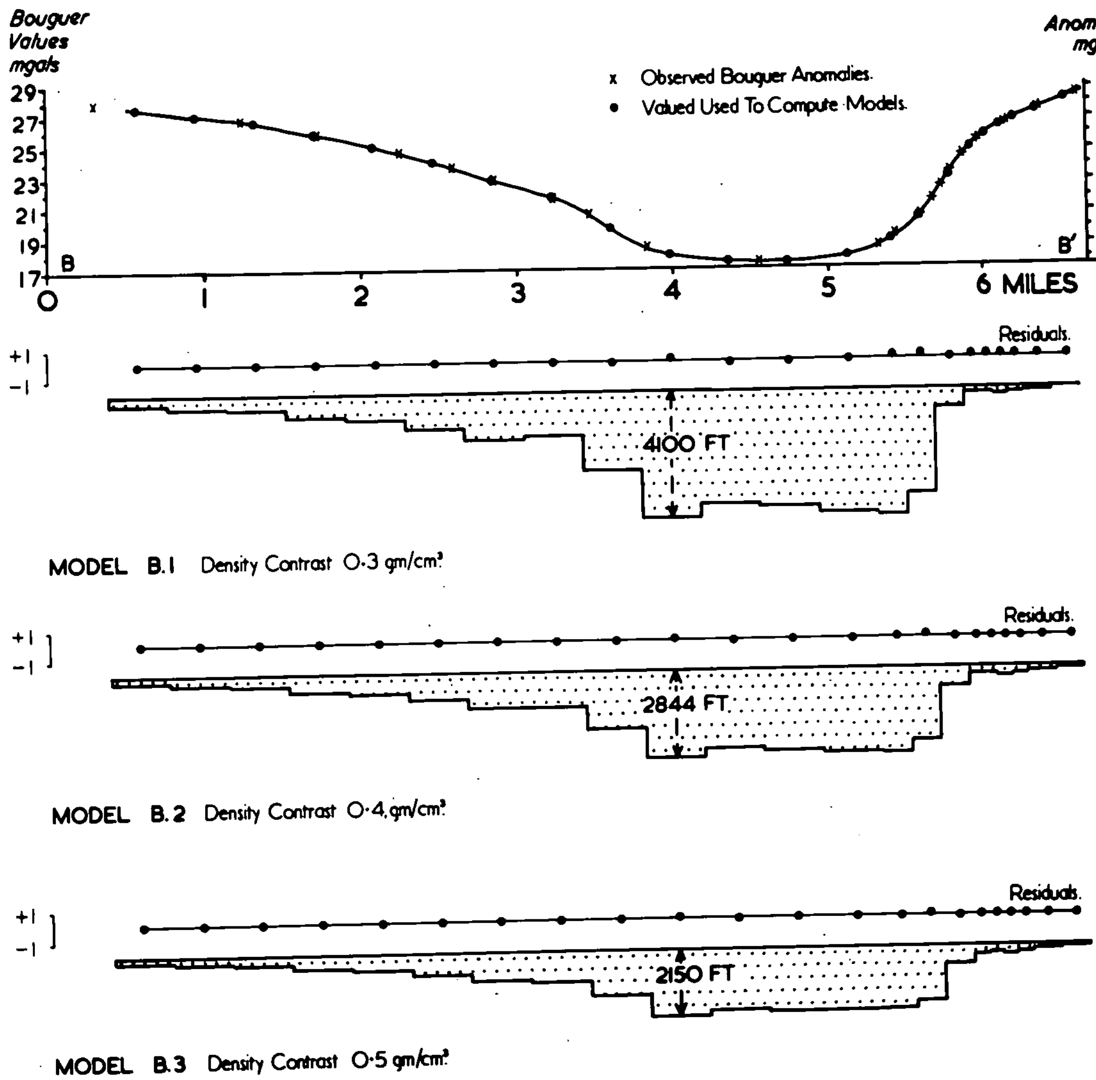
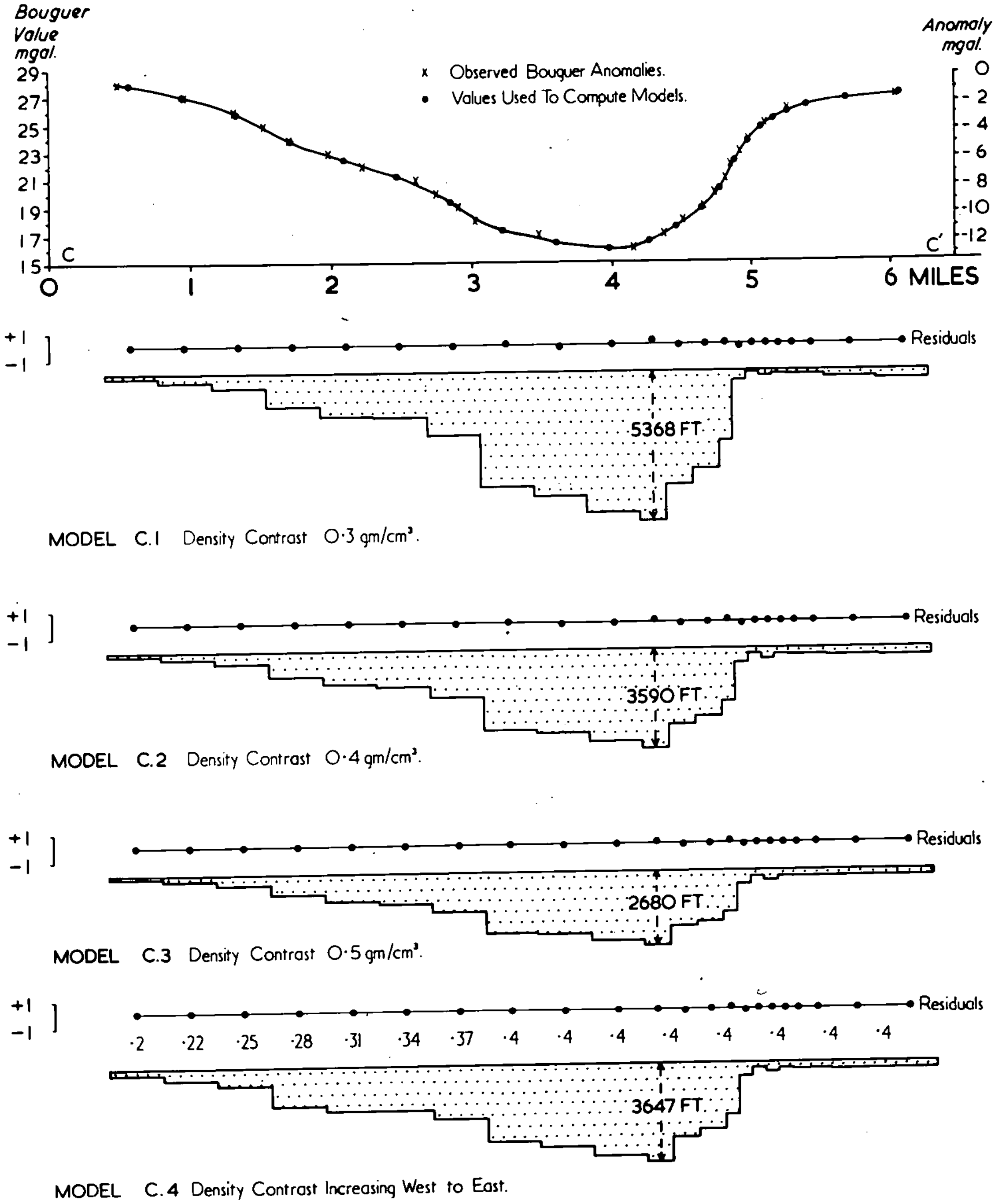

Bouguer Values mgals
Anomaly mgals
x Observed Bouguer Anomalies.
• Valued Used To Compute Models.
29
27
25
23
21
19
17
B
B'
0
-2
-4
-6
-8
-10
O
1
2
3
4
5
6 MILES
Residuals.
+1
-1
4100 FT
MODEL B.1 Density Contrast O·3 gm/cm³
Residuals.
+1
-1
2844 FT
MODEL B.2 Density Contrast O·4 gm/cm³
Residuals.
+1
-1
2150 FT
MODEL B.3 Density Contrast O·5 gm/cm³

FIGURE 5B



Bouguer Value mgal.
Anomaly mgal.
x Observed Bouguer Anomalies.
• Values Used To Compute Models.
29
27
25
23
21
19
17
15
C
C'
0
- 2
- 4
- 6
- 8
-10
-12
0 1 2 3 4 5 6 MILES
+1
-1
Residuals
5368 FT.
MODEL C.1 Density Contrast 0·3 gm/cm³.
3590 FT.
MODEL C.2 Density Contrast 0·4 gm/cm³.
2680 FT.
MODEL C.3 Density Contrast 0·5 gm/cm³.
·2 ·22 ·25 ·28 ·31 ·34 ·37 ·4 ·4 ·4 ·4 ·4 ·4 ·4 ·4
3647 FT.
MODEL C.4 Density Contrast Increasing West to East.

FIGURE 5C

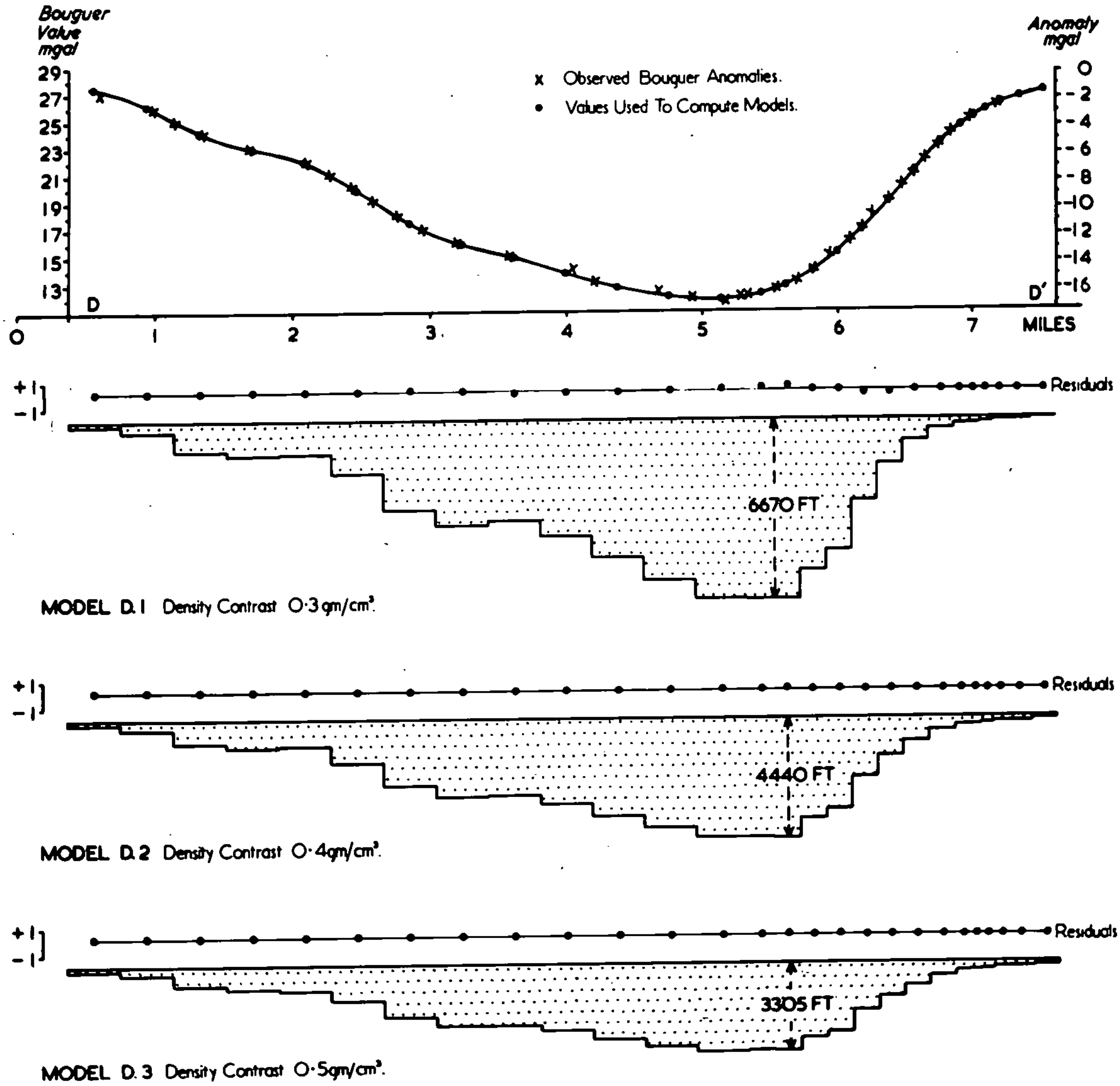

Bouguer Value mgal
Anomaly mgal
x Observed Bouguer Anomalies.
• Values Used To Compute Models.
D
D'
MILES
Residuals
6670 FT
MODEL D.1 Density Contrast 0·3 gm/cm³.
Residuals
4440 FT
MODEL D.2 Density Contrast 0·4gm/cm³.
Residuals
3305 FT
MODEL D.3 Density Contrast 0·5gm/cm³.

