Basement controls on mineralisation in the British Isles

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Attention is drawn to what appears to be a significant spatial relationship in the Variscan Foreland of the British Isles between Hercynian and Saxonian base metal and fluorite-baryte mineralisation and Caledonian granites. This is apparent as far as the Northern Pennine Orefield is concerned, and a similar relationship can be postulated for the Southern Pennine Orefield. Other examples are present in Scotland and the Mendip Orefield. Ireland affords good examples of this spatial relationship which is held to be a significant basement control for the location of many post-Devonian mineral deposits. Genetic and exploration implications of the hypothesis are considered.

ZONING in orefields, the district zoning of Park and MacDiarmid,[26] is a well known feature of many areas of epigenetic mineralisation. Normally it has a concentric arrangement with central zones believed to represent the area of highest depositional temperatures surrounded by zones whose mineral associations betoken lower crystallisation temperatures. The central zone has in many cases been regarded as overlying the emanative centre from which the mineralising solutions have risen, in the manner Dines[7] postulated for the mining region of south-western England, one of the classic areas in which district zoning is developed. Here the higher temperatures of deposition in the innermost zones have been confirmed by the fluid inclusion studies of Bradshaw and Stoyel.[4]

In Cornwall the positions of the emanative centres deduced by Dines and the innermost metal zones are coincident with ridges and cusps in the roof of the partially exposed granite batholith underlying most of the region. Here the vein deposits and the granite are essentially coeval (Hercynian) and late stage hydrothermal differentiates of the granite magma could have given birth to the mineralising solutions. As is well known such relationships led Dunham[8] in 1934 to the then logical proposition that the mineralising solutions responsible for the mineralisation in the Lower Carboniferous rocks of the northern Pennines had their source in a hidden Hercynian granite, an argument which later received support from the Hercynian model lead ages obtained by Moorbath[24] on galenas from this field.

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Such a hypothesis would clearly explain the zonal nature of the northern Pennine orefields of the Alston and Askrigg Blocks. Later the negative Bouguer anomalies delineated by Bott and Masson-Smith[3] were found to show a close spatial correlation with the central fluorite zones of mineralisation of the Alston Block and were interpreted as confirming the presence of a buried Hercynian granite, the Weardale Granite. This granite was penetrated by the Rookhope borehole which revealed that the granite lies unconformably beneath the Carboniferous and has strong petrographic similarities to the Caledonian Leinster Granite of Ireland. Isotopic dating indicated a Caledonian age and showed that the time gap between granite consolidation and mineralisation was of the order of at least 100 m.y.[9] The mineralisation in the centre of the Askrigg Block shows a similar spatial relationship to the buried Caledonian or Precambrian Wensleydale Granite,[1] whereas the mineralisation both north and south of the southern boundary of the block is spatially related to the Craven Faults.

An analogous example of Hercynian mineralisation spatially related to Caledonian granites occurs in eastern Ireland. Here along the eastern margin of the Leinster Granite, notably at Glendalough, there are galena-sphalerite veins for which Moorbath[24] obtained a Hercynian model lead age. Tremlett[30] mapped similar veins associated with, or in, small Caledonian granitic intrusions present in the Palaeozoic rocks to the east of the main granite outcrop. Recently Ineson and Mitchell[16] have shown that some base metal mineralisation in Scotland, spatially related to Caledonian granites, is of Hercynian age.

A picture is thus emerging from studies of mineralisation in the British Isles of the apparent importance of older bodies of granite in controlling the location of later formed epigenetic mineral deposits. It is the authors' contention that this relationship may hold in other parts of Great Britain, notably in the Southern Pennines, and that it may also be the case for many of the Irish base metal deposits. If such a relationship is as general as the present writers believe it to be, then it clearly has important consequences with regard to theories of mineral genesis and should influence the choice of areas for mineral exploration.

Basement granites

One of the more enigmatic features of mineralisation in the British Lower Carboniferous is the roughly linear trend of the mineral zones in the Southern Pennines which have a regional north-north-easterly trend and which, as at present exposed, do not form a closed ring or appear to be part of one (Fig. 1). As can be seen on this figure the higher temperature fluorite zone runs down the eastern part of the orefield and gradually gives way westward to a zone where baryte is the dominant industrial mineral. Baryte in turn diminishes in importance westwards and calcite takes its place. Dunham[8] suggested that the mineralising agencies originated in hidden Hercynian granite. No evidence for the existence of such a granite was then available but the inference was a logical one in view of the evidence and the then current geological theories of the mid-thirties.

