INSTITIÚID ÁRD-LÉINN BHAILE ÁTHA CLIATH
SCOIL NA FISICE COSMAÍ

Dublin Institute for Advanced Studies
SCHOOL OF COSMIC PHYSICS

GEOPHYSICAL MEMOIRS NO. 2, PART 3

# MEASUREMENTS OF GRAVITY IN IRELAND

## GRAVITY SURVEY OF CENTRAL IRELAND

BY

THOMAS MURPHY

DUBLIN
1952

Price: 12s. 6d.

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## ABSTRACT


A gravity survey has been carried out with a small Graf gravimeter in Central Ireland between the Pendulum Stations at Dublin and Galway. In all, 266 new stations were established.

The Bouguer anomaly at each station was calculated and the results analysed. With the exception of the Galway granite areas the anomaly is everywhere positive. The isostatic anomalies are also positive on any scheme of compensation.

Comparisons have been drawn between the gravity results and the magnetic anomaly map of the Geological Survey and various areas of low Bouguer anomaly have been investigated theoretically. It was found impossible to attribute all the low anomaly areas to light sedimentary rocks, and it is suggested that the density of the Lower Palaeozoics or the Pre-Cambrian metamorphics is, in these areas, less than 2·67 g/cm³ due to the existence of masses of granite or granitisation. The occurrence of mineralisation in a few of these areas is pointed out.

Thirlaway's suggestion that the Leinster granite extends westwards beneath the Palaeozoic sediments was confirmed, and the extent of the Galway granite was also found to be much greater than the mapped outcrop. It was detected beneath the limestone in north Co.Clare but on the north-east not beyond the mapped boundary. Its thickness is estimated as 35,000 ft.

A large positive Bouguer anomaly was measured north of Dundalk and from the gradient at this place much larger values are to be expected. They seem to be connected with the Tertiary Igneous activity in the Carlingford peninsula.


## INTRODUCTION

After the measurements of gravity made and described by Cook and Thirlaway in Parts 1 and 2 of this *Memoir*, Mr. B. C. Browne of the Department of Geodesy and Geophysics of Cambridge University, suggested that they lend the small Graf-Askania gravimeter to the School of Cosmic Physics to enable more measurements of gravity to be made in Ireland and to him we are indebted for this most generous offer.

Since the gravimeter is in almost continual use by the Cambridge group, the period during which it was placed at our disposal had to be utilised to the full to take measurements and this naturally led to, what might appear, large omissions. It was decided to make numerous traverses across Central Ireland to complete a grid of stations which would give a general picture of the gravity field in Ireland and would provide base stations for future surveys of economic interest. As a secondary consideration, measurements of gravity were to be taken where the first survey showed large changes in the Bouguer anomaly and in areas where it was thought, from a study of the magnetic map of the Geological Survey (1949), interesting gravity anomalies could be expected. The area of the survey is shown in *Fig.*1.

The Ordnance Survey of Ireland co-operated in this work and supplied the large number of necessary maps and the details of bench marks. The Superintendent of the Levelling Section, Mr. G. O'Neill, took part throughout the survey.

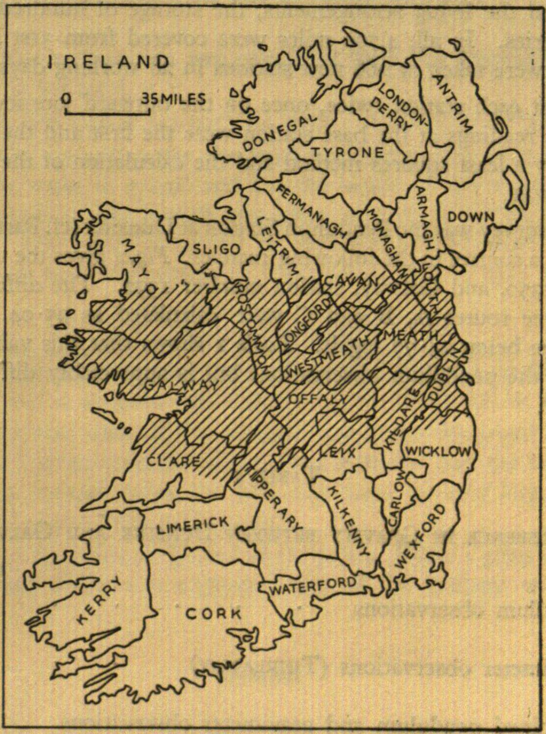


*Fig* 1.—Sketch map of Ireland showing the area covered by the survey.

We wish to thank Mr. D. W. Bishopp, at that time Director of the Geological Survey, for the loan of a station wagon, for helpful discussions and for permission to use unpublished details of the Magnetic Survey. We are grateful to members of the staff of the Physics Department of University College, Galway, who undertook the recharging of batteries when the survey was operating from that city. Finally, I wish to thank Messrs. T. J. Duffy, J. A. G. McCluskey, M. A. Cunningham, and M. F. O'Meara of the Geological Survey, for discussions on various pertinent topics.

## THE METHOD AND ERRORS OF MEASUREMENT

### Field Equipment

The gravimeter used was the same small Graf-Askania instrument used by Thirlaway and described in Part 2 of this *Memoir*. The same method of carrying the equipment, " shock mounted " on rubber cushions, was employed but the vehicle used was a Ford station wagon which, being much larger than the car used by Thirlaway, rode somewhat easier, particularly when travelling over poor road surfaces.

### Field Procedure

The main procedure followed was similar to that of Thirlaway. The stations at which measurements were to be taken were first marked on maps, scale of six inches to one mile, at four-mile intervals along main roads. Main roads were chosen for ease and speed of travel but they had considerable drawbacks. They are continually undergoing alterations and as the maps cannot keep pace with these, we were forced at times to follow the old road where new cuttings have been made. Along with large-scale alterations, the normal repair and widening which are carried out render " spot levels " unreliable and are highly destructive to the bench marks. Furthermore, and this may be a serious objection in some districts, the main roads lie in the valleys and cross lines of hills by gaps which may be of tectonic origin. Nevertheless, without an extensive reconnaissance of the route of the proposed survey, the only feasible method of carrying out gravity measurements over a large area was considered to be on the main roads and to this we adhered except where extra measurements were needed, such as around Galway.

Throughout the survey the author and assistant stayed either in Dublin or Galway, travelling therefrom each morning out to the base station for the day's work. While this entailed considerable extra travelling, it simplified the living arrangements, the storage of hundreds of large-sheet maps and the recharging of the batteries. In all, 4,700 miles were covered from 31st August until 7th October 1949, when measurements were taken at 266 new stations in 28 working days.

Readings were taken at each station twice, once on the outward journey and again on the return journey that evening. The readings at the base station were the first and the last taken each day. The " drift " was determined by a least squares method and the calculation of the results was carried out as fully described by Thirlaway.

The base for the whole survey was the Pendulum Station at Dunsink (cf. Part 1). The second Pendulum Station at Galway served as a control in the following manner. *Fig.*2 gives the values for the links between Dunsink, station number 1350, and Galway, station number 1392. The differences between these two stations taken over the three routes A, B and C were calculated as 25·04, 24·96 and 24·31 mgals. respectively, the mean value being 24·77 mgals. *Table* 1 shows that this value is close to the value of 24·4 mgals. obtained from the pendulum observations but is appreciably different from the gravimeter observations of Thirlaway.

Table 1

Difference in Gravity between Dunsink and Galway

| | mgals. |
|---|---|
| Pendulum observations | 24·4 |
| Gravimeter observations (Thirlaway) | 23·0 |
| Combined pendulum and gravimeter observations | 23·9 |
| Gravimeter observations (this survey) | 24·8 |

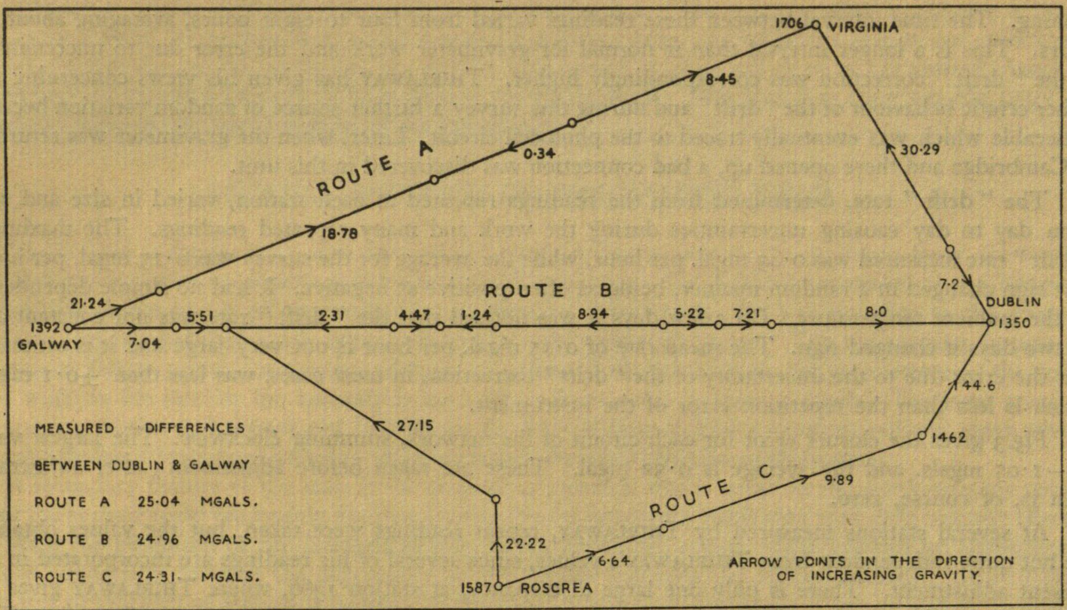


*Fig.* 2.—Differences of gravity between the Pendulum Stations at Dublin (Dunsink) and Galway along three different routes.

To simplify the reduction of the figures, this value of 24·77 mgals. was accepted as correct and adjustments were made along each route; the error being spread uniformly between each station. Along each link connecting the three routes, adjustments were made in a similar manner and the final results from this correction are listed in the *Appendix*. It is intended that a complete adjustment for the whole of Ireland will be carried out later when further gravimeter measurements have been made in the remainder of the country.

## Calculation of the Bouguer Anomaly

The Bouguer anomaly for each station was calculated from the International Formula of 1930 for the normal value of gravity at sea level, $\gamma_o$:

$$\gamma_o = 978{\cdot}049\,(1 + 0{\cdot}0052884 \sin^2\varphi - 0{\cdot}0000059 \sin^2 2\varphi)$$

where $\varphi$ is the latitude. The correction for the height of the station is $(0{\cdot}09406 - 0{\cdot}0128\,\varrho)h$ mgals. where $\varrho$ is the density of the rocks in g/cm³ and $h$ is the height of the station in feet. The density, $\varrho$, of the rock formations throughout the survey was taken as 2·67 g/cm³ so that the height correction reduces to $0{\cdot}05997h$ mgals. The values of gravity are obtained as differences, $(g - g_D)$, from the value, $g_D$, at Dunsink, so that it was more convenient to construct a table of $(g_D - \gamma_o)$ and then the Bouguer anomaly was calculated as

$$(g - g_D) + (g_D - \gamma_o) + 0{\cdot}05997h \text{ mgals.}$$

No topographic correction was thought necessary except in two cases in North Clare but here the influence of the Galway granite is so great that this correction would not be noticeable.

The density of the rocks was taken at the constant value of 2·67 g/cm³ for two reasons, namely: no very accurate values of the mean densities of the rocks is known and the heights of the stations were all less than 2,000 feet, the average being 191 feet, and hence no very large error is introduced even if the density differs in some places from 2·67 g/cm³

The results are shown on the maps at the end of the paper. *Folder* 1 gives the location of the stations with their index numbers and *Folder* 2 is a general map of the geology with the Bouguer anomaly superimposed.

## Errors

Owing to the fact that the time the instrument was at our disposal was very limited, the procedure of travelling from either Dublin or Galway each day and our endeavour to take the maximum number of readings, measurements were made at the base station only twice each day, in the morning and the evening. The time interval between these readings varied from four to eight hours, averaging about six hours. This is a longer interval than is normal for gravimeter work and the error due to uncertainties in the " drift " correction was correspondingly higher. THIRLAWAY has given his views concerning the rather erratic behaviour of the "drift" and during this survey a further source of random variation became noticeable which was eventually traced to the photocell circuit. Later, when the gravimeter was returned to Cambridge and there opened up, a bad connection was discovered in this unit.

The " drift " rate, determined from the readings repeated at each station, varied in size and sign from day to day causing uncertainties during the work and many repeated readings. The maximum " drift " rate measured was 0·43 mgal. per hour, while the average for the survey was 0·15 mgal. per hour. The sign changed in a random manner, being as often positive as negative. It had no simple dependence on the ambient temperature. On a few days it was noticed that the " drift " rate was not constant and on two days it changed sign. The mean rate of 0·15 mgal. per hour is not very large and it is estimated that the error due to the uncertainty of the "drift" correction, in most cases, was less than $\pm 0{\cdot}1$ mgal., which is less than the repetition error of the instrument.

*Fig.* 3 gives the closure error for each circuit of the network, summing clockwise. The largest value is $-1{\cdot}05$ mgals. and the average is 0·32 mgal. These are taken before adjustment; after adjustment each is, of course, zero.

At several stations measured by THIRLAWAY, repeat readings were taken, but the values obtained are not quite independent from THIRLAWAY's values, since several of his readings are incorporated in the present adjustment. There is only one large discrepancy, at station 1366, where THIRLAWAY gives for the gravity difference from Dunsink 17·0 mgals., while the present survey gives 14·8 mgals. This difference of 2.2 mgals. is outside the normal limits of error of the measurements. Since it is known that the gravimeter, both before and after the survey, has given wrong values due to random " jumps " in the readings, it is suspected that THIRLAWAY's link between Dublin and Sligo is not as good as the rest of his measurements. COOK in Part 1 of this *Memoir* has already pointed this out and later evidence in COOK's final adjustment, to be published as Part 5, supports this. With this exception at station 1366, the values of the Bouguer anomaly given in *Folder* 2 for stations measured by THIRLAWAY are those calculated by him in Part 2 of this *Memoir*.

From the residuals of the individual measurements, the standard deviation of a measured difference of gravity is found to be $\pm 0{\cdot}24$ mgal. The total uncertainty of the value of gravity at any station is the resultant of this uncertainty of the comparison with the pendulum base station and the uncertainty of

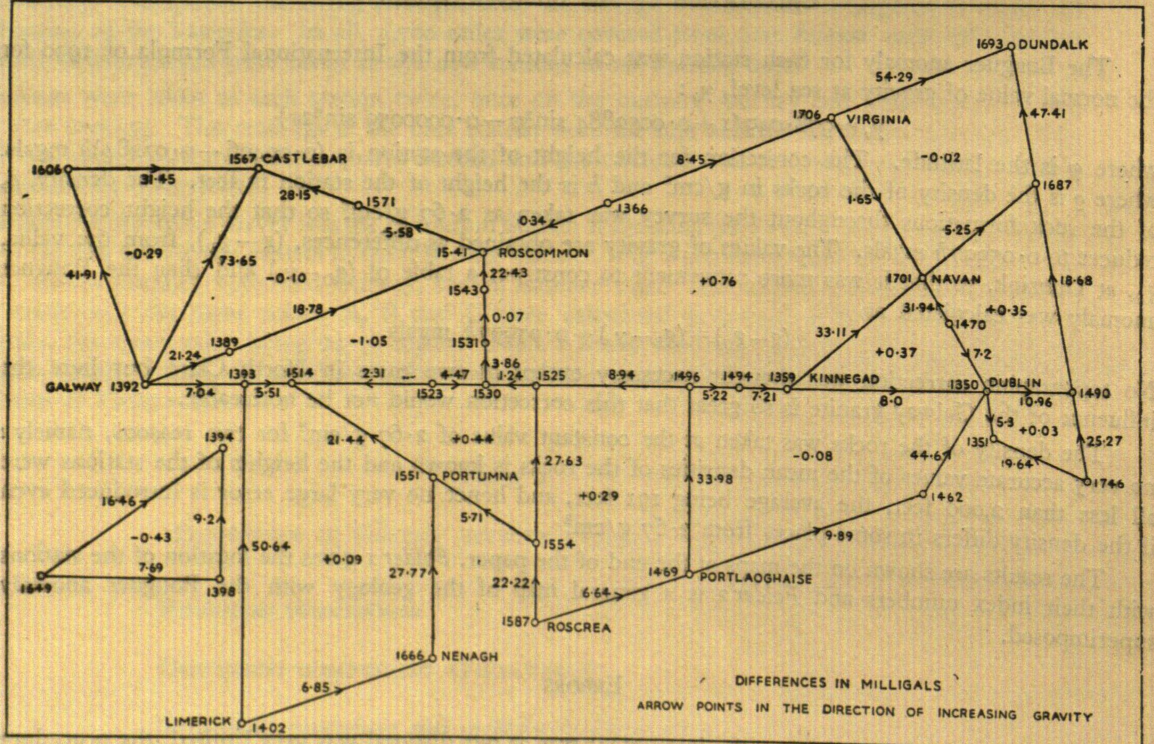


*Fig.* 3.—Closure errors for each circuit of the network, the summation being carried out in clockwise direction.

the comparison of the pendulum base station with Cambridge. The average value is about 0.4 mgal. This error is much larger than is usual for a modern gravity survey and while the results are sufficiently accurate to give the general picture of the gravity field aimed at, they fall short of the second object of our survey, to provide a network of base stations for future work. It is hoped to carry out the latter, in the future, with an improved version of the gravimeter.