FIGURE 5D

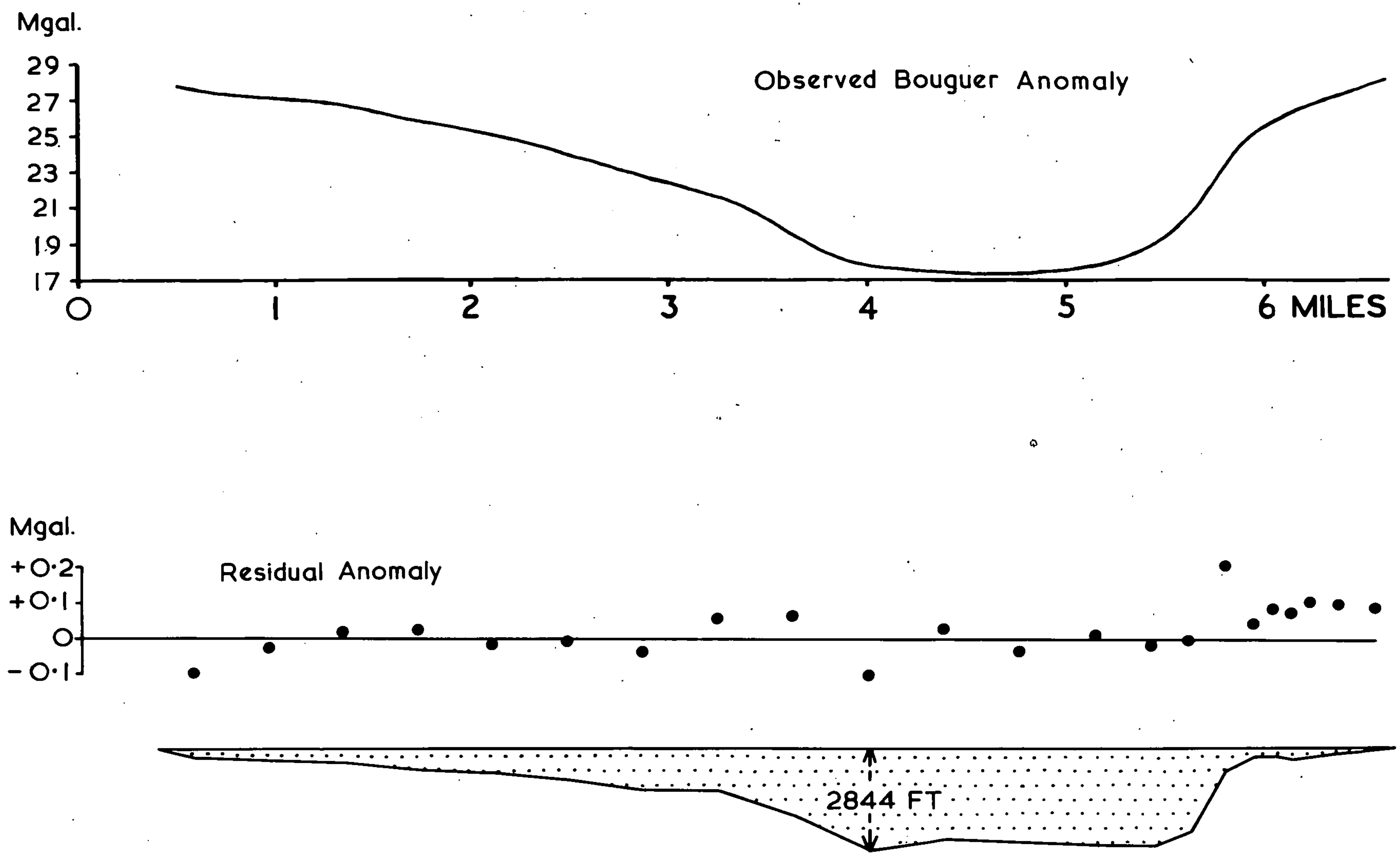


FIGURE 5P POLYGONAL MODEL B.4

The Calculated and Observed Values Coincide to the Extent Shown by the Residual Anomaly.

5.3.3. THE CONTENTS OF THE BASIN

The models in Figs. 5A to 5D are calculated as if the sediments in the basin are entirely composed of New Red Sandstone rocks whose density contrast with the Lower Palaeozoic basement may vary between 0.3 gm/cm^3 and 0.5 gm/cm^3. No account is taken in the models of the Carboniferous beds which are known to underlie the New Red Sandstone rocks in the north west of the area, or of the Pleistocene and Recent sediments which overlie them over most of the valley floor.

i) Pleistocene and Recent Deposits

The extent of Pleistocene and Recent sediments is more thoroughly known than that of the Carboniferous rocks and limits can probably be placed on the thickness of these loosely consolidated deposits. It is likely that their average thickness lies between fifty and two hundred feet (one hundred and forty feet of sands, clays and gravels were found in the West Freugh borehole - page 8). Assuming the density of these deposits to be 2.0 gm/cm^3 they would account for 0.9 mgals of the gravity anomaly per hundred feet. They probably do not account therefore for more than 2 mgal. of the total Bouguer Anomaly.

ii) Carboniferous and ? Old Red Sandstone Rocks

The extent of Carboniferous rocks in the basin is not known. From their outcrop in the north west they appear to thin southwards (page 6) but it is quite possible that they continue right under the basin and may thicken eastwards as do the New Red Sandstone rocks.

It is also possible that Old Red Sandstone rocks occur in the basin, completely hidden by the later formations. The gravity anomalies alone are not sufficient to distinguish between the different possibilities, so "geological probability" must be invoked to find the more likely solutions.

As stated in Chapter 3a (page 24) the density contrast between Carboniferous and Lower Palaeozoic rocks is likely to be 0.15 to 0.2 gm/cm^3. If the anomaly of 15 mgal was caused by these rocks their thickness would have to be at least six thousand feet which is geologically unlikely. It is not possible, however, to exclude the possibility of there being a moderate thickness of Carboniferous, and even Old Red Sandstone rocks in the bottom of the basin.

iii) New Red Sandstone Rocks

The density of the New Red Sandstone rocks is not known with certainty since the proportions of breccia and sandstone are unknown, (page 24). The three possible combinations of the two rock types described in Chapter 3a (page 24) will be discussed in turn.

a) The New Red Sandstone rocks are composed entirely of breccia having a density contrast of 0.15 to 0.2 gm/cm^3.

The validity of this hypothesis is weakened by two factors. (i) Sandstone was proved to reach a thickness of at least seventy eight feet in the West Freugh borehole (ii) At least six thousand feet of breccia would be required to cause the anomaly of fifteen mgal. This thickness is geologically improbable in such a narrow basin. (the same objection would apply to any combination of Carboniferous rocks and New Red Sandstone breccia since they both have a likely density contrast of 0.2 gm/cm^3 or less.)

b) The breccia may occur in large lenses in a main mass of sandstone.

Such lenses would possibly be indicated by relatively positive areas in the negative gravity field, though a similar effect might be caused by a knoll in the Pre-New Red Sandstone or Pre-Carboniferous floor. This possibility cannot be entirely eliminated.

c) The New Red Sandstone rocks may consist of interbedded breccias and sandstone.

By analogy with the New Red Sandstone deposits at Dumfries (Bott and Masson-Smith, 1960) this hypothesis would seem to be geologically the most satisfactory. Breccias may form up to half of the rocks in the deepest parts of the basin. They are unlikely to form a greater proportion because of the excessive depth which would be required to cause the anomaly. This possibility of there being equal proportions of breccia and sandstone has been accounted for in calculating models A1, B1, C1 and D1, for a lower limiting density contrast of 0.3 gm/cm^3. Models A3, B3, C3 and D3 were derived for an upper limiting density contrast of 0.5 gm/cm^3 because of the uncertainty as to the true density of the New Red Sandstone rocks. It is almost certain that the true density contrast lies between these limits and a third set of models (A2, B2, C2 and D2) were derived for a contrast of 0.4 gm/cm^3.

A further possibility arises, that the breccias are dominant on the western margin (as at Dumfries) and become subordinate to sandstones which thicken eastwards. Model C4 (Fig 5c) takes account of this possibility, with the density contrast increasing from 0.2 gm/cm^3 (all breccia) in the west to 0.4 gm/cm^3 (sandstone dominant) in the centre of the basin.

On the basis of the models, approximate depth contours were drawn on outline maps of the basin for density contrasts of 0.3, 0.4, and 0.5 gm/cm^3 (Figs. 6, 7, and 8).

5.4 DISCUSSION

The Lower Paleozoic floor of the Stranraer sedimentary basin is much deeper than was originally supposed (page 9). Even though the density contrast between the sediments and the basement is uncertain it seems likely that the basin has a depth of about four thousand four hundred feet beneath the north shore of Luce Bay (NX 153550), assuming a density contrast of 0.4 gm/cm^3. Even for the maximum possible density contrast of 0.5 gm/cm^3 the deepest part of the basin is not less than three thousand two hundred feet below sea level. If Carboniferous rocks and/or New Red Sandstone breccia form any large proportion of the sediments, the depth must necessarily be much greater. The geological unlikelihood of even greater depths than four thousand feet in such a narrow basin would suggest that most of the basin is filled with sandstones of New Red Sandstone age, having a density contrast of about 0.4 gm/cm^3.