Recently Ford[11] after considering the mineralogical evidence from the Derbyshire field concluded that it suggested "the possible presence of granitic sources near or under the eastern margins of Derbyshire". The present authors agree that this is the direction from which the solutions probably came, but they believe that the granite or granites from which they emerged are not coeval with the mineralisation and merely acted as channelways in a similar fashion to those of the Northern Pennine Orefield. The evidence at present available suggests that they are probably Caledonian in age.

Turner[31] suggested the existence of a hidden Charnwood-Ardennes Arc of the Caledonian mobile belt passing below the East Midlands. Le Bas[20] has reviewed the evidence from the igneous rocks of Leicestershire and its immediate neighbourhood and interprets this within the framework of the plate tectonic theory. From his study he was able to argue cogently for the presence of a north-westerly trending Caledonian igneous-tectonic province below the East Midlands. The exposed dioritic, tonalitic and granodioritic rocks of

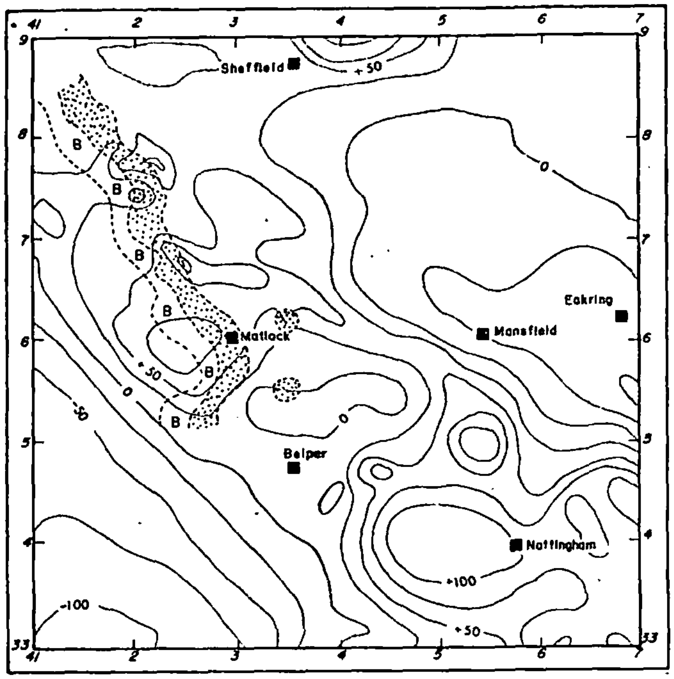

Fig. 1. Total field magnetic anomalies for the Southern Pennine Orefield and adjacent areas. Data from the Geological Survey[12] by permission of the Director, Institute of Geological Sciences (N.E.R.C. copyright). Contours are at 25 gamma intervals. Known extent of fluorite mineralisation is idicated by stippling; the baryte zone is indicated by the letter B. Zonal boundaries are taken from Ford.[11]

this area have been shown by Le Bas[20] to correlate strongly with those of the Scottish Caledonian calc-alkali suite and the geological and radiometric data now indicate the virtual certainty of their Caledonian age.[19, 20] The two known major intrusions are the Mountsorrel Granodiorite and the poorly exposed diorite-tonalite complex of south Leicestershire.

Le Bas[20] has collated the borehole evidence which indicates that this igneous province continues south-eastwards and probably joins the Brabant Massif of Belgium. Its continuation to the north-west of Leicestershire has not yet been confirmed. Ford[11] wrote that there was no conclusive evidence for a granite source for mineralising solutions east of Derbyshire and Le Bas[20] (in discussion) was loath to argue that the aeromagnetic data indicated a north-westward continuation of this province. It is the present writers' contention that the principal positive magnetic anomalies of this area are to be ascribed to the influence of Caledonian pulutonic intrusions and indicate that this igneous belt passes north-westwards in a zone running parallel to and beneath the Derbyshire Orefield.

