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No. 11

A Vertical Force Magnetic Survey of the Counties Roscommon, Longford, Westmeath and Meath

with parts of the adjacent Counties of Galway, Cavan, Louth and Dublin

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A VERTICAL FORCE MAGNETIC SURVEY OF THE COUNTIES ROSCOMMON, LONGFORD, WESTMEATH AND MEATH WITH PARTS OF THE ADJACENT COUNTIES OF GALWAY, CAVAN, LOUTH AND DUBLIN

ABSTRACT

A vertical force magnetic survey covering a rectangular area of central Ireland 108 miles from west to east and 36 miles from north to south at a density of one station per five square miles has been carried out in 1952-53. The accuracy was found to be $\pm 10\%$.

An anomaly of large extent over most of the area surveyed is interpreted as produced by the pre-Cambrian basement. In the east the Ordovician Volcanic Series is well marked and its extension can be traced under cover of Carboniferous rocks. In the west of the area a remarkable positive anomaly has been outlined in fair detail, its cause is not obvious and an interpretation would require further geological work in the neighbourhood. This anomaly probably marks a major structural line.

INTRODUCTION

The Geological Survey of Ireland carried out a Vertical Force Magnetic Survey in the years 1944-46 and the results were published in the form of maps in 1949. This survey was intended only as a preliminary one to obtain an overall picture to help in interpreting the various detailed work which was being carried out in selected areas for economic purposes. The contouring was based on readings obtained at over 900 stations; a density of one station per 25 sq.miles. No attempt was made to survey any part in detail and most of the anomalies of small extent, even though of large intensity, were noted in the records but were not all included on the maps.

In the Gravity Survey of Ireland being carried out by the School of Cosmic Physics (see References) the magnetic data of these maps proved of great importance in interpretation but the detail was usually not sufficient. To remedy this defect the present survey was started. In particular, in this survey it was hoped that magnetic disturbances would be associated with the gravity "lows" encountered near Slane, Drogheda and north of Swords (*Memoir No. 2, Part 3, p. 13*). Later it was decided to use this survey as a test area to ascertain the optimum density of readings for a complete covering of the country.

Referring again to the Gravity Survey of Central Ireland (*Memoir No. 2, Part 3*), on page 17 the suggestion is made that the limestone cover over the western part is very thin and it was hoped that a detailed magnetic survey of this region would prove of great value in estimating the thickness of the limestone both here and to the east since it was known that this rock is non-magnetic but is underlain by magnetic rocks. The boundary between the thick and thin limestone deposits is also the site of an extraordinary anomaly, "Stokes-town Anomaly", deriving its name from the proximity to that town. It was intended then to delineate this anomaly more accurately, to delimit its extent and to attempt an investigation of its geological significance.

THE METHOD

A SCHMIDT type vertical force variometer was used to measure the field. It was transported in a van. The area covered by the survey is 3,888 sq.miles and is shown in Fig. 1. The number of stations is 754 and measurements were taken at the end of 1952 and intermittently throughout 1953.

VERTICAL FORCE MAGNETIC SURVEY



Fig.1 -- Area covered by the Vertical Force Magnetic Survey

The base for the magnetic readings was the Dublin station of the Magnetic Survey (*Memoir* No.4) situated in the Phoenix Park. This is close to the base station occupied by the Geological Survey and the reasons for abandoning the latter station were because of interference from motor traffic and the suspicion that disturbance has been created by the addition or renovation of public utility services to nearby buildings. This last point will be dealt with later.

The method finally evolved and one which it is hoped to extend to the whole country consisted in establishing subsidiary bases near large towns by repeated comparisons with the base in the Phoenix Park, at least two comparisons being carried out in one day. As the distances from the Dublin base become too long for this to be done, the remaining bases are tied to the subsidiary bases. These comparisons were carried out as often as possible, for example on leaving and returning to Dublin at the beginning and ending of a period of measurement.

The measurements taken each day commenced at one subsidiary base and finished on one, preferably the same one, morning and evening. Due to magnetic storms and to changes of zero and sensitivity, which usually take place in jumps, this method was found to be essential. The sensitivity was checked by comparison with one of the control magnets as often as possible, at least once every five days at a subsidiary base. The subsidiary bases and magnetic values used are given in the following *Table*.