The elongate basin is not symmetrical in cross section. The floor slopes much more rapidly from the eastern side than from the west so that the deepest part of the basin lies not far from the eastern boundary. It is fairly certain that this steep eastern boundary is

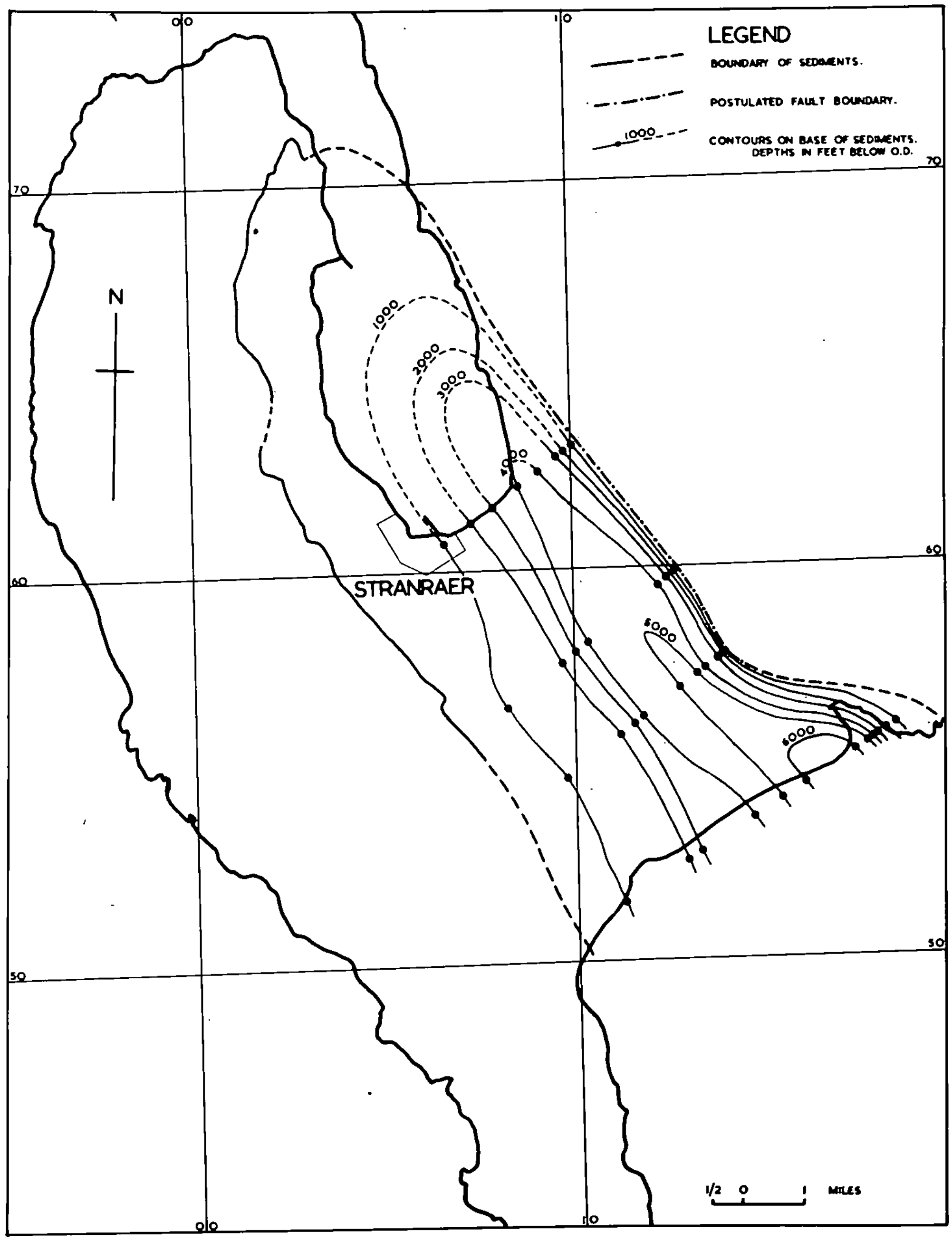


FIGURE 6 APPROXIMATE DEPTH CONTOURS OF STRANRAER SEDIMENTARY BASIN CALCULATED FOR A DENSITY CONTRAST OF 0·3 GM/CM³.

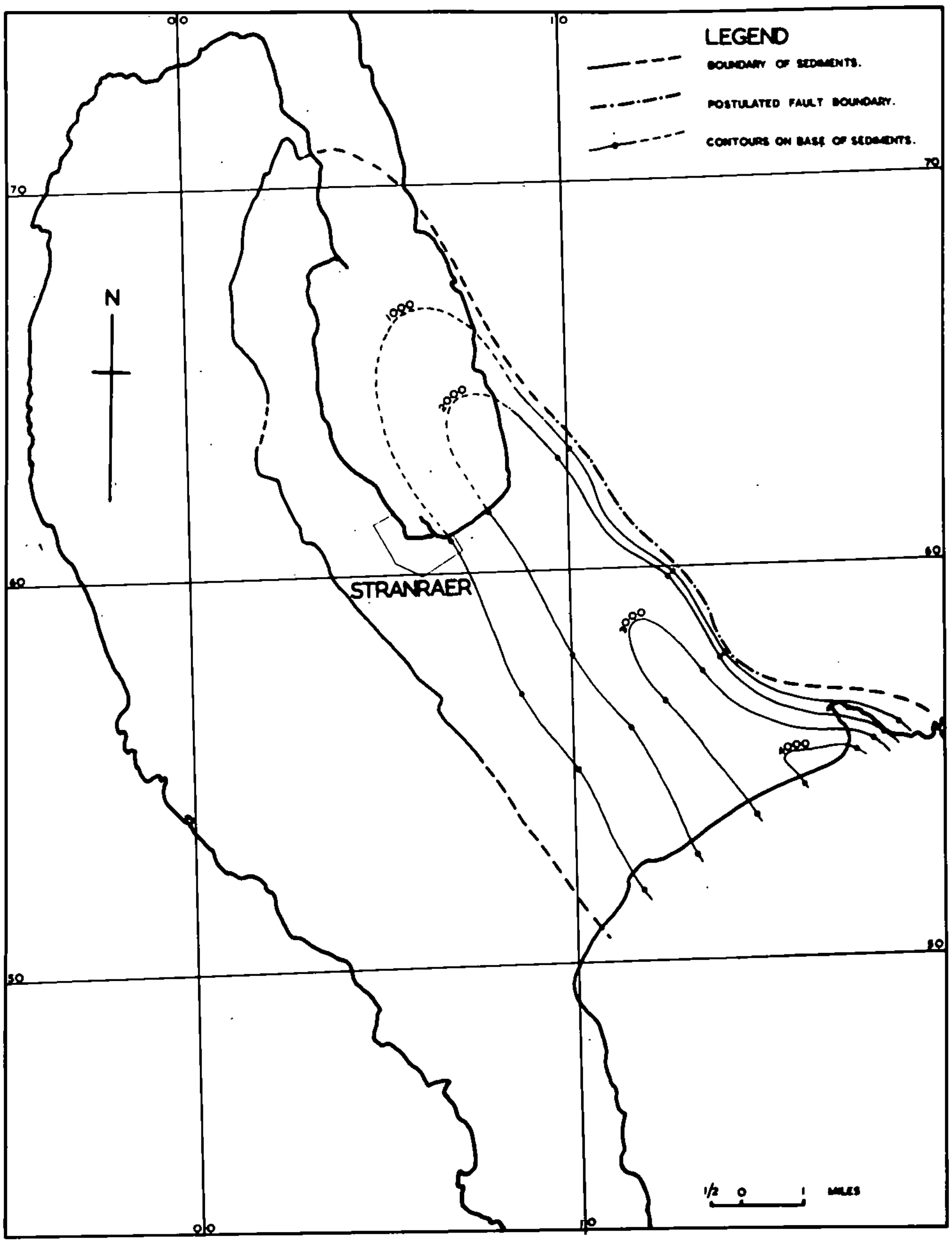


FIGURE 7 APPROXIMATE DEPTH CONTOURS OF STRANRAER SEDIMENTARY BASIN CALCULATED FOR A DENSITY CONTRAST OF $0{\cdot}4\ GM/CM^3$.

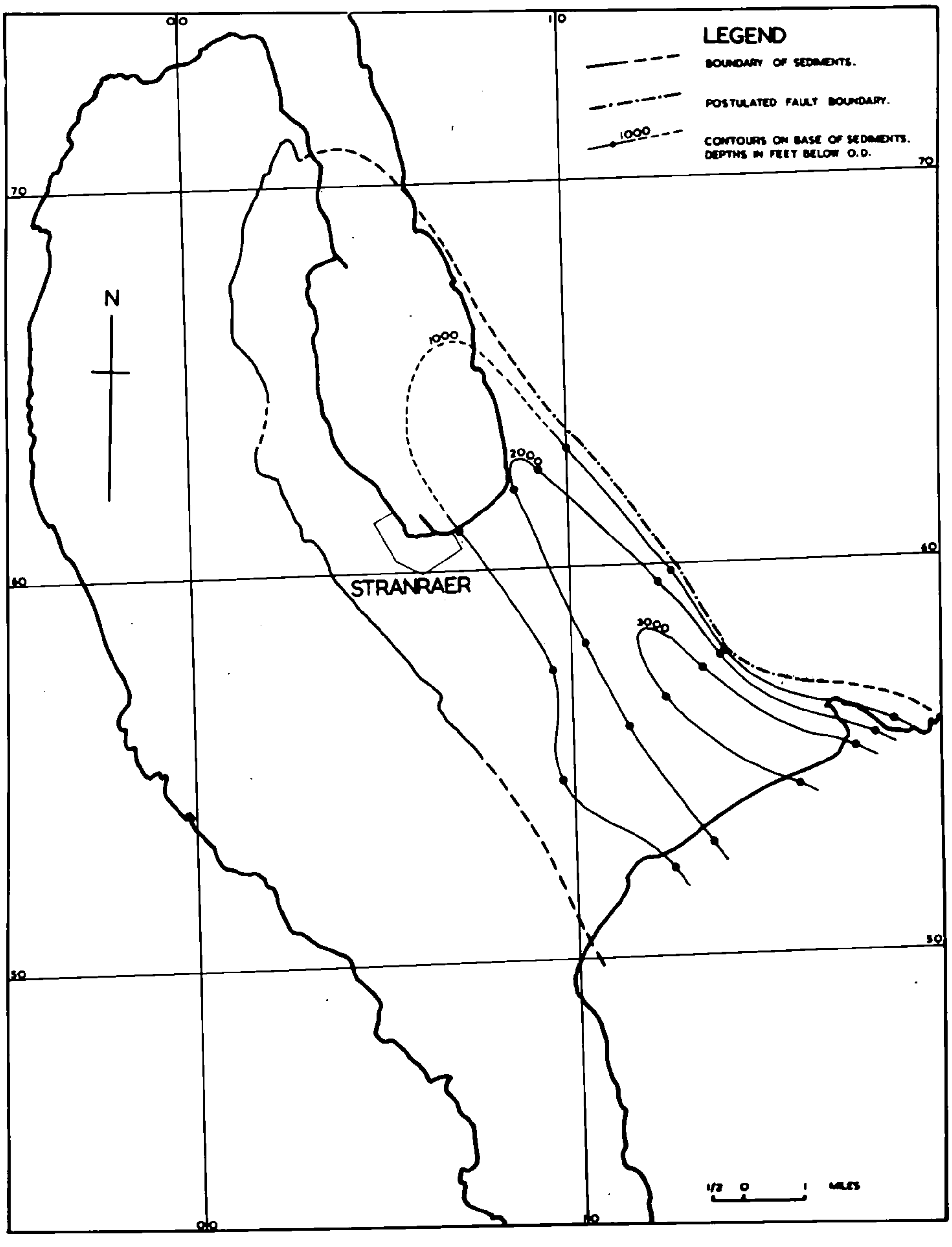


FIGURE 8 APPROXIMATE DEPTH CONTOURS OF STRANRAER SEDIMENTARY BASIN CALCULATED FOR A DENSITY CONTRAST OF 0·5 GM/CM^3.

caused by a large normal fault or series of faults, at least along the northernmost part of the valley.

The basin is closed and shallow at its northern end and from there the sediments thicken southwards, probably reaching their greatest thickness beneath Luce Bay. Later gravity measurements at sea have shown that the basin is also closed at the southern end of the bay and does not extend into the Solway Firth, (Bott et al, Private Communication).

It is unlikely that such a great thickness of sediments can be merely the remnant of a once widespread sheet of New Red Sandstone rocks. The basin, closed at both ends, must have been a separate unit during its formation and not a tributary valley of some larger system. It is most likely that the great thickness of sediments was formed by contemporaneous sinking and infilling of the basin floor. The writer considers that the downward movement of the floor of the basin was accomplished partly by faulting along the eastern margin and partly by downwarping from the western margin which acted as a hinge during sedimentation. It is possible that orientation of the basin perpendicular to the strike of the Lower Palaeozoic belt of rocks was governed by lines of tensional weakness which developed at right angles to the main compressional forces during the Caledonian orogeny.