The previous reluctance to postulate the presence of hidden granitic bodies in this zone probably stems from the fact that there are no negative Bouguer gravity anomalies coincident with the positive magnetic anomalies. One of the present writers[22] has demonstrated that in the Midlands buried granite masses do not necessarily reveal their presence by producing a negative Bouguer gravity anomaly such as is developed over the Weardale Granite. In Leicestershire and south Derbyshire this is due to the low density contrast between the upstanding parts of the basement which appear to be granite and the overlying and enclosing Carboniferous rocks. This lack of density contrast can be illustrated by reference to Table 1. The Upper Carboniferous Coal Measures and Millstone Grit have densities much less than that of the Mountsorrel Granodiorite which they surround and which may be taken to be 2,650 kg m^{-3}. (The Weardale Granite has a mean density of about 2,630 kg m^{-3}).[1] Massive limestone of the Lower Carboniferous as might be expected yields a figure of about 2,700 kg m^{-3}. Some contrast with granites and granodiorites would depend on the Lower Carboniferous being largely or wholly limestone. In this case too with a cover of Upper Carboniferous or Trias having a density of 2,450 kg m^{-3}, the density contrast is inadequate for the production of a gravity low.[22] Many boreholes in the region show however that limestone is not the only rock-type present. For example the Eakring No. 146 borehole revealed the presence of much sandstone and conglomerate. The average density for sixty samples from the Lower Carboniferous of this borehole is only 2,580 kg m^{-3}. The presence of shale beds or shaly limestone also lowers the density of Carboniferous Limestone and the limestone-shale formations of the Widmerpool Gulf probably average about 2,650 kg m^{-3}. It is this basin facies which rests upon what is believed to be a hidden northward continuation of the Mountsorrel Granodiorite which gives rise to a marked positive magnetic anomaly (Fig. 2). Seismic velocities for the formation concerned are of the right order for granite-granodiorite or limestone, but the strong positive anomaly indicates a rock of relatively high magnetic susceptibility. This fact and the continuity of the anomaly with that over the exposed portion of the Mountsorrel Granodiorite strongly suggest that the magnetic anomaly is caused by a buried extension of the granodiorite. The absence of a negative Bouguer anomaly is explained by the lack of a density contrast between the granodiorite and its Lower Carboniferous cover. The relatively high magnetic susceptibility of this granodiorite was shown by measurements on 42 samples which gave a mean of 167 x 10^{-6} SI units indicating an appreciable magnetite content which has been confirmed by microscopic studies.

Table 1. Densities of some East Midlands rocks

Formation	Locality	Number of specimens	Saturated density (kg m^{-3})	Dry density (kg m^{-3})
Coal Measures	Sproxton borehole	5		2,470
Millstone Grit		4		2,550
Lower Carboniferous	Eakring borehole No. 146	60		2,580
Lower Carboniferous Limestone	Bredon Cloud	46	2,720	2,690
Idem	Eyam borehole	4	2,720	2,710
Mountsorrel Granodiorite	Mountsorrel	60	2,660	2,640

Basement rocks

In general the basement rocks of the East Midlands may be divided into two types. The first can be recognised and its distribution charted by gravity studies alone. It forms the basement beneath south-western Derbyshire and a ridge running south-eastwards to Charnwood Forest. This type of basement material possesses relatively high density (about 2,800 kg m^{-3}) and low magnetic susceptibility.[22]

The second type of basement manifests its presence by producing a zone of marked high magnetic anomalies one of which coincides with the outcrop of the Mountsorrel Granodiorite.[12] This basement material has a relatively high magnetic susceptibility and a density in the region of 2,650 kg m^{-3}. The individual magnetic anomalies of this zone appear to be due to undulation of the magnetic basement. In the present state of our knowledge it seems very likely that this material is largely granitic (in the wide sense) and is present as a large batholith or a series of plutons. This conclusion is in keeping with

Le Bas' interpretation[20] and it is pertinent to note that a positive magnetic anomaly, comparable with that marking the outcrop area of the Mountsorrel Granodiorite, coincides with the diorite-tonalite complex of south Leicestershire (Fig. 2). Magnetite is present in all the units of this complex. The Warboys borehole near Huntingdon which entered diorite at 170m occurs in a small area of low positive anomalies which is made conspicuous by the large surrounding area of entirely negative anomalies (Fig. 2). The N.C.B. in November 1975 proved granite at a shallow depth in the Kirby Lane borehole (G.R. 732175). The granite is an altered biotite-adamellite of a facies similar to the Mountsorrel granodiorite and it contains significant amounts of magnetite. A borehole 3 km to the north was stopped in Coal Measures at a much greater depth. Reference to Fig. 2 shows that this is in agreement with the contention that the magnetic contours reflect the dip of the granite-sediment interface.

This interpretation of the magnetic anomalies provides us with a situation analogous to that of the Northern Pennine Orefield, i.e. an orefield with district zoning which is spatially related to an area underlain by Caledonian granites and in which the principal phases of mineralisation appear to belong to the Hercynian cycle, but where some activity during the Saxonian cycle is indicated.[15, 24] Since these buried granites of the East Midlands occur in a linear belt, a hypothesis that they contained the channelways up which the mineralising solutions passed would explain the linear nature of the mineral zones. It also leads on to the intriguing possibility that an undiscovered orefield is present at depth in the Eakring-Newark region where Lower Carboniferous rocks of block facies have been proved in a number of boreholes.[17] Such a postulated extension of the Derbyshire Orefield would account for the presence of fluorite and baryte mineralisation discovered during oilfield drilling operations at Eakring.[21] As Schnellmann[28] pointed out, this is an area worthy of mineral exploration since the Carboniferous Limestone is overlain by shales and the presence of volcanic layers in the limestone means that orebodies may be present at various horizons. Lees and Taitt,[21] referring to the Dukes Wood oil trap near Eakring, wrote of a highly mineralised zone in the uppermost part of the Lower Carboniferous with the development of calcite, baryte and fluorite veins. Edwards[10] mentions the additional presence of galena and sphalerite and the discovery of veins in a number of boreholes.