Subsidiary Base Stations

Station number	Town	Difference from Dublin base in gamma
130	Drumsna	+ 310
165	Lusk	+ 37
884	Roscommon	+ 227
1007	Drogheda	+ 266
1027	Navan	+ 144
1088	Kells	+ 342
1133	Enfield	+ 93
1198	Virginia	+ 430
1206	Athlone	+ 205
1207	Longford	+ 306

The stations were chosen by selecting junctions of roads on maps 12 and 13 of the Ordnance Survey "half inch to one mile series" along main and link roads at intervals of about three miles to give a density of one station per four mile square. This is a sufficiently high density to detect anomalies of the nature in which we were interested and then to investigate such anomalies the interval between stations was reduced to about one mile. An even distribution of stations was aimed at but a regular pattern or grid was not attempted for several reasons. The stations had to be on roads or very close to them both for access and for ease in locating and marking them on the small scale maps. Otherwise the time taken in merely positioning a station would be far too long.

Taking measurements on roads has certain drawbacks. From experience, it was found best to avoid taking measurements within 100 metres of a farm house chiefly because of iron gates and farm implements which are not always visible, and in some areas, because of high hedges, interference from random iron objects has always to be expected. Near towns the presence of water pipes may make this method of locating stations impossible to carry out. Sewer pipes are not so troublesome as it is usually easy to guess their presence. Under such conditions the only possible method of carrying out a survey is to choose locations in the centres of fields. When an anomaly is encountered near a town no simple procedure has been arrived at for elucidating it, as every reading therein must be treated as suspect. If, on the other hand, the stations were all taken in open locations such as fields the presence of crops severely restricts the choice and may make repetition impossible.

At each station one set of measurements comprising six readings was taken and if the deduced value differed from that at the preceding station by more than 50^7 another set was taken about 100 metres away to eliminate the possibility of water pipes or iron objects. The good agreement between readings at adjacent stations indicates that the choice of stations was sound. From repeat readings at the same stations at different times the standard error was found to be about $\pm 10^7$. The latter figure includes the uncertainty of the diurnal correction.

Included in the area of the survey are about 120 stations where measurements were taken by the Geological Survey. Whenever possible in the present survey these stations were revisited. It was found that an adjustment was necessary to reach agreement. This

VERTICAL FORCE MAGNETIC SURVEY

consisted of the simple addition of 25^γ to the earlier figures and arises from the change in intensity of the earlier base station in the Phoenix Park. It is presumed that this increase is the result of disturbance produced by iron materials, possibly waterpipes, in a nearby building which in the interval between the surveys has been converted into a hospital. No large discrepancies were discovered at other stations though one or two mistakes became apparent.

In the results of this work the system of numbering the stations is chronological. Numbers smaller than 1,000 indicate stations already established by the Geological Survey and in several instances the readings at these are taken from that survey by kind permission of the Director.

The method of applying a combined correction for diurnal and secular variations has been given in detail on pages 10 and 11 of *Memoir* No. 4 using the values for the vertical component measured at Abinger Observatory supplied by the Astronomer Royal.

The location of each station is recorded on a card index and marked on a set of half inch to a mile maps kept at the School of Cosmic Physics and details can be obtained on request.

The normal value for the vertical magnetic field at a station was obtained as follows From *Memoir* No. 4 equation 6 is rewritten

$$Z = 448^\gamma (\varphi - 50) + 65^\gamma (\lambda - 5) + 42909^\gamma$$

The values of Z were computed from this equation for the four corners of each "half inch to one mile" map. Then the values were interpolated linearly for every intersection of the grid which is printed on each map (four mile square) and finally the value at a particular point within a square was deduced with the help of a transparent graticule. In this way the normal value could be obtained as soon as a station was marked on the map and an estimate of the anomaly made as the measurements were being taken.

The measurements were taken relative to the Base Station and to obtain the actual value the value at the Base must be known. In the Magnetic Survey of Ireland for the Epoch 1950.5 the vertical component was not measured directly but was computed from the horizontal component and the angle of dip. The resulting error was calculated as $\pm 27^\gamma$ which is large for use in the present survey. In the area covered there are six stations of the Magnetic Survey of Ireland and measurements with the variometer were taken at these stations so that a better value could be obtained as a mean for the Base Station. This mean value was found to be 44470^γ which is close to the measured value at the Base Station of 44495^γ , in the 1950 survey. The vertical field at a station was then obtained by adding 44470^γ to the difference between the vertical components as measured at the Base and at the station. Since the anomaly in the field is mainly of interest no allowance was made for the secular variation and the deduced figures would then refer to Epoch 1950.5.