The Stranraer sedimentary basin fits comfortably into the pattern of other deep New Red Sandstone basins at least some of which appear to have formed by contemporaneous sinking and infilling. (Cheshire and Carlisle basins, White, 1949; Worcester basin, Cooke and Thirlaway, 1956; Dumfries and Lochmaben basins, Bott and Masson-Smith, 1960.)

ACKNOWLEDGEMENTS

I would like to express my sincere thanks to Professor K. C. Dunham for the opportunity to study in the Geology Department of the Durham Colleges. I acknowledge also the unlimited help and guidance of Dr. M. H. P. Bott, who suggested the survey area, and the valuable assistance and companionship of Mr. P. Kennett, M.Sc., during the field work. Thanks are due to the staff of Durham University Computing Laboratory for granting the use of the Pegasus Computer for the reduction and interpretative procedures. I am also indebted to the Department of Scientific and Industrial Research from whom I received a maintenance grant. Finally I must thank the technical staff of the Durham Colleges Geology Department for much hard work in reproducing diagrams.

REFERENCES

Birch, F., 1942. Geol. Soc. Amer., Spec Paper 36.

Bott, M.H.P., 1959. The use of electronic digital computers for the evaluation of gravimetric terrain corrections. Geophysical Prospecting, 7, p. 45 - 54.

Bott, M.H.P., 1960. The use of rapid digital computing methods for direct gravity interpretation of sedimentary basins. Geophys. J. Roy. Astr. Soc. 3, p. 63 - 67.

Bott, M.H.P., & D. Masson-Smith, 1957. The geological interpretation of a gravity survey of the Alston Block and the Durham Coalfield. Quart. J. Geol. Soc. 113, p. 93 - 117

Bott, M.H.P., & D. Masson-Smith, 1960. A gravity survey of the Criffell Granodiorite and the New Red Sandstone deposits near Dumfries. Proc. Yorks. Geol. Soc. 32, p. 317 - 332.

Bullard, E.C., & H.L.P. Jolly, 1936. Gravity measurements in Great Britain. Mon. Not. R. Astr. Soc. Geophys. Suppl. p. 443 - 477.

Cassinis, A., P. Dore, & S. Vallarin, 1937. Fundamental tables for reducing gravity observed values. Royal Italian Geodetic Committee, Milan.

Cooke, A.H., & H.I.S. Thirlaway, 1956. The geological results of measurements of gravity in the Welsh Borders. Quart. J. Geol. Soc. 111, p. 47 - 70.

Craig, R.M., & T.R.M. Lawrie, 1945. Water supply from underground sources of South West Scotland. Wartime Pamphlet No. 29, Geol. Surv. Scotland.

Fuller, G.J.C.M., 1954. Ph.D. Thesis, University of Cambridge.

Geikie, A., & Irvine, 1873. Explanation of One Inch Map, Sheet 3, Scotland. Mem. Geol. Surv. U.K.

Geol. Surv., 1923. One Inch Map, Sheet 3, Scotland, 2nd Edition.

Geol. Surv., 1904. Quarter Inch Map, Sheet 16, Scotland.

Heiland, C.A., 1946. Geophysical Exploration. Prentice-Hall, New York, p. 153.

Jakosky, J.J., 1950. Exploration Geophysics. p. 266.

Kelling, G., 1961. The stratigraphy and structure of the Ordovician rocks of the Rhinns of Galloway. Quart. J. Geol. Soc. 117, p. 37 - 75.

McLean, A.C., 1961. Density measurements of rocks in South West Scotland. Proc. Roy. Soc. Edinb. 68, p. 103 - 111.

Moore, J.C, 1840. On the rocks which form the west shore of the bay of Loch Ryan. Proc. Geol. Soc. Lond. 3, p. 277 - 278.

Moore, J.C., 1849. On some fossiliferous beds in the Silurian rocks of Wigtownshire and Ayrshire. Quart. J. Geol. Soc. 5, p. 7 - 12.

Moore, J.C, 1856. On the Silurian rocks of Wigtownshire. Quart. J. Geol. Soc. 12, p. 359 - 366.

Nettleton, L.L., 1940. Geophysical Prospecting for Oil. McGraw-Hill.

Peach, B.N., 1897. Ann. Rep. Geol. Surv. (for 1896).

Peach, B.N., & J. Horne, 1899. The Silurian rocks of Britain, 1, Scotland. Mem. Geol. Surv. U.K.

Smith, R.A., 1959. Some depth formulae for local magnetic and gravity anomalies. Geophysical Prospecting, 7, p.55 - 63.

Smith, R.A., 1961. A uniqueness theorem concerning gravity fields. Proc. Camb. Phil. Soc. 57, p. 865 - 870.

Talwani, M., J.L. Worzel, & M. Landisman, 1959. Rapid gravity computations for two dimensional bodies with application to the Mendocino submarine fracture zone. Journ. Geophys. Res. 64, p. 49 - 59.

White, P.H.N., 1949. Gravity data obtained in Great Britain by the Anglo-American Oil Company Limited. Quart. J. Geol. Soc. 104, p. 339 - 364.

APPENDIX I

GRAVITY BASE STATION:- LOCH INCH

TOWN:- 2m E of Stranraer. COUNTY:- Wigtownshire.

1" MAP:- Sheet 79 6" MAP:- NX 16 SW

DESCRIPTION:-

On north side of A 75 at entrance to Loch Inch Castle. Meter in line with western edge of most easterly post and 12 feet from the post, as shown.

GRAVITY:- 255.71 mgal
Rel. to Pend. House

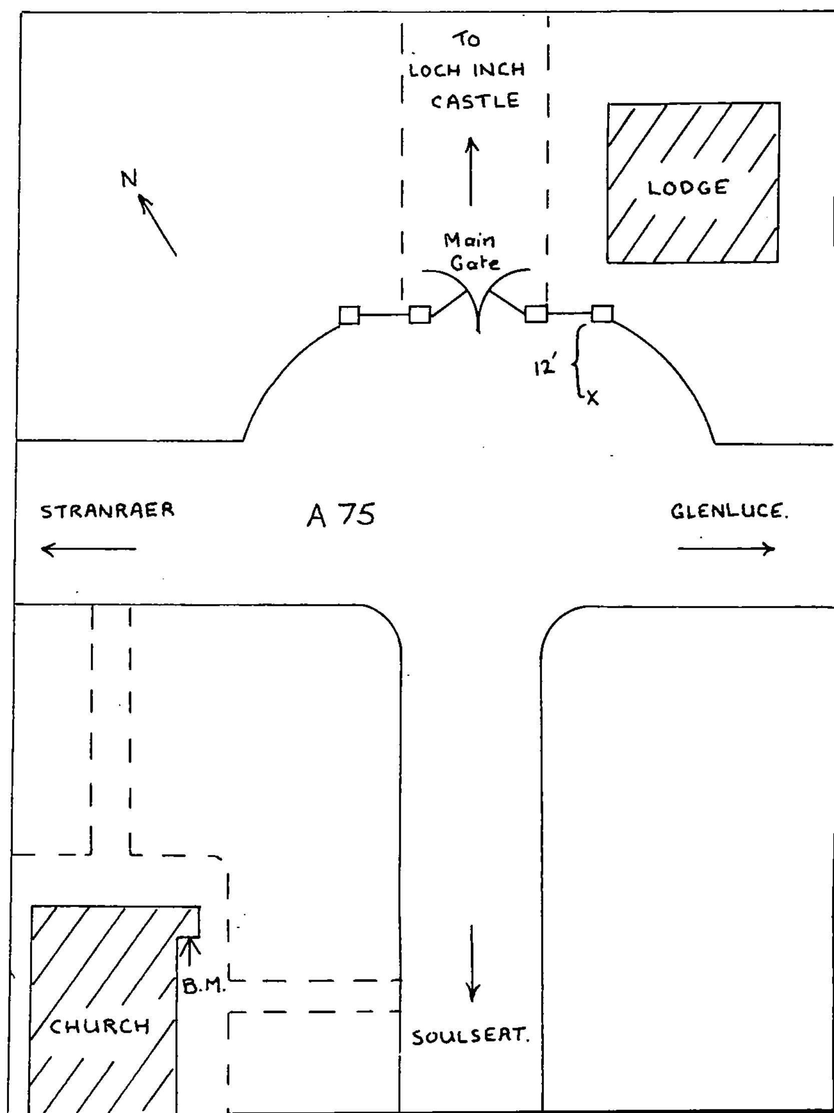
LATITUDE:- 54° 54' 05"

LONGITUDE:- 4° 57' 43"W

ELEVATION:- 85 Ft. O.D.

DATE:- August, 1956

OBSERVER:- W. Bullerwell



GRAVITY BASE STATION:- PORTPATRICK

TOWN:- Portpatrick COUNTY:- Wigtownshire

1" MAP:- Sheet 79 6" MAP:- NX 05 SW

DESCRIPTION:-

On north side of A 77 at junction with North Crescent. Meter in line with west wall of hotel and 4 feet out from railings as shown.

GRAVITY:- 264.37 mgal
Rel. to Pend. House.

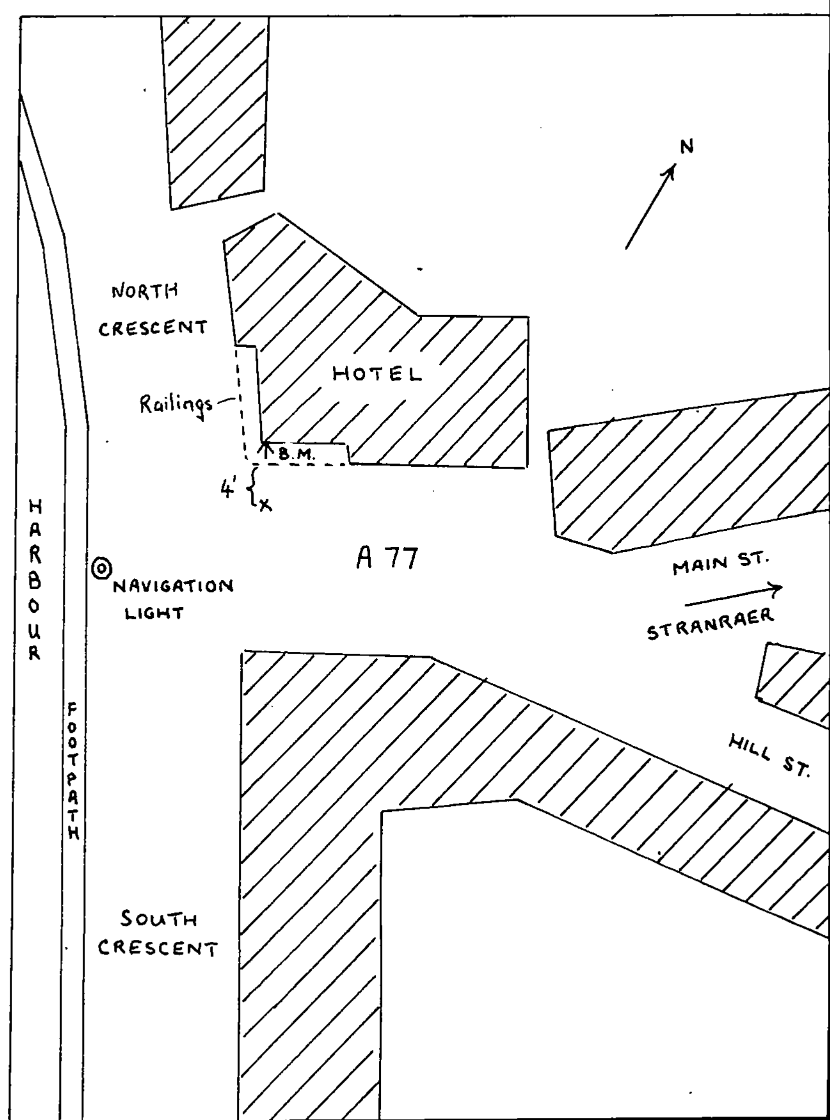
LATITUDE:- 54° 50' 31"

LONGITUDE:- 5° 06' 56" W

ELEVATION:- 20 Ft. O.D.
Approx.