Clearly the structures where investigations should be concentrated are those which bring the Lower Carboniferous limestone closest to the surface and which are also suitably placed with respect to possible buried granite. The Eakring-Foston High[18] appears to be the most promising anticlinal structure (Fig. 2). Not only does it contain known mineralisation but it runs parallel to a line of pronounced positive anomalies towards which the limestone dips under a cover of impermeable Edale Shale. The south-eastern end of this structure near Foston is probably very favourable from this point of view as it approaches closer to the line of positive anomalies and the top of the Lower Carboniferous is only a little over 450m below the surface. Further to the north-east there is another anticlinal structure, the Kiveton-Egmanton Anticline.[18] This has on its north-eastern side a broad zone of positive anomalies running north-westwards parallel to a line join-

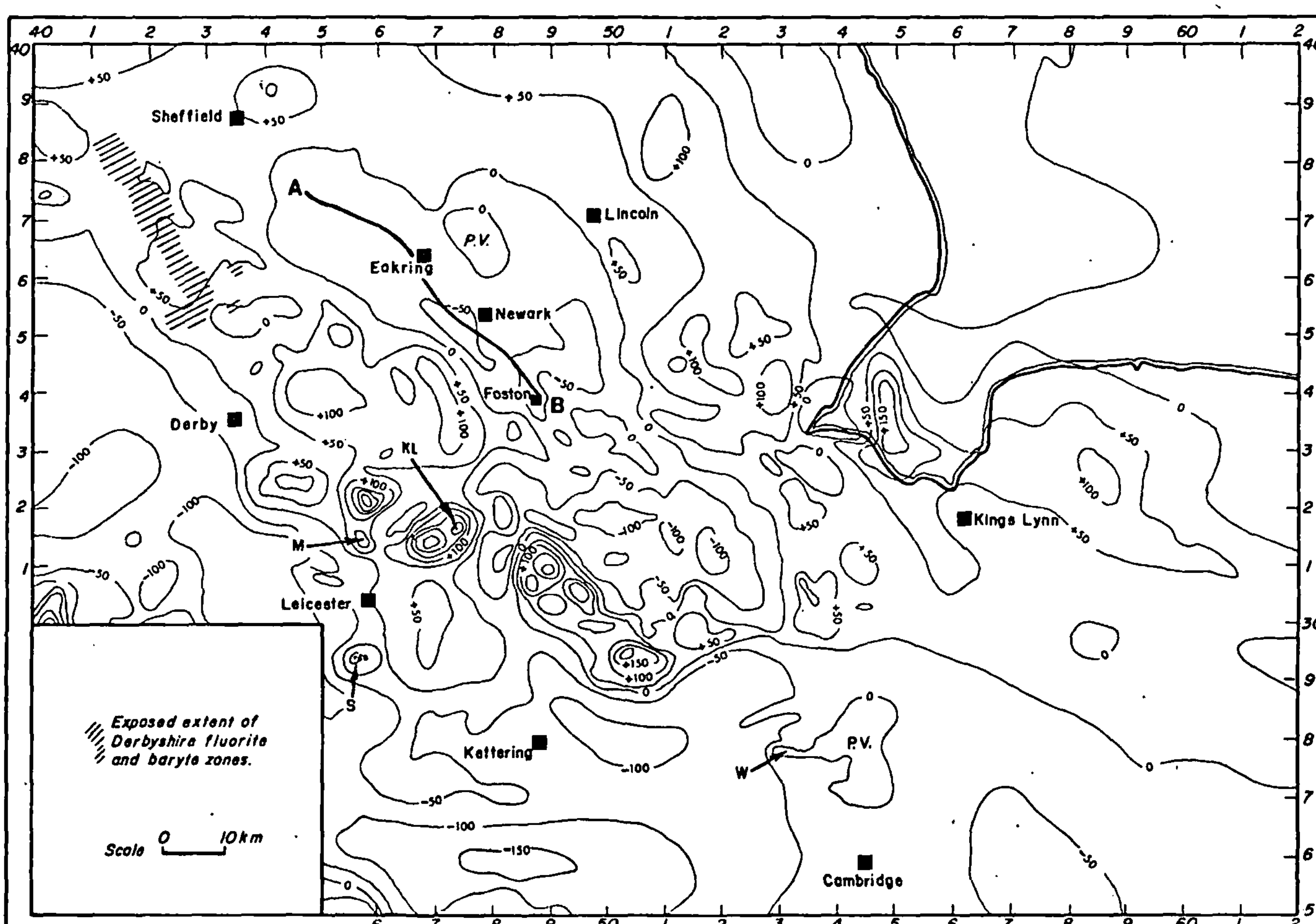

Fig. 2. Total field magnetic anomalies for the East Midlands and adjacent areas. Reproduced from the Geological Survey[12] by permission of the Director, Institute of Geological Sciences (N.E.R.C. copyright). Contours are at 50 gamma intervals. PV indicates areas of local positive magnetic values; M is position of Mountsorrel Grandiorite; S is the south Leicestershire pluton and W the Warboys borehole. AB is the line of the Eakring-Foston High. KL is the Kirby Lane borehole

ing King's Lynn and Lincoln. This zone could represent another belt of Lower Palaeozoic sediments and granites that might have been the host rocks for channelways feeding solutions to the Lower Carboniferous-Millstone Grit interface which rises south-westwards towards this anticlinal structure.

Other U.K. orefields

Orefields similar in many respects to those of the Pennines occur in the Mendips and the Halkyn-Minera region of north-eastern Wales. The extent of known mineralisation in the Mendip Hills is shown in Fig. 3. The geological relationships[13] and model lead ages[24] indicate that the bulk of the mineralisation belongs to the Saxonian cycle and the host rocks are both Carboniferous and Triassic in age. For many kilometres around the Mendip Hills the magnetic anomalies are markedly negative.[12] However, a strip of country about 35km long and up to 7km wide is characterised by positive anomalies (Fig. 3) which form a strong contrast to the regional negative background. These positive anomalies cannot be accounted for by the known near-surface geology and must reflect a marked feature in the basement geology. The general geological similarity to the Southern Pennines leads the present writers to suggest that this strip of positive anomalies is due to a buried ridge of