## GENERAL FEATURES OF THE GRAVITY FIELD

The Bouguer anomaly, in the area covered by the survey, has a range of over 50 mgals. from −10 mgals. near Galway to over +40 mgals. in the Carlingford peninsula. On *Folder* 2, contours of the Bouguer anomaly are drawn at 5 mgal. intervals over a geological sketch map. *Fig.*4 is an index to the various Bouguer anomaly profiles which appear throughout the following pages. The outstanding feature of the map on *Folder* 2 is the occurrence of large variations of the anomaly on the perimeter near the coast lines, while in the interior the anomaly is approximately constant at about 5 mgals. The large areas of outcropping granite in Leinster and Galway are the sites of large negative anomaly and the areas where the anomaly has a large positive value are areas where the pre-Devonian rocks outcrop.

A secondary feature of the map is the changes of anomaly which occur in the north-western sector where the surface rocks are mainly flatlying Carboniferous limestones exhibiting very little tectonic effects.

With the exception of the Leinster granite in the south-east corner, there appears no immediately obvious connection between the appearance of the gravity field and the surface geology. Since a very large area of this part of Ireland is covered by limestone of unknown thickness, it can be said at the outset that the cause of the main variations of the anomaly must be sought in the underlying rocks and not in the Carboniferous limestone.

## CENTRAL LOWLAND

The interior of Ireland is essentially a lowland with an average height of 200 feet, rising in places to small hills 600 to 1000 feet high. It is roughly delimited by lines drawn from Dublin to Dundalk to Boyle, thence in two concave curves from Boyle to Galway and from Galway to Dublin. This Central Plain, as it has been called, was completely submerged during Carboniferous times and covered by a

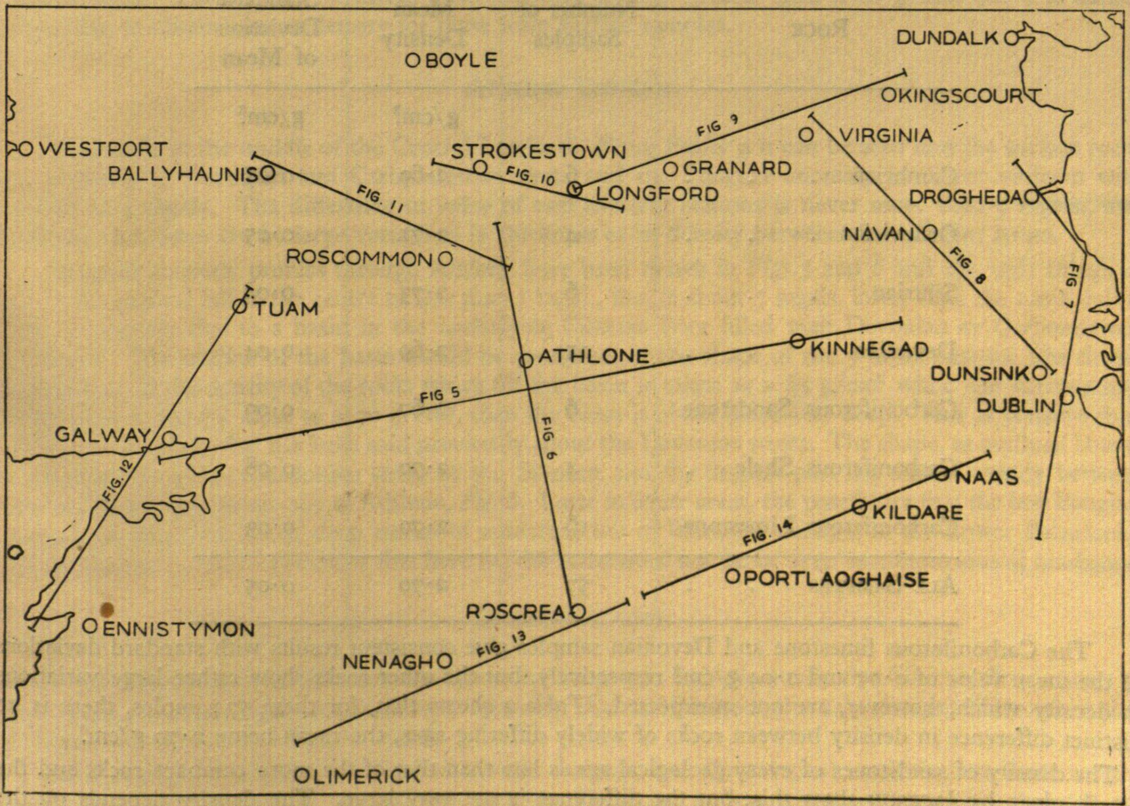


*Fig.* 4.—Index to Bouguer anomaly profiles and geological sections.

thick deposit of Limestones, Coal Measures and Mesozoic strata. Later erosion removed the Mesozoic strata and most of the Coal Measures, the latter now occur only to a limited extent as monadnocks, leaving a peneplain covered mainly by limestone. The Armorican orogeny produced only minor folding resulting in a series of anticlines with a north-east south-west trend, that is Caledonian, but further south the boundary of the Lowland is marked by a range of hills with a trend almost east-west, that is Armorican proper. The small anticlines bring Lower Carboniferous and Devonian rocks to the surface and the larger ones, the underlying Silurian.

The thickness of the Carboniferous strata, which is mainly limestone, is nowhere known but its maximum thickness has been put at 3,000 feet (COLE and HALISSY, 1924). The Old Red Sandstone, wherever it can be measured on the flanks of the anticlines, has only a very small thickness, less than 1,000 feet, and no estimates have been made for its thickness under the limestone. In the southern part of Ireland, the Devonian is of the order of 10,000 feet.

Ordovician and Silurian rocks occur in the north-east corner and in several of the anticlines and it is reasonable to assume that most of the area is underlain by these rocks. Since no Pre-Cambrian and only a small area of Cambrian rocks (in Howth) outcrop, the thickness of the Ordovician and Silurian is probably quite large, maybe of the order of 10,000 feet. To the west of the Lowland, in Galway, metamorphic rocks of Dalradian age are extensive, so that it is possible that in the western half these rocks may be close to the surface underneath the limestone without any Ordovician or Silurian strata.

To interpret the variations of the Bouguer anomaly the densities of the underlying rocks must be known with fair accuracy. Unfortunately not many determinations of the densities of the Irish rocks have been made. JACKSON (1951) has measured about 60 samples of rocks from this area and a summary of his results is presented in *Table* 2. The samples he used were not chosen for measurement of densities and cannot be classed as a representative series.

TABLE 2

SUMMARY OF DENSITY MEASUREMENTS OF SEDIMENTARY ROCKS

| ROCK | Number of Samples | Mean Density | Standard Deviation of Mean |
|---|---|---|---|
| | | $g/cm^3$ | $g/cm^3$ |
| Cambrian . . . | 6 | 2·69 | 0·05 |
| Ordovician . . . | 4 | 2·71 | 0·05 |
| Silurian . . . | 6 | 2·73 | 0·04 |
| Devonian . . . | 15 | 2·69 | 0·04 |
| Carboniferous Sandstone | 6 | 2·67 | 0·09 |
| Carboniferous Shale . | 4 | 2·70 | 0·08 |
| Carboniferous Limestone | 16 | 2·70 | 0·03 |
| ALL SAMPLES . . | 57 | 2·70 | 0·05 |

The Carboniferous limestone and Devonian samples give consistent results with standard deviations of the mean value of 0·03 and 0·04 $g/cm^3$ respectively, but the other rocks show rather large variations in density which, however, are not unexpected. *Table* 2 shows that, for these 57 samples, there is no distinct difference in density between rocks of widely differing ages, the mean being 2·70 $g/cm^3$.

The density of sandstones of every geological age is less than that of the more compact rocks and the details given by JACKSON show this, but the difference is not very large. The density depends on the size and shape of the individual grains which form the sandstone and hence it can be expected to change within wide limits even in the same strata. Furthermore, sandstones are extremely variable in thickness and extent, so that if any formation has a high component of sandstone, it would be almost impossible to give it a mean value of density for a large area.

The Devonian and Carboniferous strata are the only ones which contain great thickness of sandstone, as in the southern part of Ireland, but even here from measurements by JACKSON the sandstone is not much lighter than 2·70 g/cm.$^3$

The older sediments have densities a little greater than later rocks and have also associated with them igneous and metamorphic rocks almost absent in the others. From measurements on samples outside this area the Pre-Palaeozoic rocks are known to have a density greater than 2·73 g/cm.$^3$

To enable the Bouguer anomaly to be interpreted, mean values of the densities have to be arrived at and hence for Central Ireland the rocks were grouped as follows :

| | g/cm.$^3$ |
|---|---|
| Pre-Palaeozoics | 2·75 |
| Ordovician and Silurian | 2·73 |
| Devonian and Carboniferous | 2·70 |

The Devonian is grouped with the Carboniferous but if thick deposits of sandstone should occur, we can expect the density to be less ; about 2·65 g/cm.$^3$ This grouping is in contradistinction to the experiences of COOK and THIRLAWAY (1949), in Wales, who found a marked contrast between the Devonian and the other Palaeozoic and earlier rocks.

With the exception of a small area of Trias near Kingscourt, no other sedimentary rocks occur.

In Wicklow and Galway, to the east and the west of the Central Lowland, considerable masses of granite are known and it is feasible that these could extend further than their outcrops along with separate granite bodies of smaller extent. The Galway and Leinster granites have a density less than 2·65 g/cm.$^3$ (THIRLAWAY, Part 2).

Basic intrusive rocks are scarce in the Central Lowland, but their presence near Navan, Kinnegad, Dublin and near Limerick and Carlingford outside the area, indicate that they cannot be omitted from consideration. These basic intrusives have densities usually greater than 2·80 g/cm.$^3$ but it is almost impossible to obtain a mean density for these from surface samples.

## ATHLONE DISTRICT

Athlone is in the middle of the Central Lowland. From *Folder* 2 it can be seen that the surface rocks are confined to Devonian and Carboniferous strata and the Bouguer anomaly is almost uniform with a mean of 5 mgals. The difference in value of two adjacent stations is never more than 3 mgals., and indicates that there are no large variations in thickness or in density between the different strata.

Bouguer anomaly profiles through Athlone have been drawn in *Figs.* 5 and 6 and the only things of note is the gradual fall in the centre to less than 1 mgal., that is about 5 mgals. lower than the mean value. This is possibly due to a basin in the underlying Silurian floor filled with Devonian or Carboniferous sandstone. The outline of the basin would be somewhat of the shape of the 5 mgal. contour line drawn in *Folder* 2. If the density of the rocks which fill the basin is taken as 2·65 g/cm.$^3$ while the surrounding rocks have a density close to 2·70 g/cm.$^3$, then the basin is about 8,000 feet deep. This is considerable, taking into account what has been said previously about the Devonian strata. The shape, as outlined above, is conformable to the Caledonian strike of the Silurian and the deepest part lies almost exactly between two small anticlines south-east of Athlone, *Fig.* 6. Later in other areas, the possibility that the low Bouguer anomaly is the result not of deep basins of sandstone but of lithologic changes in the Lower Palaeozoics will be discussed, and it is possible that here too the cause does not lie in deep accumulations of sandstone.

## DUBLIN DISTRICT

North-eastwards from Athlone the limestone thins out and eventually the Silurian floor comes to the surface and from *Folder* 2 it is at once apparent that the Bouguer anomaly changes character so that no longer can any mean value be stated.

Near Dublin small areas of Cambrian rocks outcrop, but COLE (1921) suggests that these are the result of overthrusts and do not indicate that the Cambrian is here close to the surface beneath the Ordovician.

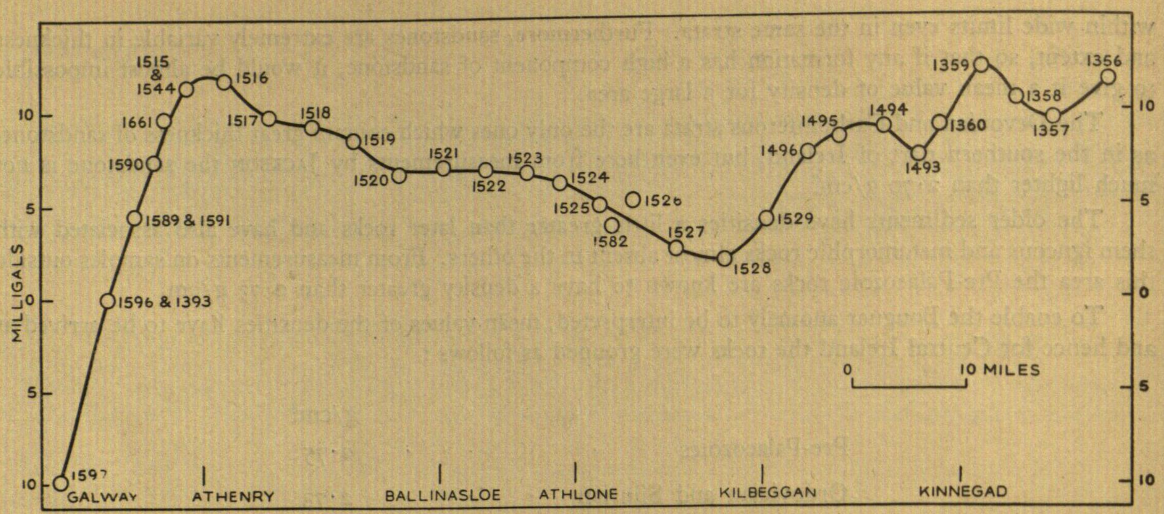


*Fig.* 5.—Bouguer anomaly profile west-east through Athlone.

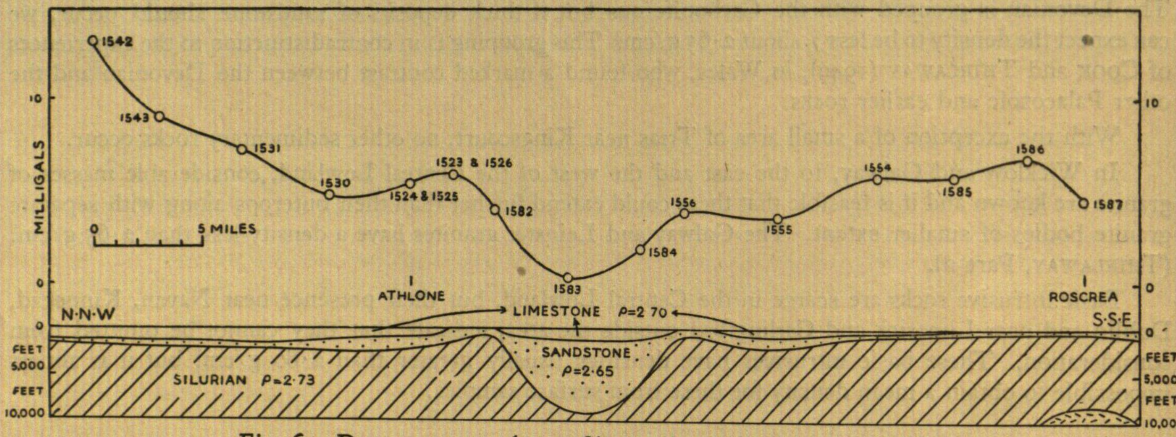


*Fig.* 6.—Bouguer anomaly profile north-south through Athlone.