DATE:- October, 1959.

OBSERVER:- J. Mansfield



GRAVITY BASE STATION:- SANDHEAD

TOWN:- Sandhead

COUNTY:- Wigtownshire

1" MAP:- Sheet 79

6" MAP:- NX 04 NE

DESCRIPTION:-

On sharp corner of A 716 half mile south of Sandhead. Meter in line with and 4 feet away from an 11" drainage pipe projecting through garden wall of cottage.

GRAVITY:- 256.79 mgal
Rel. to Pend. House

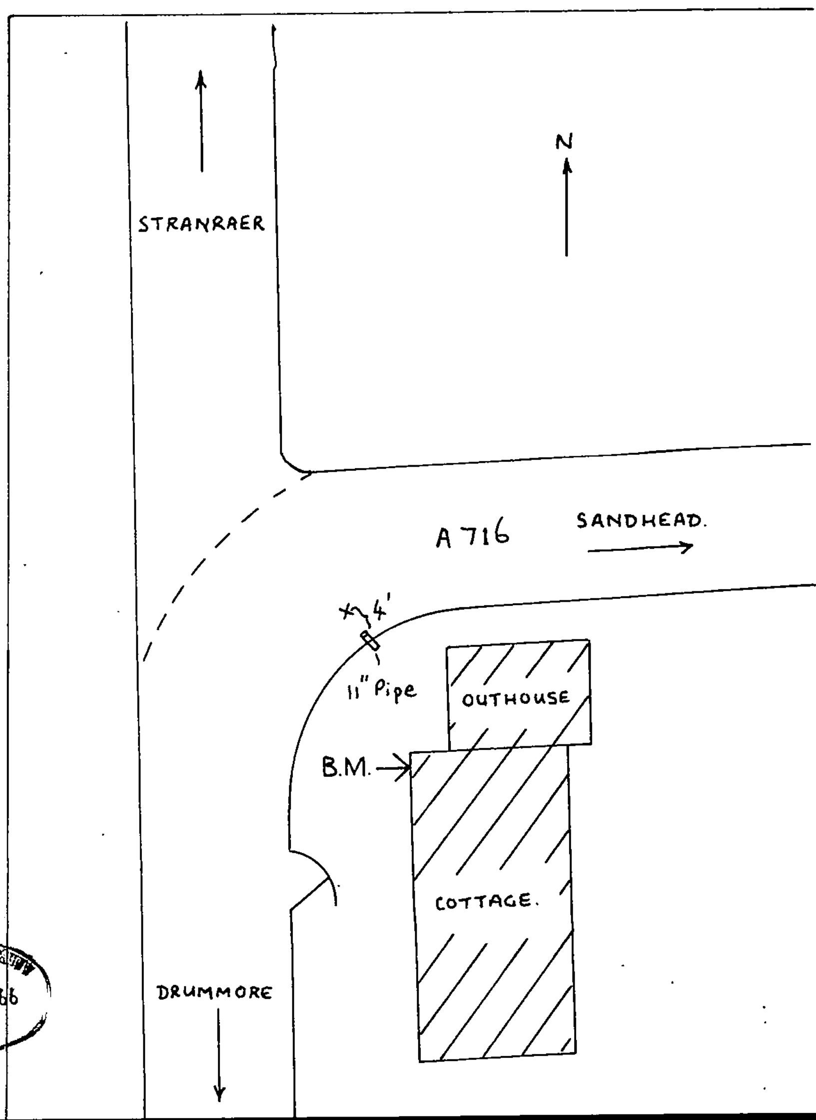
LATITUDE:- 54° 48' 08"

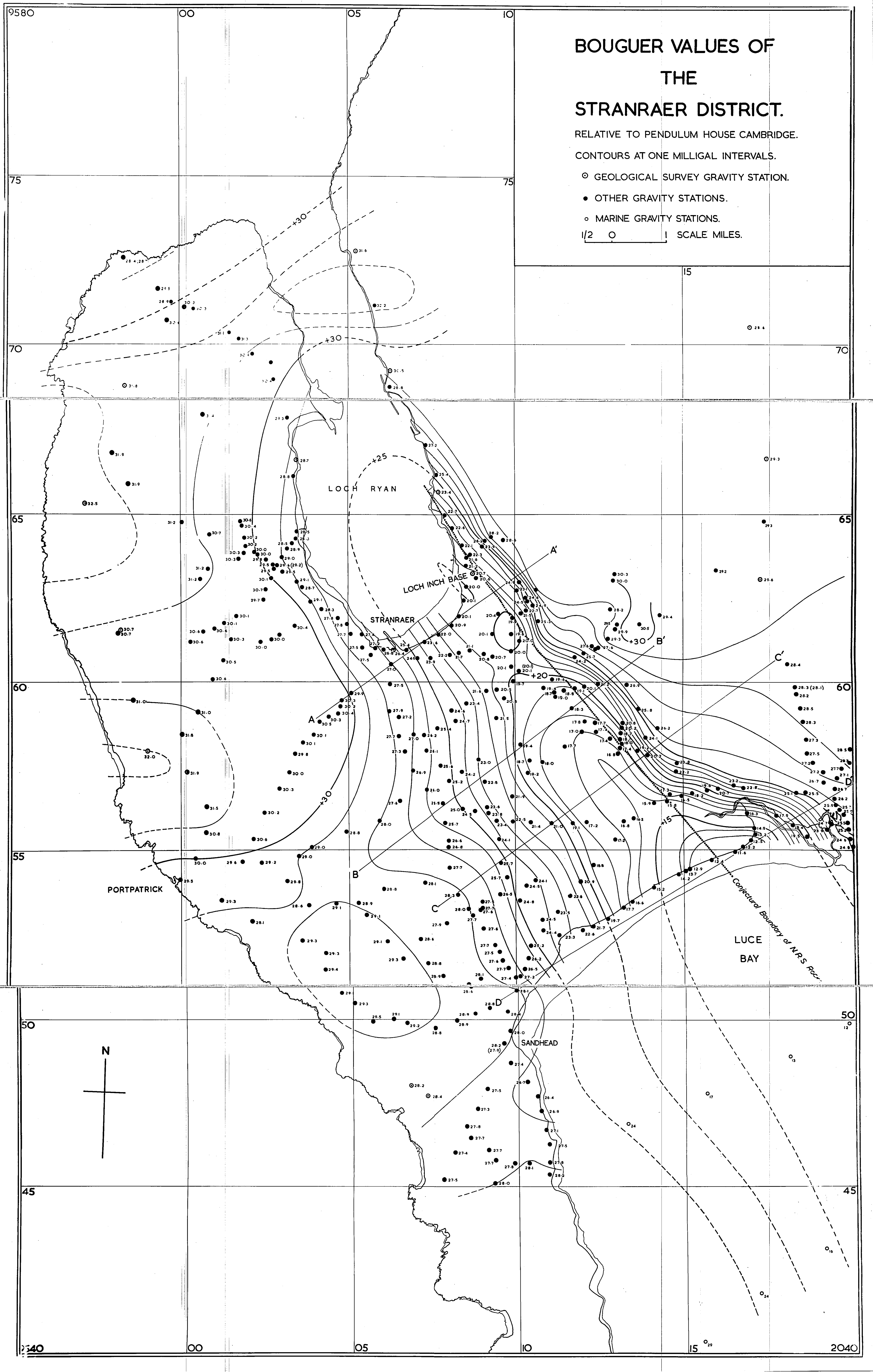
LONGITUDE:- 4° 57' 48" W

ELEVATION:- 63.3 Ft. O.D.

DATE:- October, 1959.

OBSERVER:- J. Mansfield




BOUGUER VALUES OF THE STRANRAER DISTRICT.
RELATIVE TO PENDULUM HOUSE CAMBRIDGE.
CONTOURS AT ONE MILLIGAL INTERVALS.
GEOLOGICAL SURVEY GRAVITY STATION.
OTHER GRAVITY STATIONS.
MARINE GRAVITY STATIONS.
1/2 0 1 SCALE MILES.
LOCH RYAN
LOCH INCH BASE
STRANRAER
PORTPATRICK
SANDHEAD
LUCE BAY
Conjectural Boundary of N.R.S. Rocks
N
9580
2040
A
A'
B
B'
C
C'
D
D'

Appendix 2.

GRAVIMETER SURVEY : *GRAVITY DATA SHEET*

FILE REF. :-

1 OBSERVERS STATION NUMBER	2 LATITUDE N. (°)	(′)	(″)	3 LONGITUDE (E. or W) (°)	(′)	(″)	(E/W)	4 ELEVATION feet (Newlyn O.D.)	5 STATION TO WHICH CONNECTED	6 GRAVITY DIFFERENCE MEAN VALUE (milligals)	DEVIATION	7 TOTAL GRAVITY MEAN VALUE cm/sec²	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
252. L.	54°	54	05	4°	57	43	W.	85·0	G.S. Network			981·25571			20·14	2·33 gm/cm³	0·12		Loch Inch Base Stn.
253	"	56	39	"	51	04	"	178·5	Loch Inch			·26318			29·32	2·73	0·40		
254	"	55	50	"	52	21	"	324·4	"			·25348			29·21	2·73	0·19		
255	"	54	55	"	54	27	"	352·0	"			·25145			30·50	2·73	0·57		
256	"	54	54	"	55	03	"	274·6	"			·25537			29·52	2·73	0·23		
257	"	54	30	"	55	33	"	130·0	"			·26083			27·86	2·33	0·42		
258	"	54	25	"	55	55	"	94·0	"			·26101			25·68	2·33	0·27		
259	"	54	21	"	56	11	"	92·0	"			·25958			24·18	2·33	0·25		
260	"	53	58	"	56	47	"	90·1	"			·25470			19·60	2·33	0·13		
261	"	53	44	"	57	01	"	88·0	"			·25448			19·43	2·33	0·11		
262	"	53	65	"	57	53	"	105·0	"			·25381			19·71	2·33	0·11		
263	"	53	38	"	58	07	"	47·0	"			·25789			20·52	2·33	0·17		
264	"	52	38	"	58	45	"	127·0	"			·25382			22·97	2·33	0·12		
265	"	52	26	"	59	12	"	64·0	"			·25879			24·18	2·33	0·13		
266	"	52	16	"	59	32	"	67·0	"			·25938			25·21	2·33	0·14		
267 A.	"	53	19	"	58	18	"	110·0	"			·25437			21·46	2·33	0·12		
267 B.	"	53	31	"	56	13	"	77·0	"			·25366			18·33	2·33	0·11		
268	"	53	19	"	55	50	"	69·0	"			·25333			17·76	2·33	0·10		
269	"	53	09	"	55	54	"	57·0	"			·25315			17·03	2·33	0·08		
270	"	52	54	"	56	21	"	69·0	"			·25228			17·68	2·33	0·48		
271	"	52	07	5°	00	11	W	109·0	"			·25728			25·99	2·33	0·11		
272	"	51	55	"	00	55	"	102·7	"			·26922			27·89	2·33	0·18		
273	"	51	35	"	01	28	"	167·0	"			·25548			28·02	2·73	0·30		
274	"	51	23	"	02	22	"	295·2	"			·24839			28·77	2·73	0·26		
275	"	51	07	"	03	19	"	352·0	"			·24489			28·99	2·73	0·24		
276	"	50	58	"	03	39	"	316·0	"			·24690			29·03	2·73	0·18		
277	"	50	50	"	04	42	"	280·0	"			·24896			29·18	2·73	0·22		
278	"	50	50	"	05	14	"	247·0	"			·25133			29·64	2·73	0·26		
279	"	50	52	"	06	32	"	126·0	"			·25901			29·99	2·73	0·15		
280.	"	52	38	4°	56	58	W	67·0	"			·25276			18·00	2·33	0·07		

Appendix 2.