granite. This ridge is close to the known mineralised area. Green[13] suggested that the ascending ore solutions in the Mendips were dammed during their ascent either by shales in the Carboniferous or by a blanket of Mesozoic rocks. At the south-eastern end of the orefield both these impermeable horizons dip or plunge eastwards towards the zone where buried granites may occur at depth. There is therefore a good chance that the Mendip Orefield has a south-eastward extension beneath the Mesozoic rocks lying between Shepton Mallet and Radstock.

Unfortunately the Halkyn-Minera Orefield runs across a comparatively featureless area of low negative magnetic anomalies. This of course does not preclude the possible presence of Caledonian or other granite at depth which has a low magnetic susceptibility. It must be remembered that the area underlain by the Weardale Granite is a tract of irregular negative magnetic anomalies[12] and Platou[27] has shown that the magnetic anomalies over the Precambrian granites of Bornholm are both positive and negative. The Weardale Granite has negligible magnetite[9] and hence a low magnetic susceptibility.

In the north-west of England the base metal, hematite and baryte veins of the Lake District occur in Lower Palaeozoic host rocks which, as Bott[2] has recently shown, are extensively underlain by a Caledonian granite batholith which is probably continuous with the Weardale Granite. The Lower Palaeozoics form the core of a dome which was mantled by Lower Carboniferous rocks. In a very approximate manner the geological situation here can be likened to that of the northern Pennines, but in the Lake District doming and consequent erosion have led to the removal of the Carboniferous roof and rocks of this age are only present now as a fairly continuous belt around the Lower Palaeozoic outcrop. The model lead ages[24] for this region indicate that much of the mineralisation is post-Lower Carboniferous and therefore that ore solutions could have penetrated the adjacent Carboniferous limestones. If the suggested hypothesis put forward in this paper is applied in designing an exploration programme for this Carboniferous terrain then the area west and south-west of Kendal might be thought worthy of attention in view of the marked positive magnetic anomalies which are present and which continue eastwards to the area underlain by the Wensleydale Granite. However, such a possibility must be approached with great caution as the gravity work by Bott suggests that the south wall of the Lake District batholith lies well to the north of Kendal. It must also be noted that Bott[2] was inclined to attribute the positive magnetic anomalies over the Askrigg Block to volcanic or metamorphic rocks rather than plutonic intrusions.