The actual figures for the vertical intensity and the anomaly are not included in this *Bulletin* but can be supplied on application.

GEOLOGY

The anomaly in the vertical field has been represented by the usual system of contouring at intervals of 25^γ superimposed on a geological map drawn from the published one millionth map of the Geological Survey and included as a *Folder*.

Half the area is covered by Carboniferous sediments with much limestone. These sediments, throughout the greater part, rest directly on Lower Palaeozoic rocks and volcanoes

are absent (TURNER, 1952, p. 125). None of these rocks would be magnetic and it would therefore be expected that they would contribute little or nothing to the anomalous field.

The remaining area consists of the south-westerly extension of what HARPER (1949) calls the "Southern Upland" region because of its similarity to that part of Scottish geology. It is composed of Ordovician and Silurian beds, the latter being "grey and green grits, flags and mudstones with thin black shaly bands". These would, from their description, be expected to have a low susceptibility but probably higher than the carboniferous. The Ordovician occurs as inliers and like the Silurian consists of "grits and greenish mudstones with black shale bands" but in addition there is a Volcanic Series containing beds of tuffs and andesitic lavas. The latter are known to be magnetic. The classification of the various beds between the two ages is not, as yet, well marked and the revision which is taking place now classes a larger area than is shown on the map as Ordovician (HARPER, 1952).

The Ordovician, then, containing beds of lavas and tuffs can be expected in general to be magnetic but if the Volcanic Series thins rapidly then possibly not very much so.

The remaining rocks belong to the Devonian, which is similar to the Carboniferous and in fact in places not very well differentiated from it, and a down-faulted area of Triassic. The faulting in this region has associated with it some igneous activity and strongly magnetic basalts and altered sediments are known from early magnetic surveys.

Throughout the area there are small anticlines in the Carboniferous some of which show inliers marked as Silurian on the map. The largest of these occur in a line east of Strokestown and here HARPER (1949, p. 56) reports the presence of pillow lavas which he considers are probably Ordovician. This occurrence along with other outcrops of an igneous nature were taken from the one inch geological maps and will be discussed in more detail later.

Apart from those mentioned no other indications of igneous activity can be seen and in the immediate vicinity of the area surveyed there is nothing further to note regarding the geology.

Thus of the known rocks in the area those which were expected to give magnetic anomalies were the basaltic intrusives in the Triassic near Kingscourt and these were avoided because of their complexity and the Volcanic Series in the Ordovician. From the description of the Ordovician, Silurian, Devonian and Carboniferous it was not thought possible that any distinction between them would show up.

DESCRIPTION OF THE ANOMALOUS FIELD

The anomaly in the vertical magnetic field is predominantly positive throughout the area. It is conveniently divided into three parts which will be dealt with separately as each has its origin in a different way. The central portion has already been given the name "Virginia Anomaly" from the name of the town lying near its centre. The western area is complex and dominated by the large intense "Strokestown Anomaly" while on the east there is a group of small intense anomalies associated with the Ordovician Volcanic Series.

The *Virginia Anomaly* of positive sign has considerable extent covering an area of about 400 sq. miles. The contours are widely spaced and smooth particularly to the south-west indicating the cause to lie in some large, fairly homogeneous, deep sited rock formation. It is elongated in a south-westerly direction which suggests a connection with the Caledonian folding. The thickness of the carboniferous sediments has been put at 3,000 feet (COLE and HALISSY, 1924) and the underlying Devonian is expected to be small if at all present. There is only a very small change as the anomaly progresses from east to west while the

overlying Carboniferous sediments increase by 3,000 feet so that the cause not only does not lie in the Silurian sediments but at a considerable depth below the Silurian surface. The Ordovician sediments which contain magnetic materials in the form of lavas and ashes would hardly be so widespread and so uniform as to produce such an anomaly. The most probable cause lies in the metamorphic basement rocks which would be thick, fairly uniformly magnetic, and have a Caledonian strike. No outcrops of these are near. From the two profiles in *Fig. 2* the depth to this basement must be at least 10,000 feet.