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 cm/sec^2	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
281	54°	52	27	4°	57	21	W	64·0	Loch Inch			981·25384			19·15	2·33 gm/km^3	0·07		
282	"	52	04	"	57	46	"	61·0	"			·25620			21·86	2·33	0·07		
283	"	51	52	"	58	27	"	40·0	"			·25897			23·57	2·33	0·08		
284	"	56	15	5°	07	19	W	350·0	"			·25455			31·24	2·73	0·22		
285	"	56	04	"	06	32	"	360·0	"			·25302			30·69	2·73	0·35		
286	"	55	54	"	05	31	"	80·0	"			·26903			30·24	2·73	0·24		
287	"	56	18	"	05	42	"	102·0	"			·26857			30·61	2·73	0·34		
288	"	56	14	"	05	38	"	98·0	"			·26857			30·43	2·73	0·30		
289	"	56	02	"	05	33	"	86·0	"			·26888			30·20	2·73	0·19		
290	"	55	48	"	05	33	"	97·0	"			·26791			30·28	2·73	0·25		
291	"	55	42	"	05	42	"	105·0	"			·26733			30·31	2·73	0·24		
292	"	55	49	"	05	15	"	91·8	"			·26768			30·16	2·33	0·22		
293	"	55	47	"	05	09	"	88·0	"			·26768			29·97	2·33	0·23		
294	"	55	42	"	04	55	"	78·4	"			·26793			29·78	2·33	0·29		
295	"	55	37	"	04	43	"	83·0	"			·26732			29·52	2·33	0·23		
296	"	55	37	"	04	36	"	77·5	"			·26772			29·57	2·33	0·23		
297	"	55	45	"	04	28	"	64·9	"			·26818			29·02	2·33	0·21		
298	"	55	54	"	04	21	"	68·4	"			·26805			28·87	2·33	0·19		
299	"	55	59	"	04	13	"	38·0	"			·26972			28·46	2·33	0·19		
300	"	56	03	"	04	07	"	15·0	"			·27117			28·29	2·33	0·19		
301	"	56	11	"	04	06	"	14·0	"			·27167			28·53	2·33	0·18		
302	"	55	34	"	04	41	"	96·0	"			·26635			29·52	2·33	0·28		
303	"	55	24	"	04	45	"	169·2	"			·26200			30·10	2·33	0·28		
304	"	55	13	"	04	53	"	252·0	"			·25692			30·67	2·33	0·34		
305	"	55	03	"	04	57	"	295·0	"			·25435			31·02	2·33	0·25		
306	"	54	46	"	05	42	"	290·2	"			·25489			30·12	2·73	0·20		
307	"	54	39	"	06	02	"	291·0	"			·25461			30·14	2·73	0·28		
308	"	54	33	"	06	18	"	317·1	"			·25340			30·55	2·73	0·22		
309	"	54	30	"	06	37	"	338·4	"			·25210			30·56	2·73	0·20		
310	"	54	19	"	06	57	"	343·0	"			·25158			30·61	2·73	0·23		

Appendix 2

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)	DEVIATION	7 TOTAL GRAVITY MEAN VALUE cm/sec²	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	REMARKS
341	54° 51′ 13″	5° 04 57 W	323·0	Portpatrick			981·24831			30·55	2·73 gm/cm³	0·24		
342	" 50′ 33″	" 03 58 "	306·0	"			·24767			29·84	2·73	0·23		
343	" 50′ 11″	" 03 20 "	345·0	"			·24363			28·60	2·73	0·21		
344	" 50′ 14″	" 02 35 "	336·6	"			·24472			29·11	2·73	0·19		
345	" 50′ 15″	" 01 58 "	312·0	"			·24596			28·88	2·73	0·19		
346	" 50′ 30″	" 01 15 "	329·0	"			·24517			28·80	2·73	0·25		
347	" 50′ 37″	" 00 08 "	167·6	"			·25430			28·14	2·73	0·19		
348	" 50′ 27″	4° 59 10 W	93·0	Sandhead			·25841			28·54	2·33	0·19		
349	" 50′ 21″	" 58 28 "	71·0	"			·25871			27·49	2·33	0·11		
350	" 50′ 29″	" 57 59 "	58·0	"			·25880			26·53	2·33	0·09		
351	" 50′ 39″	" 57 16 "	50·0	"			·25758			24·53	2·33	0·06		
352	" 50′ 44″	" 57 02 "	48·0	"			·25736			24·07	2·33	0·06		
353	" 48′ 20″	" 57 38 "	17·3	"			·25987			28·08	2·33	0·13		
354	" 48′ 38″	" 57 44 "	28·8	"			·25997			28·51	2·33	0·15		
355	" 48′ 59″	" 57 31 "	25·0	"			·26040			28·14	2·33	0·09		
356	" 49′ 09″	" 57 29 "	30·0	"			·25969			27·52	2·33	0·09		
357	" 49′ 12″	" 57 21 "	27·0	"			·25964			27·17	2·33	0·05		
358	" 49′ 18″	" 57 14 "	28·0	"			·25903			26·49	2·33	0·07		
359	" 49′ 29″	" 57 08 "	27·0	"			·25903			26·16	2·33	0·06		
360	" 49′ 41″	" 57 05 "	37·0	Loch Inch			·25774			25·23	2·33	0·06		
361	" 49′ 56″	" 56 46 "	38·0	"			·25723			24·43	2·33	0·06		
362	" 50′ 06″	" 56 48 "	36·0	"			·25762			24·45	2·33	0·05		
363	" 50′ 15″	" 56 23 "	38·0	"			·25679			23·53	2·33	0·05		
364	" 50′ 31″	" 56 03 "	40·0	"			·25615			22·64	2·33	0·05		
365	" 50′ 45″	" 55 46 "	42·0	"			·25465			20·94	2·33	0·05		
366	" 51′ 02″	" 55 25 "	38·0	"			·25319			18·81	2·33	0·05		
367	" 51′ 27″	" 54 52 "	35·3	"			·25236			17·23	2·33	0·06		
368	" 51′ 48″	" 54 23 "	34·0	"			·25188			16·18	2·33	0·07		
369	" 52′ 04″	" 53 48 "	35·0	"			·25194			15·94	2·33	0·08		
370	" 52′ 06″	" 53 28 "	17·0	"			·25304			15·85	2·33	0·10		

Appendix 2.

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 cm/sec²	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
371	54°	52'	14"	4°	52	47	W	20·3	Loch Inch			981·25541			18·28	2·33 gm/cm³	0·19		
372	"	52'	21"	"	51	20	"	45·8	"			·25865			22·83	2·73	0·21		
373	"	52'	23"	"	51	36	"	33·0	"			·25969			23·19	2·73	0·33		
374	"	52'	19"	"	52	03	"	33·4	"			·25719			20·69	2·73	0·21		
375	"	52'	18"	"	52	21	"	20·7	"			·25699			19·84	2·33	0·19		
376	"	52'	19"	"	49	53	"	20·0	"			·26231			25·08	2·33	0·17		
377	"	52'	20"	"	49	39	"	20·0	"			·26270			25·45	2·33	0·17		
378	"	52'	30"	"	49	10	"	26·0	"			·26364			26·68	2·33	0·32		
379	"	52'	35"	"	48	48	"	29·0	"			·26410			27·25	2·33	0·35		
380	"	52'	52"	"	48	06	"	114·2	"			·26075			28·26	2·73	0·22		
381	"	53'	04"	"	47	12	"	172·0	"			·25712			27·68	2·73	0·12		
382	"	53'	18"	"	45	55	"	261·0	"			·25171			27·14	2·73	0·06		
383	"	53'	31"	"	45	16	"	277·0	"			·25072			26·79	2·73	0·05		
384	"	53'	46"	"	58	19	"	96·0	"			·25495			20·48	2·33	0·10		
385	"	54'	09"	"	57	57	"	65·2	"			·25705			20·11	2·33	0·15		
386	"	54'	24"	"	57	58	"	113·0	"			·25421			19·99	2·33	0·15		
387	"	54'	41"	"	57	59	"	134·0	"			·25287			19·62	2·33	0·17		
388	"	54'	56"	"	57	58	"	138·0	"			·25323			19·93	2·33	0·21		
389	"	55'	00"	"	57	44	"	127·7	"			·25552			21·47	2·33	0·23		
390	"	55'	31"	"	57	48	"	88·0	"			·26239			24·93	2·73	0·55		
391	"	55'	23"	"	57	52	"	62·5	"			·26179			23·27	2·33	0·50		
392	"	56'	11"	"	58	18	"	285·9	"			·25492			28·63	2·73	0·99		
393	"	56'	14"	"	58	38	"	167·0	"			·26158			28·21	2·73	1·04		
394	"	56'	09"	"	58	49	"	111·0	"			·26328			26·24	2·73	0·56		
395	"	56'	05"	"	58	53	"	74·0	"			·26317			23·86	2·73	0·39		
396	"	55'	55"	"	59	13	"	41·0	"			·26300			22·27	2·33	0·42		
397	"	55'	52"	"	59	19	"	35·0	"			·26264			21·59	2·33	0·42		
398	"	55'	45"	"	59	20	"	31·0	"			·26236			21·16	2·33	0·36		
399	"	55'	38"	"	59	01	"	84·4	"			·25815			20·61	2·33	0·27		
400	"	55'	00"	"	58	22	"	101·6	"			·25611			20·38	2·33	0·22		

Appendix 2.

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)	DEVIATION	7 TOTAL GRAVITY MEAN VALUE cm/sec²	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
401	54° 54′ 40″	4° 58 30 W	76.5	Loch Inch			981.25708			20.14	2.33 gm/cm³	0.16		
402	" 54′ 18″	" 58 29 "	40.0	"			.25938			20.66	2.33	0.20		
403	" 56′ 33″	" 59 57 "	11.0	"			.26631			22.70	2.33	0.42		
404	" 56′ 21″	" 59 44 "	14.0	"			.26571			22.57	2.33	0.42		
405	" 56′ 05″	" 59 27 "	65.0	"			.26164			22.06	2.33	0.33		
406	" 55′ 24″	" 59 17 "	21.0	"			.26134			19.95	2.33	0.32		
407	" 55′ 11″	" 59 21 "	11.6	"			.26188			20.13	2.33	0.25		
408	" 54′ 56″	" 59 28 "	8.0	"			.26180			20.13	2.33	0.21		
409	" 54′ 46″	" 59 39 "	12.0	"			.26207			20.85	2.33	0.17		
410	" 54′ 37″	5° 00 01 W	9.0	"			.26323			22.01	2.33	0.15		
411	" 54′ 29″	" 00 24 "	11.0	"			.26450			23.60	2.33	0.15		
412	" 54′ 21″	" 00 55 "	19.9	"			.26550			25.35	2.33	0.14		
413	" 54′ 13″	" 00 35 "	28.3	"			.26429			24.85	2.33	0.13		
414	" 54′ 14″	" 00 13 "	28.0	"			.26340			23.92	2.33	0.12		
415	" 54′ 18″	4° 59 38 W	28.0	"			.26179			22.23	2.33	0.14		
416	" 54′ 20″	" 59 26 "	27.0	"			.26139			21.73	2.33	0.14		
417	" 54′ 23″	" 59 07 "	25.0	"			.26091			21.06	2.33	0.15		
418	" 54′ 20″	" 58 44 "	26.0	"			.26046			20.75	2.33	0.16		
419	" 52′ 17″	" 58 33 "	90.0	"			.25553			22.75	2.33	0.07		
420	" 51′ 47″	" 58 26 "	49.0	"			.25847			23.76	2.33	0.07		
421	" 51′ 48″	" 58 48 "	65.0	"			.25819			24.50	2.33	0.09		
422	" 51′ 50″	" 59 08 "	68.0	"			.25851			24.96	2.33	0.08		
423	" 51′ 55″	" 59 41 "	58.0	"			.25975			25.46	2.33	0.10		
424	" 51′ 40″	" 58 11 "	59.0	"			.25734			23.44	2.33	0.07		
425	" 51′ 40″	" 57 43 "	50.0	"			.25702			22.53	2.33	0.06		
426	" 51′ 41″	" 57 13 "	43.0	"			.25634			21.39	2.33	0.07		
427	" 51′ 40″	" 56 38 "	31.9	"			.25666			21.02	2.33	0.07		
428	" 51′ 41″	" 56 03 "	42.8	"			.25407			19.09	2.33	0.06		
429	" 51′ 42″	" 55 40 "	30.7	"			.25395			17.17	2.33	0.06		
430	" 51′ 45″	" 54 38 "	32.7	"			.25252			16.81	2.33	0.07		

Appendix 2.