Thirlaway, in Part 2, discussed the thickening of the Silurian and earlier sediments along the east coast, and, although conditions north of Dublin are not the same as along the south-east flank of the Leinster granite, it is to be expected that the Ordovician-Silurian strata would be thick, have a density similar to those in Wicklow and Wales and hence give rise to a Bouguer anomaly of about the same size. The measured anomaly is not as high as that measured in Wicklow, east of the granite, but it is comparable, being a little over 20 mgals.

The Bouguer anomaly profile of a section through Dublin has been drawn in *Fig.*7. Station 1750 is situated on the Leinster granite batholith and from there the anomaly rises very rapidly to the high value of 30 mgals. just north of Dublin. This abrupt increase indicates that the granite does not extend northwards and must in fact be completely absent below Dublin, stations 1747, 1742 and 1741. This is in disagreement with the theory (Cole and Halissy, 1924, p. 59) that the Leinster granite continues in a NNE direction to reappear at the surface in the tiny island of Rockabill. Turner (1950), on the other hand, supports Du Noyer (1860) and claims that there is a fault contact between the granite and the limestone. This is consistent with the deduction from the gravity data that the contact between the pre-Carboniferous strata and the granite is steep, though not necessarily a fault. The geological interpretation in *Fig.* 7 is drawn on this basis.

North of the granite contact, the anomaly increases to 30 mgals. On *Folder* 2 it can be seen that the area of high anomaly is not very extensive in any direction and is confined to a district where only post-Silurian rocks outcrop. Further north along the traverse, Silurian rocks are encountered and here the anomaly is about 20 mgals. The cause of the increase must lie in rocks denser than either Silurian or Carboniferous that is the density is greater than 2·73 g/cm$^3$. Cambrian rocks with a probable density of 2·75 g/cm$^3$ outcrop in Howth but from what has been said about them previously it is not thought likely that they are present near the surface further west than in this peninsula.

From Lambay island a series of small inliers of Ordovician strata stretch south-westwards to north of Kildare. They contain beds of andesitic ashes and flows and have been considered to represent the

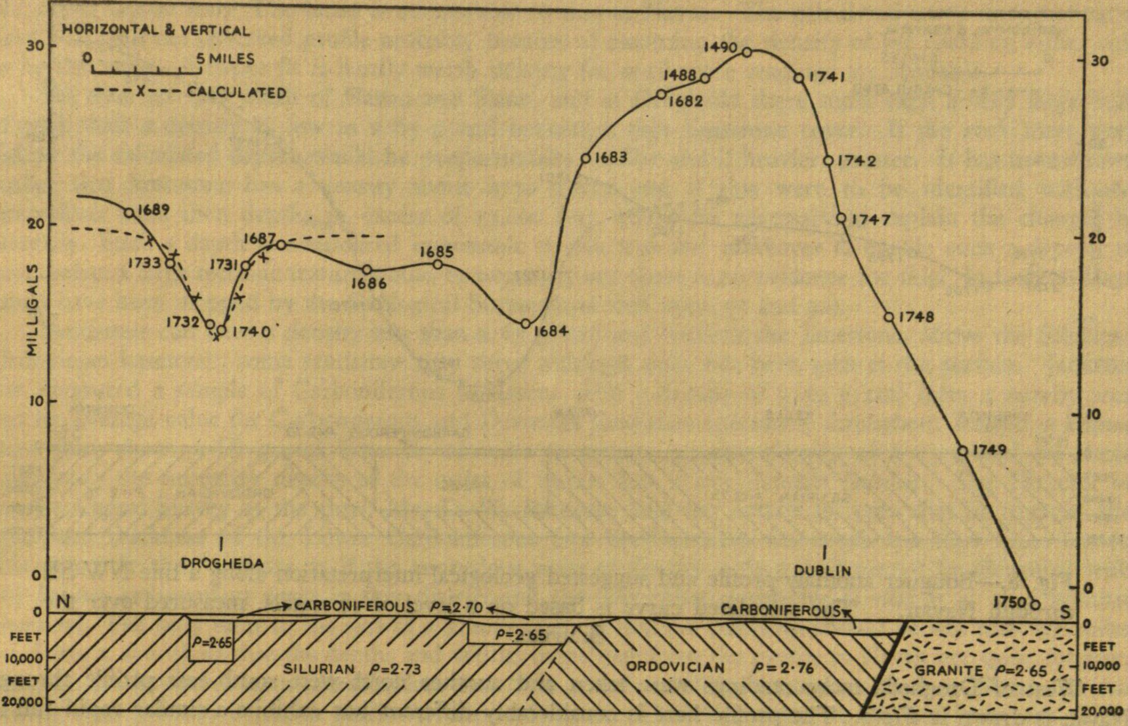


*Fig.* 7.—Bouguer anomaly profile and suggested geological interpretation along a line approximately north-south through Drogheda and Dublin.

crest of an anticline in the Ordovician strata. This occurrence of ingeous activity raises the possibility that dense intrusives may be present and further south in the Ordovician, close to the granite, large areas of basic intrusives do occur. These suggest a possible cause for the high Bouguer anomaly. In *Folder* 3 a magnetic anomaly map (Geological Survey 1949, with some additions by the author) has been combined with the geological sketch map. There are some magnetic effects in the immediate vicinity of the Ordovician anticline but no outstanding anomaly which could be correlated with the area of high Bouguer anomaly. This eliminates the near presence of any large body of basic material such as occurs at Slieve Gullion and Carlingford (Part 4).

The most likely explanation is that the increase in anomaly is produced by Ordovician strata whose density in this district is greater than 2·73 g/cm$^3$ which was taken as the mean, the high density being the result of local igneous activity either by metamorphosis or by intrusion of basic rocks. If the Ordovician and Silurian strata in general had a density greater than 2·73 g/cm$^3$ then it would be expected that the shape of the anomaly contours would have a Caledonian trend, which they have not.

Turner (1950) has shown that the Carboniferous strata at Dublin close to station 1754 is in excess of 1,000 feet but thins out rapidly to the north. This has been followed in the geological interpretation in *Fig* 7, the Carboniferous being put at 3,000 feet rapidly decreasing, for at station 1490 the lighter sediments cannot be more than 1,000 feet thick unless the heavier underlying rocks have a density greater than 2·80 g/cm$^3$, which is unlikely since they are not magnetic and most dense rock materials are.

Progressing north, the anomaly profile shows small irregularities and at station 1684 drops suddenly. It is unfortunate that this is the only reading which shows the rapid decrease and were it not for the fact that just about this station there is known to be a considerable disturbance in the Carboniferous strata (Du Noyer, 1860) this decrease would have been passed over until later confirmation could be obtained.* A return will be made to the feature after the results around Navan have been discussed.

## Drogheda District

Continuing along the profile of *Fig.*7, after the feature at station 1684, the anomaly remains at a steady value, but at station 1687 falls rapidly by about 6 mgals., increases just as rapidly and then more slowly. The latter rise is partly due to the area of large positive anomaly north of Dundalk. The lowest value of the anomaly was measured in the town of Drogheda. Here, because of the presence of factories built on alluvium, the ground was in continual unrest and it was extremely difficult to obtain satisfactory readings. It was also because of this that the feature could not be worked out in more detail.

******Added in proof :* **Recent work has confirmed the decrease in the Bouguer anomaly in this region.**

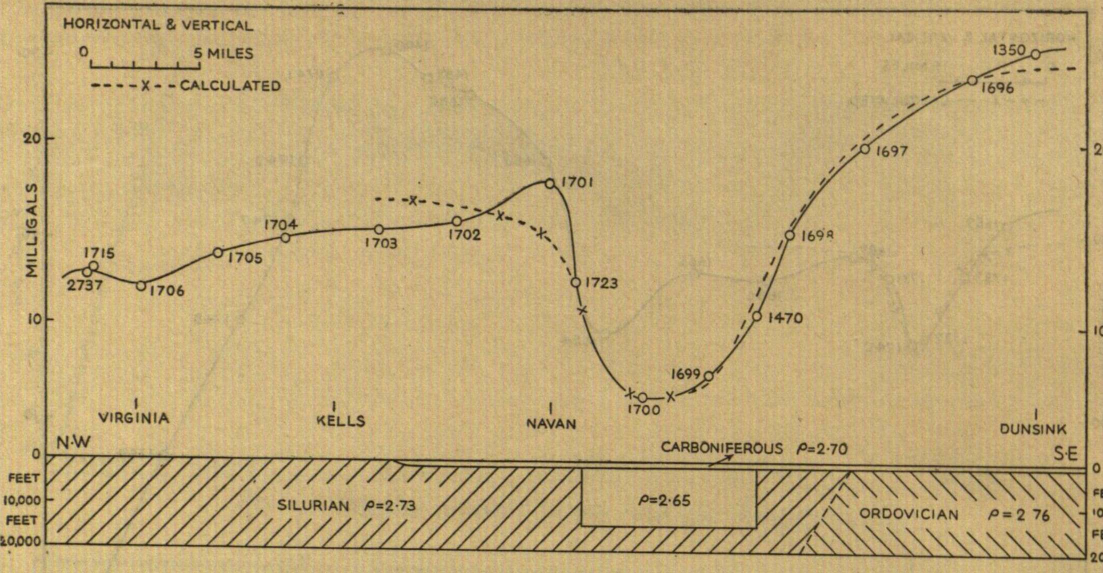


*Fig.* 8.—Bouguer anomaly profile and suggested geological interpretation along a line NW-SE through Navan. The calculated curve is based on a level of 17 mgals. measured over the Silurian.

West of Drogheda more readings were taken and another north-west south-east profile through Navan is drawn in *Fig.*8. The profile here is considerably different but exhibits a similar rapid fall in anomaly. Halfway between these sections, at Slane, the steep gradient of 16 mgals. in 5 miles was measured between stations 1736 and 1739.

A line drawn from Navan to Drogheda (*Folder* 2) marks the southern limit of the main mass of Silurian strata which stretches from here to Belfast. South of this line Carboniferous limestone outcrops and there is no indication of the thickness of the Carboniferous rocks nor of the presence of Devonian sediments. It was thought that south of Slane a small basin occurs in the Silurian basement which is filled with Carboniferous sediments.

The very rapid fall in the Bouguer anomaly means that here there is a sharp contrast in density between two rock masses. The density of the Silurian is about 2·73 $g/cm^3$ and that of the Carboniferous limestone about 2·70 $g/cm^3$ This is not sufficient density contrast to produce a gradient of 3 mgals. per mile, as measured at Slane, and hence beneath the limestone there must be a large deep mass of rock considerably lighter than either of these and for preliminary calculation we will assign to it a density of 2·65 $g/cm^3$ The profiles, neither at Drogheda nor at Navan, are symmetrical, indicating that a simple distribution of density will not be sufficient and so only a rough attempt can be made to deduce the probable extent of the anomalous mass.

At Navan the thickness of the limestone is taken to be 1,000 feet or less and since it covers both the denser rocks, presumably Lower Palaeozoics, and the lighter ones this thickness will not seriously affect the calculations. By trial and error it was found that the decrease in the anomaly could be fairly well accounted for by a mass of rock, density 2·65 $g/cm^3$, with a rectangular cross section (extending infinitely in the directions perpendicular to the profile) emplaced in a country rock with a density of 2·73 $g/cm^3$ (HEILAND, 1946, p. 152). The cross section dimensions were calculated as: width 8 miles, depth 14,000 feet. It has further to be assumed that rock formations of density 2·76 $g/cm^3$ occur south of the anomalous mass. This would apparently be the westerly extension of the denser Ordovician already inferred from *Fig.*7. The position of the anomalous mass and the calculated effect is drawn in *Fig.*8.

The calculated values fit reasonably but not very well with the measured values. The disagreement probably arises in assuming that the densities of the Lower Palaeozoics lie within the range 2·73 to 2·76 $g/cm^3$ At station 1701 in *Fig.*8 and at the adjacent stations 1737 and 1736 there are obviously some other rock masses not accounted for in this simple analysis. At Slane the readings are too few to enable further information to be added.

Returning to *Fig.*7, it can be seen that the fall in the anomaly at Drogheda cannot be produced by the simple extension eastwards of the anomalous mass encountered south of Navan. It would be much too wide and the size of the anomaly on the south is less than that on the north in contradistinction to the profile through Navan. Assuming again a density of 2·65 $g/cm^3$ for the lighter rocks, 2·73 $g/cm^3$ for the denser Lower Palaeozoics and a rectilinear cross section, the width is calculated as 2 miles and the depth 10,000 feet. The latter is comparable to that at Navan. The calculated curve does not agree very well with the observed profile probably because of assuming the density of the rocks on either side to be the same. A closer fit is hardly worth striving for until more readings are available.

We thus see that south of Navan and Slane, and at Drogheda there must exist a very large bulk of rock with a density as low as $2 \cdot 65$ g/cm$^3$ beneath a thin limestone cover. If the rock mass were lighter the calculated depths would be proportionally smaller and if heavier, greater. It has been shown earlier that limestone has a density about $2 \cdot 70$ g/cm$^3$ and if this were to be identified with the anomalous mass then depths in excess of 15,000 feet would be necessary to explain the changes of anomaly. Such a depth is considered impossible in this area and moreover to enable such a deposit to accumulate a large tectonic feature would be necessary and there is no evidence for this. In fact, no large faults have been mapped by the Geological Survey (one inch maps 91 and 92).

Sandstone can have a density less than $2 \cdot 65$ g/cm$^3$ and beneath the limestone, above the Silurian-Ordovician basement, some sandstone may occur although none has been seen at the surface. JACKSON has measured a sample of Carboniferous sandstone with a density of $2 \cdot 59$ g/cm$^3$ from a nearby area but his average value for Carboniferous and Devonian sandstone specimens throughout Ireland is higher than this, about $2 \cdot 68$ g/cm$^3$ Even if we were to assume a mean density of $2 \cdot 65$ g/cm$^3$ for these sandstones the necessary depths of the order of 10,000 feet is not thought feasible. The Director of the Geological Survey at the time, Mr. D. W. BISHOPP, told the author in 1950 that he thought the combined thickness of the Lower Carboniferous and the Devonian was much less than 1,000 feet in this area. It then appears as if the anomalous mass of density $2 \cdot 65$ g/cm$^3$ cannot be identified with any known sedimentary rocks in this district and the only other possibility is that it is of a granitic character. The only limit to the size of a granite mass is that the thickness should be less than ten miles (cf. Parts 2 and 4) so that the depths and widths calculated from the profile at Navan are quite feasible. Granites are known to have densities less than $2 \cdot 60$ g/cm$^3$ and if the anomalous mass at Navan has this density then it would be rather shallower than calculated. However, since we do not know the thickness of the Carboniferous sediments, the calculated values are near enough. With more measurements it should be possible to arrive at more accurate figures.

The small island of Rockabill, four miles from the coast, eight miles east of station 1685, is composed of granite and this is the only outcrop of granite in the district under discussion. Although it has been suggested (see earlier) that it was connected to the Leinster granite, there is very little geological evidence to support this.

Another approach to the problem can be made by referring to the magnetic map of *Folder* 3. A fairly large positive anomaly can be seen centred on Drogheda but, because of the town, no readings could be taken there and hence the magnetic profile along the route of the gravity survey cannot be drawn. There is no direct relationship between the magnetic anomaly and the gravity feature which would be quite understandable if the cause of the disturbances was granite, since the latter is usually not magnetic, but has often associated with it, at its boundaries, rocks with high non-uniform susceptibilities which give rise to anomalies with large gradients. In this district there is some indication of magnetic gradients greater than those encountered over similar Silurian or Carboniferous strata elsewhere in Ireland but, as yet, the number of magnetic stations is too small and the large anomalies to the north provide some complication. It is hoped to carry out a magnetic survey in this district soon.