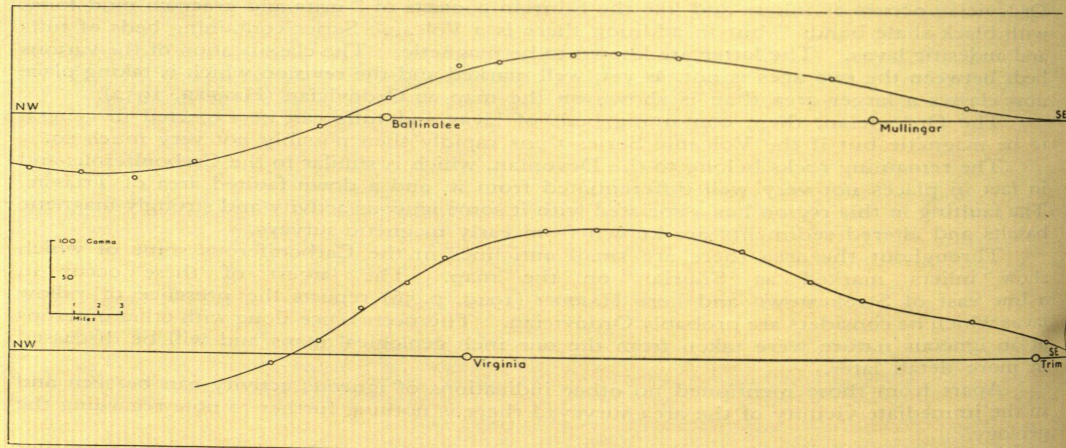


Fig. 2—Sections through the "Virginia Anomaly" of vertical magnetic intensity

Towards the north-eastern end the anomaly encloses the downfaulted Triassic deposits in the form of a small graben which has associated with it outpourings of basalt. Readings close to this magnetic rock were avoided and it was surprising to find that the total effect of this area containing the basalt was very slight. Thus the amount of basalt present must be small and all the rocks affected by the faulting, namely Silurian, Carboniferous and Triassic must have similar and small susceptibilities.

Further in this direction the anomaly ends very abruptly and, as yet, no connection between the rapid termination and the surface geology has been found which strengthens the supposition that the origin of the anomaly must lie below the Silurian and the Ordovician.

So far when the "Virginia anomaly" has been mentioned reference was made to the positive anomaly which is such a feature of the map. On the north-western boundary there is a steep decline (*Fig. 2*) and a pronounced negative trough is in evidence. This trough continues, though to a smaller degree, around the south-westerly limit but in the north-easterly direction the sea limits the extent of the survey. How much of this negative area is associated with the positive anomaly it is not at present possible to say. The lowest negative values are comparable in size to the highest positive values and this could arise from choosing the zero or base line wrongly in this area or the rock mass causing the negative and

positive anomalies is polarised in a NNW direction with a low angle of dip, in fact almost horizontal (HAALCK, 1953, p. 235). The latter is not very likely and it would be difficult to investigate this possibility. Whichever is the case the north-western limit of the postulated magnetic rock mass must be further in this direction than the zero contour, probably as far as the $-50'$ contour line. On the south-eastern edge of the anomaly the gradient is smaller indicating that the anomalous mass has not as abrupt a termination as on the north-west and so would underlie at the postulated depth out to about 20 miles from the centre.

The Ordovician Volcanic Series. South-east of the Virginia Anomaly two separate areas of small intense anomalies occur. Both are related to the volcanic series in the Ordovician already referred to. No attempt was made to work out the areas in detail; the main object was to delimit the extent and to see if any structural deductions could be elucidated so that the picture presented on the map is by no means a complete one.

The first striking feature is the abrupt ending on a north-east south-west line which has been drawn in as a straight line. The northern extremity of this line coincides with the fault between Silurian and Ordovician beds marked out by HARPER (1952) in his *Plate 7*, so that the magnetic boundary line has here a definite physical significance. The southern end of the line is three miles west of Navan in Carboniferous limestone. Further to the south-west there is no magnetic effect which could be associated with a continuation of this line. This can be expected since in this area the Carboniferous sediments are thick and would smooth out any anomalies arising from the underlying rocks. South of a line drawn from Navan to Balbriggan the magnetic effects of the Ordovician volcanics die out rather quickly but there is no evidence for an abrupt discontinuity. Near Bellewstown the geological map shows an inlier of Ordovician volcanic rocks and there is a distinct disagreement between the trend of the magnetic anomalies and the shape of the inlier. Further, there is a steep magnetic gradient cutting both the Ordovician and the Silurian outcrop and continues west beneath the Carboniferous limestone so that the latter must be here quite thin.