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 cm/sec²	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
431	54° 52' 11"	4° 53 03 W	22.8	Loch Inch			981.25349			16.46	2.73 gm/cm³	0.12		
432	" 52' 13"	" 53 23 "	21.0	"			.25443			17.35	2.33	0.12		
433	" 52' 35"	" 53 14 "	53.0	"			.25794			22.18	2.73	0.17		
434	" 52' 42"	" 53 13 "	71.3	"			.25859			23.80	2.73	0.22		
435	" 52' 49"	" 54 02 "	29.8	"			.25760			20.32	2.33	0.20		
436	" 52' 53"	" 54 20 "	53.0	"			.25513			19.18	2.33	0.14		
437	" 52' 59"	" 54 46 "	59.6	"			.25368			17.99	2.33	0.12		
438	" 53' 03"	" 55 06 "	48.7	"			.25384			17.36	2.33	0.12		
439	" 53' 09"	" 55 30 "	70.0	"			.25264			17.38	2.33	0.11		
440	" 53' 42"	" 56 41 "	87.0	"			.25389			18.95	2.33	0.11		
441	" 51' 25"	" 58 06 "	59.1	"			.25755			24.06	2.33	0.07		
442	" 50' 59"	" 58 00 "	71.0	"			.25789			25.72	2.33	0.06		
443	" 50' 46"	" 57 48 "	76.5	"			.25723			25.73	2.33	0.07		
444	" 50' 24"	" 57 27 "	54.6	"			.25719			24.79	2.33	0.06		
445	" 49' 18"	" 57 42 "	42.6	"			.25946			27.66	2.73	0.09		
446	" 49' 26"	" 57 52 "	48.9	"			.25923			27.64	2.73	0.09		
447	" 49' 34"	" 57 58 "	54.0	"			.25902			27.54	2.73	0.10		
448	" 49' 40"	" 58 05 "	67.3	"			.25853			27.69	2.73	0.10		
449	" 49' 55"	" 58 26 "	66.0	"			.25876			27.55	2.73	0.16		
450	" 50' 14"	" 58 52 "	91.0	"			.25789			28.21	2.33	0.20		
451	" 50' 52"	" 59 25 "	85.0	"			.25897			27.89	2.33	0.11		
452	" 51' 13"	" 59 29 "	78.0	"			.25897			26.97	2.33	0.11		
453	" 51' 19"	" 59 29 "	76.0	"			.25888			26.59	2.33	0.09		
454	" 54' 19"	5° 01 32 W	9.9	"			.26749			26.79	2.33	0.18		
455	" 54' 01"	" 01 19 "	30.5	"			.26611			27.01	2.33	0.15		
456	" 53' 47"	" 01 18 "	47.3	"			.26506			27.48	2.33	0.15		
457	" 53' 20"	" 01 18 "	87.0	"			.26228			27.93	2.33	0.18		
458	" 52' 57"	" 01 00 "	84.0	"			.26164			27.69	2.35	0.24		
459	" 52' 43"	" 00 49 "	71.0	"			.26182			27.31	2.33	0.18		
460	" 52' 25"	" 00 35 "	84.4	"			.26016			26.88	2.33	0.12		

Appendix 2.

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)	DEVIATION	7 TOTAL GRAVITY MEAN VALUE cm/sec²	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
461	54° 51' 36"	4° 59 36 W	71.0	Loch Inch			981·25873			25·73	2·33 gm/cm³	0·10		
462	" 52' 30"	" 59 48 "	78.5	"			·25938			25·56	2·33	0·08		
463	" 52' 44"	5° 00 13 W	72.0	"			·26064			26·09	2·33	0·10		
464	" 53' 00"	" 00 36 "	85.1	"			·26107			27·00	2·33	0·12		
465	" 53' 16"	" 01 02 "	79.0	"			·26204			27·22	2·33	0·14		
466	" 53' 44"	4° 58 36 W	88.2	"			·25650			21·61	2·33	0·14		
467	" 53' 32"	" 59 08 "	78.8	"			·25871			23·44	2·33	0·08		
468	" 53' 24"	" 59 33 "	73.3	Portpatrick			·26002			24·58	2·33	0·09		
469	" 53' 14"	" 59 26 "	56.0	"			·26098			24·67	2·33	0·10		
470	" 53' 06"	" 59 56 "	46.0	"			·26218			25·41	2·33	0·10		
471	" 52' 59"	5° 00 18 W	78.0	"			·26108			26·16	2·73	0·10		
472	" 54' 54"	4° 57 14 W	104.3	Loch Inch			·26066			25·29	2·33	0·27		
473	" 55' 04"	" 57 35 "	102.0	"			·25846			22·71	2·33	0·27		
474	" 55' 09"	" 57 25 "	69.0	"			·26269			24·90	2·33	0·47		
475	" 55' 13"	" 57 34 "	59.0	"			·26278			24·50	2·33	0·72		
476	" 55' 16"	" 57 37 "	60.0	"			·26308			24·61	2·33	0·54		
477	" 55' 24"	" 57 20 "	60.0	"			·26174			28·70	2·73			No Terrain Correction
478	" 54' 34"	" 57 44 "	116.8	"			·25417			19·98	2·33	0·17		
479	" 55' 05"	" 53 52 "	423.0	"			·24675			29·38	2·73	0·19		
480	" 54' 40"	" 55 17 "	202.4	"			·25851			29·31	2·73.	0·83		
481	" 54' 31"	" 55 33 "	148.0	"			·26005			27·59	2·73	0·57		
482	" 54' 32"	" 56 43 "	112.9	"			·26203			27·92	2·33	0·46		
483	" 54' 49"	" 55 06 "	247.0	"			·25678			29·91	2·73	0·73		
484	" 55' 09"	" 55 15 "	425.0	"			·24542			28·23	2·73	0·34		
485	" 55' 36"	" 56 12 "	511.0	"			·24254			29·97	2·73	0·50		
486	" 55' 43"	" 55 10 "	472.0	"			·24549			30·25	2·73	0·37		
487	" 50' 15"	" 58 27 "	60.0	"			·25956			27·82	2·33	0·13		
488	" 50' 13"	" 58 32 "	82.5	"			·25811			27·83	2·33	0·12		
489	" 50' 08"	" 58 44 "	94.2	"			·25742			27·66	2·73	0·25		
490	" 49' 59"	" 59 27 "	304.0	"			·24486			27·85	2·73	0·36		

Appendix 2.

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)	DEVIATION	7 TOTAL GRAVITY MEAN VALUE cm/sec²	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
491	54° 49' 42"	5° 00 12 W	358.0	Loch Inch			981.24208			28.62	2.73 gm/cm³	0.31		
492	" 49' 23"	" 00 39 "	276.0	"			.24726			29.26	2.73	0.17		
493	" 47' 23"	4° 58 13 W	148.0	Sandhead			.25033			27.54	2.73	0.12		
494	" 47' 03"	" 58 27 "	165.0	"			.24866			27.33	2.73	0.11		
495	" 46' 46"	" 58 45 "	129.0	"			.25089			27.81	2.73	0.09		
496	" 46' 20"	" 59 03 "	195.0	"			.24580			27.37	2.73	0.21		
497	" 45' 53"	" 59 20 "	142.0	"			.24850			27.53	2.73	0.18		
498	" 46' 35"	" 58 38 "	124.0	"			.25079			27.65	2.73	0.07		
499	" 46' 24"	" 58 06 "	121.0	"			.25077			27.71	2.73	0.06		
500	" 46' 15"	" 57 53 "	93.0	"			.25217			27.67	2.73	0.06		
501	" 45' 53"	" 57 54 "	79.0	"			.25280			27.99	2.73	0.07		
502	" 46' 13"	" 57 22 "	98.3	"			.25199			27.84	2.73	0.06		
503	" 46' 13"	" 56 59 "	78.8	"			.25308			28.37	2.33	0.15		
504	" 46' 14"	" 56 23 "	17.9	"			.25670			27.87	2.33	0.07		
505	" 47' 49"	" 57 36 "	60.0 ?	"			.25568			27.35	2.33	0.11		
506	" 47' 32"	" 57 06 "	68.0	"			.25434			26.89	2.33	0.08		
507	" 47' 18"	" 56 48 "	53.0	"			.25465			26.49	2.33	0.18		
508	" 47' 04"	" 56 42 "	17.0	"			.25688			26.92	2.33	0.18		
509	" 46' 46"	" 56 32 "	20.0	"			.25657			27.17	2.33	0.12		
510	" 46' 32"	" 56 25 "	18.0	"			.25673			27.50	2.33	0.09		
511	" 46' 03"	" 56 24 "	17.0	"			.25686			28.22	2.33	0.06		
512	" 48' 41"	" 58 14 "	96.0	"			.25652			28.78	2.73	0.10		
513	" 48' 35"	" 58 38 "	150.0	"			.25328			28.89	2.73	0.12		
514	" 48' 28"	" 59 08 "	198.0	"			.25028			28.91	2.73	0.12		
515	" 48' 20"	" 59 44 "	245.0	"			.24713			28.76	2.73	0.15		
516	" 48' 24"	5° 00 32 W	230.0	"			.24857			29.20	2.73	0.14		
517	" 48' 27"	" 00 56 "	250.0	"			.24737			29.12	2.73	0.14		
518	" 48' 24"	" 01 30 "	280.0	"			.24585			29.46	2.73	0.16		
519	" 49' 07"	4° 58 27 W	93.0	"			.25658			28.10	2.73	0.16		
520	" 49' 01"	" 58 47 "	152.0	"			.25340			28.57	2.73	0.17		

Appendix 2.