When discussing the profile of *Fig.*7, the rapid fall in anomaly at station 1684 was mentioned. Even if this reading were ignored, the change in anomaly thereabouts is still quite abrupt. JACKSON has measured several samples of both Devonian and Carboniferous rocks taken from the coast section east of this station. The density range is from $2 \cdot 59$ g/cm$^3$ for a sandstone to $2 \cdot 78$ g/cm$^3$ for a conglomerate, both Carboniferous. The mean density is $2 \cdot 71$ g/cm$^3$ The total thickness of Lower Carboniferous is estimated as 2,000 feet (COLE and HALISSY, p.29). There is no great thickness of sandstone showing so that here, more than at Navan, the decrease in the Bouguer anomaly cannot be attributed to the Devonian and Carboniferous rocks.

Evidence of a different kind, that the areas of low Bouguer anomaly being discussed are not caused by deep deposits of sedimentary rocks can be deduced from COLE (1922). This publication, concerning the occurrence of mineral deposits in Ireland, records that copper ore has been raised at Beaupark, Brownstown and Loughshinny, all of which are within the areas of low anomaly, but at nowhere else in the neigbourhood. The lodes consist of copper pyrites and quartz with a little lead in Carboniferous limestone. This is rather significant and would be very unlikely if at each of these places there were thick deposits of sandstone underlying the limestone. On the other hand, the presence of granite close to the surface suggests a cause for the mineralization.

It is then thought that in the small area at station 1684 and in the larger ones near Navan and Drogheda, the low Bouguer anomaly must be due to the presence of granite in the underlying Ordovician-

Silurian strata. If the 10 mgal. contour south-east of Navan is taken to approximate to the outline of the hidden granite then its longer axis is oriented with a Caledonian trend in agreement with the Lower Palaeozoics. At Drogheda it must thin out into a narrow " tongue " near the surface. Because of the complicated nature of the gravity profile and the uncertainty in the densities it is not possible to estimate the thickness of the overlying limestone. At Loughshinny the granite is possibly part of the mass which outcrops in Rockabill because this is the direction of the Caledonian folding. The relationship between the suggested granite masses cannot be deduced from the present survey nor from the magnetic map. The high value of the anomaly north of Dublin rules out the possibility that they are connected with the Leinster granite down to a depth of about six miles.

North-west of Navan some igneous rocks containing both acidic and basic types are shown in the geological map and reference has been made to the igneous rocks in the Ordovician inlier opposite Lambay. These lie very close to the boundaries of the granite masses deduced from the gravity data ; a phenomenon which will be encountered later in other areas, particularly near the Galway granite. This juxtaposition is a noteworthy feature of the Newry granite and the Slieve Gullion Complex discussed in Part 4.

On *Folder* 3 there is a very well marked magnetic anomaly, now known as the " Virginia anomaly " as the highest value of the anomaly was measured in the vicinity of that town, the contours are smooth and widespread, indicating that the cause of the disturbance is deep. The alignment is roughly in the direction of the Caledonian folding. It was thought that a large-scale intrusion of basic rock beneath the Lower Palaeozoics was responsible and later work showed that it was definitely not connected with the Carlingford Igneous Complex which is of Tertiary age.

A basic intrusive large enough to produce this magnetic anomaly should have a density in excess of 2·8 g/cm³ and could be expected to cause an increase in the Bouguer anomaly similar to the effect of the Carlingford Complex discussed in Part 4. *Fig.* 8 shows that, on the contrary, there is no increase in the Bouguer anomaly actually a slight decrease, but the latter bears no similarity to the magnetic contours. This can be seen on a larger scale by comparing *Folders* 2 and 3. This negative result means that there is no comparable anomalous mass as encountered at Carlingford and it leaves the interpretation of the magnetic anomaly open. It may be that the cause is still a basic intrusive very strongly magnetised but of such a size as not to be detected gravimetrically. If such were the case, the depth would be very great, probably in excess of twenty miles.

### Dundalk District

North of Drogheda on the Silurian rocks, with a little Ordovician showing, the Bouguer anomaly has a value which increases slowly and then more rapidly as Dundalk is approached until north-east of this town a value of +45·9 mgals. was measured. It was presumed, at the time the measurements were taken, that this high value was connected with the remarkable Carlingford Igneous Complex and since this area had not been included in our plans it was decided to forego further measurements. A later survey, described in Part 4, investigated the gravity anomaly in this district and bore out the supposition concerning the rise in the Bouguer anomaly.

### Granard District

If the rise of anomaly due to the Carlingford Complex is allowed for roughly, the anomaly measured over the Silurian area is in the region of 20 mgals. In the adjoining area, in Northern Ireland, a similar value is measured over the Lower Palaeozoics. However, in *Fig.* 9, a section drawn from Longford to Kingscourt, the anomaly measured over the same Lower Palaeozoics is not constant and, in general, is much lower than 20 mgals. The smooth shape of the profile and the lack of any correlation between it and the surface geology suggests that the fall in the anomaly is produced by the rocks under the Lower Palaeozoics. Beneath the Ordovician, one would expect to find the crystalline basement rock of the Pre-Cambrian. North of the area the Dalradian is known to have a density about 2·75 g/cm³ and in the west of Ireland, on Dalradian, the Bouguer anomaly is in agreement with this value of density and hence the low value at Granard is unlikely to be produced by Dalradian rocks.

Geologists have long supposed (Cole and Halissy, 1924, p. 60) that the Newry granite continued in a south-westerly direction to form a core, similar to the Leinster granite, under the Lower Palaeozoics. Such a continuation would pass beneath Granard roughly in the position of the minimum of the Bouguer anomaly. The geological interpretation in *Fig.* 9 follows this supposition, but it is impossible to deduce any dimensions from the few measurements available. A simple continuous granite axis from the Newry granite is ruled out by the high values of the anomaly measured between Virginia and Cavan (Part 4). The connection, if any, between the low Bouguer anomaly and the granite outcrop near Crossdoney is not known.

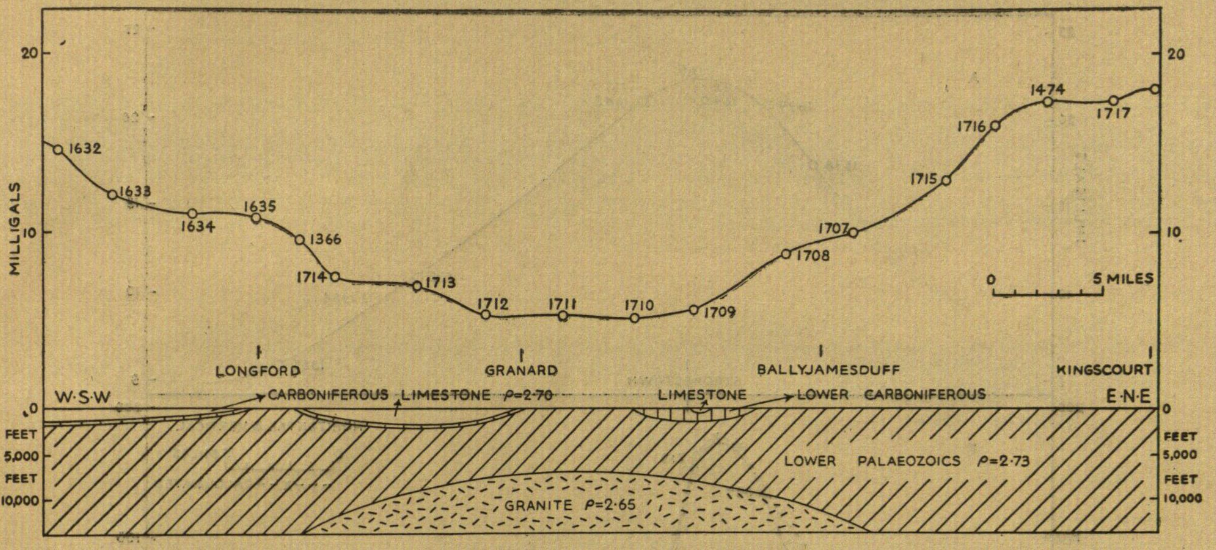


*Fig.* 9.—Bouguer anomaly profile along a line WSW-ENE from Longford to Kingscourt. In the geological cross-section the granite mass is not to scale.

## Strokestown District

Up to now we have been dealing with that part of the Central Lowland east of the River Shannon because it formed an area where the geology of the country is apparently straightforward. West of the Shannon the Carboniferous limestone gives to the district an appearance exactly the same as that of the rest of the limestone-covered Lowland and effectively obscures all signs of the underlying structure to the despair of the geologists who endeavoured to link the tectonics of Scotland with those of the West of Ireland. That a change occurs in the rocks beneath the limestone in this region is well brought out in the magnetic map of *Folder* 3. If a line is drawn from Galway to Longford, it can be seen that it forms a boundary between the south-east where the anomalies cover large areas, characteristic of deeply placed sources and the north-west where the anomalies are smaller in size and more intense, indicative of disturbing magnetic rocks closer to the surface. Since unmetamorphosed sedimentary rocks are, in general, non-magnetic it is apparent that the line drawn on the map marks a change in lithology of the rocks which constitute the floor beneath the Devonian strata. If the same line is drawn on the Bouguer anomaly map, it can be seen that there is a corresponding change, but the boundary is not as obvious.

During the magnetic survey a pronounced magnetic anomaly, later to become known as the " Strokestown Anomaly", was encountered. It is well shown in *Folder* 3. East of Strokestown there is a series of anticlines showing Carboniferous, Devonian and Silurian strata. The structure is not simple and the axes do not conform to the Caledonian or Armorican foldings. The Silurian rocks have the Caledonian strike, while on the west flank the Carboniferous and Devonian rocks dip steeply to the west, but further west the limestone is quite flat. No fault is drawn on the one-inch maps 78 and 88 of the Geological Survey.

With these facts in mind, a few measurements of gravity were made in the present survey as exploratory readings to see if there was anything unusual which could be correlated with the magnetic anomaly. Quite a remarkable similarity between the two surveys showed up, as can be seen by comparing *Folders* 2 and 3.

In *Fig.* 10 the Bouguer anomaly profile and the magnetic anomaly profile (Vertical Intensity) are shown one above the other along a traverse through Strokestown. A nearly parallel traverse from Ballyhaunis to Roscommon is shown in *Fig.* 11. At first it would seem that the increase in the Bouguer anomaly takes place with a corresponding increase in the magnetic anomaly and this would explain the similarity of the features in *Folders* 2 and 3. However, neither the magnetic anomaly nor the gravity field are quite simple and it will be shown that the similarity between the profiles is in the nature of a coincidence, but may be the results of a common cause.

The left-hand side of both *Figs.* 10 and 11 is towards the west and the present Magnetic Declination in this area is approximately 14° West (*Geophysical Bulletin* No. 2). Induction in the earth's field then, of a body with its longer axis oriented perpendicularly to the profiles, would be expected to show an increase of vertical intensity to the right of a decrease; in other words, the opposite to what is measured. The rock mass producing the magnetic effects must then be polarised in some direction

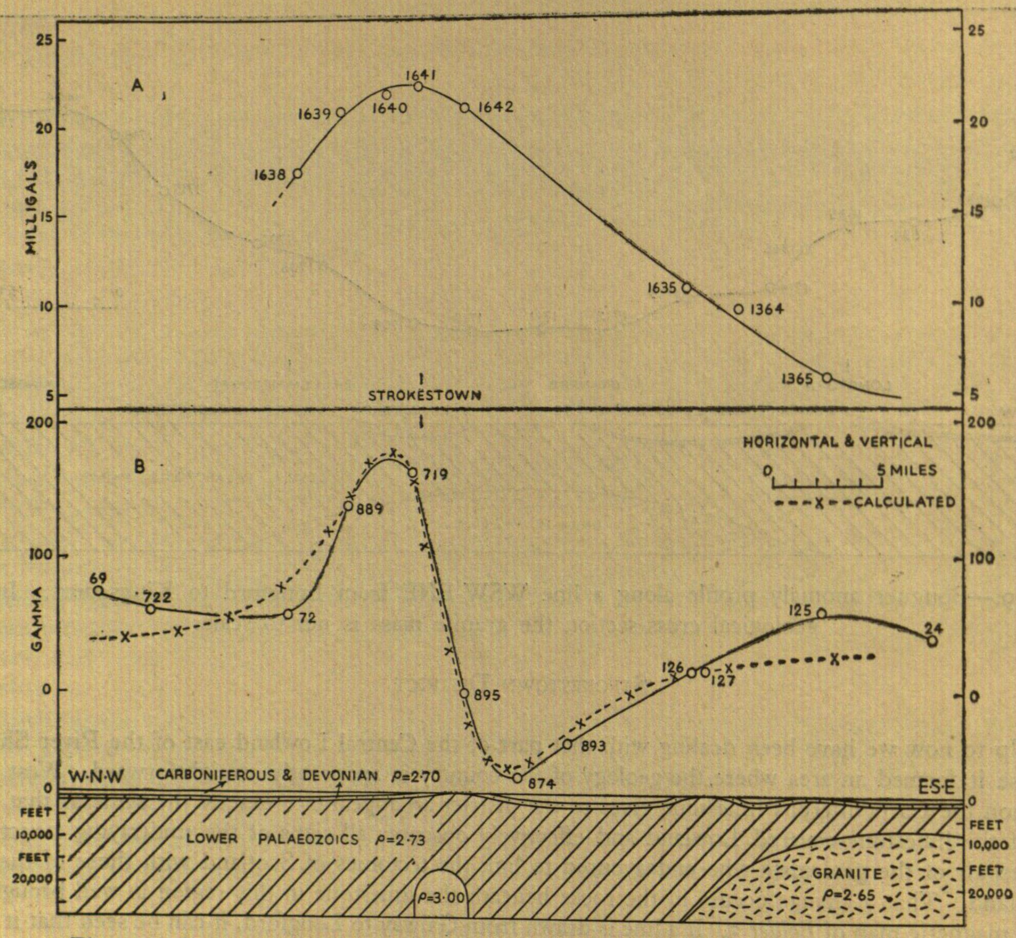


*Fig.* 10.—Bouguer anomaly and vertical magnetic anomaly profiles along a line approximately west-east through Strokestown. The base line for the calculated magnetic anomaly is taken at 30 gamma. The data for the magnetic profile was supplied by the Geological Survey of Ireland.

different from that of the present earth's field. It is probably similar to the magnetically polarised basaltic intrusives of Tertiary age which are fairly common in Ireland (Note on Magnetic Map) and nearby in England and Scotland (Bruckshaw and Robertson, 1949).

Since the magnetic anomaly has a linear extension of at least 25 miles, it is assumed, for the purposes of calculation, that the intrusive body producing the anomaly can be approximated to an infinitely long horizontal cylinder uniformly polarised. By trial and error, the position and depth of such a cylinder which would give magnetic profiles similar to those measured were estimated (Heiland, p. 392). The calculated profiles are shown by the broken lines in *Figs.* 10 and 11.

The direction of polarisation perpendicular to the axis of the cylinder points upwards to the north-west at an angle of 22° whereas the effect of induction in the earth's field would be about 70° downwards to the north. The axis is about 25,000 feet below the surface. This body will produce some induction effects which could be calculated, but it is hardly worthwhile here. To obtain some idea of the dimensions the polarisation of the cylinder is given a value of $1 \cdot 5 \times 10^{-3}$ c.g.s. units/cc. (cf. Bruckshaw and Robertson) in excess of that necessary to obscure the induction effects. The diameter of the cylinder is then calculated as 13,000 feet, which is relatively small. This figure must be treated as very approximate because the strength of the polarisation can only be guessed, but the position and depth of the axis are probably accurate to within a mile.

The calculated position of the axis is almost vertically below the series of anticlines east of Strokestown but from the calculated depth it is hard to visualize any geological connection. A more likely explanation would be that the intrusive body extends upwards as a dyke from a large reservoir. The total effect of the dyke and reservoir would not differ very much from that of the cylinder calculated.

A basic intrusive of the type suggested as producing the magnetic anomaly would be expected to have a density greater than $2 \cdot 70$ g/cm$^3$. If a value of $3 \cdot 00$ g/cm$^3$ is attributed to the cylinder and its diameter taken as 13,000 feet, then an increase of about 6 mgals. in the Bouguer anomaly would be expected.