In a private communication, DR. HARPER has pointed out that there is probably a fault bearing N of E through the Boyne Valley beneath the Carboniferous cover but such a fault or any other fault thereabouts does not show up in the present magnetic map.

South of this region the well known Ordovician inlier of Portrane and Lambay Island stands out as a pronounced magnetic anomaly of positive sign flanked on the north by a negative trough and on the south by a deep negative depression whose centre is too far away to have any connection (GARDINER, C. I. and REYNOLDS, S. H., 1897). This anomaly ends very abruptly on the west although an anticline in Carboniferous sediments continues to the south-west linking this inlier to a very similar one at the Chair of Kildare (TURNER, 1950, p. 172) and it was thought there would be a similar anticline in the Ordovician. The Carboniferous cover here at Swords is not more than a few hundred feet so that if the Ordovician Volcanic series were present beneath it there would be definite indications in the magnetic field such as were recorded east of Navan. The two areas, at Portrane and at Kildare, must then be treated as separate units.

The Strokestown Anomaly is a striking feature of the magnetic map stretching for 31 miles (50 km) in a NE-SW direction. It occurs in a district where the outcropping rocks consist almost entirely of flat lying limestones. Various sections have been drawn in *Fig. 3* and it can be seen that it is consistent throughout its length ending abruptly at either end. A simple analysis shows that the most part of the anomalous field is similar to that produced by a horizontal line of magnetic poles at a depth of about one mile. The negative trough on the south-east, as already discussed with the Virginia anomaly, is probably not connected with this anomaly. On the north-west side there is another deep negative basin probably

VERTICAL FORCE MAGNETIC SURVEY

part of the south-east trough but further to south-west the anomaly is positive and this latter is undoubtedly produced by some other cause similar to the large positive areas which occur on the western edge of the map. These additional anomalies provide such complications that a rigorous theoretical analysis would not be fruitful.

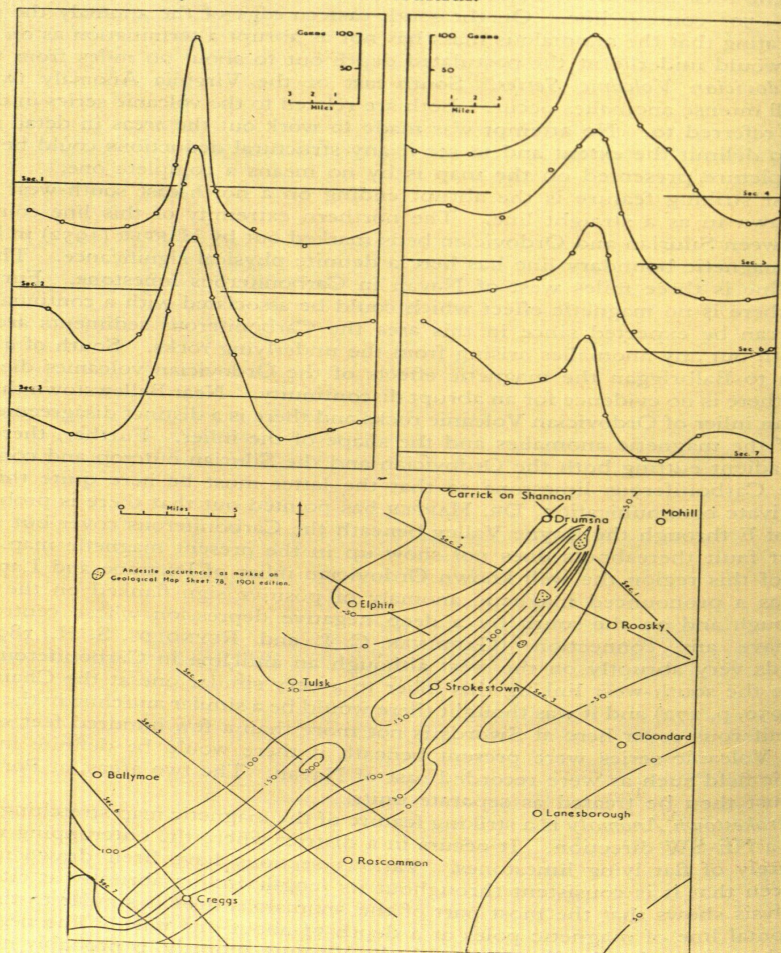


Fig.3—Sketch map and profiles of the "Strokestown Anomaly" in vertical magnetic intensity