GRAVIMETER SURVEY : *GRAVITY DATA SHEET*

FILE REF. :-

1	2	3	4	5	6		7		8	9	10	11		12
OBSERVERS STATION NUMBER	LATITUDE N.	LONGITUDE (E. or W)	ELEVATION feet (Newlyn O.D)	STATION TO WHICH CONNECTED	GRAVITY DIFFERENCE MEAN VALUE (milligals)	DEVIATION	TOTAL GRAVITY MEAN VALUE cm/sec²	DEVIATION	FREE AIR ANOMALY (milligals)	BOUGUER ANOMALY ON I.G.F. (milligals)	DENSITY VALUES USED IN BOUGUER REDUCTION	TERRAIN CORRECTION (milligals)	ZONE	REMARKS
521	54° 49' 08"	4° 59 30 W	261·0	Sandhead			981·24740			28·86	2·73 gm/cm³	0·17		
522	" 49' 20"	" 59 57 "	281·0	"			·24639			28·82	2·73	0·24		
523	" 49' 39"	5° 01 06 W	335·0	"			·24394			29·13	2·73	0·25		
524	" 50' 04"	" 01 43 "	352·0	"			·24352			29·12	2·73	0·24		
525	" 49' 37"	" 03 29 "	315·0	"			·24524			29·33	2·73	0·29		
526	" 49' 26"	" 02 48 "	390·0	"			·24048			29·32	2·73	0·34		
527	" 49' 10"	" 02 49 "	384·0	"			·24048			29·39	2·73	0·39		
528	" 48' 50"	" 02 26 "	369·0	"			·24061			29·14	2·73	0·41		
529	" 48' 41"	" 02 02 "	359·0	"			·24119			29·26	2·73	0·34		
530	" 57' 00"	" 04 18 "	9·0	Loch Inch			·27331			28·84	2·33	0·28		Lat. & Long from
531	" 57' 56"	" 04 31 "	16·0	"			·27461			29·29	2·33	0·30		One Inch Map
532	" 58' 30"	" 04 54 "	74·0	"			·27283			30·41	2·33	0·27		" " "
533	" 58' 47"	" 05 02 "	75·9	"			·27366			26·16	2·73	—		No Terrain Correction
534	" 58' 54"	" 05 33 "	90·0	"			·27342			30·90	2·73	0·17		Lat. & Long. from
535	" 59' 09"	" 05 56 "	141·3	"			·27113			31·25	2·73	0·12		One Inch Map.
536	" 59' 15"	" 06 13 "	157·0	"			·27013			31·08	2·73	0·16		" " "
537	" 59' 37"	" 07 15 "	314·0 ?	"			·26050			30·25	2·73	0·29		" " "
538	" 59' 43"	" 07 50 "	212·0	"			·26534			28·91	2·73	0·19		" " "
539	55° 00' 37"	" 02 47 "		"			·27963			—	2·73			Rejected. Heights
540	55° 01' 02"	" 02 26 "		"			·27436			—	2·73			of Bench Marks
541	55° 06' 00"	"		"			·28322			—	2·73			not known.
542	55° 05' 05"			"			·26642			—	2·73			"
543	55° 04' 40"			"			·26002			—	2·73			"
544	55° 04' 30"			"			·26683			—	2·73			"
545	54° 59' 46"	" 02 11 "	157·0	"			·26975			32·15	2·73	2·35		Lat. & Long from
546	" 58' 27"	" 01 39 "	8·0	"			·27487			28·82	2·33	0·82		One Inch Map.
547	" 57' 32"	" 00 35 "	13·0	"			·27148			27·21	2·73	1·05		" " "
548	" 57' 06"	" 00 13 "	21·0	"			·26896			25·50	2·33	0·66		" " "
549	" 52' 55"	4° 57 36 W	77·0	"			·25394			19·44	2·33	0·09		
550	" 52' 40	" 57 19 "	72·0	"			·25317			18·69	2·33	0·08		

Appendix 2.

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 cm/sec²	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
551	54° 53' 06"	4° 54 07 W	73·0	Loch Inch			981·25912			24·23	2·33 gm/cm³	0·21		
552	" 53' 15"	" 53 47 "	89·0	"			·26011			26·15	2·73	0·78		
553	" 54' 41"	5° 03 58 W.	Unknown.	"			·25306					—		Rejected.
554	" 54' 39"	" 04 02 "	296·4	"			·25301			30·37	2·33	0·28		
555	" 54' 30"	" 04 26 "	Unknown	"			·25615					—		Rejected.
556	" 54' 25"	" 04 41 "	234·0	"			·25753			29·99	2·73	0·26		
557	" 54' 23"	" 04 59 "	301·0	"			·25349			30·04	2·73	0·33		
558	" 53' 34"	4° 54 20 W	108·0	"			·25944			25·78	2·73	0·40		
559	" 53' 56"	" 54 42 "	90·0	"			·26210			26·93	2·73	0·48		
560	" 51' 30"	" 48 17 "	57·7	"			·25861			24·76	2·73	0·26		
561	" 51' 37"	" 48 23 "	84·0	"			·25704			24·58	2·73	0·26		
562	" 51' 47"	" 48 26 "	84·9	"			·25786			25·24	2·73	0·28		
563	" 51' 53"	" 48 28 "	81·0	"			·25855			25·53	2·73	0·26		
564	" 52' 00"	" 48 35 "	51·3	"			·26083			25·90	2·73	0·27		
565	" 52' 05"	" 48 42 "	48·0	"			·26101			25·71	2·73	0·22		
566	" 52' 08"	" 48 48 "	46·0	"			·26133			25·85	2·73	0·23		
567	" 52' 15"	" 48 52 "	38·0	"			·26230			26·24	2·73	0·28		
568	" 52' 24"	" 48 51 "	23·0	"			·26381			26·66	2·73	0·30		
569	" 52' 45"	" 48 40 "	89·6	"			·26153			27·74	2·73	0·20		
570	" 52' 50"	" 48 28 "	117·4	"			·26050			28·28	2·73	0·25		
571	" 53' 04"	" 48 29 "	166·5	"			·25813			28·46	2·73	0·22		
572	" 52' 40"	" 49 11 "	44·7	"			·26343			27·21	2·73	0·32		
573	" 52' 48"	" 49 28 "	66·6	"			·26232			27·20	2·73	0·32		
574	" 52' 58"	" 49 38 "	40·6	"			·26429			27·49	2·73	0·41		
575	" 53' 11"	" 49 40 "	50·0	"			·26396			27·34	2·73	0·34		
576	" 53' 28"	" 49 46 "	68·0	"			·26415			28·26	2·73	0·40		
577	" 53' 41"	" 49 53 "	104·6	"			·26263			28·54	2·73	0·35		
578	" 53' 54"	" 49 59 "	113·4	"			·26200			28·22	2·73	0·44		
579	" 54' 00"	" 50 02 "	120·0	"			·26185			28·34	2·73	0·45		
580	" 54' 22"	" 50 18 "	91·5	"			·26400			28·41	2·73	0·58		

Appendix 2.

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)	DEVIATION	7 TOTAL GRAVITY MEAN VALUE cm/sec²	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
581	54° 49' 52"	4° 56' 18" W	10.0	Loch Inch			981·25779			23.28	2.33 gm/cm³	0.06		
582	" 49' 58"	" 55' 41" "	8.0	"			·25734			22.55	2.33	0.05		
583	" 50' 02"	" 55' 23" "	8.0	"			·25654			21.65	2.33	0.05		
584	" 50' 10"	" 54' 58" "	8.0	"			·25475			19.67	2.33	0.05		
585	" 50' 22"	" 54' 33" "	8.0	"			·25303			17.67	2.33	0.05		
586	" 50' 28"	" 54' 19" "	8.0	"			·25205			16.55	2.33	0.05		
587	" 50' 43"	" 53' 48" "	8.0	"			·25104			15.18	2.33	0.05		
588	" 50' 56"	" 53' 03" "	8.0	"			·25032			14.17	2.33	0.06		
589	" 51' 00"	" 52' 51" "	8.0	"			·24996			13.71	2.33	0.06		
590	" 51' 03"	" 52' 42" "	8.0	"			·24923			12.91	2.33	0.06		
591	" 51' 11"	" 52' 09" "	8.0	"			·24891			12.41	2.33	0.06		
592	" 51' 20"	" 51' 33" "	8.0	"			·24834			11.63	2.33	0.07		
593	" 51' 44"	" 51' 01" "	8.0	"			·25128			13.99	2.73	0.10		
594	" 51' 58"	" 51' 14" "	8.0	"			·25389			16.29	2.73	0.12		
595	" 51' 38"	" 50' 59" "	8.0	"			·25034			13.18	2.73	0.09		
596	" 51' 32"	" 51' 05" "	80	"			·24952			12.49	2.73	0.08		
597	" 51' 25"	" 51' 18" "	10.0	"			·24885			12.16	2.33	0.08		
598	" 53' 18"	" 55' 35" "	76.5	"			·25316			17.71	2.73	0.11		
599	" 53' 19"	" 54' 45" "	66.4	"			·25681			20.79	2.73	0.16		
600	" 52' 49"	" 54' 53" "	54.6	"			·25286			16.80	2.73	0.11		
601	" 52' 56"	" 54' 49" "	60.6	"			·25321			17.36	2.73	0.11		
602	" 53' 03"	" 54' 50" "	61.6	"			·25404			18.08	2.73	0.12		
603	" 53' 09"	" 54' 49" "	62.6	"			·25476			18.74	2.73	0.14		
604	" 53' 14"	" 54' 47" "	64.6	"			·25422			20.21	2.73	0.15		
605	" 53' 46"	" 56' 42" "	88.7	"			·25404			18.65	2.73	0.11		
606	" 53' 48"	" 56' 29" "	86.2	"			·25435			18.77	2.73	0.12		
607	" 53' 51"	" 56' 07" "	84.8	"			·25476			19.05	2.73	0.14		
608	" 53' 53"	" 56' 52" "	82.0	"			·25598			20.08	2.73	0.16		
609	54° 53' 56"	" 55' 30" "	79.8	"			·25728			21.24	2.73	0.20		
610	55° 00' 23"	5° 09' 14" W	75.0 ?	"			·27384			28.42	2.73	0.26		Lat. & Long:-1" Map

Appendix 2.

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 cm/sec^2	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
611	54° 59' 52"	5° 08 11 W	154·0	Loch Inch			981·26961			29·49	2·73 gm/cm^3	0·15		Lat. & Long. from
612	" 59' 36"	" 07 28 "	279·0	"			·26252			30·29	2·73	0·26		One Inch Map.
613	" 59' 18"	" 08 13 "	284·0	"			·26213			30·60	2·73	0·24		" " "
614	" 47' 14"	4° 59 53 W	152·0	"			·25076			28·44	2·73	0·15		
615	" 47' 23"	5° 00 22 "	151·0	"			·25075			28·17	2·73	0·16		
616	" 47' 48"	" 00 42 "	208·0	"			·24870			28·92	2·73	0·18		
617	" 49' 54"	" 04 54 W	413·0	"			·23808			28·07	2·73	0·79		
618	" 50' 13"	" 05 46 "	208·0	"			·25236			29·29	2·73	0·32		
619	" 51' 17"	" 06 16 "	238·0	"			·25358			30·78	2·73	0·33		
620	" 51' 42"	" 06 17 "	338·0	"			·24894			31·47	2·73	0·32		
621	" 52' 14"	" 06 52 "	323·0	"			·25109			31·89	2·73	0·24		
622	" 52' 50"	" 07 03 "	429·0	"			·24543			31·77	2·73	0·35		
623	" 53' 13"	" 06 38 "	468·0	"			·24296			31·04	2·73	0·34		
624	" 53' 18"	" 08 26 "	257·0	"			·25556			30·96	2·73	0·27		Lat. & Long. from
625	" 54' 27"	" 08 56 "	241·0	"			·25794			30·68	2·73	0·18		One Inch Map
626	" 56' 46"	" 08 48 "	292·0	"			·25943			31·87	2·73	0·15 ?		" " "
627	" 57' 18"	" 09 18 "	212·0	"			·26497			31·88	2·73	0·12		" " "
628	" 57' 54"	" 06 49 "	167·0	"			·26806			31·44	2·73	0·10		" " "
629	" 51' 37"	4° 49 33 W	8·0	"			·25660			19·47	2·73	0·10		
630	" 51' 56"	" 50 25 "	8·0	"			·25546			17·91	2·73	0·12		
631	" 51' 47"	" 49 57 "	8·0	"			·25576			18·40	2·73	0·10		
632	" 51' 45"	" 49 02 "	9·0	"			·26115			23·94	2·73	0·14		
633	" 51' 51"	" 48 55 "	9·0	"			·26194			24·65	2·73	0·22		
Portpatrick	54° 50' 31"	5° 06 56 W	20·0 ?	"			981·26437			29·53	2·73	0·11		
Sandhead	54° 48' 08"	4° 57 48 W.	63·3	"			981·25679			28·24	2·33	0·13		