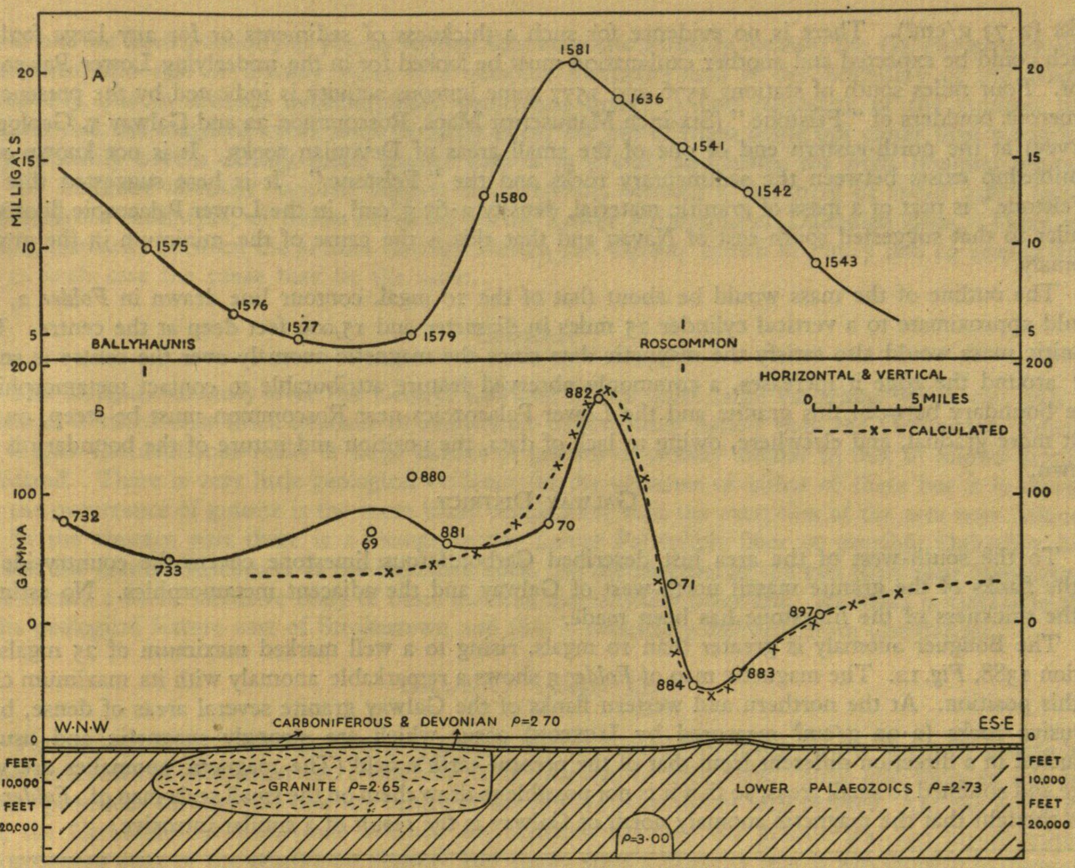


*Fig.* 11.—Bouguer anomaly and vertical magnetic anomaly profiles along a line approximately west-east from Ballyhaunis to Roscommon. As in *Fig.* 10 the base line for the calculated magnetic anomaly is taken at 30 gamma. The data for the magnetic profile was supplied by the Geological Survey of Ireland.

The maximum would occur above the axis of the cylinder, that is between stations 1641 and 1642 in *Fig.* 10 and between stations 1636 and 1541 in *Fig.* 11.

Returning to the Bouguer anomaly profiles of *Figs.* 10 and 11 we have already seen that east of Strokestown the floor beneath the limestone cover consists of Lower Palaeozoic rocks, density 2·73 g/cm³, with probably a granite intrusive so that the Bouguer anomaly is less than 10 mgals. If west of Strokestown, the same Lower Palaeozoic floor, without granite, is close to the surface, then the anomaly could be expected to rise to approximately the value north of Navan, namely about 17 mgals. The measured rise is somewhat greater than this and the difference could then be attributed to the presence of the basic intrusive deduced from the magnetic data. The maxima in the gravity anomaly in both profiles is about two miles west of the position of the axis of the cylinder calculated from the magnetic data, so that the distribution of other rocks must play a part. The gravity measurements are too few to enable a full analysis, such as the application of Poisson's theorem (GARLAND, 1951), to be made.

West of Roscommon, *Fig.* 11, the Bouguer anomaly falls rapidly between stations 1581 and 1579, amounting to 16 mgals. and it is possibly this decrease which makes the maximum at station 1581 appear so well defined. If we take 17 mgals. as a base level for interpreting the Bouguer anomaly, then the higher value at the station 1581 could be attributed to the basic intrusive, but the rapid fall of 12 mgals. must be produced by lighter rocks beneath the limestone. The contrast in densities between the rocks below station 1581 and station 1579 must be considerable and the contact between them must be steep.

At the centre of the low Bouguer anomaly several small areas of Lower Carboniferous and Devonian rocks are shown on the map, *Folder* 2. The structure of these areas is nowhere definite because of the lack of outcrops and the surrounding limestone is flat lying. The rocks consist of conglomerates whose density is probably about 2·67 g/cm³ and, as has been pointed out previously, the deposit is not thought to be thick, certainly not greater than 1,000 feet. A very large thickness, about 10,000 feet, of both Carboniferous and Devonian sediments would have to be present to account for this decrease, even assuming a large density contrast of 0·1 g/cm³ between these sediments (2·63 g/cm³) and the basement rocks (2·73 g/cm³). There is no evidence for such a thickness of sediments or for any large faulting which could be expected and another explanation must be looked for in the underlying Lower Palaeozoic floor. Four miles south of stations 1576 and 1577 some igneous activity is indicated by the presence of numerous boulders of " Felstone " (Six-inch Manuscript Maps, Roscommon 32 and Galway 5, Geological Survey) at the north-eastern end of one of the small areas of Devonian rocks. It is not known what relationship exists between the sedimentary rocks and the " Felstone." It is here suggested that the " Felstone " is part of a mass of granitic material, density 2·65 g/cm³, in the Lower Palaeozoic floor very similar to that suggested south-east of Navan and that this is the cause of the minimum in the gravity anomaly.

The outline of the mass would be about that of the 10 mgal. contour line drawn in *Folder* 2, and would approximate to a vertical cylinder 15 miles in diameter and 15,000 feet deep at the centre. This granitic mass would also satisfy the magnetic data since the magnetic anomaly over the centre is small, but around the edge it increases, a commonly observed feature attributable to contact metamorphism. The boundary between this granite and the Lower Palaeozoics near Roscommon must be steep, on the west more gradual, and elsewhere, owing to lack of data, the position and nature of the boundary is not known.

## Galway District

To the south-west of the area just described Carboniferous limestone covers the countryside up to the flanks of the granite massif north-west of Galway and the adjacent metamorphics. No estimate of the thickness of the limestone has been made.

The Bouguer anomaly is greater than 10 mgals. rising to a well marked maximum of 25 mgals. at station 1388, *Fig.* 12. The magnetic map of *Folder* 3 shows a remarkable anomaly with its maximum close to this position. At the northern and western flanks of the Galway granite several areas of dense, basic intrusive rocks (2·92 g/cm³ measured by Jackson) occur which are strongly magnetic and usually polarised in a direction different from that of the present earth's field (The magnetic anomalies are very large and confined to small areas, so that it is not possible to draw them on the small scale map of *Folder* 3). It is thought that the magnetic anomaly north of Galway is the result of a similar intrusive.

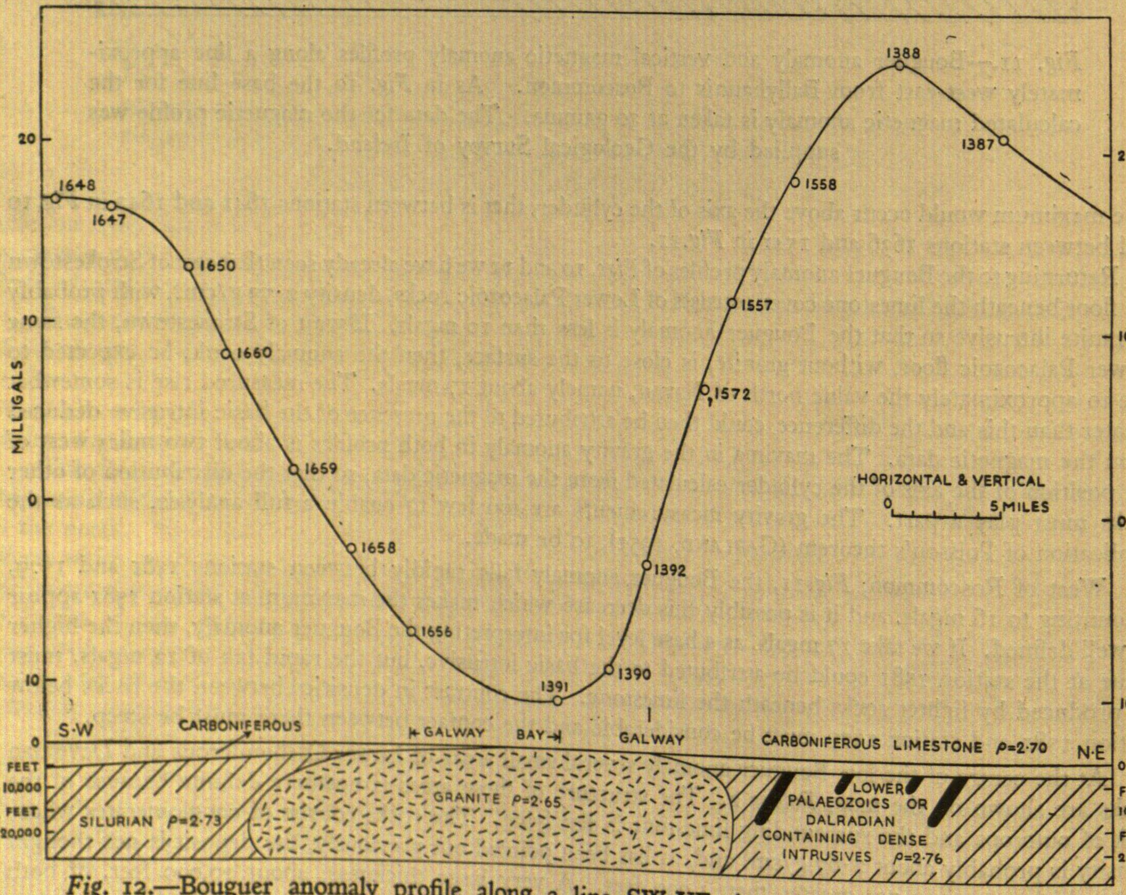


*Fig.* 12.—Bouguer anomaly profile along a line SW-NE through Galway with suggested geological interpretation.

It has not been possible, as yet, to analyse this magnetic anomaly because the Galway granite itself is magnetic and east of Galway there is a complex magnetic field at the boundary of the granite, presumably due to contact metamorphism mentioned before. The regularity of the contour lines indicates that the magnetic rocks must be fairly deep, the top of them being not closer than 3,000 feet. They probably have a density much greater than 2·73 g/cm$^3$, and hence the high Bouguer anomaly and the magnetic anomaly together suggest the presence, beneath a thickness of about 3,000 feet of Carboniferous sediments, of dense intrusives in the Lower Palaeozoic or Dalradian floor. There is a striking similarity between the profiles through Dublin and Galway shown in *Figs.* 7 and 12 respectively, and in each case the cause may be the same.

### Summary

The Bouguer anomaly over the Central Lowland shows quite large variations which can only be explained if there exist thick deposits of sandstones considerably lighter than the Ordovician, Silurian and Upper Carboniferous rocks or large masses of granite of density similar to that of known granites in Ireland. There is very little geological evidence for the presence of either of these but it is thought that the occurrence of granite is the more likely explanation with the exception of the area near Athlone.

In the western part there is a change in the Lower Palaeozoic floor or possibly Dalradian here replaces the Lower Palaeozoics as the basement rock. At the junction of the two parts near Strokestown there occurs a dense intrusive body of basic material magnetically polarised. Its strike is similar to that of the geological feature east of Strokestown and this is noticeably different from Caledonian.

## GALWAY GRANITE

The geology map shows a large area of granite west of Galway bounded on the north by a wide belt of metamorphics of Dalradian age containing large amounts of quartzites. Here and there in this belt granite protrudes through, so that the centre of the granite mass is not well marked. On the north-east side, the Carboniferous Limestone overlaps the junction between the granite and the metamorphics. The southern edge of the granite on Galway Bay shows such a linearity that it was thought to terminate here against a large east-west fault (Cole, 1921).

The Bouguer anomaly on *Folder* 2 is quite well defined and the contours on the north follow the outcrop of the granite, but the outlines indicate that the centre of the mass lies in Galway Bay. The profile drawn in *Fig.* 12 SW—NE through Galway shows this centre fairly well and moreover, indicates that there is a greater area of granite now covered by limestone or water. The eastern edge of this mass is well traced by the contours in *Folder* 2.

Both north and south of the low in *Fig.* 12 rocks of Carboniferous age outcrop. On the south the sediments increase in thickness and at the end of the profile are probably about 5,000 feet (Private communication from Mr. McCluskey, of the Geological Survey, taken from a forthcoming publication). Inferring from the geology to the east, they are underlain by Devonian and Silurian strata. The thickness of the Devonian is not known but at Galway it is probably of the order of a hundred feet. The northern end of the profile has already been discussed and there we saw that the Carboniferous and Devonian deposit is not more than 5,000 feet thick, probably much less. For the upper sediments a density of 2·70 g/cm$^3$ can be taken. There may be a difference in density in the underlying basement rocks but in general these will be about 2·73 g/cm$^3$ Only a few measurements of density of the Galway granite have been made by Jackson. They lie between 2·60 and 2·68 g/cm$^3$ The granite is magnetic and hence is probably not very light. A mean value of 2·65 g/cm$^3$ will be taken and then for simple calculation it can be said to be 0·08 g/cm$^3$ lighter than the surrounding rocks; the Carboniferous rocks will be unimportant.

The base line for estimating the effect of the granite is taken at the 15 mgal. level, the value near the southern end of the profile. The northern end shows an increase which has been attributed to denser materials in the basement rocks but outside this limited area there are stations nearby with values close to 15 mgals. The granite is thus producing a decrease of 26 mgals. and its thickness must be of the order of five miles. Because of the asymmetry of the profile it is not profitable to make detailed calculations.

From Galway eastwards the anomaly rises abruptly, as shown in *Fig.* 5, indicating that the boundary is quite sharp. At this point there are large variations in the magnetic field but the flat-lying limestone obscures the contact completely. On the west, at Maam Cross, station 1612, the anomaly rises abruptly in a similar manner and this is interpreted as being the north-western limit of the main mass of granite which up to here must have a comparable thickness to that at Galway. Further west at Clifden the anomaly falls once more on a small area of granite. The readings here are too few for one to say how large this granite mass is, but at station 1624 the Bouguer anomaly is 2·5 mgals., which is much lower than one would expect and hence it must have a considerable thickness possibly of the order of that at Galway

North-east of this area another smaller area of granite is marked on the geological map. This is close to station 1605 but produced no noticeable effect on the anomaly and so there must be no connection between it and the large masses at Galway or Clifden. Furthermore, north-east of this granite outcrop the anomaly is high, showing that this small patch of granite is not connected with the granite of the Ox Mountains to the north-east either.

The Galway granite is then about twice as large in extent as the mapped outcrop, stretching on the east about eight miles further under the limestone and on the south about ten miles under Galway Bay and under the limestone of North Clare. On the west its boundary has not been reached and at station 1628 it is still as thick as at Galway, so that in all probability it underlies the Aran Islands. If it connects with the granite near Clifden, then this granite massif would rank in size with the Leinster granite.

## WESTPORT AREA

North of the area just discussed the Lower Palaeozoics outcrop up to Clew Bay, where a narrow ridge of metamorphics occur at Westport. The Bouguer anomaly increases steadily towards the north to a value of about 20 mgals. over the metamorphic belt. A further rise takes place until at Castlebar values in excess of 25 mgals. were measured.

There is a good correlation throughout with the Vertical Magnetic field which at Castlebar has a large positive anomaly. Since no gravity readings have been taken north of Castlebar it is not profitable to compare the gravity and magnetic results but it does, at the present, appear as if there is a common cause. From the magnetic map the anomalous rocks must be deep-seated, no nearer the surface than 3,000 feet. Because the anomaly is large they are probably intrusive basic rocks and the effect is very similar to that north of Galway.