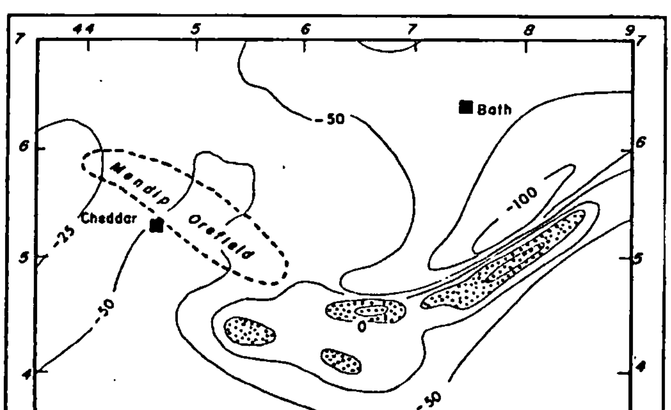

Fig. 3. Total field magnetic anomalies for the Mendip Orefield and its surrounding region. Data from the Geological Survey[12] by permission of the Director, Institute of Geological Sciences (N.E.R.C. copyright). Contours are at 25 gamma intervals. Stippling marks the areas with positive values.

Ireland

Reference was made at the beginning of this paper to the spatial relationship of Hercynian mineralisation and Caledonian granite in eastern Ireland. This was only remarked upon very briefly by Tremlett[30] and indeed the possible role of granite masses in controlling the location of mineralisation in the Irish Lower Carboniferous rocks has received but scant attention in the literature. Morrissey *et al.*[25] touched upon this subject and mentioned the possibility of the presence of concealed plutons listed by Charlesworth.[5]. They suggested that some of these might be post-Devonian in age. Most of the possible igneous masses listed by Charlesworth[5] are suggested on the basis of negative Bouguer anomalies and would therefore be granitic. A number of these anomalies are clearly due to buried extensions of the Caledonian Leinster and Galway Granites (Fig. 4). The probability is that the other negative anomalies, which tend to reflect a Caledonian trend, are also caused by further bodies of granite of this age. The presence of concealed Hercynian granites is highly unlikely as the region concerned lies north of the northern boundary of the Variscan orogenic belt which follows the Killarney-Mallow Thrust Front. The little that is known of the sub-Palaeozoic basement in central Ireland suggests the presence of high amphibolite and granulite facies rocks.[29] The densities of these rocks will be about 3,000 kg cm^{-3} and any near surface approach of these would increase the gravity field.

Fig. 4 (p.409) shows the distribution of known base metal and baryte deposits of post-Silurian age, the outcrops of Caledonian granites and the areas of low to negative Bouguer gravity anomalies which may represent buried granites of the same age. The map indicates a marked degree of proximity between much of the mineralisation and the known or postulated bodies of Caledonian Granite.

In the north of Ireland the Hercynian (and perhaps later) mineralisation is of very minor importance. In Donegal some of this is clearly related to the Donegal granites. Moving southwards the first deposits of some note are the Abbeytown mine and deposits to the north-east of it. These are clearly grouped along a gravity low which has a pronounced Caledonian trend and which extends north-eastwards to include exposed granite at Barnesmore.

At a slightly lower latitude over in the east a group of minor deposits occurs in County Monaghan. These may well be spatially related to a buried continuation of the Newry Granite. Reference to Fig. 4 will show that the area underlain by this granite is not obviously delineated by a gravity low. This is due to the development of a very strong gravity high associated with the basic rocks of the Tertiary Carlingford Complex. Away from the disturbance of this later effect the gravity field suggests near surface granite reaching out from the actual outcrop for up to 15km from the contact. If this buried extension continues around the south-western end of the outcrop then it would underlie the Monaghan field.

Further south a greater density of deposits is present including the larger deposits discovered during the last two decades. Most of these deposits, both big and small, are grouped around exposed Caledonian granites or obvious buried continuations of these. The gravity anomaly map suggests that throughout the Central Plain rocks with a density of about 2,650 kg m^{-3} underlie large areas. They may be either very thick masses (up to 3,000m) of Devonian and Carboniferous sandstones or granite.[5] Many of the areas of low gravitational attraction clearly mark buried continuations of known granites, e.g. the Galway granites in the west and the Leinster Granite in the east.

All these gravity lows, except for that around the Galway granites, have obvious Caledonian trends and in addition they continue over the Lower Palaeozoic inliers of the Central Plain from which the Upper Palaeozoic rocks have been stripped by erosion, suggesting that they represent deficiencies of mass present in the Lower Palaeozoic basement rather than in its Upper Palaeozoic mantle. If this is the case and if the +15 to +10 mgal contours are taken to indicate the approximate outline of this hidden granite batholith, as appears to be the case for much of the postulated Lake District batholith of north-western England,[2] then practically all the large and small base metal deposits of this region lie over or right beside this buried granite mass. In particular places, the decrease in gravity suggests a nearer surface approach of granitic material. Thus in the area of Navan and Slane a pronounced low coincides with known mineralisation including the newly found and large Navan deposit. About 75km west of this lies another gravity low, with a Caledonoid trend and a grouping of deposits, including the Keel deposit, along it. Further north the general gravity low surrounding the Keel region embraces the outcrop of the Crossdoney Granite.