The anomaly is not resulting from a single continuous source, for example in *Sections 3* and *4* minor irregularities can be seen on the south-eastern side and south of Strokestown there is a broad high plateau with several peaks. The most likely cause of such an anomaly is a large intrusion in the form of a dyke swarm or dyke echelon.

In *Section 1* the peak of the anomaly coincides with an outcrop of rock marked "Andesite" on sheet 78 of the one inch geological maps of the 1901 edition. It occurs in a Silurian inlier. Elsewhere, the anomaly maximum is covered by flat lying Carboniferous limestones.

The possibility of the presence of a dyke swarm will be discussed first. Throughout the north of Ireland there are dyke swarms of Caledonian and Tertiary ages (ANDERSON, 1951, chap. iv).

The Tertiary dyke swarm has associated with it large batholiths of basic material (*Memoir No. 2*, Part 3). It has been sketched by WALKER and LEEDAL (1954) and it can be seen from their figure that the average strike is northwest-southeast and that the number of dykes decreases rapidly on approaching the area under discussion. The intrusives which occur near Kingscourt already mentioned belong to this system. They cut through all the rock formations up to the latest without preference. Numerous magnetic measurements in the field and in the laboratory show that dykes and basalt flows of this age in Ireland are magnetised in a direction opposite to that of the present earth's field (see note on Magnetic Maps of the Geological Survey, 1949; BULLERWELL, 1954 and RUNCORN, 1954). From the different directions of the strikes, from the absence of any intrusives thereabouts in the Carboniferous and from the magnetic standpoint it would be unlikely that the Strokestown anomaly is caused by an intrusive formation of Tertiary age.

The Caledonian intrusives have not been well studied in Ireland. They are widely distributed in the north and are similar to those in Scotland which have been given in detail by RICHEY (1939). In Scotland and north-eastern Ireland the trend is northeast-southwest in conformity with the mean Caledonian folding but in Donegal they lie closer to north-south. They include acid and basic types; the acid predominating. WALKER and LEEDAL give analyses of several Caledonian dykes in Donegal and they found very little magnetite.

The strike of the Strokestown anomaly would be in conformity with the general Caledonian trend but in the Lower Palaeozoics nearby northeast of Longford, very few dykes are recorded so that a dyke swarm of this age at Strokestown would be unexpected.

To the east of the anomaly lies a series of anticlines in which the Basal Carboniferous, the Devonian and the Lower Palaeozoics are brought to the surface. The agreement between the trends of the anticlines and the magnetic anomaly is striking and suggests there is a connection between the two. The Armorican movements, which produced the anticlines, are not associated with any igneous activity in Ireland (CHARLESWORTH, 1953, p. 101).

Reference has already been made to the presence of Andesite at the northern end. The earlier editions of the one inch Geological maps and the six inch manuscript maps record all the outcrops, with a small exception in the extreme north, as grits. In a revision, portions of these have been changed and are marked "Andesite". MR. M. A. CUNNINGHAM of the Geological Survey accompanied the author on a short visit to these various places and from hand specimens he identified certain rocks as definitely intrusive. However, he could find no well marked boundaries and came to the conclusion that what is marked as "grits" in some areas contain considerable quantities of volcanic ashes. Various samples from these outcrops were appreciably magnetic (tested by bringing them close to the variometer) and it would appear then that a Volcanic Series is present in the Lower Palaeozoics but its extent is not well known and will have to await revision of the Geological maps.