## NENAGH AREA

The south-western boundary of the Central Lowland is marked by a range of hills rising to 2,200 feet. They are the northern limits of the intense Armorican folding, and consist of anticlines in the Devonian and Carboniferous rocks with cores of Silurian rocks. The thickness of the Devonian and Lower Carboniferous rocks is not great and does not exceed 1,000 feet. The Silurian consists of grits and slates and its density is about 2·73 g/cm³.

There is no change in the lithology of the above-mentioned rocks from other areas where they outcrop, such as north of Dublin, but the Bouguer anomaly is somewhat lower, being within the range from 4 to 10 mgals., *Folder* 2. There is very little variation from place to place and hence the cause of the low anomaly must have its origin in the deeper-seated rocks.

The gravity and magnetic profiles along a line from Limerick through Nenagh to Roscrea are drawn in *Fig.* 13. The roads along which the surveys were made are not in a straight line but wend their way about the hills. This may have some effect on the profiles. The Bouguer anomaly profile shows a minimum at station 1667 which coincides with a maximum in the vertical magnetic anomaly. Further along, at station 1587, the Bouguer anomaly exhibits another smaller dip corresponding to a small magnetic increase. Turning now to the magnetic map of *Folder* 3, it is apparent that the increase in magnetic anomaly is part of a very large anomalous area. This anomaly, previously noted in 1897 by Rücker and Thorpe in their magnetic survey, must have its origin in some extensive and deeply-placed source and is unlikely to be produced by Silurian or later sediments.

Because of the correspondence between the magnetic and gravity profiles, it is reasonable to assume that the magnetic rocks are also causing the decrease in the Bouguer anomaly, that is they are lighter than the overlaying sediments. A possible cause would be a deep-seated granite batholith similar to the granites in Galway and Carnsore, which are both light and magnetic, but then one would expect a more pronounced fall in the Bouguer anomaly as encountered over the above-mentioned granites. If, however, the anomalous rocks take the form of "granitised" sediments, it is feasible that the resulting density would be less than 2·70 g/cm³ but not as low as 2·65 g/cm³. Such rocks would be appreciably magnetic.

At Silvermines, five miles south of Nenagh, besides silver as the name implies, copper, lead and zinc have been raised (Cole, 1922). The main deposits of ore are connected with the large fault, marked on the map, in the Devonian. Other smaller occurrences nearby point to an extensive mineralisation which can be related to the "granitisation" just deduced.

It is not possible to determine the extent or depth of the anomalous rocks from the gravity data.

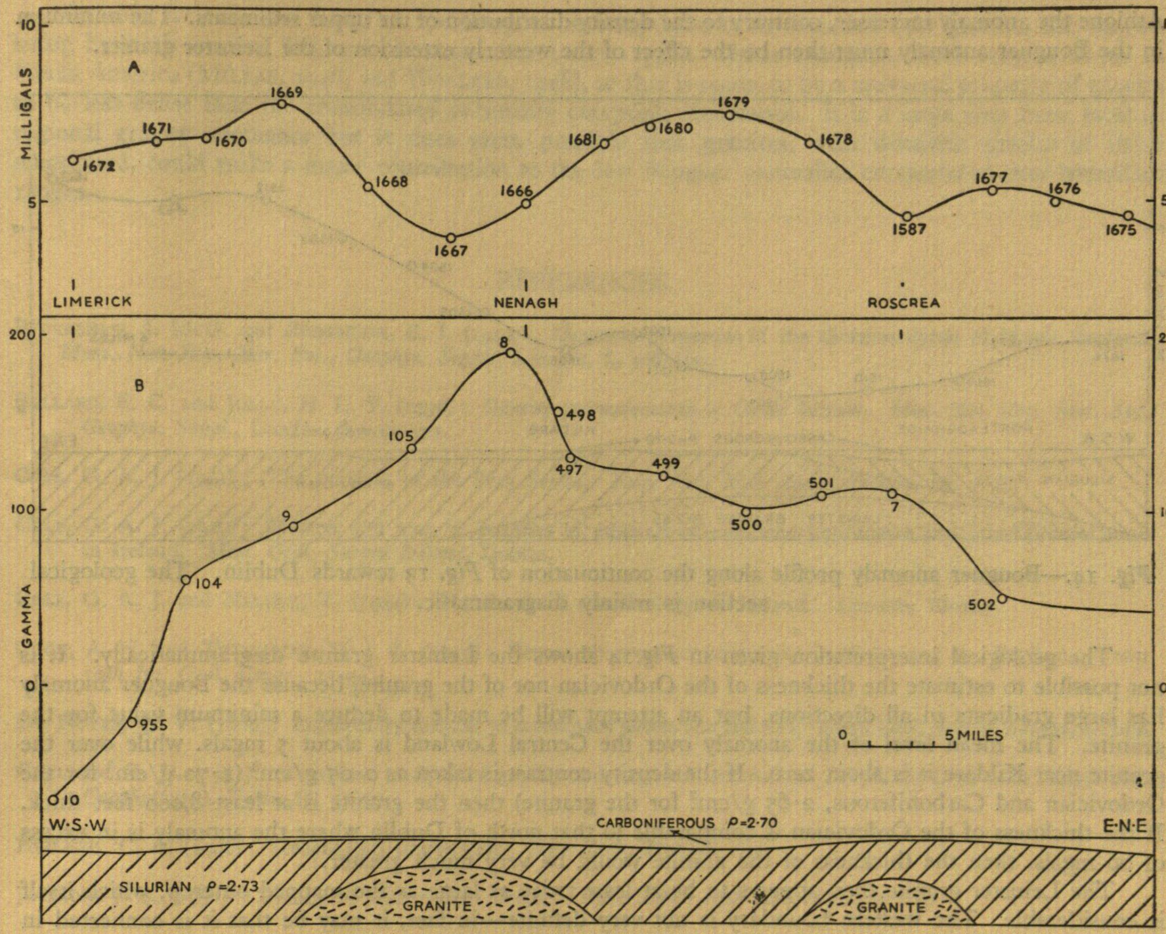


*Fig.* 13.—Bouguer anomaly and vertical magnetic anomaly profiles along a line WSW-ENE from Limerick to Roscrea. The Geological section is diagrammatic and not to scale. The magnetic data was supplied by the Geological Survey of Ireland.

South of Limerick, at the southern limit of the map, basic intrusive rocks are shown. These are of Carboniferous age and take the form of ring-dykes, volcanoes etc. No high Bouguer anomaly was measured hereabouts which is in contrast to the Tertiary intrusive centres north of Dundalk.

## LEINSTER GRANITE

THIRLAWAY, in Part 2, has shown that the Leinster granite has its maximum thickness beneath Carlow. This point is at the western limit of the mapped outcrop, so that the granite must continue out under the Carboniferous sediments. If we assume that it extends as far to the west as it does to the east of Carlow, then one would expect it to reach Portlaoghise (Maryborough). Confirmation that it does extend this far can be inferred from the magnetic map of *Folder* 3 at Abbeyleix, where a positive anomaly is drawn. This cannot be attributed to the Carboniferous sediments and is thought to indicate either a basic intrusive or a metamorphic zone close to the granite.

*Fig.*14 shows the Bouguer anomaly profile from Roscrea to beyond Naas, being the continuation of *Fig.*13. The value decreases fairly steadily until after Portlaoghaise, where the reading is one mgal., and then increases fairly rapidly to the high values encountered over the Ordovician near Dublin. Throughout this distance only Carboniferous rocks, mainly limestone, occur. These cannot be very thick as near Kildare, close to station 1507, there is an inlier of Ordovician rocks. These are the rocks already mentioned as being the south-western limit of an anticline which stretches from here to Lambay Island. They contain andesite with densities as high as 2·90 g/cm$^3$ and sediments with densities greater than 2·73 g/cm$^3$ (cf. JACKSON). The thickness of the Devonian is only about 100 feet (Geological Survey Memoir for sheets 119 and 120) and hence cannot have much influence on he anomaly. Thus density considerations preclude the upper sediments from being the cause of the decrease in the anomaly. This is further supported by the fact that from Portlaoghaise towards the Central limestone basin at

Athlone the anomaly increases, contrary to the density distribution of the upper sediments. The minimum in the Bouguer anomaly must then be the effect of the westerly extension of the Leinster granite.

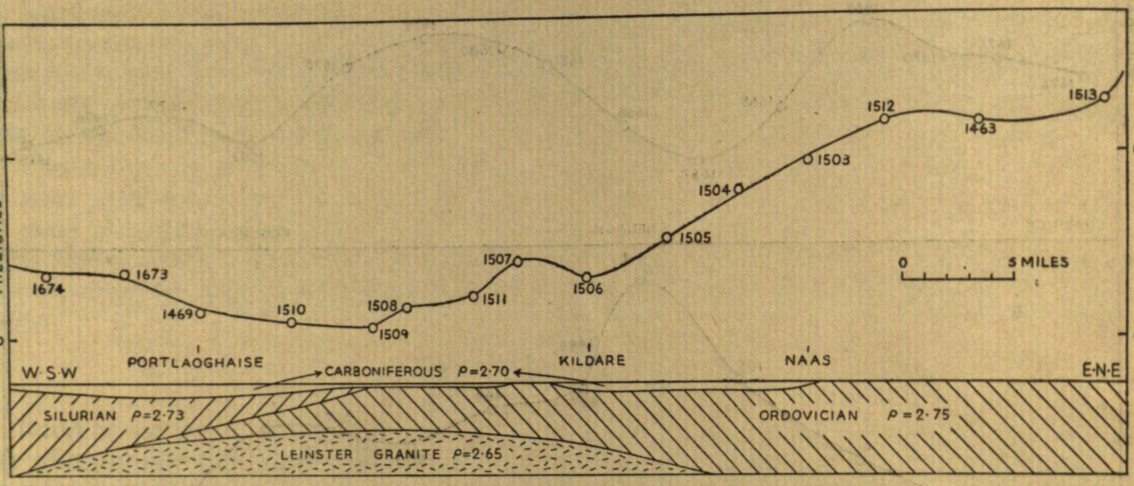


*Fig.* 14.—Bouguer anomaly profile along the continuation of *Fig.* 13 towards Dublin. The geological section is mainly diagrammatic.

The geological interpretation given in *Fig.* 14 shows the Leinster granite diagrammatically. It is not possible to estimate the thickness of the Ordovician nor of the granite, because the Bouguer anomaly has large gradients in all directions, but an attempt will be made to deduce a minimum value for the granite. The mean level of the anomaly over the Central Lowland is about 5 mgals. while over the granite near Kildare it is about zero. If the density contrast is taken as 0·05 g/cm³ (2·70 g/cm³ for the Ordovician and Carboniferous, 2·65 g/cm³ for the granite) then the granite is at least 8,000 feet thick. If the thickness of the Ordovician is comparable to that north of Dublin where the anomaly is in excess of 20 mgals. then the thickness of the granite would be very much greater.

The Leinster granite then appears to be at least twice as large as the mapped outcrop, which itself is considerable. The western boundary is not very definite—in fact, it may be that it is connected in some way with the "granitisation" suggested to have taken place below Nenagh. This is in great contrast to the abrupt ending north of Dublin, discussed earlier, and the sharp boundary on the south-east flank. The different type of contact on the two flanks probably accounts for the fact that the east boundary is characterised by mineralisation which is absent on the west.

Returning to the profile in *Fig.* 14, the small feature observable about station 1507 can be attributed to the Ordovician inlier at the "Chair of Kildare," where dense intrusives are known to occur.

## COMPARISON BETWEEN THE VARIOUS GRAVITY SURVEYS

To date, three gravity surveys have been carried out in Ireland which have been recorded in Parts 2, 3 and 4 of this *Memoir*. The Bouguer anomaly shows a range of 81 mgals. from −25 mgals. over the Leinster granite to +56 mgals. over the Slieve Gullion—Carlingford Igneous Complex. The interpretation of the Bouguer anomaly in Parts 3 and 4 has been based on density determinations made on samples of Irish rocks while that in Part 2 had necessarily to depend on inferred values from the corresponding rocks in England and Wales. This has given rise to completely different interpretations in the area covered by the present survey.

Thirlaway explained the low values of the anomaly he encountered outside the known granite areas as caused by thick deposits of Old Red Sandstone. In Parts 3 and 4 very few of the areas of low anomaly can be attributed to Old Red Sandstone or to Carboniferous Sandstone and the reasons have been given in detail in the appropriate sections. Whichever is correct will have an important bearing on the understanding of the morphology of Ireland. The present interpretation puts great emphasis on the occurrence of granite below the Upper Palaeozoic rocks, so that the total area underlain by granite would be quite large; while the other explanation, that there are basins of the order of 10,000 feet full of Devonian sediments, would require revision of the estimates of sedimentation and investigation of the tectonics to explain such features. It is hoped that in the future more geophysical measurements will be undertaken in an endeavour to determine which is the correct explanation.

The presence in Ireland of so much granite and its absence in Central Wales and the bordering counties of England may offer an explanation for the different types of sedimentary basins in England and Ireland.

Outside Ireland, low values of the Bouguer anomaly have been recorded over granite, the nearest being in south-western England (BULLARD and JOLLY, 1936). Other examples, more remote, occur in North America (MILLAR, 1946, and WOLLARD, 1948), so that it seems to be a universal property of granite to be less dense than the consolidated sediments excepting sandstones. It is a large step from local to regional gravity anomalies but it does seem possible that granites, with densities similar to those mentioned, could make a major contribution to the low Bouguer anomalies encountered over mountain ranges.