South of this low is a larger, more irregular one but still having an evident Caledonoid trend. This has a group of smaller deposits spread along it. The south-westward prolongation of this low reaches westwards towards a similar prolongation from the anomaly marking the Galway granites. This suggests the presence of a granite ridge at depth. Several deposits lie along this ridge including that at Tynagh. The Galway granites have quite a number of deposits spatially associated with them in both Counties Galway and Clare. To the south-east the deposits of the Silvermines district and its neighbourhood are clearly related in space to a gravity low, whose axis crosses the Silurian-Carboniferous boundary at a high angle, suggesting that it is related not to a great thickness of Upper Palaeozoic sandstone, but to a mass deficiency below the Silurian rocks.

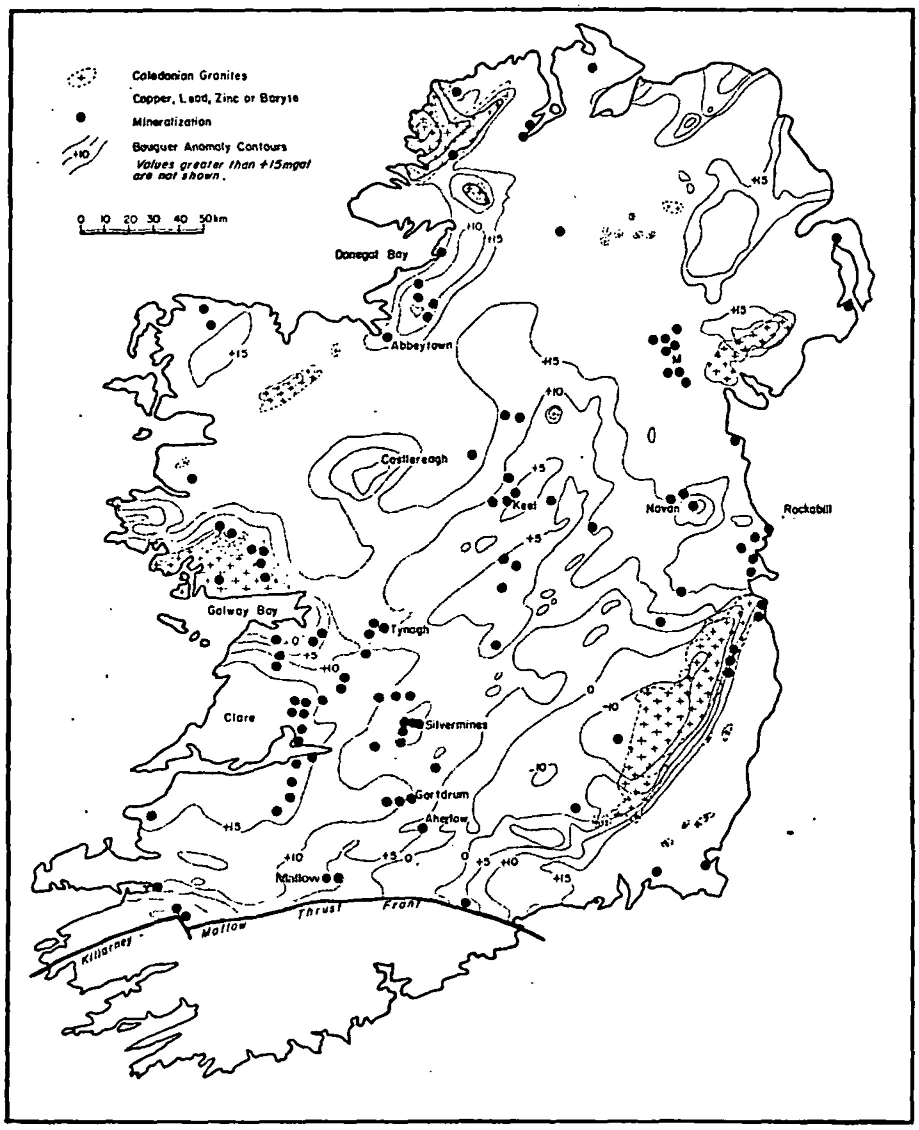

Fig. 4. Distribution of Caledonian granite outcrops and post-Devonian base metal and baryte deposits in the Variscan Foreland of Ireland. Gravity anomaly contours are reproduced from the Dublin Institute for Advanced Physics (1974). Gravity Anomaly Map of Ireland by permission of the Director. M indicates the location of the Monaghan deposits.