VERTICAL FORCE MAGNETIC SURVEY

These problematical rocks lie close to the boundary of the Carboniferous and the Lower Palaeozoics but with the exception of the northern limit the magnetic anomaly lies to the west. At one station, namely 1913, a local anomaly was encountered but no outcrops here were visible. Along *Section 2* the peak of the anomaly is half a mile to the west of the outcropping "Andesite". It is possible that the Strokestown anomaly is produced by thick volcanic deposits but to produce the linearity they would have to be sharply folded or faulted etc. in this line. The strike approximates the line of anticlines, which are Armorican, but the covering limestones are perfectly flat and hence the folding would have to be pre-Armorican. Thus it may represent a major structural line possibly connected with the continuation of the Southern Uplands fault of Scotland. The abrupt endings at both ends would require additional explanations.

Summing up, the Strokestown anomaly is best explained magnetically by a dyke swarm but this has no confirmation geologically while from the geological side the presence of magnetic rocks in the Lower Palaeozoics suggests an obvious cause but this is difficult to understand without making further suppositions. Neither explanation is satisfactory but when further geological work is carried out in the neighbourhood, particularly on the range of anticlines, it might be possible to analyse the magnetic map anew with additional readings if they are required. Further gravity work planned for this area will probably give some help.

The Granite Areas. One of the objects of the present survey was to investigate the effects, if any, of the suspected hidden granite, discovered by gravity work, near Navan (*Memoir No. 2, Part 3, p. 14*). To the north and east of Navan the magnetic effects of the Ordovician volcanics mask any effect that might be present but to the south it is obvious that there is no noticeable effect. The small granite suspected south of Balbriggan (*Memoir No. 2, Part 3, p. 15*) probably contributes to the negative magnetic anomaly encountered but some of this, a small amount—certainly not all—is associated with the positive anomaly over the Ordovician inlier to the south.

There is a small area of granite outcropping near Crossdoney. The gravity survey has shown (*Memoir No. 2, Part 4, pp. 15 and 16*) that this granite is only a small mass not part of a large batholith as suggested by COLE and HALISSY (1924, p. 60) and this is corroborated by the magnetic survey in as much as readings taken on or near the granite give a positive anomaly but at a distance of a few miles the readings are unaffected by it.

Ordovician and other areas. The anomalies near Navan, Balbriggan and Portrane have been related to the Ordovician Volcanic Series but there are several other small inliers of Ordovician near Ardee and north of Virginia which are quite indistinguishable, magnetically, from the Silurian. A much larger area occurs at the edge of the map north of Longford and here the anomaly is negative. This has been discussed in connection with the Virginia anomaly and it is not thought to be connected with the Ordovician. This cannot be investigated until a much larger area can be surveyed as it is known that the largest negative anomaly readings are centred near Cavan. Nevertheless since no anomalies, negative or Volcanic Series cannot be very close to the surface. The inlier at Ardee, in particular, showed none of the characteristics of its close companion.

The small inliers lying to the southeast of Longford do not show any irregularities in the general pattern of the Virginia anomaly.

Tertiary Intrusives occur extensively in the form of dykes and sills in and around the Triassic deposits near Kingscourt. Moreover there is considerable alteration of the sediments whereby strongly magnetic rocks are produced. The magnetic field is much disturbed. This was known before the survey was undertaken and the area avoided. Some readings

taken near this area showed disturbances which are most probably due to Tertiary dykes. The stations involved are as follows : nos. 1090, 1314, 1663 and 1639. At the first mentioned the anomaly is negative and of considerable size. No attempts were made to investigate these occurrences. It was most surprising and welcome that so few stations were affected.

Other Anomalies were encountered at the western edge of the map and further readings showed they are connected with an extensive area of high positive anomalies and steep gradients. They do not seem to bear any relation to those already described such as the Strokestown anomaly and it will be more convenient to deal with them separately in a later survey.

CONCLUSIONS

(1) A large magnetic anomaly through Virginia has been attributed to magnetic Pre-Cambrian basement rocks.

(2) There are anomalies associated with the Ordovician Volcanic Series which occur north of Slane, northwest of Balbriggan and in the inlier at Portrane. The first two are shown to be connected under the cover of the Carboniferous Limestone. The anomalies provide a means of tracing the contact between this Series and the Silurian.

(3) The most likely causes of the large magnetic feature through Strokestown are either a Caledonian dyke swarm or sharp folds in a Lower Palaeozoic Volcanic Series.

(4) No marked effects were discovered near the sites of the postulated hidden granites deduced from gravity surveys.