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DUBLIN,
JANUARY 31, 1952

## APPENDIX

### Details of Gravimeter Stations and Gravity Values

| Station Number | Six Inch Map Sheet Number | | Latitude N | Longitude W | Height above M.S.L. | g(Station) minus g(Dunsink) | Bouguer Anomaly |
|---|---|---|---|---|---|---|---|
| | | | ° ′ ″ | ° ′ ″ | ft. | mgals. | mgals. |
| 1488 | Dublin | 14 | 53 25 49 | 6 14 43 | 223·0 | 9·8 | 28·8 |
| 1489 | Dublin | 14 | 53 23 46 | 6 18 14 | 205·5 | 6·1 | 26·8 |
| 1490 | Dublin | 14 | 53 23 50 | 6 14 40 | 183·0 | 11·0 | 30·2 |
| 1491 | Dublin | 15 | 53 23 05 | 6 08 31 | 14·5 | 18·4 | 28·7 |
| 1492 | Dublin | 15 | 53 22 51 | 6 03 59 | 222·0 | 0·5 | 23·6 |
| 1493 | Westmeath | 27 | 53 27 00 | 7 12 01 | 266·0 | − 12·1 | 7·6 |
| 1494 | Westmeath | 33 | 53 25 52 | 7 16 07 | 314·5 | − 15·2 | 9·1 |
| 1495 | Westmeath | 33 | 53 23 45 | 7 21 21 | 409·0 | − 24·3 | 8·6 |
| 1496 | Westmeath | 38 | 53 22 28 | 7 25 19 | 297·0 | − 20·4 | 7·7 |
| 1497 | Offaly | 9 | 53 19 50 | 7 30 42 | 254·0 | − 23·9 | 5·3 |
| 1498 | Offaly | 17 | 53 15 59 | 7 29 12 | 205·5 | − 26·5 | 5·5 |
| 1499 | Offaly | 25 | 53 13 17 | 7 28 29 | 275·0 | − 34·4 | 5·6 |
| 1500 | Leix | 1 | 53 11 51 | 7 25 12 | 298·0 | − 38·2 | 5·2 |
| 1501 | Leix | 3 | 53 08 22 | 7 21 46 | 242·0 | − 41·2 | 3·9 |
| 1502 | Leix | 8 | 53 05 38 | 7 20 10 | 261·0 | − 48·3 | 1·8 |
| 1503 | Kildare | 19 | 53 12 58 | 6 39 49 | 309·0 | − 32·9 | 9·5 |
| 1504 | Kildare | 18 | 53 12 23 | 6 44 40 | 290·5 | − 34·2 | 8·0 |
| 1505 | Kildare | 23 | 53 10 06 | 6 48 50 | 335·5 | − 42·9 | 5·4 |
| 1506 | Kildare | 22 | 53 09 19 | 6 54 22 | 347·5 | − 46·8 | 3·3 |
| 1507 | Kildare | 22 | 53 09 49 | 6 59 53 | 262·0 | − 40·1 | 4·2 |
| 1508 | Leix | 9 | 53 07 21 | 7 06 14 | 237·0 | − 44·6 | 1·7 |
| 1509 | Leix | 9 | 53 06 26 | 7 08 25 | 270·0 | − 49·0 | 0·6 |
| 1510 | Leix | 13 | 53 04 08 | 7 12 57 | 310·5 | − 54·4 | 1·0 |
| 1511 | Kildare | 27 | 53 06 16 | 7 00 53 | 229·0 | − 45·0 | 2·4 |
| 1512 | Kildare | 19 | 53 14 47 | 6 35 32 | 323·5 | − 29·1 | 11·6 |
| 1513 | Dublin | 21 | 53 18 46 | 6 23 25 | 262·0 | − 18·5 | 12·8 |
| 1514 | Galway | 95 | 53 16 34 | 8 51 13 | 57·0 | − 12·3 | 9·9 |
| 1515 | Galway | 84 | 53 17 13 | 8 46 39 | 134·0 | − 12·8 | 13·1 |
| 1516 | Galway | 96 | 53 16 18 | 8 41 39 | 125·0 | − 14·9 | 11·8 |
| 1517 | Galway | 85 | 53 17 04 | 8 36 10 | 169·0 | − 18·4 | 9·8 |
| 1518 | Galway | 86 | 53 17 35 | 8 30 29 | 272·0 | − 24·3 | 9·3 |
| 1519 | Galway | 86 | 53 19 32 | 8 25 20 | 387·5 | − 29·1 | 8·6 |
| 1520 | Galway | 87 | 53 19 41 | 8 19 15 | 187·5 | − 18·9 | 6·7 |
| 1521 | Galway | 88 | 53 19 50 | 8 13 27 | 134·5 | − 14·9 | 7·1 |
| 1522 | Roscommon | 54 | 53 20 12 | 8 07 54 | 231·0 | − 20·4 | 6·9 |
| 1523 | Roscommon | 54 | 53 22 05 | 8 02 50 | 178·0 | − 14·7 | 6·8 |
| 1524 | Roscommon | 52 | 53 24 27 | 7 59 03 | 150·0 | − 10·2 | 6·2 |
| 1525 | Westmeath | 29 | 53 24 52 | 7 53 50 | 160·0 | − 11·5 | 4·9 |
| 1526 | Westmeath | 30 | 53 23 32 | 7 49 06 | 240·0 | − 17·9 | 5·2 |
| 1527 | Westmeath | 30 | 53 23 42 | 7 43 18 | 229·0 | − 19·7 | 2·6 |
| 1528 | Offaly | 2 | 53 23 54 | 7 36 46 | 207·5 | − 18·6 | 2·1 |
| 1529 | Westmeath | 38 | 53 22 18 | 7 30 53 | 220·0 | − 19·5 | 4·2 |
| 1530 | Roscommon | 49 | 53 27 29 | 7 59 50 | 139·0 | − 6·6 | 4·8 |
| 1531 | Roscommon | 45 | 53 30 44 | 8 03 09 | 259·5 | − 6·7 | 7·3 |
| 1532 | Galway | 70 | 53 21 47 | 8 54 43 | 97·0 | 5·2 | 22·2 |
| 1533 | Galway | 57 | 53 24 20 | 8 49 29 | 226·0 | − 0·6 | 20·6 |
| 1534 | Galway | 58 | 53 26 12 | 8 44 58 | 140·0 | 4·2 | 17·5 |

APPENDIX—continued

| Station Number | Six Inch Map Sheet Number | | Latitude N | Longitude W | Height above M.S.L. | g(Station) minus g(Dunsink) | Bouguer Anomaly |
|---|---|---|---|---|---|---|---|
| | | | ° ′ ″ | ° ′ ″ | ft. | mgals. | mgals. |
| 1535 | Galway | 44 | 53 27 56 | 8 39 59 | 206·0 | − 0·7 | 14·0 |
| 1536 | Galway | 45 | 53 29 19 | 8 34 28 | 245·0 | − 2·8 | 12·2 |
| 1537 | Galway | 46 | 53 28 13 | 8 30 00 | 197·0 | − 0·7 | 13·1 |
| 1538 | Galway | 32 | 53 30 43 | 8 23 58 | 197·0 | 1·7 | 12·0 |
| 1539 | Galway | 33 | 53 31 26 | 8 18 30 | 176·0 | 4·4 | 12·3 |
| 1540 | Roscommon | 41 | 53 34 01 | 8 15 19 | 165·5 | 9·7 | 13·3 |
| 1541 | Roscommon | 39 | 53 37 22 | 8 11 40 | 194·0 | 15·2 | 15·6 |
| 1542 | Roscommon | 42 | 53 36 02 | 8 07 42 | 139·5 | 14·1 | 13·1 |
| 1543 | Roscommon | 42 | 53 33 43 | 8 04 31 | 149·0 | 6·2 | 9·1 |
| 1544 | Galway | 96 | 53 15 01 | 8 46 33 | 81·0 | − 15·2 | 10·7 |
| 1545 | Galway | 104 | 53 12 53 | 8 42 00 | 145·0 | − 19·9 | 12·9 |
| 1546 | Galway | 105 | 53 12 17 | 8 35 45 | 264·0 | − 28·0 | 12·8 |
| 1547 | Galway | 106 | 53 12 47 | 8 29 59 | 260·0 | − 29·2 | 10·6 |
| 1548 | Galway | 106 | 53 11 48 | 8 23 47 | 230·0 | − 30·1 | 9·4 |
| 1549 | Galway | 107 | 53 10 00 | 8 18 07 | 163·0 | − 31·7 | 6·4 |
| 1550 | Galway | 117 | 53 07 32 | 8 14 36 | 168·0 | − 35·1 | 6·8 |
| 1551 | Galway | 127 | 53 05 28 | 8 11 36 | 112·0 | − 33·6 | 7·9 |
| 1552 | Tipperary | 4 | 53 06 42 | 8 06 42 | 209·0 | − 37·9 | 7·7 |
| 1553 | Tipperary | 5 | 53 06 03 | 8 00 30 | 173·0 | − 37·7 | 6·6 |
| 1554 | Offaly | 35 | 53 05 06 | 7 54 53 | 164·0 | − 39·2 | 5·9 |
| 1555 | Offaly | 30 | 53 09 28 | 7 53 00 | 185·5 | − 36·4 | 3·7 |
| 1556 | Offaly | 22 | 53 13 22 | 7 53 05 | 184·5 | − 30·6 | 3·9 |
| 1557 | Galway | 82 | 53 19 45 | 9 01 12 | 27·0 | − 4·3 | 11·5 |
| 1558 | Galway | 69 | 53 22 38 | 9 00 55 | 45·5 | 5·5 | 18·2 |
| 1559 | Galway | 56 | 53 25 54 | 9 03 23 | 51·0 | 7·7 | 16·0 |
| 1560 | Galway | 41 | 53 28 10 | 9 06 27 | 84·0 | 5·5 | 12·5 |
| 1561 | Mayo | 123 | 53 30 59 | 9 10 49 | 108·0 | 9·1 | 13·6 |
| 1562 | Mayo | 121 | 53 34 06 | 9 13 55 | 129·0 | 15·0 | 16·1 |
| 1563 | Mayo | 118 | 53 37 25 | 9 13 17 | 110·0 | 22·4 | 17·7 |
| 1564 | Mayo | 109 | 53 39 59 | 9 15 52 | 68·0 | 31·4 | 20·5 |
| 1565 | Mayo | 99 | 53 43 41 | 9 17 40 | 110·0 | 39·2 | 25·5 |
| 1566 | Mayo | 89 | 53 47 44 | 9 18 50 | 99·0 | 44·3 | 24·1 |
| 1567 | Mayo | 78 | 53 50 56 | 9 17 16 | 143·5 | 48·9 | 26·8 |
| 1568 | Mayo | 79 | 53 50 34 | 9 13 02 | 105·0 | 50·0 | 26·1 |
| 1569 | Mayo | 90 | 53 48 39 | 9 08 26 | 141·5 | 42·3 | 22·4 |
| 1570 | Mayo | 91 | 53 46 43 | 9 04 24 | 181·0 | 32·7 | 18·9 |
| 1571 | Mayo | 101 | 53 43 54 | 9 00 22 | 268·5 | 20·7 | 16·2 |
| 1572 | Galway | 82 | 53 18 29 | 9 01 38 | 62·0 | − 13·0 | 6·7 |
| 1573 | Mayo | 102 | 53 43 14 | 8 56 22 | 208·5 | 22·2 | 15·1 |
| 1574 | Mayo | 102 | 53 44 31 | 8 50 49 | 256·0 | 18·0 | 11·9 |
| 1575 | Mayo | 93 | 53 45 46 | 8 45 48 | 250·0 | 18·3 | 10·0 |
| 1576 | Roscommon | 25 | 53 45 16 | 8 39 50 | 306·0 | 10·4 | 6·2 |
| 1577 | Roscommon | 26 | 53 45 16 | 8 34 53 | 266·0 | 11·5 | 4·9 |
| 1578 | Roscommon | 26 | 53 46 05 | 8 29 27 | 217·0 | 15·9 | 5·2 |
| 1579 | Galway | 2 | 53 42 35 | 8 27 53 | 226·0 | 10·2 | 5·0 |
| 1580 | Roscommon | 34 | 53 41 10 | 8 23 43 | 218·0 | 16·7 | 13·0 |
| 1581 | Roscommon | 35 | 53 39 52 | 8 17 48 | 230·0 | 21·5 | 20·5 |
| 1582 | Westmeath | 35 | 53 21 37 | 7 50 59 | 135·0 | − 15·6 | 4·0 |
| 1583 | Offaly | 6 | 53 18 37 | 7 49 20 | 260·0 | − 31·1 | 0·3 |
| 1584 | Offaly | 14 | 53 15 42 | 7 50 06 | 171·0 | − 28·4 | 1·9 |

APPENDIX—continued

| Station Number | Six Inch Map Sheet Number | | Latitude N ° ′ ″ | Longitude W ° ′ ″ | Height above M.S.L. ft. | g(Station) minus g(Dunsink) mgals. | Bouguer Anomaly mgals. |
|---|---|---|---|---|---|---|---|
| 1585 | Offaly | 38 | 53 02 01 | 7 54 01 | 311·0 | − 52·7 | 5·8 |
| 1586 | Offaly | 42 | 52 59 13 | 7 51 21 | 177·0 | − 47·7 | 6·9 |
| 1587 | Tipperary | 12 | 52 57 28 | 7 47 58 | 327·5 | − 61·4 | 4·6 |
| 1588 | Galway | 94 | 53 16 18 | 8 58 57 | 51·0 | − 21·1 | 1·2 |
| 1589 | Galway | 95 | 53 16 34 | 8 53 21 | 45·0 | − 12·8 | 8·7 |
| 1590 | Galway | 95 | 53 14 59 | 8 50 40 | 56·0 | − 17·0 | 7·4 |
| 1591 | Galway | 95 | 53 13 40 | 8 52 47 | 15·0 | − 23·0 | 0·8 |
| 1592 | Galway | 103 | 53 11 51 | 8 49 46 | 85·0 | − 28·4 | 2·4 |
| 1593 | Galway | 104 | 53 12 15 | 8 47 08 | 116·0 | − 20·3 | 11·7 |
| 1594 | Galway | 104 | 53 10 00 | 8 47 04 | 123·0 | − 28·3 | 7·4 |
| 1595 | Galway | 114 | 53 09 26 | 8 48 23 | 130·0 | − 32·6 | 4·3 |
| 1596 | Galway | 95 | 53 13 57 | 8 57 00 | 35·0 | − 27·4 | − 2·8 |
| 1597 | Galway | 102 | 53 13 11 | 9 01 41 | 20·0 | − 34·6 | − 9·8 |
| 1598 | Galway | 83 | 53 18 15 | 8 55 57 | 87·0 | − 8·1 | 13·5 |
| 1599 | Mayo | 78 | 53 49 12 | 9 22 20 | 146·0 | 43·4 | 23·9 |
| 1600 | Mayo | 88 | 53 48 11 | 9 28 09 | 301·0 | 31·9 | 23·1 |
| 1601 | Mayo | 88 | 53 48 00 | 9 32 50 | 14·5 | 46·9 | 21·3 |
| 1602 | Mayo | 87 | 53 46 45 | 9 38 09 | 43·0 | 42·2 | 20·0 |
| 1603 | Mayo | 86 | 53 46 20 | 9 44 19 | 67·0 | 39·7 | 19·6 |
| 1604 | Mayo | 86 | 53 45 50 | 9 48 37 | 17·0 | 42·0 | 19·8 |
| 1605 | Mayo | 96 | 53 42 08 | 9 48 28 | 218·0 | 23·7 | 18·7 |
| 1606 | Mayo | 106 | 53 38 33 | 9 44 46 | 105·0 | 17·3 | 10·7 |
| 1607 | Galway | 81 | 53 18 49 | 9 08 55 | 34·0 | − 21·4 | − 3·8 |
| 1608 | Galway | 68 | 53 21 20 | 9 12 27 | 39·0 | − 14·4 | − 0·1 |
| 1609 | Galway | 54 | 53 23 50 | 9 15 34 | 39·0 | − 8·2 | 2·5 |
| 1610 | Galway | 54 | 53 25 33 | 9 20 12 | 73·0 | − 10·6 | − 0·5 |
| 1611 | Galway | 53 | 53 25 53 | 9 25 48 | 140·0 | − 17·4 | − 3·7 |
| 1612 | Galway | 38 | 53 27 20 | 9 32 26 | 139·0 | − 10·8 | 0·7 |
| 1613 | Galway | 25 | 53 30 39 | 9 33 51 | 31·0 | 10·0 | 10·3 |
| 1614 | Galway | 25 | 53 32 47 | 9 37 25 | 80·0 | 13·3 | 13·5 |
| 1615 | Galway | 12 | 53 35 44 | 9 41 37 | 14·0 | 19·7 | 11·7 |
| 1616 | Mayo | 115 | 53 36 27 | 9 45 06 | 18·0 | 21·3 | 12·4 |
| 1617 | Galway | 38 | 53 27 15 | 9 38 23 | 191·0 | − 5·6 | 9·1 |
| 1618 | Galway | 37 | 53 28 01 | 9 43 55 | 75·0 | 7·8 | 14·6 |
| 1619 | Galway | 37 | 53 27 57 | 9 49 01 | 72·0 | 5·6 | 12·3 |
| 1620 | Galway | 36 | 53 28 39 | 9 54 39 | 117·0 | 0·1 | 8·5 |
| 1621 | Galway | 35 | 53 29 19 | 10 00 34 | 75·0 | − 1·0 | 3·8 |
| 1622 | Galway | 22 | 53 31 03 | 10 02 23 | 179·0 | − 7·1 | 1·5 |
| 1623 | Galway | 22 | 53 32 59 | 10 05 37 | 123·0 | 7·1 | 9·5 |
| 1624 | Galway | 21 | 53 33 05 | 10 09 45 | 58·0 | 4·1 | 2·5 |
| 1625 | Galway | 53 | 53 24 19 | 9 32 33 | 30·0 | − 18·2 | − 8·8 |
| 1626 | Galway | 66 | 53 21 09 | 9 32 33 | 37·0 | − 23·1 | − 8·7 |
| 1627 | Galway | 78 | 53 17 41 | 9 32 58 | 22·0 | − 27·5 | − 9·0 |
| 1628 | Galway | 91 | 53 14 30 | 9 30 16 | 77·0 | − 35·8 | − 9·5 |
| 1629 | Galway | 92 | 53 14 42 | 9 23 09 | 96·0 | − 32·1 | − 5·0 |
| 1630 | Galway | 92 | 53 14 37 | 9 18 31 | 25·0 | − 30·6 | − 7·5 |
| 1631 | Roscommon | 40 | 53 39 09 | 8 06 32 | 167·0 | 20·5 | 16·7 |
| 1632 | Roscommon | 37 | 53 40 34 | 8 00 19 | 153·5 | 21·2 | 14·6 |
| 1633 | Longford | 17 | 53 40 10 | 7 56 10 | 147·0 | 18·5 | 12·0 |
| 1634 | Longford | 18 | 53 41 25 | 7 51 01 | 159·0 | 18·5 | 11·0 |