Large deposits

To the south of Silvermines lie the large deposits of Gortdrum and Aherlow with associated minor deposits. These are clearly related to the south-westward continuation of the Leinster Granite. The exposed parts of this granite have a number of deposits along their margins particularly at the suggests an abrupt termination of the Leinster Granite south of Dublin. The minor mineralised occurrences just north of Dublin may therefore be related to another granite which is not very clearly revealed by the gravity field but which crops out at Rockabill. The deposits which correlate least well with an area of lower gravitational attraction are the east Clare deposits which continue southwards across the Shannon estuary. These however do show a marked parallelism with the gravity contours suggesting the possibility that a feature at depth has controlled their distribution.

Implications

The authors agree with Bott[1] that the spatial relationships described above suggest that the granitic masses have been able to act as channelways for the mineralising solutions because their physical properties permit the ready development of clean vertical tension fractures, whereas the less homogeneous rocks of the basement will tend to present the solutions with more devious paths or with none at all. This, as Bott suggests, may indicate that the mineralising solutions originated in the upper mantle or lower crust. One of the clear demonstrations of the manner in which older granites may develop fractures providing channelways to the upper mantle is to be seen in the distribution of Tertiary dykes in northern Ireland. These are well developed in the Caledonian Newry, Barnesmore and Donegal granites, but are few and far between in the intervening areas of Lower and Upper Palaeozoic rocks. Clearly the well jointed competent granites have provided the best pathways for ascending basaltic magma.

Of course not all the mineralising solutions necessarily followed channelways through granite for the whole of their passage through the upper crust. The association of base metal deposits in Ireland with east-north-easterly faults is well known and the mineralisation of the Greenhow area in the north of England is probably related to the Craven Fault System. However, if these solutions did rise from the mantle, then they would in all likelihood have followed a granite pathway as far as it extended into the upper structural levels of the crust, before being forced into connecting faults in the manner which drilling has revealed to have been the case at the top of the Weardale Granite. Thus the connexion between the location of mineral deposits and buried granite in Ireland could be even stronger than the present geological data suggest and it will be possible to test this hypothesis when geophysical investigations provide more knowledge of the deeper structure of central Ireland. That the mantle must be seriously considered as a possible source of the mineralising solutions has been shown by the isotopic investigations of Greig *et al.*[14] who consider that the geographical zoning of lead isotope ratios in central Ireland indicates a deep source for the lead. A similar regional increase in radiogenic lead occurs in the English Pennines.[32] This too suggests a deep source perhaps continuous with that of the Irish leads supporting the suggestion that the Hercynian mineralisation of the British Isles north of the thrust front is but a part of the larger Variscan metallogenic province and that this mineralisation together with that of Belgium and the Netherlands, forms the metallogenic foreland zone. In addition their work on sulphur isotopes suggests that the δS^{34} value for sulphur in the hydrothermal solutions responsible for the formation of the Mogul orebodies at Silvermines was around zero indicating a juvenile origin for the sulphur. Similar values were obtained by Mitchell and Krouse[23] from sulphides collected from deposits near the Craven Fault System which runs close to the southern boundary of the Northern Pennine Orefield.

A reconnaissance study of sulphur isotopes from Derbyshire[32] obtained sulphide δS^{34} values close to meteoritic values from samples from the fluorite zone, whilst a sample from the calcite zone gave a higher negative value, the same trend as reported by Greig *et al.* This is in keeping with the suggestion of ore fluid flow from east to west and continuous reaction during this flow between the ore solutions and the carbonate wall rocks.

However current hypotheses for the origin of the mineralising solutions responsible for the formation of Mississippi Valley-type deposits are probably more numerous to-day than they have ever been and it is not proposed to make this paper the vehicle for reiterating all the various mechanisms so far proposed. The present purpose is to focus attention on what seems to be a significant structural control of mineralisation in the British Isles and which may eventually provide a guide in the exploration for deep hidden mineral deposits as and when economic factors force this country to make greater use of its own metallic deposits. As Schnellmann[28] indicated nearly twenty years ago, exploration for lead-zinc ores in the region of the Notts-Derby Coalfield is probably economically viable particularly if use is made of existing colliery workings. These come within 55m of the Carboniferous limestone.[10]

In Ireland various regions appear to be worthy of investigation (or more probably reinvestigation). These include the area over and around the gravity low by Castlereagh and the region north-north-east of Port Laoigse where two prominent negative anomalies occur.

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