ACKNOWLEDGEMENTS

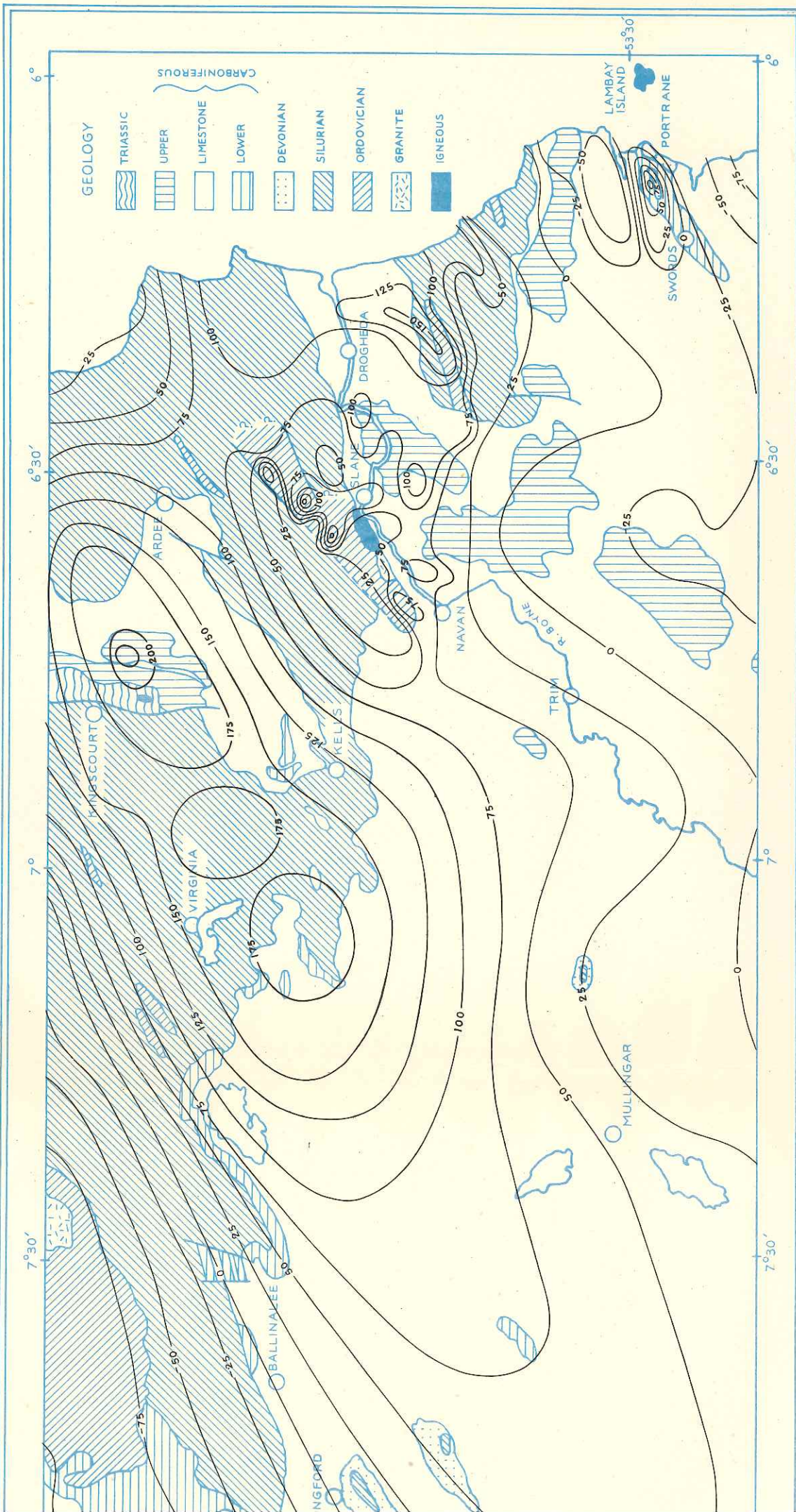
I wish to thank the Director of the Geological Survey, Mr. M. V. O'BRIEN, for permission to use data from their magnetic survey and for arranging for Mr. M. A. CUNNINGHAM, also of the Survey, to visit various localities near Longford to investigate the Lower Palaeozoics and I am grateful for the trouble the latter took in going through the manuscript maps to give me every possible help.

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**T. Murphy, A Vertical Force Magnetic Survey
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