APPENDIX—continued

| Station Number | Six Inch Map Sheet Number | | Latitude N | Longitude W | Height above M.S.L. | g(Station) minus g(Dunsink) | Bouguer Anomaly |
|---|---|---|---|---|---|---|---|
| | | | ° ′ ″ | ° ′ ″ | ft. | mgals. | mgals. |
| 1635 | Longford | 13 | 53 43 32 | 7 47 56 | 174·0 | 20·5 | 10·8 |
| 1636 | Roscommon | 39 | 53 39 11 | 8 15 00 | 308·0 | 13·8 | 18·4 |
| 1637 | Roscommon | 35 | 53 42 42 | 8 12 28 | 275·0 | 24·8 | 22·3 |
| 1638 | Roscommon | 22 | 53 46 39 | 8 15 02 | 199·0 | 30·1 | 17·4 |
| 1639 | Roscommon | 28 | 53 45 59 | 8 12 08 | 190·0 | 32·9 | 20·7 |
| 1640 | Roscommon | 29 | 53 46 25 | 8 08 27 | 215·0 | 33·0 | 21·7 |
| 1641 | Roscommon | 29 | 53 46 25 | 8 06 09 | 160·0 | 36·7 | 22·1 |
| 1642 | Roscommon | 29 | 53 45 56 | 8 03 09 | 244·0 | 29·6 | 20·8 |
| 1643 | Clare | 33 | 52 52 27 | 9 02 04 | 75·0 | − 40·1 | 18·0 |
| 1644 | Clare | 32 | 52 52 07 | 9 09 44 | 179·0 | − 44·6 | 20·2 |
| 1645 | Clare | 24 | 52 54 34 | 9 13 51 | 155·0 | − 40·5 | 19·4 |
| 1646 | Clare | 15 | 52 56 19 | 9 17 37 | 67·0 | − 34·5 | 17·5 |
| 1647 | Clare | 15 | 52 56 49 | 9 21 09 | 25·0 | − 32·5 | 16·3 |
| 1648 | Clare | 14 | 52 26 15 | 9 26 54 | 106·0 | − 37·6 | 16·8 |
| 1649 | Clare | 14 | 52 58 49 | 9 25 21 | 524·0 | − 63·1 | 12·8 |
| 1650 | Clare | 8 | 53 00 28 | 9 21 12 | 291·0 | − 46·5 | 12·9 |
| 1651 | Galway | 103 | 53 11 05 | 8 54 34 | 62·0 | − 36·1 | − 5·7 |
| 1652 | Galway | 113 | 53 08 22 | 8 57 10 | 45·0 | − 38·3 | − 4·9 |
| 1653 | Clare | 3 | 53 08 56 | 9 03 10 | 90·0 | − 38·7 | − 3·5 |
| 1654 | Clare | 3 | 53 07 17 | 9 04 16 | 16·0 | − 37·7 | − 4·6 |
| 1655 | Clare | 2 | 53 07 13 | 9 08 10 | 39·0 | − 39·4 | − 4·7 |
| 1656 | Clare | 2 | 53 08 19 | 9 13 23 | 72·0 | − 42·2 | − 7·2 |
| 1657 | Clare | 1 | 53 09 13 | 9 15 47 | 77·0 | − 39·9 | − 5·9 |
| 1658 | Clare | 1 | 53 06 54 | 9 17 11 | 68·0 | − 39·5 | − 2·7 |
| 1659 | Clare | 4 | 53 05 03 | 9 19 33 | 111·0 | − 40·5 | 1·6 |
| 1660 | Clare | 8 | 53 02 45 | 9 20 27 | 295·0 | − 48·3 | 8·1 |
| 1661 | Galway | 95 | 53 15 55 | 8 49 22 | 74·0 | − 14·4 | 9·7 |
| 1662 | Tipperary | 7 | 53 03 20 | 8 08 35 | 173·0 | − 40·0 | 8·3 |
| 1663 | Tipperary | 19 | 52 59 39 | 8 07 38 | 207·0 | − 48·3 | 7·4 |
| 1664 | Tipperary | 15 | 52 56 06 | 8 09 21 | 279·0 | − 59·0 | 6·0 |
| 1665 | Tipperary | 15 | 52 53 34 | 8 11 16 | 192·0 | − 59·4 | 4·2 |
| 1666 | Tipperary | 20 | 52 51 51 | 8 11 59 | 191·0 | − 61·0 | 5·0 |
| 1667 | Tipperary | 20 | 52 50 05 | 8 16 31 | 202·0 | − 64·2 | 4·0 |
| 1668 | Tipperary | 25 | 52 47 44 | 8 21 04 | 305·0 | − 73·4 | 5·4 |
| 1669 | Tipperary | 31 | 52 45 58 | 8 26 16 | 146·0 | − 64·0 | 7·8 |
| 1670 | Limerick | 1 | 52 42 32 | 8 29 22 | 126·0 | − 68·8 | 6·8 |
| 1671 | Limerick | 6 | 52 40 14 | 8 31 19 | 62·5 | − 68·5 | 6·7 |
| 1672 | Limerick | 5 | 52 39 58 | 8 37 24 | 20·0 | − 66·7 | 6·2 |
| 1673 | Leix | 17 | 53 00 25 | 7 22 27 | 340·0 | − 58·8 | 3·7 |
| 1674 | Leix | 17 | 53 00 16 | 7 27 56 | 342·5 | − 59·3 | 3·5 |
| 1675 | Leix | 16 | 52 57 33 | 7 32 05 | 422·0 | − 67·0 | 4·6 |
| 1676 | Leix | 22 | 52 56 25 | 7 36 31 | 360·0 | − 64·5 | 5·0 |
| 1677 | Leix | 21 | 52 57 04 | 7 41 20 | 391·5 | − 65·2 | 5·3 |
| 1678 | Offaly | 45 | 52 55 10 | 7 53 20 | 355·0 | − 64·3 | 6·7 |
| 1679 | Offaly | 46 | 52 52 45 | 7 57 30 | 386·0 | − 68·9 | 7·5 |
| 1680 | Tipperary | 22 | 52 51 05 | 8 01 58 | 408·0 | − 73·0 | 7·2 |
| 1681 | Tipperary | 21 | 52 51 36 | 8 06 01 | 316·0 | − 67·2 | 6·7 |
| 1682 | Dublin | 11 | 53 27 14 | 6 13 20 | 83·0 | 19·4 | 27·8 |
| 1683 | Dublin | 8 | 53 30 07 | 6 11 35 | 14·0 | 24·1 | 24·2 |
| 1684 | Dublin | 8 | 53 32 40 | 6 12 16 | 111·0 | 12·6 | 14·7 |

APPENDIX—continued

| Station Number | Six Inch Map Sheet Number | | Latitude N | Longitude W | Height above M.S.L. | g(Station) minus g(Dunsink) | Bouguer Anomaly |
|---|---|---|---|---|---|---|---|
| | | | ° ′ ″ | ° ′ ″ | ft. | mgals. | mgals. |
| 1685 | Dublin | 5 | 53 36 17 | 6 11 01 | 65·0 | 23·7 | 18·0 |
| 1686 | Meath | 28 | 53 38 27 | 6 14 08 | 63·0 | 26·7 | 17·7 |
| 1687 | Meath | 28 | 53 41 12 | 6 17 46 | 97·0 | 29·8 | 18·9 |
| 1688 | Louth | 24 | 53 42 57 | 6 21 22 | 37·5 | 30·3 | 13·3 |
| 1689 | Louth | 21 | 53 46 14 | 6 23 58 | 406·0 | 20·3 | 20·6 |
| 1690 | Louth | 18 | 53 49 19 | 6 23 35 | 140·0 | 42·8 | 22·8 |
| 1691 | Louth | 15 | 53 52 49 | 6 23 17 | 94·0 | 52·3 | 24·5 |
| 1692 | Louth | 12 | 53 56 10 | 6 22 50 | 14·5 | 66·9 | 29·5 |
| 1693 | Louth | 7 | 54 00 05 | 6 24 17 | 18·0 | 77·3 | 34·6 |
| 1694 | Louth | 7 | 54 01 44 | 6 20 58 | 24·0 | 90·7 | 45·9 |
| 1695 | Dublin | 18 | 53 21 49 | 6 20 52 | 153·0 | 3·1 | 23·5 |
| 1696 | Dublin | 13 | 53 24 23 | 6 24 56 | 194·0 | 4·5 | 23·7 |
| 1697 | Meath | 44 | 53 27 56 | 6 29 27 | 277·0 | 0·9 | 19·9 |
| 1698 | Meath | 44 | 53 30 19 | 6 32 22 | 348·0 | − 4·5 | 15·2 |
| 1699 | Meath | 38 | 53 33 28 | 6 34 35 | 415·0 | − 11·9 | 7·4 |
| 1700 | Meath | 31 | 53 35 57 | 6 36 47 | 177·0 | 4·7 | 6·1 |
| 1701 | Meath | 25 | 53 38 57 | 6 40 46 | 109·5 | 24·8 | 17·9 |
| 1702 | Meath | 24 | 53 41 11 | 6 46 04 | 162·0 | 22·8 | 15·8 |
| 1703 | Meath | 17 | 53 43 06 | 6 50 32 | 167·0 | 24·8 | 15·3 |
| 1704 | Meath | 10 | 53 44 55 | 6 56 30 | 291·0 | 19·5 | 14·8 |
| 1705 | Cavan | 44 | 53 46 35 | 7 00 10 | 337·5 | 18·1 | 13·9 |
| 1706 | Cavan | 39 | 53 49 17 | 7 03 15 | 284·0 | 23·2 | 11·9 |
| 1707 | Cavan | 39 | 53 51 13 | 7 08 33 | 442·0 | 14·6 | 10·0 |
| 1708 | Cavan | 38 | 53 51 23 | 7 13 47 | 248·5 | 24·3 | 7·8 |
| 1709 | Cavan | 38 | 53 49 50 | 7 19 30 | 274·0 | 18·5 | 5·7 |
| 1710 | Cavan | 41 | 53 48 07 | 7 23 15 | 239·0 | 17·5 | 5·2 |
| 1711 | Longford | 11 | 53 46 57 | 7 27 28 | 413·0 | 5·6 | 5·3 |
| 1712 | Longford | 10 | 53 46 02 | 7 32 29 | 227·0 | 15·5 | 5·4 |
| 1713 | Longford | 9 | 53 46 31 | 7 38 00 | 193·0 | 19·8 | 7·0 |
| 1714 | Longford | 9 | 53 45 51 | 7 43 35 | 159·0 | 21·3 | 7·5 |
| 1715 | Cavan | 39 | 53 51 47 | 7 02 44 | 401·0 | 20·9 | 13·0 |
| 1716 | Cavan | 34 | 53 54 09 | 7 00 01 | 539·0 | 19·0 | 16·0 |
| 1717 | Cavan | 35 | 53 55 25 | 6 52 06 | 569·0 | 20·4 | 17·4 |
| 1718 | Monaghan | 31 | 53 57 20 | 6 45 17 | 107·5 | 50·6 | 17·1 |
| 1719 | Louth | 11 | 53 58 20 | 6 35 58 | 118·0 | 58·6 | 24·3 |
| 1720 | Louth | 11 | 53 58 26 | 6 31 39 | 68·0 | 63·4 | 26·0 |
| 1721 | Louth | 6 | 53 59 31 | 6 27 46 | 87·0 | 67·5 | 29·7 |
| 1722 | Louth | 6 | 54 01 23 | 6 28 26 | 139·5 | 68·3 | 31·0 |
| 1723 | Meath | 25 | 53 37 55 | 6 39 50 | 123·0 | 17·1 | 12·5 |
| 1724 | Meath | 31 | 53 35 56 | 6 41 51 | 178·0 | 10·1 | 11·7 |
| 1725 | Meath | 36 | 53 33 19 | 6 47 25 | 182·0 | 7·8 | 13·3 |
| 1726 | Meath | 36 | 53 31 37 | 6 52 06 | 200·0 | 3·8 | 12·9 |
| 1727 | Meath | 35 | 53 32 03 | 6 56 25 | 204·0 | 3·8 | 12·4 |
| 1728 | Westmeath | 21 | 53 32 08 | 7 02 59 | 248·0 | 0·1 | 11·3 |
| 1729 | Westmeath | 20 | 53 30 52 | 7 08 29 | 312·0 | − 6·9 | 10·0 |
| 1730 | Westmeath | 27 | 53 28 42 | 7 06 55 | 250·0 | − 8·1 | 8·2 |
| 1731 | Meath | 20 | 53 42 19 | 6 19 23 | 117·0 | 29·1 | 17·8 |
| 1732 | Louth | 24 | 53 43 12 | 6 21 20 | 106·0 | 27·7 | 14·4 |
| 1733 | Louth | 24 | 53 44 39 | 6 22 51 | 192·0 | 27·7 | 17·8 |
| 1734 | Louth | 24 | 53 43 08 | 6 22 11 | 62·0 | 29·3 | 13·5 |

APPENDIX—continued

| Station Number | Six Inch Map Sheet Number | | Latitude N | Longitude W | Height above M.S.L. | g(Station) minus g(Dunsink) | Bouguer Anomaly |
|---|---|---|---|---|---|---|---|
| | | | ° ′ ″ | ° ′ ″ | ft. | mgals. | mgals. |
| 1735 | Louth | 24 | 53 43 15 | 6 27 00 | 156·0 | 27·7 | 17·4 |
| 1736 | Meath | 19 | 53 42 32 | 6 32 46 | 149·0 | 30·3 | 20·5 |
| 1737 | Meath | 25 | 53 41 02 | 6 37 53 | 248·0 | 22·0 | 20·4 |
| 1738 | Meath | 26 | 53 39 57 | 6 31 46 | 213·0 | 11·0 | 8·8 |
| 1739 | Meath | 26 | 53 38 25 | 6 29 55 | 178·0 | 6·8 | 4·8 |
| 1740 | Louth | 24 | 53 42 52 | 6 20 46 | 10·0 | 32·6 | 14·1 |
| 1741 | Dublin | 18 | 53 21 47 | 6 15 25 | 34·5 | 15·5 | 28·8 |
| 1742 | Dublin | 18 | 53 20 29 | 6 14 51 | 17·0 | 10·2 | 24·4 |
| 1743 | Dublin | 18 | 53 19 13 | 6 12 53 | 11·5 | 3·7 | 19·3 |
| 1744 | Dublin | 23 | 53 17 38 | 6 09 01 | 32·5 | − 7·9 | 11·2 |
| 1745 | Dublin | 23 | 53 16 14 | 6 05 34 | 83·0 | − 14·6 | 9·7 |
| 1746 | Dublin | 26 | 53 14 00 | 6 07 22 | 104·0 | − 14·3 | 14·4 |
| 1747 | Dublin | 18 | 53 19 45 | 6 16 16 | 71·5 | 2·5 | 21·0 |
| 1748 | Dublin | 22 | 53 17 57 | 6 17 02 | 167·0 | − 11·4 | 15·4 |
| 1749 | Dublin | 25 | 53 15 13 | 6 19 10 | 836·0 | − 62·9 | 7·9 |
| 1750 | Wicklow | 6 | 53 11 46 | 6 17 40 | 1207·5 | − 99·1 | − 1·0 |
| 1751 | Wicklow | 11 | 53 08 15 | 6 18 42 | 1627·0 | −128·6 | − 0·2 |
| 1752 | Wicklow | 11 | 53 05 02 | 6 21 24 | 1386·0 | −121·6 | − 3·1 |
| 1753 | Wicklow | 7 | 53 11 33 | 6 10 10 | 215·0 | − 23·7 | 15·2 |
| 1754 | Dublin | 19 | 53 21 33 | 6 11 41 | 11·0 | 13·5 | 25·7 |

g (Pendulum House, Cambridge) = 981·265 cm./sec.$^2$
g (Dunsink Gravimeter Station) − g (Pendulum House, Cambridge) = 120·4 mgals.
The Irish Ordnance datum is about 8 ft. below Mean Sea Level.

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L. W. POLLAK, The Climate of Dublin City.

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Dublin, Ireland.